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Ceiling Shape in industrial building effect on fire behavior

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Abstract

Considering the many possibilities of industrial buildings are being under fire, human losses or casualties are a big challenge to be spared in addition to asset and properties losses as well.

The improvement of fire simulations via FDS (Fire Dynamic Simulators) programs is very helpful to investigate the transient fire and its spread inside the building under fire to be used for the methods of fire spread reduction within the industrial building inner space in case of partially space is under fire.

This paper illustrates the effect of ceiling shape of the industrial building in the spread and thermal effects of the fire hot gases for triangular ceiling shape with symmetrical and unsymmetrical shapes.

The model of industrial building is built for the usage by PyroSim fire-modelling program which is a typical industrial building dimensions reduced to one tenth, the initial parameters are kept constant to investigate the change of ceiling shape in fire behavior using three different positions.

Keywords: Fire, FDS, PyroSim

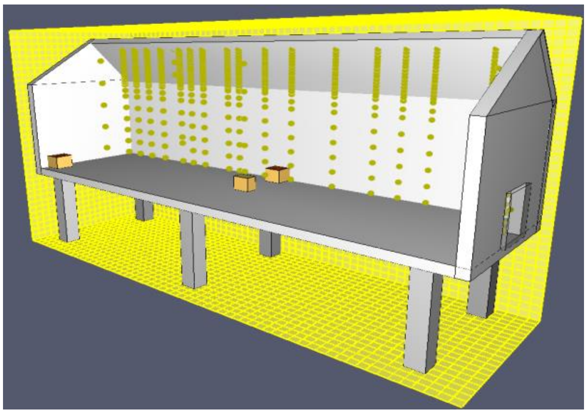
INTRODUCTION

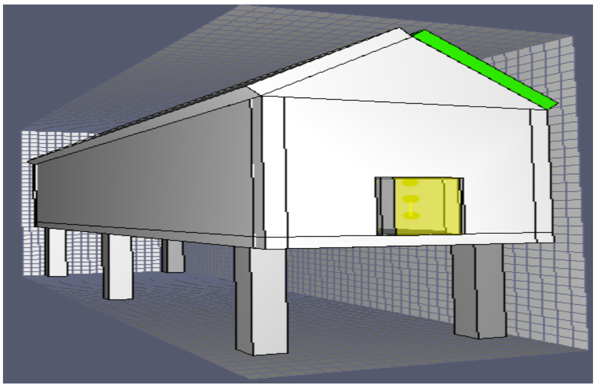
Numerical simulation programs are widely taking place in beside of the full-scale fire tests after the successful multiple validation tests against a full-scale test of the same parameters as P. Ayala and A. Cantizano [1]. They made experimental and numerical fire tests on a Full-Scale Atrium. It was full-scale 20 m^3 atrium, they tried four different heat release rates, steady and transient exhaust extraction rates and symmetric and asymmetric make-up air configurations. Temperature measurements in both fire plume and close to the walls recorded using 59 thermocouples in addition to the smoke layer interface. They performed experimental tests and in addition to it, they used FDS version 6 for simulations of these experiments. Another experiment is also used to investigate the fire Spread in Large Industrial Premises and Warehouses without the comparison of the results with the numerical programs [2]. In addition to that, similar experiments are also experienced to test the model case experimentally and numerically [3, 4 and 5]. Validation and numerical tests and simulations are previously investigated [6, 7, 8 and 9], FDS has been used in the numerical simulations as it has an open program structure, post processing ability is good so that many simulation tests are using it [10, 11 and 12]. In this paper, a continuation of previously described experimental test and its validation of scaled one tenth of Industrial Building 30 m x 10 m and a height of 10 m, the model is made from gypsum with un-symmetric triangular shape ceiling and inner space temperature is witnessed by thermocouples to record the change of temperature with time until steady state which found reached after 20 minutes. Three different positions inside the model for the burner are tested with PyroSim to simulate the fire cases and then all simulation are repeated with symmetric ceiling shape to discover the symmetry effect of the ceiling in the fire spread.

MODEL DESCRIPTION

Gypsum plaster model material is used of dimensions 3 m x 1 m x 1 m. The model ceiling is triangular un-symmetric shape with one door of dimensions 0.3 m height x 0.25 m width and uniform wall thickness 0.6 cm. The fire source top elevation is 10 cm from the floor and its top surface area 0.01 m^2 to produce net HRR of 2.4 Kw. Fire source positioned in multiple positions inside the model ground, positions are at the corner, side and center position.

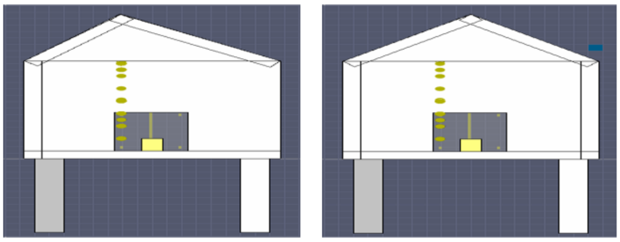
Figures 1-a and 1-b are showing PyroSim model and temperature measurement thermocouple's positions that recorded the temperature from the ignition time until the steady state after 20 minutes. In our model we have the advantages to show completely the inner space temperature pattern which will be presented in the results.





Figures 1-a and 1-b, model showing the three fire source positions and thermocouples.

Figures 2-a and 1-b are showing ceiling shape symmetric and unsymmetrical areas. The ceiling slope is $\alpha = 35^0$ and 48^0 in unsymmetrical shape and 40^0 in symmetric ceiling shape

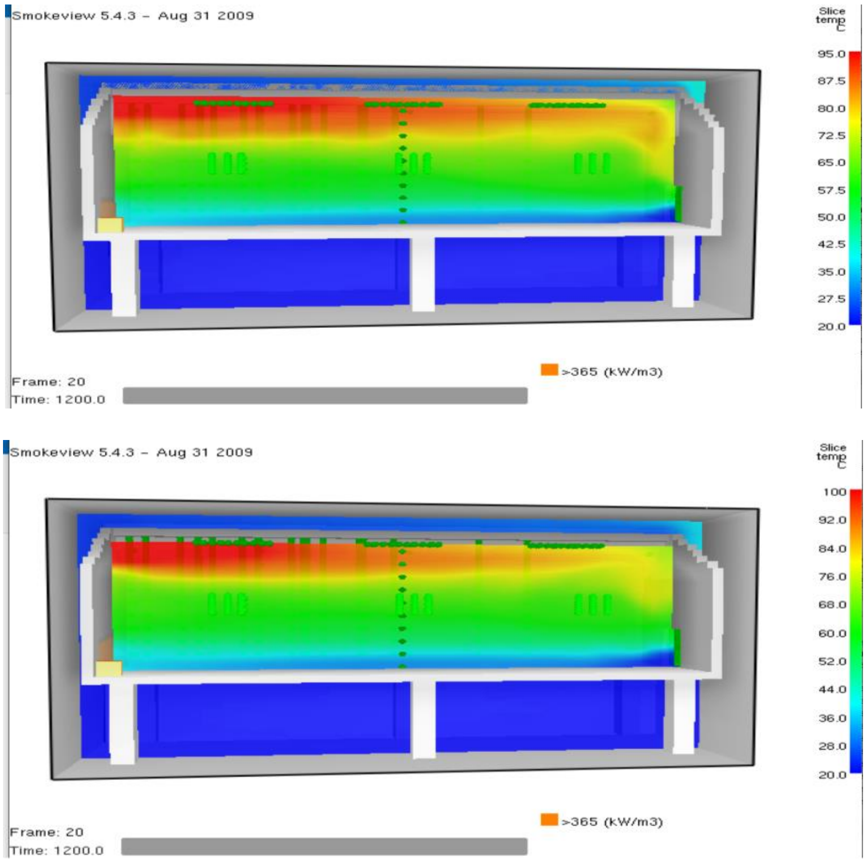


Figures 2-a and 2-b, model showing the ceiling un-symmetric and symmetric shapes.

RESULTS

For three different fire positions corner, side and center, below figures are showing the temperature pattern in case of symmetrical and unsymmetrical ceiling respectively. In each two ceiling shapes of the comparison, and for each fire position, three figures are shown. First figure is showing the temperature pattern at the center of the model while the second one is showing the pattern at the fire source position except in center case as they are the same positions and the third is showing the ceiling section temperature pattern.

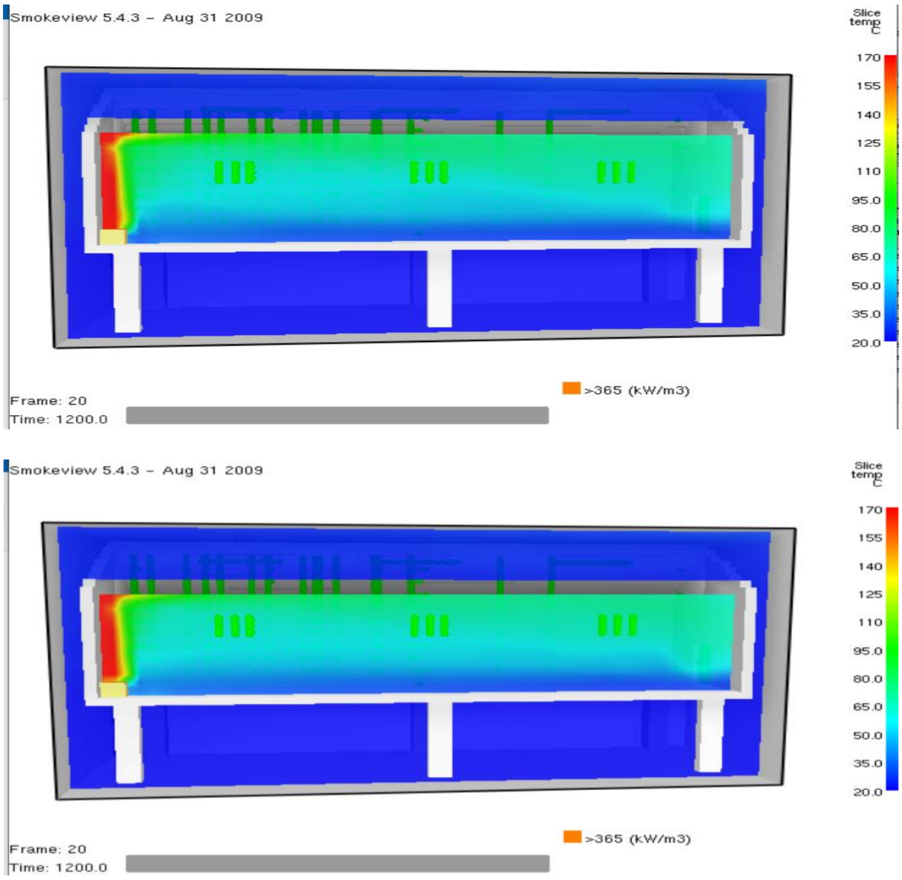
❖ Corner Burner Position



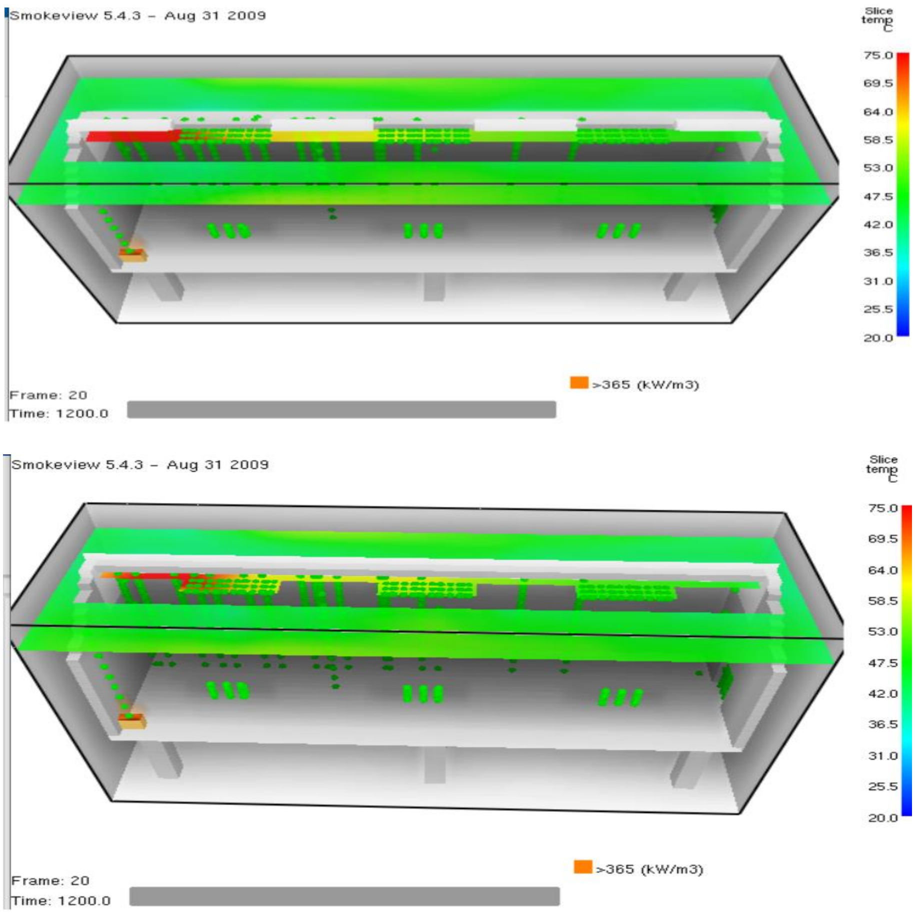
Figures 3-a, b, Symmetrical and Un-symmetrical model temperature pattern results at model center in corner fire position.

In the above two model thermal patterns, temperature distribution is showing higher temperature degree in unsymmetrical ceiling and more hot gases concentration in the upper area of the model in its center width longitudinal line. The two below temperature patterns are showing the same patterns of the above two but in the burner longitudinal line and it shows little higher temperature concentration in the fire plume.

The same four patterns are shown below in side and center cases which are showing the same analysis of the corner case above.



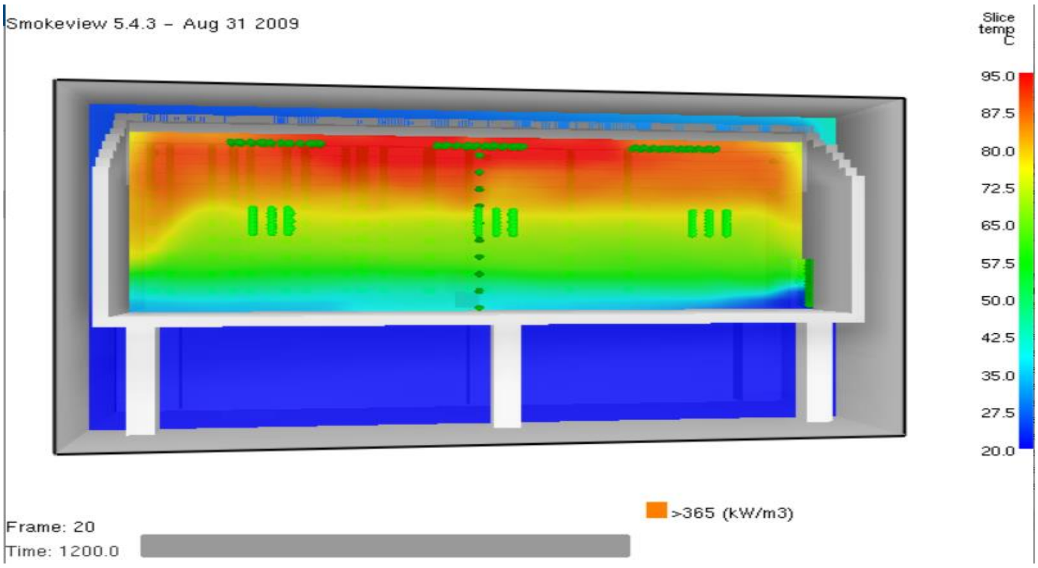
Figures 4-a, b, Symmetrical and Un-symmetrical model temperature pattern at corner fire position.

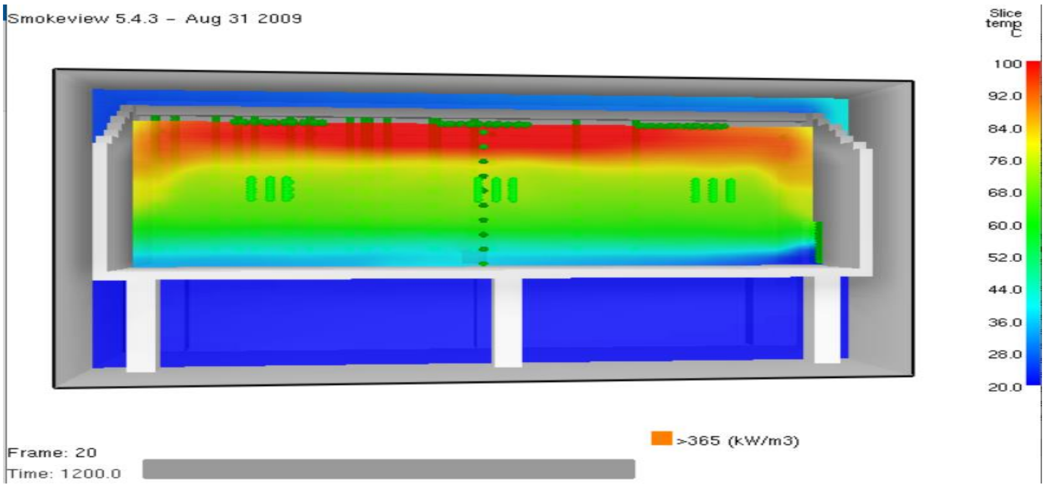


Figures 5-a, b, Symmetrical and Un-Symmetrical model ceiling temperature pattern at corner fire position.

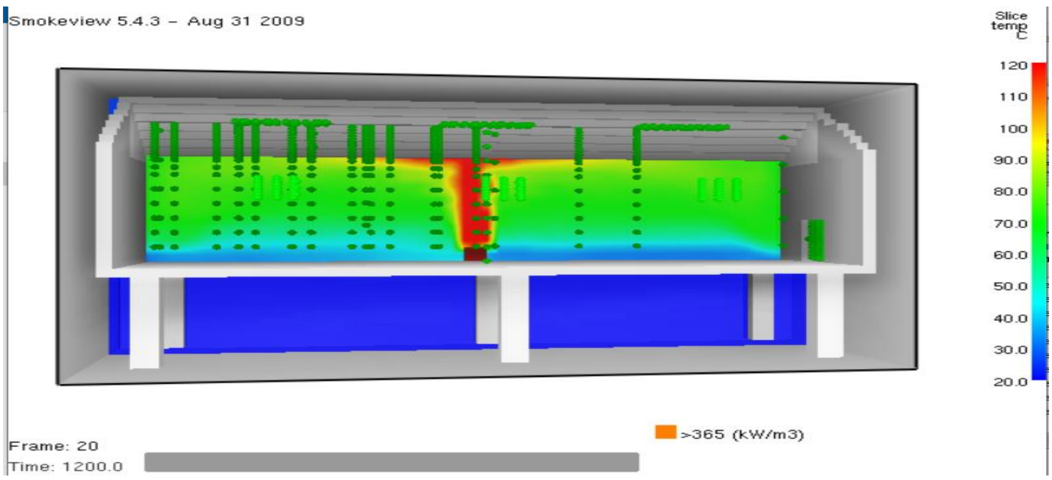
In the above two model thermal patterns, temperature distribution is showing higher temperature concentrations in unsymmetrical ceiling with ununiform distribution unlike the other one of the symmetrical case, the same patterns are shown for side and center cases as well below.

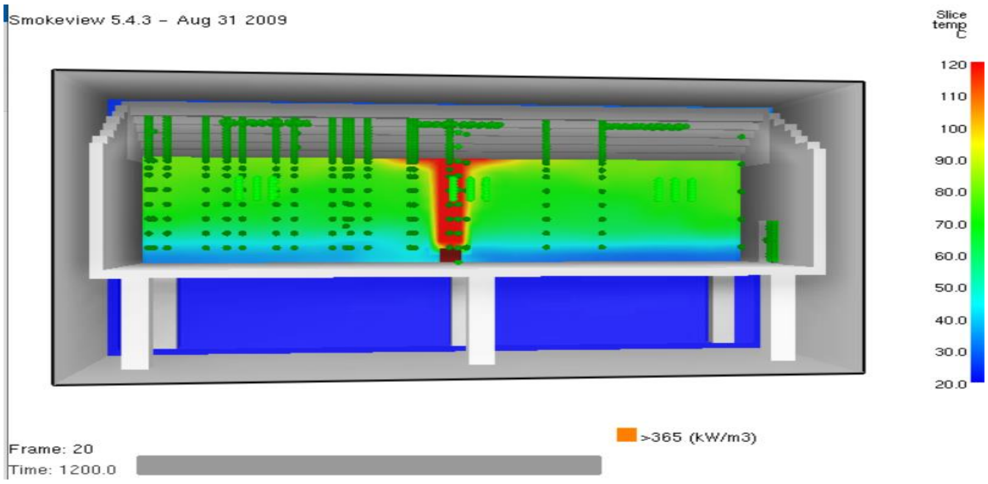
❖ **Side Burner Position**



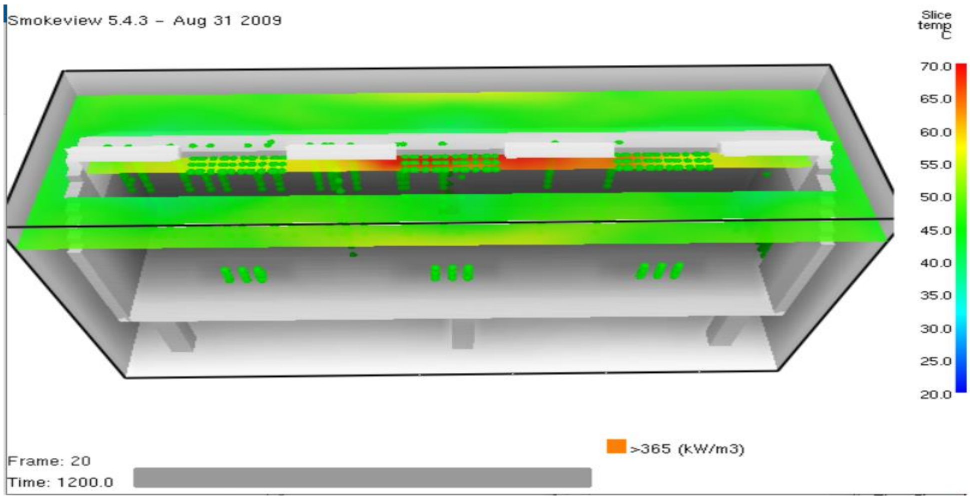


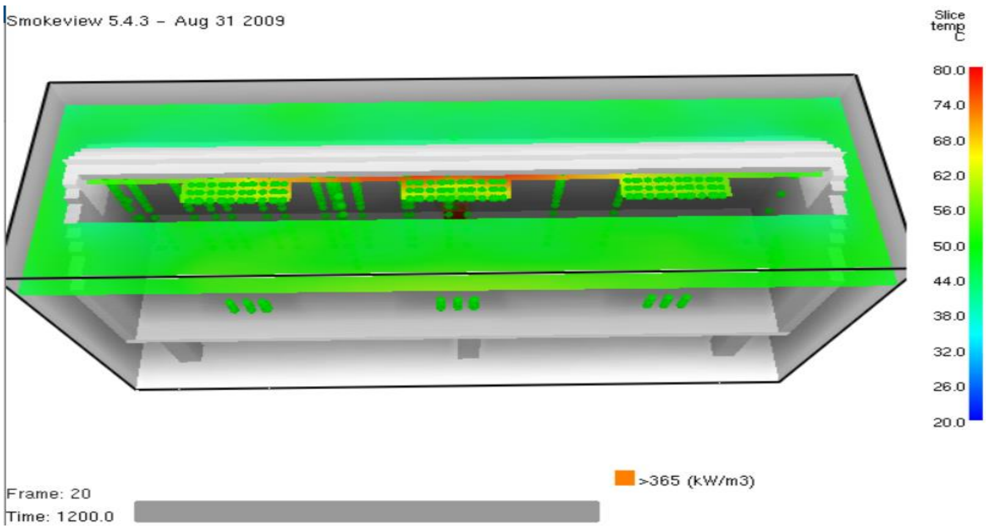
Figures 6-a, b, Symmetrical and Un-symmetrical model temperature pattern results at model center in side fire position.





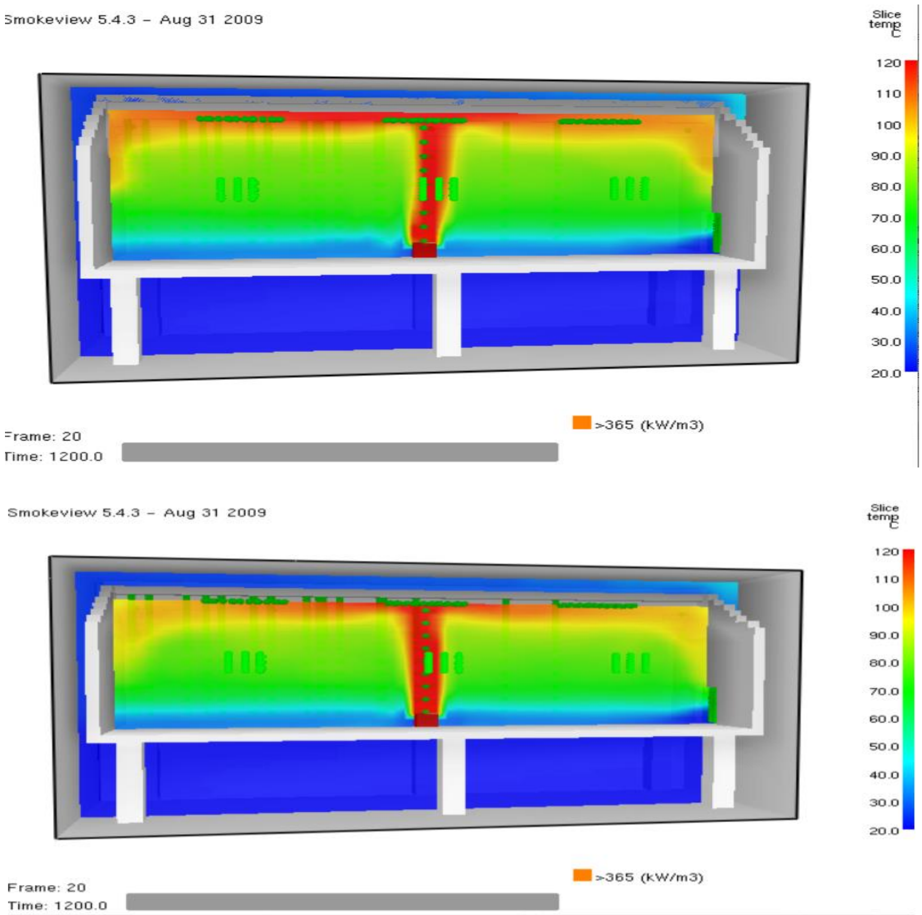
Figures 7-a, b, Symmetrical and Un-symmetrical model temperature pattern at side fire position.



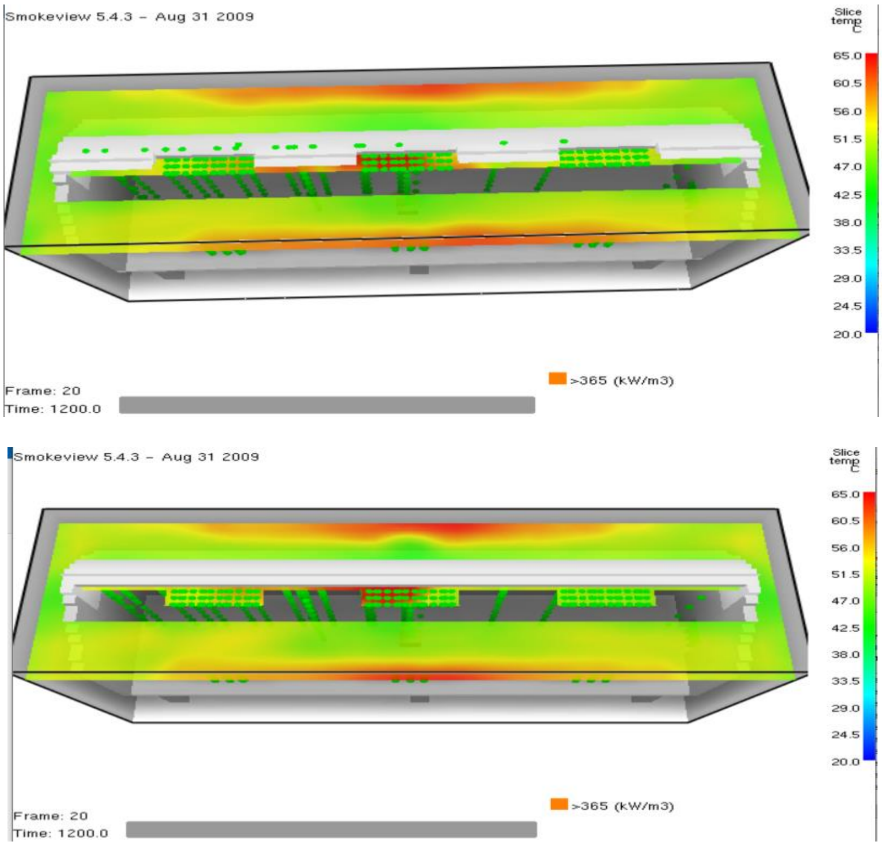


Figures 8-a, b, Symmetrical and Un-Symmetrical model ceiling temperature pattern at side fire position.

- **Center Burner Position**



Figures 9-a, b, Symmetrical and Un-symmetrical model temperature pattern results in center fire position.



Figures 10-a, b, Symmetrical and Un-Symmetrical model ceiling temperature pattern at center fire position.

CONCLUSIONS

This research introduces one of the important comparisons for the fire spread simulations regarding the ceiling shape symmetrical effect on temperature profile.

The results showed that the symmetric ceiling shape is good for the gradient distribution of the temperature rather than the unsymmetrical ceiling for the following.

1. The highest temperature occurred within the region of the triangle ceiling.
2. The ceiling temperature is gradient vertically and taking the shape of the ceiling, un-symmetry provides higher spots than the other sides, which allows for unsymmetrical temperature gradient for the two sides of the model.
3. This difference in temperature gradient makes unrequired heat transfers across the model between higher and lower spots along the model length.
4. This interruption in the flow of temperature gradient is making the overall temperature along the model inner space is higher than the symmetric ceiling.
5. Ceiling symmetry gave a smoother flow velocity and reduced the flow turbulence occurred in un-symmetric model ceiling shape.
6. The effect of fire positions is also with the same results and conclusion according to the previous research in both cases of ceiling shape.

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