Study of Wall Temperature and Heat Flux Distribution in Flashover Compartment Fires

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Abstract- **Newer construction materials and techniques are being introduced in construction industry to conserve materials and energy [21]. Conventionally, fire safety of these materials is evaluated by imposing standard time – temperature profiles during testing [6-12]. Choice of these profiles is based on the wall temperature & heat flux during real fire scenarios and it will have consequences on structural fire safety. Fire Dynamics Simulator, FDS, an appropriate and popular tool [18-22] for the fire driven flows in the built environment will be used to evaluate heat flux and temperature distribution in a 1 m3 size room for several size pan fires. Results will be compared with experiments to validate the model. Wall temperature and heat flux distribution in a standard IS 9705[7] size (3.6 x 2.4 x 2.4 m) compartment normally used for testing building materials will be studied. FDS results obtained will be compared with literature. Realistic heat flux distribution will provide more accurate boundary conditions to structural analysis resulting in improved structural fire safety.**

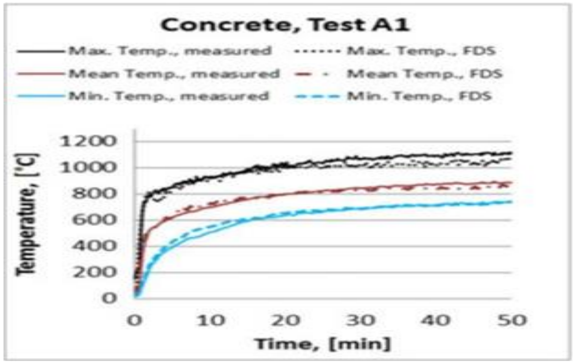
INTRODUCTION

Post flashover fires are important to understand the response of the structure during fire scenarios. The fire accidents [15] happened in various types of buildings explains that how vulnerable the conditions will be when the structure is not able to withstand the longer duration fires especially in larger buildings which are highly populated. If a fire broke out in larger buildings [13] like shopping complex, theater or high-rise structure, the ability of the building to withstand structural loads plays a key role in the evacuation of the people present in the building. The post-flashover fires are a fully developed stage of fire at which the directly exposed combustibles material in an enclosed area will ignite simultaneously and the fire will spread faster throughout the building causing severe structural damages and the buildings experience high temperatures during that scenario. Flashover occurs [22] when the gas temperature of the hot gas layer is increased to 600°C, heat flux to the floor level is about 20 kW/m2, or HRR is up to 1MW. Hence this considered to be an important criterion to look after structural fire safety.

LITERATURE REVIEW

A number of studies have been conducted to understand the flashover, methods to predict flashover in compartment fires, calculating temperature rise and heat flux rate in compartment fires and conditions affects flashover. Brief reviews of some of the literature are given below.

The work was done by Alexandra Bystrom and Ulf Wickstrom [19] describes and validate temperature of fully developed post-flashover compartment fires. He created a room model of size 1.8m by 2.7m in the plan by 1.8m height, with a 0.6m wide door of height 1.5m and with a propane burner producing standard HRR rate of 1000kW to predict ultimate temperature and maximum temperature in a variety of structural boundaries. Totally three experiments were conducted in the enclosure with lightweight panels, insulated and non- insulated ceilings. The temperature values are recorded with the help of thermocouples and plate thermometers. He calculated parametric temperature curve for the enclosure through mathematical model and simulations(FDS) method. The predicted temperature from the experiments is compared with the temperature acquired from simulations done for same enclosure details to prove that the results calculated from the simulations have good agreement with the measured temperature of compartment fires. (main uncertainty parameter in this model is combustion efficiency of fuel, the value of 60% is used for all cases). Figure shows the comparison made out of the result.



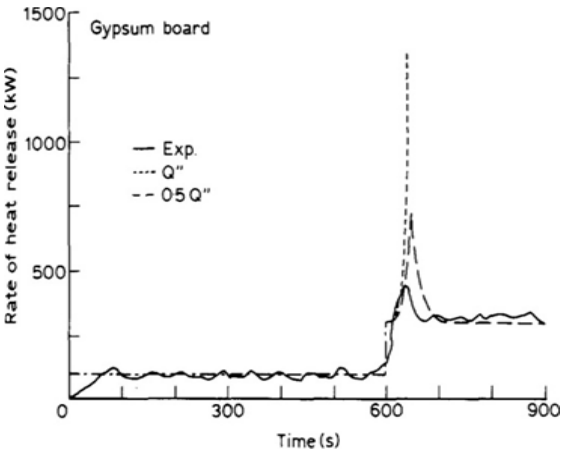
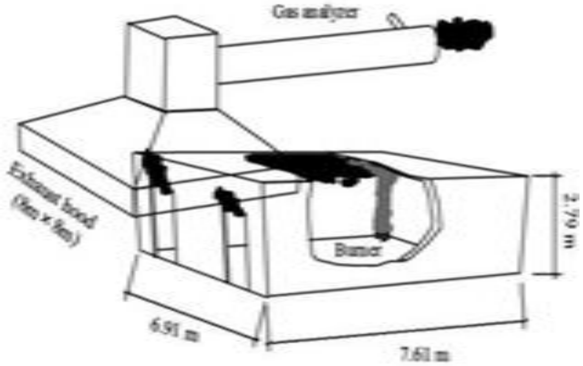
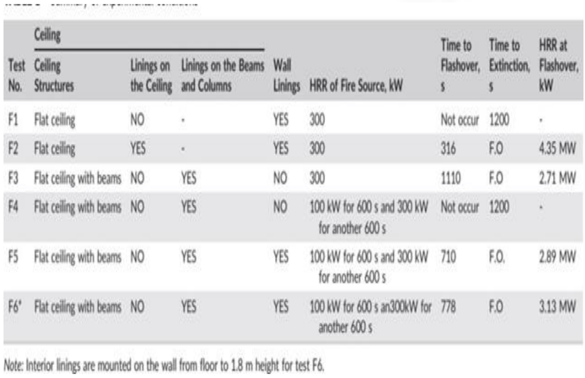


Fig 2.1 (b): Comparison of HRR with Swedish room corner test

Fig: Experimental result vs FDS comparison of measured and calculated temperature at three different boundary conditions

W. W. Yuen and W. K. Chow [8] conducted field zone model and zone model to show the importance of thermal radiation for the transition to flashover in a compartment fire. A zone model of size 1mX1m in the plan by 1m height is developed to determine the flashover and its parameters leading to flashover. The external heat transfer coefficient and particulate volume fraction are shown to be important parameters which can lead to thermal instability and flashover. The experimentally calculated results are compared with the field zone model for accuracy. This work shows that inaccurate theoretical model of radiation can generate misleading conclusion about the effects of various design parameters of the flashover. An accurate radiation model is a key to overcome these effects. James G. Quintere [1] created a room model according to ISO 9705[7]1, recommendations (to predict the energy release rate. He modeled the combustion of the interior materials present in the building by a set of equations to address the fire growth in the wall and ceilings of the room and he compared the energy release rate rise obtained with the experimental heat release rate and Swedish room corner test fire property data. Totally 13 materials were tested and experimentally calculated results are compared with the Swedish room corner test data and results are tabulated. Axelson, Jesper and Andersson [4] addressed the error in calculating HRR and SPR in the ISO 9705[] room corner test. The room interior materials will consist of multiple compositions and each material is tested under ISO 9705 room corner test for predicting HRR and SPR, the combined effects of a variety of materials will have effect in the computation of the HRR and SPR of individual. From the individual errors, the combined expanded uncertainty is calculated with the coverage factor of 0.2. The results show that overall 5% reduction in the confidence level of the calculation of HRR and SPR in room corner test subjected to combined effects of material. Jamie Stern- Gottfried and Angus Law [17] conducted a parametric study on traveling fires and obtained that considering only uniform fires scenario in structural design may not always be as conservative as previously assumed in traditional methods of calculating fire scenarios like room corner test, temperature curve etc. It also shows that traveling fires also have an important role to play in the fire spread in the building and its study proceeds. The work done by Xuemin Niu’ and Yuji Hasemi [22] deals with the different distribution of interior linings in an enclosure to reveal the influence of time of flashover. This paper deals with two kinds of ceiling structure, one flat ceiling and another one is ceiling with beams were used for enclosure. He conducted six full scale experiments namely F1, F2, F3, F4, F5, F6(explained in figure2.1(c)) were performed to investigate the occurrence of flashover in large enclosure. Experimental results show that time to flashover is extended for enclosure with large surface areas and large doors. He observed changes in flashover duration due to effect of ceiling fires on the spread of flame on the wall. The time to flashover is reduced for the test fitted with interior linings on the wall of the enclosure. This study used ISO9705 room corner test method for performing experiment. The enclosure used was measured to be of size 6.91mx7.61m in plan by 2.79m height. The walls and ceiling were iron framing, covered with 12.5-mmthick gypsum boards. There were 2 doors that were 0.9 m wide and 2.11 m high on the front wall. Fifteen-millimeter-thick Japanese cedar, which was combustible, was lined on the interior surface of the enclosure for all the tests to minimize the difference generated by materials. A square propane burner of 0.45m wide is placed on the left corner of the enclosure. The fire source was ignited until flashover or 1200s.





Test No.	Ceiling Ceiling Structures	 Linings on the Ceiling	 Linings on the Beams and Columns	Wall Linings	HRR of Fire Source, kW	Time to Flashover, s	Time to Extinction, s	HRR at Flashover, kW
F1	Flat ceiling	NO	-	YES	300	Not occur	1200	-
F2	Flat ceiling	YES	-	YES	300	316	F.O	4.35 MW
F3	Flat ceiling with beams	NO	YES	NO	300	1110	F.O	2.71 MW
F4	Flat ceiling with beams	NO	YES	NO	100 kW for 600 s and 300 kW for another 600 s	Not occur	1200	-
F5	Flat ceiling with beams	NO	YES	YES	100 kW for 600 s and 300 kW for another 600 s	710	F.O.	2.89 MW
F6*	Flat ceiling with beams	NO	YES	YES	100 kW for 600 s an300kW for another 600 s	778	F.O	3.13 MW

Note: Interior linings are mounted on the wall from floor to 1.8 m height for test F6.

fi g 2.1(c): experimental setup of enclosure

Fig 2.1(d): Table explains the type of experiments conducted, flashover time and HRR rate

This work is chosen for comparison of FDS simulation and compartment flashover fires for quantifying the results. In this study surveyed F2 (flat ceiling condition) is taken for performing FDS calculation and validating the results as a proof for quantification of FDS and addressed method in this paper. The boundary conditions for simulations are taken out from the experimental results mentioned in this study. The FDS simulation for this is performed and results are compared with the results calculated in this study for providing accuracy check.

Experimental calculations

All the quantitative and qualitative measurement in an experiment are calculated with the aid of measuring tools. In this study, the tools listed in table3.1 are used to measure mass flux and temperature.

Sl. No	Tools	Least count	Used for
1	Flashover apparatus	-	Identify flashover
2	Square Pan	-	Holds fuel source
3	Weighing balance	0.01g	Measures weight
4	Digital engineering weighing scale	0.01g	Display values of weight
5	Balance reader software	0.01s	Plot the mass loss per second
6	Thermocouple	0.1□C	Wall, ceiling temperature measurements
7	Data Acquisition Unit	1s	Data Acquisition
8	Thermometer	0.1□C	Measure ambient temperature
9	Flange	-	To connect pan to weighing balance

Table. List of tools used in experiments

- Flashover apparatus

The flashover apparatus (shown in fig:3.1.1(a)) is a square box of 1m wide and 1m height. It is made out of MS sheet with a ceramic coating inside the box to resist flame heat. It also has a wheel in the base to transport from one place or position to other. The box is designed in a way that, it has a wide opening in the front to provide an opening as required for the respective experiments. The box maintains a confined environment inside to give accurate results. The box is designed well to identify flashover in varying air supply conditions. The apparatus is used to identify the duration of flashover, mass flux details, wall temperatures etc.; respective to the experimental requirements and its setup.

Fig3.1.1(a): Front and Back view of Flashover apparatus

Square pan

A square pan of size 0.335m wide and 0.200m height (shown in fig:3.1.2(a)) is used to holds the fuel which serves as a fuel for the testing. The gross weight of the pan is 5.890kg. The square pan is placed inside the flashover apparatus in respective position according to the experiment orientation.

Fig3.1.2(a): Square pan. Fig3.1.3(a): The Weighing Balance

Weighing balance

A weighing balance of capacity 60kg (shown in Fig:3.1.3(a)) is used to measure the mass of the pan and fuel. The least count of the balance is 0.01g. The minimum capacity of the balance is 50gm and maximum capacity is 60kg. The weighing balance is connected to the Orion digital scale to display the mass details.

Digital engineering weighing scale

In this study, Orion digital weighing scale of capacity 60kg (shown in fig:3.1.4(a)and (b)) is used. It is connected to the weighing balance by means of the USB cable, the mass details of the load placed in the balance are displayed on the digital scale. The display is clear and visible red in color for easier visualization. The least count of the scale is 0.01g. The BAUD rate of the scale is 9600. The digital values are recorded by means of Balance Reader software and plotted in excel sheet.

Fig 3.1.4(a): Digital weighing scale Fig 3.1.4(b): Digital weighing scale connected to weighing balance

Balance Reader Software

The 'Balance Reader Software' is developed by National Instrument LabView to evaluate the digital readings of weighing scale. The software is used to read the digital scale values, the values of mass are loaded into the software by means of USB cable connected to the digital weighing scale. The software gives the 'mass loss rate of fuel per second' providing the following information in the table 3.1.5; an input setup in the software. The data recorded and calculated are provided in Excel sheet for further reference. Fig:3.1.5(a) represents the software details and the Fig:3.1.5(b) represent the full connection setup of the balance data recording.

input data	Values	Purpose
BAUD rate	9600	Speed rate of data sent over the line in bit per second
Logging interval	1 s / 1 data	Time interval to record data

Table 3.1.5: List of input data

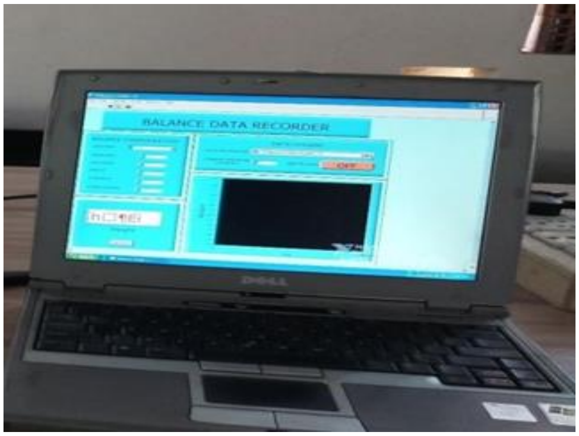


Fig3.1.5(a): Balance reader software Fig3.15(b): Full connection setup of the balance recorder

Thermocouple

It is an electrical device which consists of two dissimilar metals forming an electrical junction at a different temperature. The temperature gradient between these metals will generate an Electromotive Force(EMF). The voltage existing at the end of the conductors will represent the sum of the EMF's generated along with it. There are many types of thermocouple and they are classified based on the metal alloy used in the thermocouple as conducting material. K type thermocouples (chrome – alumel) were used. (showed in fig 3.1.6(a)) for temperature measurement in the experiments. The thermocouple wires are connected to the connection channel and the connection channel (as shown in fig:3.1.6(b)) is attached to the Data Acquisition Unit. The values are recorded by data acquisition unit is then brought into an excel sheet and plotted.

Fig3.1.6(a): Thermocouple

Fig3.1.6(b): thermocouples connected to the Connection channel

Data Acquisition Unit

Data Acquisition unit is developed by Io-Tech. It's a compact unit which uses universal serial bus shown in fig:3.1.7 to transmit data to the computer. In this study personal DAQ/ 50 series module is used. It consists of 2 channel units which hold connection channel unit. Each connection channel unit holds five thermocouples. It is compatible with connecting K, R, J type thermocouples. The DAQ is connected to the computer through USB cable to record the data. It also acts as a millivoltmeter. The data from the thermocouples are recorded in millivolts and converted into temperature parameters in the software used. The extracted data can be brought into the excel sheet. Using this we can easily calculate temperature data during the experiment and after the experiment also.

Fig 3.1.7: Data Acquisition unit and thermocouple connection to the channel

Thermometer: The calibrated 100^0C thermometer is used to measure the ambient temperature of the room, water and fuel used. The least count of the thermometer taken as 1^0C. Fig3.1.8 shows the thermometer used to measure temperature.

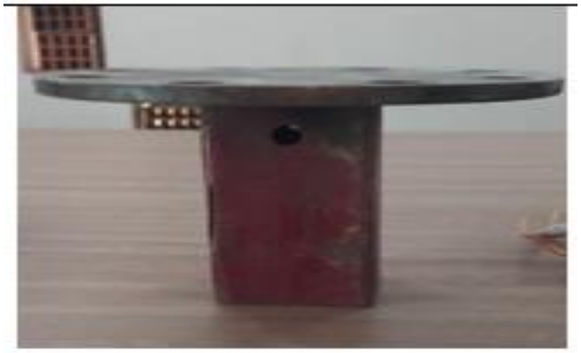


Fig3.1.9: Flange

Flange:

A square steel box connected to a circular steel plate (shown in fig: 3.1.10) is used as a flange. The flange serves as a connection unit to the balance to record the mass load kept inside the flashover apparatus. The flange is of 0.3m is kept inside the hole provided in the center of the apparatus. The fire pan is placed above the circular base of the flange.

EXPERIMENTAL DESCRIPTIONS

All the experiments were conducted at Fire Combustion Research Center. The experiments studies were conducted to understand the behavior of fire in a confined environment and to observe the contribution of fuel load and atmospheric condition to flashover duration and its temperature. In this study, two experiments were conducted to determine mass flux and temperature data in a compartment fire for analyzing respective boundary conditions in FDS. The atmospheric conditions of indoor also monitored while performing the experiments.

Experimental layout

Fig 3.2.1(a),(b) shows the experimental setup of flashover apparatus. The flashover apparatus is a square box (fig.3.1.2(a)) was measured 1m wide by 1m height and consisted of three walls with an opening in the front side of the box. A door of size 0.5m wide and 0.8m height is formed out of galvanized sheet is placed in the front side of the apparatus. The apparatus resembles a compartment or a room. A square pan with a wide 0.335m was placed in the center of the apparatus which holds the fire source for testing. About '27kg of water' mixed with '1kg of Heptane' is filled in the square pan with a freeboard of 0.025m which serves as a source of the fire.

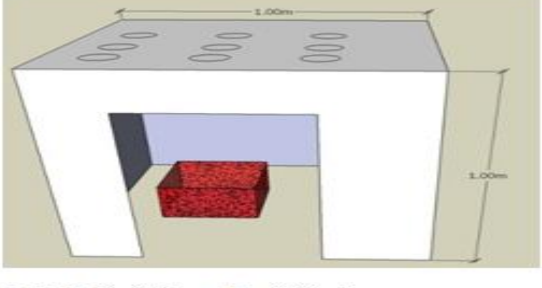


Fig3.2.1(a): Sketch of flashover apparatus

Fig: 3.2.1.(b): Flashover Apparatus setup

Orientation of apparatus in the porous wall room

The apparatus is positioned in the center of the room with porous wall arrangement. The room is surrounded by the porous wall on three sides and a solid wall on one side. The porous arrangement of the wall helps the room to carry experiments without any disturbance in the indoor ambiance due to outdoor atmospheric changes. It helps to maintain indoor environments like the supply of air, temperature, and pressure. This arrangement of the room helps to carry experiment accurately without any disturbance due to air flow; if the air supply in the room changes its effects the physics of the flashover, hence the porous wall arrangement helps in acquiring accurate results. The apparatus is arranged in such a way that the front door faces the solid phase wall of the room. The experiment is conducted in a closed confined environment.

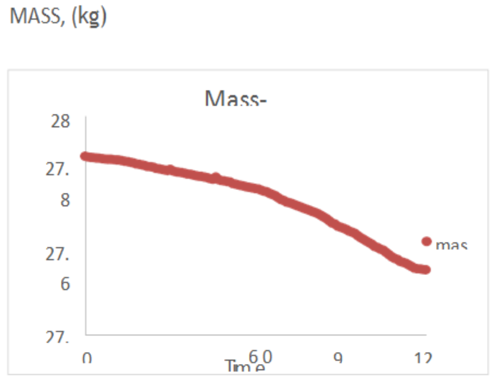
Mass loss experiment

The objective of this experiment is to calculate the mass flux data through loss of fuel mass per second. The experiment is carried out in the enclosure explained above. In the flashover apparatus, the pan has placed the center of the apparatus over the flange attached to the hole in the center of the apparatus. The square pan is filled with 27kg of water and 1kg of heptane as a fuel source with 25mm freeboard. The ambient temperature of the surrounding, water, heptane and the gross weight (shown in table 3.2) of the pan is measured for reference (total gross weight of the pan is 28.535kg). The flange is kept above the weighing balance [3.3,3.4,3.5] to record the data. After understanding the surrounding temperatures and the connection ability to record the data the experiment is started. The fire is ignited and the mass loss data is recorded per the second interval and reported in excel sheet or further analysis.

S. No	Item	Weight in kg	Temperature in ^{0}C
1	Flange	3.59	-
2	Pan (gross)	5.585	-
3	Water	27 kg	30
4	Heptane	1 kg	28
5	Ambient room temperature	-	33

Table 3.2.2: Gross weight and temperature of items used in the experiment

Fig 3.2.2(a): Mass loss graph



The data recorded in excel sheet gives the mass loss of fuel per second in CSV format. The recorded data are analyzed and the graph is plotted for the fuel consumption or mass loss. Using the graph peak (fig 3.2.2(a)) nodes, the mass loss per second is calculated and by averaging the highest the flux is calculated for the total area which serves as a boundary condition for simulation.

The mass loss is calculated by the equation follows:

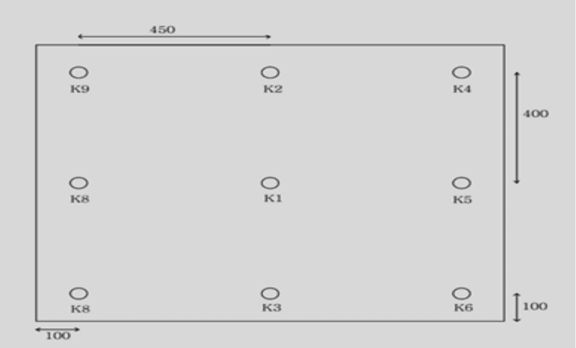
$$\text{Peak Massloss} = \frac{\text{mass loss in grams}}{\text{respective time taken to mass loss}} \text{----}(3.2.2.1a)$$

$$\text{Mass flux} = \frac{\text{peak mass loss}}{\text{area of the square pan}} \text{---------}(3.2.2.1b)$$

These values are used as a ramping boundary condition for the simulation of this experiment.

Measurement of temperature

The temperature experiment is conducted to identify the realistic temperature of ceiling and wall in the fire scenario. The temperature calculated in this experiment is compared with the calculated temperature out of the simulation. The experiment is performed in the flashover apparatus with same mass loss setup and thermocouples are attached in the ceilings to analyze the temperature. The thermocouples namely K1, K2upto K9(fig3.2.3(a)) is placed on the ceiling of the apparatus, each spaced 0.4m vertically and 0.5m horizontally. and K10 placed just above the door. K type[3.1.6] thermocouple is used to measure a temperature which is connected to PDAQ for acquiring data. The thermocouples placed observe temperature due to flame heat spread in the compartment. The temperature data recorded is reported in excel sheet for further processing.



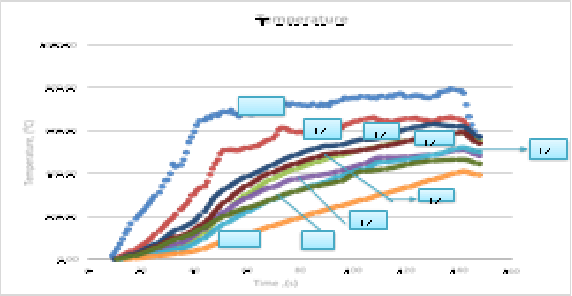


Fig 3.2.3(a): Position of thermocouples o20n ceilings and its spacing Fig 3.2.3(b): Temperature values are given by the thermocouples placed on the ceiling

Simulation:FDS software is used for simulating the experimental results and extract the heat fluxes and temperature profiles. Fire Dynamic Simulator (FDS) is a computational fluid dynamics(CFD) model for a fire driven fluid. The software solves numerically a form of the Naiver-Stroke equation appropriate for low speed, thermally driven flow, with an emphasis on smoke and heat transport from fires. Smoke View (SMV) is a visualization program that is used to display the output of FDS and CFAST simulations. FDS is a free software downloaded by the National Institute of Standards and Technology (NIST) of the United States Department of Commerce.

Results and Discussion (Mass loss experiment)

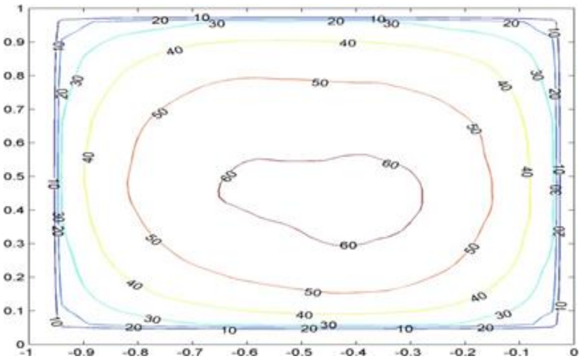
The moss loss experiment conducted to calculate the mass loss data of the fuel helps in predicting mass flux (burn rate of the fuel) in the compartment for simulating the model. The mass loss data extracted using the excel sheet and peek variations observed in the graph (fig 3.2.2(a)) are given in table 5.1.

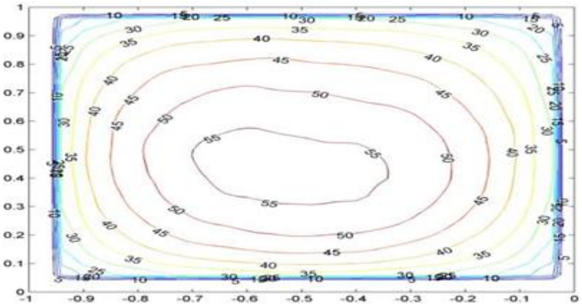
S. No	Time, (s)	Total Time, (s)	Mass loss (g)	Burn rate (g/s)
1	0-20	20	98	4.9
2	21-58	37	295	7.9
3	59-78	20	182	9.5
4	79-116	37	450	12.16

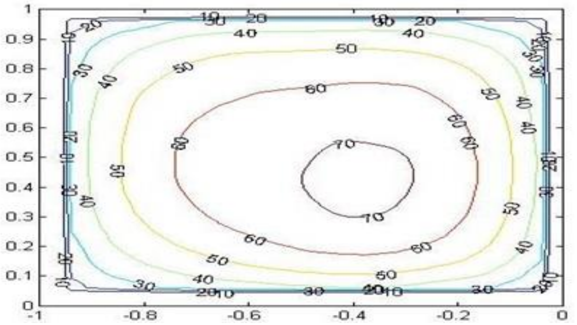
Total mass loss =1025g Table 5.1: Calculation of Burn rate in (g/s)

Using the peak mass loss in the mass flux is calculated using equation (3.2.2.1.b). The mass flux for this experiment is: Mass flux= 12.16/ (0.335*0.335) =108.35g/m2 s= 0.108kg/m2 s

The mass flux calculated is used as a boundary condition for rating the heat release rate in the simulation of the experimental setup and total duration of the simulation is 116seconds which is taken similar to the experimental duration. It is observed that flashover occurred at 42ndsecond during experimentations. The same is observed in the simulation results. The simulation predicts the net heat flux and wall temperature occurs for the given mass flux (burn rate). The heat flux is predicted for two conditions, ideal and conductive condition, because the flashover apparatus used for experimentation is coated with ceramic on the walls and ceilings which will not conduct much heat and act as an ideal boundary for the fire scenario but in actual room fire scenarios the wall will conduct heat, to understand the changes occur because of the conductivity of wall two scenarios heat flux is predicted and compared for difference identification. The predicted results are extracted and plotted as contour using MAT-Lab for comparison and understanding the different values of heat flux at various points in the enclosure. It is seen that the wall which conducts heat will have less heat flux than a wall which acts as a cool boundary (ideal condition) during the fire scenario. The comparison of the simulated inert and conductive conditions of the ceiling as shown in figure 5.1 (a). The heat flux predicted for the ideal condition and conductive condition shows totally 20kW/m² in difference at peak condition.







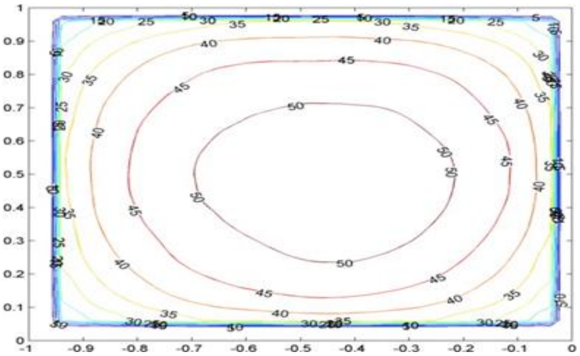
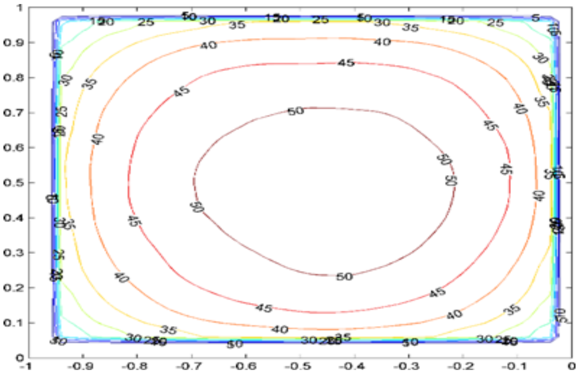


Fig: 5.1(a): Comparison of heat flux of ceilings at the ideal condtion (i) at 30s (ii) 80s and conductive condition at (i) at 30s and (ii)80s

The duration 30s and 80s is chosen to compare because it shows a clear value difference for starting of fire growth stage and peak reached after flashover stage.

The heat flux and temperature distribution contours are calculated for the conductive condition are compared at 30s, 80s and 116s respectively to have a clear idea about pre-growth stage, peak stage of flashover and decay stage of fire respectively. This time duration is chosen with the help of mass loss graph (difference in burn rate). The contours are plotted using MATLAB r2007b. The plotted contours help in understanding the heat flux and temperature distribution at various levels of fire at various points in the building. The parameters are predicted at ceiling level and back wall for comparison to understand the distribution level of heat flux and temperature at different boundaries, ceiling is taken because during a fire scenario the hot gases immediately goes up and affects the ceiling first, to know the condition of side wall back wall is chosen as common for both experimental simulation and Niu [22] simulation, anyways in this simulation the fire source is at the center it will have same distance to all the side walls so contours plotted at back wall helps in understanding distribution well. The contours for heat flux at ceiling level and back wall level is shown in fig 5.1(b) and the temperature plots are shown in figure 5.1(c). The variations in the heat flux and temperature at different levels are observed. The peak heat flux fir ceiling is observed as 55kW/m² and 50kW/m²at back wall and peak temperature as 600^{0}C at ceiling and 550^{0}C at back wall.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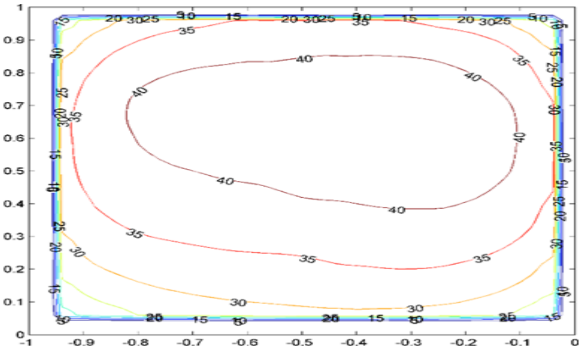
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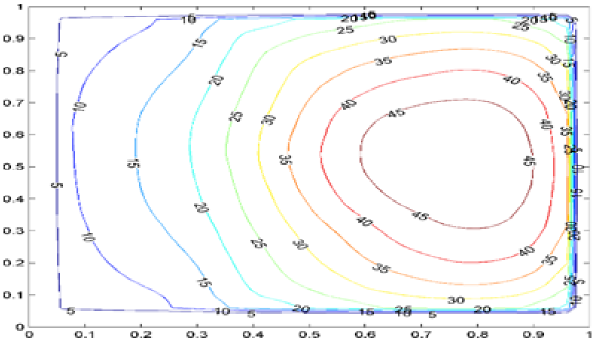
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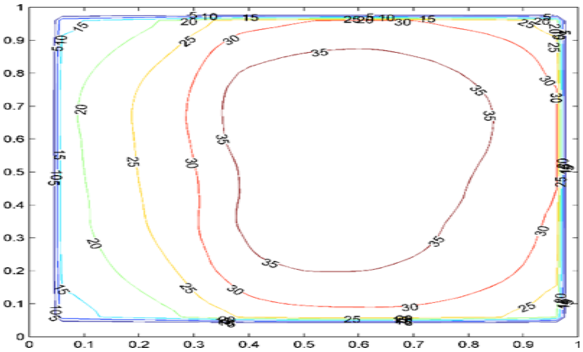
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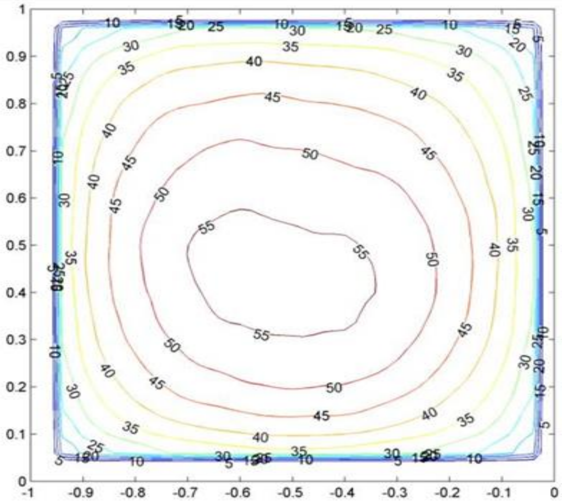
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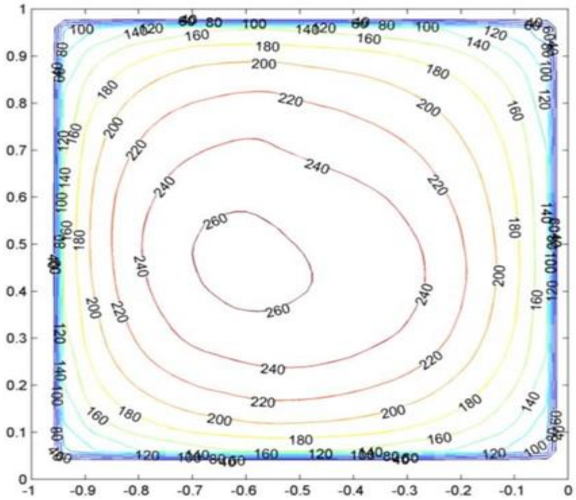
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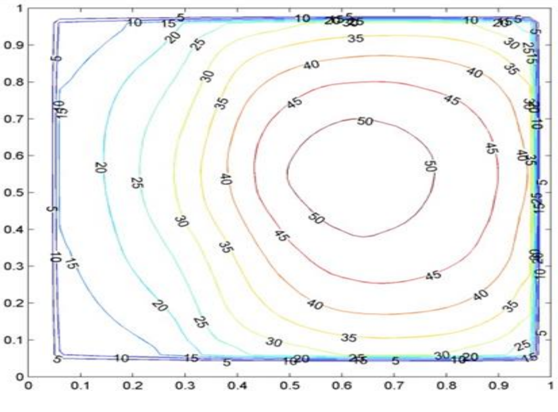
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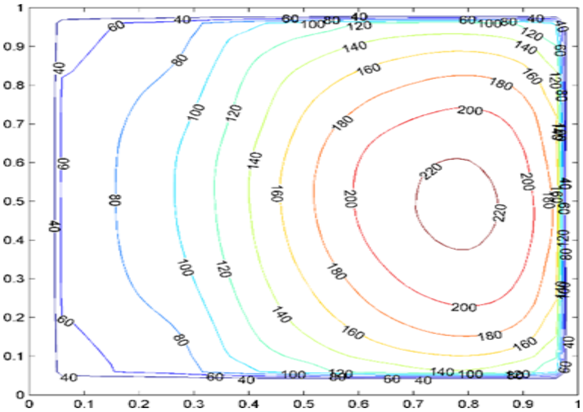
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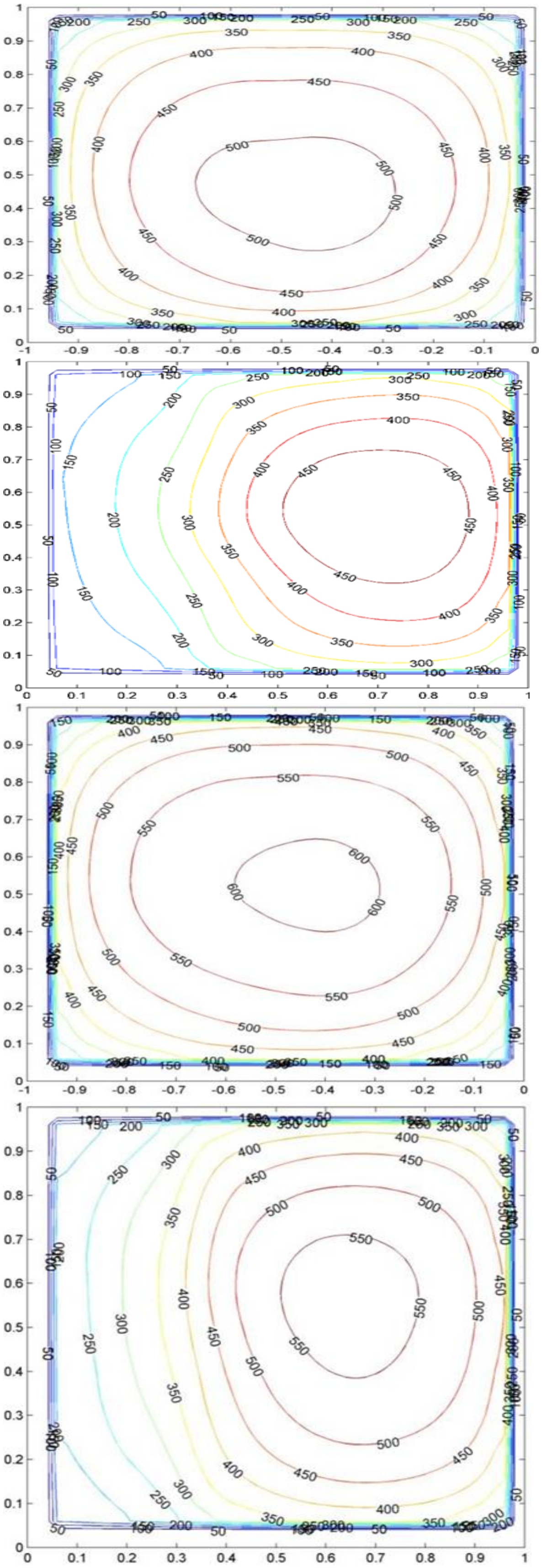


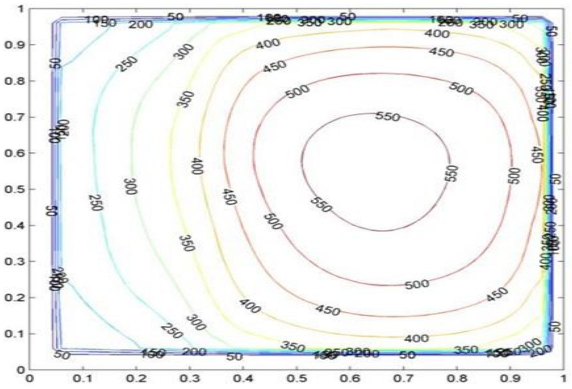


Fig:5.1(c): Temperature distribution contour at 30s 80s and 116s at ceiling (a), (b), (c) and back wall (d), (e), (f) respectively

The results predicted from the simulation shown in fig.5.1(c) helps to get a clear view of the flux distribution and temperature likely to occur in bigger fire scenarios. The fig5.1(c) shows the temperature predicted by simulation in the simulation model and flashover condition of the compartment modeled

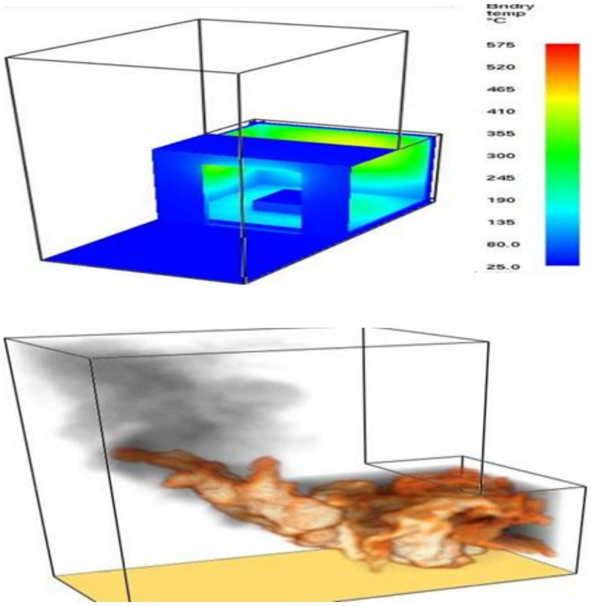
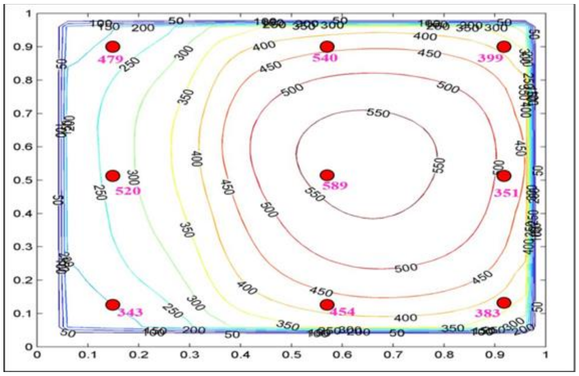


Fig 5.1(d): Heat flux and flashover results shown in simulation model at 42.6s

Temperature measurement

The ceiling temperatures are calculated from the thermocouples attached to the ceiling in the thermocouple experiment [3.2.3]. The temperatures measured through thermocouples are compared with the predicted temperatures obtained from the simulation of the experimental data [5.1]. The temperature obtained at the position of thermocouples are compared with the temperature contour at flashover stage for better comparison. The comparison of experimentally calculated temperature with the predicted temperatures of the simulation helps in understanding the ability of FDS in simulating the real case fire scenario. The experimentally calculated temperatures at various points are imposed on the simulated contours. The results show that simulated temperatures have good agreement with the experimentally calculated temperature at various points of ceilings. The figure 5.2(a) shows the compared results of temperature at the position of thermocouples.



● = position of

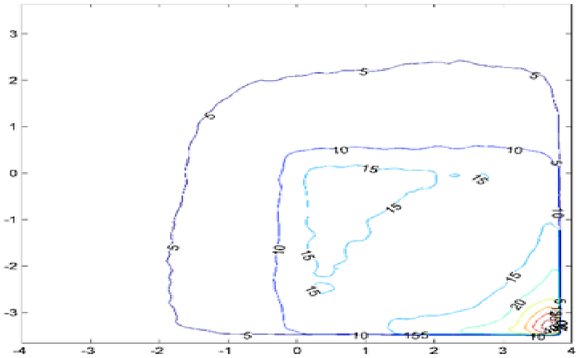
No: thermocouples with experimentally calculated values

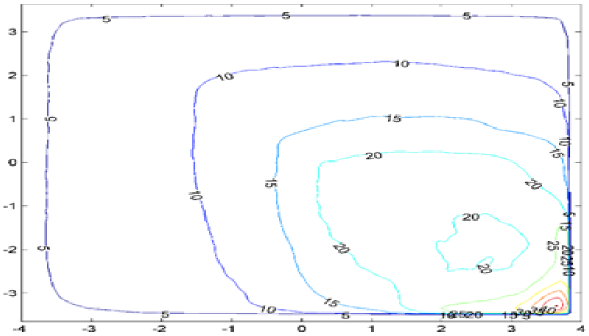
Fig: 5.2 (a): Comparison of simulated temperature contour with the experiment calculated data at flashover time

Simulated results and Discussion of Niu [22] scenario

The model is created for the F2 condition mentioned in the Niu's survey [22].The created model holds input parameters as mentioned in the simulation modeling [4.2]. The HRRPUA for the propane burner is taken as 1481kW form the fig.4.2.3(a). Due to the effect of interior linings the HRRPUA value is ramped for interior linings at 90s,244s,286s. But in the paper, it is mentioned as 120s,274s,316s, the reason behind the reduction in time levels while simulation was, it is clearly seen in the graph (shown in fig. 4.2.3(a)) the burner was considered to be ignited after 30s in experimental setup, hence the 30s error value in graph is deducted and the simulation duration is provided for ramping. By tuning the vent condition at proper time intervals helps in analyzing the contribution the interior linings had in the heat release of the enclosure. The HRRPUA for the vent condition is taken as 58kW and ramped accordingly for different time intervals. The interior linings fuel load given by different vent condition helps in predicting the temperature rise and flux distribution accurately. The flashover was observed at 286s in the simulation model which matches with the experimental results. The flashover model is shown in fig. 5.3(f). The predicted results of the simulation are compared with experimental results given by Niu [22] for validating simulation work. The contours are plotted using Mat-Lab for temperatures at ceilings and back wall according to the experimental results provided and compared for the accuracy. The fig5.3(a) shows the predicted heat flux at the ceiling. The fig5.3(b) shows the heat flux at the back wall. The paper considered here doesn't deal with the heat flux but the simulated heat flux is predicted for comparing it with the experimental simulation performed in [5.1]. The heat fluxes compared with the fig5.1(c) has good agreement with the values at flashover stage.

The predicted temperatures are compared with the experimental data for validation of the simulation and accuracy. The figure5.3(d) shows the comparison of temperature of ceilings at specified duration and Figure 5.3(e) shows the simulation model view. The back wall contours are compared with the simulation model for better accuracy and understanding is shown in fig 5.3(e).





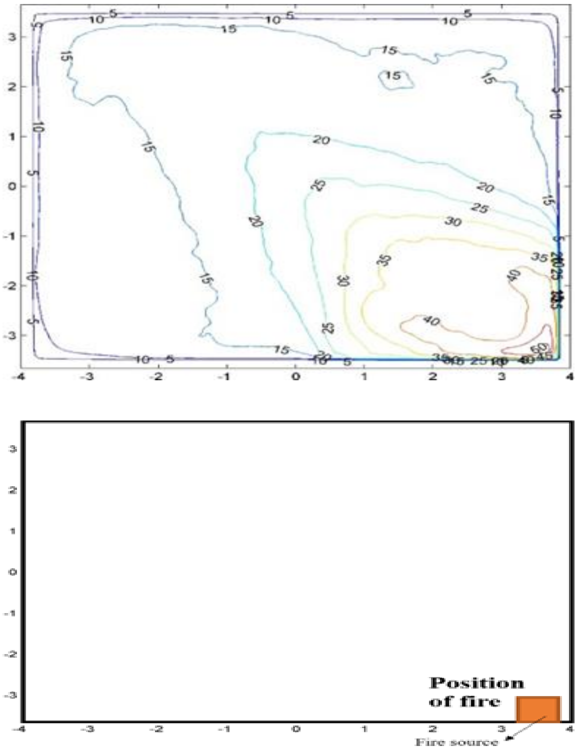
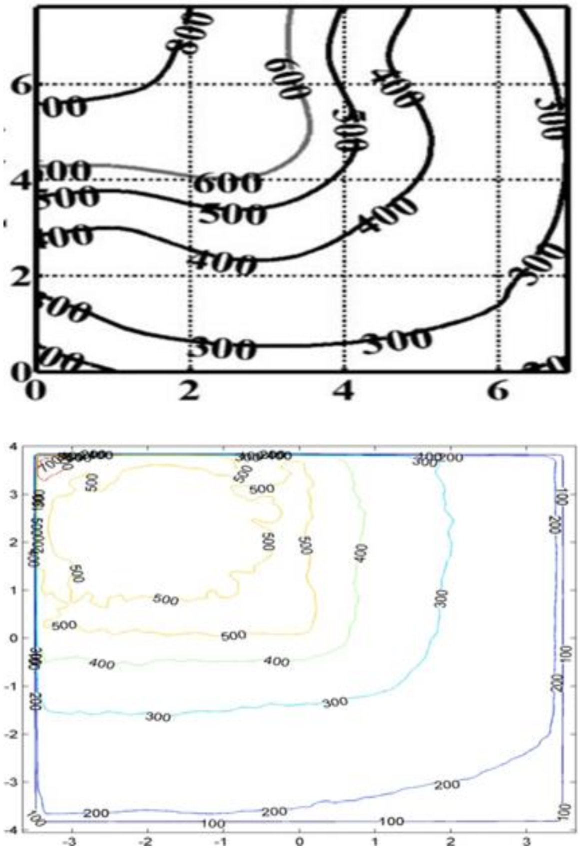


Fig 5.3(a): Heat flux distribution contour of ceilings at (i) 90s, (ii)244s, (ii)286 s respectively



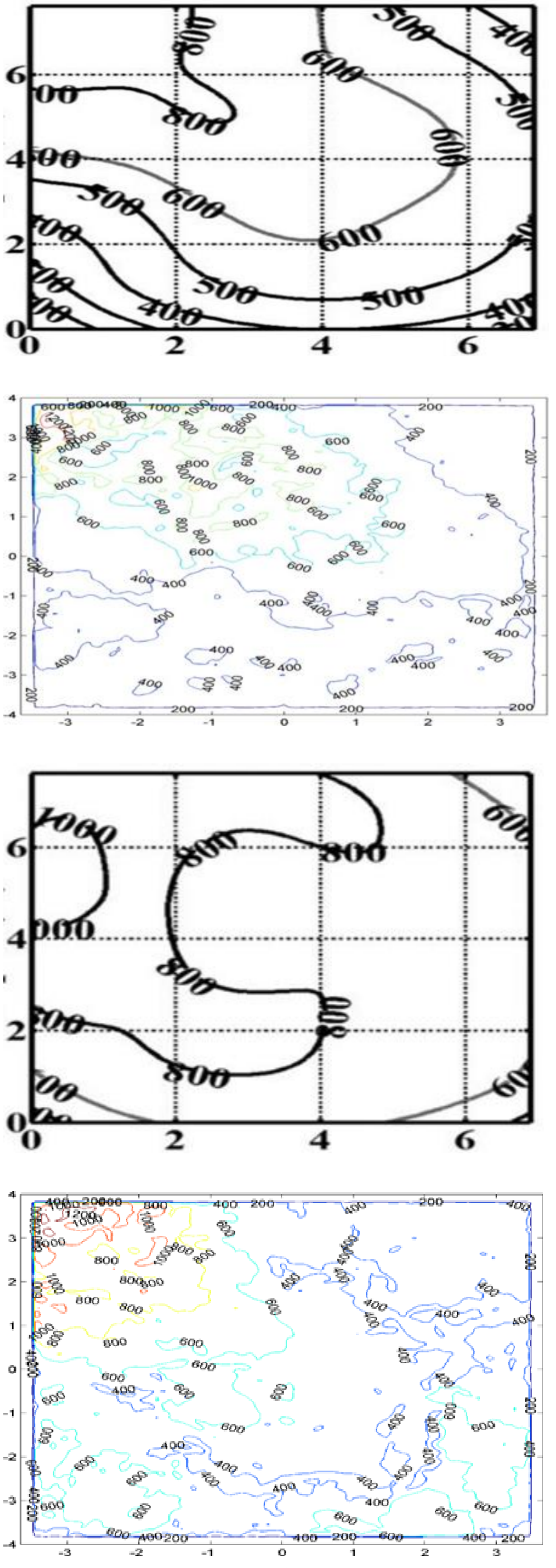


Fig 5.3(c): Comparison of temperature contour at ceiling level (i) 120s, (ii)274s, (iii) 316s

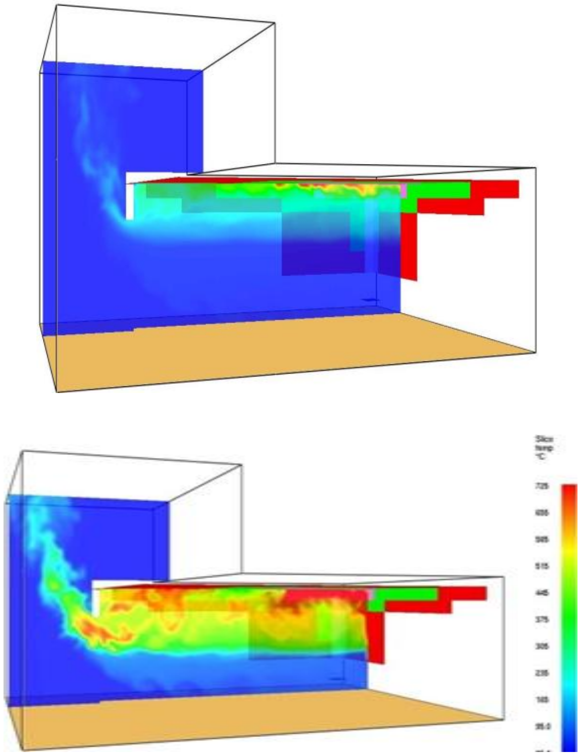


Fig 5.3(d): a simulation model of temperature at 90s and 286 s on the ceiling

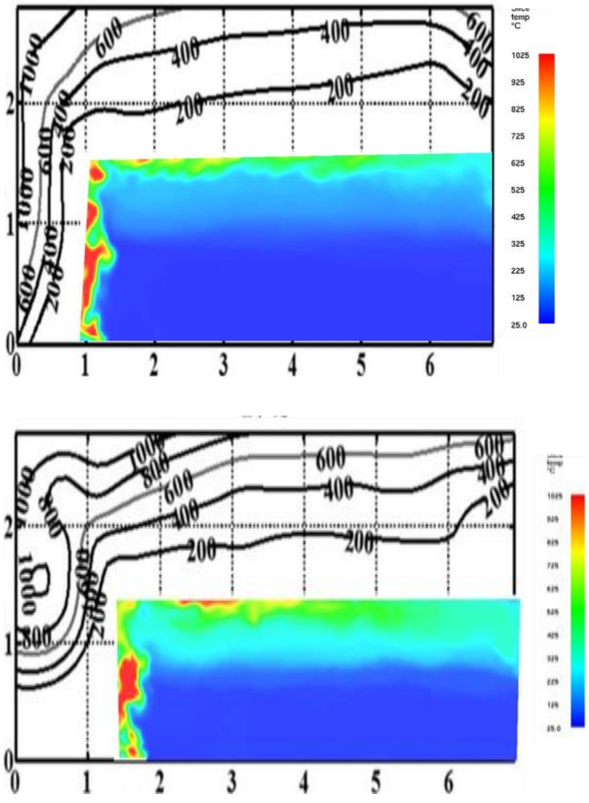


Fig 5.3(e): simulation comparison of temperature contours of the back wall at(i)120s (ii)274s

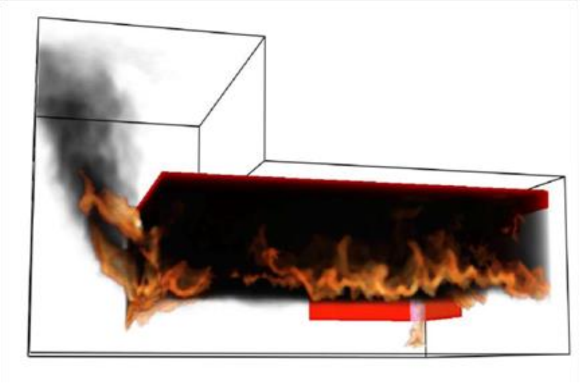
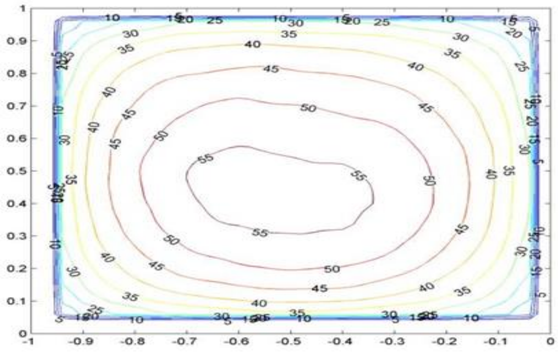


Fig 5.3(f): Flashover observed in simulation

From the comparison made at the ceiling and back wall level it is clearly seen the values obtained from the experiments have good agreement with the predicted simulated results. The ceiling temperature contour temperature ranges at 1000^0C at flashover which exactly matched with the experimentally calculated results and for back wall its shows 1025^0C which also exactly relates with the distribution in the experiments. The simulation images are kept for the understanding temperature distribution in the model. The comparison of the heat flux and temperature distribution stated a clear view in understanding, how a compartment fire scenario helps in the simulation of the bigger enclosure and its comparison. The temperature and heat flux results of both flashover apparatus simulation and bigger enclosure [22] seem to have a reasonable comparison in the distribution rate. The peak heat flux of the smaller compartment fire is 55kW/m^2 where as in Niu [22] scenario it is seem to 50kW/m^2. From this value, it is seen that the het flux of smaller room relates accurately with heat flux of bigger room. The difference in heat flux is, may be considered as the result of higher conductivity condition in the bigger room. Fig 5.3(g) shows the comparison of ceiling level heat flux at smaller room and bigger room simulation.



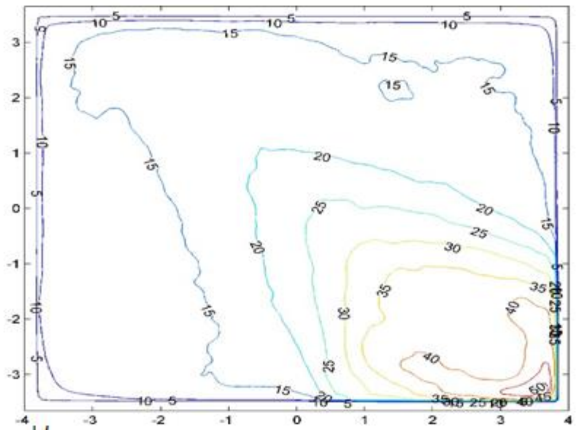


Fig 5.3(g) Comparison of heat flux (i) in experimental compartment fires and (ii) Niu [2scenario simulation

CONCLUSION

The comparison of temperature and heat flux contours show that FDS have good agreement with the experimental results. FDS appears to be an effective tool for studying smoke and fire distributions during fire events. Results from the study has effectively validated this aspect. Heat flux or temperature distributions on the wall will serve as a boundary conditions for studying flashover fires in building to identify its response at different stage of fire. The results show ideal conducting wall has higher surface heat flux compared to real wall. The conductivity and thermal response of the wall plays a role in the heat flux distribution on the wall. The heat flux calculated in the smaller room for ideal condition is 1.4 times higher than the conductive condition of the room at 500kW power provided uniformly for both the condition. This has confirmed wall with highly conductive nature will have lower heat flux distribution.The flashover occurred at 42nd second in both smaller fire scenario with 500 kW power and in larger fire scenario with 4300kW HRRPUA. The flashover occurred at mostly same time interval because in the larger fire scenario the peak HRRPUA was experienced or turned on at 244 second. So, the flashover duration for both the cases remain similar. This shows that how flashover depends on the room heat release rate and its temperature present in the enclosure, no matter what's the room size. The study of temperature distribution and heat flux distribution in the wall helps in understanding the time for flashover inside the enclosure.

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