NATIONAL WORKSHOP

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Indoor Fire Test Facility and the FDS Studies on them

CS Bhaskar Dixit and Prof. HS Mukunda

JGi JAIN DEEMED-TO-BE UNIVERSITY | FIRE & COMBUSTION RESEARCH CENTER

Overview

- Background
- Description of Facility
- Design Considerations
- FDS Studies
- Conclusion

Overview

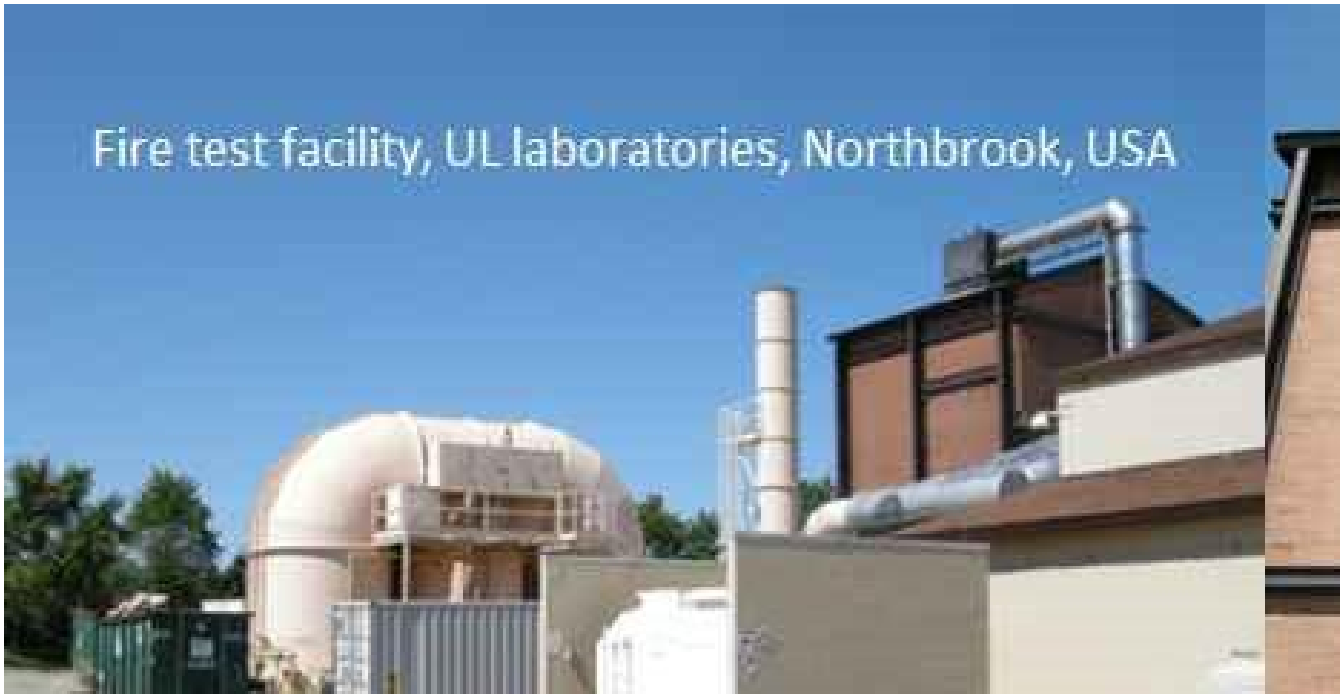
- Fire related products/equipment are generally meant for Fire Suppression or Fire Protection
- Fire protection products testing will involve exposure to specified t-T curves in Test furnaces
- Several global standards like NFPA, UL, FM, ICAO specify **standard test fires** (oil pool fires or wood crib fires) for fire suppression products ranging from few kW to hundreds of MW
- Based on practical experience highest indoor test fire size is limited to about 13 MW. Test fires larger than this are generally conducted outdoors
- Indoor facilities must have ample air supply arrangement to replace air transported out by test fire to prevent O_2 starvation

Let us examine a few indoor fire test facilities

Fire Testing Facilities

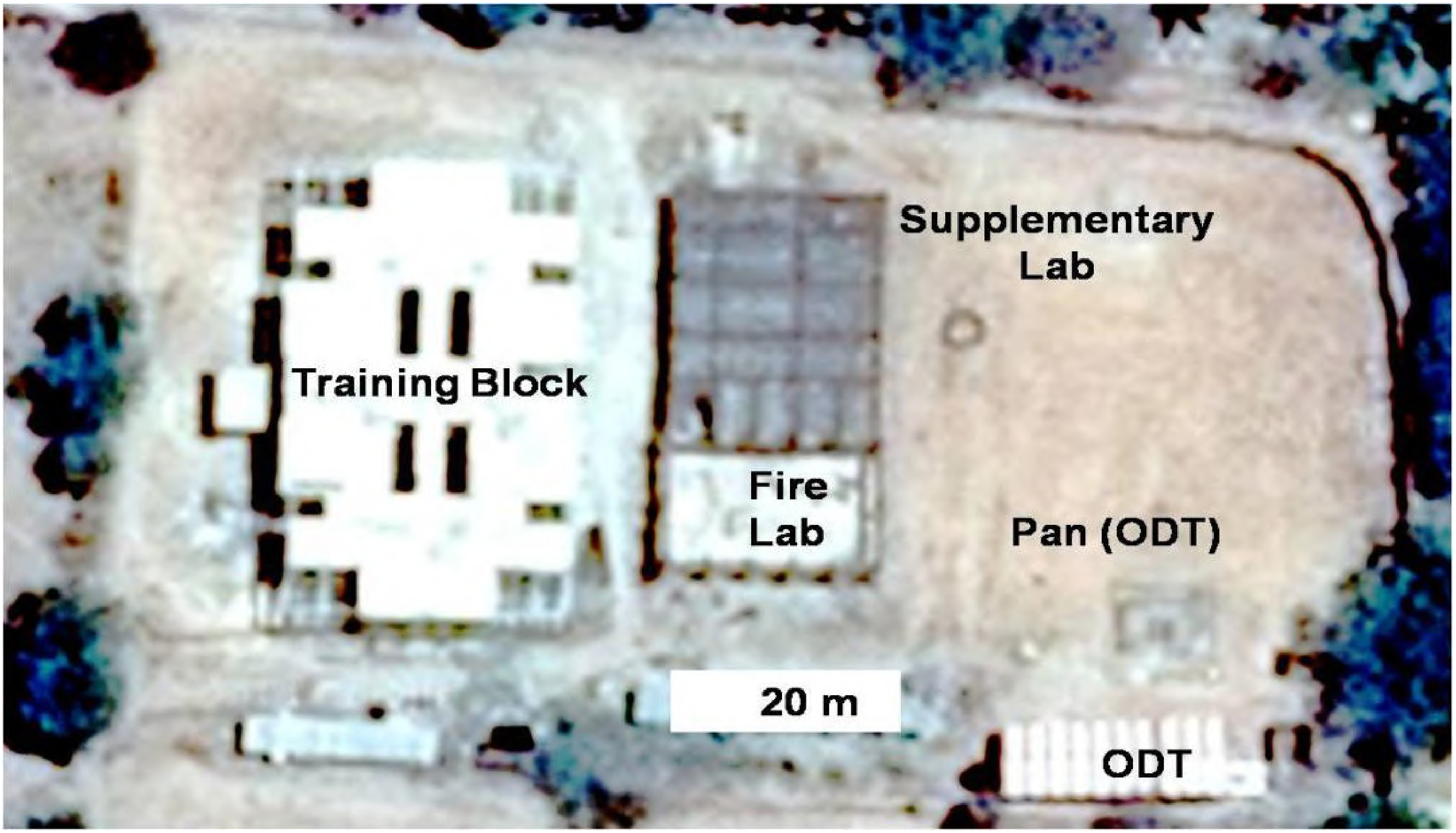
Facility	Size m x m x m	Vol. m^3	Air flow m^3/s	Use	Comments
UL, Northbrook	18 x 12 x 7	1425	13	Active fire suppression	Large mechanical ventilation
Waterloo, Canada	20x 17x12	4000	310	Aircraft fire Tests, R & D	Sloped roof
Murcia, Spain	20x20x17	6800	37	Fire R & D	Pyramidal roof, Large mechanical ventilation
Kosori, S. Korea	30x25x16	12000	-	Passive, active fire tests	
Hefai, China	22x12x27	7200	59	Fire R & D	Natural + mechanical ventilation
UL-JFL	18x12x11	2600	-	Active fire tests Fire R & D	Natural ventilation

UL Northbrook Test Facility

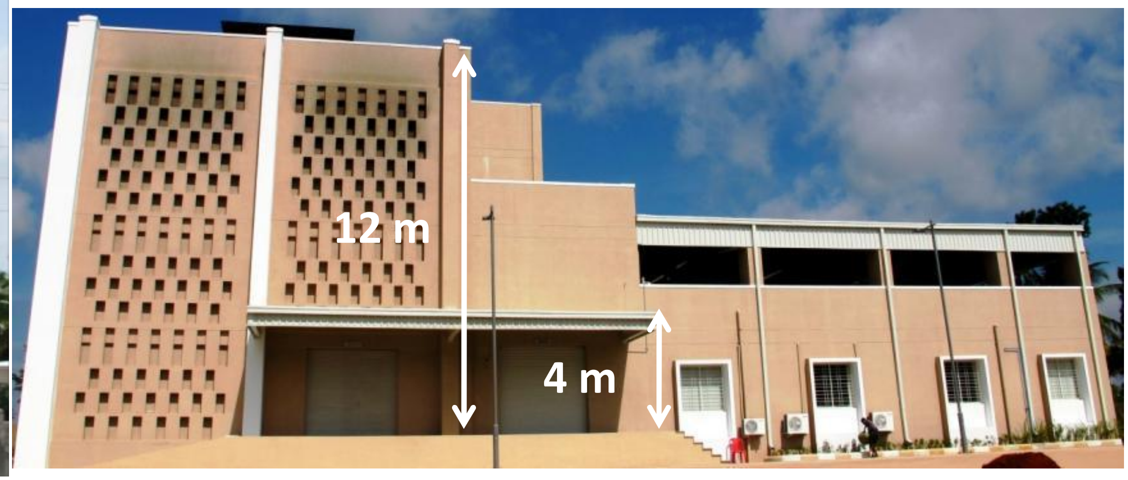


- In 2009 technical team from JGI visited UL Northbrook
- UL facility in Northbrook has roof mounted blowers to push air in..
- Largest indoor fire tested is Heptane pool fire of 2.1 m x 2.1 m size
- Mechanical Ventilation – if inadequate, smoke will fill the room
- **12 m^3/s Air supplied to 4 corners, Total blower power, – 250 kWe**
- **Now the JGI efforts…**

UL-JFL Bengaluru Under Construction



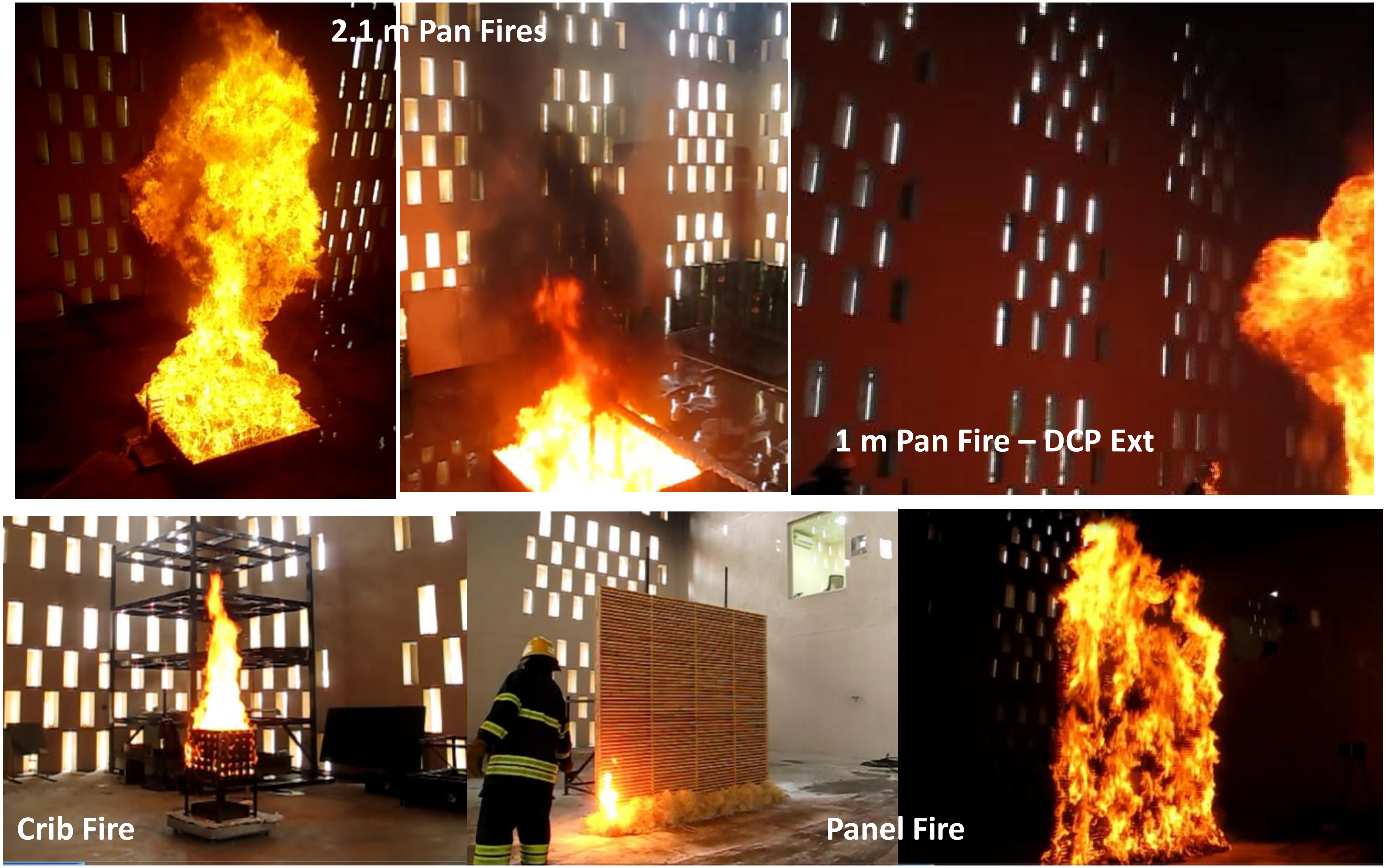
UL-Jain Fire Lab



- A fire test facility with 12 m high roof, central chimney and an adjoining extinguisher test lab was conceived and foundation was laid
- Subsequent to this discussions took place on ventilation requirements of the facility. The prohibitive investment and running cost of mechanical ventilation led to rethink and Idea of porous wall was explored
- A 3 sided porous wall configuration- conceived since adjoining extinguisher lab wall could not be porous due to architectural reasons

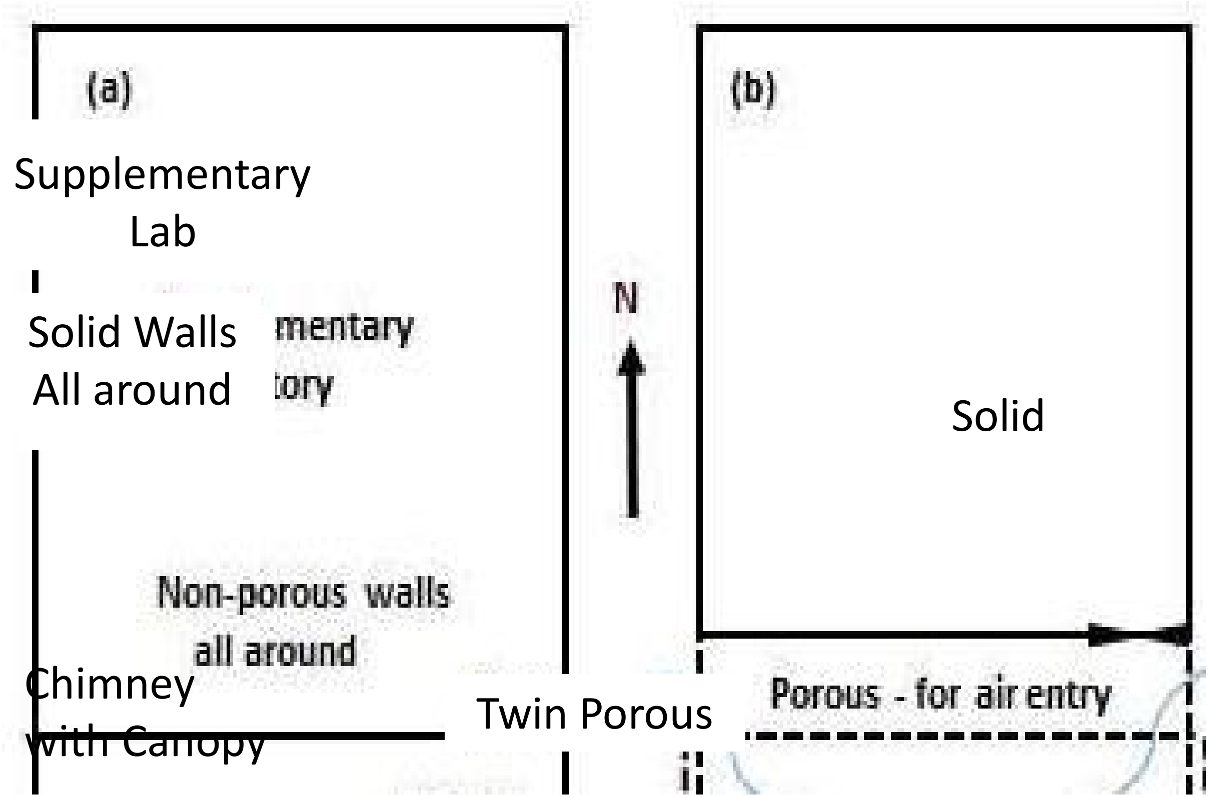
More about the design considerations..

Test Fire Images at UL-JFL



Design Considerations -1

- Outdoor Experience – Wind effects
- Basic design came from UL (Fig. a)
- Alternate design – 1 was 3 sides twin porous one side porous (Fig. b)
- Alternate design - 2 (Fig. c) was evolved to meet the requirements of management teams - North wall set out as solid
- **Will this create differential flows?**



- Is height of roof adequate to contain smoke?
- Will velocities be within acceptable limits?
- Are inside wall Ts detrimental to structure?

These are considered now……

Design Considerations - 2

- Roof Height: For a standard 2.1 m x 2.1 m n-heptane fire, the visible flame is below 4 m, the intermittent fire zone is below 6 m and the plume goes beyond. The height of the roof is set at 11 m - adequate with chimney above the pool fire and gases can also flow out of the porous walls

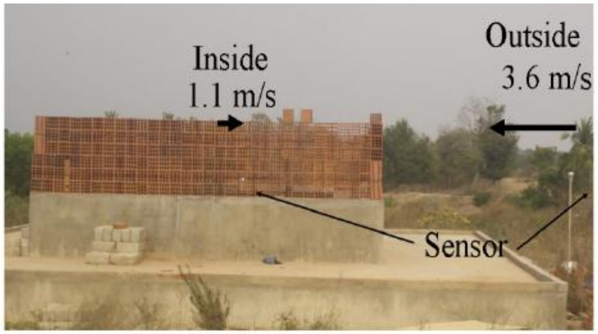
- Velocities: Estimate of transverse velocities obtained from Koseki and Yumoto (1988). For a 2.1 x 2.1 m pan fire, air entrained is 15 to 20 times the fuel flow rate at a height of 0.5 m. Measured burn rates peak to 0.3 kg/s in about 75 to 85 s. This leads to an air ingestion of 4.5 to 6 kg/s. If air is drawn from the side walls with a porosity of 50 % (say), then velocities into the inside fire bay will be 0.3 to 0.4 m/s and outside will behalf this value (because entry c/s is doubled)

What about gusts?...

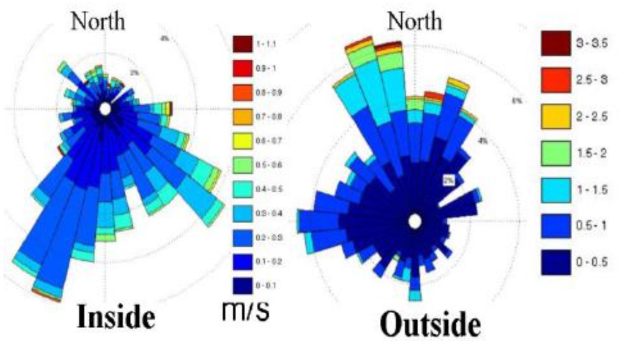
Design Considerations - 3

- Sonic anemometers in and out of a 6 m x 6 m enclosure used to measure wind velocities
- The porous wall structure able to bring about 3 fold reduction in peak velocities
- Outside values vary up to 1.5 m/s on the basis of a local mean, the inside the porous wall are about a third in the mean. The wind speeds close to the pan are clearly between 0.2 to 0.3 m/s

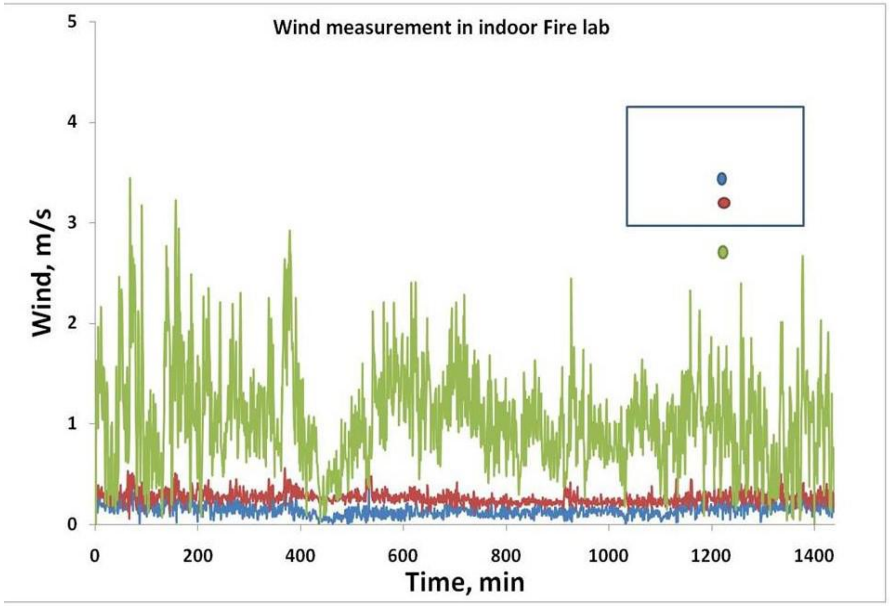
Effect of differential flows due to solid North is analyzed next



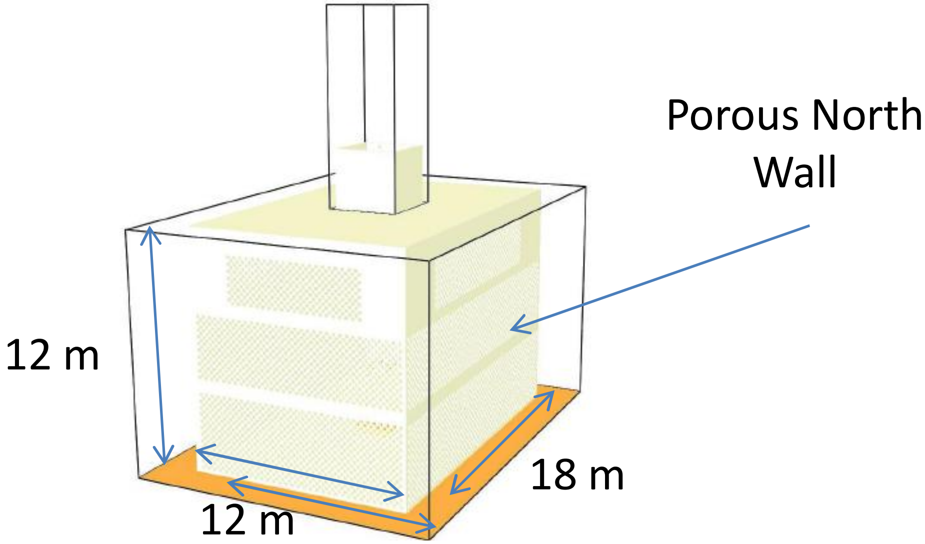
Wind Velocity Measurements

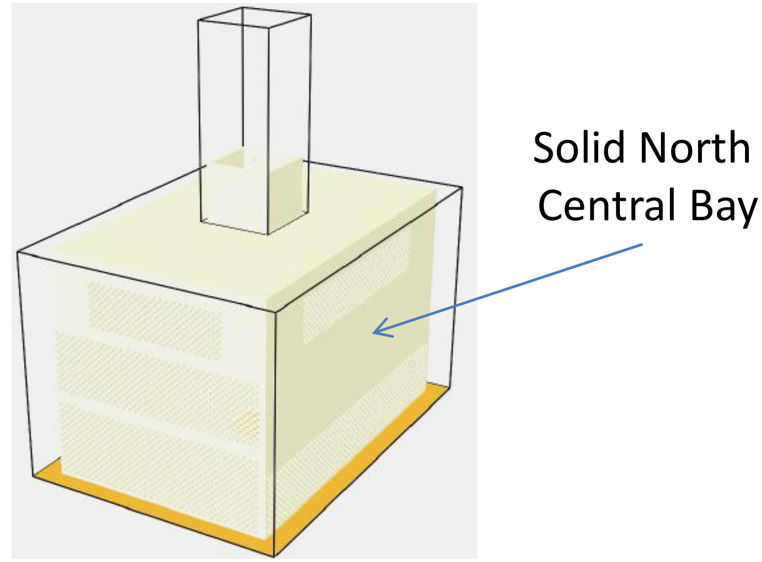


Wind Rose Diagrams



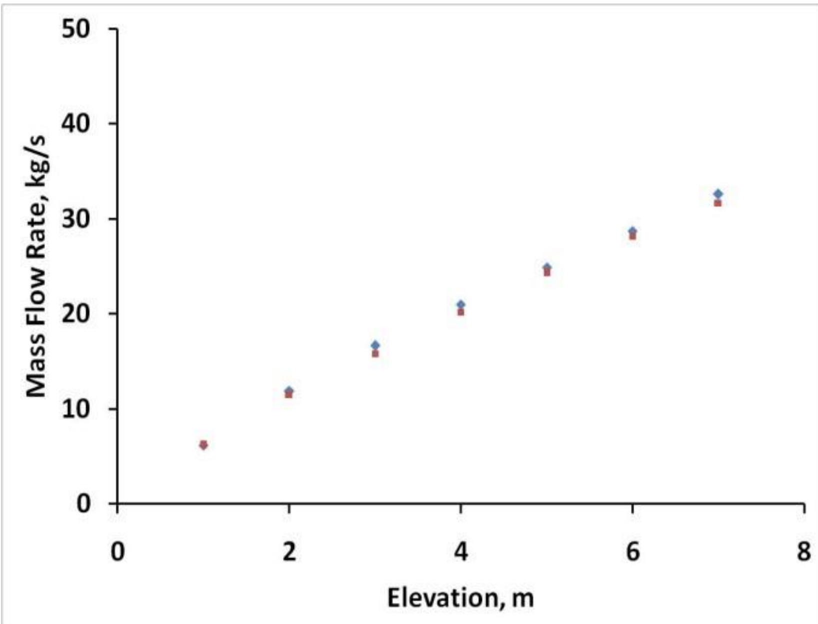
Fire Dynamics Simulator (FDS) Studies

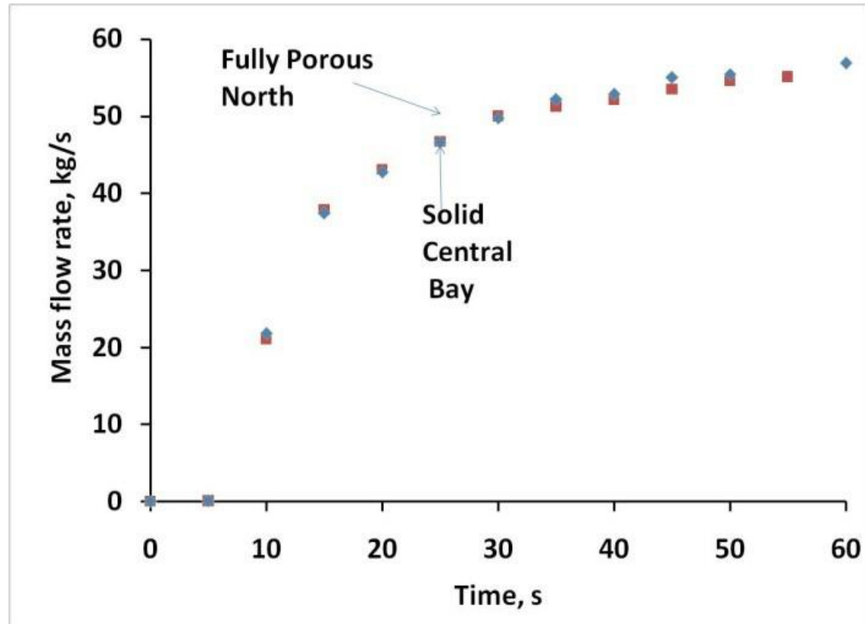




- To determine the differences between the North wall condition (porous or non-porous), it was necessary to make fire growth and flow calculations for the cases. FDS software was employed
- FDS release 6.2 (open downloadable software of NIST, USA) used
- Calculations are run on a mesh - 0.1667 m along *X* , 0.175 m along *Y* and 0.1667 m along Z - based on heat release rate criterion giving a minimum of 13 nodes across the pan with about a Million nodes
- A fixed 35% radiation fraction is assumed. Fire- modeled as HRRPUA of 3.178 MW/m^2 with peak heat release achieved in 50 s

FDS Studies - ṁ (mass flow rate)

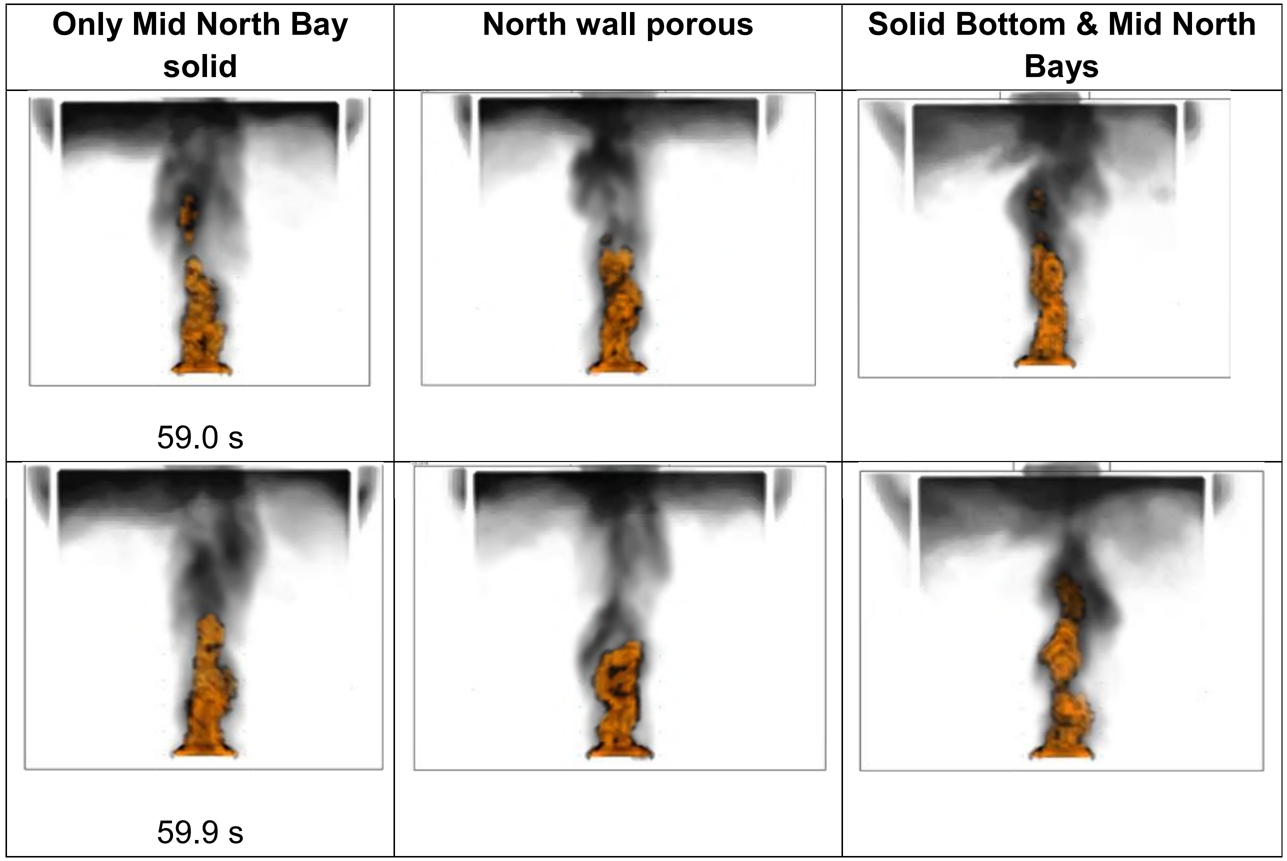




- 10 s average ṁ increases nearly linearly with height and reaches 33 kg/s at a height of 7 m when fuel burn rate is 0.280 kg/s (63.5 g/m^{2}s)
- The air flow rate - about 8 times the stoichiometric air flow needed.
- Air ingested at the exit ~60 kg/s, nearly double that of 7 m height
- It can be seen that fully porous North and solid central bay cases can be differentiated
- Dilution also helps keep the roof temperatures below 200 °C

FDS Studies – Inst. Images

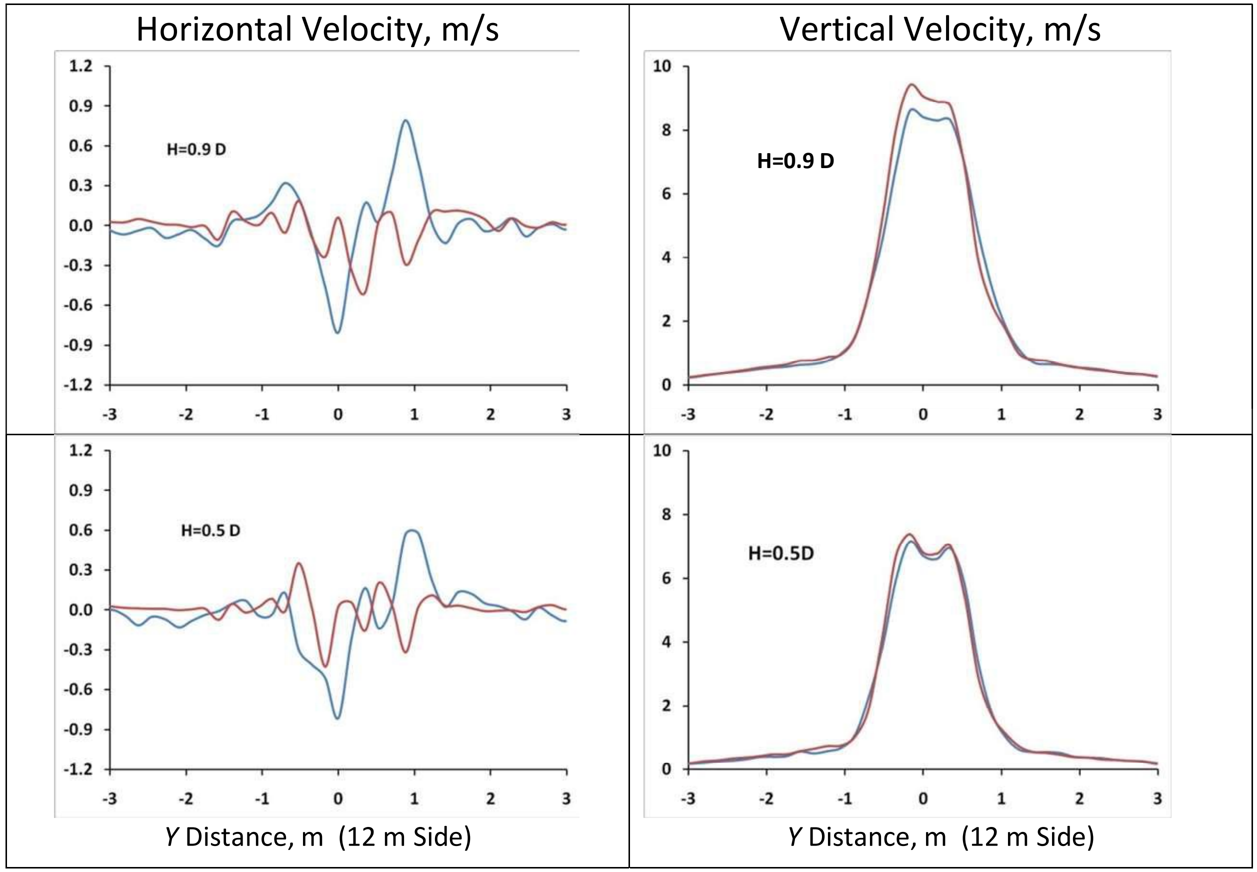
- The instantaneous pictures of the smoke and fire are set out in Figs
- The middle set of photographs refer to all side porous (case a)
- left refers to top and bottom segments of North wall being porous
- the right one for only the part top bay being porous (case b)



If we examine the pictures, it will not be possible to identify one or the other from them.

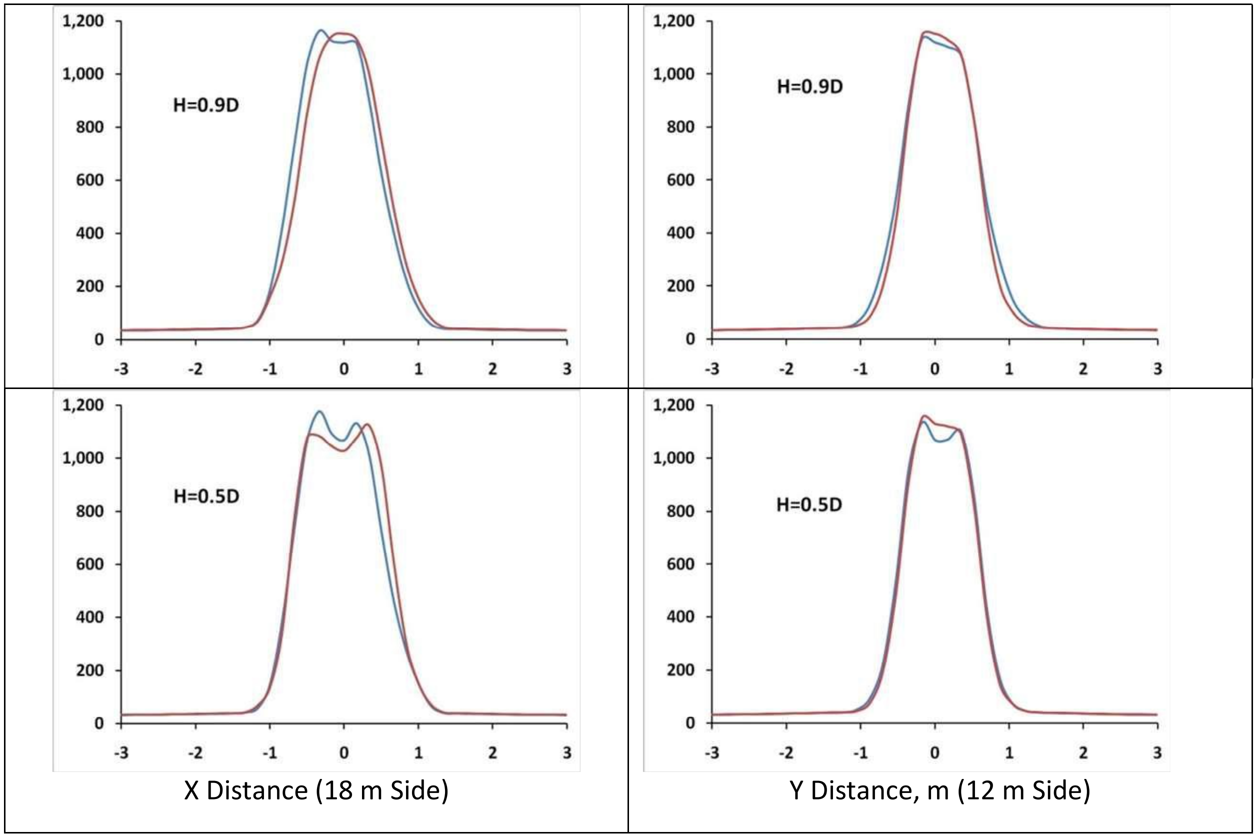
FDS Studies – Velocities

- H & V Vel along the 12 m side at two heights, 0.5 D and 0.9 D and at two instants of time – 59 and 60 s shown
- Blue lines -blocked central bay while red lines - fully porous North region
- The H. Vel small ~ ± 0.3 m/s.
- These values are comparable to those obtained by Xin et al (2008)



FDS Studies – Temperatures

- T distributions are presented in Figure 12. As can be seen, there is very little to choose between the two cases.
- Many more details of the flow and thermal behavior extracted to reaffirm the broad conclusion fire behavior is similar.



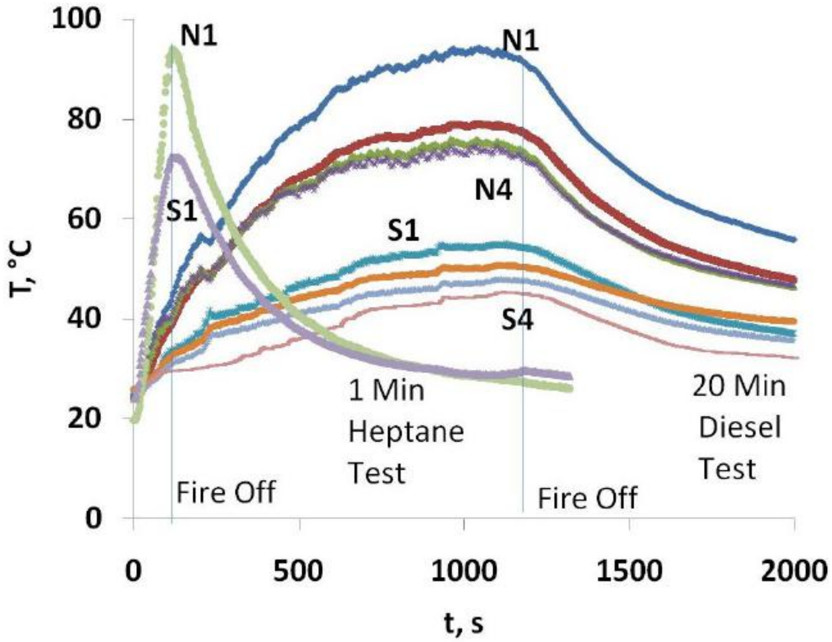
2.1 m Pan Fire: FDS – Expt. Comparison

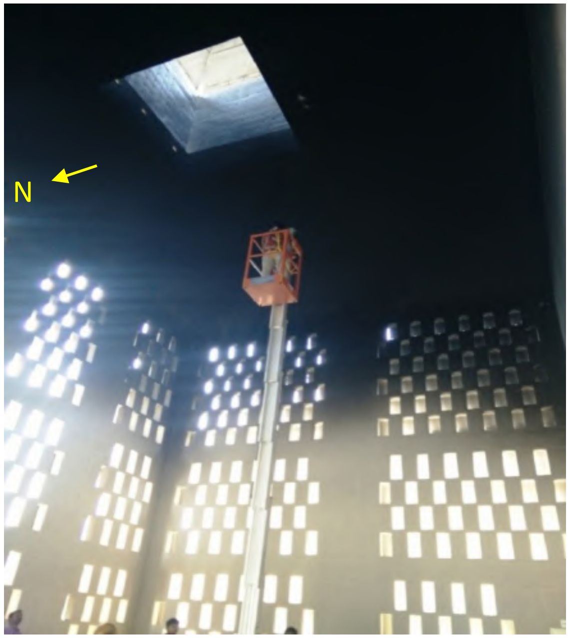
- After construction of the fire test lab in 2016, over 300 foam qualification fire tests with n-heptane and other tests conducted.
- In all the tests conducted under widely varying wind and rain conditions, the exhaust going from the top region was limited to a height about 1.5 m below the roof. This would leave a clear 9.5 m space for observations of fire during any tests.
- This result is in conformity with the FDS simulation results

Experimental Observations

- An interesting observation made during the tests was that the flame was vertical with the hot gases going upwards towards the exit over the forty-five seconds of a typical 1 min pre-burn expected of n-heptane tests.
- Beyond this period, the flame would bend towards north-west for the next fifteen seconds before the foam is switched on.
- This puzzling feature was inferred to be due to the north wall heating up to 60 to 65 °C while other three sides would go up to 50 to 55 °C.
- This temperature difference caused a buoyancy driven differential pressure drawing the fire towards the north wall.
- This feature could not be obtained in FDS simulations since they were completed before the fire facility was built and the wall heating was not simulated.

Studies on Roof T Distribution





- In order to determine the validity of the design from the view point of structural integrity, two experiments were conducted.
- The bottom region of the roof was instrumented with thermocouples at four locations on either side of the exit
- Two tests with measurement of roof top temperatures
- Peak temperatures reached do not exceed 100°C and the peak temperature lasts for a short time (~10 mins)

Conclusions -1

- Studies on a novel and new design of the fire bay of an indoor fire test laboratory are presented
- Free-convective exhaust of the product gases of fire was adopted - twin staggered porous wall design.
- The facility was tested for compliance of ambient wind disturbances and structural safety
- Wind speeds measured close to the pan was below 0.3 m/s and has been considered acceptable for all weather operation.
- Measurements of inner roof temperatures showed values up to 100 °C

Conclusions - 2

- FDS calculations up to 60 s showed that the fire was unaffected even if one of walls was made non-porous.

- Initial observations up to about 45 s followed this behavior; beyond that the fire had a tilt towards the direction of the wall. - inferred to be due to the wall heating leading to buoyancy driven pull that causes the bending over.

- A recommendation that emerges from this finding is that all the four walls of a rectangular fire bay should be made porous.

- A better solution would be to adopt a circular geometry or many-sided polygon (say hexagon or octagon)

Acknowledgments

- Grateful thanks is placed on record to Mr. Chenraj Roychand, Chairman, Jain Group of Institutions and Mr. M. S. Parswanath, the Director of facilities directly responsible for the construction of the fire facility.

- Without their trust in new approach, the expensive facility would not have been built.

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Thank You