Fire and Evacuation Modeling Technical Conference 2011
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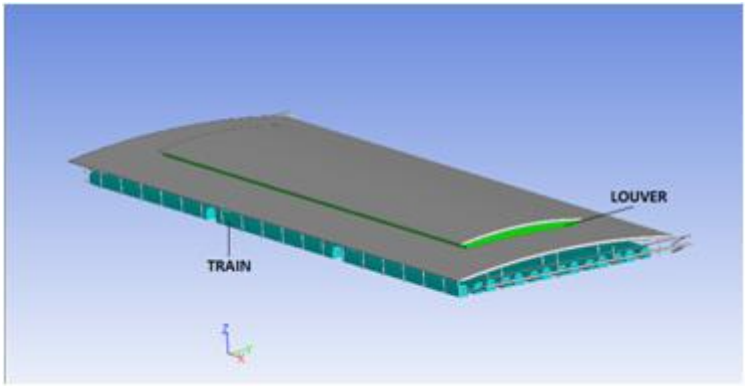
PERFORMANCE BASED FIRE ENGINEERING TO MITIGATE NON-COMPLIANCE IN EXIT PROVISIONS

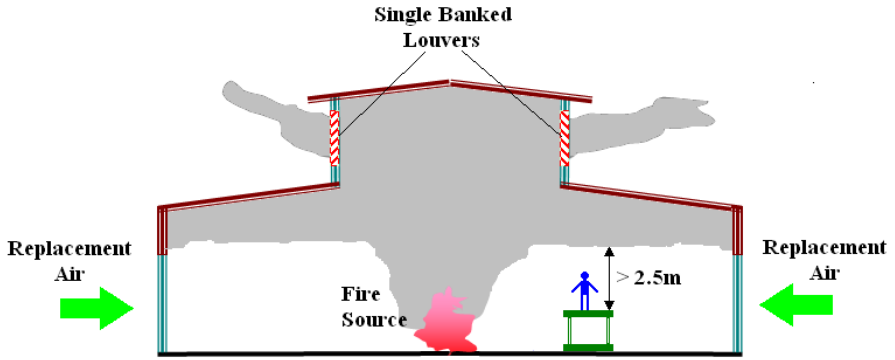
By Computational Engineering Solutions LLP

Performance Based
Fire Engineering in Singapore

- Land area ~ 712km^2
- Population density ~ 7,126people/km^2
- Central business district ~ 50km^2
- Numerous aging buildings Require major A&A works

Common Performance Based Fire Engineering Issues



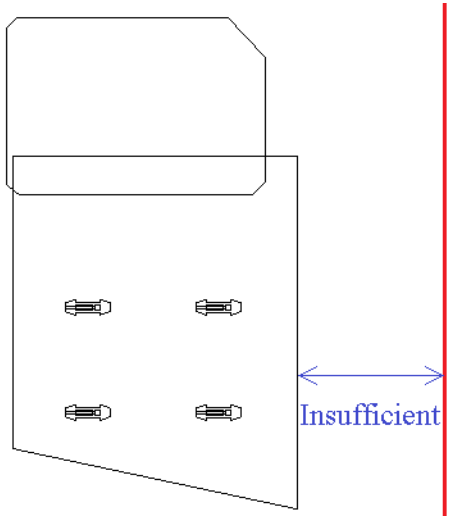


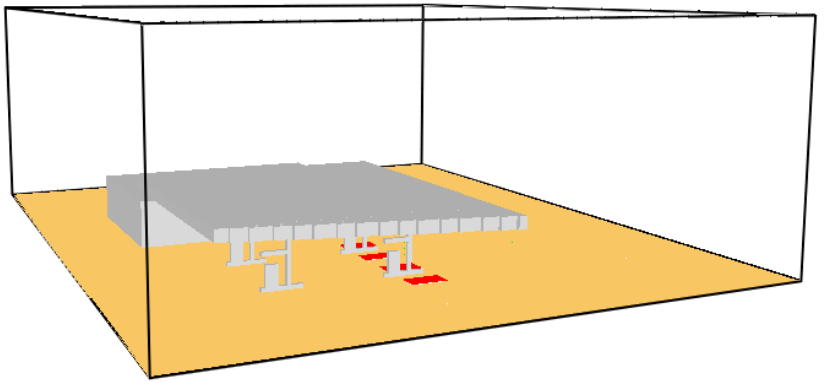
- Smoke Reservoir Size < 2000sqm / 2600sqm
- Smoke Reservoir Length < 60m
- If size ~ 20,000sqm, then up to 10 smoke control zones
- Numerous aging buildings Require major A&A works

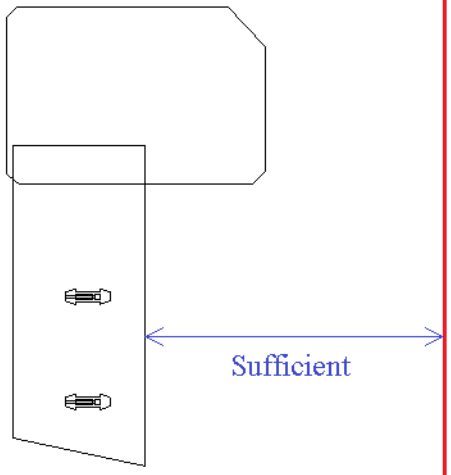
Common Performance Based Fire Engineering Issues

- Bare Steel Structure (process concern)
- Column next to fire deem to fail
- Conditions of neighboring structures assessed
- Structural analysis performed

Common Performance Based Fire Engineering Issues







- Insufficient set back distance
- Less dispensers possible
- Cannot maximize space and profits
- Proof that heat flux less than 20kw/m2

Change of Use…..

- Constructed in mid 80’s
- Below Grade Parking (2 levels below grade and 4 above grade)
- Basement level connected to underground rail system
- Large human traffic to basement level
- Large rental yield from F&B and Retail
- Insufficient escape provisions
- Cannot optimize space and profits

Change of Use…..

B1 Usage	Floor Area (m^2)	Usage Density (m^2 /person)	Required Occupant Load (persons)
Retail	2622	5	525
F&B	1951	1	1951
Super-market	1716	5	344
		Total:	2820

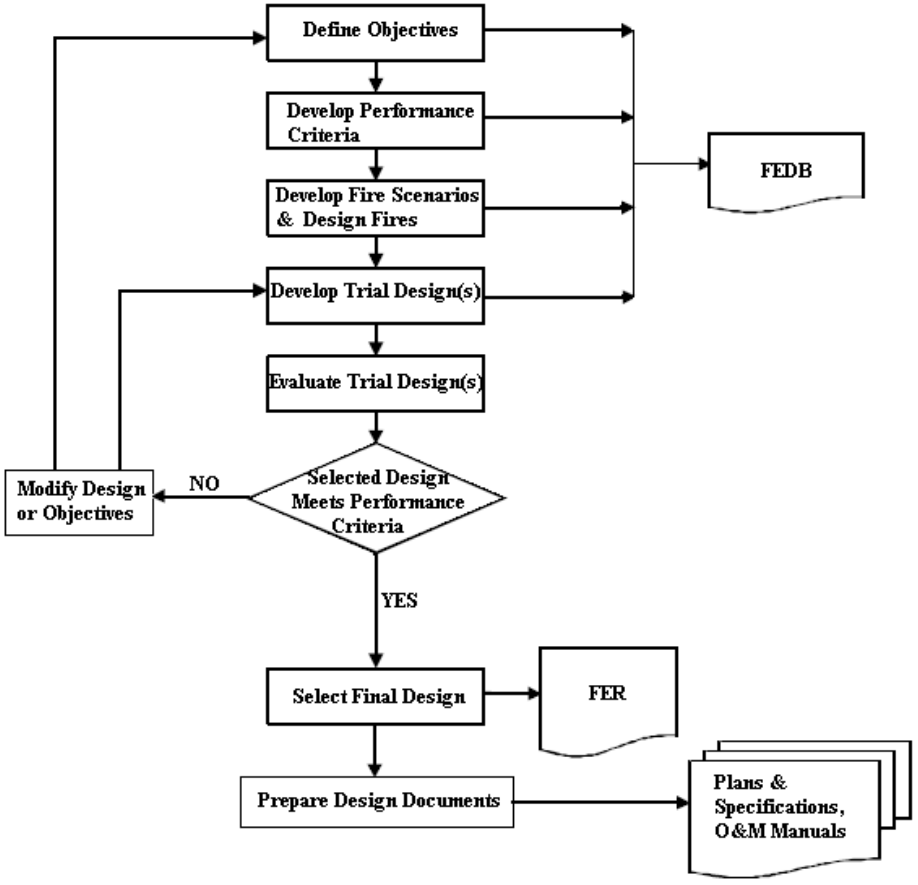
B2 Usage	Floor Area (m^2)	Usage Density (m^2 /person)	Required Occupant Load (persons)
Retail	973	5	195
F&B	2213	1	2213
Mech. Plant Room	270	30	9
		Total:	2417

Change of Use.....

	Unit of Egress Width (0.5m = 1 unit width)	Persons per Unit Width	Permitted Occupant Load (persons)
B1	12.5	60	750
B2	11.5	60	690

	Provisional Occupant Load (people)	Desired Occupant Load (people)
Basement 1	750	2820
Basement 2	690	2417

PBE Approach



Schematic of the performance based fire engineering study (Adapted from SFPE 2007)

Goals and Objectives

- Safeguard occupants from injury due to fire until they reach a safe place
- Safeguard fire fighters while performing rescue operations or attacking the fire
- Add internal escape paths (where possible) to maximize the number of occupants that can safely be admitted to Basement 1 and Basement 2

Performance Criteria

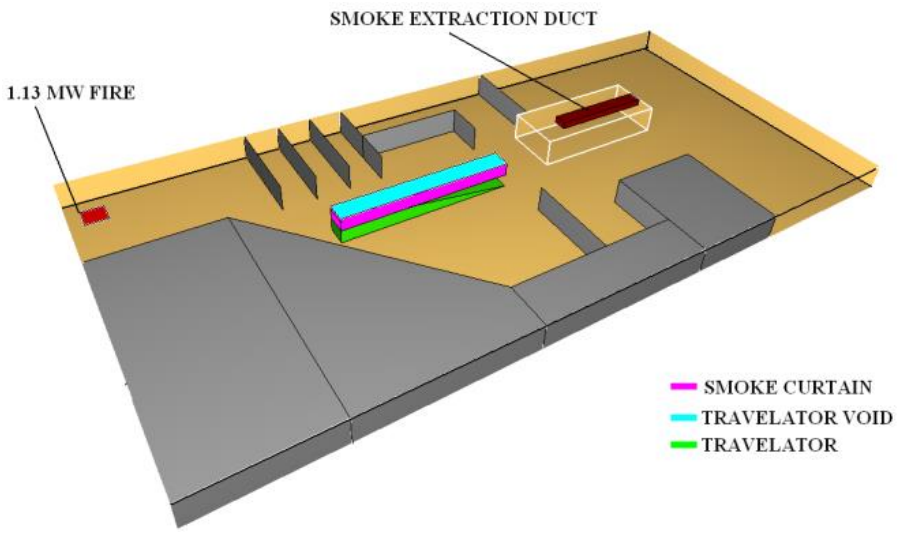
- In the event of a fire, visibility > 10 meters at 2.5m above finished floor level for the duration of the egress (i.e. ASET > RSET)

- In the event of a fire, temperature at 2.5m above finished floor level < 100^{o}C for the duration of the egress (i.e. ASET > RSET)

- The ASET must be at least 1.5 times of the RSET

Fire Scenarios

- For B1 (using DETAC-T2), maximum fire size of a fast t^2-fire is 1.5MW.
- For B2 (using DETAC-T2), maximum fire size of a fast t^2-fire is 1.13MW.
- Possible causes; electrical fault, unattended cooking, flammable stores, carelessly discarded cigarette butt, arson attack, etc.
- The Design Fire considered for B2 is a 1.13MW fast t^2-fire at the most remote corner of the floor and the burning material considered is PU

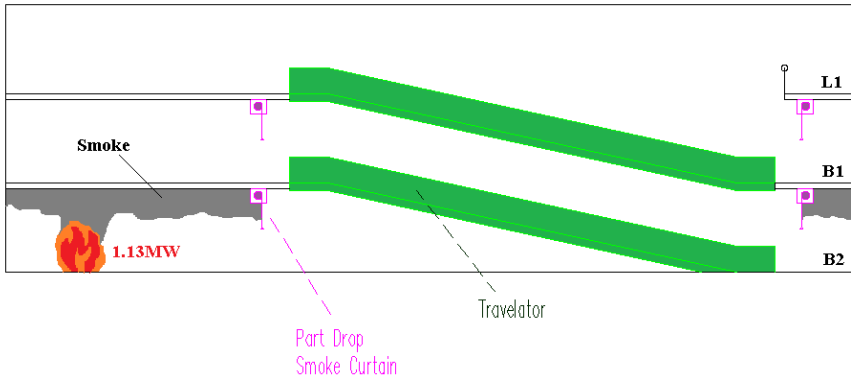


Fire and Life Safety Strategies

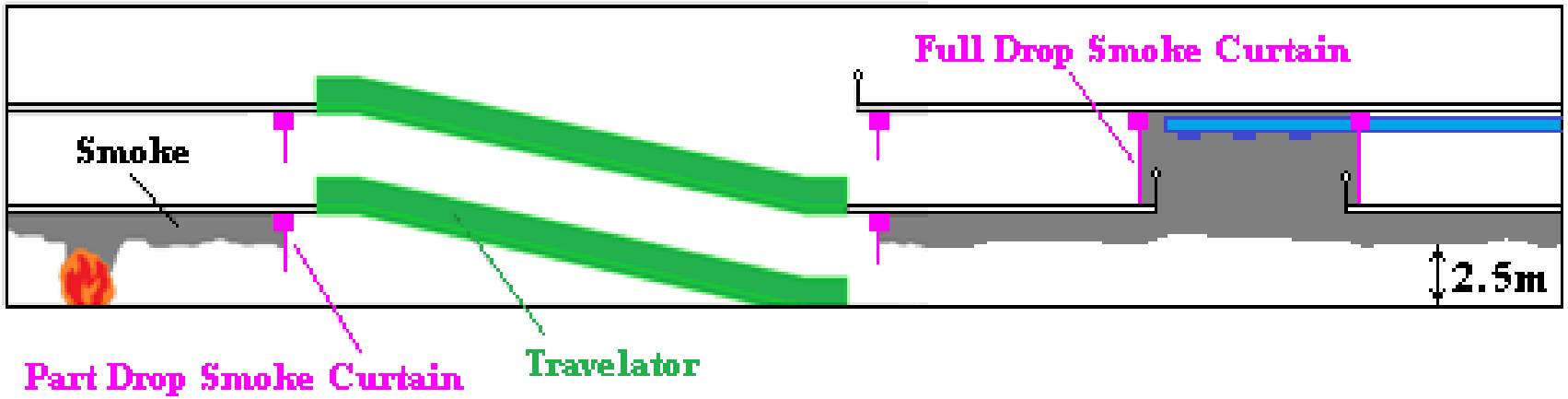
- Fire Detection and Notification
- Suppression and Fire Fighting
- Evacuation Control
- Compartmentation of Rooms
- Staircase and Lobby Pressurization
- Engineered Smoke Control of the entire retail mall
- Enforcement of No Smoking Rule
- No serving of alcohol within B1 and B2

Provision of Internal Escape Path

- Internal escape (e.g. an internal escalator) cannot be considered as an egress path
- Smoke from a fire may spill into the unprotected internal escape path
- Effective ESCS can keep internal escape path sterile
- Evacuees have to manually walk up the escalator, because the escalator would be shutdown (30° Slope)
- Escalator (30° slope) leading from B2 to Level 1 will be replaced with a gradually sloped travelator (12° slope)



Engineered Smoke Control System



- From BRE186, $M = 0.38PY^{3/2}$
- To maintain smoke layer above 2.5m, M = 18kg/s
- Activation of smoke detector will trigger the alarm as well as the engineered smoke control system

Evaluation of Trial Design - Evacuation Modeling

	B1 Occupant Load (persons)	B2 Occupant Load (persons)	Percentage of Provisional Occupant Load
1.	750	690	100% (Provisional)
2.	825	759	110%
3.	975	897	130%
4.	1050	966	140%
5.	1875	1725	250%
6.	2820	2417	376% (Desired)

- Evacuation timing of 100% to 376% of allowable occupant load
- Horizontal travel speed of 1m/s and vertical travel speed of 0.4m/s
- Manage Stakeholder expectations Case 1.avi, Case 2.avi, Case 3.avi

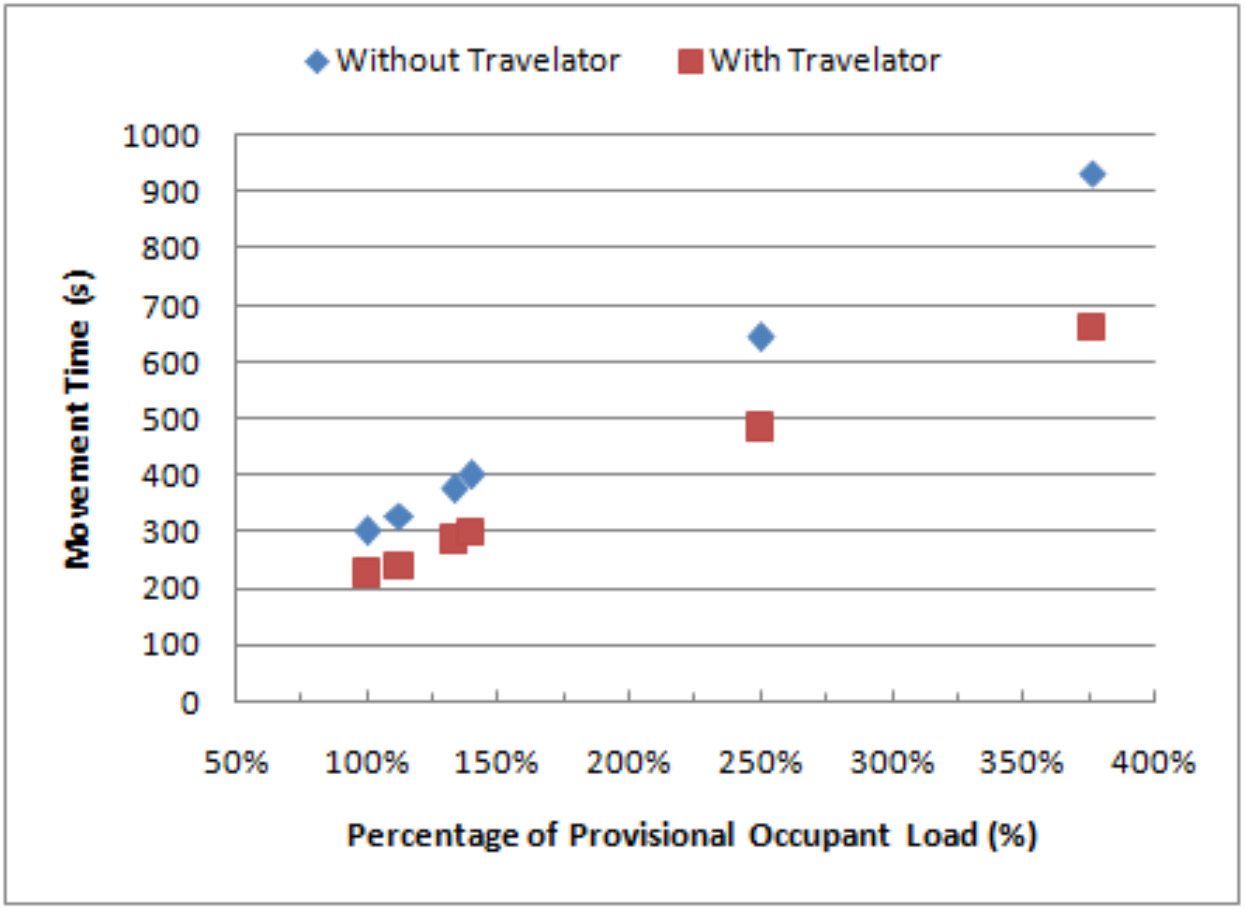
Evaluation of Trial Design - Evacuation Modeling

		Movement Time (s)	
	Percentage of Provisional Occupant Load	Without Travelator	With Travelator
1.	100% (Provisional)	300	227
2.	110%	325	241
3.	130%	370	279
4.	140%	392	298
5.	250%	643	484
6.	376% (Desired)	933	660

- The movement time of 140% of the provisional occupant load (with travelator) is the same as that of 100% of the provisional load (without travelator).

- So increasing the occupant load to 140% of the provisional occupant load, will not compromise the level of fire life safety (with an internal escape path / travelator).

Evaluation of Trial Design
- Evacuation Modeling

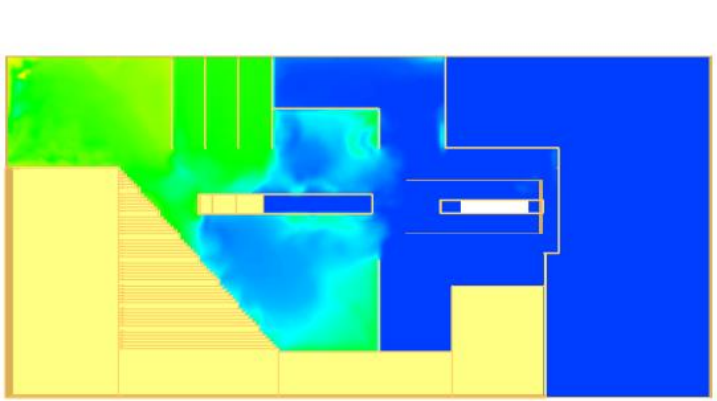


Evaluation of Trial Design - RSET

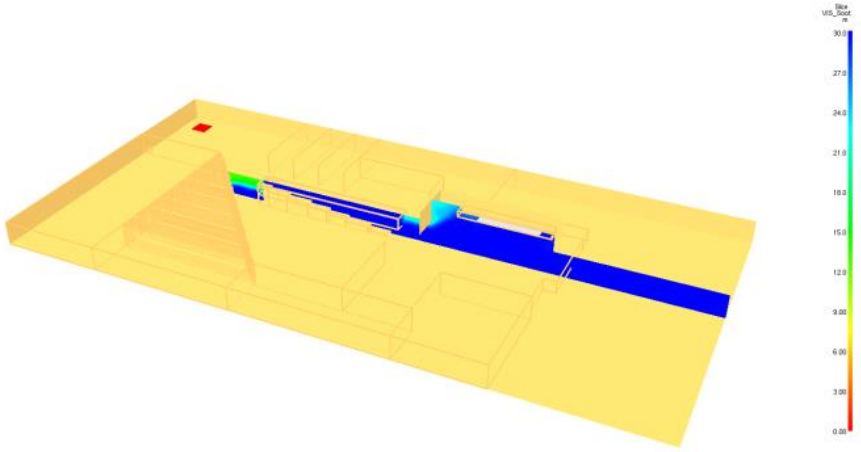
- RSET = (alarm activation time) + (pre-movement time) + (movement time)
- The Alarm Activation Time for B2 is 156s (from DETAC-T2) by sprinkler activation timing.
- Smoke detection timing will be much shorter (about 1-2 mins)
- From the database compiled by Fahy and Proulx, the maximum pre-movement or delay time recorded for unannounced drills in department stores with trained staff is 1.7mins. To add a degree of conservatism, the pre-movement time is taken as 120s.

		RSET (s)	
	Percentage of Provisional Occupant Load	Without Travelator	With Travelator
1.	100% (Provisional)	576	503
2.	110%	601	517
3.	130%	646	555
4.	140%	668	574
5.	250%	919	760
6.	376% (Desired)	1209	936

Evaluation of Trial Design - ASET

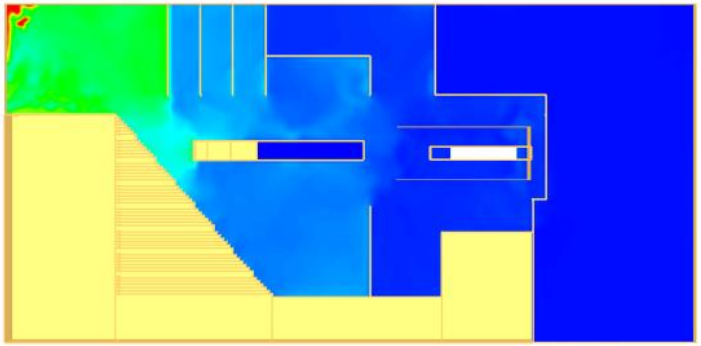


Contours of Visibility at horizontal plane 2.5m from the floor, at 20mins after start of fire.

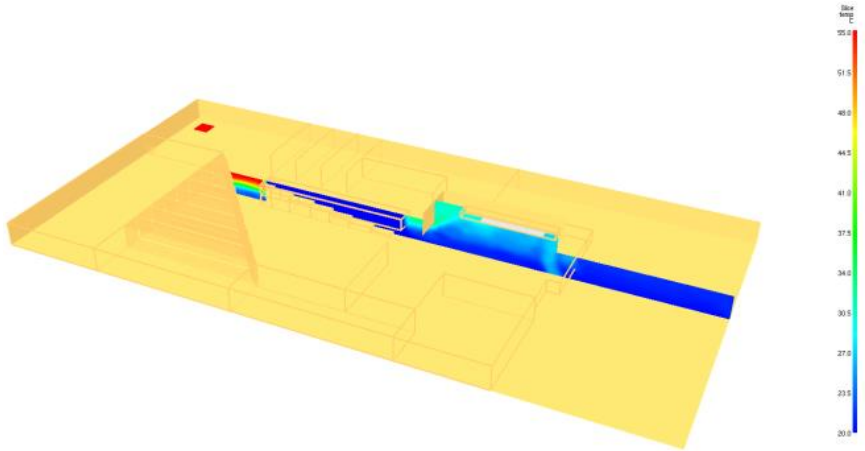


Contours of Visibility at vertical plane across travelator, at 20mins after start of fire.

Evaluation of Trial Design - ASET



Contours of Temperature at horizontal plane 2.5m from the floor, at 20mins after start of fire.



Contours of Temperature at vertical plane across travelator, at 20mins after start of fire.

- Fire products do not spill into the travelator void for at least 20mins
- ASET > 20mins

Evaluation of Trial Design - ASET vs. RSET

Percentage of Provisional Occupant Load	ASET (s)	RSET (s)	ASET / RSET
100% (Provisional)	> 1200	503	2.39
110%	> 1200	517	2.32
130%	> 1200	555	2.16
140%	> 1200	574	2.09
250%	> 1200	760	1.58
376% (Desired)	> 1200	936	1.28

- Fire Simulation for a 1.5MW at the most remote corner of Basement 1 (not presented in this paper), also gives an ASET > 1200s for B1

- According to Performance Criteria, ASET > 1.5 x RSET. So 250% of the Provisional Occupant Load for B1 and B2 is chosen as the Trial Design or Occupant Load (i.e. 1875 persons allowed for B1 and 1725 persons allowed for B2).

Critical Design Features

- All the Fire and Life Safety Strategies discussed above shall be implemented and maintained

- The area surrounding the travelator shall be strictly kept clear of any combustibles and obstructions. The usability of the travelator is critical in ensuring fire life safety

Conclusion

- The Performance Based Engineering Study of B2 and B1 has demonstrated that the proposed system is able to comply with the required performance criteria. Therefore, the increase of the occupant load (250% of provisional load) does not compromise the life safety of occupants.

- The ability to increase the occupant load allows the client to increase the amount of shops and F&B outlets in B1 and B2. This will potentially greatly increase their rental revenue.

THANK YOU