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Computer Simulation Investigation on the Effect of Channelled and Unchannelled Screens on Smoke Contamination in Atriums Upper Balconies

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Abstract. This paper performed the effect of installing channel screen on smoke contamination in the presence of 0.5 m deep down stand in a fire compartment. The results are then compared with smoke contamination occurrence when the channel screens were removed. The results showed that there will be 96% increase in upper balconies smoke contamination in an atrium when no channel screens at fire compartment opening are used. This work provides new correlation obtained from numerical study which can predict the smoke contamination height in upper balconies of the atrium in the presence of 0.5 m down stand and no channel screens. The proposed correlation will be useful design tool for building designer to design safe shopping malls (atrium).

1. Introduction

Smoke is recognized as one of the biggest threats to occupant of the building especially in atrium. Smoke has mainly three hazards which disturb the evacuation or even cause death of occupant in a building. These hazards include toxicity, visibility and thermal hazards.

Atrium is considered more dangerous as compared to any conventional building because atrium has open spaces between the floors. Smoke can easily spread from these open spaces and cause smoke contamination in upper balconies of the atrium. Every shop in atrium (shopping mall) does not contain channel screens at fire compartment opening. Harrison *et al.* [1] compared the air entrainment in between channelled screen installed at the opening of fire compartment with unchannelled screen fire compartment. They suggested that presence of channel screens can reduce the air entrainment of balcony spill plume by restricting smoke spread beneath the balcony. They also found that removal of channel screen will result in greater lateral smoke spread under the balcony.

Past research [1-2] did not study the effect of unchannelled screen on smoke contamination in upper balconies an atrium. Hasnain *et al.* [3] studied the effect of 0.5 m and 1 m deep down stand in the presence of channel screen (Figure 1c) at fire compartment opening. In this study, channel screens has been removed and its effect on smoke contamination in upper balconies of the atrium has been investigated. Therefore this paper compares the smoke contamination of upper balconies of the atrium with and without channel screens in the presence of 0.5 m deep down stand structure.

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2. Model Development

Five storey atrium with down stand depth of 0.5 m and no channel screen is studied by using CFD software, Fire Dynamics Simulator (FDS) version 5. Figure 1 shows the schematic drawing of atrium and fire compartment.

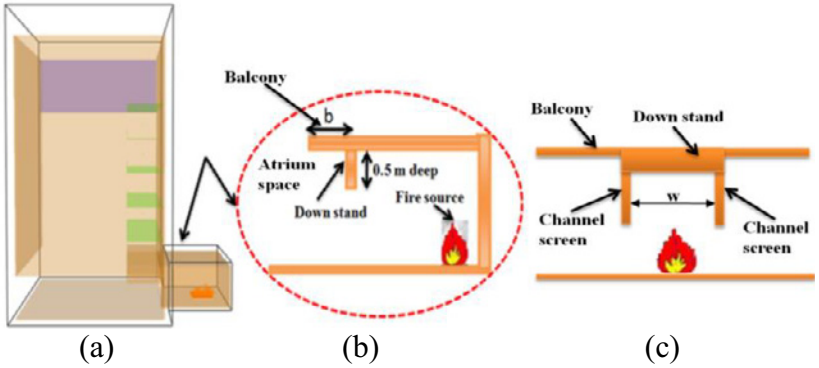


Figure 1: Schematic drawing of atrium and fire compartment (a) Side view of atrium, (b) Section view of fire compartment and (c) front view of fire compartment with channel screens

Mesh size of 200 mm has been used for all numerical study. This mesh size was selected by using the criterion mentioned by Harrison [4]. The total number of mesh elements in the atrium space and fire compartment is 2332800 and 81000 respectively. The criterion for mesh selection is given in equation (1) and (2)

$$n^* = \frac{D^*}{\Delta X} \geq 0.9 \quad (1)$$

$$D^* = \left(Q_c / w / \rho\, C_p T \sqrt{g}\right)^{2/3} \quad (2)$$

Where D^* is characteristic length of plume for determining the grid size (m), n^* is coefficient for determining the grid size, ΔX is grid dimension in x-axis, Q_c is convective heat flow layer below spill edge, ρ is air density at ambient condition, C_p is specific heat, T is absolute temperature and g is gravity acceleration.

The width of fire compartment w, heat release rate HRR, balcony breadth (b) has been varied in each numerical simulation but the depth of down stand is kept constant which is 0.5 m deep. a 4.8 MW design fire is used in this research which is considered acceptable based on previous research performed for fires in shopping malls in the presence of sprinklers fire protection system [5] therefore maximum heat release rate of is simulated in this study is 4.8MW.

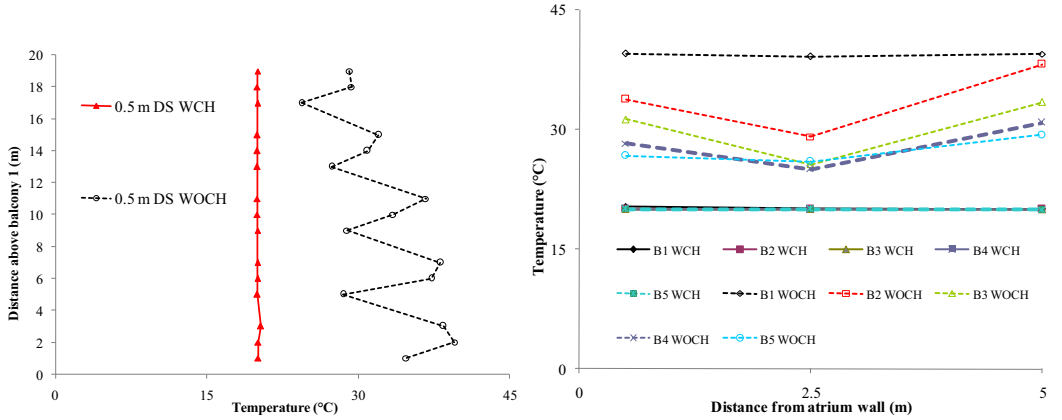
3. Results and discussion

Comparison between the effect of channel screens and unchannelled screens on smoke contamination in atrium upper balconies is explained. A correlation has been developed to predict the smoke contamination height without channel screens at fire compartment opening and compared with correlation which predicts smoke contamination occurrence when channel screens are used. The channelled screen correlation has been previously developed and published by Hasnain *et al.* [3]. In all numerical simulations, 0.5 m deep down stand has been used at fire compartment opening.

3.1. Comparison of Smoke Temperatures

Past research [2] showed that the smoke temperature can be used as one of the criterion to predict the presence of smoke contamination in upper balconies of the atrium by using FDS. If the smoke temperature inside the balcony reaches 10°C above ambient temperature, it shows that smoke is present inside the balcony. The same criterion has been used in this study to determine exactly the smoke contamination height.

During comparison between smoke contamination of channelled and unchannelled screen, it is shown that the smoke temperature along the edges of balconies and inside each balcony is 10°C to 20°C higher for unchannelled screens fire compartment in comparison with channelled screen. Smoke temperatures along the balcony for non channel screens is very high as compared to channel screens, which shows that there is more smoke contamination when the channelling screen were removed in atrium upper balconies. Figure 2 (a) shows that smoke temperature for non channel screen is higher than that of channel screens. In Figure 2 (a) temperature from 0.5 m deep down stand (DS) with channel screens (WCH) are compared with 0.5 m deep DS but without channel screens (WOCH).



(a) (b)

Figure 2: Smoke temperature (a) along the balcony edges and (b) inside each balcony

In Figure 2 (b) temperatures inside each balcony are shown and compared between with channel screens (WCH) and without channel screens (WOCH). Results showed that temperatures inside each balcony for WOCH are higher as compared to WCH. As an example, temperatures in balcony number 1 (B1) for WCH has temperature around 20°C but for WOCH temperature reaches around 43°C. This indicates that the temperature inside the balcony WCH is lower than WOCH.

3.2. Comparison of correlation

Visual observation of smoke temperature contours is used to predict the smoke contamination height in upper balconies of the atrium. A correlation has been developed to predict the smoke contamination height which indicates the clear height above balcony 1. Figure 3 shows that the comparison of correlations WCH and WOCH. Both correlations are developed in the presence of 0.5 m deep down stand.

In the correlation there are four variables *b, d, H,* and *w*. Height of smoke contamination *H* can be measured from visual observation of temperature contour while depth of the plume below spill edge *d* is taken from FDS results. Balcony breadth *b* and width of fire compartment opening *w* are atrium structural dimensions. Comparison of correlations showed that the smoke contamination height for WOCH configuration atrium would be low which indicates that there is more smoke contamination for WOCH atrium.

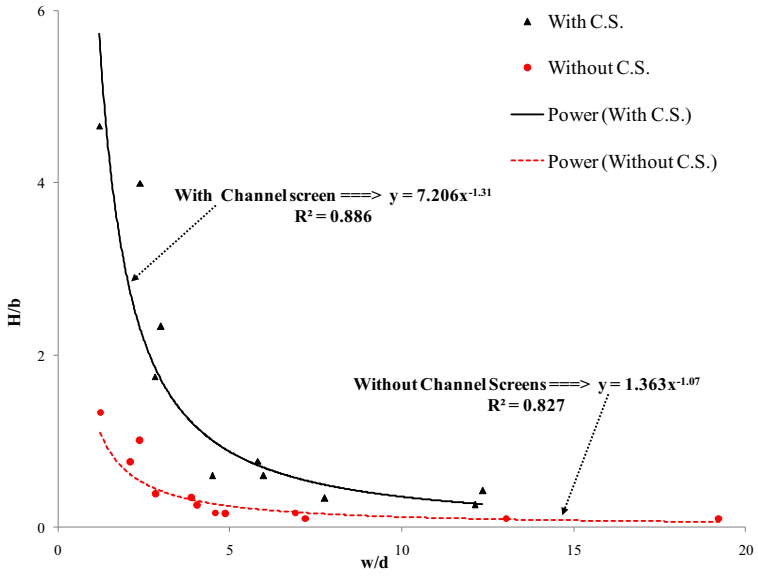


Figure 3: Correlation to predict the smoke contamination height

3.3. Comparison on smoke contamination

Table 1 shows that for all numerical simulation, there is significant increase in smoke contamination height for WOCH atrium. The maximum increase in smoke contamination between two configurations is found in case number 4 and 10, where the increase has been observed as 96.25 and 92.50 percent respectively. In most of the cases, the depth of the plume below spill edge is higher in the presence of channel screens at fire compartment but depths are equal for case number 11. The maximum difference in depth of the plume below spill edge is observed in case number 4 and 10 where the differences in both configurations (WCH and WOCH) are 59 and 36.67 percent.

Table 1: Comparison of depth and height of smoke contamination

Cases	b (m)	w (m)	WCH		WOCH		Comparison	
			H(m)	d (m)	H(m)	d(m)	Δd (%)	ΔH (%)
1	5	10	2.1	0.81	0.5	0.52	35.80	76.19
2	5	10	1.3	0.825	0.5	0.768	6.91	61.54
3	5	6	3.0	1.005	0.5	0.834	17.01	83.33
4	5	2	20	1	0.75	0.41	59.00	96.25
5	3	8	1	1.032	0.5	1.162	11.19	50.00
6	3	6	2.3	1.337	0.5	1.317	1.50	78.26
7	3	4	7	1.34	1	1.03	23.13	85.71
8	2	6	1.2	1.425	0.5	1.481	3.78	58.33
9	2	4	3.5	1.52	0.75	1.4	7.89	78.57
10	2	2	20	1.5	1.5	0.95	36.67	92.50
11	1.5	4	6	1.68	1.5	1.68	0.00	75.00
12	1.5	2	7	1.847	2	1.639	11.26	71.43

4. Conclusion

In this paper, CFD simulation study is carried out by varying different parameters including width of fire compartment, balcony breadth and heat release rate to compare the effect of unchannelled screen fire compartment with channelled screen fire compartment on smoke contamination in upper balconies of the atrium. A correlation has been developed which predicts the smoke contamination height for no channel screens in the presence of 0.5 m deep down stand at fire compartment opening. Then correlations from WCH and WOCH are compared with each other. The following conclusions prevail:

- The absence of channelling screen cause the plume to move in lateral direction along width of the balcony, which cause more smoke contamination in upper balconies of the atrium.
- In case of unchannelled screen fire, there is severe increase (up to 96 percent) in smoke Contamination in upper balconies of the atrium.
- Channelling screens should be used in the shops of shopping malls to reduce possibility of smoke contamination in upper balconies of the atrium.

References

1. R. Harrison and M. Spearpoint, Build. Ser. Eng. R. and Tech., 31(3), 265-277, (2010).
2. C. L. Ho, Fire Eng. Res. Rep., University of Canterbury, (2010).
3. S. A. Hasnain, M. S. Nasif, W. Pao and R. Al-Waked, App. Mech. and Mat., Vol. **465-466**, pp. 480-484, (2014).
4. R. Harrison, PhD thesis, University of Canterbury, (2009).
5. H. P. Morgan, B. K. Ghosh, G. Garrad, R. Pamlitschka, J-C De Smedt and L. R. Schoonbaert. Des. meth. for smoke and h. ex. vent., London, UK: CRC., (1999).