SHORT NOTES ON INTERNAL VOIDS IN HIGHRISE BUILDINGS: ARE THEY SAFE IN A FIRE?

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ABSTRACT

Internal voids are now commonly found in new highrise buildings. There are concerns on fire safety associated with their design. Two aspects are pointed out in this short note:

- Fire aspects of a room such as kitchen or bathroom opened to an internal void.
- Spread of smoke from the fire level to adjacent levels.

Fire models including Computational Fluid Dynamics are used for the analysis. Preliminary results indicated that further studies, including full-scale burning tests, should be carried out to investigate the potential fire hazard.

1. INTRODUCTION

Natural lighting and ventilation should be provided for every room used for habitation in a building as required in the local Building (Planning) Regulations Cap. 123F Part IV [1]. One or more windows have to be constructed in every room. This gives lots of constraints on the architectural features, say blocking good harbour views for some units. A new trend in the flat layout is to put in an internal void where kitchens and bathrooms of every storey are opened to.

However, there are concerns on the fire safety aspects. At least two points should be considered [2]:

- Likelihood of flashover in a room opened to an internal void and the amount of smoke flowing out.
- Spread of smoke from the fire level to adjacent levels.

2. FIRE ASPECTS IN A ROOM OPENED TO AN INTERNAL VOID

Combustibles stored in a room might be ignited to give a fire with the fire severity depends on the fire load density. For a room of size 2.25 m by 1.55 m by 3 m, with an opening of 0.6 m wide and 1 m high opened to an internal void, the required heat release rate to cause flashover is only 0.5 MW as established from Thomas equation [3]. Burning items with peak heat release rate higher than 0.5 MW and sufficiently long duration would lead to flashover. It is easy to find materials and products burning with heat release rate higher than 0.5 MW!

High quantity of smoke will be generated in a flashover fire. Not only that, flames would be moving out of the opening and spread to other levels, depending on the air flow pattern. Natural driving forces of air flow in the internal void are [4,5]:

- Stack effect.
- Wind-induced action.
- Buoyancy of hot smoke.

The quantity of smoke generated is, therefore, an influential issue in assessing the hazard. The rate of smoke production depends on many factors such as the size of the fire [e.g. 4,5]. In fact, a two-layer zone model [e.g. 6] can be used to estimate how much smoke would flow out of the compartment into the internal void.

The program WINDOW in FIREWIND [6] was used to calculate the mass flow rate of smoke. A NFPA slow T' -fire with cut-off value of 300 kW was assumed. The amount of smoke flowing out of the room to the internal void will be 0.53 kgs⁻¹ for the door of 0.8 m wide and 2 m high opened. Note that this small fire will not give flashover and so the value is just the minimum figure. If flashover occurs, flame would spread out as well.

3. SMOKE SPREADING

If a flashover fire occurs in a room adjacent to an internal void with windows opened, the smoke (and
perhaps flame) would spread to the internal void. Stack effect, wind-induced force, buoyancy of hot gases and thermal expansion caused by the fire are the driving forces of airflow. For most cases, unless under adverse effects such as strong wind action and opening different doors and windows, smoke would rise up due to buoyancy.

Simulations with Computational Fluid Dynamics (CFD) [7] were carried out by taking a room (room A) opened to an internal building void as a fire room. Room A is of length 2.3 m, width 1.5 m and height 3 m. There is a window of width 0.6 m and height 1 m located at 1 m above the floor of the fire room. The internal building void is of width 4.6 m and length 1.5 m. An internal void section of 21 m high is considered, with the fire room at the third level, i.e. 9 m above the ground level as in Fig. 1. A fire of heat release rate 300 kW less than the minimum value for flashover is considered. Five scenarios were simulated with the CFD simulator PHOENICS [8]:

- Scenario 1: Fire room at the 3rd level, all other windows closed.
- Scenario 2: Another room, room B of the same geometry as room A, at an upper level above the fire room with window open.
- Scenario 3: The door of room B open to free space.
- Scenario 4: There is a pressure difference of -50 Pa at the door of room B, due to wind effect or mechanical ventilation and air-conditioning (MVAC) systems.
- Scenario 5: There is a pressure difference of -5 Pa at the door of room B.

Results of the simulation were reported elsewhere [2].

4. THE WORST SCENARIO

The worst case is when there is a negative differential pressure induced at the door of room B, i.e. scenarios 4 or 5. Air with high velocity would be drawn into room B due to the negative pressure as in Fig. 2. It is obvious that hot smoke, or even flame would spread to room B and then to the other parts of the upper level apartment. This case is very dangerous and should be watched carefully.
5. CONCLUSIONS

The above preliminary analysis suggests that it is unclear whether the internal building void would give fire hazard. Further investigation on fire safety for internal void design should be carried out urgently. Both Computational Fluid Dynamics [7,8] and full-scale burning tests [5,9] should be used for fire hazard assessment:

- Preliminary CFD simulation indicated that there is a possibility of spreading hot smoke or even flame from the fire level to the adjacent levels through the internal building voids. It is obvious that the dimension of the void, wind environment, and whether there is any MVAC system operating are the key factors, in addition to whether there is a flashover fire.

- Full-scale burning tests should be carried out on apartments with at least 5 storeys to justify the design and verify the numerical works. The PolyU/USTC Atrium [9] is a good site for experimental studies.

Other factors such as fire spreading over the finishes had not yet been considered. There would be flame spreading even over paint surfaces [10]!

REFERENCES