

Evacuation with smoke control for atria in green and sustainable buildings

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Abstract

The concepts of green buildings and sustainable buildings are promoted actively in the developed countries. Targets are on protecting the environment, using less energy through natural ventilation provisions and daylight utilization, developing better waste management and taking water conservation into account. Architectural and building design, electrical and mechanical systems, and building management have to be upgraded.

However, there are problems in dealing with fire safety, especially in complying with the existing prescriptive fire codes. An obvious example leading to hot arguments is the green or sustainable buildings with an atrium. Smoke spreading would give problems and evacuation design under smoke was identified to be a key issue. Providing more emergency exits might give a faster evacuation time, but would give security problems.

An alternative solution is to install a smoke management system to keep the smoke layer high. Better designs can be achieved by integrating the evacuation time with the smoke filling time under different scenarios. Evacuation design can be improved by installing a smoke exhaust system. System performance by fire safety management would provide adequate safety. This point will be demonstrated in this paper.

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1. Introduction

'Green buildings' are of great interest to the developed countries towards the end of the last century. Now, this is extended further to 'sustainable buildings' [e.g., 1]. Similar actions are taken in big cities of the Far East including Hong Kong. Although the concepts behind the two are different, the assessment procedure is roughly the same [2]. A 'relative scale' to a typical building in a region will be applied for a green building. Sustainable building is more 'absolute' on controlling energy and mass flows internationally. Indoor environment, environmental protection, energy-saving through better provisions of natural ventilation and utilization of

daylight, water consumption and waste management are the common approaches to satisfy the assessment criteria for those green or sustainable buildings. Normally, three items will be covered [e.g., 3]:

- Architectural features including building construction element.
- Electrical and mechanical systems to give a comfortable environment, but the system would use energy, directly or indirectly.
- Management including energy management, environmental management and fire safety management.

However, some architectural features of those buildings might not comply with the fire safety codes. In fact, fire safety should be provided by passive building construction, active fire protection system, and fire safety management. The hidden fire safety problems

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encountered in some big projects with new architectural features for green buildings in Hong Kong were pointed out [4,5]. Examples are internal building voids, double-skin façade, excessive provisions of natural ventilation, using materials with better thermal insulation, and fire safety in atria.

For those green or sustainable building designs in conflict with the fire safety codes [e.g., 6–8], a ‘fire engineering approach’ [9,10] for fire safety design similar to engineering performance-based fire codes [e.g., 11,12] would be allowed, say since 1998 in Hong Kong. Atria [13,14] are designed commonly in those green and sustainable buildings to provide better natural ventilation, more daylighting, and better thermal control on both heating and cooling. It would also satisfy the plot area ratios of usable floor criterion on town planning. But many such atria have difficulties in complying with the prescriptive fire codes. For example, if an atrium is located in a shopping mall, it is classified as a shopping mall. Fire services installations [8] for a shopping mall such as sprinkler systems are then required at the high headroom ceiling. Scenario analysis on hazard assessment [15] indicated that it is unlikely to have a big fire at the atrium floor for the sprinkler to control. Activating the sprinkler head by hot smoke at adjacent high-level shops would draw smoke to the floor level. As most atria in green or sustainable buildings in the Far East are of open design to other levels, smoke spreading out from the shop fires would bring psychological ill-effects to the occupants. Evacuation design with appropriate smoke management system should be the key item to get fast enough egress time in those green and sustainable buildings with an atrium. A normal practice is to install a smoke exhaust system to keep the smoke layer at a high enough level.

Geometry, escape route designs and other key parameters of 69 local atria were surveyed [16,17]. Evacuation at the floor levels in those atria with different sizes and geometrical shapes were studied with an evacuation software. As the number of occupants staying at the atria floor is difficult to control, two occupant load densities [6,7] under ‘crowded’ and ‘normal’ conditions were considered. Numerical results on evacuation indicated that the evacuation time might be very long under crowded conditions.

Providing more exit doors is not a good solution as this will bring about security problems. Widening the exit might not necessarily give a faster flow rate of occupants out of the door. ‘Crowding force’ with mass occupant flow would bring problems [18]. A smoke exhaust system [19] is proposed to be installed though the original objective was to keep smoke at higher levels for firefighting [e.g., 20]. How this design is integrated with evacuation will be demonstrated in this paper. A fire safety plan [e.g., 21–23] can then be worked out based on those engineering data.

2. Evacuation on the atrium floor

Previous studies in local atria [14,16,24] showed that the atrium floor might have many uses, such as a food court, an exhibition area, or a public transport interchange. The number of occupants may be significantly different according to the design values. The maximum travel distance and the maximum sum of the direct distance and travel distance for different buildings appear in the local fire codes [e.g., 6,7], and had been reviewed before. The common figure is 30 m for atria used as a shopping centre. But the maximum distances might be changed when the atrium floor is used for temporary exhibition with big exhibition boards blocking the sight of the escape signs and the escape routes.

A field survey on 69 atria was carried out to study their geometry and escape route design [24]. The length of the atria varied from 10.2 to 144 m, width from 5.9 to 42 m, height from 7.4 to 28.7 m, floor area from 86 to 1802 m², and space volume from 760 to 28728 m³. The number of exits varied from 1 to 14, depending on the architectural design. Evacuation of occupants staying at the floor of those 69 atria under different occupancy loading following the local codes on evacuation [6,7]: normal condition for shopping malls of 3 m²/person; and crowded condition for public accessible areas of 0.5 m²/person, was simulated using the software building EXODUS [e.g., 25].

In the simulations, the maximum number of occupants N_{\max} was calculated from the floor area. Occupants were assumed to be 50% male and 50% female with ages 17–29 assigned randomly in the atrium floor. Evacuation time t_{eg} for N_{\max} at each atrium under the two conditions was simulated and the details were

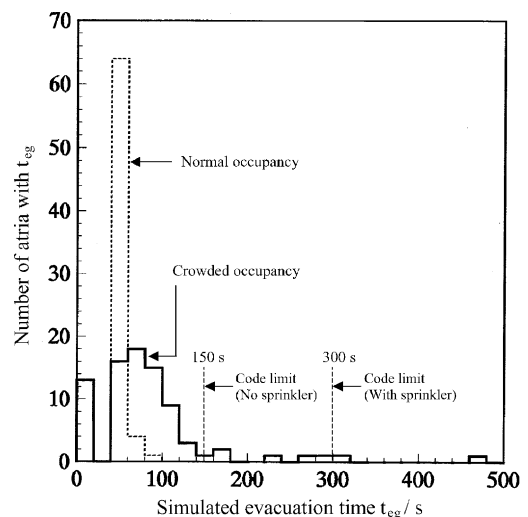


Fig. 1. Number distribution of evacuation time.

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