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SMOKE CONTROL IN ATRIA AND LARGE SPACES

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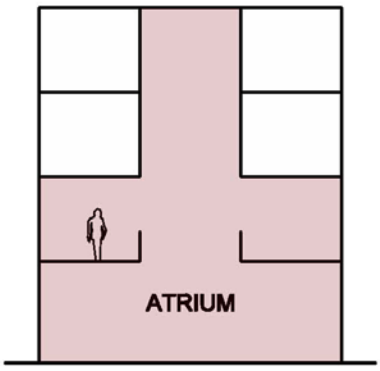
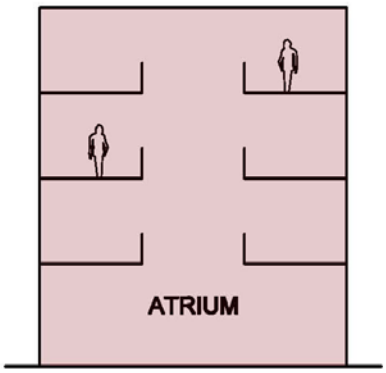
by Andrew Harmsworth, M Eng, P Eng, PE, CP, FEC and K. M. Gary Chen, MASc, P Eng

Often, the most significant threat posed by a fire in a building is not the fire itself, but the smoke produced. Unlike a burning fire, which can be controlled to the point of origin by sprinklers and fire separations, it is generally more challenging to control the movement of smoke as it can infiltrate separations through leakage in the construction. Smoke is of particular concern in interconnected floor spaces, such as in buildings with atriums, large shopping centres and stadiums. This newsletter provides a short summary of the Building Code requirements for interconnected floor spaces and a recent GHL project where a performance-based smoke modeling analysis was prepared to demonstrate Building Code compliance.

OVERVIEW OF ATRIUM REQUIREMENTS

The current BC Building Code, which is modeled after the National Building Code of Canada, provides 3 acceptable solutions for atrium design:





A. Provide walls that have the same fire resistance as floors to separate the atrium space from adjacent floor areas.

B. Limit the extent of the interconnected floor space to those described in Article 3.2.8.2; for example, 1st and 2nd storeys only.

C. Provide full atrium design per Articles 3.2.8.3 – 3.2.8.9; a summary of the Code requirements for full atrium design is shown in Table 1.

The increasingly popular trend of creating large and spacious floor areas with minimal use of walls often results in the need to design the building for full atrium requirements per Articles 3.2.8.3 – 3.2.8.9. However, these requirements often conflict with design objectives. In addition, new fire research and engineering practice are revealing that the prescribed solutions provided by the Code can prove difficult, if not impossible, to achieve. Therefore, fire engineers who specialize in smoke management and atrium design are often involved in large buildings with complex interconnected floor spaces to provide a performance-based analysis based on fire science principles in lieu of the prescriptive measures.

Table 1 Summary of generic full atrium design requirement from Division B of the BC Building Code 2006

Code Reference	Division B Acceptable Solution
3.2.8.3	Noncombustible construction or heavy timber construction in limited circumstances
3.2.8.4	Sprinkler protection for the building
3.2.8.5	Smoke control (pressurized) vestibules for exits to limit infiltration of smoke into the exits to not more than 1%
3.2.8.5	Provide one or a combination of: ▪ Cumulative exiting ▪ Provide protected floor spaces (temporary holding space)
3.2.8.6	Fire separation and smoke control vestibules for protected floor spaces if utilized
3.2.8.7	Draft stops and smoke detectors along edge of floor opening. Note that close-spaced sprinklers may be waived based on the size of the floor opening
3.2.8.8	Manually operated smoke exhaust at 4 air changes / hour
3.2.8.9	Combustible content limit of 16g/m^3 at where the ceiling height exceeds 8m in the atrium

Some past examples where GHL has successfully developed performance-based Building Code alternative solutions for full atrium design requirements include:

- Timed-egress analysis and smoke modeling to demonstrate evacuation of occupants prior to onset of untenable conditions as an alternative to increasing exit stair width required by Code for cumulative exiting;
- Design of stairwell pressurization criteria to achieve the 1% contaminated air requirement in exits in lieu of pressurized vestibules required by Code;
- Assessment of sprinkler and smoke detector response for elimination of draft stops;
- Fire hazard assessment and recommendation for modified sprinkler protection approach as an alternative to limiting combustible contents to 16g/m^3 in areas where the ceiling height exceeds 8m.

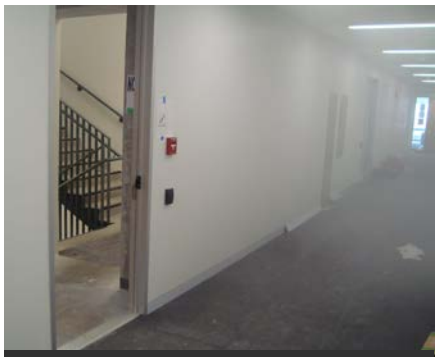


Fig.1 Pressurized exit stair keeps smoke in the corridor.

RECENT EXPERIENCE AT ALLARD HALL (UBC FACULTY OF LAW)

Designed by Diamond + Schmitt Architects in Toronto and CEI Architecture in Vancouver, the Allard Hall building, which opened in September 2011, houses the premier law institution in western Canada. To exemplify the openness of the Canadian legal system, the building is designed with extensive interconnection between all floor levels; as such, it is required to comply with the measures found in Articles 3.2.8.3 – 3.2.8.9. However, one of the challenges with the prescribed solutions of the Code is the need for smoke control vestibules for the exit stairs and protected floor spaces (temporary areas of refuge).

Fig.2 Pressurization fan prevents smoke from infiltrating the protected zone

Smoke control vestibules were developed in the Code with the intent of limiting the movement of smoke into exits, which are facilities critical to the evacuation of occupants and access by emergency responders. Although there is a lack of documentation, it is generally thought that vestibules are needed to create an 'air lock' such that as occupants flow through the set of doors to access the exits, smoke infiltration is minimized. The requirement for vestibules, however, can be problematic in terms of day-to-day usage. In addition to the exiting function, stairs are also used for access between floors. A

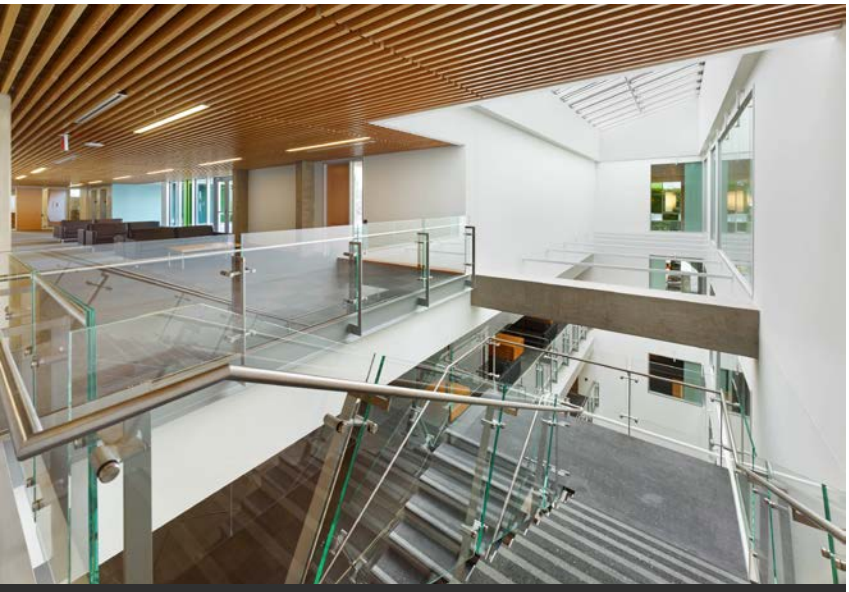


Fig.3 View of the Allard Hall from the top of the atrium (photograph courtesy of UBC Properties Trust).

set of 2 doors in series to enter and leave the stair for day-to-day use can often become an inconvenience for occupants. It is observed that doors in high traffic areas are commonly wedged open.

In this instance, in a real fire emergency, the intent of the code can be severely compromised. Economically, vestibules also take up valuable usable floor space that could be used for other purposes as after all, fire is a rare event. In order to provide effective and reliable smoke protection to the exits while maximizing usable floor area, GHL developed a performance-based smoke modeling analysis to permit the protection of exits with direct pressurization of the stair shafts and the protected floor spaces, eliminating the Code-required vestibules.

The analysis looked at the probable worst-case fire scenarios, coupled with a comprehensive evacuation analysis. Based on the smoke exhaust system for the atrium and pressurization system for the exit stairs and protected floor spaces, it was shown that an acceptable pressure differential can be created to prevent infiltration of smoke into the exits and protected floor spaces. During the occupancy demonstration, field testing with forced smoke showed that the stairwell pressurization was capable of resisting the infiltration of smoke into the stairs without vestibules (see Figure 2).

About the Authors

Andrew Harmsworth (M Eng, P Eng, PE, CP, FEC) is an accomplished fire engineer and Building Code consultant, bringing over 20 years of experience in fire safety design, Code consulting and construction practice to a project. Having obtained his Master's Degree in Fire Protection Engineering at UBC, and continuing to enhance his education, Andrew is familiar with recent developments, techniques and tools of Fire Science and Engineering which has assisted in the development and successful negotiation of numerous equivalent approaches to Building Code compliance and successful resolution of several legal disputes.

K. M. Gary Chen (MASc, P Eng) is a professional engineer registered in British Columbia, Alberta, Manitoba, and Ontario with specialized expertise in fire science, thermal fluid mechanics and structural design for fire. As a PhD candidate, he has completed a Master's Degree in Mechanical Engineering from University of Waterloo, specializing in fire engineering, and a Bachelor's Degree in Chemical Engineering from UBC.

About GHL Consultants Ltd

Led by Principals David Graham, Andrew Harmsworth, and Teddy Lai, and Associate Principals Khash Vorell and Adam Nadem, GHL is a team of fire protection engineers and technologists who have extensive experience and advanced training in fire safety codes and fire engineering. With expert knowledge in fire safety and established working relationships with many authorities having jurisdiction, we are capable of solving a wide variety of fire engineering challenges that arise from the prescriptive codes. Our fire science background provides us with a strong capability in fire modelling and evacuation/egress modelling. With a dedicated team of fire modelling engineers, GHL can advise clients when fire modelling adds value to a project and when fire modelling analysis is required.
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