International Journal on Engineering Performance-Based Fire Codes, Volume 1, Number 3, p.123-128, 1999

COST-EFFECTIVE FIRE-SAFETY RETROFITS FOR CANADIAN GOVERNMENT OFFICE BUILDINGS

D. Yung and G.V. Hadjisophocleous
Fire Risk Management Program, Institute for Research in Construction, National Research Council Canada
Ottawa, Canada K1A 0R6

ABSTRACT

The risk-cost assessment model FiRECAM™ was used to identify cost-effective fire safety options for upgrading eight Canadian government office buildings. Based on the results of the model, a number of cost-effective upgrade options were identified that could save a total of $1.2 million Canadian, without lowering the levels of life safety in these eight buildings from the levels intended by the building code. In this paper, the results of applying FiRECAM™ to one of the eight buildings are described to illustrate the approach used to identify cost-effective fire safety upgrade options. A similar approach was used to identify cost-effective upgrade options for the other buildings.

1. INTRODUCTION

In the retrofit of existing Canadian government office buildings, the cost associated with the requirements of the current prescriptive-based building code is often the single largest portion of a retrofit project. As progressively more older buildings undergo rehabilitation or retrofits, the cost of fire protection becomes an important issue. With this in mind and with the pending introduction of an objective/ performance- based code in Canada in the year 2003, Public Works and Government Services Canada (PWGSC) and the National Research Council of Canada (NRC) entered into a partnership agreement in 1990 to develop a version of NRC's risk-cost assessment model for PWGSC use. The NRC model, called FiRECAM™, can be used to assess both the expected risk to life to the occupants and the expected costs of fire protection and fire losses in a building [1-8]. Thus, the model can be used to identify cost-effective, alternative fire safety designs that provide the same or better life safety to the occupants as that of a code-compliant design, but cost less than that of the code-compliant design. With PWGSC's inventory of older buildings, the potential cost savings could be significant.

During 1996 to 1997, FiRECAM™ was applied to eight government office buildings. In this paper, the results of applying FiRECAM™ to one of the eight buildings are described to illustrate the approach used to identify cost-effective fire safety upgrade options. The building selected for presentation in this paper is PWGSC's East Memorial Building, located in Ottawa, Canada. The approach used to identify cost-effective upgrade options for this building was the same for the other buildings. The results showed that some of the proposed upgrade options were not cost-effective. Using the cost-effective upgrade options that were identified by applying FiRECAM™ to these eight buildings, a total of $1.2 million Canadian could have been saved without lowering the levels of life safety in these eight buildings from the levels intended by the building code.

1.1 Building Description

The East Memorial building, located in Ottawa was constructed in 1955. The building was designated as a historical monument in memory of those killed during the Second World War. The building is currently being renovated. When completed, the building will become the new headquarters of the Federal Department of Justice. Because of its historical significance, considerations were given to maintaining its architectural heritage in the renovation design.

The East Memorial Building is a 7-storey building with two below-grade levels (ground floor and basement). A small nine-storey tower is located at the Northwest corner of the building. The basement will be used mainly for various services, records management, storage, mechanical systems and building maintenance. The ground floor will contain a library, training centre, cafeteria and lounge areas. Five exits are located on the first floor: two on the south side, two on the north side and one on the west side. There are 4 stairshafts and 4 pairs of elevators located at the four corners of the building. Floors from the first to the sixth will be used as office space. The building will have two interior atrium spaces extending from the ground floor to the 6th floor. The 7th floor has limited floor space and contains only building services, which are not counted as an occupied area. In each atrium, there will be new boardrooms

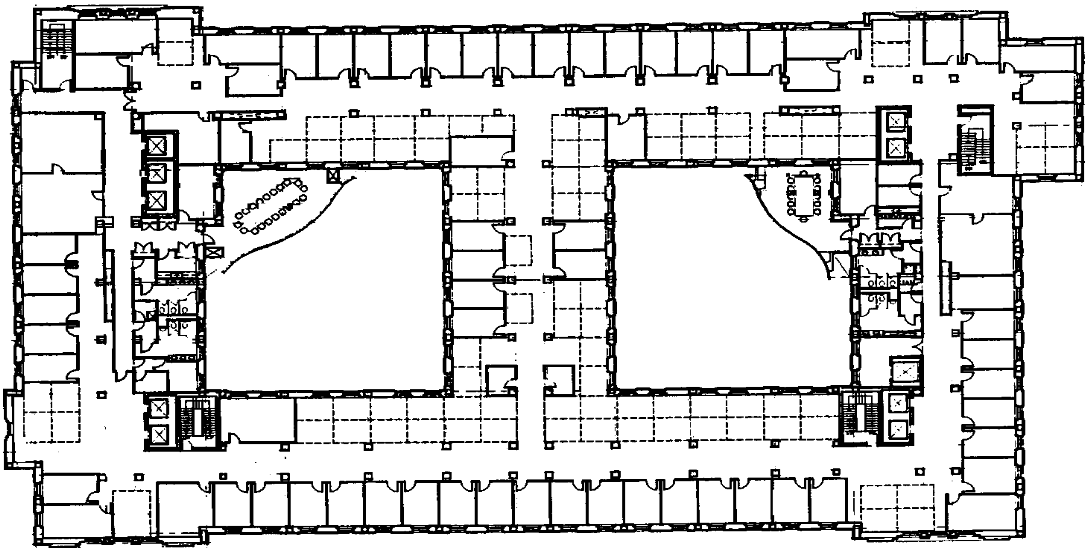

Fig. 1: Typical floor layout of the East Memorial building, Ottawa

constructed on floors from the 2nd to 5th. A typical floor layout is shown in Fig. 1.

1.2 Building Occupants

The East Memorial Building will be mainly occupied by office workers of the federal Department of Justice. The maximum occupant load is estimated to be 2749, based on the 1995 National Building Code of Canada's (NBCC) minimum space requirement of 9.3 m^2 of rentable space per occupant. On the other hand, based on PWGSC's practice of a minimum of 12 m^2 of usable space per person, the building may contain a maximum of 1742 occupants. The occupant loads per floor, based on both the NBCC and PWGSC's practice, are shown in Table 1.

2. EXISTING CONDITIONS AND CODE REQUIREMENTS

The previous fire protection systems, before the current renovation, consisted of a central alarm system with manual pull stations and sprinklers on the lower two levels only (basement and ground). Typical stairshaft exit doors were metal doors with wired glass panels and they were not fire rated. The 1995 NBCC requirements are as follows:

- Sprinklers are required because both the building height and building area exceed the non-sprinkler limits. Also, the building has two inter-connected atria that are also required to be sprinklered.

Table 1: Assumed occupant loads for the East Memorial building

Level	Rentable area (m^2)	Occupant load at 9.3 m^2 of rentable area per person	Usable area (m^2)	Occupant load at 12 m^2 of usable area per person
Basement	3900	419	2804	233
Ground	3835	412	3068	255
1st	2767	297	2189	182
2nd	3165	340	2705	225
3rd	3165	340	2705	225
4th	3161	339	2729	227
5th	3057	328	2635	219
6th	2552	274	2120	176
Total	25602	2749	20957	1742

- Smoke detection is required in all exit stairshafts and HVAC ducts that recirculate air to more than one floor.
- Heat detection is not required if the building is sprinklered throughout.
- Maximum travel distance to exits is limited to 40 m in unsprinklered floor areas and 45 m in sprinklered floor areas. Portions of the centre wing floor area on the 1st to 6th floors currently exceed the 45 m distance by approximately 5 to 10 m. To comply with the NBCC requirements, an additional stairshaft is required at the midpoint of the building on the north side.
- The fire resistance rating of stairshafts is required to be 2 hours. The fire resistance rating of stairshaft doors should not be less than 1.5 hours. Since the building will be occupied by a single tenant, fire separation of compartments and corridors is not required.
- Stairshaft pressurization and voice communication systems are not required, since the building is not considered to be a highrise building.

3. PLANNED FIRE SAFETY UPGRADES

The planned upgrades are not strictly Code compliant because of the high construction costs involved and the need to maintain historical integrity. However, the planned renovation by PWGSC is intended to increase the level of safety so it is comparable to that of the NBCC.

The building will be fully sprinklered, which will be electrically supervised by the fire alarm system. Proposed sprinkler protection will include the following locations:

- along the perimeter of the atrium ceiling,
- inside the perimeters of the new boardrooms,
- inside of windows facing atria,
- general office space, library, data processing and records storage.

The building will be equipped with a 2-stage central alarm system. Smoke detectors will be installed in stairshafts, HVAC systems, atria, elevator shafts, storage facilities for important or vital documents and record storage rooms exceeding 200 m^2. Heat detectors will be installed in rooms, which may be unsprinklered, such as the transformer vault.

Stairshaft doors will be retained as the doors, which are considered to be part of the historic fabric of the building. There will be no additional stairshaft in the building because of the high construction cost and the reduction of floor usable areas. Stairshaft pressurization and an atrium smoke exhaust system will be provided.

4. ALTERNATIVE FIRE SAFETY DESIGNS

Alternative fire safety design options considered are listed in Table 2. The Reference Option is the code-compliant option. In this option, the building is equipped with sprinkler protection and a central alarm system that can be activated by smoke detectors, sprinklers and manual pull-bar devices. Smoke detectors are installed in stairshafts and in HVAC systems. An additional stairshaft is added. All stairshaft exit doors have a fire resistance rating of 90 minutes.

Table 2: Design options for the East Memorial building

Options	Sprinkler	Smoke Detection	Central Alarm	Voice Alarm	Fire Rated Stair Doors	Add a Stairshaft	Stairshaft pressurization	Building population
Reference	X	Partial	X		X	X		2749
Current		Partial	X					1742
Proposed 1	X	Partial	X				X	1742
Proposed 2	X	Partial	X		X		X	1742
Case 1	X	Partial	X		X	X		1742
Case 2	X	Partial	X					1742
Case 2a	X	Partial	X		X			1742
Case 3		Partial	X				X	1742
Case 4		Full	X				X	1742
Case 5		Full	X		X		X	1742
Case 6		Full	X	X			X	1742
Case 7		Full	X	X	X		X	1742

The Current Option is the existing system in the building before renovation. The building had a central alarm system and partial smoke detection with smoke detectors mainly in the stairshafts. The building population is based on the lower PWGSC population density.

Proposed Option 1 is the planned renovation option. The building is fully sprinklered with a central alarm system and partial smoke detection. The central alarm system is connected to sprinklers and smoke detectors. Stairshaft doors are retained and their fire resistance rating is assumed to be only 30 minutes. The stairshaft pressurization system is installed. Proposed Option 2 is the same as Proposed Option 1 except that the stairshaft doors are replaced with fire-rated doors.

Case 1 is the same design as the Reference Option but the population density is reduced to the PWGSC level. Cases 2 and 3 are the same as the Proposed Option 1 except that there is no stairshaft pressurization system in Case 2 and no sprinklers in Case 3. Case 2a is the same as Case 2 except that the stairshaft doors are replaced with fire-rated ones. Cases 4 and 5 have central alarms with full smoke detection systems but no sprinklers, with Case 4 keeping the existing stair doors and Case 5 replacing them with fire-rated doors. Cases 6 and 7 are the same as Cases 4 and 5, but with added voice communication.

5. MODELLING APPROACH

The building was modelled as an 8-storey building, counting from the basement floor to the 6th floor. All building exits were assumed to be located at the lowest level, the basement level, and not at the first floor due to the limitations of FiRECAM™. This assumption is a conservative one for occupants from the 1st floor to the 6th floor because they will have to travel down two more levels in order to evacuate the building. This assumption, however, is not conservative for those on the basement level or on the ground level because they now have direct access to the outside of the building without having to climb up two levels to the first floor.

6. FIRE RISK RESULTS

FiRECAM™ was used to determine the expected number of deaths for the 12 fire safety options shown in Table 2. The expected number of deaths for each option, normalized by the Reference Option for relative comparisons, is plotted in Fig.2. The Reference Option is the code-compliant option, which has a relative deaths value of 1.

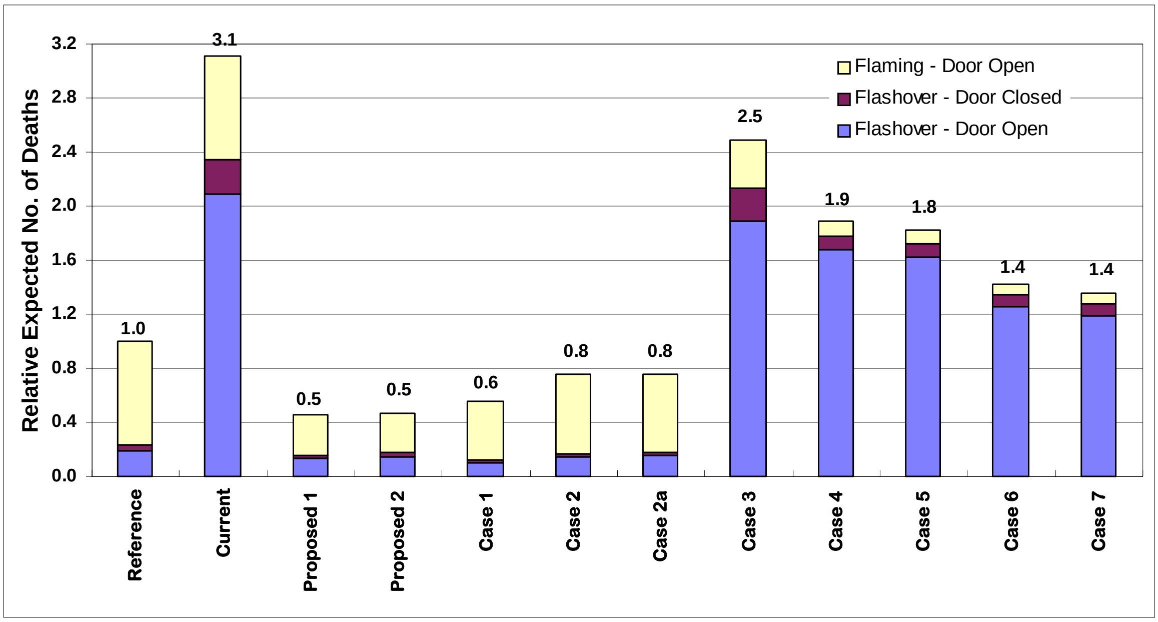

Fig. 2: Relative expected number of deaths for various fire safety options
Contribution of the three most hazardous fire scenarios to the relative number of deaths is also shown (contribution of other less significant fire types is negligible)

The results show that the options with sprinklers, such as the Reference Option, the two Proposed Options, Cases 1, 2 and 2a, have much lower relative deaths values when compared to the options without sprinklers. This is expected because sprinklers suppress most of the flashover and non-flashover fires.

For those options where the only difference is the fire resistance rating of the stairshaft doors, the predicted relative deaths values are very close. Part of the reason is that the original stairshaft doors were assumed to have a 30 minute fire resistance rating. Most of the occupants would have evacuated the building in less than 30 minutes; thus replacing the doors with a 90 minute fire resistance rating does not improve the safety level by much.

The two Proposed Options have the lowest relative deaths values, which are 50% lower than the Reference Option. This is possible since the Proposed Options have the additional safety features of stairshaft pressurization and a lower population.

Case 1 is the same as the Reference Option, except that it has a reduced population density. The results show that a lower population density has a lower relative deaths value. This is reasonable since a lower population would lead to a quicker evacuation and therefore fewer occupants trapped in the building.

Cases 2 and 2a are the same as the Proposed Options, but have no smoke control systems in the stairshafts. The relative deaths values for Cases 2 and 2a are higher than those for the Proposed Options. However, Cases 2 and 2a are still better than the Reference Option because of a lower population.

Case 3 is the same as the Proposed Option 1, but has no sprinkler protection. The relative deaths value for Case 3 is much higher than that for the Proposed Option 1. The reason, as mentioned earlier, is that sprinklers are very effective in suppressing most of the flashover and non-flashover fires. Comparing Case 3 to the Current Option, Case 3 is better because it has the added protection of stairshaft pressurization.

Case 4 is the same as Case 3 but with full smoke detection instead of partial detection. Case 4 has a lower relative deaths value than Case 3 because a full smoke detection provides an earlier detection, which allows the occupants to leave the building earlier.

Case 5 is similar to Case 4, except that the stairshaft doors are replaced with fire-rated doors. The results for these two cases are very close for the reason explained earlier.

Cases 6 and 7 are the same as Cases 4 and 5, except that voice alarms are added. Adding voice alarm reduces the relative deaths values by approximately 20%. This is expected since a voice alarm provides instructions to occupants that will lead to a quicker occupant response and, therefore, earlier evacuation. When compared to the Current Option, Cases 6 and 7 reduce the relative deaths values by about 50%.

7. COST-EFFECTIVE FIRE SAFETY OPTIONS

The results indicate that only the two Proposed Options, Cases 1, 2 and 2a can be considered equivalent in life safety when compared to the Reference Option. Case 1 is the same as the Reference Option except that it has a lower population density. Both the Reference Option and Case 1 require an additional stairshaft which is difficult to construct and expensive. Cases 2 and 2a have a relative deaths value of 0.8 when compared to the Reference Option. Cases 2 and 2a are the same as the Proposed Options, except that they have no stairshaft pressurization.

One of the most expensive and unnecessary code-prescribed protection measures is the construction of an additional stairshaft. With assistance from estimators from PWGSC’s Architectural and Engineering Services, National Capital Area, the cost of adding a new set of stairs was assessed at $360,000. Further savings, conservatively estimated at $70,000, are also available for this building by not replacing the existing brass stairshaft doors with fire-rated doors; additional consideration of the heritage aspects of this building could dramatically increase the door replacement cost. Stairshaft pressurization is not required for code compliance and, as noted above, has very marginal additional life safety benefit and should not be installed in this building.

FiRECAM™ was also applied to seven other government office buildings to identify cost-effective fire safety upgrade options. The results showed that the combined savings could total $1.2 million Canadian without lowering the levels of life safety in these eight buildings from those as intended by the building code.

8. CONCLUSIONS

The primary objectives of this study were to examine whether FiRECAM™ can be applied to a wide range of PWGSC’s office buildings to identify alternative, equivalent, fire protection options to demonstrate potential cost savings for these buildings. Eight PWGSC’s buildings with various fire safety design options were studied. The results of the study showed that some of the proposed upgrade options were not cost-effective. Using the alternative options suggested by FiRECAM™, a total of $1.2 million could have been saved without sacrificing the level of life safety as intended by the building code.

ACKNOWLEDGMENTS

The authors would like to thank Ms. Quin Liu who assisted in the running of FiRECAM™ for the East Memorial Building. Funding support from PWGSC for the current study is also greatly appreciated.

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