M7-030 Evaluation of Means of Escape in a Campus Library

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ABSTRACT

Campus library is considered to have a crucial role in a campus life. It preserves precious collections of books, journals, and research reports, some in the form of electronic collections. In general most of the library collections are made of combustible materials producing a lot of smoke in the event of fire. This article reports an evacuation study for a campus library building through modeling work using buildingEXODUS software [2] and an evacuation (fire drill) exercise. The modeling and evacuation exercise took advantage of the existing Engineering Faculty library of the University of Indonesia in Depok campus. The information of occupant behavior was collected using video recording at various locations during the fire drill exercise. The buildingEXODUS software takes into consideration people-people, people-fire and people-structure interactions. The model tracks the trajectory of each individual as they make their way out of the enclosure. In this early study no effects of fire hazards such as heat, smoke and toxic gases are considered. The simulation work considered two routes for evacuation scenarios. The measured evacuation times for both floors have similar trends to the buildingEXODUS predictions. In addition, the predicted congested areas by the buildingEXODUS were confirmed by the sequences of the evacuation exercise. Evacuation times can be shortened by adding the number alternative exit doors and widening the emergency stairs.

Keywords: Means of escape, evacuation modeling, fire drill, buildingEXODUS

1. Introduction

Library is one of the main facilities of a university campus. Library preserves precious collections such as books, journals, and research reports. The electronic forms of the collections are stored in servers, compact disk and hard-disks. Thus, in general most of the library collections are made of combustible materials. During its operating hours, especially during the examination periods, library is packed with students, researchers, and member of staffs of different departments and faculties. In an event of fire, library collections made of papers and plastics can produce a lot of smoke and heat which influence the time to clear the library space of people. The time to evacuate is also greatly affected by the overall building design, especially the design of escape routes to assembly points.

Compliance with the fire safety requirements in the prescriptive building and fire codes would no doubt reduce the fire risk by ensuring the standard of fire service installations and providing adequate means for safe evacuation in the building design [1]. However, the success of these measures depends heavily on the behavior of building occupants in case of fire [2]. When fire occurs, people are found to behave differently, for example, some may move to the exits immediately, some may ignore the alarms and keep working for a while, some may prefer to stay in a room and wait for the assistance from the fire brigade and others may attempt to fight the fire. How occupants will respond to a fire has aroused much more concerns for architects, building designers, building control officers, building managers, insurers, as well as the occupants themselves [3].

Evacuation calculations are increasingly becoming a part of performance-based analyses to assess the level of life safety provided in buildings . To achieve a more realistic evacuation calculation, engineers have been looking to evacuation computer models to assess a building's life safety. Kuligowski, E. D. and Peacock, R.D. (2005) provides a review of building evacuation models [4].

This article reports an evacuation study for a campus library building through modeling work using buildingEXODUS software [5] and a fire drill exercise. The information of occupant behavior was collected using video recording at various locations during the fire drill exercise. The buildingEXODUS software takes into consideration people-people, people-fire and people-structure interactions. The model tracks the trajectory of each individual as they make their way out of the enclosure, or are overcome by fire hazards such as heat, smoke and toxic gases.

2. Review of FTUI Library Building

The evacuation study was carried out in the library building of Engineering Faculty of the University of Indonesia (FTUI library). Some possible scenarios related to evacuation routes were considered in this study excluding fire-hazard factor. The aims of this work are to obtain total evacuation time and visitors behavior during evacuation at different evacuation routes.

Prior to the modeling work, it is necessary to review conditions related to the actual library evacuation routes. FTUI library has 2 floors, located in the forth and fifth floors of the Graduate School building. FT UI library is a curved shape building with a sweep length of 61 m and 9 m width. Figures 1 and 2 show the geometry of the 4^{th} and 5^{th} floors.

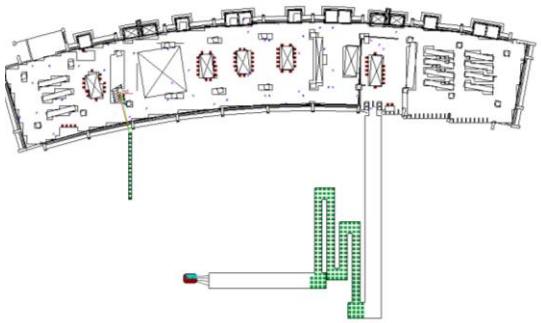

Figure 1. Geometry of the library building, 4th floor.

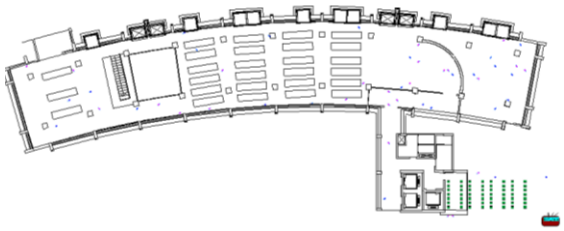

Figure 2. Geometry of the library building, 5th floor.

The 5th floor is used as the collection of books organized into 4 columns and 6 rows. The 4th floor areas are mostly used as a reading area with a large reading table. It results in a rather spacious condition for the 4th floor than that of the 5th floor. The dimensions of the evacuation routes are summarized in Table 1.

Table 1. Dimensions of evacuation routes

Object	**Width /Dimension**
Door (average)	1.5 m
Doors to the stairs	0.8 m
Emergency ladder	1.1 m with 8 stairs per landing point (± 1.44 m)
The Ladder	1.1 m with 16 stairs per landing point (± 2.88 m)

Inter-book rack	± 0.84 m
Wall-book rack	± 1 m

3. Evacuation Modeling

In this modeling study, two evacuation scenarios were evaluated.

The first scenario represented the actual circulation of the library where the main entrance and exit are located at the fifth floor. The visitors can move from the fifth to the forth floor, vice versa, through a connecting stair. In a case of emergency, it is assumed that the evacuates from the forth floor will walk through the connecting stair to the fifth floor to reach the emergency stairs outside the building.

In the second scenario, an alternative exit door was added for the forth floor. For security reasons this alternative door is normally closed. Using the alternative door, the evacuates of the forth floor can take the emergency route through a connecting bridge to the Engineering Centre building next to. The evacuates can reach the assembly point near the main gate of the building through stairs of 1.5 m width. The evacuates on the fifth floor uses the same evacuation route as the first scenario. Thus, in the second scenario, the evacuation routes between the forth and the fifth floors are separated.

Some assumptions for the modeling work are taken as follows:

- The number of visitors are assumed about 50 people on each floor.
- The visitors are aged 17 to 29 years and assumed understanding the emergency routes and exits.
- Each visitor in the library represented with special properties:
  - each visitor has a maximum travel speed for fast walk 1.5 m / s with the changing conditions on a particular node
  - only 1 user can fill in the node
  - a node has a 1-dimensional grid of 0.5m * 0.5 m
  - they have personal responses, such as patience, waiting time, response time, drive, etc.
  - there are interaction between people with people, and people with rooms.

The second scenario modeling is also aiming to obtain more rapid evacuation route by considering building parameters, such as the number of exit doors, venue gate, number of obstacles, as well as width of doors and stairs.

4. Evacuation (Fire Drill) Exercise

The evacuation exercise was carried out on the 1st of May 2009. At least 130 students aged 19 to 23 years old took part in the exercise. The proportion of male and female participants are maintained at about 50 to 50%. Since this was the first evacuation exercise took place in the library ever, a well-controlled measures were in place. This includes posting 6 security personnel in some critical part of the evacuation routes, i.e. emergency doors, stairs and the connecting bridge. Details of the evacuation exercise and the location and method of alarm initiation using smoke machine were provided to all participants. However, the exact time of smoke machine initiation was controlled by a coordinator.

Due to safety reasons, the evacuation exercise only took for only one scenario, i.e. the second scenario where two separate exit doors were available for the each floors of the library. Movements of the evacuates and the evacuation times were recorded using several video cameras located in some strategic locations.

5. Results and discussion

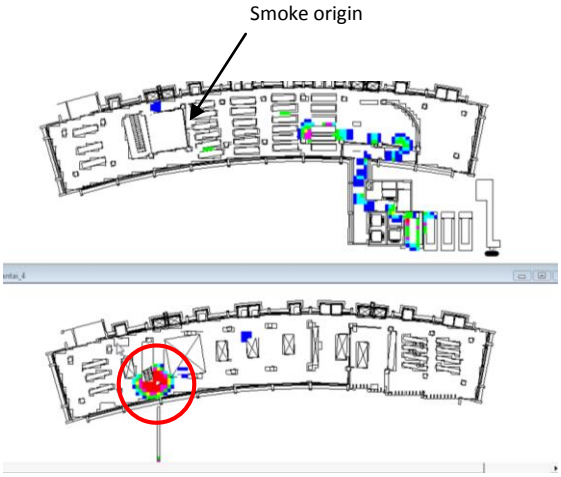

Figure 3. Density distribution density for the first scenario, 44s after alarm activation.

Figure 3 shows the results of building EXODUS modeling obtained for the first scenario. Figure 3 shows some potential high density areas on each floor. On the fifth floor the potential areas for overcrowding include the last row of the book shelf, the main entrance/exit, the connecting bridge and the emergency stairs outside the building. A heavier congested area near the connecting stair on the forth floor was also identified. The density of this congested area was 4 visitors/m^2 (red) and it lasted for about 12 minutes. In a real fire situation, the high density crowds can have dangerous impact to the evacuates due to longer time spent in the affected room with toxic combustion gases. Other concerns are also on the strength of the stair material to withstand the repeatedly impact loads.

The effect of overcrowding on evacuation time was clearly shown on Figure 4. The slopes of the number of people to reach the assembly points decreased dramatically at about 360s after alarm initiation. Although the time needed for the first evacuate was only 1 minute and 31 seconds, but the total evacuation time required was 14 minutes and 8 seconds, The farthest distance to assembly point was about 182 m.

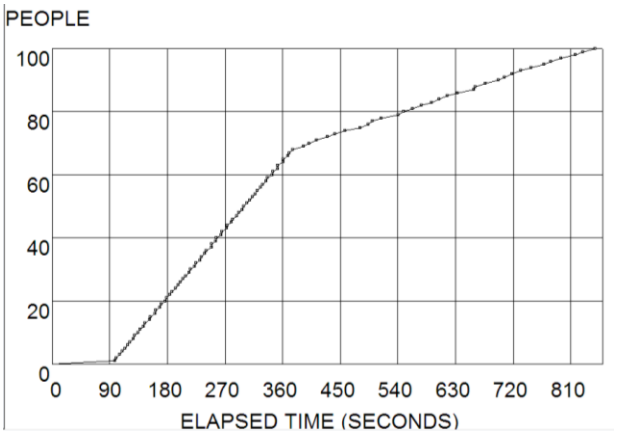

Figure 4. Graph of elapsed time after alarm initiation against the number of evacuates to reach the assembly points for the first scenario.

As mentioned earlier, on the second scenario the evacuation routes for the forth and the fifth floors were separated. The evacuates on the fifth floor used the same evacuation route as the first scenario, meanwhile visitors on the forth floor had an alternative emergency exit through a connecting bridge to the Engineering Centre building next to. The farthest distances to assembly points for each floor is 121m for the fifth floor and 131m for the forth floor.

Figure 5 shows the outcomes of modeling work for the fifth and the forth floors at 25s after alarm initiation. The overcrowding areas for both floors were identified by the red circles #1 to #3 on Figure 5. Again, the areas closed to the main entrance / exit and the book shelf alleys are the critical zones for the fifth floor. Meanwhile, on the forth floor, the evacuates mostly took the outer passage before reaching the floor exit to the connecting bridge. A higher density on the emergency stair was only identified for the fifth floor (Figure 6). This is due to the emergency stair for the forth floor (inside the Engineering Centre building) has twice width than the emergency stairs outside the library building.

As shown on Figures 7 and 8, the total evacuation time were 4 minutes and 49s for the fifth floor and 2 minutes and 23s for the forth floor respectively. The times for the first evacuates to reach the assembly points were 1 minute and 13s for the forth floor and 1 minute and 19s for the fifth floor.

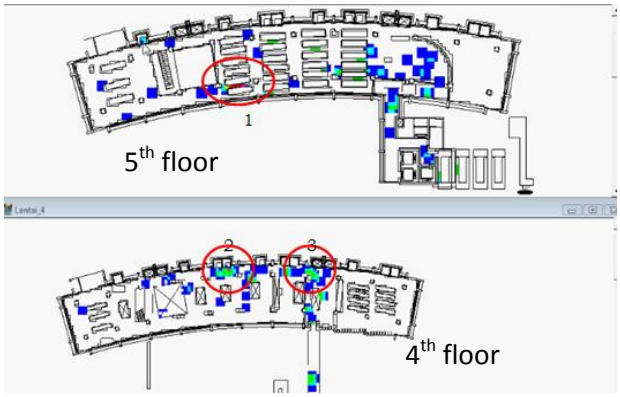

Figure 5. Identified overcrowding areas on each floor at 25s after alarm initiation.

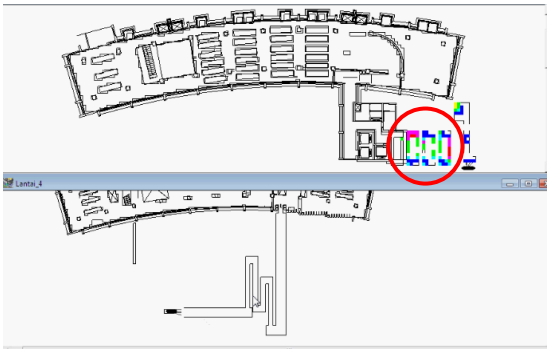

Figure 6. Crowd density on the emergency stairs, top for the fifth floor and below for the forth floor inside the Engineering Centre building.

It is obvious that by adding an alternative exit door for the forth floor, the total time for evacuation decreased dramatically. This is due overcrowding condition near the connecting stair for evacuates on Floor 4 (on the first scenario) can be avoided by providing their own evacuation route. The density shown on Figure 5 was much lower than that of shown on Figure 3.

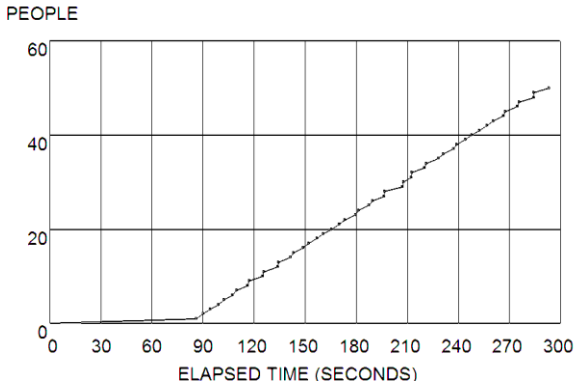

Figure 7. Graph of elapsed time after alarm initiation against the number of evacuates to reach the assembly points for the second scenario (the fifth floor).

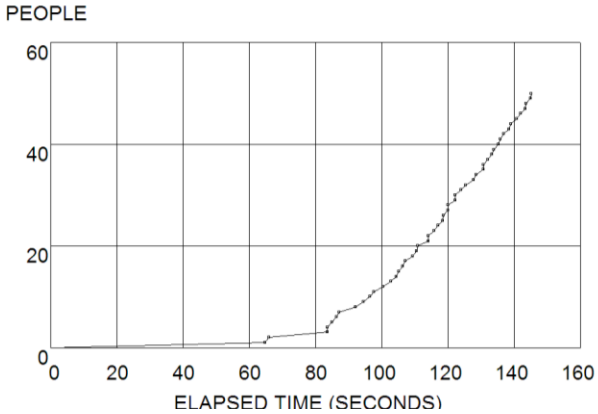

Figure 8. Graph of elapsed time after alarm initiation against the number of evacuates to reach the assembly points for the second scenario (the forth floor).

The outcomes of the evacuation modeling using buildingEXODUS are compared with real evacuation time measurement of the evacuation exercises (Figure 9). Although the exercise was designated for about 100 students, in fact more students took part during the study. There were 59 students on the forth floor and 70 students on the fifth floor of the library building. Figure 10 shows outcomes of the evacuation (fire drill) exercise using the second scenario approach. The first evacuates of the forth floor reached the assembly point faster than the fifth floor evacuates.

This could be contributed by wider evacuation stair available for the forth floor evacuates inside the Engineering Centre building.

Figure 9. The evacuates walked through the emergency stairs outside the building (on the right) and the connecting bridge to the next to building (on the left).

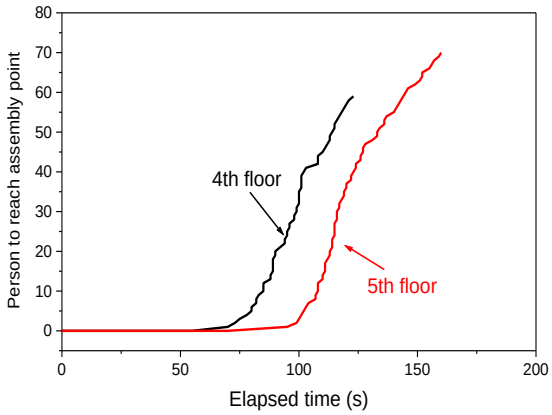

Figure 10. The plots of elapsed time after alarm initiation against the number of evacuates to reach the assembly points for the evacuation exercise.

In general the measured evacuation times for both floors have similar trends to the buildingEXODUS predictions, i.e. the evacuates of the forth reached the designated assembly point faster than the fifth floor evacuates. However the nominal times measured in the evacuation exercises are shorter than the buildingEXODUS outcomes. One must realized that the evacuation exercise was carried out in a well-controlled manner where the movement of the evacuates were directed by some security personnel. From the video recordings it was observed that some students were running instead of fast walking. Nevertheless, the predicted congested areas by the buildingEXODUS were confirmed by the sequences of the evacuation exercise.

Conclusions

The modeling work and the evacuation exercise provide important information regarding the evacuation performance of library building of a campus library. It is obvious that in a case of emergency an alternative exit door for the forth floor visitors must be added to reduce the total time for evacuation. The predicted congested areas by the buildingEXODUS are confirmed by the sequences of the evacuation exercise. The measured evacuation times have similar trends to the buildingEXODUS predictions. A regular fire drill exercise is suggested to improve readiness of the students, security personnel and library staff on emergency situations.

Acknowledgements

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