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Effect Of Steering and Comfort Distances on Evacuation Time for a College Building – A Case Study

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Abstract: *Time taking by the occupants to reach maximum speed from rest or to reach rest from maximum speed may affect the total evacuation time. Also, the comfort distance during evacuation can play significant role in determining overall evacuation time. This paper presents evaluation of the total evacuation time for a college building due to change in steering and comfort distances of occupants. A college building called PC-block has maximum number of class rooms in Caledonian College of Engineering, Muscat. This block has high occupant density compared to other blocks and has been chosen for the present study. Computational models have been prepared to find the evacuation time for PC-block, in two phases i.e. without exit doors and with exit doors. Computational analyses have been carried out for different values of steering and comfort distances of occupants. Significant changes in evacuation time have been found for different values of steering and comfort distances in first phase as compared to values obtained in second phase.*

Keywords: *evacuation time, steering, comfort distance.*

1. Introduction

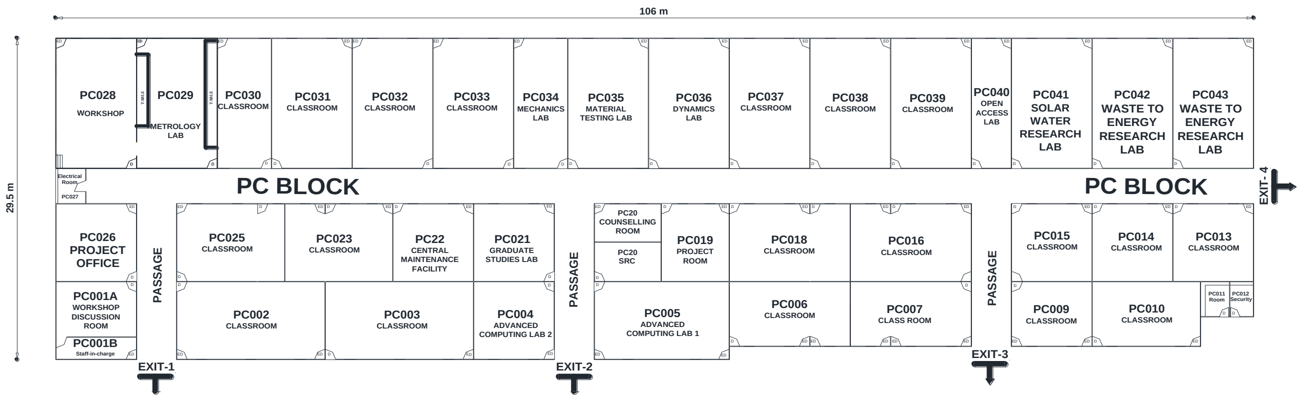
Closed building areas, with high density of occupants, need to be studied for evacuation time especially if building has inadequate number of exit doors. Such situations should be commonly assessed to evaluate for fire safety in college/school building, shopping malls, cinema/assembly halls etc. [1] Studied fire safety models for residential buildings in Malaysia. Mixed methodologies i.e. quantitative and qualitative methods were adopted in their research. There are three research methods adopted i.e. observation, simulation, and questionnaire.

Conceptual approach to the control of fire hazards in buildings and mentioned that "what can be done to control a fire hazard? How can a building designer be sure that he is not creating a death trap for the occupants? These problems can be addressed by three basic methods for controlling fire hazards in buildings: prohibition, isolation and protection" [2]. Careful selection is also important in choosing the most effective method for controlling a particular hazard. The prohibition, isolation and protection methods, taken individually, may be inadequate; consequently, most designs specify a combination of methods to achieve the desired result.

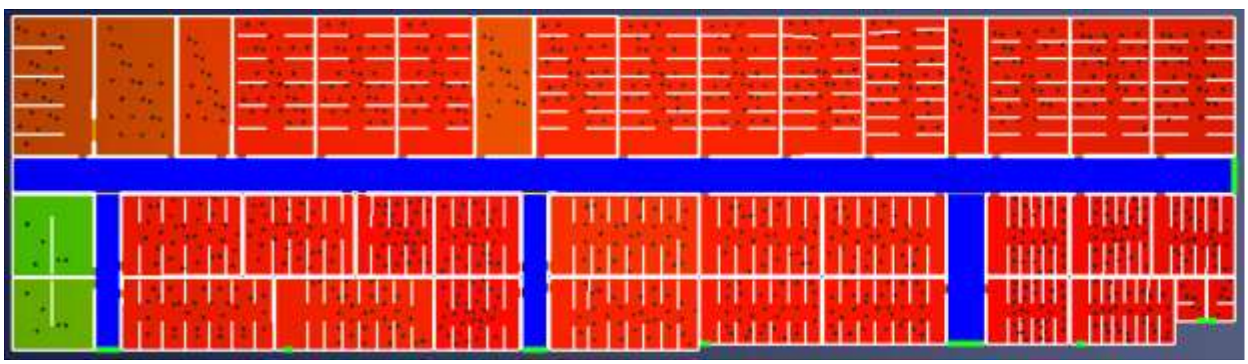
Study of evacuation from a four storey building at Tsinghua University for five evacuation scenarios were conducted to study occupant route selections and crowd movement under different conditions [3]. Authors have concluded that the results have been useful implications for understanding the psychological characteristics and crowd movement of people in evacuation. [4] Studied the evacuation for a large retail store and it was found that 50.1% choose the nearest exit to evacuate from the building and 19.5% choose a familiar exit to evacuate from the building. [5] Studied behaviour and characteristics of people on unannounced fire drill for large retail stores.

[6] Studied human behaviour approach to occupancy classification. They suggested that there are four categories of occupants' data that are necessary to implement a performance approach to life safety i.e. location of occupants with regards to the allowable minimum travel distance, occupants response to fire, number of occupants, and staff training. [7] Conducted numerical study on factors affecting capability of a fire-protection walk in underground buildings. Authors have found that the largest capacity of evacuation can be reached when the exit width is almost same or wider than the width of the fire-protection evacuation walk.

From the above literature, it is clear that the evacuation time from the building is a major concern during hazardous situation like fire. In this paper, evacuation time has been evaluated by computational analysis for the college building in two phases. In first phase, the building model has been analyzed by considering normal doors i.e. no exit doors were considered. Whereas, in second phase, exit doors have been considered in addition to normal doors for evacuation.



(a)



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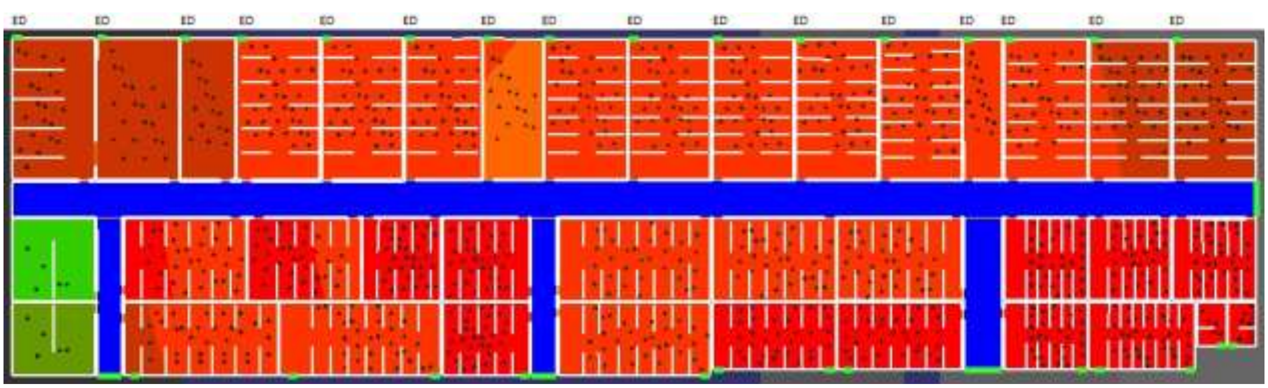

(c)

Fig. 1: Plan of PC-block a) various class rooms b) computational model without exit doors c) computational model with exit doors.

2. Building parameters

Assessment of evacuation time for the college building has been carried out for PC-block of Caledonian College of Engineering, Muscat. Figure 1a shows the plan of PC-block and location of four main exits 1, 2, 3 and 4. Number of occupants in various class rooms, laboratory and service rooms are mentioned in Table 1.

TABLE I: Configuration of college building

Room types	Occupants per room	Number of rooms	Number of occupants	Total occupants In PC-block
Class rooms	30	29	870	975
Laboratory-1	15	3	45	
Laboratory-2	20	2	40	
Services	4	5	20	

The plan dimension of PC-block is 29.5 m width and 106 m length. Out of 975 occupants mentioned in Table 1, 100 occupants have direct exit without interference of inside corridor and any of four exits in PC-block. Therefore, in first phase of analysis, 870 occupants will use corridor and exits 1, 2, 3 and 4 to evacuate PC-block.

3. Evacuation parameters

Acceleration Time / A steering mode parameter: It specifies the amount of time it takes for the occupant to reach maximum speed from rest or to reach rest from maximum speed [8]. The resulting acceleration of each occupant is maximum-speed/acceleration-time. Acceleration time of 0.1, 0.3 and 0.5 seconds have been considered.

TABLE II: Evacuation time of occupants for PC block without exit doors

Comfort Distance (m)	Steering (sec)	Occupants' Speed (m/s)					
		0.5	0.7	0.9	1.1	1.3	1.5
0.1	0.1	136.5	99.0	84.0	73.3	65.8	61.8
	0.3	158.0	116.3	104.0	96.0	87.3	84.5
	0.5	196.5	156.8	138.0	131.0	126.8	116.5
0.3	0.1	160.3	116.3	97.0	83.8	75.5	69.8
	0.3	175.5	133.0	116.5	103.3	96.0	91.0
	0.5	213.8	165.3	149.8	131.3	131.8	119.0
0.5	0.1	175.8	125.0	108.3	93.5	81.5	76.3
	0.3	193.3	148.0	120.3	107.5	103.8	94.8
	0.5	231.3	170.3	161.0	139.0	134.5	129.8

TABLE III: Evacuation time of occupants for PC block with exit doors

Comfort Distance (m)	Steering (sec)	Occupants' Speed (m/s)					
		0.5	0.7	0.9	1.1	1.3	1.5
0.1	0.1	64.8	49.3	42.0	35.8	34.0	31.8
	0.3	68.0	55.5	47.3	44.0	40.8	42.0
	0.5	76.3	67.0	54.3	54.8	59.3	50.5
0.3	0.1	65.0	53.8	40.3	39.0	37.3	32.5
	0.3	67.8	56.8	48.0	44.3	44.0	40.0
	0.5	78.3	71.3	59.8	51.8	51.5	52.8
0.5	0.1	65.3	53.8	42.3	38.5	35.5	32.5
	0.3	68.5	53.3	48.8	43.3	46.3	42.0
	0.5	81.0	70.3	62.5	58.5	53.0	53.3

Comfort Distance: Specifies the desired distance one occupant will try to maintain with others nearby such as when waiting in queues [8]. In this study, comfort distance of 0.1, 0.3 and 0.5 m have been considered.

Speed of occupants: It specifies the maximum speed with which an occupant may travel in an open room. In this study, speed of 0.5, 0.7, 0.9, 1.1, 1.3 and 1.5 m/sec was considered.

Exit doors: The evacuation analyses have been carried out in two phases. In first phase, building model has been analyzed by considering normal doors as shown in Figure 1b. In second phase, exit doors have been considered in addition to normal doors for evacuation, as shown in Figure 1c.

4. Computational model

To study flow of occupants and evacuation time, computational models were prepared. All the buildings and evacuation parameters mentioned above were considered for determination of evacuation time for each combination of parameters. Location of normal doors (D), and main exits (EXIT - 1, 2, 3 and 4) are mentioned in Figure 1a. In the computational model, size of occupants as 45.6 cm, density of occupants as 0.338 pers/m^2, and total number of occupants as 975 were considered. Pathfinder [8] considers the size of occupants (shoulder width), as the diameter of the cylinder representing the occupant. This is used for collision testing and path planning during the simulation. This value will also affect how many occupants can be added to a room without overlapping.

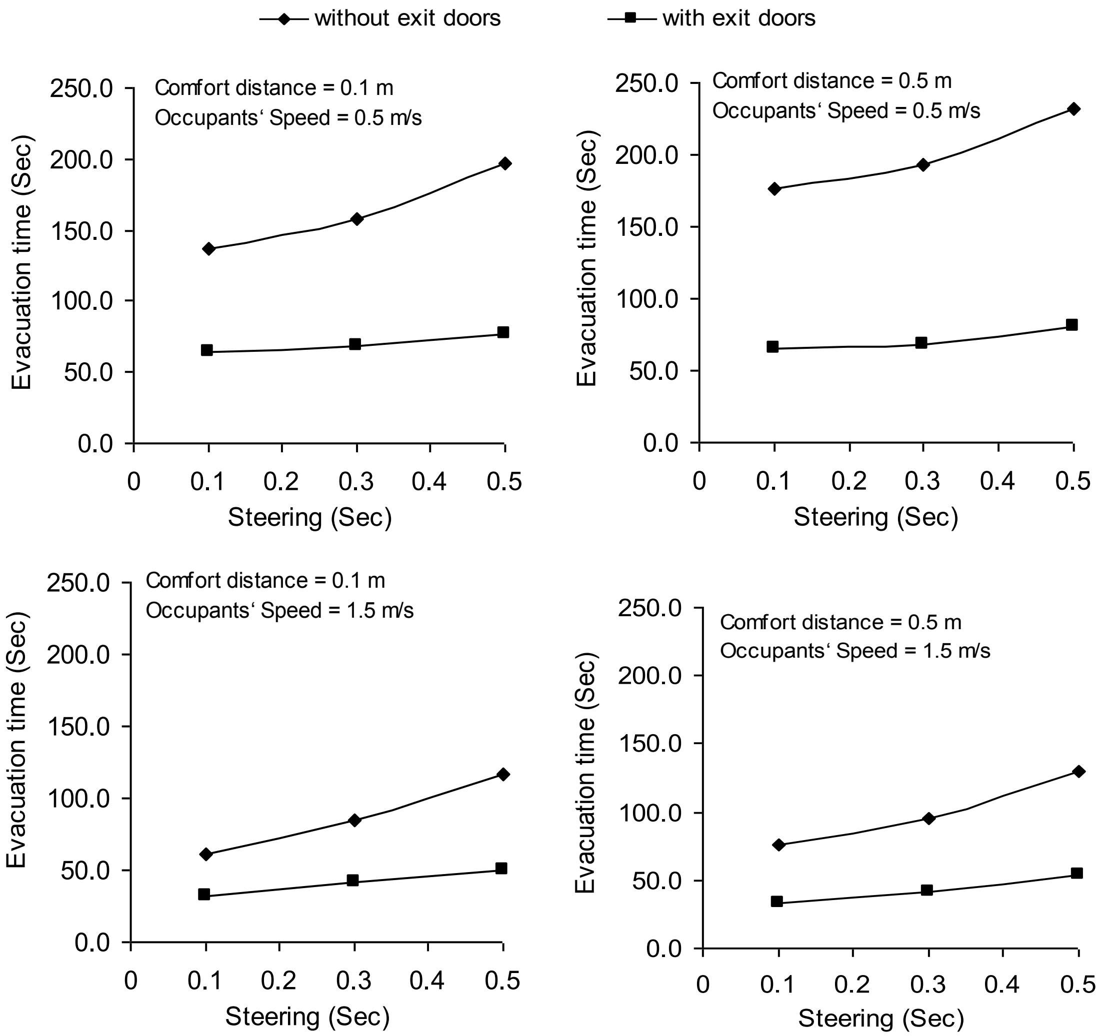

Fig. 2: Variation of evacuation time of PC-block for without and with exit doors.

5. Results and discussion

In the first phase of analysis, evacuation times for PC-block were computed by considering only normal doors in various rooms. Different values of steering were studied to compute evacuation time for different occupants' speed and comfort distances. In the second phase, analyses were repeated for the PC-block with exit doors in addition to normal doors. Evacuation of different combinations of steering, occupants speed and comfort distances have been mentioned in Table 2 and 3.

Effect of steering: three values of steering (0.1, 0.3 and 0.5 sec) were considered for analysis. It is observed that as steering values increases the duration of evacuation time (without using exit doors) by 45% for lowest occupants speed and by 90% for the highest occupants speed for a comfort distance of 0.1 m. However, for comfort distances of 0.3 m and 0.5 m, the increase in evacuation time has observed to be 32% and 74% respectively.

It is found that the effect of steering is significant when speeds of occupants are high and there is chance of congestion in corridor while exit. However, results of evacuation time indicated that there is less effect of steering if occupants are using exit doors to evacuate i.e. less congestion in corridor.

Effect of comfort distance: The values of evacuation time given in Table 1 and Table 2 shows that comfort distance is an important parameter which affect the evacuation time. However, this effect is not that significant as steering parameter if overall evacuation time is compared. From Table 2 and Table 3, it is evident that comfort distance revealed change in evacuation time of about 18 to 28 % when occupants' speed is minimum and exit door have not been considered. However, this percentage is reduces as occupants speed increases. At maximum occupants' speed, the effect of comfort distance on evacuation time is almost null.

6. Conclusion

This paper has reported results of a computational study carried out to determine the appropriate variation in evacuation time during emergency/hazardous situation for the college building. The speed of occupant varied from 0.5 to 1.5 m/sec at an interval of 0.2 m/s. From the relation between occupant and evacuation time it is concluded that evacuation time dropped in first three intervals of occupants' speed and then effect tapered off when occupants were using exit door.

Effect of steering showed that evacuation time of occupants is almost double when speed of occupants is maximum. This is because of congestion near the main exit (EXIT 1, 2, 3 and 4). There is no significant change in evacuation time for change in comfort distance except when occupants' speed is less and when they are using only normal doors.

The above conclusion is based on a case study of a college building. For more general conclusions as well as to determine effect of occupants' speed and steering on evacuation time, other buildings are also required to be considered.

7. Acknowledgement

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