OCCUPANT LOAD FACTOR IN LOCAL RESIDENTIAL OLD HIGH-RISE BUILDINGS

L.T. Wong
Department of Building Services Engineering, The Hong Kong Polytechnic University, Hong Kong, China

ABSTRACT

The occupant load factor for apartments of a typical old high-rise residential building in Hong Kong was studied with interview survey. Difficulties encountered in the study were discussed and suggestions to further investigations on similar studies on occupant load assessment were made. Statistical summaries of the surveyed occupant are presented. The average occupant load factor is 11 m^2 $person^{-1}$. The result showed that 95% of the surveyed samples have an occupant load factor of 4.5 m^2 $person^{-1}$ or above. The investigation result would be representative of other similar buildings in the region and therefore this study would be significant in providing information to assess whether the currently specified occupant load factor in the local code of practice is appropriate, given the actual occupant loads measured.

1. INTRODUCTION

A building is designed to satisfy the social demands on accommodations and activities [1]. Reasonable estimation in the building occupant load plays an important role on practical building design [1-3]. However, those data are absent in the local literature. It is difficult to carry out fire hazard assessment without a good database. Occupant load is defined as the maximum probable number of occupants expected to inhabit a building or space [3-5]. The means of escape is designed to satisfy the estimated 'occupant load' in the building. The occupant load factor is defined as the designated floor area occupied by each person [4-5]. Building occupant load factor are specified in codes of practice and design guides for building fire safety designs for various occupancies [4-5]. The factors adopted for evacuation designs will satisfy the legislative requirements for the means of escape in case of fire emergency [5-6].

There are 50,000 private buildings in the built-up areas in Hong Kong [7]. About 40% of those existing buildings were built at least 28 years ago when fire safety was not seriously considered as nowadays. There might be problems on the fire safety [7-10]. Consequent to several big fires occurred in those old high-rise buildings in the past years, people are now aware of the fire safety issues and fire safety improvement programmes are proposed for many old high-rise buildings [11-13]. The means of escape for the building is one of the major concerns for fire safety [5]. In many old high-rise residential buildings, the number of apartment in a floor per escape staircase is 5 or more. Compared to the newly constructed residential buildings, a higher occupant load in old high-rise residential buildings is believed and a higher occupant load has been specified in the local code for the egress system designs [5]. Following the occupant load assessment in the local code, staircases in most of the old high-rise buildings have to be upgraded in terms of number and width. Queries on the occupant load factors on the existing in-use buildings have recently been reported for assessing the staircase capacity. The modification on the staircases in occupied buildings may create structural difficulties, financial implications and management problems during the construction. Occupant load factor describing the usage of the old high-rise building today has to be investigated so that a reasonable provision can be made. An interview survey on the occupant load factor in a typical old high-rise residential building in Hong Kong was conducted. The investigation result would be representative to other similar buildings in the region and therefore this study would be significant in providing information to assess whether the currently specified occupant load factor in the local code of practice is appropriate, given the actual occupant loads measured. The difficulties encountered in the survey study are discussed and the study can be extended to other buildings for a more complete database of occupant load factor.

2. OCCUPANT LOAD FACTOR

Occupant load factor OLF (m^2 $person^{-1}$) is defined as the minimum area allowed for an occupant expected to inhabit a building space [5],

$$\mathrm{OLF} = \frac{\mathrm{A}}{\mathrm{n_p}} \qquad (1)$$

where, A (m^2) is the area of the building space and n_p (person) is the maximum probable number of occupants expected to inhabit the space.

The design occupant load factors OLF (m^2 $person^{-1}$) specified in local code of practice to assess the provisions of building egress system for domestic buildings are shown in Table 1 [5]. The building spaces for domestic use are categorized into 3 groups, namely, (1) tenement house or space of similar design, (2) self-contained flat that a staircase that serves 5 or more flats on a floor and (3) others. An OLF of 3 m^2 $person^{-1}$ is specified for tenement houses, barracks, dormitories and self-contained flats comprising a single room or having the main living area subdivided by rooms; 4.5 m^2 $persons^{-1}$ is allowed for self-contained flats with corridor or balcony access having five or more flats on each floor served by each staircase. For unlisted space of domestic use, 9 m^2 $person^{-1}$ is the designed OLF as shown in the table. The OLF specified in life safety code is 18.6 m^2 $person^{-1}$. The occupant load factor would vary significantly for different domestic designs and a large deviation would be recommended in different design guides.

3. SURVEY STUDY

A typical old high-rise residential building of 13 m wide by 90 m long by 35 m high was selected for this study. The top six storeys of the building (4/F to 9/F) serve for domestic purpose and the lowest four storeys are commercial centre, where is physically separated from the domestic floors in terms of compartmentation. Each of these domestic floors consists of 21 apartments, with a total of 126 apartments in the six storeys served by three protected staircases. The floor area of the apartment, ranged from 30 to 40 m^2, was obtained from information provided by facilities management, direct measurement or inspection in the Hong Kong Buildings Department's records.

An interview survey to the building occupants in the apartments was conducted to study the occupant load factor. The survey forms part of the building fire safety improvement programme. An invitation notice detailing the purpose, date and interviewing procedures was sent to building occupants prior the conduction of the survey through the building management. The respondents were asked to indicate the number of years of occupying the current apartment, usual occupancy patterns in the apartments throughout a day at the specified time period, number of occupants living in the apartment, location of staircase and the designation of the staircase identified on the floor.

The survey was conducted in daytime from 09:00 to 17:00 in apartment basis and witnessed by building owners' association's representative and building management representative. No occupant was there in 63 out of 126 (50%) apartments at the time of survey because no one answered the door call (denoted as AP0 = 63). According to the tenancy records, there are 10 unoccupied apartments during the survey period. Occupants were found in 63 (50%) apartments (denoted as AP1 = 63) during the survey. They were invited to attend an interview for occupant load survey but occupants in 20 apartments (denoted as AP10 = 20) (16%) were unwilling to response. The occupants were home helpers, children below 12 or workers with shift duties that the survey with them was considered as inappropriate. The interview with the occupants in AP10 was not conducted. Talks with their neighbour of apartments AP0 and AP10 found that most of them were of only 1 to 4 occupants. However, these results are subject to unknown uncertainty and have not considered in determining the occupant load factor. Occupants in 43 apartments (denoted as AP11 = 43) (34%) were interviewed successfully and the surveyed results were summarised in Table 2.

Table 1: Occupant load factor of domestic use

Description of the space of domestic use [5]	Occupant load factor, OLF (m^2 $person^{-1}$)		
	NFPA [4]	COP [5]	Current study
Tenement houses	18.6	3	Not surveyed
Self-contained flats on a floor that each staircase serves 5 or more flats		4.5	9 (Median) 11 (Average with standard deviation of 5.6) ≥ 4.5 (95% samples)
Others		9	Not surveyed

Table 2: Survey results

Survey details	Results			
The apartment has been occupied by the same occupants for	Over 20 years	10-20 years	5-9 years	Less than 5 years
	13/ 43 (30%)	17/43 (40%)	5/43 (12%)	8/43 (18%)
The respondent can correctly indicate	*Yes*		*No*	
1. the nearest staircase and its designation	43/43 (100%)		0/43 (0%)	
2. all the staircases and its designation	28/43 (65%)		15/43 (35%)	
3. the second nearest staircase and its designation	14/43 (33%)		29/43 (67%)	

4. RESULTS AND DISCUSSION

Several challenges of using interview to collect data in residential buildings were encountered. The major challenges are:

- Residential apartments are private areas and the survey must be fully supported by the property owner's associations and the building management. The survey procedure must be agreed by the occupants and the building management. The survey cannot be lengthy. The interview survey must be designed carefully.
- Only occupant representatives in 43 (34%) apartments were interviewed successfully during the time required to complete the survey. This was attributed to the four factors, (1) occupants were not available during the survey; (2) occupants may be unwilling to respond for keeping privacy; (3) occupants may be inappropriate to attend an interview, (4) some apartments were vacant during the survey. Talking with their neighbour may obtain useful information on the occupant load factor for those apartments unavailable to the interview study.
- It is difficult to account for occupants walking in landlord's area. Other persons such as visitors, management personnel, maintenance staff would be there occasionally but are difficult to identify during the survey. They may be distinguished by the security records kept in the building entrance.

Table 2 shows the surveyed result of the 43 apartments. It was found that 13 apartments (30%) were occupied by the same family for more than 20 years, 17 (40%) were occupied between 10 and 20 years. The results show that 5 apartments (12%) were occupied between 5 and 9 years and 8 (18%) were occupied for less than 5 years. All the respondents were able to indicate the nearest staircase leading to ground floor discharge and 28 (65%) of them knew the number and the locations of all the three staircases. It was found that 14 (33%) of them were able to indicate the second nearest staircase in the building and correctly indicate the designation.

The surveyed occupant load factors are shown in Fig. 1 in terms of cumulative percentage distribution. The median is 9 m^2 $person^{-1}$, and the average OLF is 11 m^2 $person^{-1}$ with the standard deviation of 5.6 m^2 $person^{-1}$. The probability density function of the OLF is not normally distributed and is skewed to the right. By plotting the OLF of 4.5 m^2 $person^{-1}$ as recommended in the local code of practice [5] on Fig. 1, it was found that 95% of surveyed samples were covered.

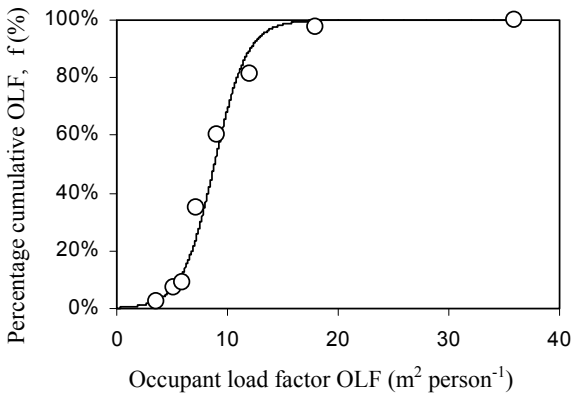

Fig. 1: Occupant load factor OLF

By observing the distribution pattern of OLF in the figure, a simple logistic regression model was assumed and the following correlation equation for the percentage cumulative frequency distribution f with correlation coefficient of 0.9906 was found:

$$f = \frac{\exp(-6 + 0.68\,OLF)}{1 + \exp(-6 + 0.68\,OLF)} \quad (2)$$

The unoccupied apartments were excluded from the above analysis and equation (2) would over-estimate the occupant load for whole building. It is because the probable number of occupants in the apartment AP0 is only 1 to 3 and the corresponding OLF is 12 to 40 m^2 $person^{-1}$. However, the exclusion of the building visitors would under estimate the occupant load.

5. CONCLUSION

The occupant load assessment is of prime importance in the fire safety improvement for the old high-rise buildings. The occupant load factor for apartments of a typical old high-rise residential building in Hong Kong was studied with interview survey and the results were reported in this paper. The survey study would be significant in providing information to assess the occupant load factor and assess whether the currently specified occupant load factor in the local code of practice is appropriate, given the actual occupant loads measured. However, the survey study in the in-use building is not always possible. Difficulties encountered in the survey study were discussed and suggestions to further investigations on similar studies on occupant load assessment were made. The investigation result would be representative of other similar buildings in the region.

The results showed that large variations on the OLF (from 3.6 to 40 m^2 $person^{-1}$) would be encountered in the apartments of the old high-rise residential buildings. The OLF sample median, mean and standard deviation is 9, 11 and 5.6 m^2 $person^{-1}$, respectively. The probability density function of the OLF is not normally distributed and is skewed to the right. By plotting the OLF of 4.5 m^2 $person^{-1}$ as recommended in the local code of practice [5] on Fig. 1, it was found that 95% of surveyed samples were covered.

ACKNOWLEDGEMENT

This project is supported by PolyU research fund with account number G33.09.T699.

REFERENCES

1. D. Adler, Metric handbook - planning and design data, Architectural Press, Oxford (2002).
2. A. Ebrahimpour and R.L. Sack, "Modeling dynamic occupant loads", Journal of Structural Engineering, Vol. 115, No. 6, pp. 1476-1496 (1989).
3. J.A. Milke and T.C. Caro, "Survey of occupant load factors in contemporary office buildings", Journal of Fire Protection Engineering, Vol. 8, No. 4, pp. 169-182 (1997).
4. NFPA 101: Life Safety Code, National Fire Protection Association, Quincy (2000).
5. Code of Practice for the Provision of Means of Escape in Case of Fire, Hong Kong Buildings Department (1996).
6. Laws of Hong Kong, Chapter 123F, Building (planning) regulations, Hong Kong (1997).
7. An introduction to the building safety inspection scheme, Hong Kong Buildings Department (1997).
8. S.M. Lo, "Fire safety design in buildings of Hong Kong: a preliminary view", Asia Pacific Building and Construction Management Journal, Vol. 1, No. 1, pp. 41-50 (1995).
9. W.K. Chow, L.T. Wong and E.C.Y. Kwan, "A proposed fire safety ranking system for old highrise buildings in the Hong Kong Special Administrative Region", Fire and Materials, Vol. 23, No. 1, pp. 27-31 (1999).
10. L.T. Wong, W.K. Chow and E.C.Y. Kwan, "A brief review on fire regulations for old highrise commercial buildings in Hong Kong", International Journal on Engineering Performance-Based Fire Codes Vol. 2, No. 4, pp. 153-160 (2000).
11. South China Morning Post, Hong Kong, 22 November (1996).
12. South China Morning Post, Hong Kong, 9 April (1997).
13. Hong Kong Standard, Hong Kong, 7 January (1998).

Q & A

Q1: Do the samples of the old high-rise buildings include public and private housing?

Dr. Wong: Yes, in the study, both types of the buildings will be included in further investigation. It is understood that public housing may be exempted from the MoE requirement for other residential buildings.

Q2: From the studies, it shows that the OLF for old high-rise buildings deviated from the standard requirement a lot. So why does the government permit this situation to happen? How to improve fire safety by some management schemes?

Dr. Wong: Due to the long-term utilization, like move in, new born and so on situations will increase the OLF inside the building. However, no regulation has been set up for documenting them. On the whole, the fire safety management schemes are very important. For the single-owner buildings,

it is easy to achieve fire safety by a good fire safety management scheme. However, for some multi-owner buildings, there are some difficulties to apply the pre-set management schemes completely. Therefore, how to set up an appropriate management scheme is a challenge for the fire safety engineers and building owners.

Q3: In the survey of occupant load inside the old high-rise buildings, were the number of domestic persons and visitors included?

Dr. Wong: No. In the survey, it only focused on the number of domestic persons. The number of visitors was excluded in the survey.