BUILDING OFFICIALS' PERCEPTION ON THE USE OF PERFORMANCE-BASED FIRE ENGINEERING APPROACH IN BUILDING DESIGN – A SECOND STAGE STUDY

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(Received 27 November 2002; Accepted 3 January 2003)

ABSTRACT

With the increasing demand on multi-function and appearance of the buildings, a conventional prescriptive approach would impede the development of innovative and cost-effective designs. It has been accepted worldwide that the fire engineering approach would be a suitable alternative to satisfy the demand. In the context of the building control system in Hong Kong, whether a fire engineering design can be put into practice is subject to the approval of building officials. The acceptance from the building officials is decisive in promoting the application of the fire engineering approach. This paper aims at investigating whether the building officials' perception on the fire engineering approach has changed since the last study in 1999. A questionnaire has been conducted, and the findings are compared with those obtained from the previous survey. The results revealed that more building officials have agreed to the use of the fire engineering approach. However, they are still unfamiliar with the techniques and models required for design evaluation.

1. INTRODUCTION

The prescriptive approach is a norm for many designers to achieve fire safety because it provides a deemed-to-satisfy solution so that approval from the Building Authority can be ensured. However, as more and more novel designs evolve, the prescriptive approach, which simply specifies design requirements based on the occupancy types of buildings, may not be able to provide an adequate level of fire safety. Wakamatsu [1] listed the disadvantages of the prescriptive approach, including low flexibility in architectural design, difficulty in the use of new technology, and providing no incentives to improve safety. Hadjisophocleous et al. [2] also summarized these disadvantages and suggested that a performance-based approach should be a suitable alternative.

The government in Hong Kong has recognized the need for the fire engineering approach to demonstrate the adequacy of any fire safety design. The latest versions of the fire codes in Hong Kong [3-5], which were published in 1995-1996, explicitly allow such an approach. In addition, a practice note [6] has been issued to provide a preliminary framework of what should be considered in the fire safety engineering study. However, neither guidance notes nor engineering handbooks have been published to explain the rationale behind each prescriptive requirement and to illustrate the acceptable evaluation methods [7]. The scrutiny of the adequacy of safety provided by this approach is the responsibility of the building officials on the basis of the recommendation of the Fire Safety Committee. As a result, their opinions are influential in the popularity of the fire engineering approach.

In this study, we are going to investigate whether the building officials' perception for the use of the fire engineering approach has changed. The methodology and results of this study will be presented in the following sections.

2. METHODOLOGY

According to the conclusion drawn by Lo et al. [7], the officials, in general, agreed with the need to use the performance-based approach. However, they were not fully comfortable in accepting the fire engineering design because of their limited knowledge, inadequate fire and evacuation prediction tools, and the unclear liability of various parties for the problems arising in the approved fire engineering designs.

In view of these problems, an effort has been made to provide education to all the members of the building industry. For instance, a master's degree course has been established by the Department of Building Services Engineering, The Hong Kong Polytechnic University to boost members' knowledge. Some courses for continued professional development (CPD) were also organized by the joint effort of universities and the Hong Kong Institute of Engineers and Hong Kong

Institute of Surveyors to provide an introduction to the concept of fire engineering design [8]. Therefore, it is logical to hypothesize that more building officials are willing to accept fire engineering designs, compared to the situation two years ago.

In order to investigate whether the building officials' attitude towards the fire engineering approach has changed, the questionnaire drafted in this study (see Appendix) is based on the previous one adopted by Lo et al. [7], which was conducted in 1999. In fact these two surveys referred to the survey carried out at the 1995 annual conferences of BOCA (Building Officials and Code Administrators), ICBO (International Conference of Building Officials) and SBCCI (Southern Building Code Congress International) in the United States [9]. Three more questions were newly incorporated with an aim to examining the views of the officials on their own levels of understanding the fire engineering approach, the adequacy of guidelines, and the training that is currently being provided.

Five scale points are used in this survey. They are *strongly agree*, *fairly agree*, *neither agree nor disagree*, *fairly disagree,* and *strongly disagree*. The percentages responding to each of the five scale points are calculated, and then aggregated into two categories. The "agree" category comprises the responses of *strongly agree* and *fairly agree*, while the "disagree" category comprises the responses of *neither agree nor disagree*, *fairly disagree*, and *strongly disagree*. Such a categorization is the same as the previous study so that direct comparison is possible.

3. RESULTS

The questionnaire was conducted in the Buildings Department in March 2002. There were 55 questionnaires distributed to the building officials and 41 sets were returned (response rate: about 75%). Twenty sets were distributed randomly, while 21 sets were completed through short interviews with the officials so that the reasoning behind the officials' options could be understood.

The respondents are building officials of Buildings Department. One of their main duties is to scrutinize building proposals. Thus, they normally neither have any experience in performing fire safety engineering design nor using fire models, including fire and evacuation simulation packages, for engineering design.

The questionnaire can be categorized into five aspects, which are the main concerns in the implementation of the fire engineering approach in building design:

- Acceptance of engineering performance-based fire codes
- Application of computer fire models to design and evaluate equivalence on prescriptive requirements
- Acceptability of the use of risk-based fire protection analysis
- Request for registration of fire specialists
- Adequacy of guidelines and training for evaluation of the fire engineering design

It was found that most findings are consistent with the previous one, but there are obvious changes concerning the applicability of prescriptive codes, ability of the fire engineering approach in ensuring adequate fire safety, and the registration of fire specialists. The results will be further discussed in accordance with the five major aspects. The findings are summarized and tabulated against the results obtained from the 1999 survey in Table 1.

It was revealed that the more experienced building officials were more capable of understanding the theories about fire engineering design (Gamma = -0.788 and Somers' d_{yx} = -0.483 at the 0.001 significance level, Table 2)[1]. The data is, however, not stratified according to the officials' years of experience. The reason behind this is that the majority of the officials (about 95 percent) did not think that they could understand most of the principles applied in the fire engineering design. Therefore, it is reasonable to believe that the little difference in the level of understanding between the more experienced and less experienced officials would not result in much diversification in the perception towards the fire engineering approach.

[1] Computation of the Cramer coefficient is adopted for the analysis as it provides a measure of the degree of association between two sets of attributes. It is particular useful for categorical information. The results of the questionnaire captured imprecise information with nominal scale. Thus, it provides an initial measure to the possibility of relationship between two sets of attributes. Somers coefficient is an additional test to that of Cramer in that it gives the directional assessment. Spearman rank-order correlation coefficient is not adopted as some of the variables are not exactly measured in precise ordinal scale.

Table 1: Summary of findings of surveys conducted in 1999 and 2002

Questions	Percentages			
	Agree		Disagree	
	1999	**2002**	1999	**2002**
3. Prescriptive building regulations/building codes, as they are written now, cannot be appropriately applied to all buildings or occupancies.	35%	**54%**	65%	**46%**
4. I can understand most of the basic principles or theories about the fire engineering design.	N/A	**5%**	N/A	**95%**
5. Currently available computer fire-prediction models are adequate to support performance-based fire safety codes and life safety codes.	17%	**18%**	83%	**82%**
6. I am comfortable using currently available fire-prediction models to evaluate performance-based design specifications.	17%	**10%**	79%	**90%**
7. Prescriptive building and fire codes, as they are currently written, are necessary to ensure reasonable levels of fire protection and life safety	90%	**88%**	10%	**12%**
8. Performance-based codes are necessary to provide reasonable levels of fire protection and life safety in our rapidly changing environment.	71%	**85%**	29%	**15%**
9. Performance-based codes should require a plan review and code enforcement personnel to be certified by a recognised agency.	75%	**90%**	25%	**10%**
10. It is necessary to provide more guidelines for the verification of designs using the fire engineering approach.	N/A	**95%**	N/A	**5%**
11. It is necessary to provide more on-the-job training regarding the use of computer fire-prediction models and other techniques involved in the analysis of design using the fire engineering approach.	N/A	**93%**	N/A	**7%**
12. I am comfortable with specifying a number for acceptable life loss as a part of risk-based analysis for building construction.	15%	**12%**	81%	**88%**

14. How frequently are you called upon to rely on computer fire models in your decision making process for the equivalent alternative to fire-protection and life-safety code requirements?	Percentages	
	1999	**2002**
Never	88%	**71%**
Yearly	8%	**27%**
Monthly	4%	**0%**
Weekly	0%	**0%**
Daily	0%	**0%**

Table 2: Years of experience vs. ability of understanding fire engineering principles and theories (Question 4)

		Years of experience (x)				
		0-3 years	4-6 years	7-10 years	over 10 years	Total
Ability of understanding fire engineering principles and theories (y)	Strongly agree	0	0	0	1	1
	Fairly agree	0	0	0	1	1
	Neither agree nor disagree	1	5	6	11	23
	Fairly disagree	4	5	5	0	14
	Strongly disagree	1	1	0	0	2
	Total	6	11	11	13	41

C = 0.388; Approximate significance = 0.102
d_{yx} = -0.483, d_{xy} = -0.627 at the 0.001 significance level

- **Perception of Performance-Based Fire Codes**

Analysis of the response to Question 8 of the questionnaire indicates that building officials in Hong Kong generally agreed that the use of performance-based fire codes could cope with the changing built environment. Compared to the findings in 1999, there was a noticeable increase (from 71 percent to 85 percent) in the acceptance of the use of engineering performance-based fire codes by the officials.

The results in Question 8 were further compared with those in Question 7. It was revealed that a higher percentage of officials agreed that the prescriptive codes could ensure an adequate level of fire safety. It seems that the officials still prefer a prescriptive code to a performance-based code. This finding is in line with the one conducted in 1999, but the difference between the percentages of Question 7 and Question 8 in the current study (3 percent) was much less than the previous one (19 percent).

In addition, from the previous study, it was found that officials generally believed that the prescriptive codes can normally be applied to most buildings and can ensure adequate fire safety (about 65 percent). However, in the current study, it was found that less than half of the officials (about 46 percent) recognized that the traditional prescriptive approach can be appropriately applied to all kinds of premises.

- **Perception of the Use of the Computer Fire Model**

It was found that many officials have not heard of any computer fire models. None of the officials with less than three years' practical experience had any knowledge of the currently available models for performance-based fire codes. The majority of the officials (about 90%) did not feel comfortable using the models to evaluate performance-based design. There was a substantial increase (11%) in the number of officials who were wary of using fire models compared to the results in 1999.

When the relationship between the willingness of officials to use fire models and the perception of adequacy of the models was analysed, it was found that these two variables are significantly and positively associated (Table 3). This indicated that the officials were not confident with the ability and adequacy of the models, and hence were unwilling to use them. This idea is supported by the value of d_{yx} (0.465), which shows that the perception of the adequacy of fire models has a moderate impact on the degree of comfort in using the model. This result is in agreement with the one obtained from the study in 1999, which had a Cramer's V of 0.591 and Somers' d of 0.623.

- **Perception of the Registration of Fire Specialists**

Most of the officials (about 90%) thought that fire engineering reports should be certified by registered fire specialists. This is probably associated with the fact that most officials do not possess adequate knowledge on the techniques required for design evaluation, and therefore feel uneasy in analysing the fire engineering design.

- **Perception of the Use of the Risk-Based Fire Protection Analysis**

About 88 percent of the officials said that it was difficult to accept the risk-based fire protection analysis. This finding is in agreement with the findings of previous studies (81 percent).

Table 3: Comfort in using fire models vs. adequacy of existing fire models (Question 6)

		Adequacy of existing fire models (x)				
		Agree somewhat	Neither Agree nor disagree	Disagree somewhat	Strongly disagree	Total
Comfortable in using fire models (y)	Agree somewhat	2	1	0	0	3
	Neither Agree nor disagree	0	4	1	0	5
	Disagree somewhat	1	3	2	3	9
	Total	3	8	3	3	17

C = 0.546, Approximate significance = 0.119
d_{yx} = 0.465, d_{xy} = 0.529, Approximate significance = 0.013

Most of the officials cannot accept the idea that there is any assumed loss of life in the building design, because protecting human lives is the main function of fire safety design. They commented that it was ridiculous to have a design which presumed that not all people can be saved in the outbreak of a fire.

However, some[2] officials believed that the fire engineering approach, which takes into consideration the interaction of human and fire behaviour, does have certain merits. This approach enables any deviation from the prescriptive requirements to be justified in a more scientific way rather than just supported by qualitative arguments provided by the designer. Therefore, it cannot be concluded that the unacceptability of the risk-based analysis by the building officials will affect the suitability of the fire engineering approach.

- **Perception of the Provision of Guidelines and Training**

The majority of the building officials (93 percent) thought that there were not sufficient guidelines and training courses for the evaluation of the fire engineering design, and more should be provided. This is not surprising, as it is not obligatory for building officials to possess intensive understanding of fire engineering. This is evidenced by the findings of Question 4, where 95 percent of the officials were not able to understand the principles relating to fire engineering design.

Although it has been mentioned that years of experience is significantly associated with an ability to understand the fire engineering principles, it cannot be concluded that the experienced officials are more capable of evaluating the design. Some experienced officials said that their degree of understanding was not so intensive and rendered them less confident in approving the fire engineering design without any reference from the Fire Safety Committee.

Furthermore, there are many approaches to building up a fire engineering design. Some designs may be so extraordinary that it cannot be evaluated by conventional approaches. It is essential to provide guidelines and training courses to equip the officials with adequate knowledge to deal with those special designs. In fact, the government has been aware of this need and has decided to commission a study to produce relevant codes of practice and handbooks on the fire engineering approach.

4. CONCLUSION

This study revealed that the building officials' acceptance of the fire engineering approach has increased compared to the situation two years ago. However, most building officials still felt uneasy about using the computer fire models, as their knowledge of these models was still very limited. It is necessary to provide more guidelines and on-the-job training for the building officials. The government has already launched a consultancy study of the fire engineering approach with an aim to producing the relevant codes of practice and a handbook for local building professionals [10]. It is expected that the current situation can be improved if clearer guidelines are issued.

[2] Less than 20% had such comment. Whereas, the others did not have specific comment on this aspect.

Besides the issue of guidelines, the establishment of a registration system of fire specialists may also be necessary. Since the officials are not conversant with the fire engineering approach, they may not be able to judge whether the proposed fire engineering design can provide adequate fire safety. With recognition by registered fire specialists, the officials would be more confident with the justification provided. Therefore, the processing of the fire safety design evaluation can be facilitated.

In fact, the smooth implementation of the fire engineering approach does not only rely on the perception of building officials. Opinions of designers, authorized persons, and other professionals are also important. Further investigation into these aspects can give us a more complete picture of the problems involved.

ACKNOWLEDGEMENT

The authors acknowledge the collaboration of the building officials in the Hong Kong Buildings Department in answering the structured questions. The work described in this paper was fully supported by a grant from the Research Grant Council of the Hong Kong Special Administrative Region, China (Project No. CityU1112/99E).

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APPENDIX

Survey on the Performance-Based Fire Engineering Approach

I am a year 3 student of the Department of Real Estate and Construction, the University of Hong Kong. I am conducting a survey which aims to investigate the views of building control officers towards the use of the fire safety engineering approach, as well as the adequacy of currently available computer software supporting this approach. Your support in completing this questionnaire will be very helpful towards the investigation.

(Please tick the appropriate box)

1. You are in which of the following professions?

   □ Architect □ Building Surveyor □ Quantity Surveyor □ Structural Engineer

   □ Others (Please specify)_____

2. How many years have you been practicing in the building industry?

   □ 0-3 years □ 4-6 years □ 7-10 years □ Over 10 years

3. The existing prescriptive building regulations/building codes, as they are written now, cannot be appropriately applied to all buildings or occupancies.

Strongly Agree				**Strongly Disagree**
1	2	3	4	5
□	□	□	□	□

4. I can understand most of the basic principles or theories about the fire engineering design.

Strongly Agree				**Strongly Disagree**
1	2	3	4	5
□	□	□	□	□

5. I have heard of some available computer fire-prediction models.

   □ Yes □ No
   (If yes, please proceed to the following question.)

   Currently available computer fire-prediction models are adequate to support performance-based fire safety codes and life safety codes

Strongly Agree				**Strongly Disagree**
1	2	3	4	5
□	□	□	□	□

6. I am comfortable in using currently available fire-prediction models to evaluate performance-based design specifications.

Strongly Agree				**Strongly Disagree**
1	2	3	4	5
□	□	□	□	□

7. Prescriptive building and fire codes, as they are currently written, are necessary to ensure reasonable levels of fire protection and life safety.

Strongly Agree				**Strongly Disagree**
1	2	3	4	5
□	□	□	□	□

8. Fire engineering approach/performance-based codes are necessary to provide reasonable levels of fire protection in our rapidly changing environment.

Strongly Agree				**Strongly Disagree**
1	2	3	4	5
□	□	□	□	□

9. The fire engineering approach/performance-based codes should require a plan review and code enforcement personnel to be certified by a recognized agency (registered fire safety specialist)

Strongly Agree				**Strongly Disagree**
1	2	3	4	5
□	□	□	□	□

10. It is necessary to provide more guidelines for the verification of designs using the fire engineering approach

Strongly Agree				**Strongly Disagree**
1	2	3	4	5
□	□	□	□	□

11. It is necessary to provide more on-the-job training regarding the use of computer fire-prediction models and other techniques involved in the analysis of design using the fire engineering approach.

Strongly Agree				**Strongly Disagree**
1	2	3	4	5
□	□	□	□	□

12. I am comfortable in specifying a number for acceptable life loss as a part of risk-based analysis for building construction.

Strongly Agree				**Strongly Disagree**
1	2	3	4	5
□	□	□	□	□

13. Please specify your priority in the following basis for building decision.
(1 = highest preference, 2 = second preference, 3 = least preference)

□ Fire Potential risk to building occupants.
□ Fire Potential risk to fire-suppression personnel.
□ Fire Potential risk to adjacent occupancies.

14. I have come across submission(s) in which fire engineering codes have been used.

□ Yes □ No
(If yes, please proceed to the following question.)

How frequently are you called upon to rely on computer fire models in your predictions during your decision-making process for equivalent alternatives to fire code requirements?

□ Daily □ Weekly □ Monthly □ Yearly □ Never

□ Others (Please specify the frequency)_____

~ END ~

Thank you very much for your kind cooperation

Remark: The questionnaire is established on the basis of the survey performed by Van Rickley [9].