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"Safety and Health Hazards in Buildings"

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Keynote Address

"Safety and Health Hazards in Buildings", in medical terminology as doctors (or "building doctors") use, could be translated into "Health and Sicknesses of Buildings".

Given proper designs and quality constructions, buildings normally can be born safe and healthy. From inception to completion for occupation, it is a one-off exercise that usually lasts for just a couple of years. However during the life span of buildings of many decades, it will be a tedious process to keep them always safe and healthy, and free of hazards and sicknesses. It requires continuous attention and commitment from those who own them, from those who occupy them, from those who use them, and from those who manage them. It is the useful life of the buildings that we care about. Not only because they are our most valuable assets, even during economic recessions, but more importantly because they exist to serve our basic need for accommodation and security.

Building sicknesses and hazards could deteriorate into epidemic diseases. We only need to look back at the building design characteristics and the construction practices in the past decades and we will notice how some common practices that we are so accustomed to could suddenly be deemed hazardous. For instance, some of the means of escape arrangements which have always been accepted in the past have transformed over-night and become death traps by today's safety standards. Since those arrangements have been adopted in many buildings, people suddenly find death traps everywhere and they start to panic, because they have lost their sense of security.

Some of these aspects I must admit are truly inherent hazards and they only surface themselves after certain disasters or tragedies have occurred, or when society has awakened to realize the hazards at exceedingly great costs. But some of these might have been deemed hazards simply because of recent changes of safety standards. Some of such changes might have been subjectively imposed by the authorities, or have only been endorsed by hearsay consensus, sometimes even without any analytical verification whether the changes are rational and justified. Is the risk assessment for the changes realistic or exaggerated? Are the changes moderate or drastic? Are the remedies to satisfy the changes practicable and enforceable? Are we genuinely and effectively upgrading the safety margin of buildings? Are we imposing a social cost commensurate with the anticipated social benefits? These are just some of the questions that sometimes have not been answered or fully accounted for before changes are made.

And when standards are being applied and enforced, unfortunately there are always differences in opinion, or variations in interpretation, even within the authorities. Safety standards are like drugs that should be administered with a diagnostic and healing approach, avoiding or removing hazards according to the characteristics and the special conditions of the subject buildings. Particularly when new standards are being enforced in existing buildings, they should be administered in a holistic approach taking into account all aspects of the building and its occupants, in the context of both technical and social conditions. Building doctors should aim at a total re-vitalization of their patients rather than to accelerate their deaths due to organic incompatibility.

For the inherent hazards, we need technical and scientific research for the more efficient cures and the more effective rehabilitation. Similar to assessing the side effects before introducing any new drugs, we also need research and assessment of the probable effects of any proposed changes, especially mandatory "improvements" or new safety standards. When a problem is not just a technical problem, it will call for a remedy that does not aim merely at the technical surface but also addresses the socio-economical phenomenon of society. For building problems, it is not enough just to look at the hardware of building structures. We should also tackle the software of building management and maintenance. In this regard, perhaps we also need research for the more facilitating ownership mode and the more inspiring building management format so that building safety and healthiness could be more readily sustained at a more affordable cost for the more practical and satisfying results.

So the bigger problem as I see it is not just the technical aspects which are so apparent to the technical eyes, but the socio-economic aspects which are more deep-rooted. Buildings can become aged and obsolete so readily but the ever-changing performance requirements they need to meet with are rapidly becoming more sophisticated and challenging, almost to the extent of suffocating their remaining useful lives. Re-engineering and retrofitting may provide technical solutions but for the longer term radical remedy, we may need major surgeries on the building ownership and management framework.

How about re-defining ownership in strata-titles? Is it possible to demarcate ownership in such a manner that liabilities are readily identifiable and enforceable? How about re-formatting the Deed of Mutual Covenant? Is it possible to change the discouraging restrictions into more enabling provisions? Is it possible to introduce something like a "surveyor enforcement clause" so that property management and maintenance is subject to professional supervision? How about creating a mandatory levy of sinking funds for preventive maintenance? How about introducing mandatory management of buildings? How about providing for statutory closure of unsafe commercial premises? Would it be more effective to have a Commissioner of Buildings to regulate the use and management of premises? Would it be more expedient to have a Building Management Tribunal to adjudicate or arbitrate on management and maintenance disputes? Should Government offer more assistance, for example, improvement grants for the upgrading of sub-standard or hazardous buildings, especially when such "hazards" do not result from the owners' fault?

I do not have the answers but I believe to improve our body's immune systems is much more effective than to take in a lot of health drugs. We can live longer if we also relinquish unhealthy habits, and conduct our lives within both physical and ethical limitations. Buildings are likewise. At birth, they should be rid of all likely causes of future diseases while during their existence, they should be rid of unsuitable and incompatible occupancies as well as improper uses and handling. Sanctioning is necessary but civic education to induce people's care and respect for the built environment is also necessary, and it'd better start early, maybe in primary schools. If kids should be taught to love their motherland, I don't see why they should not be taught to love the natural as well as the man-made environment they live in. As the environmentalists would say, "On Spaceship Earth, there are no passengers, we are all members of the crew." Everybody should take part in keeping our buildings safe and free from hazards and they should develop their proper attitudes as early as possible in their childhood. To respect the built environment is respecting the human rights of safe and healthy enjoyment of the built environment and we could only prolong such enjoyment by mutual respect.

My fellow building surveyors, apart from tackling building problems as our daily routine for our rice bowls, what else can we do? Yes, we sure can do something more, as I trust we are either owners or tenants of premises. Have you taken part in the management of your own premises? Have you ever brought safety issues to the attention of your building management? Do you have the guts to display professional integrity to your co-owners or building managers? Building safety must start at our own homes and work places. Are we helping to improve the situation or are we actually abetting in the creation of hazards?

Subject : Upgrading Fire Safety in Commercial Premises and Commercial Buildings.

Speaker : Mr. HO Nai-hoi - Acting Senior Divisional Officer (Legislation and Control Division, Fire Services Department)

Fire Service Installations and Equipment in Buildings

1. Pursuant to the Buildings Ordinance, all new buildings are required to be provided with the necessary fire service installations and equipment in accordance with the Code of Practice for Minimum Fire Service Installations and Equipment (hereunder referred to as the Code) published by the Director of Fire Services. This Code is, however, reviewed and updated regularly to keep abreast of new fire protection technology and building designs. As such, buildings constructed more recently are provided with more comprehensive fire service installations.

2. In 1973, there was a major revision to the Code and as a result the provision of automatic sprinkler installation was required for commercial buildings over 30 m in height. This height limit was then removed in 1987 to require all new commercial buildings to be provided with automatic sprinklers.

Shek Kip Mei Hong Kong Bank Fire

3. The Investigation Team that investigated into the fire at the Shek Kip Mei Branch of the Hong Kong Bank on 10.1.1994 recommended improvements to fire safety measures in commercial premises of a similar nature. In putting forward the Team's recommendations, the Fire Safety (Commercial Premises) Bill was introduced into the then Legislative Council on 29.5.1996. The gist of the Bill was to provide better protection from the risk of fire for users of certain kind of commercial premises with a total floor area exceeding 230 m^2. These included banks, off-course betting centres, jewellery and goldsmith shops, supermarkets, department stores and shopping arcades. The required additional fire service installations and equipment to be provided include :-

(a) automatic sprinkler system;
(b) automatic cut-off devices for mechanical ventilating systems;
(c) emergency lighting;
(d) manual fire alarm system; and
(e) portable fire extinguishers.

Furthermore, construction requirements will be imposed by the Director of Buildings on provision of adequate means of escape, means of access for fire fighting and rescue services, and fire-resisting construction for better protection against the effects of fire.

4. The Fire Safety (Commercial Premises) Ordinance was subsequently enacted and came into operation on 2.5.1997.

Garley Building Fire

5. The disastrous No. 5 alarm fire at Garley Building No. 233 - 239, Nathan Road on 20.11.1996 resulted in 40 fatalities and 81 injuries. Following the fire, the Government set up a number of inter-departmental working groups to consider lessons learnt and to co-ordinate programmes and plans to improve fire safety for old commercial buildings.

6. It was considered that the coverage of the Fire Safety (Commercial Premises) Ordinance should be extended to old commercial buildings irrespective of their size or uses. The first priority is to deal with the some 400 commercial buildings which were constructed before there were mandatory requirement for installation of sprinklers in 1973 i.e. most buildings with occupation permits issued before 1975. The second priority will be to upgrade the fire safety standards of the 1000 or so commercial buildings which were constructed before a substantially revised edition of the Code took effect on 1.3.1987. All commercial buildings designed to the standards laid down in this 1987 Code would have modern fire service installations and equipment with standards that are very close to, if not the same as, current standards. Based on the experience gained from the first group, the government will conduct a review on the efforts and further extend the scope to the second group.

7. The Fire Safety (Commercial Premises)(Amendment) Ordinance 1998 was enacted by the Provisional Legislative Council on 25.3.1998. It was brought into operation on 1 June 1998.

8. The additional fire service installations required for specified commercial buildings are similar to those for prescribed commercial premises, with the exception that fire hydrant/hose reel installation is required in lieu of fire extinguishers. Furthermore, powers are also bestowed upon the Fire Services Department to improve or integrate the existing fire service installations in the building.

Fire Safety Improvement Loan Scheme

9. To address the concern of owners who may need financial assistance in carrying out the upgrading works, a $200 million Fire Safety Improvement Loan Scheme has been set up by the Government in June 1998. The Scheme is administered by the Director of Fire Services and aims to provide loans to owners of prescribed commercial premises and specified commercial buildings who are in receipt of the fire safety directions or fire safety improvement directions issued under the Ordinance. Borrowers are required to pay interest at the average best lending rate from time to time quoted by the three note-issuing banks. The principal and interest of the loan will be repaid by equal monthly installments up to 36 months.

10. For the purpose of executing the new legislation, a Legislation and Control Division was established in the Fire Services Department on 1.4.1998. For enquiry on the new legislation, please contact the Division on **21709622**. For further information on the Fire Safety Improvement Loan Scheme, please contact the Fire Safety Improvement Loan Scheme Secretariat at **27337884**.

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A Conceptual Model on Fire Risk Ranking for Existing Buildings

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Abstract:

Fire safety is one of the major concerns of the Government as well as the people in Hong Kong especially after several large fire tragedies happened in the past few years. There is evidence from analysis of the fatal disasters suggesting that life safety hazard was mainly originated in the misuse of buildings, inadequacies of maintenance and sub-standard design on the fire protection measures in the buildings. Accordingly, fire safety is one of the major problematic areas that should be considered in assessing the safety level of a building. It is a major component for setting the priority of maintenance/ improvement works. Vast majority of buildings is not economically amenable to in-depth fire safety analysis by fire and evacuation models. Statistical inference methods are also difficult to be adopted, as historical data is often insufficient or too non-indicative. A risk-ranking model based on intuition and experience is a way to assess fire safety. Such model is proposed in this paper and is considered as a decision support tool.

Introduction

Fire safety is one of the major concerns of the Government as well as the people in Hong Kong especially after several large fire tragedies happened in the past few years. There is evidence from analysis of the fatal disasters [1,2] suggesting that life safety hazard was mainly originated in the misuse of buildings, inadequacies of maintenance and sub-standard design on the fire protection measures in the buildings. Accordingly, fire safety is one of the major problematic areas that should be considered in assessing the safety level of a building.

In fire safety legislation, there has not much credible technology input and a form of judgement decision has dominated. Accordingly, a rigid set of requirements has been made which implies the safety level that is acceptable to the society. As the objectives of fire safety requirements are not clear, the simplest way to assess the fire safety level of an existing building is to check the fire safety items of the buildings against standards prescribed in the fire codes. There exist a huge number of buildings that have been constructed according to the old prescriptive requirements. The fire safety level provided in these building might not be the same as the standard enforced today, even if all fire safety items are maintained at the original design standard. Assessment on the basis of current prescriptive requirements might be regarded as "sub-standard". However, whether such standard warrants immediate improvement action might subject to contention. It is because the rigid prescriptive requirements in the fire codes do not provide a holistic picture of the fire safety level in these buildings. Indeed, if all the buildings that are constructed according to previous prescriptive requirements are required to improve at the same time, the society may be difficult to admit the huge cost burden. Therefore, a priority of improvement should be established for these buildings and such priority should be governed by their corresponding risk ranking. Figure 1 illustrates a general approach for assuring the safety standard of an existing building.

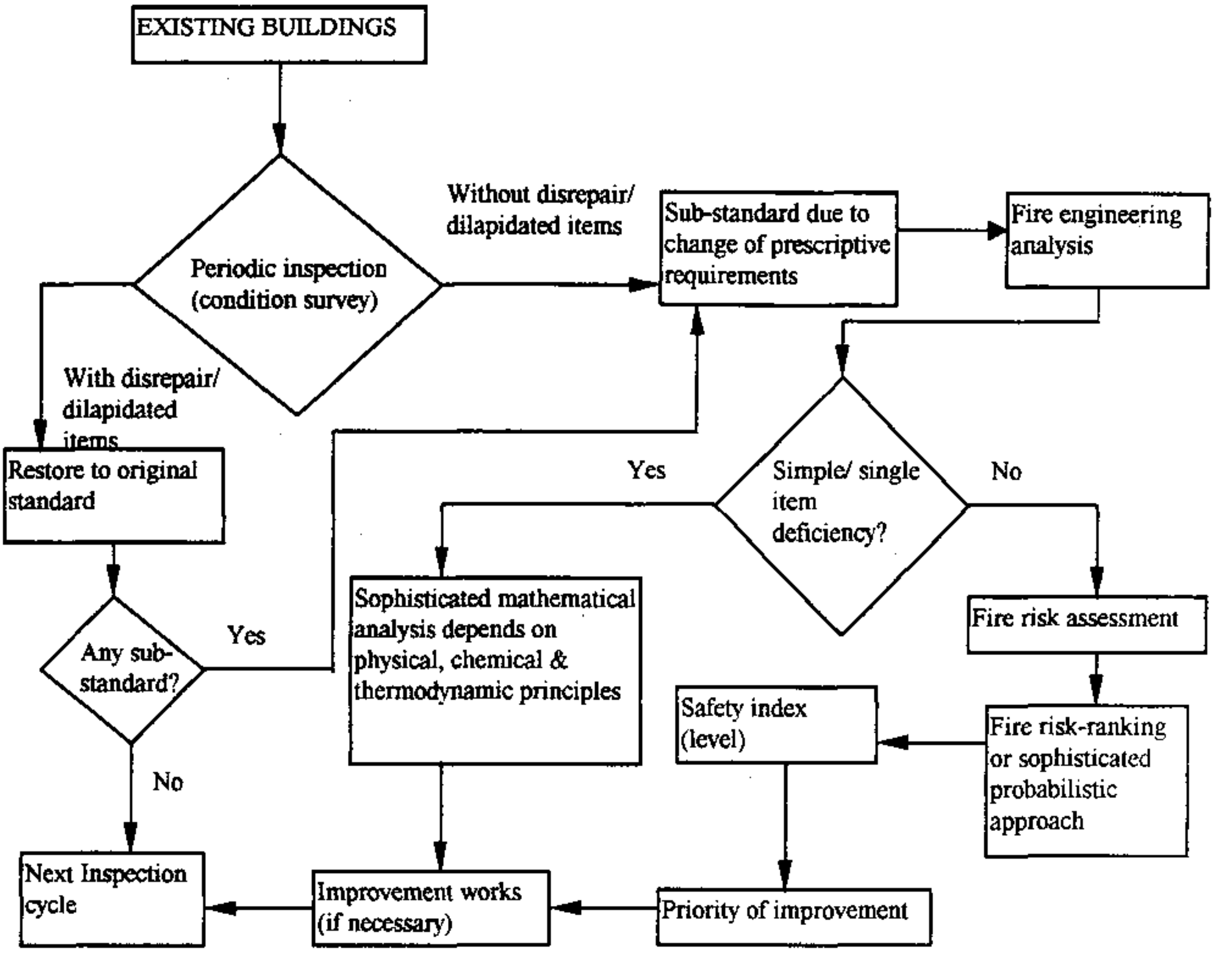


Figure 1: General Approach to Fire Safety Assurance

Although one may say that the fire risk level of existing buildings can be analyzed by using fundamental physical, chemical and thermodynamic models, the vast majority of such buildings are not economically amenable to in-depth fire safety analysis [3]. Such simulation models cannot be applicable for all situations. Statistical inference methods are also difficult to be adopted, as historical data is often insufficient or too non-indicative. In the circumstance, intuition and experience can be a way to provide adequate and appropriate solution. The aim of this paper is to propose a conceptual fire risk ranking model to systematically manipulate the intuition and experience. The legal, political and economical implications of the assessment are outside the scope of this paper. However, such aspects can also be easily included in the model.

Fire Risk Assessment

The fire safety level of a building can be inferred by using fire risk assessment techniques. There are various approaches to fire risk assessment. For examples, statistical/ probabilistic approach, hazard analysis by using event trees/ fault trees, stochastic computer simulation models, and fire risk ranking on the basis of multi-criteria evaluation.

In Hong Kong, the fire data collected in the past two decades is insufficient to carry out statistical inference tests. Statistical and probabilistic approaches are difficult to apply. Moreover, almost all the buildings in Hong Kong are multi-storey complex buildings. The records for construction methods and materials used for existing buildings are insufficient. Especially, numerous unauthorized structures have been constructed because of the rapid increase in population. In view of the uncertainties with respect to the building construction details and complexity, it is difficult to adopt computer simulation models that are based on physical, chemical, thermodynamic and psychological principles to evaluate the safety level of a building. A hazard analysis based on event trees or fault trees approach may also be difficult to implement as the uncertainties may create difficulties in identifying the risk agents. A fire risk ranking system, which integrates technical information to the extent possible and based on intuition and experience, may be an effective way to evaluate the safety level as well as safety index of the existing buildings, and from the established safety index to rank the priority of improvement actions for limited resources situations.

Watts [4] mentioned that: "Fire risk ranking is a method of fire risk assessment. It constitutes various processes of analyzing and scoring risk parameters to produce a rapid and simple estimate of relative fire risk. Values are assigned to the parameters (passive and active fire safety features) based on professional judgement and past experience and then aggregated by some arithmetic function to arrive at a safety index. The safety index can be compared to other similar assessment to rank the fire risk."

It originated with the insurance rating schedule and had been developed in some applications [5-9]. For example, a Fire Safety Evaluation System (FSES) has been developed on the basis of fire risk ranking (NFPA101A, 1995 [10]) in the United States. The FSES provides a multi-attribute approach to determine equivalencies to the NFPA101

Life Safety Code [11] for certain occupancies. The Dow Chemical Company developed the fire and Explosion Index and Risk Guide [12]. The Central Office Fire Risk Assessment (COFRA) methodology has been developed for Telecommunications Central Offices in the United States [13]. A fire safety evaluation system for national park service overnight accommodations by Nelson [14] has been developed for assessing existing buildings.

The Establishment of a Fire Risk Ranking System

In order to ensure a uniform assessment adopted by the investigation experts, quantitative methods to evaluate building fire safety within a broad, risk-based context should be available. Such assessment system should be user-friendly, suitable for the practice in the area and can be easily recorded for future monitoring usage.

It is noted that fire safety is a complex system with large number of parameters that may affect it. The overall level of safety will be determined by the parameters affecting fire safety.

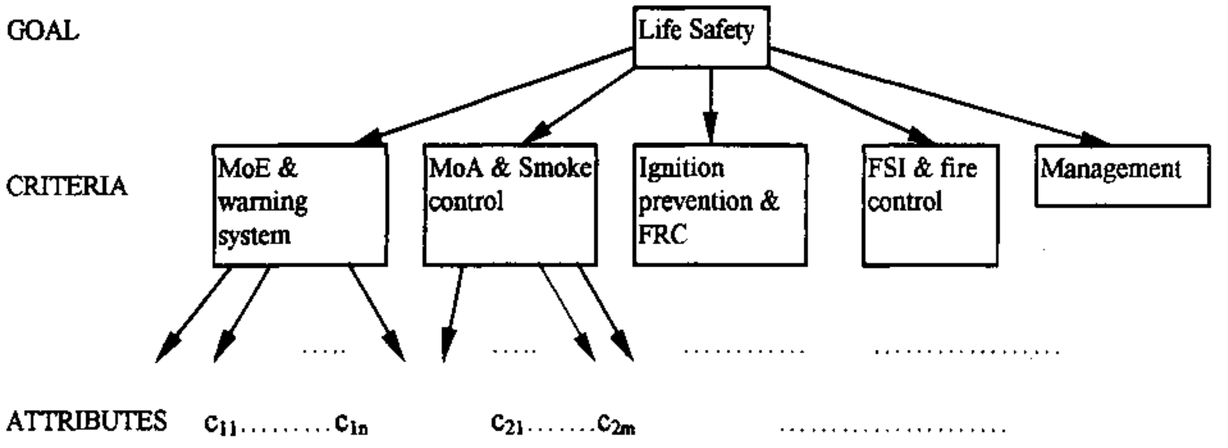
i.e. $FSL = f\,(SL_E, SL_S, SL_C, SL_A, \ldots\ldots)$ (1)

where FSL = *total fire safety level*
SL_E = *safety level with respect to exit routes*
SL_S = *safety level with respect to smoke control*
..........Etc.

FSL is a function of a list of fire safety attributes (parameters) and such attributes are not directly measurable. This is especially true for existing building where only limited information is readily available.

Although the attributes are numerous, it can be said that a relatively small number of factors account for most of the problems [15] and it is possible to reduce the large number of attributes to an appropriate number which can be handled with appropriate effort. For example, the NFPA101A addresses 14 general areas affecting building life safety [10].

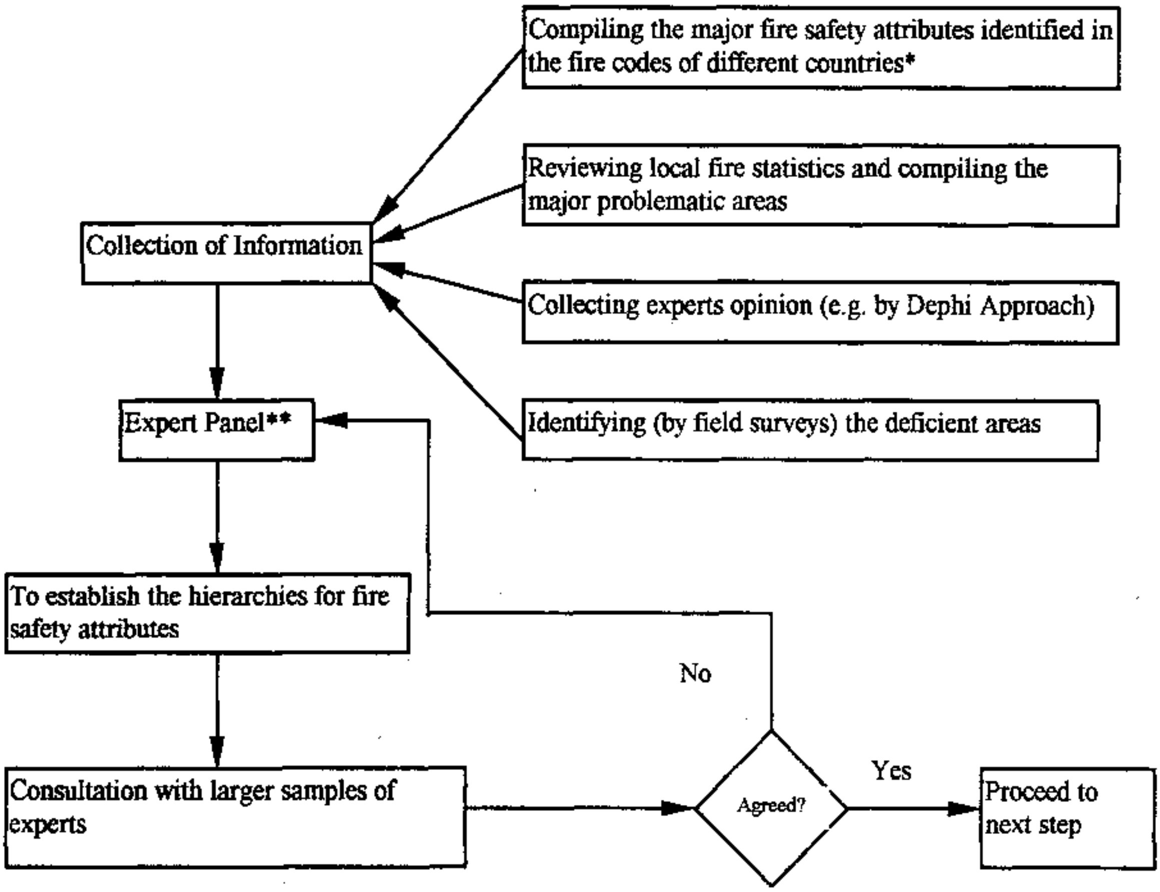
As the number of attributes that need to handle is large, the mathematical operation of equation (1) will be complicated if all the attributes are analyzed at one operation. In the circumstance, a hierarchy of three or more levels in which similar attributes are grouped into a category is established. Each group of attributes are analyzed and the result will be used for analysis at next level in the hierarchy. Figure 2 shows the structure of a hierarchy of attributes:



Remarks: *MoE : Means of Escape*
MoA : Means of Access for Firefighting & Rescue
FRC : Fire Resisting Construction
FSI : Fire Services Installations
c_{ij} *: Attributes*

Figure 2: The Structure of a Hierarchy of Attributes

Delphi technique can be for determining the attributes and the establishment of the hierarchy structure [7-8]. A systematic way to set up the attributes is illustrated at Figure 3 below. The attributes identified may be different amongst different cities because of the different building forms, maintenance levels and culture of building users. Accordingly, the attributes identified in other countries may not be directly applicable in Hong Kong.



Remarks:

* *study the fire safety attributes identified in different countries (e.g. NFPA101A)*

** *set up an expert panel including various types of professionals (experts with different background may have different attitudes towards the significance of different fire protection means)*

Figure 3: Simplified Approach for Identifying Attributes

Mathematical Operation in the Assessment

The operation of equation (1) should be simple from the practical point of view and flexible from the management point of view [15]. The simplest way to handle the operation in the fire risk ranking models is based on linearity assumption. A simple additive function may produce different scores for different risk level. However, it is also well known that fire risk variables do not necessarily behave in a linear fashion. A simple additive operation may not truly represent the real situation. The risk-ranking model will depend on the subjective evaluation of fire safety items. It is not easy to provide consistent measure values to the items. The relative importance is another aspect that may be difficult to determine.

In fire safety system, incomplete data and information are available. The evaluations of fire safety attributes which are carried out by experienced investigators[a] (surveyors) are predominantly subjective and imprecise. In a study conducted by Kochen and Badre [16], it was found through experimentation that when people were asked for subjective evaluations, they responded more consistently when they were allowed to give a verbal imprecise response than when they were forced to give a numerical answer. Accordingly, the evaluations are general suitably expressed in linguistic terms rather than a numerical value. Watts [17] had also pointed out that most fire safety problems are not clear cut and fuzzy logic approach could be a way to provide a reasonable answer. In the circumstance, a fuzzy set approach [18-22] can be developed to manipulate the imprecise information. Such approach is not as complicated as probabilistic approach and is considered as more practicable. A brief explanation of the mathematical operations is given in Appendix I.

The Weighting of the Criteria for Evaluation

The accuracy of the evaluation will depend on the accuracy of the weighting assigned to each criterion. It can be determined by setting up an expert panel and synthesis (e.g. by approximate reasoning) the average ranking of the criteria for evaluation purpose. If a large number of criteria are needed to analyze, it is difficult to obtain a consistent result amongst each expert. Therefore, a systematic method is required to determine the ranking of the criteria.

The process of deriving the ranking of each fire safety attributes can be regarded as a multi-criteria decision making process. The prioritization of the attributes can be synthesized by numerous methods such as the direct point allocation, paired comparison (e.g. Saaty [23]), multiple regression models, explicit trade-offs (e.g. Keeney-Raiffa [24]), and equal/ unit weighting. A comparison of the methods can be found in the article [25] by Schoemaker and Waid.

The Analytical Hierarchy Process (AHP), developed by Saaty [23], which is one of the methods used in multi-criteria decision making process, may be employed to assist individuals and groups to deal with ranking of the fire safety attributes [26]. ASTM: E1765-95 Standard Practice for Applying Analytical Hierarchy Process to Multi-attribute Decision Analysis of Investments Related to Buildings and Building Process can serve as a guide for implementing the process. By incorporating both subjective and objective data into a logical hierarchy framework, AHP provides decision makers with an intuition approach to evaluate the importance of every element on a decision through a pairwise comparison process. The AHP is one of the most suitable methods for a multi-criteria

[a] The surveyor responsible for the inspection should have adequate training in building surveying technique and have adequate knowledge of fire safety design in buildings.

problem in which accurate quantification of the impact of the alternatives on the decision-making problem is not possible. For this reason, the AHP is good for setting the ranking of each fire safety attributes in the fire safety evaluation because the attributes, which involve people interaction, are difficult to quantify [17]. Furthermore, it is preferable because of the following characteristics:

1. Relative judgements rather than absolute are adopted in the process. A more accurate representation of the decision-maker's thoughts is provided.
2. When using EXPERT CHOICE [27] computer software), judgements can be expressed entirely in a verbal mode and no numerical guesses are required. Priorities for the decision criteria are derived based on such judgements.
3. Redundant judgements are used in AHP for two purposes. Since any judgement is likely to contain some "experimental" error, calculating priorities using redundant judgements will result in increased accuracy. Secondly, a measure of the inconsistency of judgements can be derived (the 0.1 inconsistency ratio).

Summary

In order to assure the fire safety level of buildings, the prescriptive requirements form a basic standard for checking. If a building is found to have disrepaired items, remedial works should be carried out to restore to original standard. For buildings constructed in accordance with previous prescriptive standards, a fire risk assessment may be needed to determine their fire safety level (index) and from the index to rank the priority of improvement actions.

Fire risk ranking is not a new system for use in fire risk assessment. It has been adopted to demonstrate the equivalencies to prescriptive requirements in US (NFPA101A). By developing it into a multi-attribute fire risk evaluation system it can provide a standard assessment tool for the professionals or the regulator to follow.

In Hong Kong situation, the buildings and environmental conditions are complex. Fire and evacuation models based on physical, chemical, thermodynamic and psychological principles can hardly be carried out efficiently for massive evaluation. In view of the imprecise and vague nature of the values of fire safety attributes, a fuzzy evaluation approach is suggested in this paper which may be found effective to establish the risk grading of existing buildings.

The model outlined in this paper is a conceptual framework. Further studies are required to provide details on how to: 1) form expert panels, 2) formulate the hierarchy structures and the weightings of the attributes, 3) develop the most suitable methods for setting up the weightings and the mathematical operation of the model, and 4) set up the reference levels for the priority list. Moreover, a monitoring system should be established to review the system implementation and provide system refinement. The authors are seeking for the funding to develop the conceptual model and to produce a computer program, which should be user-friendly and adaptable for different building occupancies.

Appendix I: Aggregation Using Fuzzy Set Theory

Every evaluation work identified during an inspection by surveyors will be measured and a linguistic score will be given in respect of each criterion determined.

Suppose m criteria are used in the evaluation process for an occupancy j in that a set of attributes C_j can be expressed as:

$$C_j = \{ c_{j1}, c_{j2}, \ldots\ldots\ldots, c_{jm} \} \quad (2)$$

and an evaluation set E_j with n evaluation levels representing the FSL can be expressed as:

$$E_j = \{ e_{j1}, e_{j2}, \ldots\ldots\ldots, e_{jn} \} \quad (3)$$

Now, define a set of evaluation of individual attributes:

$$R^* = \{\frac{r_1 *}{c_1}, \frac{r_2 *}{c_2}, \ldots\ldots \frac{r_m *}{c_m}\} \quad (4)$$

where r_k* is expressed in linguistic terms (which is determined by the surveyor).

For example, if c_{j1}, c_{j2}, ………, c_{jm} represent MoE (means of escape), MoA (means of access), ………, and r_1*, r_2*, ……. r_n* represent VG (very good), G (good), ………, then R* can be expressed as an m-row evaluation matrix:

$$R^* = \begin{matrix} MoE \\ MoA \\ \vdots \\ \vdots \end{matrix} \begin{bmatrix} r_1 * \\ r_2 * \\ \vdots \\ \vdots \end{bmatrix} \quad (5)$$

Suppose there exists a mapping such that:

$$\varphi : R^* \rightarrow R \quad (6)$$

where φ is called the membership function of R*.

Then,

$$R = \begin{array}{c} MoE \\ MoA \\ \vdots \\ \vdots \end{array} \begin{bmatrix} \varphi(r_1*) \\ \varphi(r_2*) \\ \vdots \\ \vdots \end{bmatrix} \tag{7}$$

For example, R* can be defined as:

$$\varphi(r^*) = \begin{cases} \{0.3/1, 0.5/0.8, 0.2/0.6, 0/0.4, 0/0.2, 0/0\} & \text{for } r^* = VG \\ \{0.1/1, 0.3/0.8, 0.5/0.6, 0.1/0.4, 0/0.2, 0/0\} & \text{for } r^* = G \\ \{0/1, 0.1/0.8, 0.4/0.6, 0.4/0.4, 0.1/0.2, 0/0\} & \text{for } r^* = M \\ \{0/1, 0/0.8, 0.1/0.6, 0.5/0.4, 0.3/0.2, 0.1/0\} & \text{for } r^* = P \\ \{0/1, 0/0.8, 0/0.6, 0.2/0.4, 0.5/0.2, 0.3/0\} & \text{for } r^* = VP \end{cases} \tag{8}$$

The elements of support are written on the right side of the slash and the grade of membership on the left. A fraction between 0 and 1 represents the grade of membership of each subjective measure. A membership grade closer to 1 represents closer association with "yes", meaning that the level tends to very good. Membership grades closer to 0 represents closer association with "no" (non-membership), meaning that the level tends to very poor. The membership function can be established by surveys amongst the surveyors.

For m rows of criteria and n columns of levels, R can be written as:

$$R = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1n} \\ \vdots & \vdots & \cdots & \vdots \\ \vdots & \vdots & \cdots & \vdots \\ r_{m1} & & \cdots & r_{mn} \end{bmatrix} \tag{9}$$

Now, let A = the weighting of the attributes in C :

$$W = \{w_1, w_2, \ldots\ldots\ldots\ldots w_m\} \tag{10}$$

Then, the evaluation B can be given by:

$$B = W \circ R \tag{11}$$

It is the direct product: W x R = {w, r | w ∈ W, r ∈ R}, and is characterized by a membership function in [0, 1].

The composition of equation (10) can normally be handled by four models:

$$\textit{Model 1:}\quad b_j = \bigvee_{i=1}^{m} (w_i \wedge r_{ij}) \qquad \forall \quad b_j \in B \qquad (12)$$

In this max-min operation, only the major attributes are considered and other minor attributes will be ignored. This model is suitable for single item optimisation problems. For fire safety assessment, each attribute should have its influence on the safety level. Accordingly, this model is not suitable for the composition.

$$\textit{Model 2:}\quad b_j = \bigvee_{i=1}^{m} (w_i r_{ij}) \qquad \forall \quad b_j \in B \qquad (13)$$

This model is also similar to model 1 in which some attributes will be ignored.

$$\textit{Model 3:}\quad b_j = \min\{1, \sum_{i=1}^{m} w_i r_{ij}) \qquad \forall \quad b_j \in B \qquad (14)$$

This model is suitable for the problems where many attributes are considered and the difference of the weighting for each attribute is not great. Accordingly, this model is suitable for fire safety assessment.

$$\textit{Model 4:}\quad b_j = \sum_{i=1}^{m} (w_i \wedge r_{ij}) \qquad \forall \quad b_j \in B \qquad (15)$$

The min-operation in this model will miss some information with smaller weighting. Therefore, it has similar effect as model 1 and 2.
For an evaluation set similar to equation (7), B can be written as:

$$B = \{b_1/1 , b_2/0.8 , b_3/0.6 , b_4/0.4 , b_5/0.2 , b_6/0 \} \qquad (16)$$

B is a fuzzy set and can be normalized to B* where:

$$b_i^* = \frac{b_i}{\sum_{i=1}^{n} b_i} \qquad \textit{for} \quad b_i^* \in B^* \qquad (17)$$

B* can then be transformed back to a fuzzy index to describe the safety level of a building. The Euclidean distance can be adopted to find the appropriate fuzzy index. It should be noted that the criteria adopted in the safety evaluation process and their weightings might be different amongst different types of occupancies. This reflects the differences in the form of building, the management level and the habit of the users.

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RISKS ASSOCIATED WITH RENOVATION WORKS

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In my 22 years of professional life, I always find that renovation work is one of the most challenging and risky exercise confronting a building surveyor as we have to work under a lot of constraints. I therefore want to take this opportunity to share with you some of my thoughts.

However, since this is a very large topic, I shall concentrate our discussion on the following 6 issues:-

- External Finishes
- Structural
- Fire
- Asbestos
- Rodents
- Building Services

Particular items of importance in the design and execution stage for these issues are presented in a tabular form (attached as Appendix I).

Other aspects which are also of important include:-

1. Site safety both before and during renovation - including safety aspects of temporary works
2. Statutory requirements
3. Coordination with management office for storage and rubbish removal

In conclusion, I hope that the above give you all a better understanding of the risks, particularly on professional side, associated with renovated works which should not be looked upon lightly. The successful implementation of a major renovation task starts with a thorough initial investigation of the subject building, identification of defects and physical constraints, evaluation of alternative design approach and use of materials, etc., together with a carefully thought-out execution plan to ensure minimum risks during the course of work and afterwards, as well as maximum possible benefit to the client and the occupants.

Thank you for your kind attention.

October, 1998.

APPENDIX I

	DESIGN (to include preparation stage)	EXECUTION (to include reinspection @ end of DLP)	OTHER ASPECTS
1. External Finishes	a. Survey of existing condition b. The need to remove immediate danger c. Specification of new finishes - workability + durability d. Repair to existing defects e. Incorporation of new details to existing design to avoid defects	a. Method statement b. Protection against falling objects c. Testing of new finishes before removal of scaffolding d. Proper removal of temp fixings at completion of work e. Control of workmanship to ancillary works e.g. expansion joints, sealant, etc.	a. Assess pros and cons of testing and repair methods
2. Structural	a. Assessment of existing structure b. Access problem c. Use of assumptions d. Safety factor e. Workability	a. Cross checking of structural design assumptions by opening up b. Method statement - temp support c. Structural steelwork - mill cert. d. Checking of anchorage e. Structural defects @ end of DLP	a. Review typical design assumptions
3. Fire	a. Compartmention b. Use of material c. MOE (temp/permanent) d. Evaluation of fire risk	a. Site safety: fire / MOE b. Accumulation of debris c. Execution of permanent fire protection works d. T & C of FSI	a. Check past history of outbreak of fire:- i. Garley Building ii. Mei Foo Sun Chuen iii. Top One Karaoie @ TST

	DESIGN (to include preparation stage)	EXECUTION (to include reinspection @ end of DLP)	OTHER ASPECTS
4. Asbestos	a. Inspection & verification b. The need to remove or encapsulate c. Need for temp protection d. Removal programme before main works	a. Method statement b. Actual execution c. Contamination - contingent plan Note: Mr. Gordon Wong's talk on asbestos accoustic plaster	a. Check existing legislation and guidelines
5. Rodents	a. Signs of rodents e.g. terminate b. Design to avoid rodents e.g. ingress points	a. Effectiveness of eradication works b. Protection of new works	
6. Building Services	a. Existing condition b. Changes required - either due to new requirement or existing defects e.g. illegal connections	a. Temp. re-routing b. Contingent plan for failure - control of damage caused c. T & C of building services	

FIRE SAFETY IMPROVEMENTS IN PRACTICE

Samson Wong San
FRICS FHKIS ACI Arb RPS
AUTHORISED PERSON

1) Overview

The provision of fire safety in buildings is a reflection of a complex interaction between the social, economic and legal aspects of society. Fire Safety in buildings is largely controlled by building regulations, many of which are based on the bitter experience gained from major fires in history. Some of the recent examples are:

i) **The Fire Safety (Commercial Premises) Ordinance 1997**, which came into operation in May 1997 as a response to the fire at Shek Kip Mei Branch of the Hong Kong Bank on 10th January 1994. 12 people died and 1 was injured.

ii) **The Fire Safety (Commercial Premises) (Amendment) Ordinance 1998**, which came into operation on 1st June 1998 as a result of the fire in Garley Building in November 1996. 41 people died and some 80 were injured.

iii) **New Licensing System for Karaoke** – Fatal blaze at Top One Karaoke in Tsim Sha Tsui on 25th January 1997. 17 people died and 13 injured.

Regrettably there were more to come.......... such as the fires in Mei Foo Sun Chuen (April 1997) and Golden Court, Causeway Bay (January 1997).

2) Change in Fire Safety Regulations

During the last 20 or 30 years considerable progress has been made in the development of fire safety standards. Currently, the **Fire Safety (Commercial Premises) (Amendment) Ordinance 1998** is the major instrument enforced by the Buildings Department (BD) and Fire Services Department (FSD) to provide better protection from the risk of fire for occupants, visitors and anybody using certain kinds of Prescribed Commercial Premises (P.C.P.) and Specified Commercial Buildings (S.C.B.) which were constructed before 1973 when the installation of sprinklers was not a statutory requirement.

Before we can appraise the potential problems in satisfying the requirements under the new Ordinance, it is necessary to review those standards contained in those Buildings Ordinance, Building Regulations, Fire Service Regulations or Codes of Practice in force in the old days and recognize the differences amongst them in detail.

2) Change in Fire Safety Regulations (Cont'd)

Basically, the following Codes of Practice form the back bone for determining the detailed requirement of fire safety measures in relation to building structure and fire services installations:-

- Code of Practice for the Provision of Means of Escape in Case of Fire (MOE) 1996;
- Code of Practice for Means of Access for Fire Fighting and Rescue (MOA) 1995;
- Code of Practice for Fire Resisting Construction (FOC) 1996; and
- Code of Practice for Minimum Fire Services Installations and Equipment (FSI&E) 1994.

It should be noted that the standards now in force are generally more stingent than the old standards in the following aspects:-

(1) Width, number and arrangement of exit routes;
(2) Fire and smoke protection for exit routes;
(3) Provision of fireman's lift with associated fire and smoke protection;
(4) Fire resistant separation between units;
(5) Means of escape and prevention of accumulation of smoke in basements;
(6) Automatic sprinkler systems;
(7) Automatic cut-off devices for mechanical ventilating systems;
(8) Emergency lighting;
(9) Manual fire alarm system; and
(10) Fire hydrant/hose reel system.

3) Possible Constraints & Difficulties

The new standards carry benefits commensurate with costs. For some old buildings, achievement of absolute fire safety whilst desirable is sometimes not practical and not economically achievable. Anticipated major constraints and difficulties in implementation of fire safety upgrading works would be :-

- The requirement to alter building structure;
- The requirement to modify existing layout;
- The requirement to vacate some part of the premises; and
- The requirement to interrupt existing tenants' business.

According to the ordinance, the owners or occupiers would only need to comply with the requirements as set out in the **Fire Safety Direction** or **Fire Safety Improvement Direction** issued by BD or FSD.

3) Possible Constraints & Difficulties (Cont'd)

During preparation of the legislation, the enforcement authorities agreed to apply fire safety provisions in a flexible manner where there are genuine and practical difficulties in complying with the fire safety measures. They are prepared to assess the fire safety measures provided in a premises according to the overall provision of facilities, including fire service installations and equipment, means of escape, means of access and fire resisting construction. When there are practical difficulties in complying with the requirements in one area, it may be acceptable to remedy the deficiencies by compensatory measures in elsewhere. In addition, a reasonable length of period will be given for the commercial premises to comply with the required safety standard. Clearly, this is a very flexible approach, capable of considerable variations in interpretation. Therefore, close liaison with officers of BD and FSD is considered necessary.

4) Job Opportunities

Buildings Department (BD) estimated that there were some **420 commercial buildings** with occupation permits issued before 1975. The implementation of the Ordinance is being phased in over a period of 10 years or more, prudent building surveyors should advise their clients to make an early assessment of their premises and prepare an action plan for implementation in a reasonable time frame. It would be sensible for major landlords of commercial properties to appoint a consultant to carry out a detailed study as early as possible and work out a forward strategy which can be incorporated into their business plan. In doing so, this would not only minimise their administrative difficulties in dealing with any disruption caused to existing tenants' business, but also enable their consultant to have sufficient time to identify any existing constraints and hence develop a practical solution. To arrive at the most cost-effective proposition, considerations must be given to the existing tenancy and overall space planning avoiding extensive remodelling or making substantial structural alterations with technically complicated solutions.

Different premises have different characteristics in their construction, installations and spatial arrangement. They must be treated on individual merit. The task demands input from experienced professionals from different disciplines. A professional building surveyor with 'authorised person' (A.P.) qualification is the ideal leader of the consultancy team. It is also desirable if circumstances permit to have a building service engineer, a registered structural engineer, and a quantity surveyor as team members. Occasionally, the input from a fire engineering expert is valuable for conducting fire engineering studies and develop alternative proposals and remedial options for the consideration of the Buildings Department (BD) and the Fire Services Department (FSD).

As we all know that many old buildings were of multi-ownership with poor building management. In the period of economic down-turn, working out a satisfactory funding arrangement may become a problem for the necessary upgrading works, particularly where common areas are involved. As a value added service to their clients, the consultant may consider assisting them to apply for financial assistance under the $200

5) **Consideration of Cost-effectiveness in Practice**

Under the fire safety engineering principles, there are possible ways to consider a cost-effective approach on prescribed fire services requirements. This is illustrated in the following examples:-

1) Sprinkler System

Due to the need for the provision of a water tank, the retrofitting of a standard sprinkler installation to existing buildings may not meet the space and structural constraints. An improvised sprinkler system with water supply from a direct town's main connection or from the existing fire hydrant/hose reel system would be considered acceptable. In those cases where a sprinkler tank is to be added to the building, the size of the tank can be reduced when taking into account the proximity of the building from the nearest fire station. Installing a direct fire alarm link to the Fire Services Communication Centre will also help to reduce the required sprinkler tank capacity. In addition, the compliance with FOC rules instead of LPC should be considered for the additional sprinkler system to reduce installation cost. Certainly, the selection of a strategic location for the tank could considerably decrease the amount of pipework and structural work costs.

2) Emergency Lighting

Consideration may be given to the use of high efficiency fluorescent lamps for lighting the fire escape routes if emergency generator supply is available, otherwise battery operated fluorescent lamps would serve the purpose. In some cases, it may be possible for the supply company to provide an additional power supply to the building from a different source.

3) Protected Lobby and Fire Doors

Instead of replacing of existing fire doors, improvement can be achieved by upgrading the door hinges and provision of additional instruescent door strips. With the support of fire engineering study protected lobby may be replaceable by a design with roller shutter arrangement.

4) Adoption of Previous Fire Safety Engineering Solutions

Examples of approved trade-offs and alternative engineering solutions that have been accepted by the relevant authorities for other development projects can be very useful reference material without the need to go through the expensive analysis process.

6) **Fire Precautions During Works**

Fire Safety upgrading works creates its own fire hazards, even though they are temporary. To reduce such hazards, it is necessary for everyone involved to become acutely aware of the possible dangers arising from any fire accidents. Strict instructions concerning fire precautions must be formulated for each phase of the building renovation. These instructions must be understood and accepted by all sub-contractors and their workers involved; and a qualified supervisor should be made responsible to oversee their implementation.

Should alteration and improvement activities be carried out without vacating tenants, special attention must be given to the tenant's safety and health. Stringent guidelines should be adhered to during the period of upgrading work to minimize nuisance. Improper design may cause interruptions which will significantly hinder the overall progress. A methodical and sequential approach will minimize the concerns over safety and complaints. Significant cost savings will hence always be achieved because of less abortive work.

A Case Study

The following sections present a case study which discuss the fire safety improvement requirements for a 30 years old commercial building in Central, Hong Kong.

The Way Forward

Today, the public at large does not yet have a clear understanding of appropriate fire safety levels.

So many known and unknown factors contribute to the safety of a building in the event of a fire. It is not yet possible to establish a database to supply the building professional with a full range of possible options deemed to meet the required minimum standard.

In the meantime, we have to rely on the cooperation of all parties involved in the process to achieve a balance between the social, economic and legal aspects.

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Appendix I Checklist for Fire Safety Site Inspections
Appendix II Common Major Deficiencies Under Old & Current Standards
Appendix III Considerations for Adopting Fire Safety Engineering Approach

Appendix I

Checklist for Fire Safety Sire Inspection

Means of Escape

- Insufficient width or number of exit door/staircase;
- Lack of alternative exist or access thereto;
- Inadequate protection to exit corridor or staircase;
- Unsatisfactory arrangement of exit route;
- Presence of electric cables within staircase enclosure;
- No provision of directional sign in basement staircase;
- Inadequate number/size of smoke outlets for basement;
- Door/gate across exit route not operable from inside without a key or upon power failure;
- Unauthorized structure, doors, gate and other obstructions rendering ineffective a means of escape;
- Removal or alteration of smoke lobby or fire door;
- Removal or alteration to enclosure to staircase/exit route;
- Internal alteration resulting in excessive travel distance;
- Obstruction to an exit route or wedging open of a fire door; and
- Blocking of a smoke outlet from a basement.

Means of Access for Fire Fighting and Rescue

- No provision of or sub-standard fireman's lift;
- No provision of or sub-standard fireman's lift lobby;
- Substandard access to fireman's lift at ground level; and
- Removal or alteration of a fireman's lift lobby or lobby doors.

Fire Resisting Construction (FRC)

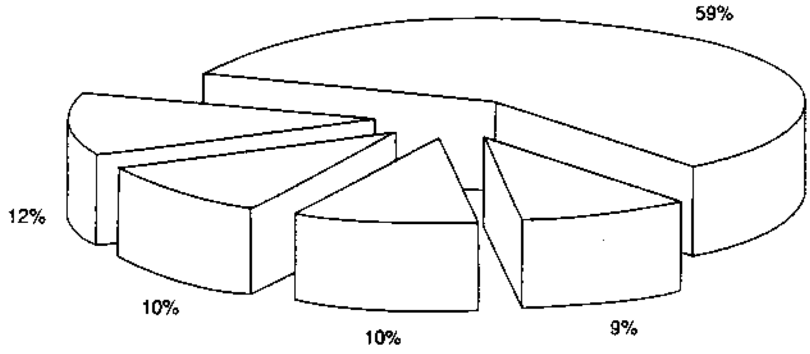
- Inadequate protection of compartment wall or floor;
- Inadequate FRC for separate/different uses/occupancies;
- Inadequate FRC for elements of construction; and
- Removal or alteration of a fire separation wall or floor.

Fire Services Installation and Equipment

- No provision of automatic sprinkler system either standard or improvised;
- No automatic cut-off devices for mechanical ventilating systems;
- No provision of emergency lighting;
- No provision of manual fire alarm system; and
- No fire hydrant/hose reel system or dry system only.

Appendix II

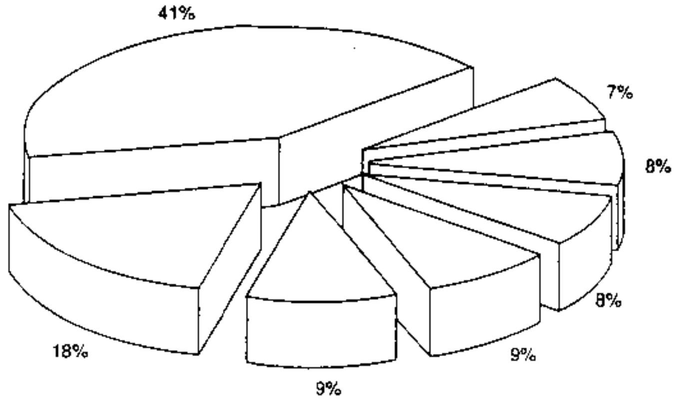
Common Major Deficiencies in 40 Sample Commercial Buildings under Old Standards



Note: The above analysis is based on simple interpretation of the data as shown on
"Appendix D to Report on Sample Survey of Old Commercial Buildings, Buildings Department (Jan. 97)".

- Door of smoke lobby or staircase wedged open (MoE - Misuse) — 9%.
- Floating obstruction in staircase (MoE - Misuse) — 10%.
- Door/gate across exit route, other than the final point of discharge, with locking device not openable w/o a key or with electrical locking device which cannot be released upon power failure (MoE - UBW) — 10%.
- Removal of smoke lobby or smoke lobby door or replacement with wall/door of inadequate fire resistance/smoke seal (MoE - UBW) — 12%.
- Miscellaneous — 59%.

Common Major Deficiencies in 40 Sample Commercial Buildings under Current Standards

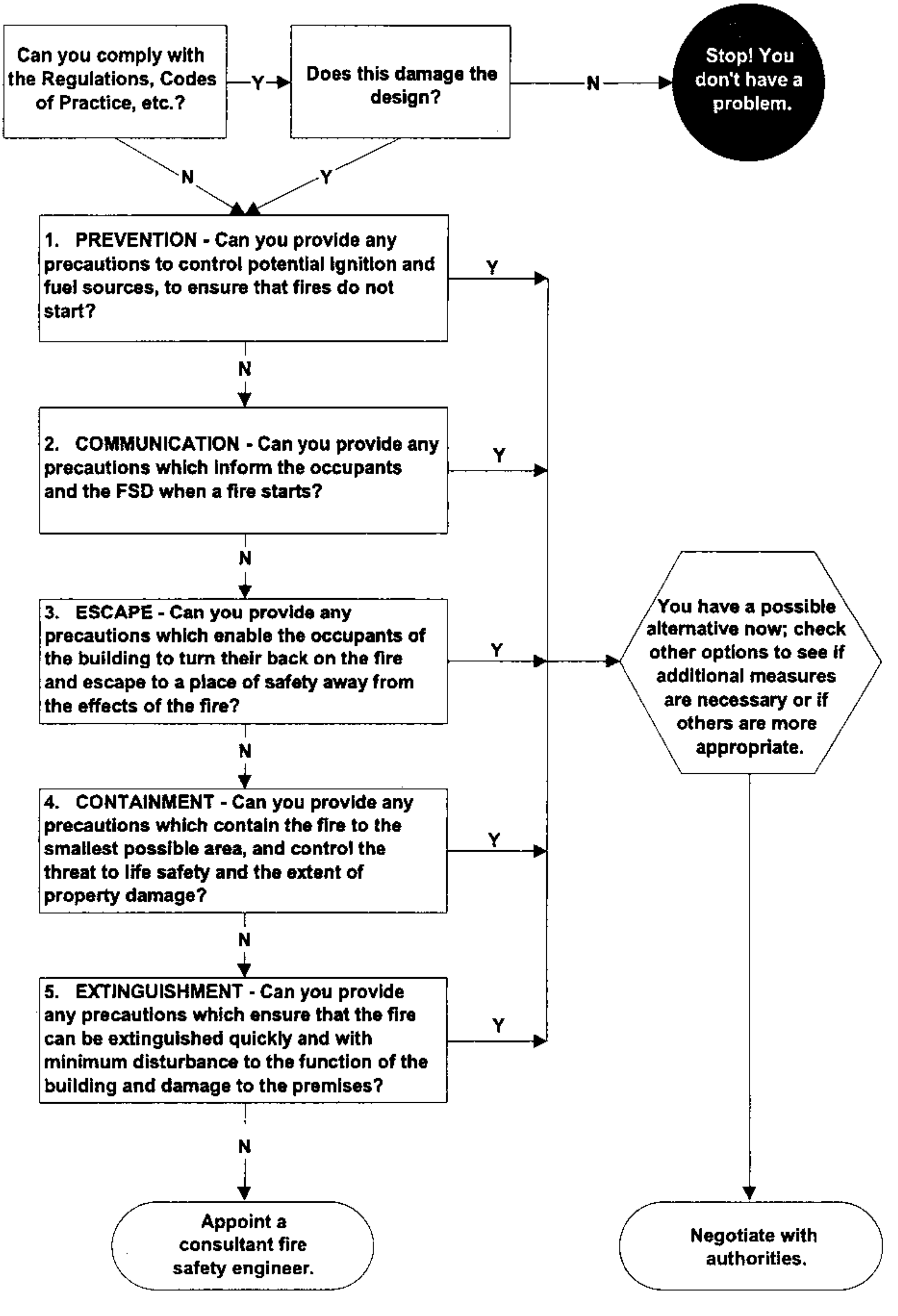


Note: The above analysis is based on simple interpretation of the data as shown on "Appendix D to Report on Sample Survey of Old Commercial Buildings, Buildings Department (Jan. 97)".

- Inadequate FRC to separate different uses/occupancies (FRC) — 7%.
- Inadequate FRC to external walls (FRC) — 8%.
- Services other than FH, sprinkler system, emerg. lighting, and exit signs, within staircase enclosures w/o proper protection (MoE) — 8%.
- Unprotected openings/ windows openings at external walls of stircase close to adjoining buildings (MoE) — 9%.
- No directional sign installed in basement staircase (Safety standards for basement) — 9%.
- Door opening to internal corridor w/o adequate fire resistance (MoE) — 18%.
- Miscellaneou — 41%.

Appendix III

Considerations for Adopting Fire Safety Engineering Approach



INDOOR AIR QUALITY STUDY IN HONG KONG BUILDINGS

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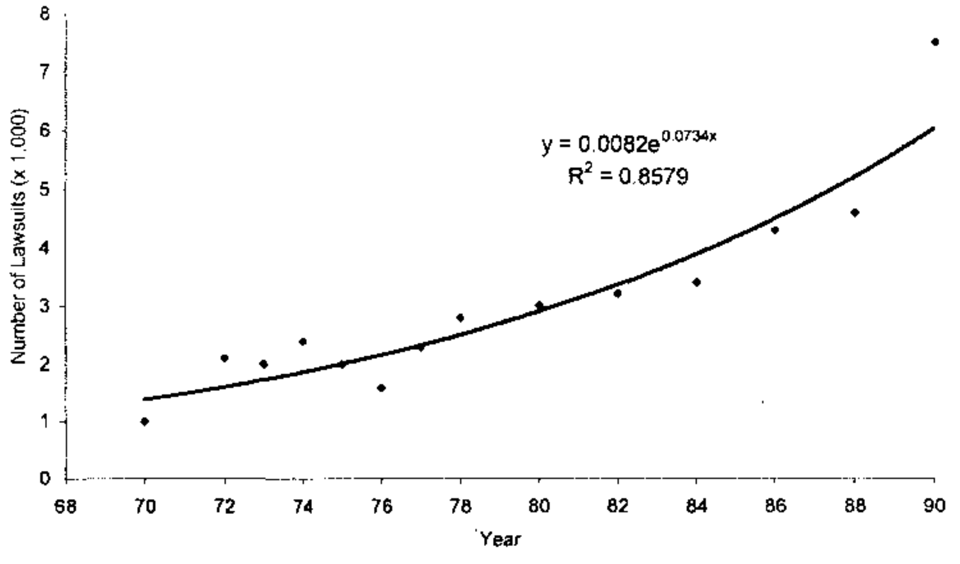
1. INTRODUCTION

The energy crisis in the year 1973 started a campaign for energy conservation. The building services engineers responded to this quest by over-trimming the quantity of outdoor supply to the building. At the same time, the design of the buildings also changed to a service core type design. The building design not only preserves the view from the building at the perimeter zone, but also makes the building tighter and cooling energy is further saved. However, the tightness further reduces air infiltration which may release part of the problem induced by inadequate ventilation. While the tight building concept is correct in a better control of the indoor environmental quality, the ventilation is not right to sustain an acceptable indoor air quality. Adverse indoor environmental conditions was first investigated by WHO (World Health Organization) in the late 1970s and early 1980s. WHO expressed the type of complaints from building occupants as various sick syndromes and called them Sick Building Syndrome (SBS). Since then, many research and survey had been conducted. Unfortunately, the cause for SBS remained a mystery even today.

2. LEGAL LIABILITY OF UNACCEPTABLE INDOOR AIR QUALITY

If the syndromes are of respiratory track problem, in many situation, there may be obvious link with inadequate ventilation. Law suits are on the increase. The number of IAQ lawsuits in America rises rapidly since the 1970's. In the late 1980's, the number of cases even increases exponentially. Figure 1.1 is adopted from Hansen (1993). The total amount of claim for damages, together with the legal costs, is in the order of billion US dollars.

Figure 1.2. Number of IAQ Lawsuits in USA (x 1,000)



The representative case would be the Waterside Mall. In the Waterside Mall building litigation on the 23rd December 1993, five employees of the USA federal Environmental Protection Agency was awarded a total of US$950,000 from the building's owners and managers for ailments they said were related to the indoor air quality. The ailments were respiratory and neurological disorders and there were no physical injuries. The case left the defendants liable to redemption to another 14 plaintiffs. There are now hundreds of cases involving indoor environmental quality awaiting for a verdict. Damages claim and legal costs amounts to billions of US dollars.

In Hong Kong, the obvious case is the case 1996, P.I. No. 580 in which an ex-musician of the Hong Kong Philharmonic Society Ltd. accused five defendants on his brain damage leading to disability of work due to over-inhalation of pesticide during a rehersal in The Hong Kong Academy for Performing Arts. The High Court, earlier this year, ruled that the plaintiff to be awarded HK$20 millions. More shockingly was that the five defendants had to share the HK$200 millions legal fees.

After the Waterside Mall case, Jim Dinegar, Vice President for Government and Industry Affairs, Building Owners and Managers Association (BOMA) International exclaimed, "The floodgates have opened. We are not trying to poison our tenants, but we feel frustrated in not knowing what we will have to do." Indeed there is no indoor air quality criteria or objectives to follow. There is no systematic easy to measure methodology for the facility managers to follow so that they can evaluate the indoor air quality conditions at any time.

3. INDOOR AIR QUALITY STUDY IN HONG KONG

Since 1980s, much resources and research effort have been put into the study of indoor environmental quality and methodology to combat the adverse indoor environmental conditions, there are still may indoor environmental problems existing in buildings, especially high rise buildings. The Department of Building Services Engineering of the Hong Kong Polytechnic University therefore conducted a large scale study in Hong Kong buildings in 1994 to 1995. The study covered 30,000 m^2 of office floors.

This large scale study involved the physical measurement of parameters related to thermal comfort, indoor air quality, lighting and noise. At the same time, a comprehensive questionnaire was used to find out the subjective responses to the four indoor environmental qualifiers and sick building syndrome.

The study did not only aim to find out the physical and subjective conditions to indoor environmental quality, but also planned to develop measurement methodology which could be applied by facility managers in their buildings. Section 4 describes how the building characteristics and some of the ventilation parameters can be measured and quantified or qualified. Section 5 reported some of the finding in the subjective responses.

4. EVALUATION OF INDOOR AIR QUALITY BY METABOLIC CARBON DIOXIDE

Metabolic carbon dioxide is non-toxic. The design concentration for healthy building is 1,000 ppm. The level of concern is usually taken as 5,000 ppm. In fact, according to ACGIH, carbon dioxide concentration can be as high as 30,000 ppm without causing any harm to human being. We take metabolic carbon dioxide concentration as a surrogate indicator. Since human being is a major pollutant source inside buildings, a high carbon dioxide concentration indicates an inadequate ventilation for dilution of other pollutants generated inside the building. The usual background carbon dioxide is around 350 – 400 ppm. A carbon dioxide concentration of 1,000 ppm will usually gurantee adequate ventilation to maintain an acceptable indoor air quality in general case.

Table 1. General Description of Offices

For Location Zones: C = Commercial, R = Residential, I = Industrial

Office	Approximate Size (m^2)	Nature of Business	Grade of Building	Ownership	Location Zone	Office Configuration
A	1060	Building Management	A	Tenant	Town Centre	Half floor, with perimeter view
B	1,090	Banking	A	Tenant	Town Centre	Whole floor, with perimeter view
C	770	Banking	A	Tenant	C	Whole floor, with perimeter view
D	2,500	Semi-Government	A	Owner	C/R	Whole floor, view, central atrium to outside
E	1,580	Banking	A	Tenant	C/R	Whole floor, view, internal central atrium of 5 floors
F	2,100	Banking	B	Tenant	C/R/I	Whole floor, view
G	500	Trading Firm	C	Owner	I	Whole floor, no view, no outdoor air
H	320	Trading Firm	C	Owner, same as G	I	Whole floor, no view, no outdoor air

Offices B and C belong to the same organization in different buildings. Offices G and H belong to the same organization in the same building. The grades of building given are an indication of their prestige and the quality of service facilities available to the tenants. It is the subjective judgement based on their rental value, type of business, building facade, locations, attitude of the building management team, etc. Although there is a local guideline for the assignment of grades, the grades given in Table 1 are the opinion of the authors. All offices are air-conditioned. The spaces are clean and apparently well managed. The location zones of the buildings reflect the outdoor conditions of the buildings. G and H manifest an extreme case in Hong Kong. The outdoor air is so polluted by the adjacent factory exhaust that the management preferred to close all outdoor air vents.

Table 2. Classification of Ventilation System and Tightness of Building

VAV = variable air volume, FCU = fan coil unit, CAV = constant air volume

Office	System	Fresh Air System	CO_2 Growth Rate	Classification of Adequacy of Fresh Air Supply	Classification of Tightness of Building
A	VAV	Central	Grow and become steady in the afternoon	Adequate	Open
B	VAV	Central	Grow and become steady in the afternoon	Adequate	No data
C	VAV+FCU	Central	Grow and become steady in the afternoon	Adequate	No data
D	CAV	Central	Grow and become steady in the afternoon	Marginal	Open
E	FCU	Central	Grow and become steady in the afternoon	Marginal	Open
F	FCU	Central	Grow rapidly, no trend of becoming steady	Inadequate	Tight
G	FCU	None	Grow rapidly and did not become steady	Inadequate	Moderate
H	CAV	None	Grow rapidly and become steady	Inadequate	Tight

Table 3. Ventilation Indices

Office	Air change rate / hr		CO_2 level		m^2/person
	System ON	System OFF	Steady Peak	Residue	
A	3.96	0.53	700	426	5.66
B	3.55	no data	802	no data	7.13
C	3.2	no data	886	no data	6.42
D	1.01	0.43	1065	385	6.9
E	1.23	0.34	1205	331	9.5
F	1.04	0.17	2573	622	5.66
G	2.08	0.30	1618	343	4.34
H	2.68	0.24	1980	450	3.90

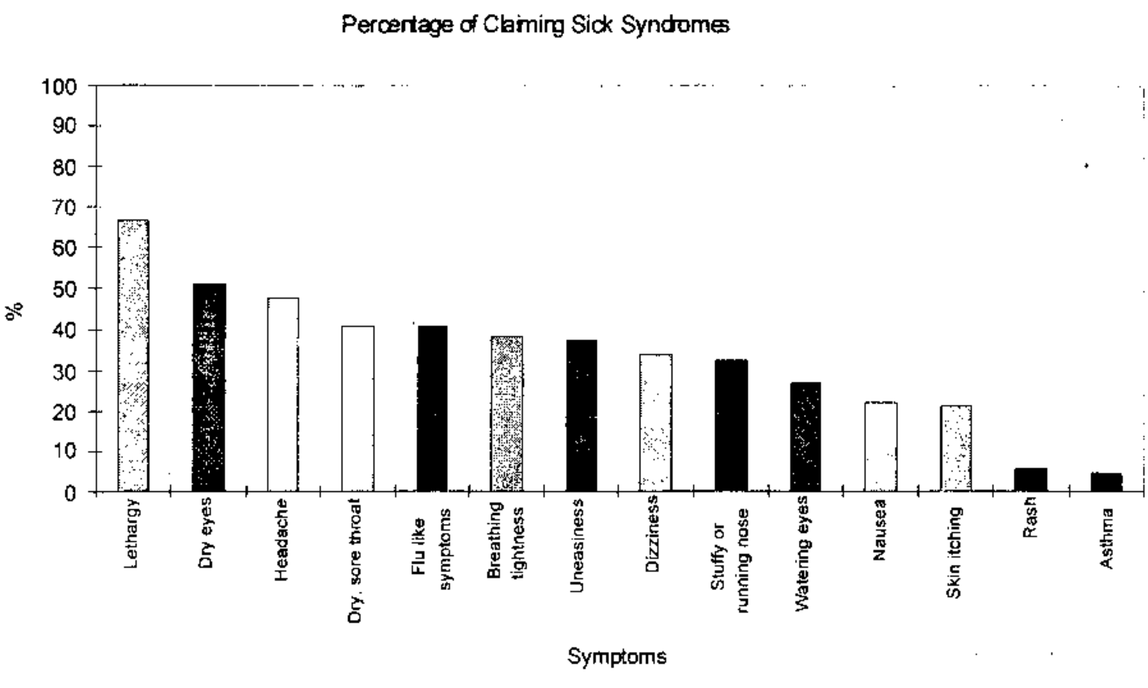
5. SICK BUILDING SYNDROME SURVEY

The subjective response on sick building syndromes were collected by a questionnaire on the following 'stressors':

Lethargy
Uneasiness
Nausea
Dizziness
Headache
Breathing tightness
Asthma
Skin itching
Dry, sore throat
Dry eyes
Stuffy nose
Rash
Watering eyes
Flu like symptom.

Figure 1 shows a typical response in an office.

Figure 1.



The overall subjective response to the indoor environmental quality is usually measured by the average number of complaints. Table 2 shows the results of measurement in 17 offices.

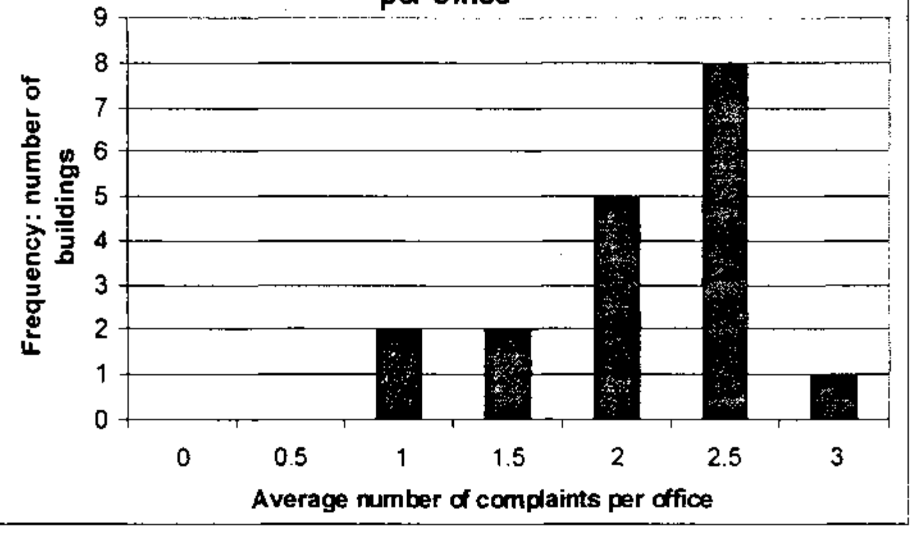


Figure 2. Frequency of number of complaints per office

6. CONCLUSION

From the study, it is found that simple carbon dioxide measurement can give a good indication of the ventilation performance of the ventilation system and the building characteristics. Together with the results from sick building syndrom survey results, the indoor air quality in the buildings studied is in general acceptable. In this study, a measurement and analysis protocol is being developed to identify problem issues in problem buildings.

Air Ducts in Offices - A Health Hazard !

Presented By : Mr. Thomas Y. S. Lee
General Manager
RoboClean (Hong Kong) Co Ltd
Air Duct Cleaning Contractor for Government Hospitals and Various Venues

Most of the people spend up to 90 percent of their time indoors. The amount of time spent indoors is a significant concern, given the fact that studies conducted by the EPA, National Institute for Occupational Safety and Health (NIOSH), and others, show indoor pollutant levels may be 10 to 100 times higher than outdoor concentrations. In addition, there is a trend in construction toward energy-efficient, relatively airtight structures. Sometimes, the fresh air in-take is adjusted to a minimum level for the reason of energy saving. These factors taken together have raised increasing concern about the potential adverse health effects of indoor air pollution.

Different kinds of pollutants are trapped in the indoor environment. The major sources of Polluted Air are from :

- Building Shell
- HVAC System
- Outdoor Environment
- Building Occupants

<u>Function of Air Duct System</u>
Air duct is a system of passageways for distribution and extraction of air. Air is drawn from outdoors through air duct to an HVAC unit where it is conditioned. Small particles of dust and debris are transported from the air stream into the air duct system. Over time, these deposits may form sizeable accumulations.

Pollutants inside Air Duct System :

- Mold
- Bacteria
- Dust
- Dead Insects
- Viruses
- Pollen
- Rodents

2 Common Types of Pollutant inside Air Duct :

Particles
- Outside Environment through HVAC
- Shedding of Building Material, HVAC Components & Copiers
- Occupant Activities e.g. Smoking, Photocopying

Bioaerosols
- Outside Environment through HVAC
- Shedding of Bioaerosols from Human Activity (Primarily Skin Cells, Bacteria)
- Amplification / Growth of Bioaerosols on Indoor Surface

Health Effect of Pollutants :
Long term health effects : Respiratory Diseases, Cancer
Short term health effects : Asthma, Hypersensitivity Pneumonitis

Occupational Safety and Health Ordinance
The new Occupational Safety and Health Ordinance was enacted in May 1997. One of the purpose of this Ordinance is to ensure the safety and health of employees when they are at work. The maintenance of air duct system which directly affects the indoor environment is also governed by this Ordinance. A number of guidelines concerning indoor air quality and air duct maintenance are formulated by the Commissioner of Labour Department.

How to evaluate the cleanliness of air duct system ?
Visual
- RoboInspection

Laboratory Testing
- Dust Weight Measurement
- Yeast & Mould Count
- Total Bacterial Count

Air Duct Cleaning Method
Air duct cleaning is necessary if the air duct system is contaminated. Cleaning involves the physical removal of debris and other foreign matter from the air duct system surfaces.

Video Presentation
Hidden scenery inside the air duct system

Health Monitoring of Canopies in a Dynamic Way

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Abstract

Canopies are very popular type of sub-structure in Hong Kong, and their safety has been an issue for many years. There are about 30,000 canopies in Hong Kong and a significant proportion of them has illegally constructed structures attached. As concrete gets old and steel starts to rust, the integrity of canopies downgrades and becomes a potential hazard to operations below. In the case that the canopy is in a high position, progressive failure of lower units may occur after an initial collapse. The traditional static type of inspection of canopies can gives a good result or estimation of the health of a canopy, however they are usually time consuming and their efficiency is heavily depends on the personal experience and skill of the individual investigator. This paper discusses how dynamic monitoring techniques, using ambient vibration, can aid the inspection process and can give a very quick indication of the overall integrity during the initial screening process.

Introduction

Traditional techniques for inspecting cantilevered systems or canopies required expert eyes or checking of steel corrosion. Many different types of instruments are developed to assist such inspection in order to understand the health conditions. This kind of approach is classified as local inspection or static monitoring and a timely inspection is usually required before conclusion can be drawn. If a lot of canopies are required to inspect, an alternative technique that known as dynamic monitoring can be used. The dynamic method or sometimes known as system approach, usually reflects the overall condition or integrity of a structure rather than giving localized information. This report, instead of using complex approach that generally require for dynamic analysis, highlights two different dynamic monitoring techniques, namely the frequency monitoring approach and the non-linear damping monitoring approach together with examples that can be used in the initial health screening process before the detail inspection scheme is called.

Data Collection Unit

A black box type device is developed that powered by DC battery with an accelerometer that serve as the sensor. The device can be connected to a PC via the serial port and raw data can be downloaded and stored. Servo-type accelerometers are chosen for its size and sensitive instead of other types of sensors. Vibration of the sub-structure is captured by an accelerometer that mounted vertically with the sensitive axis towards the gravitational field. The response is feed into a signal conditioning unit which will low pass and amplified the signal before it is digitised and stored in the PC. A 30Hz low pass filtered to reject any higher frequencies that are not of interested and the signal is digitised at 460Hz. The communication rate between the device and the PC is 28.8K. A schematic diagram of the data collection unit is shown in figure 1.

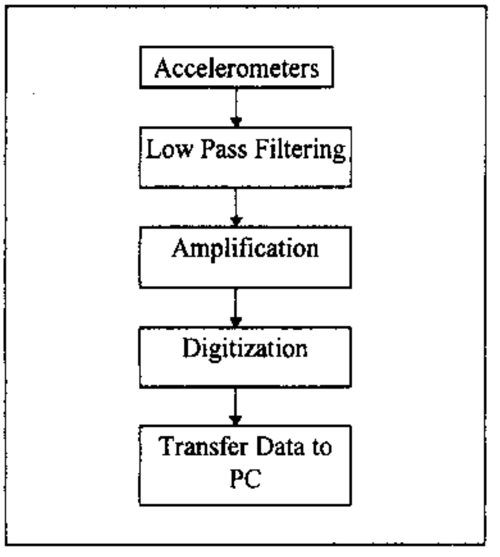

Figure 1. Schematic diagram of the data acquisition unit.

Frequency Monitoring

The dynamic monitoring technique usually require a collection of signal and obtain its frequency spectrum that effectively is the frequency of vibration of the structure. For canopies, since it is attached to a main building, the majority of vibration is therefore on the vertical axis. Figure 2 shows the direction of interest and how the black box should be placed on a canopy. As the building is usually vibrate laterally, the movement of the building will not affect the vertical acceleration of the canopy. However, very often, a second mode of vibration is usually exist in the canopy but it is the lowest frequency that are of interest and affect in the largest extend to the major integrity of the canopy.

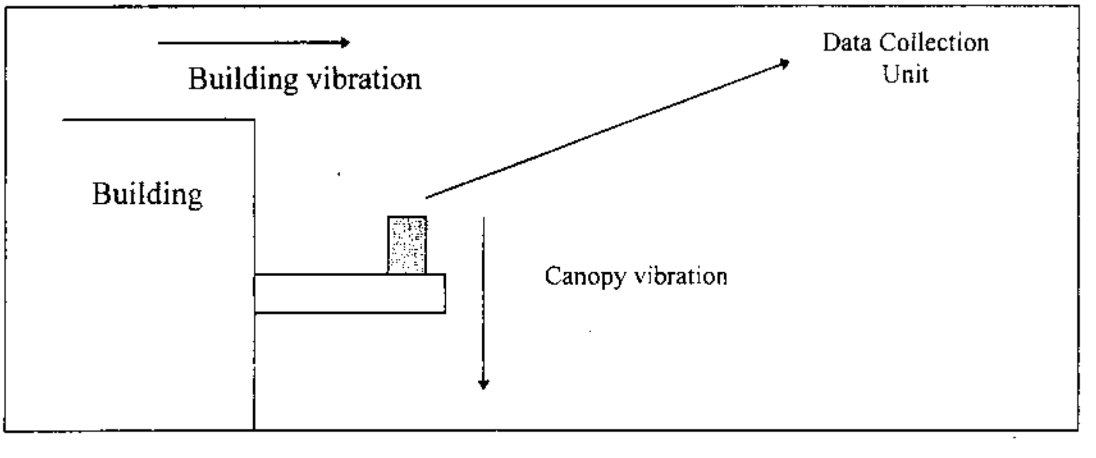

Figure 2. The movement of a canopy and its relationship to the building

Whenever a change of the lowest frequency occurs, this may indicate a change of the integrity of the structure. Figure 3 and 4 shows a typical response of a canopy and its associated spectrum with frequency of interest at 12.91Hz.

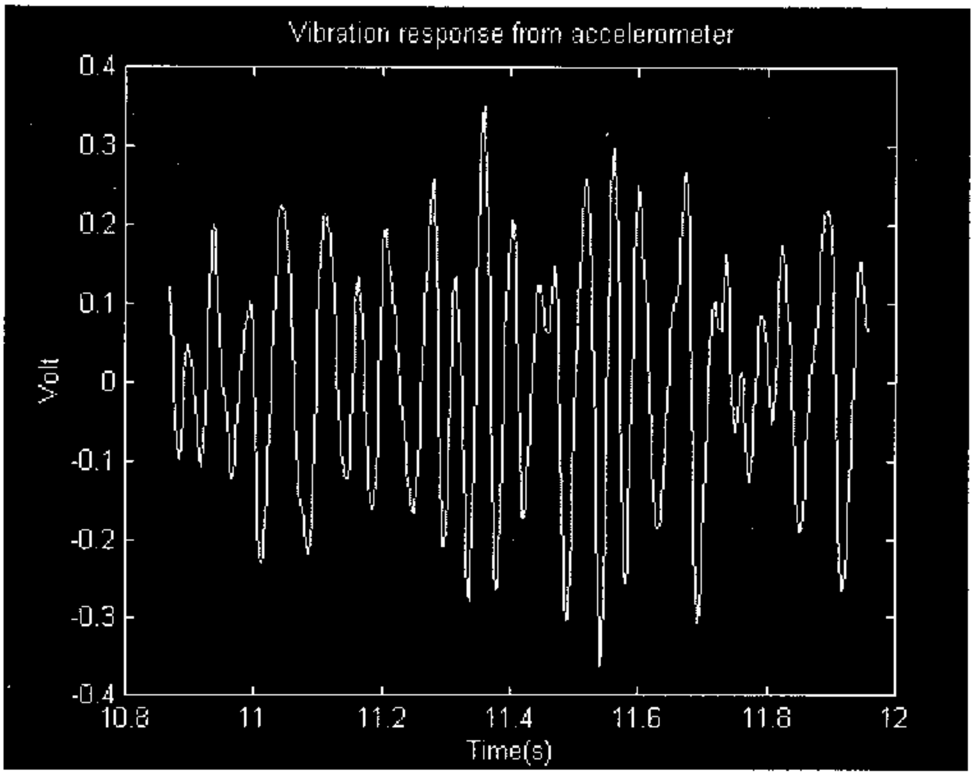

Figure 3 The time response of a canopy

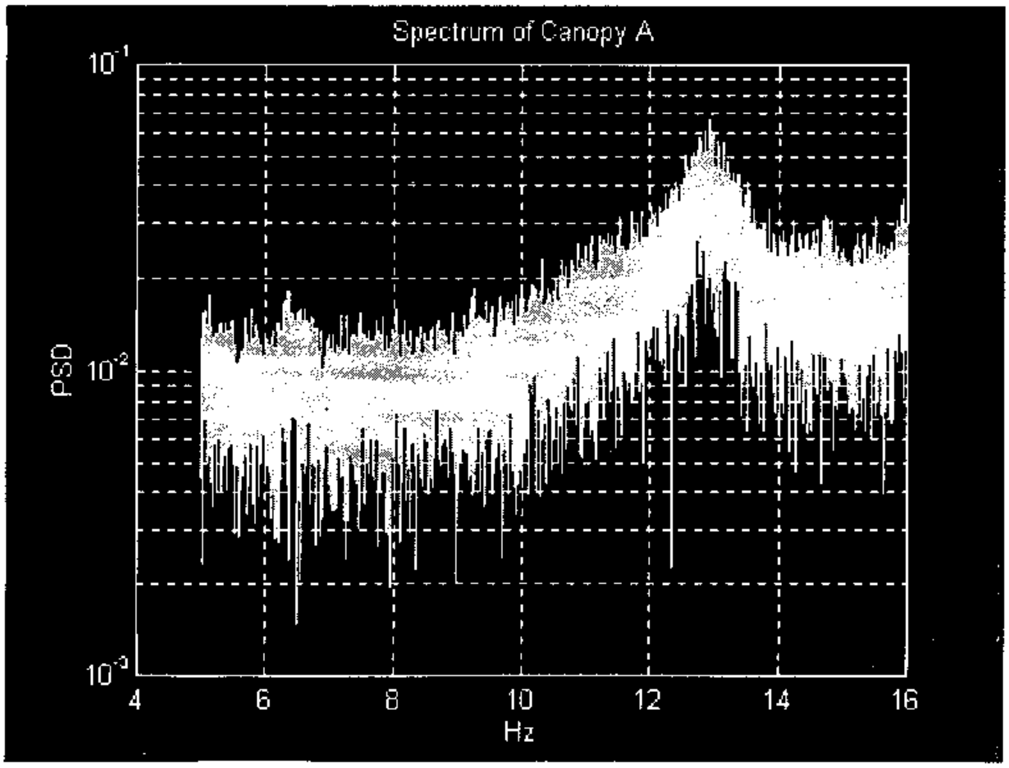

Figure 4 The frequency spectrum of a typical canopy showing it's mode of interest at about 5 Hz.

The frequency spectrum of a canopy is calculated by a standard technique known as Fast Fourier Transform (FFT) that perform transformation for a given signal from the time domain to a frequency domain. The length of the data must be sufficiently long in order to achieve a good frequency resolution.

By regularly comparing the frequency spectrum of a canopy, say every 6 - 12 months, any changes can be easily identify. If the frequency value that are of interest shift down, it indicates that the stiffness of the canopy has been reduced and remedy action should be taken. There are several different cases that will affect the lowest frequency:

1. The bonding between the canopy and the building.
2. The integrity of the canopy itself.
3. The mass of the canopy.

It is important to note that the identification of the lowest frequency is absolutely crucial because in real life, canopies are usually coupled by other frequencies and the initial spectrum must be made correct in order to make the subsequent comparison become meaningful. It is recommended that the spectrum should be plot on semi-log scale instead of linear scale.

Non-linear Damping Monitoring by Random Decrement Technique

Though frequency spectrum method is easy to use and straight forward, however they are usually less sensitive when compare with changes in damping. Damping is a mechanism that describe the dissipation of energy. If the damping value of a structure is high, it indicates that it can dissipate external force efficiently and therefore this structure can withstand a larger force compare with one that has lower damping value. When the damping value is changed from high to low, it indicates that the ability to dilute the external force is low and thus, energy will go into the material of the structure and may create damage inside the material by dissipating it's energy. It has been a practice for many years that damping is design as a constant value in buildings or sub-structures by employing the equivalent viscous damping model. However, in real life damping mechanism has been proved and accepted that it's not behavior in a linear manner but in a non-linear process. Unfortunately there do not exist many technique that can visualize this non-linear process and Random Decrement Technique (RDT) has been the most successful one among the others.

Random Decrement Technique is developed back in 70s' by Cole [1] when he wants to develop a technique for real-time damage detection in space industry. Since then, the technique has been evaluated by many researcher [3 - 11] and Jeary [2] starts using this technique in tall buildings. RDT is a spectral and time series analysis technique that require the processing of the signal of the system to be stationary enough and when averaging the signal under a particular scheme, the resultant signal will become a signature that only contains damping and amplitude information. The resultant signature is known as Random Decrement Signature and describe the changes of damping against it's magnitude of movement. This technique can be used in both linear and non-linear damping systems.

Following the steps in the identification of the frequency of interested in the former spectrum method, the RDT require to isolate or band-pass filtered the frequency of interest before it can be post-processed. A digital band pass filtered is applied and depends on the range of the frequency and the duration of the data set, different band-pass filter can be used. For simplicity, a 8 pole Butterworth filter is used in this study. Figure 5 shows a filtered time history that are ready for the RDT.

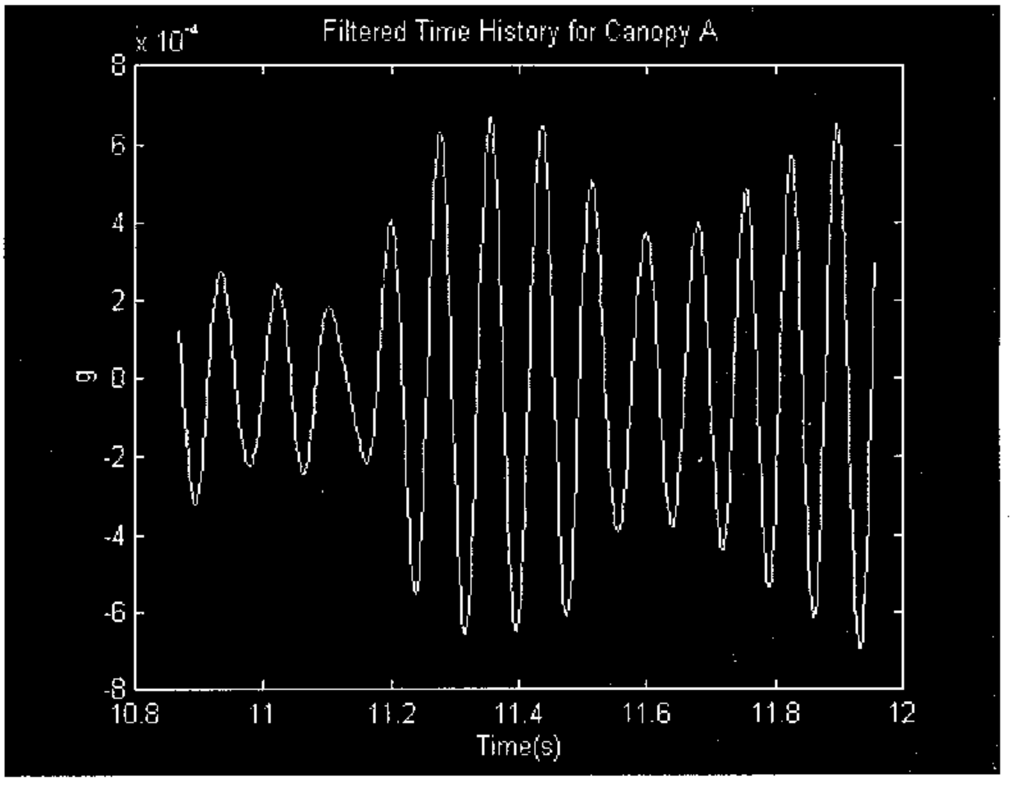

Figure 5 A filtered version of the time history of figure 3.

The filtered data will then pass into a threshold selection process in which it will be selected based on the particular amplitude of movement. Segments of samples being fall into the group of threshold will be taken out and averaged. The number of samples taken is crucial and must be able to average out the unwanted noise and left behind a decade of damping against that particular threshold.

A cosine damping function is then curve fitted to obtain a damping ratio at that amplitude of movement. By repeating this process at different threshold, a non-linear damping curve can then be constructed.

A typical non-linear damping curve being processed is shown in figure 6.

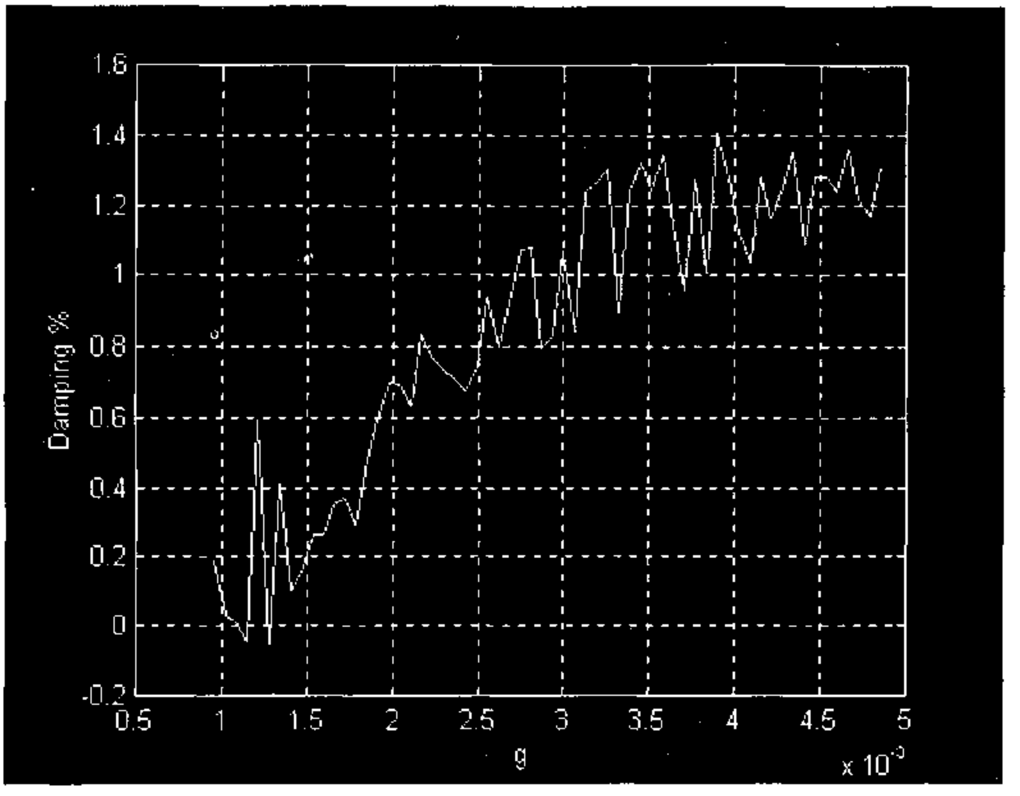

Figure 6 The non-linear damping curve of a canopy

The graph in figure 6 is known as the non-linear damping template of the canopy and subsequent comparison is made against this one. Any structural changes in a canopy will be reflected on this curve which may not be seen by visual inspection.

Discussion

Two different methods of dynamic monitoring is present in this paper that gives a brief idea on how dynamic methods can be used to perform health monitoring of canopies. It is a fact that the RDT is much more difficult to perform compare with the spectrum method and detail calibration is require before one can apply on canopies. However, the advantage of the RDT is the sensitive of detecting changes and it can be done without an expert eyes and takes a very short time to perform. A good signature can be obtained by 30 minutes of data and there is not calibration or mounting required for the black box system used in this study. The frequency spectrum can be used in conjunction with the RDT as it forms part of the analysis of the RDT anyway.

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ENHANCED FIRE SERVICES INSTALLATIONS

Wicky W.K. Lo & Peter O.K. Lam

The Association of Registered Fire Services Installation Contractors of Hong Kong

ABSTRACT

Following a number of major fire incidents in recent two years, the Government has introduced Fire Safety (Commercial Premises) Ordinance (1997), Fire Safety (Commercial Premises) (Amendment) Ordinance (1998), and has issued consultation paper for the proposed improvement for Fire Safety in Private Buildings in June, 98, it outlines a general picture of Government's step by step approach for enhancement of Fire Services Installation in various types of Old Buildings.

Our Association Projects that based on a ten years programme timeframe, the annual average expenditures of these enhanced Fire Services Installation will be HK$1267 million.

Needless to say, increasing attention from various relevant consultants (Architects, Engineers and Surveyors), contractors (Building and Fire Services Installation) are being paid to these projects as it is expected that these Fire Safety enhancement projects will generate business opportunities to them.

This paper concludes the views of our Association with suggestions for this territory-wide Fire Safety Upgrading Project to achieve the objectives of this project.

Introduction

To the owners of approximate 1400 commercial buildings, the introduction of Fire Safety (Commercial Premises) (Amendment) Ordinance 1998 brought into operation on 1 June 1998 brings new tasks to them. To complete these tasks, they need to pay cost for meeting specific objectives within define schedules and performance parameters. In BS6079 [1] these activities are classified as typical characteristics of a project.

In Hong Kong, as we know, most Building related projects start off with expectations of financial return. Normally, when a client decides to develop a piece of project, he/she has quantified the prices of or returns of this development/project, in this case, the inception of a project is the legislation. The Administration introduces legislative means to bring Fire Safety in 1400 nos. pre-1987 commercial buildings, and in future, after the legislation of Private Buildings, 9000 Private Buildings to modern standards. Under such circumstance, we believe that it is tempting not to interpret the responses and behaviour of these clients in the same way that the clients whom we are dealing with in other construction projects.

In this paper, we attempt to predict the determinants of making success, the barriers and the differences between this client group and other clients that we are dealing in other construction projects.

What Makes Success

A good place to begin our look at what makes success is to ask ourselves what makes "this group of client" & "this type of Project" different from any other client groups and projects that we are dealing with in our day to day business. Can we apply other project's skills in this area ? What are the differences ?

- Inception
- Objectives
- Design
- Modification / update

Inception

Commercial projects always start off with business feasibility study of which the prices and returns of this project has been carefully estimated, or clients would have in their mind a rough idea of what the revenue would be, and this inception usually results in the development of next step – objectives. In this case, the inception of a project is the legislation, what the client pay for is to trade-off the potential punishment according to the ordinance.

Unfortunately, obedience to law is not taken as granted, therefore, both public and private resources are required in order to enforce the rules and regulations, and to apprehend offenders.

Besides, conviction must be considered sufficient punishment in itself in order to keep the inception having sufficient driving force.

In view of the nature of this inception force, we believe that the more support from the public, the higher successful rate in future. Therefore, the public view to this Fire Safety enhancement is important.

After the issue of Public Consultation Paper for Private Buildings in June 98, our Association issued the Paper to a more specific targeted Group in order to collect more data for our analysis. We also specified 2 months consultation period in order to predict the result of whole population survey to a certain degree. Regrettably, we only received less than 1% feedback from this targeted Group.

Through the assumption that the targeted Group's response rate should be much more higher than the public, we have been assuming in effect, most comment received by Government to this paper are generated by industry practitioners. Therefore, we are worrying about the commitment from public.

Objectives

In a Building Project, it is at all times proceeding with three types of objective :

- Quality Objective
- Time Objective
- Cost Objective

The priority of each of these three objectives depends on the comparative weight of each objective. The client, consultant and contractor should have a mutual understanding on the priority and the comparative weight, this understanding will affect the reaction from the project team when any problem might arise. Chan [2] ranks the project team actions as 2nd best predictor for project success. In such a situation, when a problem arises, there are three possible reactions:

1. Relax Quality Objective
2. Extend time scale
3. Pay more to mobilize more resources

If there is a mutually agreed priority / ranking of these objectives, it is likely that the project team reaction could be made a correct choice of alternative reaction.

However, particularly, the clients for these Fire Services Installation enhancement projects have very little freedom on their Quality Objective, they are not allowed to relax their Quality Objective unless it is endorsed by Government Departments, or to describe more correctly, this group of clients will only set their Quality Objective equal to the minimum requirement set by the Government, therefore, there is no room for relaxation of any Quality Objective.

Secondly, as the time scale is fixed by the orders served to these clients, again, they can extend their time scale only when it is agreed by the Government.

Based on the above assumption, in general sense, the other two objectives cannot be relaxed within the authority of the project team.

The client will have only one reaction to be made – to increase the cost to mitigate the other two fixed objectives.

Design

The different types of client would lead to a different design. A typical example is :

The passenger terminal of New Airport could be either protected by sprinkler or a VESDA System. Airport Authority decided to equip VESDA to protect the passenger terminal.

In this case, who will influence the design ?

"The Government"

In the ordinances, it is said that the Fire Services Systems to be installed shall be "modern" and "current" standard. One may urge that the "current" and "modern" standard is out of date the minute that you have specified it. There is a school though that "anything can be built", but all these buildings are in place for many years, there have been so many restrictions for applying today's design. Fortunately, it has been awared by Fire Services Department as well as Building Authority. They have been prepared to compromise according to problems that might arise to relax their Quality Objectives (the term is used as a rather broad meaning here covers rules, regulation as well as all other technical requirement).

The Fire Safety design then starts with the conceptual design meeting the "modern" and "current" requirement, the system is expected to fulfil physical constraints of the Building as well as the fundamental requirement in the regulation for "modern" and "current" standard. In our experience, most of these Buildings would have different degree of constraints for applying today's standard, at the present moment, the system designer has to seek relaxation from these today's standard from the Government.

According to our estimation, the annual expenditures of the proposed enhancement in Private Buildings plus the two ordinances for commercial premises is about HK$1267 million, which is about 40% of the total expenditures of New Fire Services Installation HK$3109 million (at 1996 value). In view of the huge expenditures, long duration and technical complexities, we believe that if we treat this enhancement work as a 10 years project, all professionals and Government shall give careful though on how we could standardize the design for these buildings in order to reduce the time spent on project by project design negotiation. As all these buildings in place for many years, we (the Government and the designer) need little protection against impact on the change of design parameter.

Modification / Update

As I mentioned before, this is a Hong Kong long term project. A project normally shall have following features :-

• Definition	-	Rules & Regulation
• Planning	-	Work Breakdown
	-	Organization Structure
• Implementation	-	Time, cost considerations
• Review & Learn	-	Modification / update

Modification / update should take place at every stage, for example, in the stage of implementation it is quite possible that it will become apparent that there is a deficiency in the planning which has been previously set. Of course, care in original establishment of each stage should minimise these occurrence, but if it is exit, these deficiency should be minimized by continuous modification / update process.

For the current standard & regulation, there is mechanism built for communication between all professionals and the Government to review and update.

As this enhancement is a complete new project to the community, we believe that a new mechanism should be established for constantly review (Fig. 1), to benefit all parties.

Conclusion

The purpose of this paper is not to reach specific conclusions but rather to raise issues and ideas that can provoke discussion. However, it will help us to understand the situation we might learn. We will also pose some questions, the answers to which we hope will help us to formulate future strategy.

To maintain firmed commitment from public, both the Government and practitioners have to effect constant publicity campaign or issue to remind the public the importance of the subject issue.

Source of funding is also another major problem for the project having a number of small scale of owners. The cost for upgrading fire safety standards for old buildings will depend on the difference between the existing and the new standards of fire services installations and the deficiencies in building structure. The cost for each unit relies on the number of co-owners of the buildings, which may varies widely between buildings. Budget control will be exercised by both the owners or professionals (Architects, Surveyors and Consultants... etc.) employed by them.

Furthermore, it also demands competence and professionalism from contractors to cope with sophisticated design, difficult site conditions, demanding construction requirements and many other technical problems. Unlike new building construction, each old building is very often unique and contractors have to deal with each project based on its special conditions. Therefore, owners and their representatives have to choose competence contractors that are properly screened.

Finally, the Project as spoken is obviously not without problems. These problems can only be overcome with co-operation from the Government, building owners, professional bodies and contractors. The continued success will depend on the continued partnership between the public and private sectors.

- END -

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The Comments from the Fire Safety Study Group,
Building Surveying Division,
Hong Kong Institute of Surveyors
on
The Proposals to Improve Fire Safety in Private Buildings
Issued by the Security Bureau

In August, 1998, the Fire Safety Study Group made the following comments and suggestions on the Security Bureau's paper "the Proposals to Improve Fire Safety in Private Buildings".

1.0 URGENT SOLUTIONS - Fire hazards which are easily rectifiable
(Paragraph 17 of the Consultation Paper)

We all know one major kind of obstructions in escape routes is the storing of refuse bins for collection of refuse from flats. This is a very common method for collecting refuse from flats in residential buildings before transporting to main collection points on ground floor. This method of collection is adopted throughout in Hong Kong and even by housing estates known with good management. The stepping up of enforcement actions alone will not resolve this kind of obstructions. We would propose the followings:

1.1 New buildings:

1.1.1 Facilities of refuse hopper room and refuse chute on every floor of high-rise building should be made mandatory for new buildings.

1.1.2 All facilities of this kind should be given incentives such as gross floor area and site coverage concessions.

1.1.3 We understand that there may be problems such as security, hygiene and noise to be resolved in operating these facilities. Guidelines on the design and construction of these facilities should therefore be issued to building professionals.

1.1.4 For buildings already provided with these refuse disposal facilities, the use of which should also be mandatory (this can be implemented through building management companies).

1.0 URGENT SOLUTIONS - Fire hazards which are easily rectifiable (cont'd)

1.2 Existing buildings:

We agree that there is no easy solution mainly due to physical constraints in existing buildings. However, the Authority should research on the following issues:

1.2.1 Practical refuse disposal methods.

1.2.2 Management measures such as restricting the hours for dumping and collecting refuse.

1.2.3 Permitting proposals to install these provisions over scavenging lane or in light well – the installation of the refuse disposal facilities may become feasible for some existing buildings with these kinds of relaxation given.

1.2.4 Considering the improvement or addition of refuse disposal facilities as fire safety improvement works and give assistance.

2.0 FURTHER PROPOSALS TO IMPROVE FIRE SAFETY

We agree in board term to the Government's proposal to improve the fire safety measures of private buildings but would suggest the followings for the Government's consideration:

2.1 Building Management

2.1.1 The proposal to apply compulsory/mandatory management to neglected private buildings is welcome. Suitably experienced and qualified Building Managers should be selected from a list of Firms employing Licensed Building Managers.

2.1.2 The suggestion to require certification by Authorized Persons that buildings are free from fire hazards should be extended to include suitably experienced Registered Professionals under the various Registration Ordinances who may not be Authorized Persons.

2.1.3 To bring this issue even further, it is suggested that the BMO be revamped to require that the interest of common areas of development be assigned to Owners Corporation (or to be known as "Management Corporation").

2.1.4 The introduction of automatic formation of O. Cs. for new development warrants serious consideration. This will necessitate the revamp of the Building Management Ordinance to clearly define the duties and obligations of the O. Cs. The enactment in Singapore in 1987 appears to be a good model for carrying out further studies for reference. It is further suggested that the effectiveness of actual implementation of the same should be carefully studied before applying this modality.

2.1.5 A Maintenance Fund for the common areas of developments should be set up at the time of formation of the O. Cs.

2.0 FURTHER PROPOSALS TO IMPROVE FIRE SAFETY (cont'd)

2.2 Upgrading the Fire Safety Standards

2.2.1 We all know that there are difficulties for existing buildings to be upgraded to meet the current fire safety standards. Alternatives supported by fire engineering design would not resolve all the difficulties but increase the degree of uncertainty in obtaining the authority's approval of the upgrading works. The alternatives very often are accepted after extensive work done in preparing justifications, seeking examples, producing test results and making calculations. All these result in higher cost, greater disturbance and delayed completion for building owners and occupants. The fact is that there are not too many tested, practical and cost-effective alternatives available for application to existing buildings in Hong Kong. To identify alternatives and seek approval from the authority through the approach of fire engineering design is too costly and time consuming for resolving a fire safety deficiency in an old building. In fact, the deficiency very often is created simply by a change in the fire codes or building regulations after the building was approved and built.

2.2.2 The recommendation for upgrading fire safety measures in existing buildings to fully meet the current standards should be applied to the common parts and escape routes of building only. Privately occupied units should be assessed further as the full application of all the current fire safety measures may not be necessary and feasible. For privately occupied units, we consider that more emphasize should be placed on controlling the spread of fire and giving out fire warnings to occupants in other units.

2.2.3 The authorities should make a list of "deemed" acceptable alternatives to current fire safety measures. The adoption of these alternatives will require no further proof of genuine difficulties or justification from the building owners' consultants. We suggest this on the understanding that the old buildings were designed to the same codes and would have the same deficiencies. This will speed up the process of designing and approving upgrading works.

2.0 FURTHER PROPOSALS TO IMPROVE FIRE SAFETY (cont'd)

2.3 Implementing Fire Safety Improvement Measures

The proposal to improve fire safety in private buildings will cover buildings most of which are not properly managed. In order to implement the proposal successfully, the followings are suggested for the Government's consideration:

2.3.1 The two authorities, i.e. the Buildings Department and the Fire Services Department should co-ordinate with each other and the directions from the two authorities for the same building should be issued together.

2.3.2 Building owners tend to do nothing until directions are issued on their buildings. Judged on the number of directions issued so far by the Buildings Department on the prescribed commercial premises and the specified buildings, it is unlikely that the Buildings Department will accomplish within the proposed time frames, all the buildings as proposed without the input of additional manpower.

2.3.3 Under the Fire Safety Loan Scheme, a building owner who has not been served with a direction is not eligible to apply for a loan from the Government. This will deter willing building owners to upgrade the fire safety measures of their buildings voluntarily.

2.3.4 Building owners and even members of the O. Cs. are mostly laymen and may have never dealt with an A.P. before. In order to reduce the building owners' time and effort in approaching A. Ps. for assistance. The Buildings Department should establish a Special List of A. Ps. who are willing to offer service for this kind of improvement works. Better still, a name list of say, 10 A. Ps should be provided in each direction to building owners. The names of these 10 A. Ps. can be drawn systemically from the Building Department's Special List.

2.3.5 In the default of building owners to comply with a direction, the Buildings Department may enforce compliance by applying for a Compliance Order or even a Use Restriction Order. We would propose an intermediate action in which the Buildings Department shall assign an A.P. from the Special List to implement the works on behalf of the defaulting building owners. The fees and the costs of works should be lent by the Government and recovered from the defaulting building owners.

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REMOVAL OF ASBESTOS ACOUSTIC PLASTER - A CASE STUDY

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Keywords:

Asbestos Abatement

ABSTRACT

Asbestos has the characteristics of incombustibility, resistance to wearing, resistance to acid and the capability of reinforcing other materials which make it practically valuable. Before asbestos became known to be hazardous to health, it had been widely used in many industries including the construction industry. One of the uses was in acoustic plaster. It is a friable material, easily damaged and prone to release asbestos fibre. The removal of such material requires extreme care and is to be carried out in containment. This case is about the removal of asbestos acoustic plaster in a shopping centre using a full containment method. Problems encountered and how they were tackled are highlighted.

INTRODUCTION

Asbestos has the characteristics of incombustibility, resistance to wearing, resistance to acid and the capability of reinforcing other materials which make it practically valuable. Before asbestos became known to be hazardous to health, it had been widely used in many industries including the construction industry. One of the uses was in acoustic plaster. It is a friable material, easily damaged and prone to release asbestos fibre. The removal of such material requires extreme care and is to be carried out in containment. This case is about the removal of asbestos acoustic plaster in a shopping centre using a full containment method. Problems encountered and how they were tackled are highlighted.

BACKGROUND

Mei Lam Shopping Centre is a three-storey building with a main block for shops and an annex carpark block. Shops are located at G/F and 1/F while a restaurant occupies the 2/F. There is a large atrium with skylights in the centre of the shopping centre and the restaurant has full height glazing in the dining area overlooking the atrium. Acoustic plaster had been sprayed on the ceiling of the atrium. It was not known to be asbestos containing until 1992, a bulk sampling exercise confirmed that it contained 5-10% chrysotile. Although the acoustic plaster was in good condition, the part of it near the restaurant entrance could be vandalised. It was decided to have the asbestos acoustic plaster removed in conjunction with the renovation works to the shopping centre.

ASBESTOS REMOVAL

Asbestos acoustic plaster is a friable material. The removal of such material must be carried out using a full containment method. In essence, the asbestos containing material is to be wetted and removed under total containment and negative pressure (0.15 - 0.5 inch of water with respect to the external environment) to prevent release of asbestos fibre to the environment.

In Mei Lam's case, a temporary platform supported by scaffolds was erected (Plate 1 in Appendix). Total containment was achieved by covering the platform and walls with 4 layers and 2 layers of 0.15mm polythene sheeting respectively. Air was extracted via the skylight through two air movers fitted with High Efficiency Particulate Air (HEPA) filters (Plate 2 in Appendix). Workers' ingress and egress were through a three-chamber decontamination unit connecting to a large skylight on the roof (Plate 3 in Appendix) . There was also a two-chamber debris port for controlled transfer of bagged wastes and equipment. Bagged wastes were transferred to a buffer store on the roof and later transported to a nearby container pending disposal to chemical waste landfill.

CRITICAL FACTORS

Asbestos removal is a hazardous work. Extreme care must be placed on :

- security
- containment integrity
- supervision and air monitoring

Security

It is dangerous if the containment is vandalised and asbestos fibre is released as a result. In Mei Lam's case, very frequent patrol by guards had been arranged. Nonetheless, during the setting up of the containment, some vandals managed to sneak into the containment at night and cut holes in the plastic sheets. All access points at the roof were then guarded overnight to prevent vandalism.

Containment Integrity

The containment basically comprised two parts:

- Temporary structures with layers of plastic sheets - temporary platform, decontamination unit, plywood sheeted walls, etc.
- Permanent structures of the building - ceiling and walls with asbestos plaster.

Great care had been taken to build the temporary structures - they were designed to serve the purpose. For the permanent structures, possible leakage through the structure had been identified. In particular, the sprinkler pipes were housed in ducts within the ceiling beams. At the perimeter of the atrium there were duct chambers covered by screwed-on metal plates, on which were also with asbestos plaster sprayed. It was therefore necessary to carry out preliminary abatement to remove the metal plates and seal off the ducts (Plate 4 in Appendix). To ensure safety, the preliminary abatement was carried out after the operating hours of the restaurant and under negative pressure.

Smoke test

Before asbestos abatement work commences under full containment, a smoke test is carried out to ensure the air-tightness and integrity of the containment (check for smoke leakage when the entire containment including the various chambers of the decontamination unit is filled with smoke). Another function of the smoke test is to check whether the air filtration system is functioning properly (how long it takes to extract all the smoke and whether there is any visible smoke coming out from the air mover).

In Mei Lam's case, the first smoke test failed. Traces of smoke were found leaking from the restaurant's suspended ceiling in the dining area near the kitchen where there were large exhaust fans in operation (Plate 5 in Appendix). The suspended ceiling was inspected to trace the leakage, but obstructions and the perimeter light fittings blocked the investigation. Inside the containment, plastic sheets, duct tapes and sealant on the walls were thoroughly checked, but no defect was noticed. Another attempt was made to trace the leakage using the "Draeger"

test (smoke tube test). A small amount of smoke near the possible leakage areas was generated. With the kitchen exhaust fans in full operation, air (smoke) movement was monitored. However, it failed to identify the leakage possibly because there was a general diffusion of smoke through a large area of the structure. It was most probable that the gap between the windows and the window opening had not been properly filled with mortar and was therefore not air tight.
Further preliminary abatement was carried out under negative pressure after the closing hours of the restaurant. Asbestos plaster above the windows was removed and the exposed beam sealed with duct tape. Another smoke test was then carried out. This time it was successful.

Since the dining area was under negative pressure with respect to the external environment, it was decided to increase the pressure differential of the containment with respect to the external environment, such that the pressure differential between the containment and the restaurant was within the range of 0.05 - 0.15 inch of water. The pressure differentials at various locations of the restaurant were measured and found to be 0.02 inch the highest (Plate 5 in Appendix). So a minimum pressure differential of 0.07 for the containment was established and maintained throughout the entire course of asbestos removal. To ensure that the required negative pressure differential was maintained, a pressure gauge fitted with an audible alarm to give early warning of insufficient pressure differential was used. It also printed a time record of pressure differential on a regular basis.

Supervision and Air Monitoring

Asbestos removal is a process. There is no finish product to inspect. Therefore it is easy for contractors to cut corners and contamination to the environment may be resulted. Close supervision is necessary. The Code of Practice on Asbestos Control for Asbestos Work Using Full Containment or Mini Containment Method requires that sufficient number of clear viewing panels (300mm x 450mm) are to be provided to facilitate inspection. In Mei Lam's case, there was no way to install effective viewing panels; the skylights had only limited viewing angles and it was not desirable to have viewing panels installed inside the restaurant. Therefore, instead, a viewing tower of 1.0m x 1.5m x 1.0m clear acrylic sheets was constructed in the centre of the platform (Plate 6 in Appendix), with access from the atrium stairway.

Not only the removal work itself, but also the entire process was under close supervision: from workers preparing for work to the removal process to cleaning the asbestos waste bags at the debris port to workers leaving the decontamination unit and to transporting the asbestos waste to the container. Records such as replacement of pre-filters and pressure gauge readings and air monitoring were also meticulously checked.

To ensure that asbestos fibre was not released during the course of removal, leakage air tests were carried out every day outside the containment (on the roof and below the platform), inside the clean room of the decontamination unit and at the discharge of the air movers. The fibre level of the air was monitored to ensure that it was not greater than 0.01 fibre/ml.

Although at the time of this project the said Code of Practice was in a draft stage, the key requirements were followed, in particular the work acceptance test. Having had the final clean up of the work area, the plastic sheet inside the containment was sprayed with polyvinyl acetate (PVA) to lock any dust that might be left over. Then the innermost plastic layer was removed. The exposed plastic sheet (2nd layer) was HEPA vacuumed and wet-wiped. Then a penultimate air test was carried out to check if the fibre level was less than 0.01 fibre/ml. After a visual inspection, the plastic sheet was PVA sprayed and disposed of. Then the work area was again HEPA vacuumed, wet wiped and followed by a final clearance air test (Plate 7 in Appendix). A final visual inspection was then carried out before dismantling the containment and certifying the work complete.

CONCLUSION

The full containment asbestos removal methodology is itself straight-forward. Complications usually arise in providing and maintaining an air tight containment, in particular if the containment relies on the air tightness of existing walls/ceiling/floors. There may also be obstructions that need to be removed before asbestos removal can be proceeded. In some cases removing such obstructions may result in temporarily loss of some facilities to the building users. The abatement process must be closely monitored. Any asbestos leakage during abatement could be disastrous. Contingency plans for situations such as typhoon, fire and asbestos leakage should be in place. Prevention is always better that cure. It is suggested that a pre-work meeting be held to ensure that all parties involved understand the removal methodology and inspection requirements at each stage of work, and that all necessary documents relating to compliance with legislation and fitness of all equipment are obtained.

REFERENCE

1. Environmental Protection Department (1997), "Code of Practice on Asbestos Control for Asbestos Work Using Full Containment or Mini Containment Method", Hong Kong Government

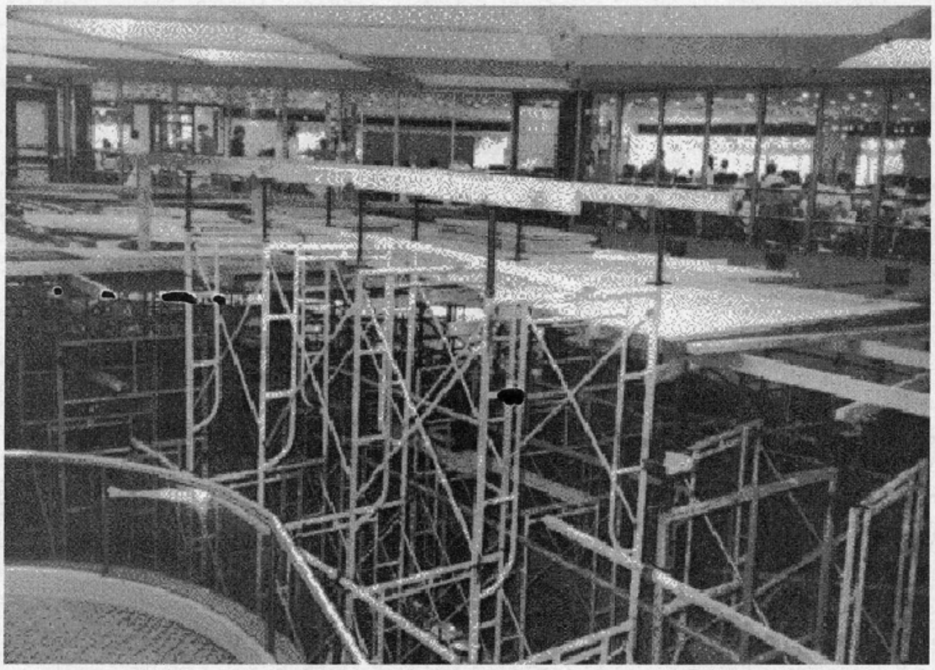


Plate 1 Erection of Temporary Platform in Progress

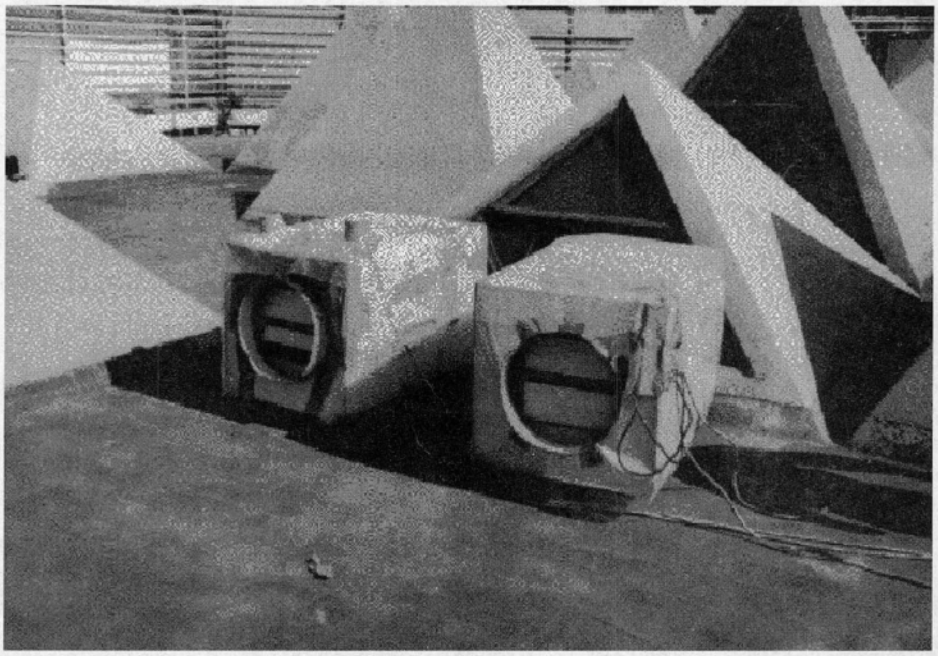


Plate 2 Air Movers on Roof

Plate 3 Decontamination Unit and Debris Port

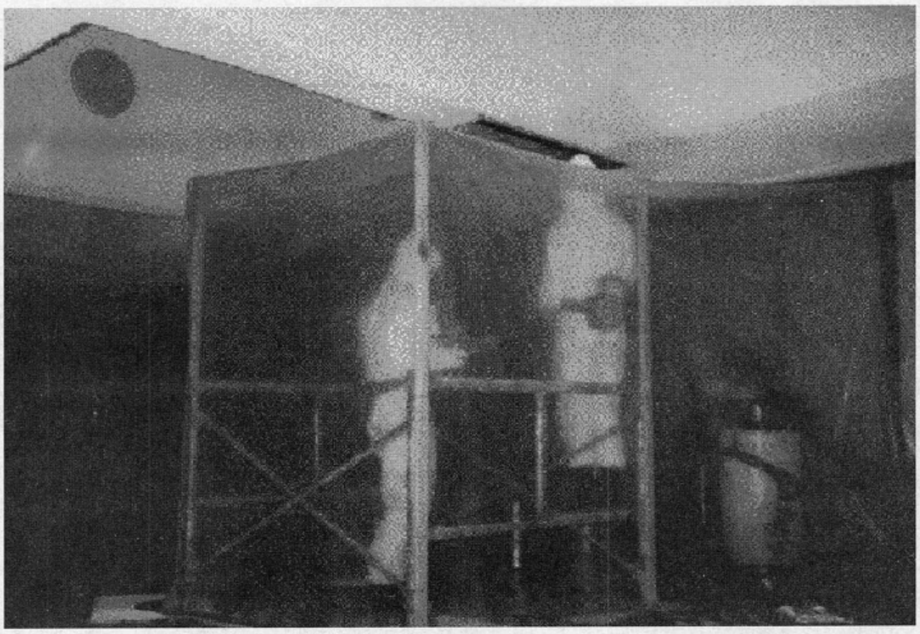
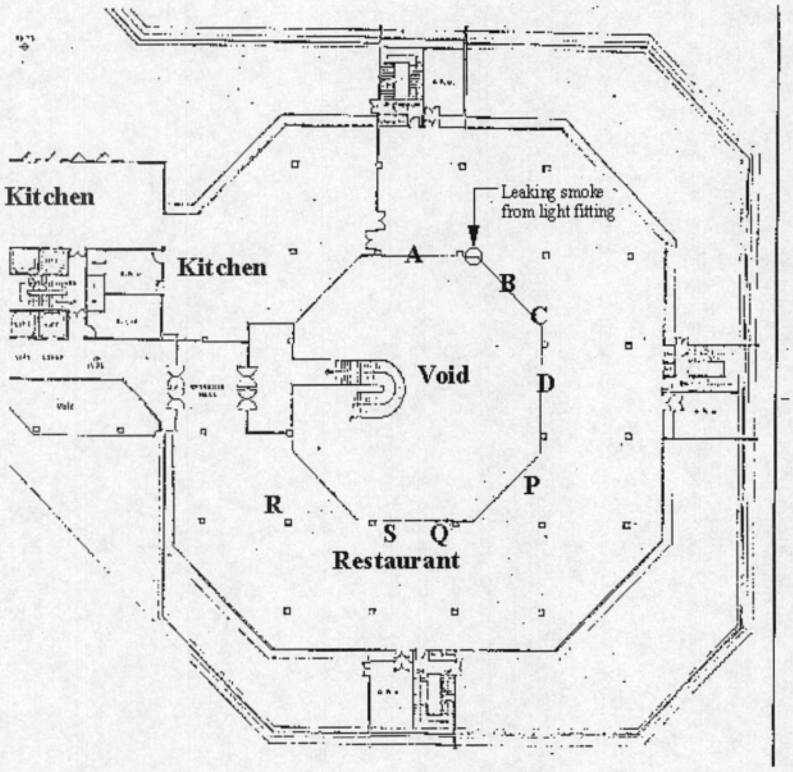


Plate 4 Preliminary Abatement



Pressure gauge reading (inch) above false ceiling:

A	0.020
B	0.019
C	0.018
D	0.019
P	0.018
Q	0.018
R	0.015
S	0.018

Plate 5 Smoke Test and Pressure Measurements

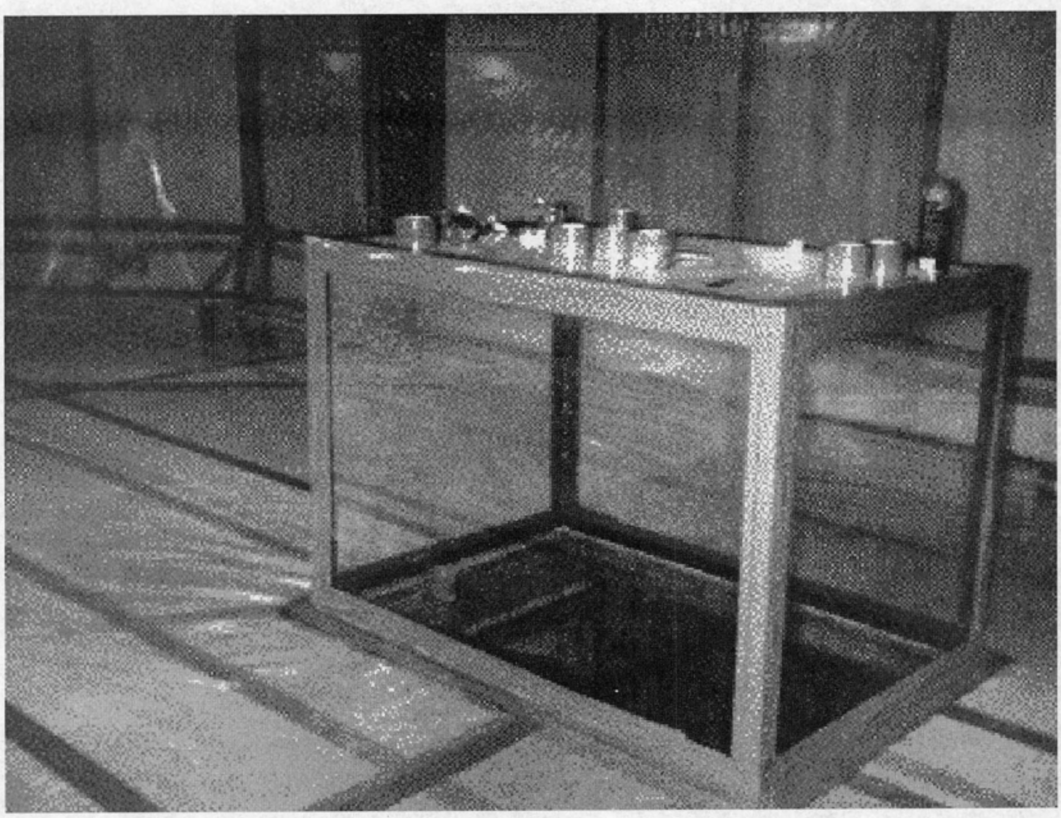


Plate 6 Viewing Tower

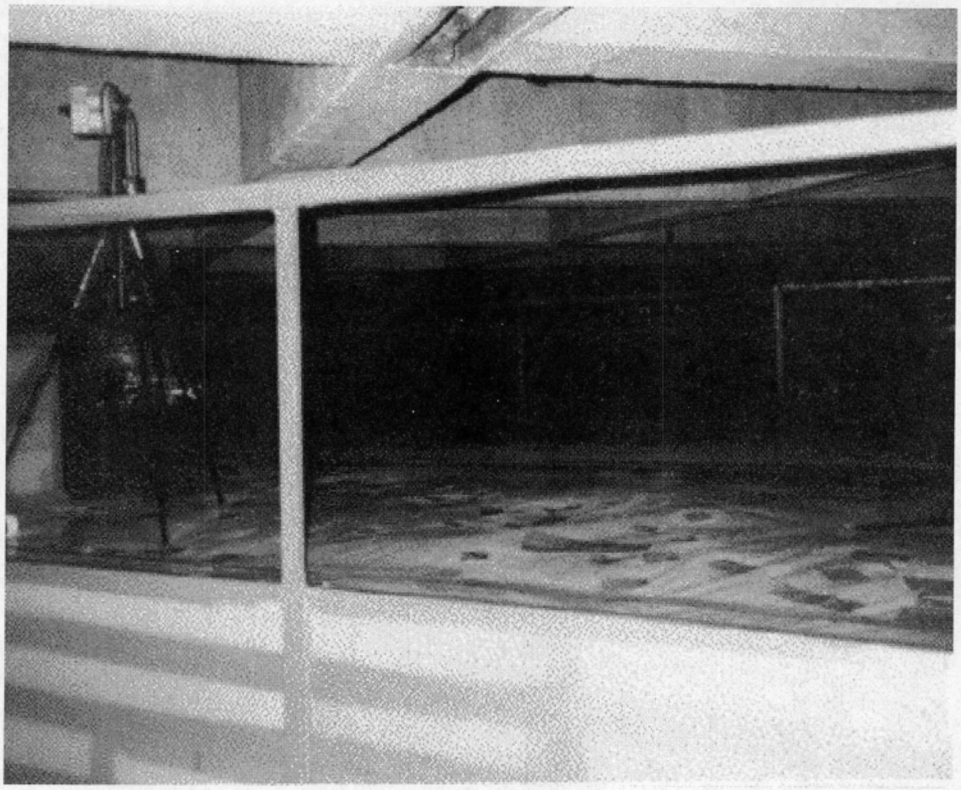


Plate 7 Final Clearance Air Test