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Immediate action in providing fire safety in cities with dense highrise buildings: The possibility of incorporating skybridges

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Abstract

As the number of major building fires around the world appears to be increasing, the general public is worrying whether they are safe in the event a building fire. Evacuation is a key issue, especially for cities with dense urban areas as in the Far East. This paper, in reviewing fire safety provisions and fire safety engineering approaches in the context of Hong Kong, proposes the 'skybridge' concept as a way of providing immediate action in the consideration of adequate egress paths.

1.0 Introduction

The number of major building fires in recent times around the world appears to have increased. In Hong Kong alone in the past few years, there has been the 1996 Garley Building fire [1], caused whilst refurbishing lift shafts without temporary fire protection, the 1997 Tsimshatsui Top One Karaoke Bar fire caused by arson [2], and the 2004 MTR fire, also caused by arson [3]. Loss of life in these three fires were 36, 15 and 17 respectively. Around the world, we have seen the 2001 New York World Trade Centre terrorist fire [4], the 2003 Chicago Building fire [5] and the 2003 underground railway arson fire in Korea [6], amongst many others. It is obvious that the fire safety of our buildings and infrastructure is becoming increasingly paramount.

In parallel, public perception of the fire safety of buildings is coming under increasing scrutiny. This is especially true of tall buildings, where building populations - and thus risks of loss of life - are more concentrated. Most high rise buildings around the world have been designed with a *phased evacuation strategy* in mind, i.e. evacuating a number of floors at a time, and leaving the majority of the building occupants in place. Given the high public profile of the events of the World Trade Centre Towers' collapse, it is now doubtful that tall building occupants will feel comfortable to remain in a tall building in an emergency situation, as is required of this phased evacuation approach [7]. The alternative *simultaneous evacuation strategy*, where all building occupants are evacuated at once, would have a huge impact on the design of tall buildings – an increased number and width of fire stairs, the consequential impact on floor space, retrospective incorporation in existing buildings etc?

Since September 11th and the World Trade Centre Towers collapse [4], International groups considering the implications [8,9,10] have made recommendations in 3 general areas:

(i) the improvement of structural systems, especially with respect to progressive collapse,

(ii) the improvement of fire proofing to structure, fabric and evacuation routes, and

(iii) the improvement of vertical evacuation systems, specifically elevators and stairs.

Whilst this work is vital towards making tall buildings safer, it is perhaps not enough. The risk to our cities is increasing through terrorism, war and accident as urban densities increase, and the problem needs to be tackled at a more fundamental design level, not as an alternative but in addition to the

improved safety mechanisms suggested above.

One possible method of improving the safety of tall buildings is by introducing horizontal evacuation at height through use of a *skybridge* linking towers. The concept of being able to evacuate occupants at a level other than ground, should the building be at risk, seems sensible, especially if any emergency in a tall building effectively cuts off vertical evacuation routes and thus the connection to the ground plane.

The Hong Kong Code of Practice for the Provision of Means of Escape in Case of Fire [11] already requires the incorporation of refuge floors into certain high rise buildings. By making further use of these refuge floors for means of escape and commercial activities via high level linkages 'skybridges' could not only greatly increase the level of life safety for building occupants but also add increased commercial viability to these usually 'dead' spaces.

This paper discusses the implications of incorporating skybridges in high rise buildings in Hong Kong – a city with a history of physical connections between buildings – as a strategy for the improved fire safety of cities with dense high rise buildings. It is first, however, necessary to sketch an audit of current regulations / attitudes to fire safety provision in Hong Kong.

2.0 An Audit of Current Fire Safety Provisions – Hong Kong

There are basically four types of building fires possible in a dense urban fabric such as Hong Kong [12]:

(i) Accidental fires: These are fires due to accidents, such as igniting a polyurethane sofa by an electric fault. Many fires reported in the Far East such as the Garley Building fire [1] fall under this category. The heat release rate is usually developed slowly, e.g. approximately 100 kilowatts for 10 minutes.

(ii) Arson fires: These fires are set up purposely by igniting sources such as gasoline, e.g. the Hong Kong Karaoke bar fire [2]. The initial heat release rate might be high or low, dependant on intent of the arsonist, with consequences hard to predict.

(iii) Attack fires: These might be due to military action or terrorist attack. The whole building might be destroyed within a short period of time by the explosions or resultant fire, e.g. the World Trade

Centre, New York [4]. The heat release rate might reach thousands of Megawatts.

(iv) Fires due to natural disaster: These are fires created by natural disasters such as earthquakes, e.g. the fires resulting from the 1995 Kobe-Osaka earthquake in Japan [13]. A mass simultaneously-ignited fire on an urban scale might develop, or fire may spread from building to building, attenuated by strong winds.

Hong Kong Codes of Practice

Fire safety provision for most Hong Kong buildings, as well as buildings internationally, are set up to deal with accidental fires [14]. Normally, passive building construction is combined with active fire protection systems as hardware installations. Very few fire codes ask for software fire safety management [15], until the recent release of BS 7974 [16]. Dealing with an arson fire or terrorist attack fire has been considered, until recently, as a 'security' problem, which would involve police or military expertise.

Once a fire occurs, whether accidental or non-accidental, there should be sufficient time for the occupants to leave the building safely. The Passive fire code on means of escape [11] ensures that travel distances are not too long and the number of exits is sufficient. The Code on Fire Resistance in Construction [17] ensures that the building is able to withstand the fire to give building occupants sufficient time to evacuate. The Code on Means of access for fire fighters [18] ensures that firefighters can enter the building to help evacuate occupants and control the fire. The Code on Fire Service Installation and Equipment [19] ensures that there is sufficient support apparatus for the fire fighters.

Refuge Floors

The design of commercial high-rise buildings in Hong Kong, unlike commercial high-rise buildings elsewhere in the world, require the use of refuge floors. (Refuge floors are also required in industrial, domestic and composite buildings but for the purpose of this paper we will be concentrating upon commercial buildings). All commercial buildings which exceed 25 storeys in height are required to have a refuge floor located at every 25^{th} floor throughout the building [11]. The incorporation of a refuge floor into a building obviously has a huge impact upon the design of the building, not only from the additional recommendations that are required by the other Hong Kong Codes of Practice such as

ventilation, drencher systems and fire resisting floors but also from the effect that they have upon the lettable area of the building. From the point of view of a developer, to lose two whole floors in a 75 storey building to what is in effect dead space is a massive loss to his / her lettable revenue.

Fire Safety Management

To ensure that all fire safety provisions (hardware) work and occupants know what to do in a fire, there must be an adequate fire safety management system (software) [13,14]. A fire safety plan must include at least the following:

- Building maintenance plan
- Staff training plan
- Fire prevention plan
- Fire action plan

These schemes should be clearly laid down and include what should be done on the passive building design, active fire protection system and control of fire risk factors. Different buildings have different plan layouts, uses and occupants characteristics, therefore, fire safety management schemes need to be building-specific.

3.0 Fire Safety Engineering

The use of Fire Safety Engineering in the design of buildings is becoming increasingly widespread throughout the world. Fire Engineering is a relatively new discipline within the engineering field, however, it is quickly becoming recognized as an indispensable part of any engineering design team, particularly where innovation and cost effectiveness are paramount [20].

Whilst European countries are very familiar with the use of fire engineering in the design of buildings, in Asia and the United States it is still perceived as being required only when a building is very complex in design. There is also a misunderstanding among approval authorities, often due to a lack of understanding, that a fire engineered solution should provide equivalence with the code. If this is the case then the code solution is always deemed to be correct, which is obviously not the case. Instead a fire engineered solution should be used to demonstrate the safety of the building occupants or to demonstrate that the functional objectives of the code are satisfied, as opposed to demonstrating that the code solution is always correct.

In order to persuade both clients and approval authorities that the incorporation of 'skybridges' into a buildings design aids real benefit, we need to satisfy two fundamentally different criteria. Whilst a client will always be interested in providing the most cost effective solution for the safety of his building occupants, the approval authorites, on the other hand, are not concerned about cost effectiveness but purely life safety, which can obviously cause interesting problems.

If a building design is to incorporate a 'skybridge' then the client will want to see real benefit in terms of cost and the approval authorities will want to see a real benefits in terms of life safety. By using fire safety engineering we can address both these criteria in detail.

For example if we look at the incorporation of a refuge floor into a high rise building, what is the functional objective of a refuge floor? The objective of a refuge floor can be broken up into a number of different aspects, summarised as follows [21]: -

1. Serve as a place of rest for evacuating occupants
2. Break up evacuation stairs on the refuge floor – this reduces the possibility of smoke logged stairs and also reduces the possible stack effect created.
3. Serve to protect disabled/ injured people for a long period of time until fire fighters can rescue them.
4. Act as a command point of the rescue teams to assist evacuation and achieve orderly evacuation of the building.
5. Serving as a fire-fighting base for fire fighters to attack the fire.
6. Serve as a starting point for using lifts for evacuation if this is possible depending on severity and location of the fire, lift design, and number of occupants required to be evacuated.

Therefore in order to allow the removal of the refuge floor, all of the above functional objectives should be satisfied. By incorporating a 'skybridge' between two or more buildings all of these objectives can be satisfied whilst increasing the let table area available for the client use. For example as opposed to having a 'dead' space at the 25th floor of every high rise building you could have interconnected retail areas or restaurants, and only in the case of a fire is the 'skybridge'

required to fulfil its secondary function as a means of escape to an adjacent place of safety.

The 'skybridge' also provides an increased level of life safety when compared to a refuge floor. With a refuge floor people always remain in the same building in which the fire incident has occurred, with a 'skybridge' you are moving people away from the initial fire incident into another building unaffected by fire.

4.0 An existing network of building linkage in Hong Kong

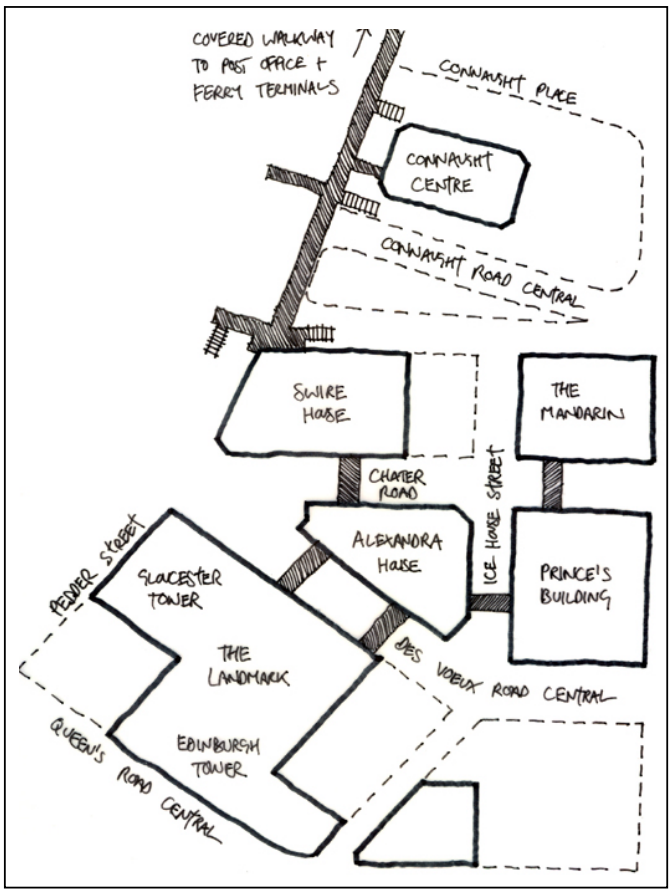

Fig. 1: The Start of the Skybridge network – HongKong Land's linking up of its buildings in the Central District of Hong Kong in the 1970's

It is currently possible to walk for a square kilometre or more in the Central District of Hong Kong without touching the ground, on a network of 'skybridges' at first floor level. This completely public, pedestrian network runs through buildings instead of around them and is made up of a series of elevated covered walkways that link up the internal circulation systems of a group of buildings. The network began in the 1970's, in the area to the west of Statue Square, where one land owner – Hong Kong Land – desired to connect all his adjacent buildings so as to maximise the access to the commercial activities contained at first floor. This internal, air-conditioned link between The Landmark, Alexandra House, Prince's Building, The Mandarin Hotel, Swire House and the Connaught Centre [see Figure 1] became the start of the skybridge network.

Today, the network is much extended [see Figure 2]. With the exception of the short area between Chater Gardens and the Hong Kong and Shanghai Bank Headquarters, it is possible to alight on this network at Pacific Place in Admiralty, and not leave it until the Macau Ferry Terminal in Sheung Wan, almost two kilometres away. There is a great variation in the physical make-up of the skybridges. Some are open pedestrian bridges over roads, others are covered walkways between buildings. Much of it is still an internal, air-conditioned link.

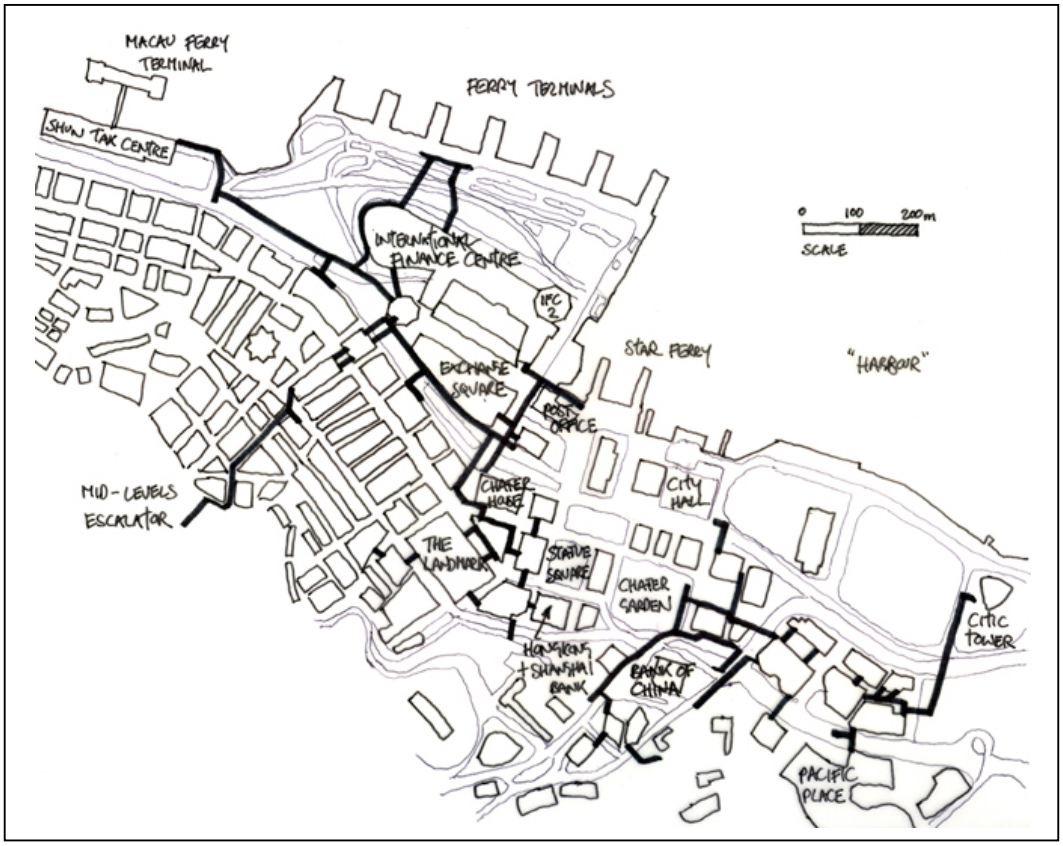

Fig. 2: Plan of the Central District of Hong Kong, showing current first floor Skybridge linkage / pedestrian network

The route is interesting since not only does it create a comfortable pedestrian environment, away from vehicular traffic and a hot, humid climate, it has diverted public routes through traditionally non-public buildings – offices, hotels, banks etc. In doing this, it has essentially elevated and extended the public domain upwards, to include both the ground and first floors. And, along this vibrant route in the air, public facilities have flourished: shops, restaurants, galleries etc.

5.0 Incorporating skybridges at height

The idea of the skybridge is not new. From the 16th Century when Antonio Contino's Bridge of Sighs joined Venice's Pallazo Ducale to the adjacent prison, connections between buildings above the ground plane have been an instrumental element of both fictional and realized visions. There are currently more than a dozen tower and skybridge arrangements in existence across the world (for more on the historical background of the Skybridge, see Wood [22]). The use of the Skybridge to date though has been restricted to these isolated, one-off examples.

Incorporation of physical connections at height throws up considerable challenges; structurally, operationally and psychologically, as well as in design and occupant terms. If skybridges are to become a realistic proposition for the improved safety of tall buildings in dense cities such as Hong Kong, we need to look at these implications in turn:

- *Impact on Client Brief*
- *Impact on Internal Planning; the Skylobby*
- *Optimum Vertical Placing of the Skybridge*
- *Strategic Planning for Incorporation*
- *Impact on Structure and Fabric; the Skyportal*

6.0 Conclusions

It is obvious that, potentially, skybridges could be a significant element in the quest to make our tall buildings safer. In addition, the use of Skybridges gives an opportunity for the maximizing of commercial floor space through increased evacuation efficiency. In Petronas Towers, for example, by fire-rating the skybridge and providing an alternative escape route, not only were evacuation times for a single tower significantly reduced, it was also possible to omit two fire escape stairs form the design which would otherwise have been needed [23].

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