Fifth International Conference on Construction in the 21st Century (CITC-V)
"Collaboration and Integration in Engineering, Management and Technology"
May 20-22, 2009, Istanbul, Turkey

Demolition Within Congested Urban Environment – Nature of Risk and System to Ensure Safety During Work, the Hong Kong Cases

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Abstract
Demolition is one of the dangerous operations in construction in particular working within congested urban environment like Hong Kong. Demolition is often carried out in close proximity to existing buildings, busy streets, sensitive slope, or even adjacent to large and complicated underground facilities such as subway station, railway tunnel or buried city services. Buildings to be demolished can also be very critical, such as of very high-rise nature, with very long span elements and high headroom, or incorporated with special structures like high-strength concrete, tensioned, precast, composite or structural steel members. In some extreme cases, the building to be demolished consists of a deep basement itself. Demolition process under these situations can hardly be performed all without human operatives. The kind of health and safety uncertainty that workers faced when getting into such work environment can easily be understood, needless to mention other disastrous consequences that may cause to third parties. This paper tries to highlight various kinds of risk and dangerous work environment that undermined during demolition within congested urban environment.

Based on real project cases, this paper tries to identify various situations encountered in demolition and categorize them according to their causes and nature of risk. Examples will be quoted to show some of the effective practices both taken by the government through statutory controls or by practitioners in the industries using practical solutions in the tackling of such situations.

Keywords
Complicated projects, Demolition risk, Accident controls

1. Introduction

On a morning back in 1993 in one of the busiest downtown roadways in Hong Kong, an external wall located on the 5th floor measured about 15m x 3m collapsed onto the street during demolition. It hit the upper deck of a bus, rebounded onto the pavement and finally killed 4 people and injured another 6. Eight years later in 2001, a 7-storey industrial building completely collapsed inward with 5 demolition machines and 11 human operatives felled during the collapse when demolition was started on the 6th floor (Figure 1, 2 and 3). Six workers were killed and the other five seriously injured. These are the two most serious demolition accidents recorded in Hong Kong after the World War II. Of course, many other accidents that injured or killed one or two workers were happening all the time especially before the

2000s, by the time when the government control was considered less stringent when compared to the industrial practices nowadays.

Serious reviews had been made after the 1993 accident. What has gone wrong? Who was to be blamed? Any effective resolution was made to ensure absolute safety in future? What is the present situation in the execution of these works? The answer may not be necessarily all positive but this paper tries to explore some of the background and provide a realistic assessment to the situation.

Figure 1: A building completely collapsed inward during demolition in 2001 that caused death to 6 workers.

Figure 2: Close up of the machines that felted and partially buried by debris after the collapse.

Figure 3: Stacking of large amount of debris can create unacceptable surcharge to damaged structure

2. Specific Urban Environment of Hong Kong

Out of the 7 million population in Hong Kong, about 3.8 million are living in downtown districts with area less than 110 km^2. Majority of the downtown areas were formed before the World War II. Hillside or sloppy landform is also quite common especially on the northern shore of the Hong Kong Island. In order to accommodate the inhabitants, every piece of habitable land including some very acute locations are wedged-in with all kind of buildings, no matter they are of high-rise or not. Except to provide new land by site formation methods, new property development unavoidably involves the demolishing of the existing structures.

Buildings to be demolished can also be very crucial, such as of super-highrise nature, with long span elements and high headroom, or incorporated with special structures like high-strength concrete, tensioned, precast, composite or structural steel members. In some extreme cases, the building may be close to a steep slope or leaning to a retaining structure; with congested and sensitive underground structure such as a mass-transit subway or storm water discharge culvert located in close proximity. Or, the building to be demolished consists of a deep basement itself.

It is also common sometimes while heavy machines are operating on the upper level to carry out demolition; pedestrians pass by as usual in the busy street and pavement underneath. Goods vans, lorry, buses, private vehicles and even electric trams are often within a few meters nearby the perimeter of the sites. Dumping trucks to remove the demolition waste enter and exit from site every few minutes passing through general public with the help of a banksman. These are the working environment for demolition in reality in the urban areas of Hong Kong.

3. Types of Building Structures to be Demolished

In a highly developed urban environment like Hong Kong, majority of the buildings that are to be demolished belong to redevelopment projects. The buildings need to be removed to give way for new development. In some occasions demolition is only part of the construction activities in a project such as making major alteration to an existing building structure to fit new design, or forming a break-through to

link up between buildings. In some cases this breaking through are required for underground structure such as inside basement or pedestrian subway, in which demolition may need to cut open an existing basement wall or even diaphragm wall. Elevated structures like footbridge or vehicular carriageway are often encountering similar situation. Below are some of the common types of buildings that usually need to be demolished during the redevelopment process.

- Buildings constructed before the World War II. Majority of these buildings were of residential nature and constructed in brickwork, sometimes with simple reinforced concrete elements, or with tiled pitch roof supported on timber joists.

- Buildings constructed after the World War II up to late 1960s. These buildings were mainly less than 10-storey tall, basically constructed in reinforced concrete. Except for a few cases, majority were of residential or mixed nature. Currently this occupies more than 80% of the total demolition operations.

- Buildings constructed after 1970s. Buildings of residential or non-residential nature share almost half of this type of demolition projects. Since this belongs to contemporary buildings, structure may be varied significantly ranging from usual RC, or incorporated with the use of structural steel, precast, tensioned elements or other special structural components, or even of super high-rise nature. Currently this occupies about 10% of the total demolition operations but the frequency will for sure become more in the near future due to the aging and re-developmental potential of these buildings.

Building structures can be very much diversified in modern city environment. The followings are some of the common forms of structure that special attention is required in the planning and carrying out of the demolition works.

- Long span structures. These are common for structures like cinema, school hall, community centre, workshop or warehouses, many of these are single storey buildings, constructed using reinforced concrete and attached to other structures to fit for congested land space within downtown districts. Structures in the form of deep beam or reversed beam, some of them may be post-tensioned, as well as in the form of RC or structural steel trusses, are usually used in these structures.

- Structures of high headroom. This kind of structure often at the same time is with relative long span in design. Some are even of multi-level layout attached to other part of an existing building forming a highly complex structure.

- Tensioned structures. Tensioned elements are sometimes incorporated in building structures such as for long-span elements, transfer structures, flat slab, continuous beams, securing of precast elements, or as anchors for retaining structures.

- Underground structures. Basements or other underground structure sometimes more than 10m deep are occasionally encountered during the redevelopment process in which the side walls are of usual RC, bore-pile or even diaphragm wall construction as the cut-off provision. The building frame of course formed part of the retaining element for this kind of underground structures.

- Heavy structures and/or fabricated components. These include precast concrete or structural steel components. The size of these elements can be up to a hundred tons and measured up to 30m in span or more.

- Other complex structures. These include, for example, arches, long cantilever, underground structures, heavy members suspended on hanger system, chimneys, elevated structures such as carriageway for vehicles.

Besides the use of the right method and careful pre-planning, the operations also involve the provision of a significant amount of temporary works such as work platform, heavy scaffold or other temporary strengthening members, which are essential for carrying out the demolition of these complicated structures.

4. Statutory Requirements to Control Demolition Works

The main framework for statutory control as set in the Building Regulation (Demolition Works) that came into operation in 1975 faced a tough challenge for review after the occurrence of a serious accident in 1993, by the time part of an external wall in size about 15m x 3m of a building under demolition collapsed and felled onto a busy street that killed 4 bus passengers and pedestrians that passing-by.

After the review by an independent investigation panel, the main causes of the accident were identified as follow:

- Many of the structural elements were dismantled and disconnected without temporary support.
- Large amount of debris was stacked on the slab that imposed heavy load to the damaged structure.
- Layout of site and access for works both for human operatives and equipment were poorly maintained.
- The immediate cause for the accident was that the partially demolished and disconnected wall was not done in the approved sequence or temporary secured after works.

Interestingly, there was no major missing found in the formal documentation or statutory procedures for demolition control except the quality of supervision should be restructured in a more stringent manner to ensure there is no safety leakage. A revision in the form of a supplementary practice notes was issued two years later after the acceptance of the report and recommendation made by the investigation/reviewing panel. The system works until now, with only one major accident occurred again in 2001 that killed 6 workers in a collapse accident. What is the actual cause of this? The dangerous nature of demolition in reality seems to be the major unavoidable factor behind, so severe that even the tightest control sometimes does not fully guarantee.

According to the current statutory procedure, an authorized person (AP) within the list of Buildings Department, the controlling authority on behalf of the government for all building related activities, should be appointed to submit application for approval of the demolition. The submission document should include an appraisal report and work plan with a method statement proposed for the demolition.

Buildings Department will approve the work subject to satisfying all precautionary measures pursuant to the Building Regulations (Demolition Works), which again include the erection of the hoardings and covered walkways or any other conditions as required. After the approva1 is obtained, another 2-stage consent procedure is required before starting the actual demolition.

Stage 1 submission is to obtain the consent for carrying out all the advanced precautionary/temporary works which include the hoardings, covered walkways, scaffolding, catch fans, dust screens and shoring etc. In case the provisions in Stage 1 is completed and to the satisfaction of the Buildings Department, Stage 2 consent for the actual demolition can be applied.

In the appraisal report, the following information should be included:

- A detail structural survey of the building to be demolished.
- Information on the type of building, its structura1 support system, the principal materials of its construction, the degree of deterioration, structural stability calculation and the possible effect during demolition etc.

- Photographic record of the site and its adjacent buildings, slopes and retaining structures.

Forming part of the submission information, the Demolition Plan should include:

- A set of drawings showing the location of the building to be demolished and other existing structures and facilities in vicinity
- Proposed methods of demolition including shoring and precautionary measures for adjacent buildings.
- Proposed shoring and protection for the building to be demolished.
- Proposed methods of handling and disposing of the demolished materials.
- Proposed sequence of carrying out work.
- Detai1of equipments used, with methods of raising, lowering or supporting the equipments.
- Structural calculation to justify the proposal.
- Proposed arrangements for site supervision under the "Technically Competent Person" system.
- Site safety supervision plan.

Since demolition consists of a series of carefully planned processes in dismantling a structure in a sequential order as documented in a method statement, the work can only be carried out safely under properly managed and supervised condition. To achieve this, proper supervision by adequately trained and experienced site personnel is essential. A full-time qualified personnel at appropriate level depending on the technical nature of the job is required to station on site during work to perform the coordination, work supervision, checking and inspection. A site supervision plan in accordance with the Technical Memorandum for Supervision Plans and the Code of Practice for Site Safety Supervision is the main framework in the overall control and site supervision process.

Besides the specific statutory requirements directly control all demolition activities, there are other related regulations or guidelines that help to monitor the whole process to ensure the disturbance so made to the community can be minimized. Below are some of the major statutory requirements that need to be complied.

- Building Regulations for Administration, Planning, and Construction.
- Codes of Practices for Demolition of Buildings.
- Practice Notes for Demolition covering Measures for Public Safety, Temporary Access, and Covered Walkway.
- Ordinance regarding Environment Protection covering Environmental Impact Assessment, Air Pollution, Water Pollution, Noise Control, and Waste Disposal.
- Factories and Industrial Undertaking Ordinance and other related regulations overseeing specific safety and health concerns within site.

5. Methods Commonly Used in Hong Kong for Demolition

In the recent years, almost 85% of buildings to be demolished in Hong Kong were constructed during or after the 1960s. The size of the buildings is quite diversified ranging from a few storeys in height to more than 30 storeys. The footprint of the buildings can be very small, with average say around 500m^2, but with some exception up to more than 2000m^2. Except for some buildings located at quite remote locations, majority of the demolition sites are within downtown where option for demolition can be limited. The most common and practical method employed for demolition under the situation in Hong Kong is usual top down arrangement using manual method, by machines, or in a more practical manner, an appropriate mix of both methods.

In general, for low-rise and small buildings, manual method is almost the only workable solution both for practicality and cost reasons. In this case, the careful planning for the demolition sequence and safe access to the work locations by workers are of critical importance (Figure 4).

While for the highrise and buildings of larger size, demolition by machines seems to be the only economical method. Machines used in demolition usually include track-mounted standard equipments such as excavating machines with pneumatic breaker, bucket and/or hydraulic crusher; bulldozers, loaders, dumpers, mobile crane, winching machine and air compressors. The operating of these machines is highly risky for their moving parts, heavy weight and strong power. Concerns like how to hoist the machines to the building top, support of the equipments, sequence of works and machine movement routing, or arrangement for debris removal, are the most important factors that require detail planning before work.

Though the cost of work is higher, saw-cutting is a method that becomes quite common in recent years for it can cause the least disturbance in terms of noise, dust, vibration or safety to the neighboring environment. It is particularly good for sensible structures like demolition for elevated or underground transportation facilities, or works involve the breaking-in to existing delicate structures with detail touching up works. The incorporation of cut-and-lift arrangement can often make the process much more efficient. However, this will involve the use of heavy lifting equipment and the associated supportive works such as the provision of temporary access or shoring for the equipments.

Other methods such as the use of large-scale deliberate collapse using wire-roping or long-boom pusher arm, wrecking ball or blasting method, are used less frequently for the lack of safe working space or separating distance within the congested urban environment in Hong Kong.

6. Hazardous Nature and Safety Arrangement Adopted During Demolition

The hazardous conditions commonly found in demolition site can be highlighted under the following categories:

Workers fallen from height – Inside a demolition site a height of 2m can be fatal for workers due to the extremely difficult environment of work. Rugged work surface with large pieces of debris scattered everywhere (Figure 5) with sharp points and projected metal can easily injure workers who fall onto it. At the same time, there are a lot of dangerous locations exist in a building being partially demolished. Most of these are not on flat ground especially at the later stage of the demolition process. Workers using hand tools such as pneumatics breaker, gas cutter, hand harmer or picks will make the situation even severe.

Prevent workers falling from height is not an easy job for there are numerous difficult locations that require workers to work at an elevated position. Very often a work spot may not be in an elevated position at the beginning but it subsequently becomes elevated when the flat ground nearby has been removed. Typical example is the demolition of floor slab where work starts from the mid-span and retracts to the sides with the beams to be demolished at a later stage (Figure 6). Temporary platform, safety net or other personal safety equipment is not practical in most of these situations. Employing workers with adequate experience, careful planning with proper work sequence and providing a safe retreating route seem to be the only way that can be done to ensure work safety.

Work access – It is already quite dangerous sometimes for a worker getting access to the work spot that he needs to carry out the demolition or getting away from the location after finishing his job. The work area can be at an inaccessible elevated location, or at an isolated spot with the nearby structures being removed in advance. The distance between the nearby accessible points may not be too far away but full of rugged obstacles. In this case, to provide some simple work platform for work or to maintain a safe access route by careful layout planning is very important.

Figure 4: Typical work condition of demolition site within congested downtown environment

Figure 5: Workers try to remove the reinforcing bars from the debris. Can machine help in this process?

Figure 6: Typical work condition of small-size demolition site using manual method

Falling materials – It is difficult to erect catch-fan to all parts of building during demolition for the large area of exposure and rapid retracting work nature. The use of powered machine for the breaking of structural materials, of course, will produce large and small pieces of flying fragments that form countless falling or evening flying objects. To catch or prevent materials of this kind from falling is not practical. However, the solution is quite simple. Prevent workers to get near to the working areas where materials may have chance to fall.

Collapse – A building under demolition is a damaged structure that is basically no longer stable by itself, needless to mention extra loads like moving plants or temporary stacked debris are often imposed on the structure that create further undesirable surcharge. Partially demolished structure can be relatively small in size like a wall with the side beams being removed. Or quite a big structure like a detached portion of building a few floors in height with the adjacent structure being dismantled in an advanced stage. In the most extreme case, the complete building may collapse inward or outward if situation come to the worst like the case in Hong Kong in 2001.

To prevent the collapse or falling of other partly demolished structure such as a self-standing column or part of a disconnected external wall, the use of temporary securing steel wire to tie it until it collapses under a controlled manner is essential. In any case, carrying out the works strictly according to the planning as stipulated in the method statement is of utmost important.

Handling of materials – The removal of huge amount of debris and recyclable materials is not an easy task. The process also involves the vertical and horizontal movement. Accident can easily occur during the removal and handling process for a site under demolition especially within congested working space (Figure 7).

Other frequent hazards – Accidents can easily occur at the site entrance during the in-and-out of heavy dumping trucks and cause injury to general public. The moving plant itself is also a dangerous source of risk for operators handling it or for labours working nearby. The equipment may fall, topple or turn over when moving on very rugged ground full of demolition debris. Poor illumination, ventilation or other house-keeping affairs may make a site more dangerous. The possible existence of large amount of dust, harmful waste, toxic materials such as contaminated soil, asbestos, dioxin or other harmful gases, can again cause health and safety hazards to human workers. These items are routine things at a demolition site and often ignored until they cause a fatal accident.

In general, basic precautionary measures such as the provision of hoarding and covered walkway, scaffold with catch fan and screen cover, appropriate temporary supports, protection arrangement for adjacent properties and traffic, are the baseline to ensure safety and protect other third parties. From the management point of views, good planning and detail study of each work situation, supervision, avoiding

fast track, good training, effective communication, carrying out all the safety measures and provisions, adequate equipment maintenance, are guarantees of work safety during demolition.

Besides statutory procedures, on-site control system can be very effective to ensure day-to-day safety. Systems like regular safety audit, work roster record, inspection-before-work system, work access permit or other work-to-rule systems, are very ensuring though time and cost of work will unavoidably increase.

7. Current Practice Adopted by the Industry to Achieve a Safe Work Environment

Since 1993 till now after a long and winding journey and cost the life of more than 10 people, both the government and the industry learn a way to carry out demolition inside congested urban environment in an almost accident free manner. The summary below shows some of the good practices being adopted by the industry to make this achievement.

- Though the availability of machinery has been much improved during the past decade, there is no such thing as advanced technology in demolition in particular for congested urban situation. Good planning and thorough supervision seem to be the key to success in this dangerous work process.

- The submission and approval procedure is kept in a stringent manner by experienced and qualified bodies.

- The strengthening of site supervision due to the implementation of the Technical Memorandum for Supervsion Plans is proved to be of great help.

- Resources in terms of manpower input in the managing, monitoring and other on-site operation of a project is significantly increased.

- Extra input for site preparation including planning for detail work operation for every diffiuclt location, provision of more spacious layout (Figure 8) for the movement of equipments, debris removal arrangement and other house-keeping supports are substantially improved.

- More realistic time schedule is adopted to allow room and flexibility in the carrying out of all necessary works during demolition.

Figure 7: Work reality in congested urban environment. With the help of a banksman, debris was removed by a small loader making use of the public roadway with temporarily blocked traffic and pedestrians passing-by

Figure 8: A temporary access way was formed inside the site for small machines for the handling of demolition materials

Finally, similar to the generally improved performance of all other major construciton activities in the recent years, thanks is needed to give for the positive work culture that has been developed as a common norm throughout the entire construction sector, where the government and other professional parties have

taken the lead after the 2000s. When doing demolition, it is not only the “hardware” that counts, but also the “software”which plays an important part in the process.

8. References

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