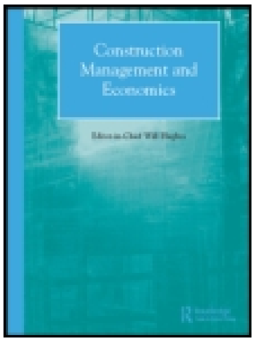

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Minimizing demolition wastes in Hong Kong public housing projects

Chi Sun Poon , Ann Tit Wan Yu , Siu Ching See & Esther Cheung

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CHI SUN POON*, ANN TIT WAN YU, SIU CHING SEE and ESTHER CHEUNG

Department of Civil and Structural Engineering, The Hong Kong Polytechnic University, Hum Hom, Kowloon, Hong Kong

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Being one of the major housing developers in Hong Kong, the Hong Kong Housing Authority (HA) carries out a large number of construction and demolition projects. As a result, a large amount of construction and demolition waste is produced. As for demolition projects, demolition wastes usually contain a large amount of reusable materials. If sorted out properly, these materials could be better reused or recycled. Two case studies have been carried out on public housing projects to quantify the recovery rates of various types of demolition wastes in demolition projects and to assess the implementation of on-site sorting requirements. The current practices of demolition contractors in Hong Kong mainly focus on the working procedures and waste generation during the main demolition stage and sorting of waste is difficult due to cross contamination although on-site sorting has been stated as a requirement in the contract. The demolition method statement should include working details of both the salvaging and the demolition stages to affect waste sorting and recycling. Selective demolition should be considered to further improve the waste recycling rate but there is a need to develop recycling markets to provide outlets for the collected recyclables.

Keywords: Demolition waste, waste minimization, on-site sorting, selective demolition, public housing, Hong Kong

Introduction

The construction industry is the major solid waste generator in Hong Kong. The extensive building and infrastructure development projects as well as redevelopment of old districts have led to a significant increase in construction & demolition (C&D) waste generation in the last decade. According to the Environmental Protection Department (EPD, 2000a), a daily average of about 37 690 tonnes of C&D waste was generated. Of this amount, 80% were inert materials (e.g. sand, brick and concrete) currently disposed/reused as fill materials at reclamation sites, and the remaining 20% were mixed inert materials and waste materials that had to be landfilled. The latter made up for 44% of the solid waste disposed of at landfills (EPD, 2000b). Government figures indicate that the territory's reclamation sites and landfill will be exhausted within 2–4 years and 10 years' time respectively unless other solutions are found (Legislative Council Panel on Environmental Affairs of HKSAR, 2000).

Demolition waste accounted for more than 18% of the C&D waste generated in 1999. The Planning and Lands Bureau of Hong Kong (Urban Renewal Strategy Study, 1999) made an assessment for the conditions of buildings in urban areas. The result revealed that there were 8500 buildings over 30 years old and of these, 2200 buildings required redevelopment. It is anticipated that with the ageing building population and the speed of redevelopment in Hong Kong, the number of demolished buildings and hence the quantity of demolition waste generated in the coming years will be considerable. In fact, the Hong Kong SAR government has already set up a construction and demolition waste sorting and recycling facility in Tuen Mun in July 2002 (Civil Engineering Department, 2002). The aim of the plant is to provide a facility for the processing and recycling suitable materials from the C&D waste

*Author for correspondence. E-mail: cecspoon@polyu.edu.hk

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streams, particular demolition waste that contains high percentage of granular hard materials. The purpose is to produce different grades/categories of recycled aggregates that can be used in a wide range of engineering projects in Hong Kong.

Internationally the management of C&D waste has become a pressing environmental issue. A number of research studies were conducted on characterizing, quantifying and minimizing construction waste production on building sites (Skoyles and Skoyles, 1987; Faniran and Caban, 1988; Ferguson *et al.*, 1995; Bossink and Brouwers, 1996; Symonds Group Ltd, 1999). The potential of reusing recycled aggregates derived from C&D wastes has also attracted a lot of interest (Kasi, 1988; Hansen, 1992; Lauritzen, 1994; Dhir *et al.*, 1998; Hendriks and Pietersen, 2000). However, few studies have been conducted on quantifying the recovery rate and on-site management of demolition wastes. The objectives of this paper are to quantify the recovery rates of various types of demolition wastes and to assess the implementation of the on-site sorting requirement of demolition waste, and the potential and constraints of implementing selective demolition in Hong Kong.

Demolition practices

In a building demolition project, almost the whole building structure including the substructure, superstructure and external landscape would end up as demolition waste. The waste usually consists of high percentages of inert materials like bricks, sand and concrete but the actual characteristics of the waste may vary depending on the types of structures demolished and the demolition technique used. For instance, a large amount of reusable materials like timber and metals can be recovered if sufficient time is allowed for salvagers to retrieve these materials before the main demolition stage, whereas a commingled pile of mixed demolition waste will be resulted when implosion or heavy mechanical demolition is used.

A building can be demolished by different demolition methods such as blasting, implosion, wrecking ball, hydraulic crusher with long boom arm, and the top-down method (Lauritzen, 1994). In Hong Kong, as demolition sites are usually located in congested areas and space is not available for large machinery like cranes, most of the demolition projects use the top-down demolition method (Building Department, 1998).

As its name implies, the conventional top-down method is the method that demolition proceeds from the roof of the building to the ground in a floor-by-floor downward sequence. The typical work statement for most demolition projects in Hong Kong is: (1) to disconnect all services including drainage, electric, water, gas, telephone and seal up existing drainage to prevent entering of debris; (2) to cut out a one-metre width floor strip along the demolition line before large scale demolition work commences; (3) to provide all necessary bamboo scaffolding and screens around the buildings; (4) to break up a debris canyon (2–3 sq m) in each floor; (5) to hoist a backhoe with hydraulic percussion breaker to the roof; (6) to demolish the beams, the columns and the slabs at the top floor, then, to demolish the next floor and so on; (7) to grub up pile caps, ground beams, unused drains and gulley; (8) to collect old materials and rubbish on ground floor through debris canyon; (9) to separate regenerated demolition materials for recycling from debris; and (10) to cart away debris (Poon, 1997).

Being one of the major housing developers, Hong Kong Housing Authority carries out a large amount of construction and demolition projects of public housing every year. With increasing public concerns on environmental protection, the Housing Authority following the practices of other public bodies in Hong Kong, has specified in its demolition contracts the requirement of on-site sorting. This requirement specifies that demolition wastes should be sorted on-site and be separated into different inert granular materials suitable for land reclamation or recycling, and non-inert materials to be disposed of at landfills.

Research objectives

The objectives of the study are to monitor the practice of on-site sorting of demolition waste, identify opportunities for reuse/recycle of demolition waste and recommend improvements for future projects.

Research methodology

To meet the research objectives, two demolition sites were selected for this study. Site A involved the demolition works for four blocks of residential buildings ranging from 7-storey to 19-storey high. The contract sum was HK$13 839 000. Site B involved the demolition works for three blocks of residential buildings ranging from 8-storey to 20-storey high. The contract sum was HK$6 380 000.

During the study, observations were carried out at high points near the demolition sites to have a clear view of the demolition process. The quantities and composition of demolition waste and the recovery rates of different types of materials were estimated by visual observations and from truckload records. Checklists and flow charts were used to record the details of the demolition process. Interviews with contractors and salvagers were carried out to collect information of the demolition procedures and waste management methods (Hong Kong Polytechnic University, 2002). The following issues were covered in the interviews:

- Responsibilities of the demolition contractor;
- Priority of materials or components to be removed;
- Storage and transportation of materials;
- Disposal of waste;
- Selling of salvaging and recovered materials; and
- Handling methods for inert and non-inert materials.

Research findings

Demolition work sequence

Figure 1 shows the sequence of the demolition processes adopted for the two projects under study. In fact, the demolition sequence was typical for most demolition projects being used in Hong Kong.

Salvaging

The main contractor of the projects allowed sub-contractors to carry out salvaging of the recyclable materials from the sites before the main demolition of the buildings began. The salvaging was carried out whilst the hoarding was being erected. The salvager paid the contractor a lump sum for the right to keep and sell all the salvaged materials from the site.

Asbestos removal

After the salvaging stage, an asbestos removal sub-contractor was called in to remove asbestos.

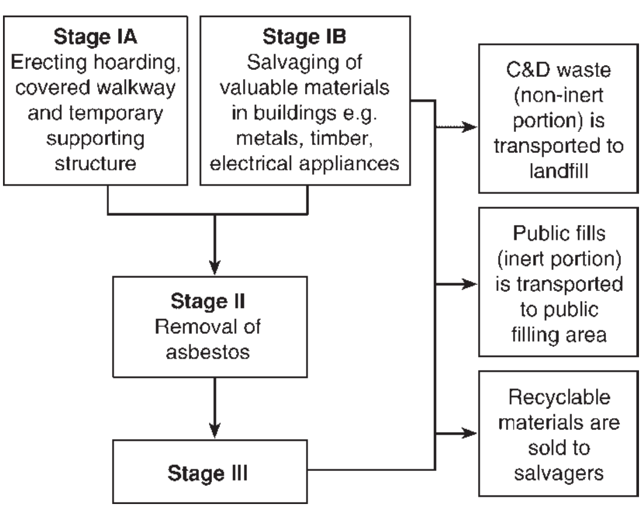

Figure 1 Sequence of demolition process for public housing projects in Hong Kong

Demolition stage

During the main demolition stage, hydraulic percussion breakers were hoisted to the roof and the structure was demolished from top down.

Material size reduction and segregation

This was mainly carried out by machine mounted percussive breakers and backhoes on the ground floor. Reinforcement bars were separated from the composite reinforced concrete and oversized concrete blocks were broken into small pieces (<250 mm). The commingled piles of demolition debris were subject to manual examination and separation of recyclable items by a crew of 3–4 workers.

Hauling demolition materials

The sorted demolition debris was temporarily stored in storage areas near the building, and taken away by a continuous fleet of dump trucks. The inert portion, mixed waste, and recyclable items were delivered to the public filling areas, municipal waste landfills and nearby scrap collection lots, respectively.

Estimation of waste generation and recovery rates

Table 1 shows the estimated recovery rates of the materials recovered at the salvaging stage. Table 2 shows the relationship between the salvaging period and the overall recovery rates. Lower recovery levels were experienced at site B. This is believed to be due to the shorter time period allowed for salvaging. According to the salvager, when they were given a shorter period for salvaging, they would focus mainly on the more valuable materials and took little attention to recover the less valuable materials. Hence, the recovery level for the materials overall was much less. From the information provided by the salvagers, both the length of the contract period and the market values of the recovered materials affect the recovery rate at the salvaging stage. However, it was noticed that the most important factor was the market value of the salvaged materials. For example, in the case studies, the salvagers usually did not recover wooden doors due to their low market values.

Table 3 shows the truckload records and the estimated quantities of waste and recyclable generated at the demolition stage. Based on the trip ticket record (please see below) the waste indexes were calculated (Table 4). The waste indexes help the contractor and the client to assess the waste generation level of each demolition site. The information can help generate base line waste indexes for other demolition contracts.

The estimated waste compositions were 90% for inert granular materials, 4% each for timber waste products

Table 1 Estimated recovery rate in the salvaging stage

Materials	Price (HKD*) per unit	Quantity recovered		Unit	Recovery rate	
		Site A	Site B		Site A (%)	Site B (%)
Steel and other metals	$0.17	48 000	21 000	Kg	35	25
Stainless steel	$1.50	5400	2800	Kg	80	70
Aluminum	$2.10	12 000	7500	Kg	70	60
Timber	$0.04	78 000	35 000	Kg	30	15
Plastic	$0.1	1200	800	Kg	0.1	0
Electrical wires	$0.90–$3.00	9600	3000	Kg	65	30
Copper	$4.50	4800	1500	Kg	75	50
Air-conditioner	$70.00	200	80	Each	100	100
Main Switch	$10.00	800	320	Each	100	90

Notes: Recovery rate is defined as the ratio of recovered amount to the total amount of the materials, i.e. % of materials separated for recycling or reuse. * US$1.0 = HK$7.8.
(a) Steel and metal is generated mainly from furniture, steel window frames and door gates;
(b) Timber waste is from the household furniture and partition walls;
(c) Aluminium is generated from window frames and louvers;
(d) Stainless steel is from the hand-railings or other fittings in the buildings;
(e) Copper wires from electric cables and wires; and
(f) Copper from the water tubes and tapes.

Table 2 Time allowed for salvaging and estimated recovery rates

Site	Time period of salvaging	No. of workers per day	Estimated recovery rate
Site A	3 months	4	30%
Site B	1 month	4	18%

Table 3 Records of trip tickets at the demolition stage

C&D waste	No. of trucks	Quantity recorded
Site A		
Granular materials	4572	45 720 m^3
Steel reinforcement and other metals	–	320 tonnes
C&D wastes	23	230 m^3
Site B		
Granular materials	2508	24 900 m^3
Steel reinforcement and other metals	–	1500 tonnes
C&D wastes	18	180 m^3

and ferrous metals and 2% for other constituents. Many demolished materials were recoverable and recyclable. The non-contaminated concrete waste below 250 mm in size can be reused as a fill material in public fills or recycled as aggregate by the recently commissioned C&D Materials Recycling Facility. Steel derived from reinforcement bars was always separated from reinforced concrete and sold. However, other than metals, most of other recyclable materials were mixed with dust and concrete in the demolition debris and had to be disposed of at landfills.

Table 4 Calculation of waste indexes

	N	W(m^3)	GFA** (m^2)	C(m^3/m^2)
Site A				
To PFA*	4572	45 720		
To Landfill	23	230		
Total	4595	45 950	114 666m^2	0.40
Site B				
To PFA*	2490	24 900		
To Landfill	18	180		
Total	2508	25 080	38 724m^2	0.65

Notes: * public filling areas; ** gross floor area.
(V) = truck volume (m^3), assumed to be 10 m3 per truck
(N) = total no. of tucks recorded
(W) = total volume of waste generated from the project (m^3) = (V) × (N)
(C) = waste index = (W)/GFA, i.e. 1m^2 area of GFA generates (C) m^3 waste

Practice of on site sorting to remove contaminants from recyclable granular materials

On-site sorting is required by the Housing Authority in its demolition contracts. The on-site sorting of C&D materials aims at minimizing waste disposed of at landfills site by facilitating the reuse and recycling of the uncontaminated inert granular materials (e.g. concrete, brick and tiles). Therefore, contractors should sort out and remove the non-inert proportion of the waste (timber, plastics, paper and metals) from the inert granular materials. Materials mixed with excessive amount of contaminants (>5%) are not accepted at public filling areas and the C&D Materials Recycling Facility, and they are required to be disposed of at landfills.

At the salvaging stage, the on-site sorting procedures at both sites were very similar. Salvagers were called in to selectively collect/remove furnishings and fittings (e.g. electrical cables, wood, metal, electrical appliances, etc.). Based on on-site observations at the two studied sites, it was found that only the high-valued materials were removed (e.g. air-conditioners, aluminium window frames, copper pipes and cables). For other materials (e.g. timber, plastics, old furniture) they were left in the buildings until the structure was demolished, as the market values of these materials were low. These materials were left behind and were allowed to be crushed together with the reinforced concrete structure using the top down method described earlier. Furnishings and fittings that the salvagers believed to be worthy in monetary terms tended to be sold to countries like Mainland China and Vietnam. With the growth in living standard in these less wealthy areas, outlets of these potential recyclables have been reduced. Hence, the salvagers had become increasingly particular on what they would remove from the demolition sites. There was no limit or account of how much and what was taken away. The salvagers claimed that they removed approximately 80% (by volume) of the loose materials, but it was estimated by on-site observations that in reality only 10–30% (by volume) was removed.

During the demolition stage, the hydraulic breakers broke all the furniture and fittings left in the flats together with the building structure. Larger objects should have been brought down by hand, but instead site workers treated them the same way as the other wastes, as it would be labour intensive to do so. Small fragments of timber, plastic metals, etc., were found in the debris and they were very difficult to remove manually. The demolished materials were delivered through a debris chute (actually, a hole on every floor of the structure to be demolished) to the ground floor.

The final sorting was carried out manually with the assistance of a backhoe after the crushed materials were delivered to the ground. Materials over 250 mm in size were crushed by hydraulic breakers/crushers. The demolished materials were sorted into three kinds of materials, they were: (1) metals (R-bars and other metallic components were retrieved separately); (2) concrete and granular materials fragments; (3) timber, rubbish and other decomposable materials. The metals were sold, whereas, the concrete and granular wastes below 250 mm × 250 mm in size were collected by trucks and transferred to public filling areas for reuse/recycling, but the concrete waste/debris was usually contaminated with small fragments of metals, plastics and other non-inert materials. Only objects that were obviously too large were removed manually by the sorting crew. If the contamination level is below <5%, the management at the public filling areas still allowed the debris to be delivered and disposed of there. However, based on observations, the estimated contamination level of the inert granular materials was between 5–15% by volume. This would have significant bearings on the operation of the public filling areas and the newly commissioned C&D waste recycling facility. The inert granular materials that were mixed with a large portion of other non-inert waste were disposed of at landfills.

Trip ticket system

Besides on-site sorting, a trip ticket system was required by the Hong Kong Housing Authority at all demolition contracts to monitor the movement of waste. Such a requirement was stipulated in the contract. A trip ticket was required for each truckload of waste delivered to the public filling areas or landfill sites. The trip ticket included information such as the name of the contract and the contractor, the locations of the demolition site and the public filling area or the landfills site where the waste was delivered to, the vehicle registration number, the approximate quantity of load (either in volume or weight) and the time of departure. The trip ticket system not only helped to avoid illegal dumping of demolition waste, but also provided a basis for evaluating the quantities of demolition waste generated at each site. However, the trip ticket system had limitations on facilitating recycling and reusing materials, as the aim of the system is only for the monitoring of the disposal of inert and non-inert materials. In order to increase the recovery rates of the recyclable materials, it may be necessary to adopt selective demolition.

Selective demolition

Selective demolition means a process in which demolition takes place as a reverse to the construction process, where different types and fractions of materials are removed from the building step by step and sorted in order to avoid the mixing of bricks, concrete, wood, paper, plastics and other materials (Lauritzen and Hahn, 1992; Hendriks and Pietersen, 2000).

In this technique, the demolition process is separated into phases that one type of materials is carefully dismantled or removed at one time. The materials generated in each dismantling stage are of similar types and natures that contamination of non-recyclable items is greatly reduced. Selective demolition is principally carried out in a reverse order to the construction process. The procedures are: (1) removal of remains and non-fixtures and furniture; (2) stripping, comprising internal clearing, removal of doors, windows, roof components, installation, water, air-conditioning, electricity, etc. leaving only the building bearing structure; and (3) demolition of the building structure (Poon *et al.*, 2001). Figure 2 shows the sequence of selective demolition. Since the work involved in the removal of non-fixtures and other internal services are primarily carried out manually, selective demolition is more labour and time consuming; therefore, it is not widely practiced in the industry. It has also been estimated that the

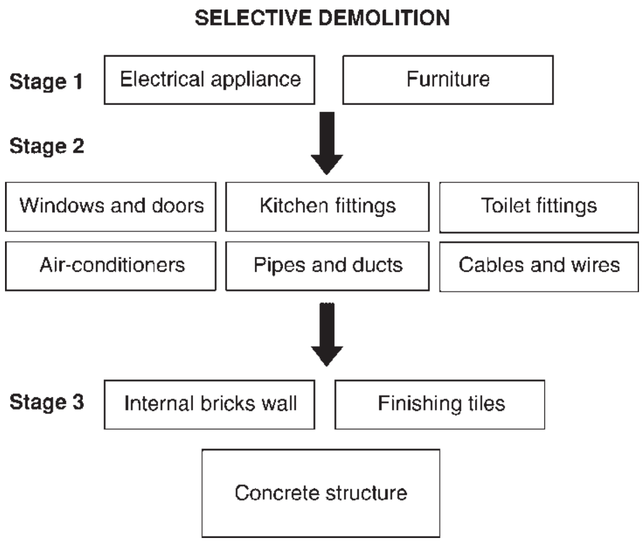

Figure 2 Sequence of selective demolition process

overall cost for the demolition work will be increased by 10–20% (Lauritezen and Hahn, 1992).

It was found from the case studies that demolition contractors are willing to carry out selective demolition (for a site similar to site B in size and features) providing the following conditions are met:

- Increase contract payment by 10–15% to cover extra time, workers and plants and machineries required (e.g. crushers); and
- Extend contract duration by 2–3 months.

Discussion

The current practices of demolition contractors in Hong Kong mainly focus on the working procedures and waste generation during the main demolition stage. It is suggested that the working details of the salvaging stage should be incorporated into the method statement so that waste sorting and segregation can be specified. Minimization of demolition waste can be effectively facilitated by contractual agreements. Better planning before demolition and effective management can increase both the quantity and quality of the recyclable and reusable materials obtained from demolition sites. At the planning stage, contractors should estimate the amount of reusable and recyclable materials including those household furnishings and fittings. Preparations before demolition would ensure sufficient time for locating possible designations and outlets for the recyclable materials in the salvaging stage.

Currently, demolition contractors are reluctant to perform material recovery during the demolition process because the disposal of demolition waste at landfill in Hong Kong is inexpensive (no landfill charge) and without limitation. It is essential to charge for the disposal of waste at landfills as well as the public filling areas. Hong Kong is one of the few places in the world that does not charge for disposing waste. Charging can create incentives for contractors to minimize and recycle waste.

Conventional demolition method does not favour the separation or segregation of demolition wastes at source, resulting in mixed waste materials unsuitable for high-grade use. For the granular materials that accounts for more than 90% of the demolition waste stream, it is essential to lower the contamination level so that the recycled materials can be utilized more beneficially besides being used as a fill material. The contractor may need to consider removing all the furniture and fittings before demolition and to introduce selective demolition. To facilitate the introduction of selective demolition, adequate site area must be available for sorting and temporary storage of recovered materials. Adequate time and resources must be made available as selective demolition would require additional labours and longer contract durations. A mature market for the recyclables is also required to ensure there are sufficient outlets for the recovered materials.

Conclusion

There is considerable quantity of demolition waste generated in the coming years due to ageing of building and the speed of redevelopment in Hong Kong. However, Hong Kong is running out of landfill space and public filling areas for the disposal of C&D waste. It is necessary to investigate ways that can minimize the production of demolition waste on building sites. This study examined the implementation of on-site sorting requirement of demolition waste, and the potential and constraints of implementing selective demolition in Hong Kong.

The current recovery rates of demolition wastes at the Hong Kong Housing Authority projects are low. In order to increase the waste recovery rate, the current specification for on-site sorting requirement and trip ticket system are not adequate. It is important to review the demolition method and waste management procedures to avoid, minimize, recycle and reuse demolition waste. The introduction of selective demolition in Hong Kong demolition projects is the key to further improve the situation.

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