Quantifying the Impact of Construction Waste Charging Scheme on Construction Waste Management in Hong Kong

C.S. Poon[1]; Ann T.W. Yu[2]; Agnes Wong[3]; and Robin Yip[4]

ABSTRACT

A considerable amount of solid wastes is generated every year from construction and demolition (C&D) activities in Hong Kong. The C&D waste can be classified into inert and non-inert wastes, in which the inert waste is normally disposed of in public fills as reclamation materials, and the non-inert part is dumped at landfills. Under the current waste generation trend, all landfills and public fills in Hong Kong would be used up within the few years. To tackle this problem, in December 2005, the Hong Kong Government implemented the Construction Waste Disposal Charging Scheme (CWDCS) to provide financial incentives to C&D waste generators to reduce waste and encourage reuse and recycling. This paper presents the results of a study to explore the perceptions of the Hong Kong construction participants towards the CWDCS after its 3-years implementation. The study was conducted by a questionnaire survey with follow-up interviews to experienced professionals in the building industry. The results revealed that there was no consensus view among the construction participants on C&D waste reduction especially on on-site waste sorting and recycling. The findings also revealed that 40% of the survey respondents believed that waste reduction is less than 5% after CWDCS has been implemented. The interviewees expressed that some waste generation were unavoidable despite a waste disposal charge has been imposed. In addition, 30% of survey respondents agreed that the cost of CWDCS was not high enough to raise the awareness on waste management on construction sites.

[1] Professor, Dept. of Civil and Structural Enginneering, The Hong Kong Polytechnic Univ., Hung Hom, Kowloon, Hong Kong. Email: cecspoon@polyu.edu.hk

[2] Assistant Professor, Dept. of Building and Real Estate, The Hong Kong Polytechnic Univ., Hung Hom, Kowloon, Hong Kong (corresponding author). Email: bsannyu@polyu.edu.hk

[3] Research Assistant, Dept. of Civil and Structural Engineering, The Hong Kong Polytechnic Univ., Hung Hom, Kowloon, Hong Kong.

[4] Research Student, Dept. of Civil and structural Engineering, The Hong Kong Polytechnic Univ., Hung Hom, Kowloon Hong Kong

KEYWORDS

Construction and demolition waste, Polluter-Pays-Principle, recycling, sorting, waste disposal charging scheme

1. INTRODUCTION

1.1 Nature of C&D Waste and the Current Problems in Hong Kong

Construction activities generally have negative effects on the environment, which includes exploitation of natural land and other resources for development, and the generation of waste and various forms of pollution (Tam et al. 2005, 2006). The quantities of waste generated from construction activities in a number of different countries are shown in Table 1. In the United Kingdom, more than 50% of landfilled materials come from construction waste (Ferguson et al. 1995), and 70 million tonnes of waste are generated from construction and demolition activities. In Australia, about 14 million tonnes of waste is landfilled annually, and 44% of the total waste is contributed by the construction industry (Craven et al. 1994; McDonald 1996). In the United States, around 29% of solid waste is from construction works (Hendriks and Pietersen 2000), and in Hong Kong about 38% of the landfilled solid waste come from the construction industry (EPD 2006).

Construction and demolition (C&D) waste is a mixture of inert and non-inert materials arising from various construction activities like excavation, demolition, construction, renovation and roadwork. Construction waste consists of two major categories: inert materials and non-inert waste. According to government statistics, in Hong Kong, soft inert materials (such as soil, earth and slurry) account for about 70% of all C&D waste and they can only be reused as fill materials in reclamation and earth filling works. The hard inert materials (such as rocks and broken concrete) represent about 12-15% of the total waste and they can be reused/recycled as granular materials or recycled aggregates for construction activities. The recycled aggregates can be used in road sub-base, drainage bedding layers and concrete mix applications. The non-inert waste (like timber, bamboo and packaging waste) account for about 15-18% of all the construction waste and they are mainly disposed of at landfills (Legislative Council Panel 2006).

Based on the information generated from a developed planning model, the government has made a forecast on the quantities of C&D material arising in 2006, 2011, and 2016 (see Fig. 1). With an estimation of about 24% annual increase in C&D waste generation it is likely that the landfills and public fills in Hong Kong will be full within the next 10 years (EPD 2007).

Management of construction wastes is a global environmental issue experienced by countries all over the world. Driven by shortage of disposal sites, means of construction waste management and minimization at work sites were initiated (Baldwin et al, 2009; Fatta *et al.*, 2003; Cosgun and Esin, 2007; Poon *et al.*, 2004). Studies that aimed to quantify and investigate the physical and chemical properties of C&D wastes were also launched (Bianchinni *et al*., 2005; Brunner and Stampfli, 1993; Jaillon and Poon, 2009). Furthermore, possibilities of recycled aggregates utilization from C&D materials have been pursued worldwide with promising results (Hansen 1996, Dhir et al. 1998, Xiao et al 2010)

As regards regulatory measures to tackle the C&D waste problem, the California Department of Resource Recycling and Recovery (CalRecycle) was established in California in January 2010. CalRecycle promotes C&D waste diversion by developing a C&D waste diversion model ordinance for local jurisdictions and general contractors. Educational materials and information about alternatives facilities that accept C&D waste are also provided in the ordinance. The ordinance establishes an Incentive Programs to encourage waste haulers to implement C&D waste diversion. Also, it provides grants and loans to help organizations to meet the State's waste reduction, reuse, and recycling goals (CalRecycle, 2010).

In Alberta, Canada, in 2008 a new landmark agreement was developed between the Government of Alberta, the Alberta Construction Association and the Canadian Home Builder's Association-Alberta to set out a timeline to create a provincial stewardship program "Too Good to Waste" to deal with the waste problem. This stewardship program targeted to increase the recycling rate of various construction wastes, including concrete, wood, asphalt, and drywall, thus preventing them from clogging Alberta's landfills. (Government of Alberta, 2010).

In UK, the Site Waste Management Plans Regulations was promulgated in April 2008. The regulation aims to increase the quantity of materials that can be recovered, re-used and recycled from construction waste and improve materials resource efficiency. The plan should includes details of construction project, estimates of the types and quantities of waste produced and confirmation of the quantity of waste generated and how they are managed. It is a requirement that waste is disposed appropriately in accordance with the duty-of-care provisions. (UK Government, 2010)

In Germany, it is a requirement by law to carry out separation, pre-treatment and recovery of C&D waste since 2003. The ordinance stated that the producers and holders of C&D waste must hold, store, collect, transport and consign the waste for the recovery of wood, glass, plastic, metals (including copper, bronze, brass, aluminum, lead, zinc, iron, steel and tin), concrete, bricks, tiles, mixture of concrete, bricks, tiles, and

ceramics, separately. The mixed C&D waste shall undergo pre-treatment prior to energy recovery, in particular by sorting, crushing, compacting or pelletizing (German Government, 2010)

1.2 Hong Kong Government Policy on C&D Waste

For the past two decades, the Government of HKSAR has implemented various measures trying to reduce waste generation, including the amendment of the Waste Disposal Ordinance, issuance of a policy paper for a comprehensive 10-year plan to reduce construction waste, launching a green manager scheme on construction sites, promulgated a waste reduction framework plan, issuance of a practice note promoting the use of recycled aggregate, implementing the policy of Waste-Management-Plan (WMP) on construction sites, commissioning a pilot concrete recycling plant, and introduced a charging scheme for the disposal of construction waste (see Table 2). All these actions are clear indications that the Government of HKSAR is determined to tackle the increasing problem of waste generation from construction activities in Hong Kong.

2 PREVIOUS WORKS ON WASTE REDUCTION AND MANAGEMENT

2.1 The Polluter-Pays-Principle

The Polluter-Pays-Principle (PPP) is in line with the principle that polluters are responsible for the damage caused to the natural environment and the PPP is widely adopted by many countries (Hao et al., 2009). In the construction industry, this ‘polluter pays’ principle provides economic incentives for building professionals to initiate means to minimize waste generation by sorting and recycling waste as part of the construction process.

This principle is strongly supported by the Organization for Economic Cooperation and Development (OECD) and the European Union (EU) and is applied in many developed and developing countries (International Coalition for Sustainable Production and Consumption 2007).

In the Unites States, there is no national landfill tax or fee. However, many states and local governments collect fees and taxes on the collection or disposal of solid waste. For example, in California, landfills fees and taxes are levied by cities and countries, as well as by the state. In order to reduce and recycle C&D waste, San Jose has implemented a “Construction & Demolition Deposit for Diversion program” by which the contractor must pay a deposit to the city, when it is granted a new construction permit. The contractor also needs to show a recycling facility has accepted all construction and demolition waste for reclaiming the deposit.

The landfill tax was found to be most effective in Belgium, Denmark and Austria, since these countries could achieve a decrease of waste disposed of landfills of over 30% after the tax was introduced. In Denmark, building waste had been reduced by more than 80%, and 61% of recycling rate was achieved (Bartelings et al. 2005). However, in France, only a drop of waste to landfill by 4% was achieved after 16 years of implementation. In Norway and the United Kingdom, the effectiveness of landfill taxes was not obvious as waste generation kept growing only at a slower rate (Anderson 1998, Glazyrina et al. 2006, Magrinho et al. 2006). In December 2005, the Hong Kong Government implemented the "Construction Disposal Waste Charging Scheme" (CDWCS). The disposal of construction waste is subject to a charge of HK$125/ton to landfills, HK$100/ton to sorting facilities and HK$27/ton to public fill reception facilities (Table 3).

2.2 Implementation of CWDCS in Hong Kong

According to Government information, the CWDCS targets to encourage construction waste producers to reduce, reuse, sort, and recycle construction waste before sending it for disposal. According to government figures, the average amount of construction waste disposed in three landfills in Hong Kong decreased by 40% from 6,600 tons per day in 2005 to around 4,000 tons per day in 2006 (EPD, 2007). However, the number of detected fly-tipping cases of waste building materials increased by more than 400 percent from 365 cases in 2005 to 1,587 cases in 2006. Although a construction waste fly-tipping spotting system has been implemented to encourage the public to report illegal dumping activities, it is difficult to find concrete proof for the illegal dumping (Chui, 2007).

3. AIM OF STUDY

It is expected that the implementation of the Construction Waste Disposal Charging Scheme (CWDCS) in Hong Kong would induce changes in the construction industry. After three years of its implementation, the study aims to evaluate the effectiveness of CWDCS in the following aspects:

(i) How much waste has been reduced?

(ii) Steps that have been taken by the construction industry both in construction planning, site operation and project management to accommodate the impacts of the waste charge.

(iii) What changes have taken place among building professionals in handling C&D waste?

4. RESEARCH METHODOLOGY

The study comprised a questionnaire survey and structured interviews with construction professionals. The research findings from both the questionnaire survey and interviews are used to cross-reference with each other to validate the research outcomes.

4.1 Questionnaire Survey and Structured Interviews

The questionnaire was developed to investigate the change of views of the building professionals since the implementation of the CWDCS in 2005. The questionnaire was designed to collect data on actions taken to respond to the implementation of CWDCS. The questionnaire targeted to capture the views of the respondents on the following issues before and after the implementation of CWDCS:

- Overall reduction in waste generation
- Actions taken to reduce waste by means of waste sorting and recycling at site level
- Barriers to waste minimization by means of sorting and recycling
- Method on Estimating construction waste disposal cost at tender stage
- Progress after the implementation of CWDCS

The survey was administered by distributing the questionnaire to 319 target professionals who were working in the areas of construction project management, construction operation and project finance. The respondents could be broadly classified into the following three disciplines:

- Project manager (representing project management stream)
- Engineer (site agent is included in this group, representing site operation stream)
- Quantity surveyor (representing project finance stream)

The survey was conducted in year 2009 and 109 completed questionnaires were received. The response rate was 34%. Out of the total 109 returned questionnaires, 89 were valid responses in which 41 respondents (46%) identified themselves as project/construction managers, 30 respondents (34%) were quantity surveyors, and 18 respondents (20%) were engineers. Thus, it is believed that each of the three groups was adequately represented in the survey.

Interviews were also carried out with selected professionals who were either construction managers (project directors and project managers) or frontline construction supervisors (site agents and construction engineers).

The questions asked in the interviews were similar to those in the questionnaire survey but they were structured in the direction to explore the views of the interviewees on the effectiveness of CWDCS and the subsequent changes in practice in the construction industry of Hong Kong.

4.2 Data Analysis and Findings from Questionnaire Survey

The results of the survey indicated that the respondents had been working in the construction industry for relatively long periods. 67% of them possessed over 10 years of experience and only 14% had less than 6-year experience. Half of the respondents are working in organizations of less than 400 employees and they were participated or in charge of projects with contract sums of > HK$100 million. The above organization size and the project size are common in Hong Kong.

4.2.1 Method of Estimation of Construction Waste Disposal Cost at Tender Stage

The survey results tabulated in Fig. 2 indicate that before CWDCS was implemented, 35% of the respondents estimated the waste disposal cost by the total contract sum, 34% by gross floor area and 18% by contract sum of selected work trades of the building project. However, after the implementation of CWDCS, more respondents prefer calculating the disposal cost by basing on the contract sum of each work trade (33%) to that of the total contract sum (27%).

Cost of Waste Management

The survey results also revealed that over 70% respondents put 0.5% of the total contract sum as waste disposal cost before the implementation of CWDCS. Up to 24% respondents placed less than 0.1% of the total contract sum on waste management (see Fig. 3). It is interesting to note, after the implementation of CWDCS the results show that 7% of the respondents opined that there would be no change in cost for waste disposal (see Fig. 4). But more than 60% of the respondents expected an increase of waste disposal cost within 1% of the total contract sum. The stated reasons for the increased cost estimation was due to (i) the increase in waste disposal cost (64%), (ii) the additional handling cost for on-site sorting of waste (47%) and (iii) complex site management (24%) (see Fig. 5).

4.2.2 The Level of Waste Generation Before and After Implementation of Waste Charging Scheme

The results of the survey investigated on the change of waste generation before and after the CWDCS (Fig.6). It revealed that more than 40% respondents believed that the waste generation level was reduced by no more than 5% after the implementation of the CWDCS and 11% of respondents opined that the reduction was 5-10%. However, about 29% of the respondents reported that there was “No Change” in waste generation level. More than 66% of all the respondents opined that the waste generation from certain work

trades on site were unavoidable, and 33% believed that it was the designers' responsibility to reduce waste at design stage rather than at construction stage (Fig.7).

This study also tried to identify actions taken in the industry to reduce waste generation. The respondent's views on the ranking of actions taken are shown in Fig. 8. The top three actions adopted to reduce waste generation included better work sequence and management, better subcontractor materials control/handling and better design input.

4.2.3 Barriers of Sorting and Recycling of Construction Waste

Analyses of the barriers of waste minimization by means of sorting and recycling are displayed in Fig. 9 and 10 respectively.

There was some consensus on the barriers for implementing waste sorting in their construction projects. All the respondents ranked 'limited waste storage area on site' as the major barrier for implementing waste sorting while the project manager's group ranked 'intensive labor cost in sorting waste' as the most important barrier. The second important barrier was 'no sorting area on site' according to all the respondents and project manager's group. This result was not surprising as construction sites in Hong Kong were very congested. The next three important barriers were 'high supervisory to subcontractors' behaviors', 'intensive labor cost in sorting wastes' and 'inference with normal site activities', which were based on the results of all the respondents.

There was also some consensus on the barriers for implementing waste recycling in Hong Kong. All the groups except quantity surveyor's group ranked 'not cost effective' as the most important barrier for implementing waste recycling. The second important barrier was "complex treatments before reusing the recycled materials' based on the survey results of all respondents and project manager's group. The third important barrier was 'no market' where the result of project manager's group was agreed with all the respondents.

4.2.4 Progress Made After Implementation of CWDCS

As shown in Fig. 11, the collective views of the respondents of the questionnaire survey on the progress made after the implementation of the CWDCS are: (1) Increase in environmental awareness, (2) Increase in material recycling awareness, (3) Reduction of site wastage level, (4) Improvement of material estimation before ordering, (5) Improvement of inventory control. However, the lowest ranked item is (6) More efficiency in waste sorting on site. It is a strong evident that on-site sorting is not supported by most of the respondents.

In view of the listed items in the questionnaire are mainly related to environmental awareness and material recycling, it is not unexpected that quantity surveyors, whose major roles are related to financial issues, were less inclined to concur with the views of the building engineers and project managers.

4.3 Interviews of Building Professionals

Seven structured interviews have been carried out with building professionals at different levels who were working in seven different building development projects in Hong Kong. The questions raised during these interviews were similar to those of the questions set up in the questionnaire survey and focused on the effectiveness of the disposal charges and actions taken to mitigate its impact on construction operation and management on sites. The interviewees were particularly encouraged to provide their views on the changes undertaken before and after the implementation of the CWDCS.

4.3.1 Overall Waste Reduction After the Implementation of CWDCS

Cross-referencing with the questionnaire results on the reduction of waste generation, one of the interviewees, a project manager of a building contractor firm, pointed out that the reduction rate of waste generation was not apparent. Some of the wastes were “unavoidable”, in particular when they were generated as a result of the design changes initiated by the developer. He also emphasized that the waste generation level from brick work and tiling work were highly dependent on design, such as matching pattern according to aesthetic requirements. Other than design changes and aesthetic requirements, it was opined that other important causes of waste generation were the traditional work practices and poor workmanship.

As for carpentry work, a building professional interviewed opined that as the major drive for reducing wastage of timber materials on construction sites was due to the soaring cost of timber rather than environmental awareness.

The project director of another building project commented that “unavoidable” was only the excuse of doing nothing for waste reduction. He stated that to achieve waste reduction, action are required not only on individual construction sites but also require a change of a company’s culture. He also pointed out that the effectiveness of CWDCS was dependent on a number of different factors. For example, public sector projects in Hong Kong have imposed more stringent contractual clauses to reduce waste generation and often provided financial incentives for waste reduction; while private sector projects emphasis on time and cost efficiency. Site conditions and project designs are other crucial issues. However, he stressed that the most important factor that influences the implementation of sustainable construction of a project is the company policy, in particular, the attitudes of the top management and the policy formulated to manage and control subcontractors.

4.3.2 Actions Taken at Site Level

According to the project managers of two different construction sites, waste reduction should be considered at the very beginning of the projects, such as choice of construction materials and construction methods, planning of construction site layouts, design of temporary and false work etc. After the implementation of the mandatory Waste Management Plan in year 2003, contractors were required to carry out monthly reviews on environmental issues. Penalty clauses that have been included in subcontract documents and training on good environmental practices provided to construction workers were effective measures to reduce waste.

The interviewees also commented that there is great reluctance for contractors to:

- carry out sorting of construction waste on site
- reuse of packaging materials, and
- use of recycled aggregate

This is because they thought that these green practices are either not practical on site, or comparatively more costly than traditional practices. Moreover, they thought that the implementation of these works on site would result in obstruction of normal work causing delay in completion dates.

4.3.3 Barriers of Sorting and Recycling of Construction Waste

Another interviewee who was involved in a private building project located in the urban area with the use of traditional construction methods commented that due to space constraints (only 20% of the total site area of 4000m^2 was available for construction circulation and logistic arrangment). Delivery of construction materials and waste removal had to be well managed to avoid obstruction and congestion. Allocating space for waste sorting within the site area was almost impossible and sending the waste off-site for sorting was costly and impractical.

The interviewees who worked on a public housing project located in the sub-urban area using prefabriaction construction method commented that the relatively larger site area allowed arrangements of sorting of construction waste onsite (with 20% of the total site area of 5,000m^2 was assigned as the circulation area and logistic arrangment). Two large enclosed waste storage areas could be located within the site, one for “inert waste” and the other for “non-inert waste”. The mechanism of waste sorting was achieved by using the main waste delivery chute to convey inert materials such waste concrete, rubbles etc., whereas the lighter non-inert materials such as waste formwork, packaging waste and waste plastic conduits were collected at individual floors by using small containers and they were hoisted to the ground floor by a tower crane. This

arrangement required coordination between the subcontractors who collected the waste and the tower crane operator. The inert and non-inert waste delivered to the ground level would be sorted manually) and stored temporarily in the enclosed storage areas and disposed of at public fills and landfills separately. The survey results indicate that the waste sorting levels (as a % of total waste) between inert and non-inert waste types before and after CWDCS were 13.74% and 24.8 % respectively with an increase of 9%. In the case study, the project manager further remarked that there were other factors contributing to achieving on-site waste sorting including the company policy in encouraging the implementation of good environmental practices, the relatively longer project duration and providing environmental awareness training to subcontractors and their workers. But project managers responsible for private construction projects expressed that the prime goal in managing a private sector project was "to complete the project within the budget in the shortiest possible time". There was no or very limited cost initiative allowed for waste sorting and recycling. They all considered that additional cost was definitely required in providing labour and plant for waste sorting and recycling on-site. Such provisions in private sector projects would increase the tender price which would jeopardize the chance in winning jobs. Moreover, under the current traditional subcontracting arrangment, removal of waste from construction sites is normally subcontracted to a General Cleaning Subcontractor who usually incorporates a number of risk factors in their subcontracting tender price with very little bargaining margin. (refer to the following sections 4.3.4 and 4.3.5). Therefore, to impose additional responsibility for waste sorting on the sub-contractor would require a very complicated estimation process to reconsile the whole tendering strategy.

4.3.4 Disposal Cost Estimation in Tender Stage

All the interviewees agreed that removal of site waste was normally subcontracted to a trade subcontractor named General and Miscellaneous Site Cleaning Work (General Cleaning). The cost of such cleaning works was non-recoverable from the client. In common practice, costs incurred in General Cleaning is allowed and priced in various items of the Preliminaries section of the Bills of Quantities.

The costs incurred for the delivery of waste from construction site to landfills or public fills (including labor and transportation costs) are paid by the main contractor and are absorbed in the contract amount. In the tender stage, site cleaning cost is priced as a certain percentage of the total contract sum which is estimated according to the total gross floor area of the project. The percentage value is based on the the company's database taking reference from past projects of similar nature. Any increase in this estimatedvalue is likely to reduce the chance of successfullt bidding the project.

However, traditional practices in the finishing trades like plastering, brick work and painting, subcontractors and workers do not pay much attention in site cleaning, it is because wastes generated by these trades are

collected by the General Cleaning subcontractor employed by main contractor, and the trade subcontractors are not responsible for paying or the management of the waste. After the implementation of CWDCS, in order to better control of wastage and waste generation by different work trades, more and more main contractors are in the process of amending the terms and conditions of subcontract work to ask subcontractors be responsible for waste generated from their respective work trades. As a result, the awareness of subcontractors in waste reduction is increased and the method of waste disposal cost estimation using the percentage of sub-contract sum of the individual work trades has become more common.

By such a change, it has been commented by an interviewee that the estimated waste disposal cost is reduced to around 0.2% to 0.3% of the total contract sum and this will increase the chance of bidding a project.

For the main contactor perspective, it was commented that although the reduction of waste as a result of the CWDCS may have reduced a few truck loads of waste, the amount in terms of cost is negligible when compared to the total contract sum. Undeniably, the CWDCS would somehow increase the cost of the main contractor. But the cost remains low. The result of interviews concurred in general with the outcome from the questionnaire survey.

4.3.5 Progress made after the Implementation of CWDCS

The direct progress is the physical reduction of waste generated in the construction industry. Also, indirectly, there have been gradual changes from the traditional work practice which are less environmentally friendly to the less waste producing waste practices. More main contractors are changing their contractual arrangements with the subcontractors by shifting the waste reduction and waste cleaning responsibilities to them. Although such a change is mainly financially driven, but the mal-practices of workers can be better controlled and they are even provided with training to raise their environmental awareness.

4.4 Comparison of the Outcomes of Questionnaire Survey and Interviews

Comparison of the research findings by questionnaire survey and interviews is illustrated by Table 4. The majority of the respondents of the questionnaire survey believed that waste reduction is not more than 5%. The interview respondents concurred with these views that the reduction rate is not apparent. The respondents of the questionnaire survey suggested various actions to be taken for waste minimization at site level. However, the interviewees raised that contactors are reluctant to implement waste sorting on site due

to site constraints. They recommended that waste reduction should be considered at the early stage of the project when materials and construction methods were decided. Nevertheless, it was agreed that progress had been made after the implementation of CWDCS. The environmental awareness of contractors is improved.

5. CONCLUSION

The study has quantified the impact of construction waste charging scheme on construction waste reduction after three years of implementation in Hong Kong by means of questionnaire survey and interviews. The following conclusions can be drawn:

The research findings revealed that 40% of the survey respondents believed that waste reduction is less than 5% after CWDCS has been implemented. The interviewees agreed that the waste reduction rate was not significant. They expressed that some waste generation were unavoidable despite a waste disposal charge has been imposed. In addition, 30% of survey respondents agreed that the cost of CWDCS was not high enough to raise the awareness on waste management on construction sites.

Changes in construction management are evident in handling C&D waste in construction operations and tender strategy. Shifting the responsibility of construction waste generation and minimization from main contractors to trade subcontractors is gradually perceived by participants of the construction industry of Hong Kong. Such a shift has evoked amendments in subcontract documents as well as the estimation of waste handling charge in the tender amount. The evaluation waste handling cost at tender stage is changed from the total floor area of the project to the total amount of selective trade subcontracts.

ACKNOWLEDGEMENT

The authors wish to thank the Hong Kong Polytechnic University for funding support. The cooperation of various construction professionals in participating in the questionnaire survey and interviews are also gratefully acknowledged.

REFERENCES

- Andersen, M.S., Dengsoe, N. (2002). "A Baumol-Oates Approach to Solid Waste Taxation". *Journal of Material Cycles Waste Management*, Vol. 4, 23-28.
- Anderson, M.S. (1998). "Denmark's Waste Taxes". *Environment*, 40, 38-41.
- Baldwin, A., Poon, C.S., Shen, L. Y., Austin, S., Wong , I (2009). Designing out waste in high-rise residential buildings: Analysis of precasting methods and traditional construction, Renewable Energy 34, 2067-2073.
- Bartelings H., Van Buekering P., Kuik O., Linderhof V., Oosterhuis F. (2005). *Effectiveness of landfill taxation*, report prepared for the Dutch Ministry of Housing, Spatial Planning and the Environment, Institute for Environmental Studies, Vrije Universiteit, and Amsterdam.
- Bianchini G, Marrocchino E, Tassinari R. and Vaccaro C. (2005) *Recycling of construction and demolition waste materials: a chemical–mineralogical appraisal*, Waste Management, 25, 149-159.
- Brunner P. H. and Stampfli D. M. (1993) *Material Balance of a Construction Waste Sorting Plant*, Waste Management & Research, 11, 27-48.
- Census & Statistics Department (ed.), accessed April 2010, from http://www.censtatd.gov.hk/hong_kong_statistics/index_tc.jsp
- California Department of Resources Recycling and Recovery, accessed April 2010, from http://www.calrecycle.ca.gov/
- Chui, T. (2007). "Fly-tipping of Building Materials on the Rise", *The Standard*, 27 March.
- Craven, E.J., Okraglik, H.M., and Eilenberg, I.M. (1994). "Construction Waste and a New Design Methodology", paper presented at the Sustainable Construction: Proceedings of the 1st Conference of CIB TG 16.
- Cosgun N. and Esin T. (2007). *A Study Conducted to Reduce Construction Waste Generation in Turkey*, Building and Environment, 42, 1667-1674.
- Dhir, R.K., Henderson, N.A. and Limbachiya, M.C (ed.)(1998). Proceedings of the International Conference on the Use of Recycled Concrete Aggregates, Thomas Telford, UK.
- Environmental Protection Department (ed.) (2007). *A Green Manager Scheme.*

- Environmental Protection Department (ed.) (2007). *Environmental Protection.*
- Fatta D., Papadopoulos. A., Avramikos E., Sgourou E., Moustakas K., Kourmoussis F., Mentzis A. and Loizidou. M. (2003) *Generation and Management of Construction and Demolition Waste in Greece – an Existing Challenge*, Resources, Conservation and Recycling, 40, 81-91.
- Ferguson, J., Kermode, N., Nash, C.L., Sketch, W.A.J. and Huxford, R.P. (1995). *Managing and Minimizing Construction Waste: A Practical Guide, London.*
- German Government - Federal Ministry for the Environment (ed.), accessed Jan 2010 from http://www.bmu.de/english/waste_management/doc/6885.php
- Glazyrina, R., Glazyrin, V. and Vinnichenko, S. (2006). "The Polluter Pays Principle and Potential Conflicts in Society". *Ecological Economics*, 59, 324-330.
- Government of Alberta, accessed on Jan 2010 from http://alberta.ca/home/
- Government of United Kingdom (ed.), accessed on Jan 2010 from http://www.defra.gov.uk/environment/waste/topics/construction/index.htm
- Hansen, T. C., RILEM REPORT 6., Recycling of Demolished Concrete and Masonry, published by E&FN Spon, Bodmin, UK, 1996.
- Hendriks, C.F. and Pietersen, H.S. (2000). "Sustainable Raw Materials: Construction and Demolition Waste", *RILEM Publication, Cachan Cedex, France.*
- International Coalition for Sustainable Production and Consumption (ed.) (2007). *Polluter Pay Principle.*
- Legislative Council Panel of the HKSARG (2007). *Construction and Demolition Waste and Landfill Charging Scheme.*
- Legislative Council Panel of the HKSARG (2006). *Progress Report on the Management of Construction and Demolition Materials, Environmental Affairs*, 24 April.
- Magrinho, A., Didelet, F. and Semiao, V. (2006). "Municipal solid waste disposal in Portugal", *Waste Management*, 26, 1477-1489.
- Jaillon, L and Poon C.S. (2009). "Quantifying the Waste Reduction Potential of Using Prefabrication in Building Construction in Hong Kong", *Waste Management*, 29, 309-320.

- Poon, C.S., Yu, A.T.W., Wong, S.W. and Cheung, E. (2004). "Management of Construction Waste in Public Housing Projects in Hong Kong", *Construction Management and Economics*, 22 (7), 675–689.
- Tam, C.M., Tam, W.Y.V., Chan, K.W.H. and Ng, C.Y.W. (2005). "Use of Prefabrication to Minimize Construction Waste – A Case Study Approach", *International Journal of Construction Management*, 5 (1), 91-101.
- Tam, W.Y.V. (2007). "On the Effectiveness in Implementing a Waste-Management-Plan Method in Construction", *Waste Management*, 28, 1072-1080.
- Tam, W.Y.V., Tam, C.M., Chan, W.W.J. and Ng, C.Y.W. (2006). "Cutting Construction Wastes by Prefabrication", *International Journal of Construction Management*, 6 (1), 15-25.
- Xiao, J.Z., Zhang, Y., Cheung, M.S. and Chu R. P.K. (ed)(2010). Construction Waste Recycling and Civil Engineering Sustainable Development, RILEM Pro 73, Proceeding of 2nd International Conference on Waste Engineering and Management.

Table 1: Comparison of Construction Waste Concentration in Various Countries

County	Concentration of Construction waste in total waste (in %)	C&D waste recycled (in %)	Sources
Australia	44	51	Hendriks and Pietersen (2000)
Brazil	15	8	Hendriks and Pietersen (2000)
Denmark	25-50	80	Hendriks and Pietersen (2000)
Finland	14	40	Construction Materials Recycling Association (2005) ; Hendriks and Pietersen (2000)
France	25	20-30	Construction Materials Recycling Association (2005) ; Hendriks and Pietersen (2000)
Germany	19	40-60	Construction Materials Recycling Association (2005) ; Hendriks and Pietersen (2000)
Hong Kong	38	No information	
Japan	36	65	Construction Materials Recycling Association (2005) ; Hendriks and Pietersen (2000)
Italy	30	10	Construction Materials Recycling Association (2005) ; Hendriks and Pietersen (2000)
Netherlands	26	75	Construction Materials Recycling Association (2005)
Norway	30	7	Hendriks and Pietersen (2000)
Spain	70	17	Hendriks and Pietersen (2000)
United Kingdom	Over 50	40	Hendriks and Pietersen (2000)
United States of America	29	25	Construction Materials Recycling Association (2005) ; Hendriks and Pietersen (2000)

Table 2: HKSAR Government Initiatives Policy in C&D Waste Reduction

1980	The Waste Disposal Ordinance [Chapter (Cap.) 354] was enacted as the principal legal framework
1989	Establishment of the framework for a comprehensive 10-year plan to reduce C&D waste and other pollution problems, such as commitments to review its progress for every two years
1995	A "Green Manager Scheme" was launched for requiring every governmental department to appoint a green manager to manage the environmental performance of individual organizations
Nov 1998	"Waste Reduction Framework Plan (WRDP)" was introduced with the aim of attempting to change the waste treatment habits of the public
Feb 2003	Building Department issued a practice note for structural engineers named "Use of Recycled Aggregated in Concrete". This technical guideline can be applied to prescribed mix concrete (20P) and designed mix concrete (25D to 35D) to adopt 100% and 20% recycled aggregate respectively
May 2003	Environmental Transport and Works Bureau produced a circular (Ref:15/2003) on "Waste Management on Construction Sites" which explained the implementation of the government's "Waste Management Plan" and "Pay for Safety and Environmental Scheme" for public construction projects
2004	Civil Engineering Department commissioned a pilot recycling plant at Tuen Mun Area 38 in a view of supplying recycled aggregate to a number of public projects from 2004 to 2006
Dec 2005	Government implemented "Construction Waste Disposal Charging Scheme" that charges who dump their waste into public landfills.

Table 3: Government Waste Disposal Facilities and Disposal Charge (EPD)

Government waste disposal facilities	Charge per tone	Type of waste accepted
Public fill reception facilities	HK$27	Consisting entirely of inert construction waste
Sorting facilities	HK$100	Containing more than 50% by weight of inert construction waste
Landfills	HK$125	Containing not more than 50% by weight of inert construction waste
Outlying Island transfer facilities	HK$125	Containing any percentage of inert construction waste

Table 4: Findings of Questionnaire Survey Versus Interview Results

Study objectives	Findings from questionnaire survey	Views of interview respondents
Overall reduction in waste generation	Respondents believed that waste reduction is not more than 5% and some believed that there is no change in waste reduction.	The reduction rate is not apparent. Some wastes are unavoidable such as wastes caused by change of design and aesthetic reasons. Workers are not keen to change their traditional practice to reduce waste but are more open to using materials in an uneconomical way in order to save material cost. The situation can be improved enforcement of company policy prescribed by top-management.
Actions taken to reduce waste by means of waste sorting and recycling at site level	• Better work sequence and management • Better subcontractor materials control • Better design • Better supervision on quality • Better inventory procurement monitoring • Better worker training • Better supervisory staff training • Reuse packaging materials • Reuse recyclable materials	Waste reduction should be considered at early stage of the project in choosing materials, construction methods, planning site layout, and imposing penalty on subcontractors and training of workers. But contractors are reluctant to implement sorting of waste on site.
Barriers to waste minimization by means of sorting and recycling	• Limited waste storage area on site • No sorting area on site • High supervisory to subcontractors' behaviors • Intensive labor cost in sorting wastes • Interference of normal construction activities • Low waste sortability • Narrow site access • Impractical in using too many waste delivery chutes	Sorting of waste and recycling on construction site is constrained by site area and transportation assess. Achieving TIME and COST saving are major objectives rather than implementation of waste reduction in construction site.
Estimation of construction waste disposal cost in tender stage	Allow 0.5% of the total contract sum as waste disposal cost before the implementation of CWDCS is the general practice, after the implementation of CWDCS, more than 60% of respondents expected an increase of waste disposal cost within 1% of the total contract sum. Only a small minority (7%) opined that there is no change in tender estimation for waste disposal cost.	In order to better control of wastage of materials and reduce waste generation; main contractors are shifting the responsibility of waste management to different work trades. Also, the estimation of waste disposal cost is being changed from based on gross floor area to a percentage of the sub-contract sums of individual work trades. By such a change, the overall cost is reduced to around 0.2% to 0.3% of the total contract sum.
Progress made after the implementation of CWDCS	• Reduction of site wastage level • Increased in environmental awareness • Increased in material recycling awareness • Improvement of material estimation before ordering • Improvement of inventory control • More efficiency in waste sorting on site	The direct progress is the physical reduction of construction waste. Indirectly, there are gradual changes of work practices to more environmentally friendly practice to reduce waste generation. Shifting of waste generation and site cleaning responsibility to subcontractors help rectify mal-practice of workers. Their environmental awareness is improved