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Quantification of Construction Waste Generated in Residential Housing Projects via Heap Survey Sampling with the Method of Visual Estimation: A Case Study in Klang Valley and Pulau Pinang

[1]Raja Nor Husna Raja Mohd Noor, [1]Siti Akmalina Rahmat, [2]Intan Rohani Endut,
[2, 3]Ahmad Ruslan Mohd Redzuan, [4]Asmawati Che Hassan and [1]Amril Hadri Jamaludin
[1]Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM),
Pulau Pinang, Shah Alam, Malaysia
[2]Institute for Infrastructure Engineering and Sustainable Management (IIESM),
Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[3]Faculty of Civil Engineering, Universiti Teknologi MARA, 40450 Shah Alam, Selangor, Malaysia
[4]Faculty of Civil Engineering, Universiti Teknologi MARA (UiTM), Pasir Gudang,
Johor, Shah Alam, Malaysia

Abstract: Construction waste management is part of a growing movement towards a sustainale world. Throughout the years, the construction industry has made an important contribution in the lives of society in Malaysia. With the demands of major residential housing project developments, it shows that the construction sector is being expanded and developed. Moreover, it has been observed that the construction waste is one of the priority waste streams. Due to the increasing population that is actively involved in economic activities and the modernisation of the country, the types of construction wastes that is being produced is becoming more complex and has yet to be identified. Therefore, the established system to record quantitative data for the generation of construction waste has yet to be formally standardized and is still lacking across much of Asian and developing countries. To address this need, the study on the major types and composition of construction waste generated is carried out as a logical first step towards assisting the construction waste management through the categorization of construction waste in Klang Valley and Pulau Pinang. Throughout this study useful information concerning waste assessment data is necessary to achieve a better understanding of construction waste obtained. Case studies involving quantification and classification of construction waste for several on-going residential housing developments in Klang Valley, Selangor and Pulau Pinang have been presented. This study concludes with the identification of database information concerning the quantification of local construction waste which was developed for the current practices of construction waste management.

Key words: Construction waste management, sustainale world, contruction, priority waste stream, practice

INTRODUCTION

Construction waste is a part of waste stream that usually ends up at landfills where the impact on the environment is given less attention either by contractors or authorities in general. Therefore, sustainable development has emerged in the construction industry by emphasizing the process of construction starting from extraction of raw materials in planning, design and construction of the structure until demolition of the structure and managing the waste on site. Apart from all, in order to protect environment, the threats such as waste should be eliminated or minimized through rational management which involves renewable raw material, reuse and recovery of waste that is generated along the process in construction. In achieving the quality of a better life among residents, Malaysia had concentrated in executing sufficient major residential housing project developments.With the demand in the implementation of the residential housing development this shows that the construction sector is being expanded and developed. Due to the factors of the construction stage, types of construction work and practices on site the construction sector would produce types of waste (Begum *et al*., 2007). The highest quantity of waste generated is from waste material or construction waste material. Therefore, in order to construct the housing residential development, this construction waste generated will have an impact on the environment. Several policies regarding construction waste has been introduced in order to reduce the waste at

Corresponding Author: Raja Nor Husna Raja Mohd Noor, Faculty of Civil Engineering, Universiti Teknologi MARA UiTM, Pulau Pinang, Shah Alam, Malaysia

landfill as reduction of construction waste could give economic and environmental benefits. The generation of construction waste from the construction activities will continuously give a negative impact on the environment. From a survey done in Hong Kong, it was discovered that the housing projects had generated the highest wastage level compared to the other types of projects. The reason may be due to the fact that the private projects are normally of non-standardized building structures which include the different sizes and shapes of building components such as formwork, reinforcement and brickwork. In addition, the generation of waste will produce a negative impact on the environment, public image and resources, raise time and cost for the building process and disposal of landfills site. Normally the conventional method is practiced when the extra waste material and construction wastes is finally disposed off in the landfills.

In order to set up the proper construction waste management system for the construction industry, a set data concerning the current structure of construction waste should be made available (Begum *et al*., 2006). Currently in Malaysia, there is very limited research being conducted on the issue of construction waste. In addition, there are few data available on the current structure of construction waste flows by the type of waste, source of waste, amount of raisings generated and disposed (Begum *et al*., 2006). Based on this situation, this means that the data concerning the amount of construction waste generated and disposed is not readily available. Therefore, the study has been conducted in Klang Valley and Pulau Pinang, to fill the knowledge gap. The objective of this study is to identify the main types and composition of construction waste generated for several on-going residential housing developments in Klang Valley and Pulau Pinang in order to strengthen the record of construction waste quantity generated and disposed for the current practices of construction waste management. To operationalise the research, a quantitative research approach througha heap-survey with the method of observation (visual estimation) is adopted.

MATERIALS AND METHODS

Method of heap-survey on selected residential projects has been adapted by the method of visual estimation or observation. In this study, the survey is called the heap-survey for estimating the volume and weight of a visual sampling or observations made on the heap of construction waste on site review. This visual characterization is the process of estimating the composition and types of the sampling volume and weight through the observation of the construction waste heap at the site of residential housing is developed. This study focuses on the construction phase of the superstructure and finishing. The selected of construction phase is referred to the previous research work in Miri, Sarawak (Poon *et al*., 2004). This research method can produce construction waste characterization which is more accurate than by estimating the percentage of respondents in the questionnaires (Abedellaah *et al*., 2013). In Malaysia, the method of visual estimation based on volume and sampling weight had been conducted in Miri, Sarawak and Ipoh.

Case study in terms of residential housing projects in Klang Valley and Pulau Pinang were preferred in this research to identify types and composition of construction waste generated. Five residential housing projects in Klang Valley and six residential projects in Pulau Pinang were selected as case studies for investigation from a visual estimation based on volume and sampling weight of construction waste in similar projects. The research study in Klang Valley has been conducted from December 2010 to September 2011 while the data collection in Pulau Pinang area has been executed from March 2015-April 2016. Due to the time constraints to complete the research study within the research period five projects in Klang Valley and six projects in Pulau Pinang has been monitored for superstructure and finishing stage. The selection of the case study on the residential housing projects was done based on three criteria which is corresponding with study done in Miri, Sarawak. The three criteria that need to be considered in the selection of the case study projects are the location and construction organization of projects which cover different location in Klang Valley and Pulau Pinang area, with the permission were granted by clients and contractors. Second criteria is based on the types of activities where the construction sites are chosen are new residential development and comprise of single or double storey terrace and semi-detached house which involved reinforced concrete construction. The last criterion is construction stage and duration where most of the studied sites selected reached practical completion within the research period.

The method of heap-survey outlined the layouts of construction waste generated on the construction site where divided into three forms: stockpiled, gathered and scattered. There are seven steps to determine the construction waste generated on site. The first step is to record the sample number and date of the heap survey form. The second is to identify the class of construction waste from these samples. The third step, the method of measurement using visual estimation that had been taken from stockpiled and gathered waste while the method of weight of unit sampling has been conducted for scattered waste. The description of the information regarding the method of estimation has been made as following:

Step 1: For stockpiled waste, it was assumed to stay in the form of rectangular base pyramidal shape. Equation 1 shows the volume (V_s) of a stockpiled waste was taken as the volume of rectangular base pyramidal shape where:

$$Vs = 1/3(B \times L \times H) \quad (1)$$

Step 2: For gathered waste, it was assumed to stay in the form of rectangular prism on the ground surface. Equation 2 shows the volume of gathered waste (V_g) was taken as the volume of rectangular shape where:

$$V_g = L \times B \times H \quad (2)$$

Step 3: For scattered waste with similar size, three samples were randomly chosen and weighed. The values obtained were averaged and assumed to be the same for all other samples. Subsequently, the numbers of samples scattered around the site were counted and recorded. Equation 3 shows the total weight of the scattered (V_{sc}):

$$Vsc = W_{average} \times N \quad (3)$$

Where:

W_{averag} = The average weight per sample
N = Number of samples

Step 4: The total volume for each sample for the gathered, stockpiled and scattered waste are separately record, measured and weight according to the class and types of the heap in respectively form
Step 5: To convert the total volume of stockpiled and gathered waste to unit weight (kg = kilogram) where the volume of each construction waste is multiplied by the density
Step 6: The measurement of floor area for houses based on a calculation of floor plans available through archival records

Finally, each class for each type of construction waste heaps are divided by floor area for each house to produce a total weight per unit meter house floor area (m^2).

RESULTS AND DISCUSSION

Research area (Klang Valley): Table 1 presents the profile of the housing construction sites involved in this heap-survey where the average total build-up area for one unit house is 122.4 m^2. The estimated quantity of construction waste disposed was calculatedseparately for superstructure and finishing works. Table 2 and 3 shows the generation rate of construction waste for one-storey unit house between site (CS 1-3). Based on the average generation rate for construction waste, it is clearly shown that the major components of construction wastes generated for superstructure stage are wood, metal and concrete. Wood refers to waste resulting from formwork, plywood, framing, roof truss and others (Begum *et al*., 2006) where is widely used in the construction industry. It was the highest waste stream by means of total weight produced at site (CS1 and 2). While, the lowest wood generation rate was identified at site (CS 3) where it was actually idealized that the wood were extensively reused in construction site. This was similar with the study done by Kofoworola where wood is reused by contractors within the project as many times as possible to avoid the

Table 1: Housing construction site profile in Klang Valley

Case Study (CS)	Location	Total of units house	Total of build-up area (1 unit house) (m^2)
1	Kota damansara	54	149.00
2	Shah alam	90	117.30
3	Klang	56	111.13
4	Setia alam	64	113.00
5	Subang bestari	26	124.80

Table 2: Generation rate of construction waste for one storey unit house between (CS 1-3) in superstructure stage

Types of waste	CS 1	CS 2	CS 3	Average of generation rate
Wood	0.0048	0.0069	0.0120	0.0079
Metal	0.0028	0.0012	0.0030	0.0023
Concrete soil	0.0020	0.0013	0.0010	0.0014
Aggregate and sand	0.0009	0.0007	0.0020	0.0012
Soil aggregate	0.0009	0.0005	0.0020	0.0010
Sand	0.0002		0.0002	

Unit = (Tonne m^{-2})

Table 3: Generation rate of construction waste for one-storey unit house between (CS 4 and 5) in finishing stage

Types of waste	CS 4	CS 5	Average of generation rate
Bricks	0.000740	0.000560	0.000650
Ceramic/tiles	0.000010	0.000270	0.000140
Packaging	0.000290	0.000170	0.000230
Paper begs	0.000230	0.000070	0.000150
Plastic begs	0.000050	0.000100	0.000075
Insulation material	0.000040	0.000100	0.000007
Gypsum	0.000016	0.000003	0.000010
Glass	0.000003	0.000004	0.000004
Concrete	0.000056	0.000220	0.000136
Soil, aggregate and sand	0.000026	0.000300	0.000161
Soil	0.000026	0.000300	0.000162
Cement	0.000233	0.000520	0.000370
Others	0.000010	0.000010	0.000010
Plaster	0.000004	0.000003	0.000004
Cement screed	0.000010	0.000010	0.000010

Unit = (Tonne m^{-2})

cost of collection and disposal and extra costs of virgin material. Metal was also one of the major waste streams in construction waste. Metals were the wastes generated from ferrous or non-ferrous materials such as reinforcing bars, metal, aluminum, copper, brass and others. It was the lowest waste generated in site (CS 2) compared to the other sites. This was mainly due to the relatively high cost and recycle value of metal in the local market. Off cuts of reinforcement were usually collected and placed properly for future use or recycling. Concrete is the waste generated from footings, piling, beams, columns, floor slabs and flow of plastering (Begum *et al*., 2006). Moreover, concretemade up the lowest percentage of construction waste on site (CS 3).

Meanwhile, concrete waste generation at site (CS 1 and 2) was quite similar.There was a large difference between site (CS 3) and another two sites (CS 1 and 2) as some of the concrete were buried or mixed with other earth materials. Thus, it was no longer identifiable for a quantification operation to be carried out since some of concrete waste was scattered around the construction site.

Table 3 shows the generation rate of construction waste for a one-storey unit house between site (CS 4 and 5). Bricks, cement and packaging (paper bags and plastic bags) are the major component of construction waste generated from finishing works. Brick is always been one of the main component of construction waste. In addition bricks refer to the waste resulting from masonry, wall and fencing works. It was the highest waste stream by means of total weight produced at site (CS 4) compared to the site (CS 5) since bricks that used in the construction work at site (CS 4) comprised more of cement bricks than clay bricks, one of the cheapest types of bricks available in the market. Cement wastes was also one of the main component waste streams in construction waste. The cement waste made up the highest weightage of construction waste at site (CS 5). It was because some of cement waste that mixed with other waste such as bricks were buried around the site and reused as temporary excess road during the construction activity. There was a large difference between site (CS 4 and 5). This was because at site (CS 4), quantification of these waste was generally difficult due to the scattered form of waste around the sites and some of waste were mixed together with other waste. The generation of waste basically dependent on the practices of the worker on the site. Even with different methods, there was a significant increase of generation rate for packaging waste. In Europe, packaging had always been the biggest waste stream sub-group (Begum *et al*., 2006).

Table 4: Housing construction site profile in Pulau Pinang

Case Study (CS)	Location	Total of units house	Total of build-up area (1 unit house) (m^2)
1	Butterworth	55	112.00
2	Bertam	40	124.50
3	Simpang ampat	54	143.00
4	Bertam	55	145.00
5	Bertam	40	117.10
6	Simpang ampat	60	132.00

Table 5: Generation Rate of construction waste for one-storey unit house between (CS1-3) in superstructure stage

Types of waste	CS 1	CS 2	CS 3	Average of generation rate
Wood	0.000230	0.000154	0.000061	0.000148
Metal	0.000134	0.000032	0.000010	0.000059
Concrete	0.000081	0.000032	0.000016	0.000043
Sand	0.000023	0.000013	0.000007	0.000014
Soil and aggregate	0	0.000002	0.000001	0.000001

Unit = (Tonne m^{-2})

Table 6: Generation rate of construction waste for one-storey unit house between (CS4-6) in finishing stage

Types of waste	CS 4	CS 5	CS 6	Average of generation rate
Bricks	0.000003	0.0000031	0.0000018	0.0000027
Ceramic/tiles	0.0000001	0.0000015	0.0000005	0.0000007
Packaging	0.0000025	0.0000004	0.0000003	0.0000011
Insulation	0.0000003	0.0000004	0.0000004	0.0000004
Gypsum	0.0000001	0	0	0.0000001
Glass	0	0	0	0.0000001
Concrete	0.0000003	0.0000006	0.0000004	0.0000005
Soil	0.0000003	0.0000013	0.0000001	0.0000006
Cement	0.0000013	0.0000018	0.0000013	0.0000015
Plaster	0	0.0000001	0	0.0000001

Research area (Pulau Pinang): Table 4 shows the information of selected case study which will represent three case study each for superstructure and finishing stage. Previous studies show waste from that timber, brick, steel, concrete, cement and packaging are the highest waste on site (Vinay *et al*., 2014; Foo *et al*., 2013).

Table 5 shows the generation rate of construction waste for one-storey unit house at three selected site during superstructure phase. It is clearly shown that wood still the highest waste produced at three selected site with average of 0.000148 tonne m^{-1} (Tewari *et al*., 1993). The second highest waste produced on site is metal where produced 0.000059 tonne m^{-2} for one storey unit house followed by concrete with the generation of waste 0.000043 tonne m^{-2}. Lastly, sand and soil and aggregate with amount of each waste is 0.000014 and 0.0000001 tonne m^{-2}, respectively. Woods and metal are mostly used in installation of formwork as the contractors are still practicing traditional method in construction.

For the finishing stage, Table 6 all the tabulated data for each three case study. Bricks contribute to the highest waste generated on site which the average for each site is 0.0000027 tonne m^{-2}. Followed as second and third highest waste generated on site is cement and packaging with 0.0000015 and 0.0000011 tonne m^{-2}, respectively.

CONCLUSION

Throughout this study, a database for estimating construction waste in residential housing projects in Klang Valley and Pulau Pinang has been determined. Based on results from both study area, it can be concluded that there are six major wastes generated on site where have a difference in terms generation rate for each type of construction waste. The major waste generated consist of from superstructure stage and remaining from finishing stage: wood, metal, concrete bricks, cement and packaging. Based on results, it can be summarized that the generation rate for wood, metal bricks, cement and packaging in Klang Valley is highest than the generation rate in Pulau Pinang while the generation rate for bricks in Pulau Pinang is highest than in Klang Valley. There are the difference on the generation rate between Klang Valley and Pulau Pinang area since the construction industry has started to use Industrial Building System (IBS) or other approach in the construction stage compared to traditional method where is more contributed to the construction waste generated. The results obtained shall help to provide the useful information concerning the representative quantities and potential for reusing and recycling to improve the current construction waste management practices as the reuse and recycling concept are alternative solution to reduce waste being disposed at landfill indirectly will conserve the landfill itself. The data obtained also could contribute in recording database system in quantification of waste generated in construction industry.

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