

Composition and Characteristics of Construction Waste Generated by Residential Housing Project

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ABSTRACT: The construction industry is a major consumer of new materials. Given that material production for construction work accounts for a significant percentage of all energy consumed nationally in newly developing countries, it becomes vital that the construction industry strives to reduce waste at all stages of construction. However, the importance of these construction wastes in terms of types and sources have yet to be identified. Established systems to record quantitative data for the generation of construction waste have yet to be formally standardised and are still lacking across much of Europe and developing countries. Although categorisation of waste assists segregation of construction waste and increases the potential for reuse and recycling, little progress has been made in Sarawak, the largest state in Malaysia. To address this need, this pilot study is carried out as the logical first step towards construction waste management in Sarawak by categorisation of construction waste at residential construction projects. Through this study, useful information concerning waste assessment data necessary to achieve a better understanding of construction waste is obtained. Case studies involving quantification and classification of construction waste for several on-going residential construction projects in Miri City, Sarawak, Malaysia are presented. A database of information concerning the quantification of local construction waste was developed, in addition to current construction waste management practices.

Key words: Construction waste, Waste quantification, Composition

INTRODUCTION

The construction industry has long been regarded as one of the major contributors of negative impact to the environment, due to the high amount of waste generated from construction, demolition, renovation and activities associated with construction. The construction industry plays a significant role in Malaysia's development both in terms of infrastructure and economic development. After some decades of an extensive "use and throw away" philosophy, it has now been recognized that this uninhibited use of natural resources and resultant pollution levels are unsustainable (Chong, Tang & Larsen 2001). Therefore, it is essential to raise the awareness and revise previous common practices within the construction industry.

Construction waste generally refers to waste resulting from construction, demolition, renovation, real estate development, infrastructure development, earthworks and land clearing operation (US EPA 1998, Tang, Soon & Larsen 2003). It consists of, but is not limited to, wood, concrete, metal, brick, drywall, roofing, material packaging, plastics, papers, cardboard and others. Categorisation of construction waste is a study into the composition and amount of construction waste generation; categorisation enhances understanding of the sources and causes of waste generation. Associated information is usually obtained via construction waste assessment, such as quantification of waste raisings, field surveys and site observations. The definition of construction waste varies and depends

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significantly on the type of construction and practices where the sampling is performed (US EPA 1998, Begum *et al.*, 2006). In this pilot study, construction waste is defined as the solid waste resulting solely from construction activities, in which waste arising from demolition, renovation, earthworks and land clearing operations is excluded from the scope. Typical components of construction waste generated from residential construction sites include wood, concrete, metals, drywall, brick, roofing and others (US EPA 1998, Tang & Larsen 2004).

Currently, The Ministry of Housing and Local Government of Malaysia (2005a) has implemented policies and provided incentives to build low and medium-cost housing for the lower-income group of society. In recent years, the numbers of housing projects have increased dramatically due to the financial support from the federal government. In addition, accessibility to housing has increased for lower income groups through government funded housing loan schemes (Ministry of Housing and Local Government 2005b). As a result, it is expected that construction waste generation within the country will increase significantly in the future if the current upward trend continues (Tang & Larsen 2004). In recent studies conducted regarding the breakdown of waste in the central and southern region of Malaysia, 28.34% of the total waste generated was contributed by construction and industrial waste-stream (Begum *et al.*, 2006). Consequently, the minimization of construction waste has been brought to the forefront of the society as an important issue.

It can be argued that an organized construction waste management system should be developed for all residential projects in order to regulate and reduce the generation of construction waste on construction sites. In order to set up a proper waste management system for the construction industry, a set of data concerning the current structure of construction waste generation should be made available (Begum *et al.*, 2006, Bossink & Brouwers 1996, Tang & Larsen 2004). Currently in Malaysia, there is very limited research being conducted on the issue of construction waste (Begum *et al.*, 2006, Tang & Larsen 2004, Tang, Soon & Larsen 2003). Hence, there are very few data available on the current structure of construction waste flows by the source of

generation, type of waste, amount of raisings generated and disposed, and the amount of waste reduced, reused or recycled (Begum *et al.*, 2006, Tang & Larsen 2004). Secondary research conducted here finds no comprehensive data available regarding the amount and composition of construction waste generation for residential projects in Sarawak.

Regulating bodies in the State of Sarawak whose remit encompasses construction waste management include Local Authorities Ordinance (LAO), Local Authorities Cleanliness Bylaw (LAC), and the Natural Resources and Environment Ordinance (NREO). The existing regulations are based on the steps of waste flow: generation, transportation and disposal. Whilst there are a number of provisions deemed available to regulate the management of construction waste in Sarawak, they are somewhat ineffective. According to surveys performed by Natural Resources and Environment Board, Sarawak (NREB), the existing provisions are currently not put into good use due to the fact that no consistent strategy or system of management is in place (Tang & Larsen 2004, Chong, and Tang & Larsen 2001). At present, there is no coherent waste management system being established in Sarawak (Chong, Tang & Larsen 2001). For the case of the construction industry in Sarawak, it is very common that local contractors and developers do not have proper construction waste management systems, or registrations of waste on site (Tang & Larsen 2004). According to Natural Resources and Environmental Board (NREB, 2005), there are a total of 45 existing landfills in Sarawak, 40 of which were visited by the NREB regularly. The total area allocated for the dumping of municipal solid waste is around 80 hectares, at which about 370,000 metric tonnes of solid waste are disposed at these sites per annum.

A study was conducted by Tang, Soon and Larsen (2003) to investigate the collection and transport of construction waste in Kuching City, Sarawak. The disposal of construction waste generated from construction activities is the responsibility of the developer or contractor. In most cases, construction waste is normally transported by private contractors, in which the construction waste usually ends up at their own premises or reallocated within the construction site

for landfilling or future construction purposes. However, the waste transported from small scale construction or renovation works is believed to be disposed of at illegal dump sites. This statement is supported by illegal dump site field surveys (Tang, Soon & Larsen 2003).

Based on the survey conducted by NREB and Danish International Development Agency (DANIDA), it is estimated that about 50% of the construction waste does not leave the site. It is either used for the preparation of site-works, left on site, or even open burnt. The remainder was fly-tipped at informal dumpsites on private land and illegally dumped at road reserves or idle land. Scrap metal is usually collected for recycling due to its high resell value at present date (Tang & Larsen 2004). Thus, only a small amount of construction waste was actually legally dumped into public landfills. Currently, there are no official facilities in Kuching City for the treatment of construction waste. Based on the surveys, it can be concluded that a majority of the construction waste generated is 'informally' landfilled, with significant quantities being dumped illegally in rural areas, road reserves or landfilled on private land (Tang, Soon & Larsen 2003).

MATERIALS & METHODS

As the selected project pilot-study sites should provide a fundamental representation of the current structure of construction waste for residential projects in the City of Miri, the locations chosen for construction waste assessment were based on the following criteria (i) The location and builder, where the construction sites cover different locations within Miri, with the condition that permissions were granted by the respective developers and contractors. The selected sites involved different developers and contractors.

(ii) Types of activities: the construction sites chosen are new residential developments in Miri. In addition, the sites selected comprise of different types of residential development, such as low cost/affordable housing. All of the residential pilot-study projects involved reinforced concrete construction.

(iii) Construction stage and duration: most of the studied sites selected reached practical completion within the research period.

The three main pilot-study sites selected are located at Desa Senadin Housing Estate, Promin Jaya Development and Piasau Residential Development. They are labelled as Sites A, B and C, respectively (Fig. 1). In addition, two other on-going residential sites, located at Desa Senadin Housing Estate and Promin Jaya Development, were selected for monitoring purposes. They are labelled as Sites D and E. The studied sites selected reached practical completion within the study period. Three methods outlined below are used to obtain the composition, generation and sources of construction waste from residential construction sites (Fig. 1).



Fig. 1. Location of Miri City, State of Sarawak, Malaysia

The layouts of the construction waste generated on the construction site were divided into four forms: stockpiled, gathered, scattered and stacked. Quantities of the construction waste generated, in terms of weight, for a particular layout were determined through the product of its respective estimated volume and estimated unit weight. For stockpiled waste, it was assumed to stay in the form of rectangular base pyramidal shape (Fig. 2). The volume (V_s) of a stockpiled waste was taken as the volume of a rectangular base pyramidal shape, where $V_s = 1/3 (B \times L \times H)$. For gathered waste, it was assumed to stay in the form of rectangular prism (Fig. 3) on the ground surface. The volume of gathered waste (V_g) was taken as the volume of rectangular shape, where $V_g = L \times B \times H$.

Scattered waste can be divided into two categories. The first consists of waste with similar size, such as broken bricks, cement bricks, roof tiles and cement bags. The second consists of waste with large variation in size, such as off cuts of steel roofing sheet, plastic packaging and off cuts of gypsum or plaster board. 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 number of samples scattered around the site were counted and recorded. The average weight per sample multiplied by the number of samples gives the total weight of the scattered waste. For stacked waste, it was measured in a similar manner as scattered waste. First, three randomly chosen samples from a particular stack of waste were weighed and averaged. This average weight is assumed to be uniform for the whole stack. This was followed by counting the number of samples in the stack. This value was then multiplied by the average weight per sample to obtain the total weight of the stack. This method was applied except where there is a large variation between sample sizes. In that case, the stacked waste was sorted out into similar sizes before the method was applied.

Adopted from the research performed by Hong Kong Polytechnic University (Poon *et al.*, 2004), the amount of construction waste

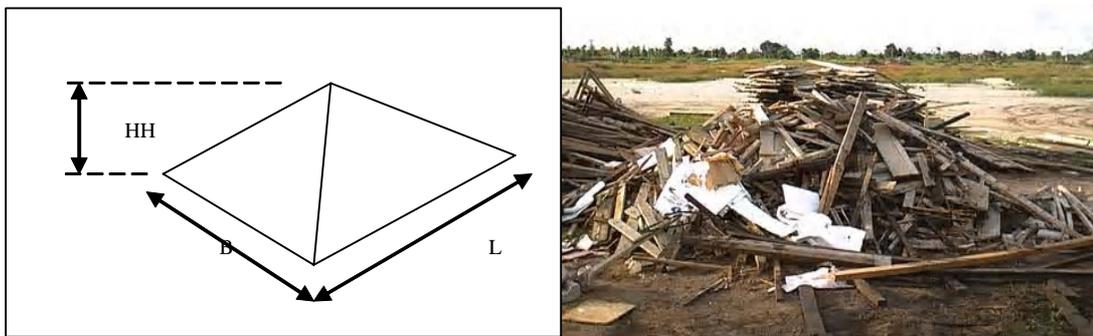


Fig. 2. Stockpiled waste

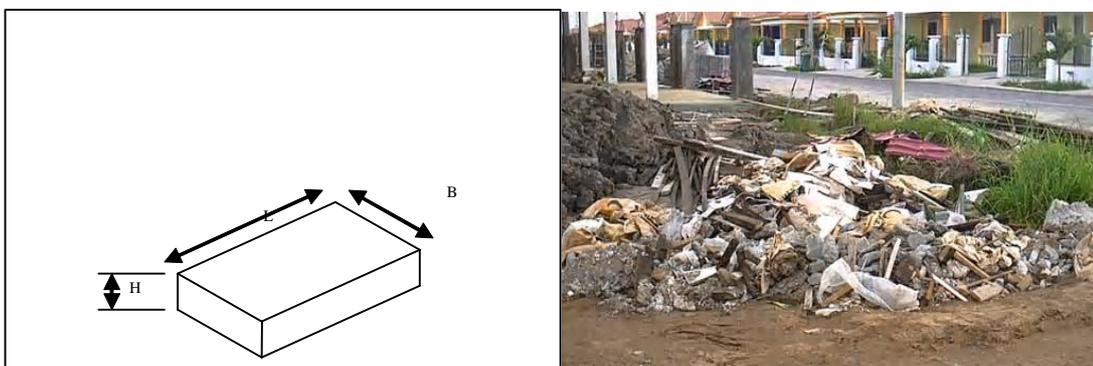


Fig. 3. Gathered waste

generated, in terms of weight, was taken as the net difference between materials ordered and actual materials needed. Interviews were conducted with the contractors and site supervisors on the study sites. The survey basically questions the characteristics of waste generated during the construction process, including the sources and causes of waste generation, and steps taken to reduce it. In addition, regular site monitoring is conducted for this research. Site inspection was carried out at least once per week on the study sites. Associated sources and causes of construction waste generation at different construction stages were documented.

Table 1. Common Sources of Construction Waste Generation

Waste Type	Descriptions	Sources
Wood	Dimensional lumber	Formwork, roof truss
	Plywood	Formwork
	Timber props	False work
	Sawn timber	Formwork, roof truss
Concrete	Substructure	Footings, piling
	Superstructure	Beams, columns, floor slabs
Metal	Drains and gutters	Drainage works
	Reinforcement bar	Reinforcement fixing
	Wire mesh	Reinforcement fixing
	Roofing sheet	Roof
Brick	Aluminium frames	Window, false ceiling
	Clay brick	Wall, fencing works, gutters
	Cement brick	Wall, fencing works, partition walling
Others	Cinder block	Wall, fencing works
	Packaging	Cement packaging, plastics, cardboard, timber pallets
	Gypsum & cement board	False ceiling
	Plaster	False ceiling, finishing works
	Ceramic	Roofing tiles, floor tiles, wall tiles
	PVC Pipe Conduit & wiring	Plumbing works Electrical works

RESULTS & DISCUSSION

The sources of construction waste generation were investigated on all pilot-study sites through field observations and site monitoring,

particularly for the main components of construction waste: wood, concrete, metal, brick and others. The common sources of construction waste generation identified were shown in Table 1. Generation of construction waste covers almost every construction stage. Common causes of construction waste generation observed on the studied sites are off cuts from cutting materials to desired length, improper handling, stacking and storage, end of life cycles, spillage and leftover materials Construction

Table 2. Summary of construction waste generation rates at sites A, B and C

Site	A	B	C
Waste Type	Rate (t/ha)		
Wood	97.99	55.28	80.71
Concrete	18.37	17.91	85.71
Brick	19.28	7.87	42.50
Metal	4.29	2.12	3.57
Others	1.03	3.16	17.22
Total	140.95	86.34	229.72

waste generated per block at Sites A, B and C amounted to 11.79 tonnes, 4.75 tonnes and 12.86 tonnes respectively. The generation rate of construction waste on these sites ranged from 86.34 to 229.72 tonnes per hectare. Based on the generation rates and composition of construction waste as shown in Table 2 and Fig. 4 obtained from Sites A, B and C.

The major components of construction wastes generated are wood, concrete, bricks, metals and others such as waste generated from finishing works, such as packaging of materials, ceramic tiles, and insulation. The associated matters with regard to those waste components are discussed in the following paragraphs. Wood refers to waste resulting from timber products, such as formwork, false work, plywood, dimensional lumber, framing, roof truss and others (US EPA 1998). It was the highest waste stream by means of total weight produced at Sites A and Site B. Wood is widely used in the construction industry and due to the relatively large timber resources available in Sarawak, as well its utilisation by the comparatively cheap labour force in the local construction industry, historically regarded as an expendable resource. Among all the studied sites, the lowest wood generation rate was identified at

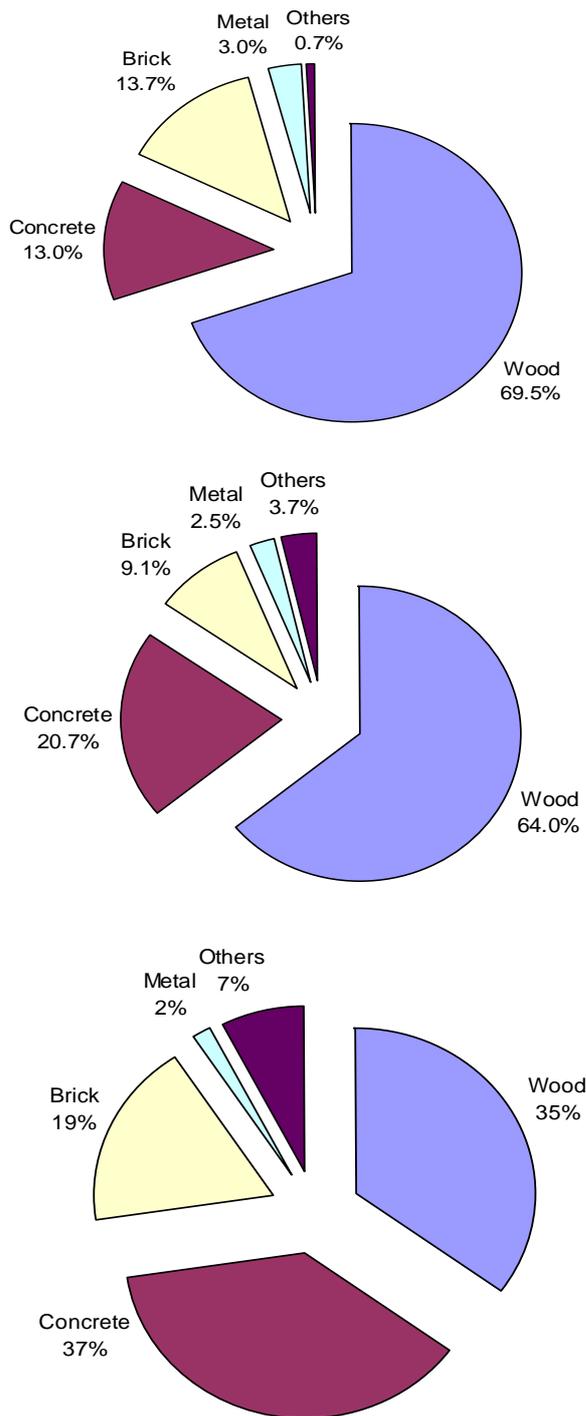


Fig. 4. Composition of construction waste at sites A, B and C

Site B. At site B, formwork and false work were extensively reused. Thus construction works in Site B utilized a comparatively lesser amount of wood in construction. Whereas site A and site C had a relatively similar generation rate. It was actually idealized in this study that 30 % of the wood turned

into waste at the end of the construction, where the remaining 70 % would be reused.

Concrete waste was also one of the major waste streams in construction waste. The concrete waste component made up the highest percentage of construction waste at Site C. Concrete waste generation rates at site A and B were quite similar. There was a large difference among these three sites as Site C's result was idealized through numerical computations and not all of the waste generated can be measured or quantified as at sites A and B. This was because some of them were buried or mixed with other earth materials. Thus, it was no longer identifiable for quantification operation to be carried out. Still, there were some concrete wastes scattering around the site even though some portions were being gathered aside. Brick had always been one of the main components of construction waste. It was lowest in terms of generation rate at Site B. Construction works at Site B consisted mainly of clay brick, comparatively expensive than cement brick or cinder block. Local unloading methods play a part in the generation of brick waste. Again, due to the different methods used for estimation, generation rate at Site C showed a relatively higher value, due to the same reason as for the case of concrete waste. The brick used in Site C comprised solely of cement bricks, one of the cheapest type of bricks available in the market.

Metals are the wastes generated from ferrous or non-ferrous materials, such as reinforcing bars, pipes, steel, aluminum, copper, brass and others (US EPA 1998). It was among the lowest waste generated from the four main components of construction waste. It was mainly due to the relatively high cost and high recycle value in the local market. Off cuts of reinforcement were usually collected and placed properly for future use or recycle. Other metal products, such as steel roofing sheet, aluminium panels and frames, made up an insignificant amount of waste around the site and were normally recollected. Other raisings usually refer to waste generated from finishing works, such as packaging of materials, ceramic tiles, insulation and others (US EPA 1998). A relatively higher

value was obtained at site C however quantification of these wastes was generally difficult due to the scattered form of the waste around the sites. The generation was basically dependent on the practices of the workers on the site. Even with different estimation methods, there was a significant increase of generation rate for this type of waste particularly packaging waste. Packaging waste had always been the biggest waste stream sub-group in Europe.

This study achieved some success despite various constraints in terms of site sampling, waste data collection and others. Due to the small number of the residential development projects in Miri City, the sites were randomly selected according to the criteria identified. However, this was a major restriction to results generated due to the variable differences of design, specification and construction methods at the different project sites chosen. It was also found that there is no collection facility for the construction waste generated on site. Construction waste could be found lying on the site compound, adjacent to the buildings, roadside or even dumped at nearby premises. Poor housekeeping habits complicated the waste data collection as many contractors were interested in other disposal alternatives as long as these alternatives did not result in increased costs. These alternatives were usually cost driven rather than carried out for environmental benefit. In many cases, recycling was driven not by the value of the materials but rather by the avoided cost of disposal. All these factors hampered the waste data collection for this pilot study. At present, no facilities were established for the recovery or recycling of construction waste in Miri City. Whilst waste was being addressed to a very limited extent by different contractors' own ad-hoc means of disposal for economic advantage, it is argued here that the local construction industry needs registration to formalise the waste management process and progress towards increased re-use and recycling of waste raisings.

CONCLUSIONS

Through this pilot study, a better understanding of construction waste generation in Miri City, Sarawak was achieved and the

common causes and sources of construction waste generation for residential projects were determined. As a result, a database of information concerning the quantification of construction waste generated by residential housing projects was developed. An appropriate methodology for performing construction waste assessment was produced and deemed appropriate for further waste assessment studies. An investigation into case-study sites was effectively undertaken with regards to construction waste generation. The results obtained shall help improve current waste management practices in Malaysia by providing useful information concerning representative quantities and the potential for reusing and recycling local construction waste.

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