DEVELOPMENT OF WASTE QUANTIFICATION MODELS FOR MALAYSIAN HOUSING CONSTRUCTION PROJECT: CASE STUDY FOR BRICK AND TILE WASTES

by

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3R	Reduce, Reuse and Recycling
ANOVA	Analysis of Variances
BIM	Building Information Modelling
BQ	Bill Of Quantities
C & D	Construction and demolition
CDW	Construction and Demolition Waste
CIDB	Construction Industry Development Board
CWG	Construction Waste Generation
CWM	Construction Waste Management
EWL	European waste List
IA	Index of Agreement
IBS	Industrialized Building System
JKR	Jabatan Kerja Raya
KPI	Key Performance Indicator
M & E	Mechanical and Electrical
MATLAB	Matrix Laboratory
MFA	Material Flow Analysis
MLR	Multiple Linear Regression
MSW	Municipal Solid Waste
MSWPCMA	Malaysia Solid waste and Public Cleansing Management Act
MWR	Material Waste Rates
NAE	Normalized Absolute Error
NSWMD	National Solid Waste Management Department
OLS	Ordinary Least Square

PA	Prediction Accuracy
PKK	Pusat Khidmat Kontraktor
R2	Coefficient of Determination
SPSS	Statistical Package for Social Science
SWM	Solid Waste Management
SWMPC	Solid Waste and Public Cleansing Management Corporation
USEPA	United State environmental Protection Agency
VIF	Variance Inflation Factor
WGA	Waste generation Area
WGR	Waste Generation Rates
WGR	Waste generation Rates
WMM	Waste Minimization and management
WMP	Waste Management Plan

PEMBANGUNAN MODEL PENGIRAAN SISA BINAAN UNTUK PROJEK PEMBINAAN PERUMAHAN MALAYSIA: KAJIAN KES BATA DAN JUBIN

ABSTRAK

Projek-projek perumahan yang dilaksanakan di Malaysia merupakan salah satu penyumbang utama kepada peningkatan sisa binaan. Sisa binaan yang dihasilkan meningkat dari tahun ke tahun dan seterusnya mendatangkan masalah kepada alam sekitar dan juga kerugian kepada pihak kontraktor. Penghasilan data bagi sisa binaan ini amat terhad terutama dari segi sumber, jenis dan kuantiti sisa binaan. Penghasilan model peramalan sisa binaan yang spesifik juga masih belum mantap. Tujuan kajian ini adalah untuk meneroka sebab-sebab dan faktor penyumbang yang menyebabkan pembaziran bahan buangan dalam projek perumahan terpilih diikuti dengan pembangunan model peramalan kuantiti yang sesuai untuk sisa bata dan jubin, yang merupakan bahan buangan yang biasa dilupuskan di projek perumahan. Kemudian, rangka kerja pengurangan sisa dicadangkan agar ianya boleh digunakan untuk projek yang mempunyai ciri yang hampir sama di tempat lain pada masa akan datang. Pemerhatian tapak dan temu bual dengan tenaga kerja dan pengurusan tapak dijalankan dalam menentukan sumber sisa, amalan pengurusan sisa dan produktiviti tenaga kerja seperti umur, pengalaman dan kewarganegaraan. Model regresi linear digunakan untuk pembangunan model. Sisa pembinaan dalam bentuk konkrit, kayu, keluli, batu bata, jubin, kekuda bumbung, dan jubin bumbung, disiasat secara individu dengan kaedah pengukuran dan isipadu. Penyelidikan mendedahkan bahawa buangan yang dijana dalam pembinaan Malaysia sebahagian besarnya disebabkan oleh masalah buruh dan pengurusan. Kajian mendapati bahawa setiap bahan mempunyai faktor penyumbang sendiri. Produktiviti tenaga kerja juga berkaitan dengan umur, pengalaman dan kewarganegaraan. Peningkatan produktiviti mengurangkan sisa yang dijana di tapak pembinaan Taman Ilmu, Seri Akasia dan Seri Putera. Dua model peramalan sisa telah dimajukan iaitu BW=-2.359+1.605A dan MW=3.361+0.544A (BW= Sisa Bata, MW= Sisa Jubin, A= Luas). Dari hasil ketepatan model ini dalam memprediksi jumlah sampah bata yang dihasilkan di Tapak Taman Ilmu adalah 77.3%, diikuti oleh Tapak Seri Akasia 74.6% dan Tapak Seri Putera 61.6%. Untuk sisa jubin, pembolehubah bebas menjelaskan 91.3% untuk Tapak Taman Ilmu, 84.7% untuk Tapak Seri Akasia dan 72% untuk Tapak Seri Putera. Berdasarkan prestasi model, regresi linear didapati lebih sesuai untuk ramalan sisa jubin. Untuk anggaran awal, model yang dijana dapat meramalkan jumlah sisa bata dan jubin berdasarkan kawasan kerja dari lukisan pembinaan. Ini akan membantu pihak pengurusan tapak bina untuk mengambil tindakan yang sewajarnya untuk meminimumkan jumlah buangan bata dan sisa jubin yang dijana.

DEVELOPMENT OF WASTE QUANTIFICATION MODELS FOR MALAYSIAN HOUSING CONSTRUCTION PROJECT: CASE STUDY FOR BRICK AND TILE WASTE

ABSTRACT

One of the main contributors to the waste generated in the Malaysian construction industry is housing projects. The construction waste has increased over years, creating environmental problems and profit loss to contractors. Limited data are available to date in Malaysia, especially in terms of sources, types and quantity. Predicting of the waste management via specific model has not been well established. The aim of this study are to explore the causes and contributory factors that cause waste generation in selected housing project followed by development of appropriate waste quantification models for the brick and tile waste, being the most waste materials normally disposed at housing project. Then, waste minimization framework is proposed which may be useable for similar project elsewhere. Site observation and interviews with labours and site management was conducted in determining the waste sources, waste management practices and labours productivity such as age, experience and nationality. The linear regression model was used for the model development. Construction waste in form of concrete, wood, steel, brick, tile, roof trusses, and roof tiles, were investigated individually by weighing and volume measurement methods. The research revealed that wastes generated in Malaysian construction are mainly caused by labours and management problems. The study found that each material has its own contributory factor. The productivity of the labours also related to the age, experience and nationality. The increased of productivity reduced the waste generated in the construction at Site Taman Ilmu, Seri Akasia and Seri Putera. Two prediction

models have been developed BW=-2.359+1.605A dan MW=3.361+0.544A (BW= Brick Waste, MW= Tile Waste, A= Area). From the results the accuracy for of the model in predicting the amount of brick waste generated at Site Taman Ilmu is 77.3%, followed by Site Seri Akasia 74.6% and Site Seri Putera 61.6%. For the tile waste, the independent variables explain 91.3% for Site Taman Ilmu, 84.7% for Site Seri Akasia and 72% for Site Seri Putera. Based on performance of the models, the linear regression is found more suitable for the tile waste prediction. For the early estimation, the generated model can predict the amount of brick and tile waste based on the work area from the construction drawing. This will help the site management to take proper action to minimise the amount of brick and tile waste generated

CHAPTER ONE

INTRODUCTION

1.1 Background

The construction industry causes a great influence on the environment. The concern for a sustainable environment has increased the level of awareness among the policymakers in most countries around the world (Lu et al., 2015; Elizar et al., 2015). However, there were several challenges in adopting sustainable issues such as in the area of construction waste (CW) management. As identified by Kamar and Hamid (2011), the challenges in Malaysia were the lack of skills and capacity in this area, overlapping roles among the government agencies, slow industry follow through on government programs, lack of research and innovation, lack of understanding of environmental implications and its solutions as well as the cost and its benefits in terms of green technology operations.

The difficulties were also related to laws and regulations, low proportion of on-site construction waste sorting, poor construction waste reduction, and lack of systemic planning of construction waste recycling facilities (Yuan, 2013). CW generated in many new construction sites such as in new housing developments area are normally buried and hidden. The improper disposal of waste becomes a major menace to the urban area and their surroundings (Williams and Kumar, 2016). Nevertheless, this contributes to the increase of energy consumption, increases greenhouse gas emissions, presents public health issues, and contaminates the environment (Choi et al., 2016). In addition to the environmental pollution, CW could also increase construction cost. The construction material constitutes the biggest proportion of the construction cost (Muhwezi et al., 2012).

Construction waste generation (CWG) is becoming an important issue in Malaysia. This view has been supported by Begum et al., (2010) who mentioned that the production of CW in Malaysia needs to be monitored. Eighty-eight (88) percent of it is generated from the residential construction (Begum and Pereira, 2011). In Malaysia, the CW accounts for approximately forty (40) percent of total solid waste generation (Eusuf et al., 2012). CIDB Malaysia reports the amount of brick and tiles waste contributes to approximately four to ten percent of total waste generation (Hamid et al., 2015). SWCorp report that brick waste contributes to around five to thirty percent of waste generated (SWCorp, 2016). The Malaysian Draft Standard for Construction Solid Waste Management-Code of Practice 2016 also supports the values above (MS 2016).

A systematic waste management practices should be established by looking at the waste generation data. CW management is a process of identifying, analysing, and managing waste on a construction project (Elizar et al., 2015). Generally, contractors in Malaysia do not have a proper waste management system in recording the Waste Generation Rates (WGR) or CW material recovery (May et al., 2016). This is due to the lack of enforcement by the authority to control waste generated at sources. The existing standards such as CIDB Final Report, and Draft Malaysia Standard also have some limitations, especially on the waste quantification data. Earlier, Osmani (2011) confirmed that there is not enough effort and no structured strategy to address the waste data at the source or known as 'design waste' to avoid it from being generated at the construction sites

1.2 Problem Statement

CWG is one of the challenging tasks that are related to the materials used on the site. The attitudes towards good waste management practice are far from what they expected to be. Designers' attitude and their perceived behavioural control are among the determining factors in implementing waste minimization by design (Li et al., 2015).

According to Oyedele (2014), one of the main barriers to become a recycling society is the insufficient knowledge about the waste stream. Waste generation is the key start of this issue. Thus, this issue needs to be addressed properly at all points (Lu et al., 2015). However, the structures of waste generation data are still not well established.

The waste contribution factors data such as labourers and their working area, productivity, management, policy etc. need to be explored. The causes, process and flow of waste generated based on each material activities' flow also has not been found in the previous study especially in the Malaysian housing projects.

The improvement in labour productivity and quality is always related to the reduction in waste. The use of skilled labourers with great age and experience will help to increase the productivity. Normal productivity is measured based on the work per unit time. For the Malaysia housing project, the use of foreign workers as labour requires detail evaluations regarding their nationality, age and skill that may influence the productivity and the amount of waste produced.

Improper waste recording data system will contribute to the difficulties in benchmarking the performance of the global waste system (Atiq and Muhammad, 2016). This has been supported by Bilal et al., (2017) who mentioned that the building materials data such as cost, dimensions, alternative materials, and waste potential remained uncaptured. According to Llatas (2011), many researchers have suggested that contractors should be responsible for quantifying the waste generated at sources. However, there are still no serious actions being taken either by the developer or contractor.

Quantifying the waste generated at sites is the most crucial step in recording the waste data (Li and Zhang, 2013). Even if the accurate amount of waste is impossible to obtain, waste quantification is required to be done. If the contractors cannot predict the quantity of waste in an exact amount, the disposal costs are likely to increase, and this will affect the project's budget considerably.

Osmani (2011) suggested that bills related to the quantity of waste at the early stage of a project will only provide a fundamental measurement of CW in which it brings to unreliable quantification method and often leads to increase wastage up to between 15 and 20 times compared to the original estimation during the construction process. Hence, an accurate quantification strategy for CW is needed to address these issues. Development of waste quantification model is found to be the future strategy for accurate waste estimation. The existing code of practices for waste quantification such as CIDB Final Report on waste minimization and Draft of Malaysia Standard for construction waste has a limitation on the types of data and the prediction on future waste generated. Both codes of practice reported on t composition of waste with a limited case study and prediction techniques s.

The previous model of waste quantification method was developed based on the (WGR) and the average composition of waste materials as mentioned by Cochran et al., (2007) and Bergsdal et al., (2007). This is due to limited site sampling data where these prediction models were not normally designed based on real data from the site. The use of Multiple Linear Regression (MLR) for the waste prediction is new as most of the previous studies predicted the total waste generated and not specific to certain material, especially on brick and tile. Previous studies also generally did not quantify the amount of waste generated per unit of built area.

Based on the problems mentioned, this research aims to predict the exact quantity of CW during the construction stages of a project to address the contributing factors in that stage and to overcome the limitations of existing models, through the development of a linear regression model. To apply this linear regression model, this study focuses on the estimation of brick and tile waste, which accounts for major waste generated in the housing construction from initial to the completion of the project.

This study proposes the development of a CW quantification model for major waste generated in construction projects. The first approach involves the identification of waste causes by using site observation and interview methods. The site observation involves the data collection from initial to completion of projects. The main causes of waste generated are identified by each material that contributes to the causes of waste at sources.

Subsequently, the second approach involves the estimation of the labour's productivity and waste generated by using a case study on selected labor. The labour's productivity relation parameter such as race, age and experience are identified. For the third approach, waste quantification models for brick and mosaic were developed based on the workers and its specified area. The waste minimization plan is proposed based on the three approaches identified.

1.3 Research Objectives

The research aimed to establish basic data on construction waste for a selected housing project from beginning to the end of the project. This research specifically established the following objectives:

a) To analyze the causes of waste generated based on the stage of construction at the selected housing construction sites by observation and interview methods.

b) To determine the relationship between labour productivity (age, experience, nationality) and the brick layer and tile installation labour which may affect the amount of waste generated.

c) To develop a waste quantification model for the brick and tile waste generated during the construction phase using Multiple Linear Regression and to propose a framework of construction waste minimisation plan.

1.4 Significance of the study

Waste quantification models is all about the good practice of site accounting and record keeping. Waste characterization is crucial to identify the composition of construction waste. It is mean to estimate the quantity of construction waste generated, thus assessing the potential for waste reduction. Through assessment or auditing of construction waste, this vital information can be obtained. Thus, a better understanding of construction waste generation regarding causes or source, amount, and compositions are achieved. However, the implementation of more sustainable practices in the industry can be hampered by lack of benchmarking.

Waste quantification can also help in decision making in assessing the feasibility of recycling programs as practised in countries like the US, Hong Kong, and Taiwan. Nonetheless, Malaysia is still lagging behind in establishing the quantified benchmark for construction waste generation rate among its contractors as compared to other countries. There are still limited numbers of studies conducted and literature available about construction waste quantification, especially in building construction projects. Publications related to construction waste for Malaysian's perspective are mainly concerning qualitative approaches such as contractors' attitude, behaviour and current status of waste management practices applied. Hence, the current research aims to fulfil and contributes to filling in some of the above gaps in knowledge.

1.5 Scope and Limitations of the Research

The study is concentrated on the construction waste generated from housing projects during the construction stages from initial to the end of the projects. Renovation and demolition wastes are excluded.

Three selected housing projects in the northern region of Malaysia were observed to quantify the waste generated in the projects. The construction of the three different projects were observed starting from the foundation stage until the completion of the project. For the waste source detection, the major types of waste generated at the housing construction sites are identified. The causes and sources of waste are discussed in detail starting from the materials entering the sites until the completion of each project. This study does not include the infrastructure and drainage work.

For the relationship between labour's productivity and waste generated, the age, experience and nationality of the labourers involved in the tile and brick activities are measured in this study. The parameter is selected based on the characteristics and productivity of the labour. The developed model focuses on the brick and tile waste only.

1.6 Thesis Layout

This thesis consists of seven chapters and brief outlines for each chapter are as follows:

Chapter One discussed an overview of construction waste management in Malaysia, problem statement and scope of the research.

Chapter Two summarized the literature review for waste management which including solid and construction waste. It introduces an overview of municipal solid waste and construction waste which includes the definitions, causes of waste generated, characteristics, waste management practices, laws, workers' productivity and waste minimization. The methods of waste quantification are also highlighted. Finally, it discusses the previous waste quantification model for the construction waste.

Chapter Three described the methods applied to this research. The methods have been discussed by objectives of the study. Data collection methods such as site observation, interview and site sampling have been used in this research. Data analysis such as correlation and regression is used in this study. Multiple linear regression models applied for this research to predict the amount of tile and brick waste generated.

Chapter Four analyzed the causes of waste generated via site sampling and developed the equation based entirely on each material activities' flow. The research presents a realistic perspective of site waste implementation in Malaysian housing construction. The main kinds of waste, including concrete, wood, steel, brick, tile, roof trusses, roof tiles, and sanitary fittings are investigated individually in this research. This chapter also described the relation of labour productivity towards waste generated. The discussion of brick and tile layer productivity and their parameters such as age, experience and nationality are discussed. This chapter also discussed finding new models for the brick and tile waste generated. The MLR models were developed and all findings for these models were discussed. The framework for the waste minimization is developed and discussed.

Chapter Five provided the conclusions of this research for further work.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter consists of three parts. The first part discusses the municipal solid and construction waste, which includes the definitions, causes of waste generated, characteristics, waste management practices, waste minimization, laws and workers' productivity. The second part explains the methods of waste quantification. Then, the last part discusses the previous waste quantification model for the construction waste.

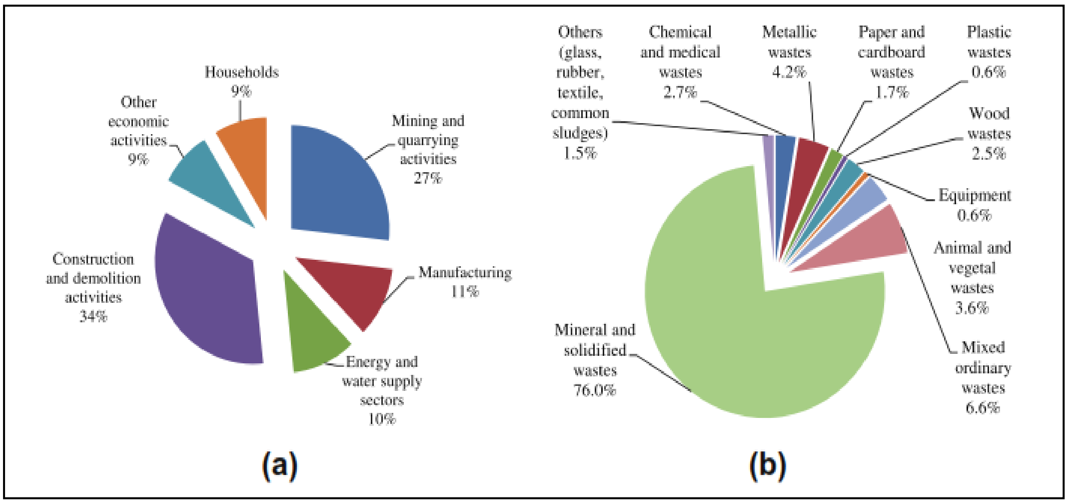
2.2 Municipal Solid Waste

Waste can be defined as the excessive use of resources more than it's needed, or an unwanted output from the production (Formoso et al., 2015; Bolviken et al., 2014). The US Environmental Protection Agency (2013) stated that Municipal Solid Waste (MSW) consists of everyday items that are used and then being thrown away. MSW includes packaging products, grass clippings, furniture, clothing, bottles, food scraps, newspapers, appliances, paints, and batteries. The sources of such wastes are from homes, schools, hospitals, and business area. MSW is a term that usually applies to a heterogeneous collection of wastes produced in urban areas, the nature of which varies from region to region (UNEP, 2005).

MSW consists of household waste, construction and demolition debris, horticulture and waste from the street. MSW can be segregated into few groups, such as bio-degradable, recyclable and hazardous waste. Biodegradable waste is the organic waste from kitchens, market and abattoir that can be converted into rich organic manure or energy. Plastics, papers, glasses and metals are to be recycled into new products (Municipal Solid Waste Management Manual, 2016).

According to Eurostat (2014), the total amount of waste generated in the European Union in 2010 was over 2.5 billion tonnes of which almost 35% (860 million tonnes) is derived from construction and demolition activities. Figure 2.1 shows the total waste generated in European Union, according to (a) economic activity and (b) waste category.

Figure 2.1: Total waste generated in European Union according to:
(a) economic activity, (b) waste category



The Malaysia Solid Waste and Public Cleansing Management Act 2007 (Act 672) defined solid waste as controlled solid wastes that include the commercial, construction, household, industrial, institutional, imported and public solid waste. “Solid waste” includes a) Any scrap materials or other unwanted surplus substances or rejected products arising from the application of any processes or b) Any substances required to be disposed due to being broken, worn out, contaminated, or spoiled, or c) Any other materials that according to this act or any other written law is required by the authority to be disposed of.

The Malaysian solid waste contains a high concentration of organic waste and consequently has high moisture content (Badgie et al., 2012). According to studies conducted by Kamaruddin et al., (2016) which is an assessment of municipal solid waste generation, composition and recyclable potential at selected Kelantan's dumping sites, the analyzed results of the component showed that organic fraction is dominant (28-44%), followed by paper (12.5-22%), tetra pack (11.5-12.5%), plastic film (3.4-8.49%) and plastic rigid (6.22-14.84%). In this study, each of waste fractions was weighed and recorded for future analysis. The mean of waste component was calculated by using the previous results of the composition from sorting samples. Each sorting sample, weigh about 90-120 kg, whereas the classification of MSW, were divided into 15 specific categories as shown in Table 2.1. The population trends and wastes arising in Malaysia in years 1970-2014 is shown in Table 2.2.

Table 2.1: Waste composition criteria based on MS2505:2012
(Sources: Kamaruddin et al., 2016)

No	Category	Description
1.	Food/organic waste	Raw food waste during food preparations, leftover food
2.	Papers	All types of papers including newspaper, cardboard, magazines, books, black and white paper, envelopes etc.
3.	Tetrapak	Carton used for packaging liquids
4.	Plastic film	All plastics including plastic bags/films, polystyrene, foam
5.	Plastic rigid	All plastic bottles, container, pipes and fittings
6.	Napkins	Disposable diapers for babies and elderly, ladies sanitary napkins
7.	Textiles	All textiles including clothes, shirt, bed sheet, curtains, pants and other household items made from man-made or natural fibres.
8.	Rubber	All rubber including gloves, handbags, shoes, rubber mat
9.	Leather	All plastics including plastic bags/film
10.	Wood	Lumber, wood products, pellets
11.	Garden	Branches, twigs, leaves, grass and other plant materials
12.	Glass	All glass such as brown glass, green glass, clear glass, other coloured glass and non-packaging glass
13.	Metal	Ferrous and non-ferrous (e.g., copper, iron, steel, tins cans and aluminium cans)
14.	Household hazardous waste	Batteries, aerosol can, medicines, light bulbs, pesticides, E-waste

Table 2.2: Population trends and wastes arising in Malaysia in years 1970-2014 (Sources: Mukhtar et al., 2016)

Years	**1970s**	**1980s**	**1990s**	**2000s**	**2010s**	**2014**
	MALAYSIA					
Population (10^6)	10.91	13.83	18.21	23.42	28.28	30.60
GDP (billion USD)	4.28	24.94	44.02	93.79	247.5	338.10
Annual waste generation (10^6 tonnes)	0.11	0.32	5.57	5.69	10.26	11.43
National recycling rate (%)	NA	NA	NA	NA	NA	NA
Per capita waste (kg.capita/day)	0.03	0.06	0.84	0.67	0.00	1.02

Based on the Ministry of Housing and Local Government data, in 2007 construction industry generated 26,459 tonnes of construction waste in Malaysia, contributed to the highest percentage of solid waste (37%), followed by households, commerce and institutions (33%); industrial (21%); special waste (7%); public places (2%) as shown in Figure 2.2.

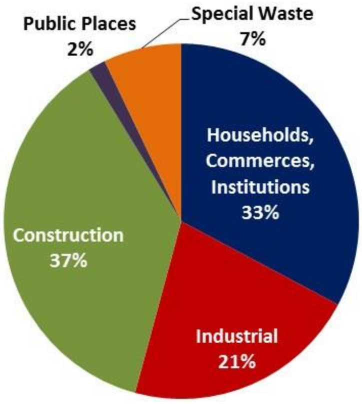


Figure 2.2: Solid waste generated by sectors
(Source: Adapted from Danida Report, 2010)

2.3 Construction Waste

The construction sector is large, complex and diverse covering a wide range of business activities. Construction projects can be classified in several ways. A common classification is either building or civil engineering projects (Al-Rifai and Amoudi, 2016). Basically, an extremely large amount of waste is believed to occur in buildings (Umar et al., 2016).

General solid waste is normally classified into three main categories which are MSW, construction and demolition waste (CDW), and other special waste for management and planning purposes (Wu et al., 2015). Construction waste means any substances or objects (such as bricks, concrete and steel) which is generated as a result of construction work and should be discarded as it no longer can be used as part of the construction process (Al-Rifai and Amoudi, 2016).

CDW has negative impacts on the efficiency of the construction industry, the country economy at large and the environment (Al-Rifai and Amoudi, 2016). The form of this impact can be either air or water pollution and its associated energy usage.

Demolition waste is waste debris from the destruction of a building (Ponnada et al., 2015). Certain components of demolition waste such as plasterboards are hazardous once landfill as it is broken down in landfill conditions releasing hydrogen sulphide, a known toxic gas.

Developing countries have practised the reusing and recycling of a portion of CDW mainly to reduce construction costs. However, industries are growing more interested in CDW treatments due to the implementation of green building standards. According to Ponnada and Kameswari (2015), the reasons to recycle CDW wastes are simple but compelling. The CDW is one of the largest waste streams in the country.

A lot of site wastes are recyclable and cost much less to recycle it at the job site than to throw them away. Moreover, these waste problems also bring burden to the government due to the high cost of cleaning and maintenance of solid waste and more troubling is the fact that the amount of waste disposal capacity cannot accommodate anymore the amount of solid waste at landfill area (Umar et al., 2016).

In a construction site, there are many types of construction waste depending on their physical, chemical, biological and also composition properties (Eusuf et al., 2012). Waste generated at construction sites is usually due to defective materials, leftover materials, wastage, etc.

Umar et al., (2016) stated that CDW is produced during the new construction, demolition, and renovation of buildings and structures. CDW consists of concretes, bricks, soil, rocks, lumbers, masonries, soil, glass, plastics, steel, aluminium, drywall, insulation, plumbing fixtures, electrical materials, asphalt roofing, materials and corrugated cardboard. Basically, an extremely large amount of waste is believed to occur in buildings. Non-physical waste also normally occurred during the construction process such as rework, waiting time, unnecessary transportation, delay in moving materials and others (Nagapan, 2014).

2.3.1 Characteristics of Construction Waste

The characteristics of the construction waste are important to understand its waste management protocol. The characteristics of construction waste differ according to the types of waste. The characteristics of construction wastes are large in size, lacks in malleability and hazardous (Agamuthu, 2008).

Special attentions are needed for the construction materials that are hazardous. However, the waste leachability, types of contaminants and the toxicity may risk the underground waters. The literature includes many citations of the groundwater contamination caused by leaching from construction sites (Merino, 2010).

Waste from construction site waste might consist of materials that contain high levels of contamination which are very hard to recycle. The prevention of construction waste is preferable to the recycling of demolition waste process "at the end of the pipeline". Construction waste may contain a relatively large amount of chemical waste. The cost reduction caused by preventing the generation of construction waste is a direct benefit for most stakeholders in the construction industry.

2.3.2 Composition of Solid Waste

The generation of the waste in a construction site is unpredictable due to the lack of construction waste data and an established system or platform for recording those data. At least 10% of the building materials for every construction project are wasted, according to Sir Egan's Rethinking, Construction report on the state of UK construction Industry, (Egan, 1998). Bossink and Brouwers (1996) conducted a waste segregation research on five construction sites in the Netherlands which demonstrated waste components in percentages of the total amount of waste generated, and the research showed that between 1% and 10% of each material type delivered to the sites was wasted. The wastage level for the building materials is shown in Table 2.3 derived from CIDB Report, (Hamid et al., 2015).

Table 2.3: Wastage level for building materials

Material	**Wastage Level (%)**	**Range of Level (%)**
Concrete (*in-situ concreting*)	5	5 –10
Bricks and Blocks	6	5 –10
Tiles and ceramic (*eg. roofing tiles, floor tiles, wall tiles*)	5	4 –10
Steel		
Reinforcement bar	5	4 – 8
Wire mesh	5	3 – 7
Steel formwork	2	1 – 5
Cement (*eg. wall/floor screeding*)	5	5 – 10
Wood		
Timber formwork	8	5 –13
Roof truss	5	2 – 7
Gypsum and Cement boards	5	4 –10
Packaging materials		

Paper	20	5 –50
Cardboard	15	5 –50
Plastic	20	6 –50
Plaster (*eg. wall and ceiling plastering*)	5	5 –10
Glass (*eg. window glass*)	2	1 – 5
PVC pipe (*eg. plumbing works*)	5	4 – 7
Conduit & wiring (*eg. electrical works*)	5	3 – 8

Compared to the research conducted by Nagapan et al., (2013) shown in Table 2.4, it stated that the dominant waste produced at the construction site was timber material, brick material and packaging. The research was focussed on the construction waste in Southern Malaysia which is in Batu Pahat, Johor.

Table 2.4 Amount of construction waste generated in Batu Pahat, Johor (Nagapan et al., 2013)

Types of wastes	**Quantities measurement in cubic meter (m^3) or percentages (%)**					
	Site A		Site B		Site C	
	m^3	%	m^3	%	m^3	%
Timber	19.69	46	39.54	50	241.43	80
Metals	1.54	4	0.44	1	13.49	5
Bricks	6.48	15	17.27	22	16.50	5
Concrete	1.44	3	7.44	9	9.14	3
Mortar	2.48	6	1.38	2	10.85	4
Packaging	11.33	26	12.43	16	10.03	3
Total	42.96	100	78.5	100	301.44	100

Referring to the composition of the construction waste, it is changeable and depends on the type of construction activities (Papargyropoulou, 2011). The major components of construction wastes are generated from wood, concrete, bricks, metals and others such as waste generated from finishing works which include packaging of materials, ceramic tiles, and insulation (Lau, 2008). Lau (2008) named the three-study site in his study as Sites A, B and C. Wood is found to be a major waste generated in Sites A and B. He also found out that brick had always been one of the main components of construction waste. It was found to be the lowest in terms of generation rate at Site B. Construction works at Site B consisted mainly of clay bricks which are comparatively more expensive than cement brick or cinder block. The local unloading methods play a part in the generation of brick waste. The bricks used at Site C comprised solely of cement bricks, one of the cheapest type of bricks available in the market. Metal was the lowest waste generated from the four main components of construction waste. This was mainly due to the relatively high cost and high recycling value in the local market. Offcuts of reinforcements were usually collected and placed properly for future use or recycle. The other study by Noor et al., (2013) in Klang Valley, Malaysia shows the generation rates in superstructure stage and finishing stage for the one-storey unit house. Table 2.5 shows the generation rate of CW in the superstructure stage.

Table 2.5: Generation rate of construction waste for one-storey unit house between Site CS1, CS2 and CS3 in superstructure stage (Sources: Noor et al., 2013)

Types of Construction Waste	**Site CS1 (Tonne/m^2)**	**Site CS2 (Tonne/m^2)**	**Site CS3 (Tonne/m^2)**	**Average of Generation Rate (Tonne/m^2)**
Wood	0.0048	0.0069	0.0012	0.0079
Metal	0.0028	0.012	0.003	0.0023
Concrete	0.002	0.0013	0.001	0.0014
Soil, Aggregate and Sand	0.0009	0.0007	0.002	0.0012
Soil	0.0009	0.0005	0.002	0.001
Aggregate	-	-	-	0.0002
Sand	-	0.0002	-	-

Noor et al., (2013) identified the major components of construction wastes generated for superstructure stages wood, metal and concrete. Timber refers to the waste resulting from formwork, plywood, framing, roof truss and others where it is widely used in the construction industry. It was the highest waste stream using total weight produced at Site CS1 and Site CS2. The lowest wood generation rate was identified at Site CS3 where it was extensively reused in the construction site.

Table 2.6 shows the generation rate of CW for a one-storey unit house between Site CS4 and Site CS5. Bricks, cement and packagings (paper bags and plastic bags) are the major components of CW generated from finishing works. Brick has always been one of the main components of CW. It was the highest waste stream using total weight produced at Site CS4 compared to Site CS5 since bricks that were used in the construction work at the Site CS4 comprised more of cement bricks than clay bricks, one of the cheapest types of bricks available in the market.

Table 2.6: Generation rate of construction waste for a one-storey unit house between Site CS4 and Site CS5 in finishing stage (Sources: Noor et al., 2013)

Types of Construction Waste	**Site CS4 (Tonne/m^2)**	**Site CS5 (Tonne/m^2)**	**Average of Generation Rate (Tonne/m^2)**
Bricks	0.00074	0.00056	0.00065
Ceramic/Tiles Packaging	0.00001	0.00027	0.00014
Paper Begs	0.00029	0.00017	0.00023
Plastic Begs	0.00023	0.00007	0.00015
Insulation Material	0.00005	0.00010	0.000075
Gypsum	0.00004	0.00010	0.000007
Glass	0.000016	0.000003	0.000010
Concrete	0.000003	0.000004	0.000004
Soil, Aggregate and Sand	0.000056	0.000216	0.000136
Soil	0.000026	0.000296	0.000161
Cement	0.000026		
Others	0.000233	0.000298	0.000162
Plaster	0.00001	0.00052	0.00037
Cement Screed	0.000004	0.00001	0.00001

As compared to the previous study, the sampling data in the current study, considered from initial to completion of projects. Waste sampling data of more than 30 samples. The variety of samples represent a good analysis.

2.3.3 Characterization of Brick Waste

Brick is the common materials used in construction. According to Eusuf et al., (2012), bricks is one of the common materials that is used to form the divider of the building. Bricks can be constructed to become walls, staircase, pavements or others in masonry constructions. The size of the bricks is commonly eight inches long and four inches thick. There are many types of bricks that are produced for the constructions such as clay brick, cement bricks, sand-lime bricks and engineering bricks.

Bricks can be reused or renewed to minimize the bricks wasted, (reusable and renewable). According to Nagapan et al., (2012), some of the construction waste like broken bricks and concrete can be reused as a subgrade of access road to the construction. The brick has multipurpose in which is more focused towards walls, fencing and pavements.

2.3.4 Characterization of Tile Wastes

A tile is a manufactured piece of hard-wearing material such as ceramic, stone, or glass (Ngapan et al., 2015). Tiles are generally used for covering roofs, floors, walls, showers and table tops. The tiles can be reused and recycled for the other purposes. Tiles that become waste can be used on landscaping. These wasted tiles can be used on the pavement so that it can function as a pedestrian area for the people in the garden to walk.

Ceramic tiles have been generated at an increased rate throughout the world today, particularly in Turkey as the leading producer in Europe and China as the world leader. The fact is that each year, approximately 250,000 of tiles are worn out, while 100 million tiles are used for repairs in the world (Topcu and Canbaz, 2007).

2.4 Code of Practices in Solid Waste Management

Legislation or regulations are very instrumental in developing markets for recycled CDW. Many recyclers believed that government mandate requiring the use of recycled materials would force new markets to develop. For example, there is a forced article to use the recycling of concrete or asphalt in the renovation works of highways in the United States (Hussein et al., 2016).

In the United Kingdom, the Site Waste Management Plan (SWMP) is applied throughout the construction phases based on the hierarchy of reuse, recycle, recover, and disposal. The contractor could be fined up to £50, 000 (USD60, 936) under The Site Waste Management Plans Regulations 2008 if they fail to manage their construction waste properly (Safety Agenda Ltd., 2015). Meanwhile, there are already best practice guidelines on the preparation of waste management plan for construction and demolition projects which revolve around the hierarchy of prevention, minimization, reuse, recycle, and dispose of in Ireland (Department of the Environment, Heritage, and Local Government, 2006).

By using REBRI tools, the same hierarchy has also been applied in developing the waste management plan in New Zealand (Branz Inc., 2016), where several steps should be taken to develop the plan by estimating the waste types and amounts at the planning stage of the project according to the hierarchy. Under New Zealand's Waste Minimisation Act 2008 (Ministry for the Environment, 2008), $10 (USD7.15) for waste disposal levy will be imposed for each tonne of waste sent to landfill will be imposed.

In Malaysia, a number of policies and legislations on environmental management and waste have been introduced such as the Solid Waste and Public Cleansing Management Act 2007 (PPSPPA) governed by Ministry of Housing and Local Development (KPKT), Standard Specifications for Buildings Works (SBW)