A COMPARATIVE STUDY OF CONSTRUCTION WASTE GENERATION RATE BASED ON DIFFERENT CONSTRUCTION METHODS USED IN CONSTRUCTION PROJECTS IN MALAYSIA

HARITHARAN A/L MANIAM

A project report submitted in partial fulfillment of the requirement for the award of the Degree of Master of Civil and Environmental Engineering

Faculty of Civil and Environmental Engineering
Universiti Tun Hussein Onn Malaysia

JANUARY 2019
DEDICATION

To my lovely mother and father, who gave me endless love, trust, constant encouragement over the years, and for their prayers.

To my sister, who gave me moral support in all forms, and motivates me always.

To my brothers, for their patience, support, love, and prayers.

To my friends, for their endless support.

This thesis is dedicated to them.
I wish to express my deepest appreciation to all those who helped me, in one way or another, to complete this thesis. First and foremost, I thank God almighty who provided me with strength, direction and showered me with blessings throughout. My sincerest gratitude to my supervisor Ts. Dr. Sasitharan Nagapan and co-supervisor Prof. Madya Ts. Dr. Abd Halid Bin Abdullah, for their continuous guidance and support. With their expert guidance and immense knowledge, I was able to overcome all the obstacles that I encountered during my journey of Master’s in Civil Engineering. I could not have imagine having a better advisors and mentors like them.
ABSTRACT

In Malaysia, the huge generation of construction waste (CW) has led to negative impact on the environment. Limited data is available on quantification methods of CW in the country. The lack of quantification methods has resulted to the improper management of CW. The consequence of the improper CW management has shortened the lifespan of landfills. The aim of this study is to compare the construction waste generation rate between different construction methods. In order to obtain CW data in terms of volume and weight, the site visit (SV) method was carried out for a 3-month period. There are two types of SV methods applied in this study, namely direct measurement and indirect measurement. The data were collected from 12 social amenities projects at the construction stage which can be divided into the Conventional Construction Method (CCM), the Mixed Construction Method (MCM) and the Industrialised Building System (IBS). The waste (tonnes) obtained from each construction method is divided by gross floor area (m²) to attain the Waste Generation Rate (WGR). Finally, the result of the study revealed that the WGRs for IBS, MCM and CCM are 0.018 tonne/m², 0.030 tonne/m² and 0.046 tonne/m² respectively. It can be concluded that the IBS method is the most effective method to reduce CW generation on site. This finding will be a contribution for construction players, policy makers and authorities in the country to promote IBS methods more rigorously.
ABSTRAK

Penjanaan sisa pembinaan (CW) yang tinggi telah memberikan impak negatif kepada alam sekitar di Malaysia. Data mengenai kaedah pengukuran CW adalah sangat terhad di negara kita. Kekurangan kaedah pengukuran telah membawa kepada pengurusan CW yang tidak teratur. Kesan daripada pengurusan CW yang tidak teratur, telah mengurangkan jangka hayat tapak pembuangan sampah. Tujuan penyelidikan ini adalah untuk membandingkan antara kadar penjanaan sisa pembinaan dengan kaedah pembinaan. Untuk mendapat data penjanaan CW dalam isipadu dan berat, kaedah melawat tapak (SV) telah dijalankan selama 3 bulan. Terdapat 2 jenis kaedah SV, iaitu pengukuran langsung dan pengukuran tidak langsung. Data telah dikutip daripada 12 projek ameniti sosial dalam peringkat pembinaan yang dibahagikan kepada Kaedah Pembinaan Konvensional (CCM), Kaedah Pembinaan Bercampur (MCM) dan Kaedah Pembinaan Industri (IBS). Berat sisa (tonne) yang didapat daripada setiap kaedah pembinaan telah dibahagikan dengan jumlah kasar keluasan lantai (m²) untuk mendapat kadar penjanaan sisa (WGR). Akhirnya, dapatan kajian ini membuktikan bahawa WGR untuk IBS, MCM dan CCM adalah 0.018 tonne/m², 0.030 tonne/m² dan 0.046 tonne/m². Konklusinya, kaedah IBS adalah kaedah yang paling efektif berbanding dengan yang lain untuk mengurangkan CW di tapak. Kajian ini akan menjadi satu sumbangan bagi pemilik pembinaan, kerajaan dan juga pihak berkuasa di dalam negara untuk menggalakkan kaedah IBS dengan lebih baik.
## CONTENTS

<table>
<thead>
<tr>
<th>TITLE</th>
<th>i</th>
</tr>
</thead>
<tbody>
<tr>
<td>DECLARATION</td>
<td>ii</td>
</tr>
<tr>
<td>DEDICATION</td>
<td>iii</td>
</tr>
<tr>
<td>ACKNOWLEDGEMENT</td>
<td>iv</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>v</td>
</tr>
<tr>
<td>ABSTRAK</td>
<td>vi</td>
</tr>
<tr>
<td>CONTENTS</td>
<td>vii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>xi</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>xii</td>
</tr>
<tr>
<td>LIST OF SYMBOLS AND ABBREVIATIONS</td>
<td>xiii</td>
</tr>
<tr>
<td>LIST OF APPENDICES</td>
<td>xiv</td>
</tr>
</tbody>
</table>

### CHAPTER 1 INTRODUCTION

1.1 Research background  
1.2 Problem statement  
1.3 Research questions  
1.4 Research aim and objectives  
1.5 Research scope  
1.6 The significance of the research  
1.7 Summary  

### CHAPTER 2 LITERATURE REVIEW

2.1 Introduction  
2.2 Definition  
2.3 Type of construction waste  
 
2.3.1 Concrete  
2.3.2 Wood
CHAPTER 2  WASTE GENERATION FROM CONSTRUCTION PROJECTS

2.3.3 Steel/Metal 11
2.3.4 Packaging waste 11
2.3.5 Ceramic and tiles 11
2.3.6 Mixed waste 11
2.4 Physical waste 12
2.5 Non-physical waste 12
2.6 Construction waste generation issues in other countries 13
2.7 Construction waste generation issues in Malaysia 14
2.8 Construction methods 16
2.8.1 Conventional construction method (CCM) 16
2.8.2 Non-conventional 16
2.8.2.1 Industrialised Building System (IBS) 17
2.8.2.2 Mixed construction method (MCM) 17
2.9 Types of projects 18
2.9.1 Residential projects 19
2.9.2 Non-residential projects 19
2.9.3 Social amenities projects 19
2.9.4 Infrastructure projects 21
2.10 Project type selection 21
2.11 Cost-analysis 25
2.12 Summary 25

CHAPTER 3  METHODOLOGY

3.1 Introduction 26
3.2 Research flowchart 26
3.3 Research location 28
3.4 Preliminary data collection 29
3.4.1 Challenges during preliminary studies 29
3.5 Quantification method 32
3.5.1 Method proposed by local researchers 34
3.5.2 Direct measurement 36
3.5.3 Indirect measurement 38
3.5.4 Generation rate calculation (GRC) 39
CHAPTER 4 RESULTS AND DISCUSSION 42

4.1 Introduction 42

4.2 Total construction waste data for each site 42

4.2.1 Construction waste from conventional construction method (CCM) 43

4.2.2 Construction waste from Industrialized Building System (IBS) method 44

4.2.3 Construction waste from mixed construction method (MCM) 46

4.3 Construction waste 47

4.4 Waste generation rate (WGR) 48

4.4.1 WGR from conventional construction method (CCM) 48

4.4.2 WGR from Industrialized Building System (IBS) 49

4.4.3 WGR from mixed construction method (MCM) 49

4.4.4 Average waste generation rate (AWGR) 50

4.5 Current construction methods practiced at construction site 51

4.6 Wastage at construction site 52

4.7 Findings from previous studies 53

CHAPTER 5 CONCLUSION AND RECOMMENDATIONS 54

5.1 Achievement of objectives 54

5.1.1 To identify the current construction methods practiced at a construction site 54
5.1.2 To quantify construction waste generation rate for each construction method 55
5.1.3 To compare the construction waste generation rate among different construction methods. 55
5.2 Importance of the study 56
5.3 Conclusion 57
5.4 Recommendation 57
REFERENCES 59
APPENDICES 66
## LIST OF TABLES

1.1 Research Scope 3  
2.1 Construction waste definition by different authors 7  
2.2 Typical construction waste 9  
2.3 Construction waste generation studies in Malaysia according to the number of sites 14  
2.4 Data collection period of waste generation studies in Malaysia 15  
2.5 Construction method studied by Malaysian authors 17  
2.6 Type of project by authors 21  
2.7 Previous studies on construction waste generation rate 23  
3.1 Project details and the average waste generated 28  
3.2 List of projects visited in Kuala Lumpur 31  
3.3 Waste measurement and method used by authors 33  
3.4 Density of the waste composition 36  
4.1 Data collection using respective construction method 43  
4.2 Construction waste from CCM site 43  
4.3 Construction waste from IBS method site 45  
4.4 Construction waste from MCM site 46  
4.5 Waste generation rate for CCM 48  
4.6 Waste generation rate for IBS 49  
4.7 Waste generation rate for MCM 50  
4.8 Average waste generation rate for the three construction methods 50
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1</td>
<td>Category of construction waste</td>
<td>12</td>
</tr>
<tr>
<td>3.1</td>
<td>Research methodology flowchart</td>
<td>27</td>
</tr>
<tr>
<td>3.2</td>
<td>Residential buildings in Kuala Lumpur</td>
<td>30</td>
</tr>
<tr>
<td>3.3</td>
<td>The research team</td>
<td>30</td>
</tr>
<tr>
<td>3.4</td>
<td>Examples of indirect measurement</td>
<td>31</td>
</tr>
<tr>
<td>3.5</td>
<td>Tree for methodology selection</td>
<td>35</td>
</tr>
<tr>
<td>3.6</td>
<td>Process of field measurement method</td>
<td>36</td>
</tr>
<tr>
<td>3.7</td>
<td>Stockpiled waste</td>
<td>37</td>
</tr>
<tr>
<td>3.8</td>
<td>Gathered waste</td>
<td>37</td>
</tr>
<tr>
<td>3.9</td>
<td>Sample DO records</td>
<td>38</td>
</tr>
<tr>
<td>3.10</td>
<td>RORO bin measurement</td>
<td>39</td>
</tr>
<tr>
<td>3.11</td>
<td>Calculation step of direct &amp; indirect measurement</td>
<td>40</td>
</tr>
<tr>
<td>4.1</td>
<td>Construction waste obtained from CCM sites</td>
<td>44</td>
</tr>
<tr>
<td>4.2</td>
<td>Construction waste obtained from IBS method</td>
<td>45</td>
</tr>
<tr>
<td>4.3</td>
<td>Construction waste obtained from MCM site</td>
<td>47</td>
</tr>
</tbody>
</table>
**LIST OF SYMBOLS AND ABBREVIATIONS**

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AWGR</td>
<td>Average waste generation rate</td>
</tr>
<tr>
<td>BQ</td>
<td>Bill of quantities</td>
</tr>
<tr>
<td>CIDB</td>
<td>Construction Industry Development Board</td>
</tr>
<tr>
<td>CITP</td>
<td>Construction Industry Transformation Programme</td>
</tr>
<tr>
<td>CCM</td>
<td>Conventional construction method</td>
</tr>
<tr>
<td>CPC</td>
<td>Central product classification</td>
</tr>
<tr>
<td>CSA</td>
<td>Classification system accumulation</td>
</tr>
<tr>
<td>CW</td>
<td>Construction waste</td>
</tr>
<tr>
<td>DM</td>
<td>Direct measurement</td>
</tr>
<tr>
<td>DO</td>
<td>Delivery order</td>
</tr>
<tr>
<td>FM</td>
<td>Field measurement</td>
</tr>
<tr>
<td>GRC</td>
<td>Generation rate calculation</td>
</tr>
<tr>
<td>IBS</td>
<td>Industrialised Building System</td>
</tr>
<tr>
<td>IM</td>
<td>Indirect measurement</td>
</tr>
<tr>
<td>MCM</td>
<td>Mixed construction method</td>
</tr>
<tr>
<td>RORO</td>
<td>Roll-on Roll-off</td>
</tr>
<tr>
<td>SV</td>
<td>Site visit</td>
</tr>
<tr>
<td>SWCorp</td>
<td>Solid Waste Corporation</td>
</tr>
<tr>
<td>UN</td>
<td>United Nation</td>
</tr>
<tr>
<td>VM</td>
<td>Variables modelling</td>
</tr>
<tr>
<td>WGR</td>
<td>Waste generation rate</td>
</tr>
<tr>
<td>WRAP</td>
<td>Waste and Resources Action Programme</td>
</tr>
</tbody>
</table>
# LIST OF APPENDICES

<table>
<thead>
<tr>
<th>APPENDIX</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Preliminary data collection</td>
<td>66</td>
</tr>
<tr>
<td>B</td>
<td>Timber and mixed wasterd</td>
<td>68</td>
</tr>
<tr>
<td>C</td>
<td>Obtained example of delivery order from site</td>
<td>75</td>
</tr>
<tr>
<td>D</td>
<td>Permission letter from CIDB</td>
<td>70</td>
</tr>
<tr>
<td>E</td>
<td>Milestone chart</td>
<td>70</td>
</tr>
<tr>
<td>F</td>
<td>Social amenities site details</td>
<td>71</td>
</tr>
<tr>
<td>G</td>
<td>Example of indirect data sheet</td>
<td>72</td>
</tr>
<tr>
<td>H</td>
<td>Example of direct data sheet</td>
<td>74</td>
</tr>
<tr>
<td>I</td>
<td>Example of Direct Measurement Calculation</td>
<td>76</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Research background

The construction industry plays an important role in promoting the growth of the economy to achieve the target of plausible development in Malaysia (Mah, Fujiwara, & Ho, 2016). Construction waste refers to unwanted substances generated during the construction period and renovation of structures (Yeheyis et al., 2016).

As the construction of infrastructure and buildings increases, the amount of construction waste (Vivian et al., 2011). A huge amount of waste produced from these activities, including concrete, wood, and metals, are disposed of in landfills (Nagapan et al., 2012).

The general components in construction waste are inert materials (e.g., concrete, timber, metal, bricks, etc.), which cause small damage to the environment. Proper measurement of construction waste is vital to initiate effective management at both project level and regional level (Bergsdal et al., 2007).

Construction waste quantification is paramount in the construction management field. As the generation of the construction waste increases and becomes uncontrolled in Malaysia, waste management becomes more difficult. The proper quantification of construction waste would help the respective authorities to understand the current environment of construction waste generation.

Different construction methods can influence construction waste generation. This theory has been proven by many researchers. The practices of CCM, MCM and IBS implementation on site need to be identified to determine whether it affects waste generation in the Malaysian construction industry.
1.2 Problem statement

The Malaysian construction industry is saturated with various types of problems ranging from safety issues, worker’s affairs and poor-quality control. One of the most famous issues emphasised by local researchers is construction waste management at Malaysian construction sites. Serious issues have resulted from the construction waste generated in different cities worldwide (Mah et al., 2016). Despite the fact the problem has long become the attention of the media, measures to control waste generation have been limited (Nagapan et al., 2013).

Construction waste in landfills is a burden to the environment and a costly issue for solid waste management (Dolan et al., 1999). These wastes have the potential to affect the well-being of humans and the environment (Arslan et al., 2012). The spotlight turned towards construction waste only after environmental implications arose (Tomas, 2015). Both the environmental and economic sustainability of countries has been affected by the generation of construction waste (Marzouk & Azab, 2014).

Very limited data pertaining to construction waste generation in Malaysia exists (Mahayuddin et al., 2013). According to Mah (2016), there is no printed and credible construction waste data related to construction waste materials. In addition, Malaysia still lacks research studies on construction waste generation (Noor et al., 2013). These reasons have become the primary motivation for construction waste generation rates to be investigated in this study.

Construction waste generation is affected by a few factors in the construction field. The factors include improper management, less awareness and rules and regulations. According to Mahayuddin (2013), construction waste generation also depends on the construction methods and materials utilised at construction sites. This statement is strengthened more by Mohamed & Mohamed (2016) who stated that construction waste varies along with different building structures and methods of construction. In addition, not many studies comparing construction waste generation rate with construction methods in Malaysia have been carried out.

A limited number of CW generation rate data is the motivating factor for local researchers to explore this field further. Besides that, the findings of this study would also contribute to the existing body of knowledge of the current construction industry, especially on the relationship between construction methods and construction waste generation rates.
1.3 Research questions

Based on the problem statement, the research questions are formulated as follows:

i. What are the construction methods used in the construction field?
ii. What is the construction waste generation rate at construction projects in Malaysia?
iii. How does the construction method affect construction waste generation in terms of waste generation rate?

1.4 Research aim and objectives

This study aims to compare the construction waste generation rate between different construction methods for on-going construction projects in Malaysia. To achieve this aim, the objectives of this study are developed as below:

i. To identify the current construction methods practiced at a construction site.
ii. To quantify construction waste generation rate for each construction method.
iii. To compare the construction waste generation rate among different construction methods.

1.5 Research scope

The study is limited due to certain restriction to ensure a valid research path. The scopes are as follows:

<table>
<thead>
<tr>
<th>Table 1.1: Research Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scope of location</td>
</tr>
<tr>
<td>Data collection period</td>
</tr>
<tr>
<td>Waste collection criteria</td>
</tr>
<tr>
<td>Types of project</td>
</tr>
<tr>
<td>Data collection method</td>
</tr>
</tbody>
</table>
The total number of sites studied was 12. The number of sites was based on the availability of waste. This is due to the consistency of the data. Besides, only the construction wastes of these 12 sites were well organised. Construction waste categorisation on site is vital for this study. CW without proper sorting was ignored. The period of data collection was 3 months. This timeline was due to the continuous availability of CW on site. This period is popular among local researchers in Malaysia who conduct studies in the same field. Data which was not obtained during this continuous period was ignored.

The type of project chosen for this study was social amenity projects. This will contribute to the body of knowledge for existing studies in Malaysia as limited studies available focus on this type of project. All these projects were at the construction stage and duration where most of the sites selected had practical completion within the period from October 2017 to August 2018.

The methodology applied in this research was the site visit method. This method was proposed and developed in different ways by multiple researchers worldwide. This method was adapted according to the nature of construction in Malaysia as it varies according to country. The site visit method can be classified as direct measurement and indirect measurement. Both were applied in this study.

1.6 The significance of the research

This research is important to identify the amount of construction waste produced by construction projects and the waste generation rate in Malaysia. In addition, the construction methods used in Malaysia vary according to project management. Thus, by comparing the construction waste generation rate with the construction method, the output results in the method that produces the least waste can be identified. This outcome will indirectly assist in determining construction waste reduction strategies and management in future. For the construction industry, effective construction method implementation can be identified through this study, especially for waste management. Besides, it is also a big contribution to the country in accordance with the requirements of the Construction Industry Development Board (CIDB) under CITP (Construction Industry Transformation Programme) which aims to reduce irresponsible waste during construction.
1.7 Summary

This chapter concludes that the construction industry in Malaysia is emerging day by day as it plays an important role in the development of the country. Simultaneously, construction waste production is increasing from day to day. Despite the focus on infrastructure development, immediate action must be taken to reduce construction waste in Malaysia. These problems may lead to bigger issues such as improper waste management in future if proper attention is not given.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This section contains studies related to construction waste quantification in Malaysian construction projects. Throughout this chapter, construction waste quantification, type of construction methods and construction projects will be explained. This review is important to gain a better understanding of the topic undertaken.

2.2 Definition

Waste is characterised as a material which is gotten rid through disposal or is intended for disposal. Construction waste consists of different forms during the extraction of raw materials, where they are processed into intermediate and final products, and final product consumption (Eusuf et al., 2012).

Activities such as building activities, road and rail development, maintenance and excavation create construction wastes. Meanwhile, Ekanayake & Ofori (2004) stated that construction waste refers to any medium separated from the earth’s existing medium which should have been moved to somewhere else from the construction site or utilised at the place due to malfunction, overabundance or mismatch with specifications. In addition to that, construction waste is interpreted as unwanted materials from construction, renovation, etc. It is also described as excess and damaged substances generated during construction work (Ponnada & P, 2015). Table 2.1 shows the definition of construction waste provided by various authors worldwide.
Table 2.1: Construction waste definition by different authors

<table>
<thead>
<tr>
<th>No.</th>
<th>References</th>
<th>Construction Wastes Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ghosh et al. (2016)</td>
<td>An eliminated substance which emerges from construction and renovation activities including land excavation, construction, site clearance, roadwork, and building remodel.</td>
</tr>
<tr>
<td>2.</td>
<td>Gayakwad &amp; Sasane, (2014)</td>
<td>Waste which arises from construction, and renovation activities and malfunctioned products and substance generated in the course of construction work or used temporarily during the course of on-site activities.</td>
</tr>
<tr>
<td>3.</td>
<td>Jr &amp; Manukau, (2014)</td>
<td>Discarded materials generally considered to be not water-soluble and non-hazardous in nature, including, but not limited to, steel, glass, brick, concrete, asphalt roofing material, pipe, gypsum wallboard, and lumber, from the construction or destruction of a structure as part of a construction project or from the renovation of a structure, and including rocks, soils, tree remains, trees, and other vegetative matter that normally results from land clearing or land development operations for a construction project, including such waste from construction of structures at a site remote from the construction project site</td>
</tr>
<tr>
<td>6.</td>
<td>Ekanayake &amp; Ofori, (2004)</td>
<td>Any material apart from earth materials, which needed to be transported elsewhere from the construction site or used on the site itself other than the intended specific purpose of the project due to damage, excess or non-use or which cannot be used due to non-compliance with the specifications, or which is a by-product of the construction process.</td>
</tr>
<tr>
<td>7.</td>
<td>Formoso et al. (2002)</td>
<td>Any inefficiency that results in the use of equipment, materials, labour, or capital in larger quantities than those considered as necessary in the production of a building.</td>
</tr>
</tbody>
</table>

In this study, construction waste can be defined as any materials that are eliminated, unwanted or disposed of during construction activities which result from excess or non-use products.
2.3 Type of construction waste

Construction wastes can be categorised into physical waste and non-physical waste (Nagapan et al., 2013). Physical waste is defined as materials which are lost, spoiled, cannot be repaired, cannot be used or losses during construction activities. Meanwhile, non-physical wastes are related to cost overrun and delay in construction projects (Nagapan, 2012). The main solid wastes found at construction sites are gravel, concrete, asphalt, bricks, tiles, plaster, masonry, wood, metal, paper and plastics (Hurley, 2003). Franklin Associates (1998) explained that construction waste from building sites typically consists of trim scraps of construction materials, such as wood, sheetrock, masonry, and roofing materials.

Table 2.2 shows the categories of waste classified by different authors. By referring to this table, construction waste materials can be filtered. The materials include timber, concrete, bricks and blocks, metal, packaging material, ceramic and tiles, glass, soil and aggregate, plastic material, asphalt and tar, cardboard, gypsum board and mixed waste. In Malaysia, Nagapan et al. (2013) have sorted construction waste into six main categories namely concrete, timber, metals, bricks, packaging wastes, ceramic and tiles. Table 2.2 shows six types of construction waste. Therefore, this study also focused specifically on these construction wastes.
## Table 2.2: Typical construction waste

<table>
<thead>
<tr>
<th>References</th>
<th>Country</th>
<th>Concrete</th>
<th>Timber/Wood</th>
<th>Steel/Metal</th>
<th>Packaging Waste</th>
<th>Ceramic and Tiles</th>
<th>Mixed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mah et al. (2016)</td>
<td>Malaysia</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Cho et al. (2015)</td>
<td>Korea</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Bakshar et al. (2015)</td>
<td>Lebanon</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Button et al. (2014)</td>
<td>Canada</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Foo et al. (2013)</td>
<td>Malaysia</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Bergsdal et al. (2007)</td>
<td>Norway</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Assari et al. (2004)</td>
<td>Malaysia</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Franklin Associates, (1998)</td>
<td>United States</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Bossink &amp; Brouwers, (1996)</td>
<td>Netherlands</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>
2.3.1 Concrete

Concrete is considered as the basis of the urban environment. Apartments and office blocks are primarily constructed using concrete. Basically, concrete is a mixture of aggregate (gravel, stone and sand), cement and water (Mulders, 2013). Concrete exists at a construction site in two forms – reinforced concrete and foundations (non-reinforced concrete) (Ponnada & P, 2015). The construction of both substructures and superstructures of buildings and other infrastructures is conducted using concrete as the generally used component. Poon (2004) identify that the material wastage in construction is mainly due to the excessive order of concrete when compared with the amount required, mostly in the case of ready mix concrete supply. identified that material wastage in construction is mainly due to the excessive use of concrete, mostly in the case of ready-mixed concrete supply. Additionally, poor planning, project delays and inefficient material handling processes by contractors can lead to material wastage.

2.3.2 Wood

The usage of wood in the construction industry can be both long-term and temporary. Structural elements (pillars and beams) and building envelope components (frames/panels, windows, and doors) belong to the long-term category (Parisi et al., 2018).

The second largest component of construction waste after concrete is wood. It contributes around 20-30 percent of construction waste from buildings (Leblanc, 2018). Wood waste contributes to a significant portion of building construction waste (Hossain & Poon, 2018). According to the California Integrated Waste Management Board (2008), the primary constituents of wood wastes are used in lumber, trim, shipping pallets, and other kinds of wood debris from construction activities. The main cause of wood wastes is natural deterioration (Poon, 2004), especially during demolition activities.
2.3.3 Steel/Metal

In the construction industry, metals are the most valuable material. Metals can be classified as ferrous or non-ferrous. Reinforced concrete bars and reinforced masonry are made up of the most essential component which is a reinforcement bar (Rai, 2005). Steel reinforcement bars are also common materials. The main causes of rebar wastage are due to the careless cutting by labourers and improper estimation of dimensions. Poon (2004) confirmed that damages during storage and rusting also contribute to the volume of wastes.

2.3.4 Packaging waste

Packaging waste is one of the contributors of construction waste, and cardboard is mainly generated during electricity works. Of the environmental impacts caused by a product, 80% is defined during the construction stage, including the impact of the packaging needed to deliver that product on site (Pericot, 2017).

2.3.5 Ceramic and tiles

Ceramic and tiles are generated from naturally existing materials containing clay minerals in high proportion. Following a process of dehydration and controlled firing at temperatures between 700°C and 1000°C, these minerals acquire the characteristic properties of fired clay (Juan & Medina, 2010). These ceramic wastes are also part of construction waste.

2.3.6 Mixed waste

One of the most common types of construction waste generated in the construction industry is mixed waste. Generally, mixed waste consists of all the wastes which are not sorted according to category. These wastes cannot be separated into its own category.
REFERENCES


Conservation and Recycling, 82, 41–49.  
http://doi.org/10.1016/j.resconrec.2013.10.015


