MANAGEMENT OF CONSTRUCTION AND DEMOLITION WASTE IN KUWAIT

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DEDICATION

This work is completely dedicated to my respectful parents and beloved wife without whose constant support this thesis was not possible. They always inspire me. At the same time, my thanks also go to my caring siblings whose advice really worked for me to complete this thesis.

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(بِسْمِ اللَّـهِ الرَّحْمَـٰنِ الرَّحِيمِ)

In the name of Allah, The Most Gracious and Merciful.

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ABSTRACT

In recent years, the construction and demolition waste (C&D waste) generation in Kuwait has increased due to the increasing population, urbanization, and construction activities. This research was aimed to evaluate Kuwait's current C&D waste situation by focusing on C&D waste generation and C&D waste management issues. The estimated C&D waste generation rates were estimated based on data collected from five construction projects and two demolition projects in Kuwait. In addition, a questionnaire survey was also conducted to evaluate the causes of C&D waste generation. The results showed that the average C&D waste quantities generated by construction activities were 49.5 kg/m^2 for public/commercial building projects and 35 kg/m^2 for residential projects. While demolition works of public/commercial construction and residential construction activities generated 1.480 ton/m^2, 0.0495 ton/m^2, and 0.035 ton/m^2, respectively. The average composition of C&D waste from the construction sector, including concrete waste, was 35.4%, followed by 19.2% of tiles/blocks, 14.2% of metals, and other materials. Meanwhile, the demolition works are composed of 70% concrete and cement waste and 20% metals. The questionnaire survey also revealed that extra labor, extra time, and cost are needed to manage the onsite sorting of C&D waste. This study recommends that all stakeholders in the construction industry, not just contractors and subcontractors, develop waste management plans. The Government of Kuwait is recommended to issue specific legislation on recycling which can improve C&D waste management, and should grant extra incentives and recognition to stakeholders.

ABSTRAK

Dalam beberapa tahun kebelakangan ini, penjanaan sisa pembinaan dan perobohan (sisa C&D) di Kuwait telah meningkat disebabkan oleh peningkatan penduduk, kerancakkan pembangunan bandar dan aktiviti pembinaan. Penyelidikan ini telah menilai keadaan semasa sisa C&D Kuwait dengan menumpukan kepada penjanaan sisa C&D dan isu pengurusan sisa C&D. Kadar penjanaan sisa C&D adalah dianggarkan berdasarkan data daripada lima projek pembinaan dan dua projek perobohan di Kuwait. Selain itu, tinjauan soal selidik telah dijalankan untuk menilai punca penjanaan sisa C&D. Kajian ini menunjukkan bahawa purata kuantiti sisa C&D yang dijana oleh aktiviti pembinaan ialah 49.5 kg/m^2 untuk projek bangunan awam/komersil dan 35 kg/m^2 untuk projek kediaman. Manakala kerja-kerja perobohan bangunan awam/komersil dan aktiviti pembinaan kediaman masing-masing menjana 1.480 tan/m^2, 0.0495 tan/m^2, dan 0.035 tan/m^2. Purata komposisi sisa C&D dari sektor pembinaan, termasuk sisa konkrit ialah 35.4%, diikuti oleh 19.2% jubin/blok, 14.2% logam dan bahan lain. Manakala kerja-kerja perobohan pula menghasilkan 70% sisa konkrit dan simen serta 20% logam. Tinjauan soal selidik juga mendedahkan bahawa kerja dan masa tambahan serta kos tambahan diperlukan untuk menguruskan pengasingan sisa C&D di tapak. Kajian ini mengesyorkan agar semua pihak berkepentingan dalam industri pembinaan, seperti kontraktor dan subkontraktor, membangunkan pelan pengurusan sisa. Kerajaan Kuwait juga di syorkan mengeluarkan akta khusus mengenai kitar semula yang boleh menambah baik pengurusan sisa C&D, dan memberikan insentif serta pengiktirafan kepada pihak berkepentingan.

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LIST OF ABBREVIATIONS

AIIP	: Arab International Industrial Projects
BIM	: Building Information Modelling
C&D	: Construction and Demolition
CDWM	: Construction and Demolition Waste Management
CSA	: Classification System Accumulation
EIA	: Environmental Impact Assessment
EPA	: Environmental Protection Agency
EPD	: Environment Protection Department
EPIC	: Environmental Protection Industrial Company
EU	: European Union
GIS	: Geographical Information System
HKHA	: Hong Kong Housing Authority
IBS	: Industrial Building System
ISO	: International Standards Organization
JRC	: Joint Research Committee
LCA	: Life Cycle Assessment
LCI	: Life Cycle Inventory
LCIA	: Life Cycle Impact Assessment
MFA	: Material Flow Analysis
MOEW	: Ministry of Environment & Waste
NSE	: National Strategy for the Environment
RCA	: Recycled concrete aggregates
UK	: United Kingdom
USEPA	: United States Environment Protection Agency
WDO	: Waste Disposal Ordinance
WGR	: Waste Generation Rate
WMP	: Waste management plan
MT	: Million Tonnes

CHAPTER 1

INTRODUCTION

1.1 Background

The State of Kuwait is situated in the north-western corner of the Arabian Gulf and occupies an area of 17,818 square kilometers. Kuwait spans around 200 kilometers (124 miles) from north to south and 170 kilometers (105 miles) from east to west. According to the population data, in 2019, the total population of Kuwait was 4.7 million, of which 3.3 million were expatriates and 1.4 million were Kuwaitis (PACI, 2019). Due to increasing population and urbanization, the construction industry in Kuwait is increasing rapidly. The construction of new buildings and various infrastructure projects is taking place as part of a strategic development plan to establish new cities and residential buildings. These construction activities will generate large amounts of construction and demolition (C&D) waste.

C&D waste is generally defined as a mixture of inert and non-inert materials arising from construction, excavation, renovation, refurbishment, demolition, roadwork and other construction-related activities. Inert materials can be comprised of either soft inert material such as soil, earth and slurry or hard inert materials of rocks and broken concrete. Non-inert materials also include wastes of metals, timber, plastics and packaging (Poon, 2007a).

Identification of construction and demolition waste quantities are an essential requirement for the implementation of successful solid waste management (Wu *et al.,* 2014). Construction and demolition waste is waste generated from construction and restoration works and building demolition. This includes building materials such as wood, bricks, concrete, insulation, electrical wiring, nails, aggregate, and etc. that are damaged or unused for various reasons during construction or generated after demolition. Construction and demolition waste may contain hazardous substances such as lead, and asbestos. On the other hand, there is the potential to recycle many components of construction and demolition waste (Purchase *et al.,* 2021). About 15 – 30 % of all solid waste by weight is generated by the construction and demolition (C&D) activities. In Kuwait, more than 90% of this waste is landfilled (Kartam *et al.,* 2004). The building construction industry plays a major role in the economy of the State of Kuwait. According to a report by the Central Statistical Bureau of Kuwait, from 2011 to 2015, the construction industry recorded a compound annual growth rate (CAGR) of 5.23 % (CSB, 2017). There is a growing concern and awareness about the environmental issues and sustainability in Kuwait among professional bodies, researchers and construction companies. In Kuwait, the green movement is still in its infancy, with sustainable projects mostly at the pioneering stage.

Various studies have reported the high amounts of C&D waste generated. For example, the U.S. construction industry generates over 700 MT of C&D waste, and the European Union is responsible for generating over 800 MT of C&D waste, annually (Wu *et al.,* 2019b). Poon (2007) reported that the annual generation of C&D waste in Hong Kong between 1993 and 2004 doubled and reached 20 million tons in 2004. The construction industry is also responsible for about 29% of landfilling in the United States, 40% in Brazil, 44% in Australia, 44% in the United Kingdom (Ajayi *et al.,* 2016), 27% in Canada (Yeheyis *et al.,* 2013), and 23% in Hong Kong (Yu *et al*., 2013). Thus, the construction industry's consumption of raw materials and waste generation is draining natural resources and producing high amounts of greenhouse gases (Kucukvar & Tatari, 2013). These overwhelming quantities are the causes of greenhouse effects and pose threats on material conservation and environmental biodiversity (Treolar *et al.,* 2003; Oyedele, Ajayi & Kadiri, 2014).

C&D wastes represent huge quantities of materials that are frequently dumped carelessly and encourage the illicit disposal of other types of waste and garbage. Thus, the building and construction industry plays a significant role in waste generation. Due to rising amounts of C&D waste, several issues are arising such as the scarcity of landfill space and the ever-increasing building costs. Hence, government agencies and private businesses alike are being forced to reduce waste production. Management of C&D waste is therefore a major objective, especially in developing countries, where such waste is poorly handled by mostly uncontrolled landfills (Kartam *et al.*, 2004). Although the Middle East construction industry suffered during the Gulf War, recent events in the region, combined with economic restructuring, membership in regional and global free trade organizations, and attracting foreign investments, have resulted in unprecedented growth in construction activities.

Indispensably generated C&D waste can have negative social, economic, and environmental consequences. The massive amount of construction waste streams in various countries has highlighted the importance of local actions in managing, recycling, and reusing waste generated during the lifecycle of buildings. C&D waste is affected by the increased use of land for new building, renovation, demolition of old facilities, and reconstruction or expansion of the road transportation network. These wastes affect human health and the natural/artificial environment.

1.2 Problem Statement

Globally, the demand for natural resources is high due to population growth and increasing living standards. The construction industry consumes huge amounts of natural resources and produces significant construction and demolition (C & D) wastes (Kabirifar *et al*., 2021). According to reports, the construction sector consumes nearly 40% of all consumed materials yearly (Kulatunga *et al*., 2006). C & D waste constitutes an enormous volume of all solid wastes (Ethaib, 2019). Various studies have reported a massive amount of C&D waste generated annually (Sáez & Osmani, 2019). Thus, the construction industry's raw materials and waste generation

consumption is draining natural resources and producing high amounts of greenhouse gases (Kucukvar & Tatari, 2013). In addition, as the population and economic activities increases in Kuwait, so does the C & D wastes. Kartam *et al.* (2004) estimated that between 1.1 and 1.8 tonnes of C & D waste were produced per person annually between 1996 and 2005 in Kuwait and census records in 2019 showed that the population in Kuwait was 4.7 million. This amount would be huge beyond 2020 as the population would probably exceeds 5.0 million. In order to prevent overfill of the landfills and illegal waste dumps, and be able to manage the C & D waste, the latest generation data needed to be estimated. This research will show that the waste is a valuable resource and must be extracted to achieve economic and environmental benefits from the C & D waste. The findings of the generation rates and potential economic benefits will provide quantitative information for future considerations by the Government of Kuwait and industrial stakeholders.

1.3 Significance of The Study

The effective management of C&D waste has become one of the significant environmental issues in the construction industry. When considering ecological and economic factors, C&D waste prevention/reduction is a top waste management priority (Arslan & Serdar, 2019). It has been widely acknowledged that proper quantification of C&D waste is crucial for establishing an effective management system at both the project and regional levels (Kurniawan *et al.*, 2022). C&D wastes are a real problem in many countries; hence various laws have been developed. Specifications and recommendations on C&D waste management are part of state policy (Bergsdal, Bohne & Brattebe, 2007). However, some countries still need integrated plans and comprehensive policies to tackle C&D problems which require filling the gap of the lack of information about C&D waste generation and diagnosing incomplete or wrong C&D waste management implementations. Kuwait has a wealthy petroleum-based economy. Due to this development plan, the economy of Kuwait is

expected to keep growing as Kuwait aims to become a developed nation. The construction industry in Kuwait registered steady growth. According to Government statistics, the initial budget set for implementing the Kuwaiti development plan during this period was $155 billion from 2012– 2016. The development plan included 500 projects for the infrastructure, housing, and expansion of energy and natural gas projects (Trading Economics, 2021). These projects magnified the environmental C&D problems. One of the main obstacles to handling these wastes is the absence of data related to quantities, cost, and environmental impact. Therefore, this study is expected to update new data in C & D waste in Kuwait.

1.4 Research Objectives

In terms of both the projected growth of the construction industry and the need for economic diversification, it is important to evaluate, measure and determine the flow of construction waste in Kuwait. The aim of this study is to explore waste minimization practices in Kuwait construction industry, with the following objectives:

1. To determine the C&D waste in Kuwait from various construction activities.
2. To identify the C&D waste minimization practices through reduce, re-use and recycle in Kuwait construction industry.
3. To propose strategies to improve waste management effectiveness of the construction sector in Kuwait.

1.5 Scope of Study

This research will be carried out in the State of Kuwait (see Figure 1.1). The samples will be limited to 7 projects only including 2 demolition projects but will exclude

infrastructure projects such as building of roads and highways, bridges, drainage projects, etc. This research project will be conducted during Covid-19 pandemic which restrict movements and therefore this research took a longer time to complete and to obtain the cooperation of Government and stakeholders to be interviewed.

This study also focuses on sorting and recycling efforts leading to the minimization of the total C&D waste that is currently landfilled in Kuwait. Whereas data was gathered through official interviews and government reports from waste management departments, as well as visits to landfills and specific construction and demolition sites, and a questionnaire was administered to determine the causes and types of construction waste. Further, this study presents the current status of C&D waste disposal system in Kuwait and identifies the potential problems to the environment, people and economy. Then, it investigates alternative solutions to manage and control this major type of waste in an economically efficient and environmentally safe manner. Thus, evaluation of the environmental performance of construction and demolition waste management (CDWM) through various sorting and recycling systems is necessary to support the decision-making process in CDWM and to raise awareness among the stakeholders.

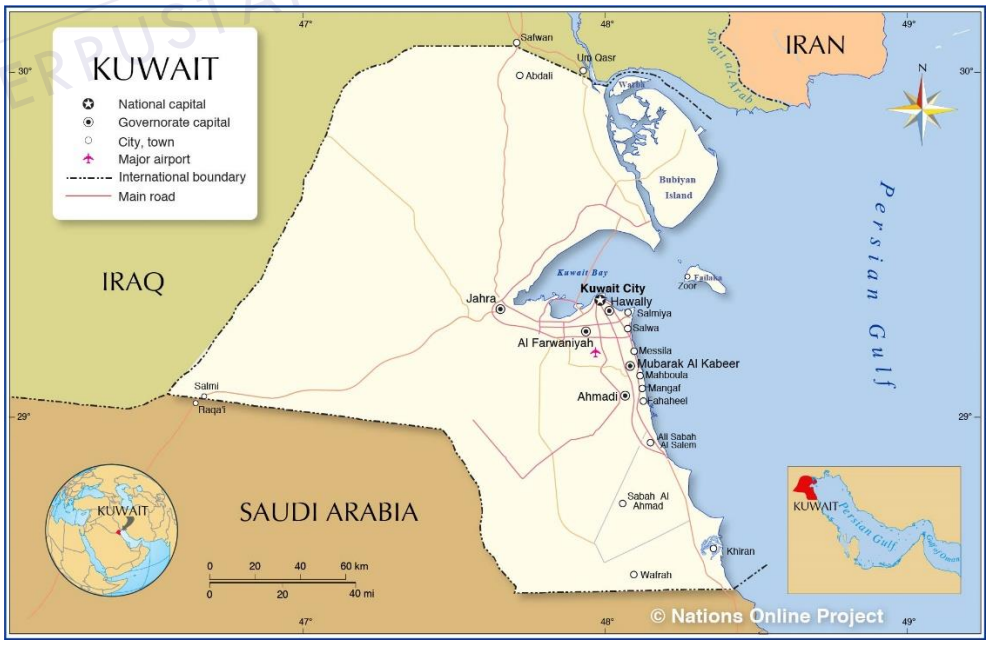

Figure 1.1: Map of Kuwait State, Middle East.

1.6 Structure of Thesis

This study focuses on the construction & demolition waste generation and management in the State of Kuwait. This thesis is divided into six chapters.

Chapter 1 elaborated on the needs of research in this study, poses problems, research objectives and scope of the study on C&D waste management in Kuwait.

Chapter 2 contains the literature review of research works related to the C&D waste generation and its management. In addition, this chapter covers various CDWM strategies adopted in developed countries.

Chapter 3 explains the research plan and methodology implemented for this study. It presents the data collection approaches and analysis methods used in this research.

Chapter 4 presents the results of the data analyses along with the C&D waste generation rates in Kuwait.

Chapter 5 discusses the current practice of CDWM in Kuwait and the challenges posed by the construction industry for effective management. The strategies for the effective management of CDWM in Kuwait are presented in this chapter.

Chapter 6 is the final chapter that presents the conclusion and recommendations from this study in order to improve the CDWM in the construction industry.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter reviews previous studies related to waste minimization, causes of waste, strategy to minimizing the losses in construction sites, and the advantages to reduce the losses of material in construction sector. This chapter also examines some of the C&D waste management strategies used by developed nations.

There are numerous definitions of waste available. Waste can be defined in a variety of ways. According to (Poon, 2007a), waste can be defined as a mixture of inert and non-inert materials arising from construction, excavation, renovation, demolition, road work and other construction-related activities. Waste, according to a straightforward definition, is "everything that can be eliminated without lowering the value of the product to the client." Resources, procedures, laws, activities, etc. might all be included (Polat & Ballard, 2004).

Anything that has no worth is typically thought of as waste. Waste, specifically, is the use of resources and labor to produce nothing of value (Macomber & Howell, 2004). Waste is the excess of everything other than the minimum amount of materials, tools, parts, room, and labor absolutely required for improving the result. As a result, waste is defined as the loss of time, resources, and money caused by actions that do

not add value to the final product or the manufacturing process and that may be eliminated without lowering the product's value to the consumer.

The modern production philosophy defines waste as any inefficiency that causes the consumption of resources such as money, labor, materials, or equipment in greater amounts than those that are deemed required for the creation of a good.

However, construction waste is defined as any losses resulting from actions that cause direct or indirect costs but do not, in the client's eyes, contribute any value to the product (Formoso *et al.*, 1999). Construction waste, in general, can be defined as the extra materials produced during construction, remodeling, and demolition activities.

According to (Shen *et al.*, 2004), "generated debris in buildings, concrete, steel, wood, rubble, earth, and a composition of materials generated from various activities in construction sites, including land excavation, construction of structures and buildings, clearance of construction site, activities relating to demolition, roadwork, and renovation of buildings," are examples of what is meant by "construction and demolition (C&D) waste." Concrete, rocks, and dirt are examples of inert materials, whereas wood, glass, and plastic are examples of non-inert materials, according to Poon & Chan (2007).

Construction waste materials, in addition to any improvement materials that may be used in construction sites, include packaging material and rubble material that results from construction, remodeling, repair, and demolition operations of pavements, houses, commercial buildings, and other structures (Kulatunga *et al.*, 2006).

According to the Chartered Institute of Building (CIOB), between one-fourth and one-third of the total waste produced worldwide is made up of construction debris. Most of it is buried in landfills due to its non-combustible nature. Additionally, it has grown more prevalent and problematic to store inert elements obtained from building debris. Such stockpiling has been caused by insufficient earth-filling efforts that were utilized to absorb the large amount of inert minerals. Additionally, sorting inert materials to meet project requirements for the use of filler materials is challenging and cost inefficient (Mou, 2008).

The idea of waste treatment is closely related to the process of transferring waste from the site to landfills for many persons working in the construction sector.

This perspective's primary justification is that "the waste issue is a reality in the building business." Although such waste is crucial in terms of the environment, this method has drawn criticism since the inception of industrial engineering. Direct waste occurs when items are completely lost because they are either lost or irreparably damaged. In this situation, the waste typically needs to be cleared away from the area. In contrast, indirect waste happens when materials are not actually wasted but instead merely suffer a financial loss, as in the case of waste brought on by concrete slabs that are thicker than required by the structural design (Formoso *et al.,* 2002).

2.2 Causes of Construction Waste

There are many causes that lead to the generation of material wastage in construction projects. According to Salgın *et al.* (2020) The causes of waste generation due to the design stage in the categories of “primary cause of waste,” “significant cause of waste,” and “cause of waste” were ranked in this order: Architects’ lack of knowledge and experience, Improper building product selection, Improper details, Lack of coordination and communication, Insufficient design data, Lack of modularization, Clients’ last minute requests for changes and Delaying drawing revisions. And the causes of waste generation during construction stage in the categories of “primary cause of waste,” “significant cause of waste,” and “cause of waste” were ranked in this order: Improper workmanship and practices, Lack of knowledge and experience, Improper storage areas and methods, Waste caused by improper cutting and shaping during construction, Delayed information about the dimensions of building products, Unused materials and products, Ordering excessive quantities of products and Climatic conditions.

Contractors and subcontractors make assumptions as a result of complex specifications and a lack of execution information, which results in excessive material purchases. Long project durations and unforeseen construction situations allow for the adjustment of designs to be more recent or modern (Poon *et al.,* 2004).

Poor estimation of quantities, inefficient transportation, inefficient storage and handling of resources, poor workmanship, lack of oversight, and inefficient site management are the main causes of waste caused during the execution phase. As a result, efforts to prevent building waste are given lower priority. Lack of awareness of waste reduction methods at the implementation stage reduces the likelihood of avoiding a significant amount of the waste produced in building sites (Chandrakanthi *et al.,* 2002).

Concern over the development of C&D garbage is developing as C&D waste quantities increase and landfill space becomes more and more limited. The main activities generating the C&D waste in Kuwait are demolition of old buildings, debris from new construction, renovation and maintenance works, and manufacturing activities. C&D waste is generated throughout the construction period of a project. Usually, C&D waste at the project site is not segregated, and consequently, the information on waste quantities is not recorded due to additional costs, delays and other effects on the efficiency of the project activities, and as a result the information on trash quantities is not documented. Therefore, it is very difficult to collect precise information about the amount of garbage generated throughout the entire project at the project sites.

2.3 Classification of Construction Waste

In order to comprehend the vast variety of potential corrective actions connected to its prevention, it is necessary to examine the classification of trash on several bases in addition to having a thorough understanding of the notion of waste in general. Organic and inert materials are frequently combined to create waste. In public filling areas and site formation projects, where the remaining wastes are frequently combined and contaminated, inert waste is typically used. It is disposed of in landfills because it cannot be recycled or reused (Shen *et al.* 2004).

According to the level of inert waste inclusion used in Hong Kong, construction wastes can be divided into Type I and Type II. According to this classification, inert

waste materials consist of soil, mud, asphalt, concrete, reinforced concrete, brick or sand, cement plaster or mortar, aggregate, rock or rubble, and aggregate. Less than 20 percent by volume or 30 percent by weight of inert materials is considered type I building waste. More than 20% by volume or 30% by weight of Type II waste is made up of inert elements. Type II, waste is generally utilized for site development or public filling areas. In 1999, roughly 79 percent of construction debris was reused in public filling areas, while the remaining 21 percent was disposed of in landfills, according to a report published by the Hong Kong Construction Industry Review Committee (HKHA, 2002). (Shen *et al.*, 2004).

Construction activities often produce chemical and other particular wastes, which are typically carefully controlled and require special handling because they can easily lead to environmental damage or major health problems. To deal with chemical and other specific wastes produced by construction activities, contractors must adhere to the Hong Kong Waste Disposal Ordinance (WDO, 2001). Separating hazardous and chemical wastes from other forms of building wastes enables the effective implementation of tailored waste management strategies for each individual category of waste (Shen *et al.*, 2004).

Salgın *et al.* (2020) grouped the construction waste sources into design error, procurement or ordering error, materials handling, machine operation error, and residual or leftover scraps. Bossink & Brouwers (1996) investigated construction wastes from the application of various building materials and classified the waste sources according to the nature and the technology of using the materials.

Generally, construction waste is classified into four categories based on the factors that cause waste generation as represented in Figure 2.1 (Mou, 2008).

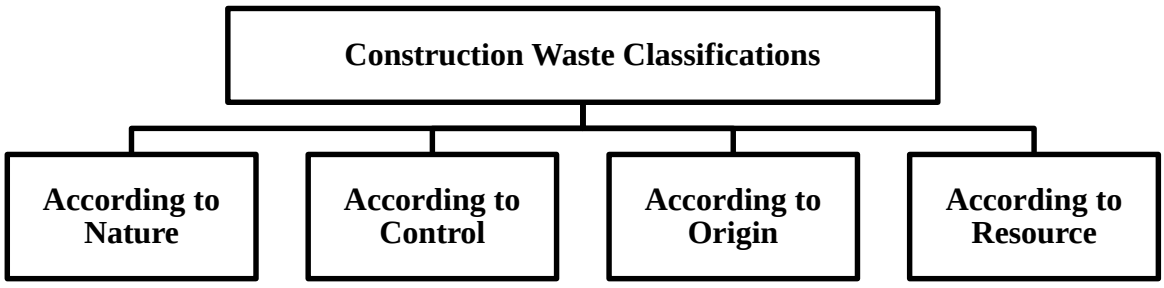

Figure 2.1: Construction Waste Classifications (Mou, 2008).

2.3.1 Classification of Waste According to its Nature

According to its nature, construction waste can be divided into two categories (Formoso *et al.,* 1999):

1. Direct waste: When materials are fully lost, there is direct waste. This occurs when the aforementioned materials are either lost or suffer irreparable damage. The waste typically needs to be removed from the area in situations like this. According to Shen *et al.* (2004), "direct waste" is the term used to describe materials that are lost during construction or that are damaged and cannot be fixed and reused.
2. Indirect waste: This occurs when items are not physically lost. Frequently, this merely causes financial loss. In general, mistakes, excessive use of materials, and material substitutions result in indirect waste. One illustration is the waste that occurs when the thickness of the concrete slab exceeds the thickness allowed by the structural design.

2.3.2 Classification of Waste According to Control

There is a degree of waste that can be tolerated in terms of the ability to regulate the way that materials are used, and this level can be reached by significantly raising the bar in terms of technical advancement. Waste can be divided into two categories as a result (Formoso *et al.*, 1999):

1. Unavoidable waste: This type of waste is a necessary part of and a byproduct of every building operation. The degree of technical innovation needed to carry out that activity typically affects the ratio. Technical innovation's expenses cannot outweigh its advantages.

2. Avoidable waste is the waste created when a particular approach is used to carry out a particular task. However, it can be prevented if a different method is used or if the cost of waste is much higher than the cost of prevention.

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Vita

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