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SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

ASSESMENT OF CONSTRUCTION AND DEMOLITION WASTE RECYCLING PRACTICES ON SELECTED BUILDINGS IN ADDIS ABABA

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A Thesis Submitted to School of Graduate Studies in Partial fulfillment of the requirements for the Degree of Master of Science in Construction Technology and Management

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DECLARATION

This thesis, "Assessment of Construction and Demolition Waste Recycling Practices on Selected Buildings in Addis Ababa," is my own original work. This thesis has not been presented at any other university in any capacity and is not being submitted for any other degree, and that all sources of materials utilized in the thesis have been correctly credited.

Name: Semhal Gebremedhin

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Signature:_____________________________

Date:_________________________________

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First and foremost, I want to thank the Almighty God for providing me with the strength to complete my thesis. I'd also like to convey my heartfelt gratitude to my advisor for his patient advice throughout the program. I am grateful to my families and friends, for their unwavering support throughout my life.

ABSTRACT

Construction and demolition waste accounts for a significant portion of global solid waste production, with the majority of it ending up in landfills. Parallel to the rise in environmental consciousness, there is a growing awareness of waste issues all over the world. As a result, developing some construction and demolishing waste management solutions has become important.

The objectives of this study is on examining the major building construction and demolishing waste materials, current practice of building construction and demolishing waste recycling, and testing the identified major building construction and demolishing waste material on selected buildings in Addis Ababa. The quantitative data gathered from the questionnaire was analyzed by straight forward percentages and frequency using SPSS. All other categories of respondents' interviews and responses/opinions to open ended data have yielded qualitative data and were summarized.

The findings of this research revealed that most contractors try to reuse materials before disposing them but do not consider recycling at the site as an option; in terms of recycling, 4% of contractors said they recycle the waste from building construction and demolishing. And as for the amount of wastage from building construction and demolishing, HCB and cement take the first and the second place with 30 and 26 percentages respectively. The study also carried out laboratory test to compare the density and compressive strength of HCB with 50% replacement of its course aggregate with recycled HCB and HCB with standard mix which the HCB with 50% replacement yielded approximately close result to the HCB with standard mix.

The study also found that contractors believe that by raising awareness, building recycling plants, and providing government incentives, recycling building construction and demolishing waste could be taken as an option by most contractors also potentially attracting private investors to invest in recycling factories

Key words; Construction and demolishing waste, Recycling, Hollow concrete block, Recycled coarse aggregate, Compressive strength

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LIST OF ABBRIVATIONS

AAHCPO	Addis Ababa Housing Construction Project Office
BATCODA	Building and transport Construction Design Authority
BMP	Best management practice
C&DW	Construction and demolishing waste
ES	Ethiopian Standard
GDP	Gross Domestic Product
GFCF	Gross Fixed Capital Formation
HCB	Hollow concrete block
LCA	Life-cycle assessment
MOWUD	Ministry of Works and Urban Development
MSW	Municipal solid waste

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CHAPTER ONE

1. INTRODUCTION

1.1 Introduction

INTRODUCTION

Natural resources have been exploited excessively to produce the energy needed for construction, consumer goods production, and transportation. This results in environmental imbalance, resource depletion, and environmental changes, as well as economic and societal ills.

One of the key sectors whose growth is correlated with the national economy in developing nations is the construction industry. It is also possibly the first sector whose decline is strongly tied to an economy's decline.(ILO.1987). It implies that the building sector's strong performance promotes economic growth. This economic achievement not only indicates the availability and demand for housing and infrastructure in the nation, but it also shows that the economy is expanding. (CSA and MoUDCo. 2011).

Ethiopia has continuously invested more than 30% of GDP in Gross Fixed Capital Formation (GFCF) expenditure since 2010, and as a result, it has become one of the world's fastest-growing economies (Carole, 2018). The construction industry is currently valued at more than $7 billion dollars. Construction activities in Ethiopia accounted for 15.9% of GDP at current prices during the 2015/16 fiscal year, according to the 2017 edition of African Economic Outlook (Carole, 2018).

Construction and demolition waste is produced as an outcome of new construction works, renovation or demolition. It consists of steel, timber, iron sheets, tiles, ceramics and waste (NEMA. 2014). Waste management is a challenge that many governments are striving to solve as they try to develop waste management policies in light of the expanding industrialization of the world.

Construction and demolition waste accounts for a significant amount of waste disposed of in landfills in the United States. Actual volumes are estimated to be between 22 and 33 percent of the overall landfill waste stream. Based on statistical forecasts from 95 projects, the US

Environmental Protection Agency (2009) projected the volume of C&D waste in 2003 to be almost 170 million tons.

Several difficulties, such as the scarcity of landfill space and ever-increasing construction prices, are harmed as a result of increased amounts of C&D waste.

Residential sources accounted for 39 percent of the total, while nonresidential sources accounted for 61 percent. According to a California EPA analysis from 2004, C&D waste made up 22% of the waste stream. This waste volume is surprisingly consistent with a much earlier US EPA study, which estimated C&D waste to account for 24% of total municipal solid garbage (Jones, 1993

Inert materials (such as sand, bricks, and concrete) are separated from non-inert materials in construction and demolition waste (i.e., plastic, glass, paper, wood, vegetation, and other organic materials). Bulk excavations are not regarded as construction and demolishing waste(C&DW) in this aspect. According to a different classification, 30% of the C&DW input is deemed separate, while the remaining 70% is mixed C&DW with an average density of 1,400 kg/m. This is due to the fact that on-site waste sorting is time and labor intensive. Construction industry activities will never achieve zero-waste status due to the nature of manufacturing methods and conditions, and a certain level of waste creation is unavoidable (C.S. Poon et al, 2001).
Land filling and fly tipping are two common techniques in many nations, especially developing ones, to improperly treat C&DW. C&DW currently accounts for 25-45 percent of waste that is disposed of in landfills. In Kuwait, for example, more than 90% of C&DW is land filled (Nabil et al., 2004). Similarly, in Hong Kong, a large portion of C&DW is disposed of in landfills (Serdar et al, 2017). C&DW, on the other hand, is unsuitable for landfill disposal due to the hazardous waste it contains.

There is a landfill prohibition for unsorted waste and recyclable items in the Netherlands, Germany, Belgium, and Switzerland. Many landfills in the United States does not take C&DW. C&DW that contain more than 20% inert material by volume (or 30% by weight) cannot be disposed of in landfills in Hong Kong, according to an administrative guideline (Serdar et al, 2017). This is due to the fact that (i) C&DW tends to take up a lot of space, (ii) is known to produce hazardous chemical leachate, anaerobic degradation that causes air pollution, landfill gas generated from organic waste materials, and other contaminants, all of which contribute to acidification and toxic effects on ground and surface water and soil via putrefaction.

As a result, C&DW land filling can only be approved at a greater cost. As an alternative to land filling, fly tipping is becoming more popular. In several countries, such as Turkey, Switzerland, Poland, the United Kingdom, and others, it is common practice to handle C&DW. Recycling of C&DW by plants has been a viable alternative to such unsustainable disposal methods in this regard, notably in the last two decades (i.e., land filling and fly tipping).

Despite accessible resources, according to Laquatra and Pierce (2004), builders are unwilling to explore waste recycling, despite the fact that up to 80% of construction waste can be diverted from landfills. Actual recycling techniques are determined by the financial cost/benefit tradeoff associated with waste collection, sorting, and transportation, as well as the return on investment.

A comprehensive construction waste management system is required at every building site. After establishing the causes of construction waste, the most cost-effective approach to any waste problem is to design ways for reducing it. Every construction industry should be required to establish a construction waste management strategy tailored to its specific mode of operation, ensuring that all personnel, from management to operations, are working toward the same goal of construction waste management. Aside from reduction measures, economic considerations in construction waste management, such as recycling and contractual ramifications, are also important (Tam and Tam, 2006).

1.2 Statement of Problem

Construction in Addis Ababa has been increasing to satisfy the need of the population that is growing year to year. This construction demand has increased the consumption of the cement, sand, aggregate, steel, wood and the likes as our modern construction is based on concrete and steel structures. Ever-increasing construction for new building, renovation and demolition of old facilities has an impact on the amount of construction and demolishing waste produced.

Construction and demolishing waste is typically disposed of in landfills; however, growing realization of the potential for diverting more and more waste components from landfills has led to construction and demolishing waste being a recycling goal (Peng et al., 1997;Trankler et al., 1996).

Since now a day the disposing areas are reaching their maximum capacity thus being as one of the issues that is concerning the government. Recycling construction and demolishing waste will greatly reduce materials being disposed into open dumpsites. These waste materials can be minimized if the recyclable materials are handled in such a manner to be used again as major ingredients.

1.3 General Objective

The objective of this study is to identify, asses current practices of building construction and demolishing waste recycling on selected buildings in Addis Ababa and recommend best practices.

1.4 Specific Objective

Specifically this paper will see to

-Identify the major types of waste materials in building construction and demolishing on selected buildings in Addis Ababa

-To study the current practice of building construction and demolishing waste recycling on selected buildings in Addis Ababa

-To test the strength of the identified major waste material in building construction and demolishing on selected buildings in Addis Ababa.

1.5 Research question

1. What are the major building construction and demolishing waste materials in Addis Ababa?

2. What are the current practice of building construction and demolishing waste recycling in Addis Ababa?

3. Does the identified major building construction and demolishing waste achieve the standard?

1.6 Significance of the Study

With increased levels of construction in Addis Ababa, there is a need to establish strategies of waste management in the construction and demolition industry.

It is agreed that construction and demolishing waste management should be given attention on different researches. Although considerable studies have been done in the field of construction waste management, it has mostly focused on understanding the reasons why waste is produced. Accordingly what should be done to the waste produced by this industry should be given more emphasis as the dumping site for solid waste in Addis Ababa has gotten to an alarming stage. To achieve this, the government should take the lead in playing the main role to exploiting the different alternatives to come up with feasible solution.

This paper describes the current status of construction and demolishing waste is handled in some construction sites of Addis Ababa city and the most effective strategies to manage and control these wastes through recycling. It presents key issues related to the benefits of recycling building construction and demolishing waste. This study includes potential demand, cost considerations, market strategy and policy regulations and concludes with a set of recommendations addressing the challenges and most important issues contributing to the success of building construction and demolishing waste recycling.

Hence, studying on building construction and demolishing waste materials recycling will benefit the stakeholders of the construction industry such as the contractors, client, government, investors and the environment. In addition this paper will also help investors who are willing to finance on recycling plant.

1.7 Scope and Limitation of the Study

Due to time and resource constraints, the research was conducted in Addis Ababa city which is experiencing a great thrive in construction. It investigates how Grade 1 contractors registered under the ministry of urban development and construction recycled construction and demolition waste on their projects; specifically on some building projects. This was because most of them were involved in large scale and complex projects which produce large volumes of construction and demolishing waste that can incorporate recycled waste back to the project.

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Waste Definition and Concept

Waste, according to Augustin (2007), is any resource utilized in a work process or non-value-adding activity that doesn't benefit the stakeholders and can occur at any time in any work system. Velinni (2007) also added on waste as any material that results from industrial or human activity but has no further use.

Waste was defined by the World Bank (2012) as any undesired material that is disposed of purposely. However, once they are taken out of the waste stream, some wastes might eventually turn into resources that are valuable to others. Wastes are characterized by their origins of solid waste streams, the types of wastes they produce, and the rates at which they are produced.

According to Mulualem et al.(2012) any materials other than earth materials, which needed to be transported elsewhere from the construction site itself other than for the planned specific purpose of the project due to damage, excess, or non-use, or which cannot be used due to non-compliance with the specification, or which is a by-product of the construction process are considered as waste.

Waste is the difference between the value of materials that have been delivered and accepted on site and those that have been properly used as specified and accurately measured in the work, after deducting the cost savings of substituted materials transferred elsewhere, in which case unnecessary expense and time may be incurred by material wastages(Shen et al., 2004).

One of the core ideas of the lean production philosophy is waste. The new production philosophy states that waste should be understood as any inefficiency that causes the use of more tools, materials, labor, or capital than are thought to be necessary for the product. Both the occurrence of material losses and the execution of needless effort, which results in higher expenditures but does not improve the product, are examples of waste (Viana, 2012). In organizations that have adopted the Lean Production concept, which is mostly employed in the manufacturing business, the removal of waste has been heavily used as a driver for improvement. Recently, this subject has also been the subject of research in the global building sector.

The three different groups of concepts identified from review of literatures are (Formoso, 1999 and Viana,2012):

i. Waste is considered as debris that needs to be removed from building sites and is often concerned with the environmental impact produced by construction and demolition material waste (based on the amount of waste generated due to excessive material consumption);

ii. Specific types of waste (rework resulting from quality deviation, modification orders, or unfinished jobs), of which the cost components are frequently not discussed;

iii. As non-value: waste Lean production theory defines waste as operations that take up time, resources, or space but do not contribute value from the standpoint of the consumer.

2.1.1 Waste in Addis Ababa

According to Mohammed et al. (2017) the municipal solid waste generation in Addis Ababa city shows an average municipal solid waste generation of 0.45kg/capita/day. The main sources of solid waste generation in Ethiopian urban areas include wastes from residents, businesses, institutions, industries, hotels, and street sweepings. However, the quantity of waste produced by each source varied. For instance, households generate 70% of Addis Ababa's total municipal solid waste, followed by commercial institutions (9%), industries (6%), hotels (3%), hospitals (1%), street sweepings (10%), and miscellaneous sources (1%) (Tassie et al. 2019).

This demonstrates that households generate the majority of municipal solid waste. Effective methods, such as volume-based waste tax system that helps reduce waste generation at sources, do not exist in Ethiopia. Nevertheless, Kim (2017) claims that South Korea's volume-based waste tax system, which was put in place in 1995 to lessen waste production and promote waste recycling, has successfully improved municipal solid waste generation and collection procedures.

2.2 Classification of waste

There is a tolerable level of waste, which can only be decreased by a great advancement in technological growth. Waste can be classified as one of several things depending on the amount of money that must be invested and the likelihood that it can be controlled (Formoso et al,1999).

- **Avoidable Waste:** when the price of waste is much higher than the price of preventing it.

- **Unavoidable/ natural waste:** in which the investment necessary to its reduction is higher than the economy produced/ reduction of waste causes higher investment than economy produced.

Waste can also be classified according to its generation; mainly there are eight major classifications of solid waste generators: residential, industrial, commercial, institutional, construction and demolition, municipal services, process, and agricultural. Table2.1 below gives sources and types of waste generated according to the World Bank Study.

Table 2.1: Source and Types of Solid Waste

Source	Typical Waste Generators	Type of Solid Wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes
Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	Schools, hospitals, prisons, government centers	Same as commercial
Construction and Demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, bricks, tiles
Municipal Services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and waste water treatment plants	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other

		recreational areas, sludge
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off specification products, slag, tailings
Medical waste	Hospitals, nursing homes, clinics	Infectious wastes (bandages, gloves, cultures, swabs, blood and body fluids),hazardous wastes (sharps, instruments, chemicals), radioactive waste from cancer therapies, pharmaceutical waste
Agricultural	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes(e.g., rice husks, cotton stalks, coconut shells, coffee waste), hazardous wastes(e.g., pesticides)

(Source: World Bank, 2012)

2.3 Concept of construction and demolition waste

Construction and demolishing waste is defined by the Environmental Protection Agency (2015) as "materials containing debris created during the construction, renovation, and demolition of buildings, roadways, and bridges." Concrete, wood (from buildings), asphalt (from roads and roofing shingles), gypsum (the main component of drywall), metals, bricks, glass, plastics, salvaged building components (doors, windows, and plumbing fixtures), and trees, stumps, earth, and rock from clearing sites are also described by the EPA as bulky, heavy material Construction and demolishing waste.

Kofoworola and Gheewala (2009); Lu, and Yuan (2011) described Construction and demolishing waste as the waste which arises from construction, renovation, and demolition activities. Construction of new buildings, demolition of old structures and roadways, and maintenance of existing buildings all generate Construction and demolishing waste on a regular basis in urban settings (UNEP, 2005).

According to the Hong Kong Environmental Protection Department Li (2013) construction waste is defined as "any substance, item, or thing generated as a result of construction work and abandoned, regardless of whether it has been processed or stored before being abandoned,"

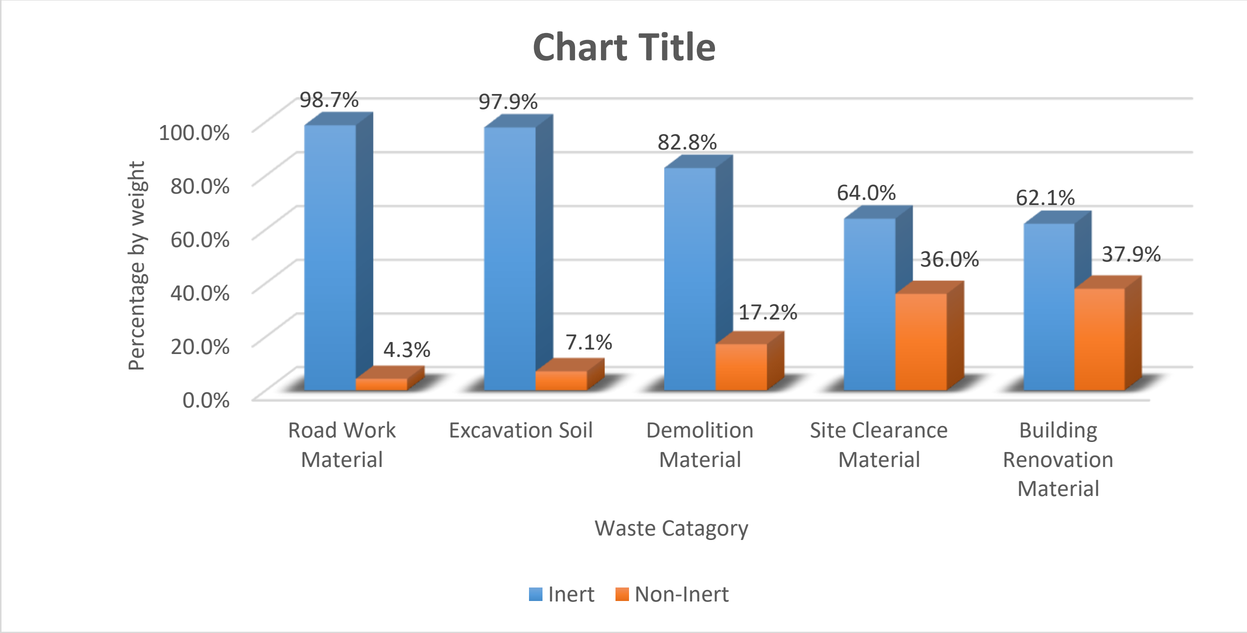
2.4 Construction Waste composition

As the name implies, C&D waste is generated during construction and demolition operations. C&D waste is split into five categories based on the nature of the operation: roadwork material, excavated soil, demolition debris, site clearance waste, and rehabilitation garbage. The relative proportions of each category are depicted in Figure 2.1. As seen in Figure 2.1, the first three groups often contain significant amounts of inert and non-putrescible materials. On the other hand, wastes generated during site clearance and renovation activities are usually polluted with organic matter and other detritus.

2.4.1. Building construction waste

Construction waste commonly contains remnants of construction materials such as wood, brick, plaster, and plastics. The waste generated accounts for 10–20% of the total weight of construction materials delivered to a job site (Cheung et al., 1993).

Figure 2.1 Percentage of inert and non-inert material in C&D waste



(Source: Cheung CM, Wong KW, Fan CN, Poon CS. Reduction of Construction Waste, 1993).

Building construction waste was divided into two categories by (Skoyles and Skoyles 1987; Poon et al., 2004), structure waste and finishing waste. During the construction process, concrete fragments, steel reinforcement, and abandoned timber plates and pieces are formed as structure waste. Finishing stage of a building generates finishing waste, which includes a wide range of waste products. For example, excess cement mortar from plastering, broken Ceramics, mosaics and the like. According C.S. Poon (2001) because of negligent use, raw resources such as mosaic, tiles, pottery, paints, and plastering materials are thrown away. Damaged bathtubs, washtubs, and window frames are also included in the finishing wastes.

2.4.2. Building demolition waste

Almost the whole building structure, including the superstructure, concrete foundations, roadways, and so on, will wind up as C&D waste during demolition. This is 10–20 times the waste generated during the construction of new structures in terms of weight. Inert materials such as bricks, sand, and concrete make up a large portion of demolition waste. Metals, wood, paper, glass, plastics, and other combined materials account up a smaller percentage of the total (Environmental Protection Department, 1991). The waste's characteristics may differ depending on the types of structures demolished and the demolition technique used. For example, in 'piece-by-piece' wrecking, workers typically use mechanical hand tools to recover as much useable material as possible. With contrast, in heavy demolition with heavy equipment, the waste generated is a commingled pile from which it is difficult to separate reusable materials.

The method of demolition used has a significant impact on the success of waste sorting on-site. Blasting, Wrecking balls, Hydraulic crushers and Top-down method are the different techniques that can be used to demolish a structure (Buildings Department, 1998).

The technique of demolition chosen is determined by the project's conditions, site limits, and equipment availability (Civil Engineering Department, 1998).

The top-down method, as the name implies, demolishes a building floor by floor from the roof to the ground level. Machine-mounted percussive breakers or hand-held pneumatic hammers are used to break apart building components like as windows, doors, piping, and lighting fixtures. In most cases, the entire structure is converted into a mixture of concrete, debris, wood, metals, polymers, and other elements. A waste chute then transports the mixed items to the ground level.

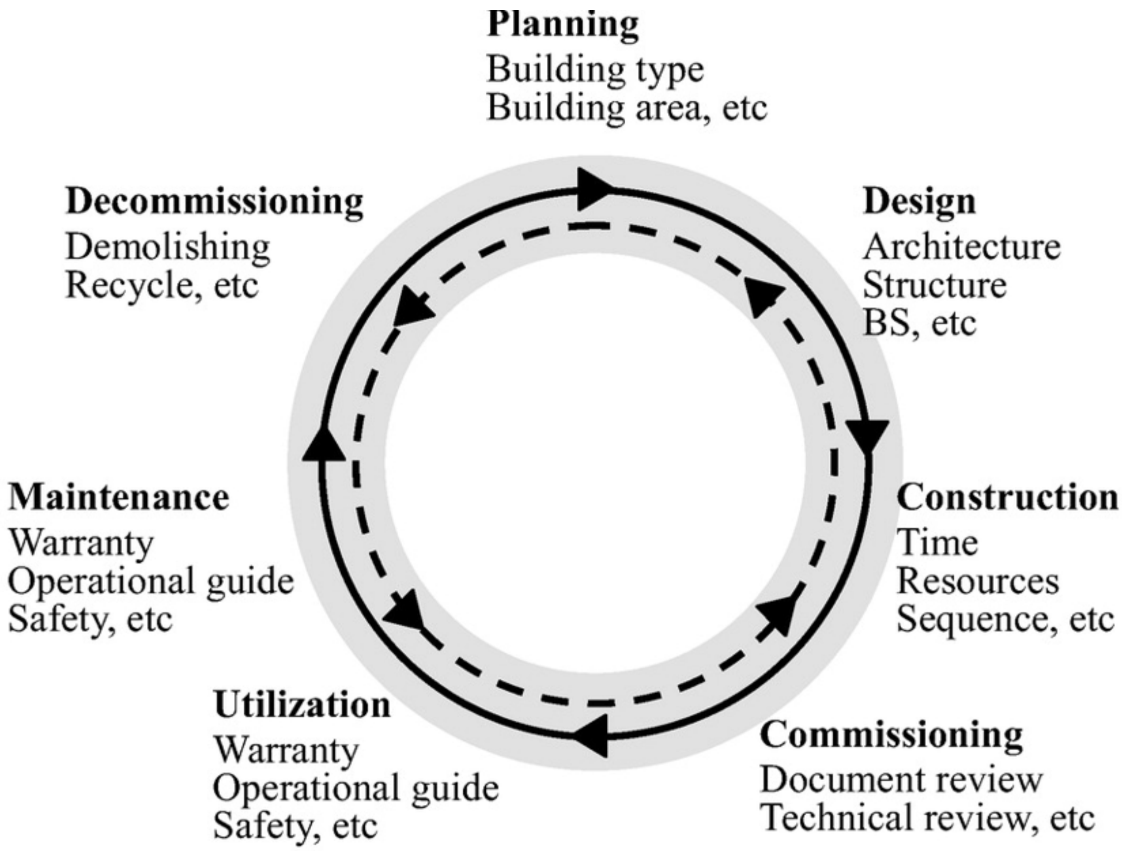
If waste sorting is not done, large amounts of potentially recyclable items will end up in landfills. However, by using a selected demolition technique in the top-down method, recyclable and reusable goods can be salvaged quickly and efficiently. Selective demolition is a well-known technique in which the demolition process is carried out in the opposite direction of the constructing phase (Construction Industry Research and Information Association, 1995). The approaches are more labor intensive and time consuming because the work involved in removing non-fixtures and other interior services/remains is generally done by hand.

The demolition waste, on the other hand, will be generally free of pollutants and non-recyclables, allowing for cost savings in waste transportation and disposal (Lauritezen and Hahn, 1992). Furthermore, selective demolition is frequently divided into phases, with one sort of material being dismantled and removed at a time. Because the wastes generated at each stage of deconstruction are comparable, the amount of recyclable materials that may be recycled can be considerably enhanced.

2.5 Factors for Construction Waste Generation

Construction waste is produced at various stages of the project, and it is also influenced by a number of different elements at each stage. Research has shown that construction waste is consistently produced throughout the project, from the beginning to the end of building activities. It may appear during the design, operational, material handling, and purchasing phases (Akir et al.,2013).

Figure 2.2 Phases in the Construction Life Cycle



On a building site, Construction and demolishing wastes(C&DW) are produced in several ways. Researches have determined that C&DW can be divided into six categories: design, material handling, operation, residual, and other sources. Depending on the materials used in each project, different waste categories have different sources of waste. The table below includes information on typical waste sources for each category (Jarman, D.S. (1996).

Table 2.2: Identification of C&D waste sources

No.	Waste	Cause/ Source of Waste
1	Design	• Blue Print Error • Detail Error • Design Changes
2	Procurement	• Ordering Error • Shipping Error
3	Handling of Material	• Improper Storage/ Deterioration • Improper Handling (on and off site)

4	Operation	• Human Error (by craftsmen or other laborers • Equipment Malfunctioning • Natural Disasters
5	Residual	• Leftover scrap • Un-reclaimable, non-consumable
6	Other Sources	

According to Akhir et al. (2013) in their research by conducting extensive literature review, have confirmed that:

- The major cause for waste that was found occurred during the construction phase, which is the most crucial phase. The design phase and the final phase come next. However, there is very little probability of waste production at the planning stage..
- Ordering errors and poor workmanship are the most frequent occurrences in the building phase that have a substantial impact on creating waste.
    - **Ordering Error** results in an excess or deficiency of orders. Over ordering could result in wasted materials and unnecessary usage of resources. While a lack of orders could result in inadequate material availability, which would suspend building at the location. Reordering the material will extend the time it takes to get the materials from the supplier.
    - **Poor Workmanship** could result from unskilled labor, inadequate tools and equipment, poor working environment, or all three. Poor workmanship is also a result of inexperienced project managers and supervisors. Poor workmanship results in abandoned work, particularly during the construction or remodeling stage, and may also lead to disagreement between workers because of departures from the original aim.
- In the design and completion phases, "last-minute client requirement" occurs most frequently.
- The incidence of construction waste elements is less frequent during the planning and finishing phases.
- Lack of a waste management plan during the planning phase is a contributing reason to waste.

Seyoum (2015) in his research identified 81 variables that contribute to material waste in the construction industry. These variables were divided into five categories: design and documentation; materials handling and storage; equipment operation (on-site); site management and practices; and site supervision. The table below displays the findings of his study and highlights the average and ranking of each group.

Table: 2.3 categories of that contribute for construction material waste

Main Groups	Weighted Average	Rank
Site supervision	0.69	1
Materials Handling Storage	0.60	2
Design and Documentation	0.55	3
Site Management and practice	0.54	4
Operation	0.53	5

(Source: Asmare, S.,2015. Managing and Minimizing Wastage of Construction Materials on Selected Public Building in Addis Ababa)

2.6 Characterization of Construction Waste

Depending on their composition, which includes inert materials such as cement, bricks, asphalt, wood, and metals, different types of waste are generated during construction, maintenance, and demolition activities (Table 2.4). During building, demolition, or renovation activities, hazardous materials such as asbestos can be released into the environment. Construction activities, overall, produce cleaner materials than demolition.

Table 2.4 Typical Construction and Demolition Debris Constituent.

Primary Inert Fractions	**High Organic Based Fractions**	**Range of Composite Materials (may require special handling)**
Asphalt	Ceiling tiles	Carpeting

Primary Inert Fractions	**High Organic Based Fractions**	**Range of Composite Materials (may require special handling)**
Brick Cinder block Concrete with rebar/wire mesh Concrete without steel reinforcing Masonite/slate Tile-ceramic Glass Dirt/earth Plastic sheet film Plastic pipe Porcelain, including bathroom fixtures Metal-ferrous Metal-nonferrous Electrical wiring Insulation-fiberglass Plastic buckets/containers	Corrugated shipping containers Insulation-treated cellulose Insulation-sheathing Pallets/spools/reels Pressboard/chipboard Roofing materials (e.g., roofing felt, asphalt shingles) Dimensional lumber & shapes (clean) Plywood, particleboard, oriented, strand board, etc	Carpet padding Gypsum wallboard (mainly gypsum with paper backing) Electrical fixtures (metal, light tubes/bulbs, ballasts) Electrical switches Rubber hosing/conduits Tires (some with wheels) Painted wood Pressure treated wood Wood composite

Primary Inert Fractions	High Organic Based Fractions	Range of Composite Materials (may require special handling)

(Source: Franklin Associates-EPA, ―Characterization of Building-Related C&D Debris in the US,1998)

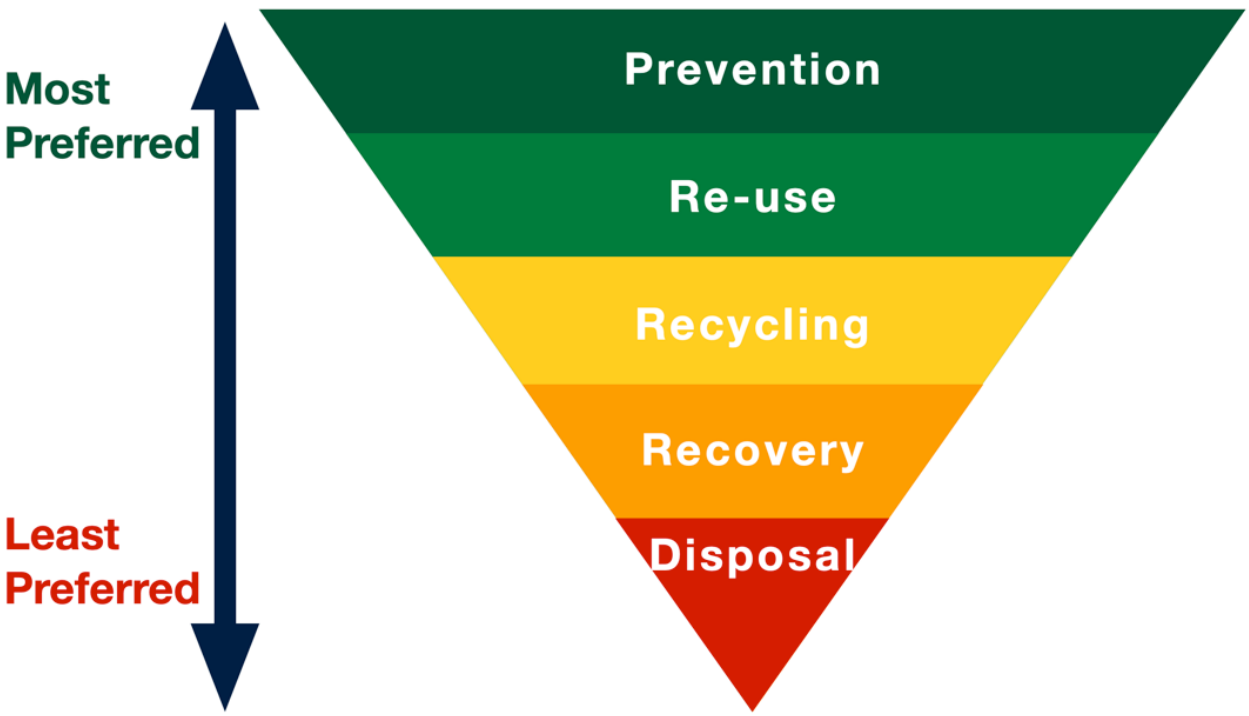
2.7 Construction and Demolition Waste Management

Information on solid waste generation, characterization, minimization, collection, separation, recycling, treatment, and disposal is presented and discussed in solid waste management. Manuscripts that address solid waste management policy, education, and economic and environmental assessments are also included (MoUDC (2012). The publication discusses a variety of solid wastes, including household hazardous waste, coal combustion residues, municipal (such as residential, institutional, and commercial), agricultural, construction and demolition, household hazardous waste, and other non-hazardous industrial wastes.

Due to its high level of pollution and heterogeneity, construction debris is difficult to recycle and reuse once it has been produced. As a result, project management's scope gives emphasis to its prevention and mitigation. There are several detrimental effects of construction and demolition waste(C&DW), including the depletion of natural resources, increased pollution, a lack of dumping sites, loss of the ecosystem and habitat that causes ecological imbalance, etc. The reduction of construction waste and its management are now major and difficult environmental issues in developing cities all over the world. Due to the growing amount of demolition debris, the ongoing lack of disposal locations, the rise in transportation and disposal costs and most importantly, the growing worry about pollution and environmental deterioration, the management of construction and demolition waste is a serious challenge (TIFAC, 2001).

The management of construction waste can be done in a number of ways. The management of construction waste involves much more than just disposing of the material. It is an all-encompassing strategy to efficiently use building resources with the goal of reducing waste generation and using that waste as effectively as possible. Dumping in landfills is the method of managing construction waste that is most frequently used. However, dwindling landfill capacity has resulted in rising waste disposal expenses for the contractor (Lingard et al, 2000). Additionally, due to inadequate material control on construction sites, a considerable amount of materials are wasted (Poon,et al.,2004). Alternative techniques and waste prevention strategies are now necessary as a result of this. The "waste hierarchy approach" is a common foundation for current waste management techniques. Concerned with the necessity to treat waste throughout the whole manufacturing lifecycle is the waste hierarchy.

Figure. 2.3 Hierarchy of construction and demolition waste



Source: EPA, Environmental Protection Agency

According to scientific research, waste management tactics that emphasize minimizing, reusing, and recycling of C&D waste help to achieve sustainable waste management. (Nagapan et al., 2012;Ram and Kalidindi, 2017).

When source separation is essential, the best management practices (BMPs) are skewed toward a market solution. If recycling centers exist in the area that will receive commingled waste from the building site and sort it off-site, the only factor is cost, because source-separation of waste requires no additional management or supervision time. According to Richard and Thomas (2010) the following are some of the accumulated best management practices for source-separation of construction waste intended for contractors:

A. Determine which items can be recycled.

Cardboard, wood, metals, and concrete, at the very least, have a high recycling potential. Review the project construction blueprints to record the materials before beginning construction:

(1) Specific types of materials utilized,

(2) Estimated material waste volumes, and

(3) Expected conditions of materials, i.e., are the materials reusable or only recyclable?

B. Find a recycling facility that would take the waste for the best price

Check to see if the items may be recycled in your area. When talking to potential recyclers about the different types of materials, bring up about the quality of materials, handling consideration, volumes of materials that the recycler can accommodate and cost of recycling services.

C. Examining the financial situation of the project to see if recycling or reuse is a viable option

Calculate the cost savings of recycling your C&D waste materials and compare them to the costs of landfilling or dumping at a transfer station.. If permits demand recycling and waste diversion from landfills, the issue may be irrelevant.

D. Create a waste management strategy

Identification of acceptable recycler(s), waste hauling contracts and considerations, monitoring processes, planning for on-site storage and source separation of building waste (if practicable), or use of a recycling center are all elements of a successful waste management plan. The capacity to store several roll-off boxes on-site or commingle and have separation occur at a recycling center is a crucial consideration in the decision to separate on-site or commingle and have separation occur at a recycling center.

E. Educate subcontractors and staff

Not only should employees and subcontractors be trained on expected waste management standards, but they should also be included in the creation of site-specific processes to gather their support and reduce the danger of contamination and non-compliance. Recycling building waste materials is now widely regarded as one of the most effective ways for reducing construction and demolition debris (Tam and Tam, 2006). However, because recycling of building waste materials is not always viable for all waste types, these recycling methods should be backed up by solid decision-making models.

Recycling these waste materials, on the other hand, will reduce the need for primary and secondary industrial activities to manufacture virgin materials, potentially resulting in significant environmental savings for various C&D waste management techniques in the United States.

2.8 Solid Waste Management Policy in Ethiopia

A significant proclamation that covers solid waste management, especially the management of construction waste, is Solid Waste Management Proclamation (SWMP) No. 513 of 2007.The declaration seeks to strengthen the ability to avert any negative effects and turn solid waste into assets that will benefit society and the economy.

Two of the proclamation's articles specifically address the management of solid building waste. Urban administrations are given the authority to take on or enter into agreements with construction businesses to refill solid waste disposal sites, quarry pits with pebbles or gravel from demolished buildings or with excavated earth under Article 12. Article 12 which deals with construction debris and demolition wastes, also specifies that building licenses should only be given to contractors after they have paid a bond that is legally legitimate or other documents that guarantee the environmentally responsible disposal of construction waste or excavated earth. Additionally, it states that before beginning any residential house development, metropolitan authorities should guarantee the availability of sufficient facilities for an environmentally sound solid waste management.

In accordance with Article 14, another article that deals with the construction of solid waste disposal sites, urban administration is required to ensure that solid waste disposal sites are built and used properly in accordance with the applicable federal environmental standard, that solid waste disposal sites are subject to environmental auditing, and that new solid waste disposal sites undergo environmental impact assessments.

A number of other provisions are included in the proclamation as well, including those relating to the duties of government agencies and citizens, planning for solid waste management, collection and storage, transportation, treatment, disposal, incineration, recycling, and hazardous waste, as well as civil and criminal penalties.

Another relevant proclamation is Environmental Pollution Control Proclamation (EPCP) No. 300/2002. The proclamation requires urban administrations to develop and put into place secure and reliable systems for managing, moving, and storing municipal waste. Urban administrations are required to oversee the collection, transportation, and, where necessary, the recycling, treatment, or safe disposal of municipal garbage through an integrated municipal waste management system, according to the proclamation under article 5, Management of Municipal Waste. Furthermore, it requires them to keep an eye on, assess, and guarantee the efficacy of municipal waste management systems.

2.9 Construction waste disposal Method

Building construction waste has a wide range of compositions, depending on the method employed to construct the structure. As an example, If precast concrete pieces are used, there will be very little waste concrete and timber forms to dispose of.

In practice, waste clearing is normally done every day at the job site by the main contractor. The waste is physically collected and dumped on the ground level through a temporary refuse chute (0.16–0.4 m2) awaiting hauling by a subcontractor.

Building construction waste is frequently polluted with a high percentage of organic materials and debris, depending on the type of the waste. However, if wastes such as wood, metals, plastics and granular materials or household items, It can be separated, the inert portion of the building construction wastes can be reused for land reclamation.

2.10 Construction Waste Management and Disposal in Addis Ababa

Landfilling is the most popular method of managing construction waste because there aren't enough landfills to dispose of solid waste in a proper manner. In Addis Ababa, for example, there is just one open dumpsite for the disposal of all forms of solid waste. Rappi or Koshe are two names for the location. It is becoming full, surrounded by residential areas and institutions, which is a nuisance and a health hazard for those who live nearby.

Building contractors for condominiums are required by contract to clear the site after construction is complete and to dispose of excavated items like soil and that waste must be disposed of up to five kilometers away from project sites in order to meet the contractual responsibility. Where and how it should be disposed of are not specified in the provision. Additionally, contractors are not required to dispose of waste in a safe and healthy manner for the environment. Enforcing contractual responsibilities is a challenge, and there are occasions where contractors fail to dispose of construction waste in accordance with their commitments. The requirement to remove waste from the site is also a general one, and there is no mechanism in place to guarantee that waste is disposed of correctly after projects are finished.

Metal, wood, and electrical components are recyclable materials found in construction waste. However, due to infrastructure and technological issues, recycling is not commonly used. The infrastructure and facilities already in place are insufficient for efficient waste reuse and recycling. Information on the quantity and composition of construction waste, technical, institutional, and organizational capabilities, prevalent attitudes, and access to technology and financing are not readily available. Tewodros et al. (2021) discovered through their research that recycling and reuse are not as commonly implemented as disposal in the management of building waste. The most favorable technique is indicated as illegal dumping, followed by reuse and recycling. It is clear that if enough awareness is raised, more than 75% of the trash produced by the building industry could be recycled and used again. They discovered that effective waste management requires the cooperation of all relevant parties, including the city administration, to control illegal dumping sites and that enacting pertinent regulations could support source reduction, reuse, and recycling that reduce the number and size of illegal dumping in the Mekekle city.

Teshome (2021) used the three I's (Irregular, Appropriate, and Inefficient) to define Ethiopia's existing waste management system. These three I's stand for Sporadic and Inconsistent Collection, Low Coverage, Technical Weaknesses, and Lack of Law Enforcement, respectively.

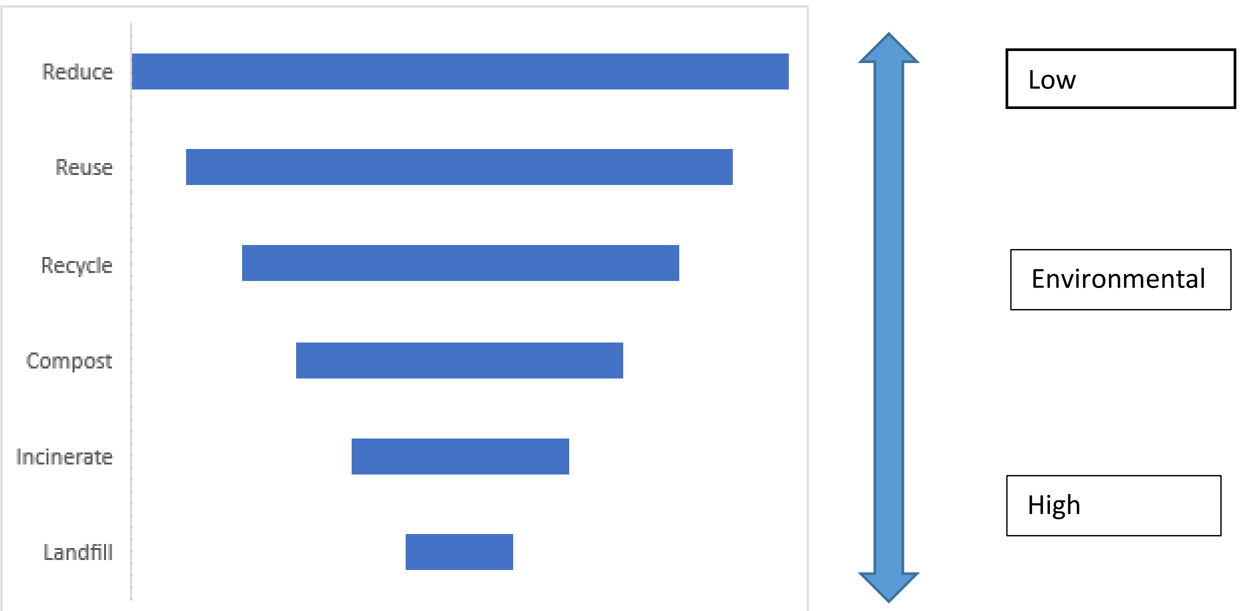
Therefore, it should be a top priority to implement the new system suggested in this study (Teshome, 2021).

2.11 Integrated Waste Management

Environmental management and the objective of sustainable development have pushed all industries including construction, to adopt appropriate environmental protection practices. Natural construction is not an environmentally beneficial practice.

Reduce, reuse, recycle, compost, incinerate, and landfill (Peng et al., 1997) is a hierarchy of disposal choices that categorizes environmental impacts into six stages, from minimal to high (see Fig. 2.4). The "3Rs" are a collection of three key waste minimization strategies: reuse, recycling, and reduction. To reduce construction waste generated on site, coordination among all those involved in the design and construction process is essential.

Figure. 2.4 Hierarchy of construction and demolition waste



(Source: Peng CL, Scorpio DE, Kibert CJ. Strategies for successful C&D waste recycling operations, 1997)

Apart from agriculture waste, C&D waste generation in the EU is expected to exceed 450 million tons per year, making it the single greatest source of garbage. Annual construction and demolition waste production is expected to be 180 million tons without soil and certain other wastes, and with a population of over 370 million, annual garbage generation per capita is around 480 kg (European Commission and Report, 1999).

Although exact recycling figures for individual EU nations are not available, an EU study revealed that an average of 28% of all C&D waste was recycled in the late 1990s. The majority of EU member countries have established recycling goals ranging from 50% to 90% of their C&D waste production to replace natural resources such as timber, steel, and quarry materials. In Germany, Holland, and Denmark, recycled materials are generally less expensive than natural materials, and recycling is less expensive than disposal. The United Kingdom consumed about 330 million tons of aggregates in 1989, with just around 10% of those being recycled resources. Despite the fact that each building and demolition project is unique, all stakeholders participating in the process should think about the layout of the collecting area, collection, contract issues for disposal and hauling, material separation and/or preprocessing, and hazardous waste handling Patrick J. Dolan et al. (1999).

2.12 Construction and Demolition Waste Management Barriers

Cochran, (2001) and Barnes, (2002), assessed the potential demand for construction and demolishing waste materials in order to see if low recycling rates were due to a lack of a market for recovered products. To estimate prospective recycled material demand, these research examined industry data on the consumption of natural resources that may be substituted with recycled materials. The most crucial stage in establishing a recycling program is to find a market for recycled waste products. The poor recycling rates of C&DW could be due to a lack of markets. Concrete, wood, drywall, and asphalt roofing shingles account for the largest percentages of C&DW (by weight) and have the greatest potential for recycling.

The materials that were tested for material reuse and recycling were wood, drywall, and concrete. The difficulty of on-site sorting to ensure that the product stream is generally pure is a common obstacle to reuse/recycling of these products. The lack of understanding about how to reuse/recycle treated wood, as well as the ease of landfilling, are additional hurdles to wood reuse/recycling. The lack of gypsum recycling facilities is one of the most significant hurdles to drywall reuse and recycling. Contamination of the crushed product diminishes the strength of the aggregate and raises the cost when compared to virgin material, which is a key hurdle to reuse/recycling concrete (CIB Publication, 2014).

The following are the common barriers to deconstruction and reuse/recycling that apply to all materials in Canada:

1. A lack of knowledge about the value of reused material,
2. The perception among industry professionals that demolishing costs more,
3. The short deconstruction turnaround time,
4. Poor waste management planning,
5. A lack of cooperation among subcontractors, and
6. The lack of a market for reused material.

The following are the major barriers to demolishing in Germany: existing buildings are not designed to be dismantled, major building components are not designed for dismantling, suitable deconstruction equipment is not available, disposal to landfills is often more cost effective, material separation can be time consuming, building codes may limit the reuse of some structural components, dismantling costs are uncertain, there are no "best practices," in place.

Political, technical and research efforts such as policies, market strategies and viable technology for recycling are advocated to overcome the barriers to deconstruction. Ordinances allowing for more material reuse and a federal legislation called the "Act for Promoting Closed Substance Cycle Waste Management and Ensuring Environmentally Compatible 11 Waste Disposal" are two political measures for encouraging construction waste reuse. Standards such as ATV DIN 18459 for contracting issues for deconstruction materials, advancement of building certifications, and work instructions for the recycling of deconstruction material are among the technical techniques used to overcome deconstruction barriers (CIB Publication, 2014).

2.13 Concept of Recycling

Recycling is the process of repurposing a recycled substance into a new material or another application (Dolan, 1999). Additionally, it is described as the procedure that subjects an item to physical or chemical changes between the moment it is separated from waste and the time it is processed into its final form (EPA. Environmental Protection Agency, 1993).

C&D waste is typically disposed of in landfills; however, growing realization of the potential for diverting more and more waste components from landfills has led to C&D waste being a recycling goal (Peng et al., 1997; Trankler et al., 1996). Despite the fact that numerous material recycling plans are advised, C&D waste recycling is only administered for a few types of solid wastes. According to (Mindess et al. 2003) when choosing a recyclable material, three factors must be considered: cost, compatibility with other materials, and material qualities.

Only when the recovered product is cost and quantity competitive with natural resources is recycling of C&D waste attractive from a purely economic basis. Recycled materials will be more competitive in regions where both raw resources and landfilling sites are scarce (Mindess et al. 2003). Patrick J. Dolan et al., (1999) stated that project managers in charge of organizing a construction project recycling program must keep in mind that recycling operations necessitate market analysis and extensive planning; as the variability of recycling economics necessitates management preplan of a project as much as possible to avoid unforeseen problems.

2.13.1 Viable technology on construction waste recycling

Despite the fact that a variety of material recycling methods are recommended, C&D waste recycling is only used for a few forms of solid waste.

When considering a recyclable material, three crucial characteristics must be addressed (Mindess et al., 2003); economy, compatibility with other materials and material properties.

Only when the recovered product is cost and quantity competitive with natural resources is recycling of C&D waste attractive from a purely economic basis. Recycled materials will be more competitive in regions where both raw resources and landfilling sites are scarce. It investigates the potential of building waste recycling technology. The following ten practices for material recycling are investigated: asphalt, brick, concrete, ferrous metal, glass, masonry, non-ferrous metal, paper and cardboard, plastic, and wood

Asphalt

In the Netherlands, 50 percent of asphalt waste was used to make new asphalt in 1990, with 10–15 percent recycled asphalt added to the mix (Hendriks and Pietersen, 2000). The shattered asphalt can be combined with cement and used as a sub-base instead of sand or cement sub bases. Old asphalt materials are crushed and combined with sand and binder to make asphalt aggregate. Cement or a liquid in the form of a bituminous emulsion can be employed as the binder; a combination of cement and a liquid binder can also be utilized.

In addition to these binders, blast furnace slag or fine slag can be utilized to stabilize asphalt aggregate. Due to the relevance of the composition of these combinations, only a tiny fraction of asphalt can be reused in very permeable road surfaces. To recycle asphalt products, several recycling technologies were used (Hendriks and Pietersen, 2000):

(i) cold recycling, water, and a stabilizing ingredient such as cement, foamed bitumen, or emulsified bitumen are mixed together (Cheung, 2003);

(ii) heat generation causes a reorganization of the bitumen's original physical qualities and chemical compositions;

(iii) the Minnesota method heats the old asphalt to a temperature above normal (180°C) for heat transfer to reorganize the materials; Preheating is done in a separate dryer and heater drum in the parallel drum method.

(v) The extended drum process involves drying and heating the aggregate, then adding asphalt aggregate, filler, and bitumen, and finally mixing all of the components together.

(vi) The microwave asphalt recycling system involves de-ironing and crushing the asphalt rubble;

(vii) The Finfalt method can create recycled asphalt immediately before to dosing by a mobile plant handling the materials;

(viii) Surface regeneration refers to any technology that involves heating asphalt in the road to a depth of several centimeters beneath the surface and then reprocessing it in a slurry.

Brick

Demolition bricks may be polluted with mortar, rendering, and plaster, and are frequently mixed with other materials like wood and concrete. Separating the possibly valuable face bricks will usually be difficult and will necessitate manual sorting. Only 10–15 percent of bricks from old structures in Denmark are face bricks (Kristensen, 1994), making brick sorting and cleaning more labor-intensive and costly. Any major contamination of the bricks will make their use uneconomical, as the costs of remediation greatly outweigh the price of natural brick. It burns the demolished bricks into slime and ash at the procedures of a building site in Kyoto, Japan in 2004. In Hong Kong, bricks are increasingly being broken to make infill materials and hardcore this days.

Concrete

The two most frequent ways to recycle concrete rubble are bound (natural aggregate replacement in fresh concrete) and unbound (road base, trench, etc.). Despite the fact that unbound use consumes more than 90% of the volume, recent studies have shown that concrete quality may be maintained with up to 30% aggregate substitution in fresh concrete (Coventry, 1999; Hendriks and Pietersen, 2000; Masters, 2001).

Lucy Feleke et al.,(2019) tested concrete with 25%, 50%, 75%, and 100% replacement of sand with recycled hollow concrete block. With a percentage increase, the compressive strength decreased and the targeted compressive strength was attained at 50% replacement.

Ferrous metal

Ferrous metal recycling has a well-developed market all around the world. It is the most profitable and recyclable material on the market. The demand for ferrous metal has long been well established, and as a result, the material's applications have been widely accepted on the job site. Steel should be reused as much as possible. If it can't be reused directly, it's melted to make new steel. In the Netherlands, more than 80% of scrap is recycled, with over 100% of it being claimed to be recyclable. According to the Steel Organization, about 100% of steel reinforcement is made from recycled scrap, and 25% of steel sections are made from recycled scrap. Scrap steel is almost entirely recycled, allowing for several recycling cycles (Coventry, 1999). In Japan, steel for construction, such as steel form and rebar, is produced or cut to size off-site, and the cutting debris can be recycled to prevent wastage on the job site.

Glass

Glass may be reused for a variety of reasons in the construction industry

(i) Window: If care is taken throughout the demolition phase, glass window units can be reused right away (Coventry, 1999), depending on how well they are handled, kept, transported, and contaminated.

(ii) Glass fibre: Glass is recycled in the creation of glass fibre, which is used in thermal and acoustic insulations and can be mixed with stronger cement, gypsum, or resin products to improve material qualities (Coventry, 1999). Glass wool mat; pipe cover and thermal insulation board with facing for plant; ceiling board and acoustical insulation board for industrial and commercial building; glass wool board and glass wool blanket without binder for automobile are all examples of recycled glass used as isolation materials in Japan.

(iii) Filling material: In the United Kingdom, recycled glass is utilized as a fine material for cement replacement called "ConGlassCrete," which is used to improve concrete strength.

(iv) Tile: In the United States, tile has been accepted as a 100 percent replacement for recycled glass. After polishing, the surface has a beautiful shiny aspect.

(v) Paving block: This type of paving block is created in the United States using crushed recycled glass aggregate. This recycling method is also being developed in Hong Kong.

1. create a beautiful reflecting appearance after polishing;

2. reduce water absorption in concrete blocks;

3. provide improved compressive strength, Instability, aggregate sharpness, and alkali-silica reaction expansion are all challenges that must be addressed. To increase the quality of recycled glass aggregate paving blocks, powdered fly ash must be used as an alkali-silica reaction depressant and to remove impurities.

(vi) Asphalt in road: old glass is required to crush into very fine material in replacing asphalt. Taiwan practices replaced 15% recycled glass for asphalt use.

(vii) Aggregate in road: Crushed glass has been produced for use as an aggregate in bituminous concrete pavement, sometimes referred to as 'glassphalt,' and has been tested in the United States (Coventry, 1999).

(viii) Aggregate in concrete: In Sweden, a unique fine aggregate made primarily of glass has been created for use in concrete. The presence of glass in secondary aggregate used in the manufacture of concrete or asphalt may impair the material's strength

(Hendriks and Pietersen, 2000). 'Microfiller' is the product of an industrial process that includes separation and washing procedures to purify the glass material. The glass is then dried, crushed, and ground to the requisite specifications, with particle size grading defined as the difference between cement and aggregate size grading. The pozzolanic ingredient was added to the concrete batch during the mixing process, along with other constituents. The Microfiller will improve the qualities of the concrete in both the fresh and hardened states.

(ix) Man-made soil: Japan's waste glass is used as ultra-fine particles in high-temperature soil.

Masonry

Masonry is typically broken into masonry aggregate that has been recycled. Hendriks and Pietersen (2000) used recycled masonry aggregate in a thermal insulating concrete with polystyrene beads, resulting in a lightweight concrete with high thermal insulation (Hendriks and Pietersen, 2000). Another use for recycled masonry aggregate is in traditional clay bricks and sodium silicate brick (Hendriks and Pietersen, 2000):

(i) A little portion of recycled masonry aggregate is used as a replacement for clay in brick and as a sand replacement in sodium silicate brick.

(ii) For use in traditional clay brick, this fraction should not contain any lime to prevent adverse effects on strength, shrinkage, durability and colour.

(iii) This percentage may contain lime when used in sodium silicate brick, however sodium silicate brick should be made at a pressure of 15 bar and at lower temperatures than clay brick. Adhesive cement must be removed by a mechanical or thermal procedure when recycled masonry aggregate is utilized for sodium silicate brick. When a cement-covered brick is heated to 900°C, interfacial stress is formed, and the cement can then be extracted as fines (Hendriks and Pietersen, 2000). Clinker can be made by heating this material. When natural material is used, the amount of carbon dioxide (CO2) created by this method is reduced. After heating, lime mortar can be reused; however, while processing sodium silicate brick, the adhesive must be physically removed.

Non-ferrous metal

Aluminum, copper, lead, and zinc are the most common nonferrous metals gathered at C&D sites (Coventry, 1999). Products can be sold to scrap metal merchants for recycling or straight to end-users by melting once they have been sorted. Up to 228,700 tons of lead are recycled (about 85 percent of lead utilized is recyclable); zinc is recycled in the production of galvanized steel strip (almost 60,000 tons) and protecting steel galvanized after fabrication (40,000 tonnes). For roofing cladding and to some extent flashing, a very limited amount of zinc sheet (2000 tonnes per year) is utilized. In addition, a substantial amount of zinc (approximately 30% of the composition) is utilized in the manufacture of brass (Coventry, 1999).

Paper and cardboard

By volume, paper and paperboard account for around 37% of C&D waste (EPD, 2002). It frequently attracts recyclers who purify them and reprocess them into new paper products (Hendriks and Pietersen, 2000). Furthermore, material suppliers have been advised to reuse their original packing materials in recent years.

Plastic

If polyethylene (PE), polypropylene (PP), polystyrene (PS), and polyvinylchloride (PVC) are collected individually and cleanly, high-level reuses of these materials are available for recycling (Hendriks and Pietersen, 2000). When plastic waste is mixed with other plastics or impurities, recycling becomes challenging. Due to the deterioration of old plastic's characteristics, the scope for high-level recycling is limited. For recycling, virgin material must be introduced.

In the Netherlands, recycling material is used in the creation of new plastic profiles that contain 70% recycled material and 30% virgin material to ensure adequate UV protection (Hendriks and Pietersen, 2000). It may be possible to raise this replacement ratio to 80 or 90 percent in the future. When it comes to plastic recycling, there are three major issues to consider (Coventry, 1999):

(i) PVC Roofing: the recycling of transparent PVC roofing panel started in 1992. Due to contamination and the reinforcement, the recycling material has a poorer quality than new roofing element, and therefore they can only be used for the lower face. The panel is converted to powder by cryogenic milling. The powder is then mixed with plasticizers and other materials for the production of new panel (Hendriks and Pietersen, 2000).

(ii) Plastic may be recycled and used in products specifically designed for the utilization of recycled plastic, such as street furniture, roof and floor, piling, PVC window, noise barrier, cable ducting and pipe, panel, cladding and insulation foam (Tam & Tam, 2006).

(iii) Technology is being developed that will enable building materials to be progressively infused with recycled plastic constituent in order to increase strength, durability and impact resistance, and enhance appearance. This has resulted in companies creating versatile product for plastic lumber and aggregate in asphaltic concrete (Tam & Tam, 2006).

(iv) Plastic can be used in future construction projects. Plastic component recycling is limited to landfill drainage and asphalt due to volume, time, and price constraints (Sustainable Construction, 1994).

(v) Man-made soil: Japan practices adopted after burning wasted plastic at high temperature and turning them into ultra-fine particles (Hussein and Mona, 2018).

Timber

Timber waste from C&D work generated in significant quantities all around the world. More than 2.5 million tons of wood waste are generated in the UK each year, according to estimates (Coventry, 1999; Masters, 2001). Timber waste has the potential to be recycled in the following ways:

(i) After cleaning, de-nailing, and sizing, whole timber resulting from C&D activities can be simply and immediately reused in future construction projects. Planks, beams, doors, floorboards, rafter, panels, balcony parapets, and piles can all be made from undamaged wood (Hendriks and Pietersen, 2000). In 2004, Japan developed a new technology for recycling wood waste into furniture, including a shoring wooden pile for relocated pine trees, a wood bench, and a wooden stair (Tam & Tam, 2006).

(ii) A special lightweight concrete can be produced from aggregate made from recycled small wood chunk (Tam & Tam, 2006).

(iii) In Japan, wood waste can be recycled as energy in the form of fuel and charcoal for power generation. In the Netherlands, 400,000 tons of wood are generated as a result of C&D activities (Hendriks and Pietersen, 2000); the majority of this wood is landfilled or incinerated as a by-product in a coal-fired power plant or a cement kiln; prior to incineration, the wood will have been drastically reduced in size. Deoxidization in a blast furnace is also used in the recycling of wood (Tam & Tam, 2006).

(iv) Timber can be recycled as a chemical product after hydrolysis by gasification or pyrolysis in incinerating or decomposing waste wood (Hendriks and Pietersen, 2000).

(v) Timber fragments generated during C&D work can be recycled and used to make new construction commodities such wood-based panels for roofs, ceilings, and floors, cladding for agricultural buildings, hoarding as an alternative to packaging, and sound barriers (Tam & Tam, 2006).

(vi) In Japan, recycling timber uses paper, recycled board, and insulating material. Furthermore, waste wood in the form of woodchip can be combined with topsoil to improve soil texture and then covered with plastic to create plastic wood (Tam & Tam, 2006).

(vii) In Japan, clipped timber is recycled by spraying it onto a sloped soil surface, a process known as "geofibre" (Tam & Tam, 2006).

(viii) Timber waste can be recycled into insulating board, cooking utensils, and furniture by pressurizing chipped timber at around 180°C for 40 minutes with steam, water, and the addition of a binder. In 2004, Japan implemented this technology for converting wood chips into pavement material (Tam & Tam, 2006).

Hollow concrete block

Hollow concrete blocks are produced using the cement, fine aggregate, course aggregate and water. Kumar et al., (2020) found that by replacing 20% of the course aggregate from recycled construction waste, the compressive strength can still be achieved.

2.13.2 Marketing strategy

The market penetration rate of recycled things has become an ambiguous issue due to a lack of regulation. The public's antipathy to recycled items remains strong, making commercial penetration difficult. Due to historical and psychological barriers, the general attitude toward recycling in the construction industry is preventing the utilization of recycled materials. As a result, all parts of the construction industry must qualify and accept recycled materials (Nabil et al., 2004).

Because some application testing and permits are necessary, it is unrealistic to expect that every recycled material generated will be automatically accepted as a substitute in the market. Recycled aggregates, as previously said, are the most valuable material that will be recycled. However, the most valuable applications for recycled aggregates, such as concrete (reinforced and unreinforced) and asphalt, are also the most limited. As a result, in order to be conservative, the penetration of that substitute market is expected to occur gradually. The recycling facility will be able to take feedstock sourced from landfill mining once market access has been acquired and recycled aggregates have gained widespread acceptance in the market (Nabil et al., 2004).

2.13.3 Economics

Recycling's economics must be weighed against the costs of other waste management solutions such as landfilling and incineration. Recycling is definitely aided by the high relative costs of the alternatives. Another major issue in the economic attractiveness of recycling is the cost of virgin raw materials, which can be viewed as excellent equivalents for secondary raw materials from a recycling standpoint. The choice between recycled and natural materials in a market economy is based on cost and quality (Nabil et al., 2004).

According to the solid waste association of North America(SWANA), (1993) the cost of competing products at the site of application determines the value of the final marketable waste, or market price. This "free market price" (MP) is based on the following criteria.

$MP = MC+PC+TC+P$

Where:

MC is material cost

PC is processed cost

TC is transportation cost

P is profit

The cost of obtaining the raw waste stock from the generator is included in the material cost. The complexity of the amount of labor required to handle, process, and prepare/package the product determines the processing cost. Administrative expenditures, for example, should be factored into the processing cost. The cost of transportation is determined by the distance from the processing facility. The greater the distance between markets and the items, the higher the market price. The cost of transportation will be determined in part by the density of the substance to be transported. Materials like expanded polystyrene or timber scraps will cost more to transport if the carrier charges by volume because they require more volume per unit than other denser garbage. The cost of transportation may be the most important component in determining the market price. The processing facility sets the profit to offset the risks of running a waste processing facility. After calculating the free market price, this information can be used to compare items made using "virgin materials.”

Many regulations and guidelines consider recycled materials to be of lower quality than virgin materials (Lave et al., 1994), hence purchasing products created from recycled materials would be considered an environmental investment. Concrete using recycled aggregates, on the other hand, has the same quality as concrete with natural aggregates. As a result, where the price of recycled concrete aggregates is significantly cheaper than the price of natural aggregates, recycled concrete materials will be favored (Nabil et al., 2004).

2.14 Incentives to recycling or policies

Recycling is frequently advocated as the most effective waste management strategy. However, in many places, waste generators do not prefer recycling as a waste management approach. Economic factors, convenience, and contemporary thinking are all factors in the absence of recycling. Some governments have enacted legislation aimed at removing these obstacles, although the impact of these initiatives is unknown (Cochran, 2006).

Because it is difficult to change one's perspective about disposal, psychological hurdles to C&D debris recycling persist. People are accustomed to the current system and are difficult to change, particularly when there is no compelling reason to do so. They frequently have little idea how their behaviors affect the environment. Barr and Gilg (in press) emphasize the importance of understanding individual behavior patterns when developing local waste policies. Understanding what obstacles exist in a region and which policies can be used to overcome them is critical.

Previous innovative recycling projects in Florida have shown that markets exist for many of these commodities and assessed various processing systems, but the results clearly show that other variables operate as roadblocks to widespread recycling. In many parts of the state, additional barriers, most notably economic ones, have made C&D waste recycling problematic (Cochran, 2006).

Although these obstacles exist, it is crucial to note that in some parts of the country, recycling of these materials has been successfully done. Recycling becomes feasible in certain circumstances due to regional economic variations, while in others, government officials and policymakers take specific activities that make C&D debris recycling more appealing. Trying to encourage recycling is a difficult task for state and local governments. Environmental economists have long believed that standards-based programs are wasteful and, in certain cases, have worsened corporate hostility to future environmental legislation (Bailey, 2002). As a result, market-oriented policies are chosen. Environmental costs are supposed to be factored into the economy through these mechanisms. Market-based policies, on the other hand, have flaws when markets are so volatile (Ackerman and Gallagher, 2002).

2.14.1 Policy Options

Many different policies can be used to encourage the recycling of any waste. These policies are listed in Table 2.3. Direct regulation, market incentives, and education are the three types of policies (Barron and Ng, 1996). Direct rules compel or incentivize generators to divert waste. Direct regulation includes disposal bans, percentage and material recycling requirements, green building requirements, recycling goals, and salvage requirements, to name a few. By making waste diversion a more cost-effective choice, market incentives make it more desirable. Market incentives include disposal taxes, subsidized recycling, company development, and advance disposal fees/deposits/rebates

Table 2.3 Definitions of policies types that may encourage C&D debris recycling

.**Name**	**Description**
Disposal ban	A law or regulation that prohibits the disposal of

.Name	Description
	certain waste products in landfills or restricts the disposal of certain waste materials to landfills with enhanced environmental protection.
Disposal tax	Inflating the expense of disposal artificially to make recycling and reuse a more cost-effective choice for the general public.
Subsidized recycling	Artificially lowering the cost of recycling in order to make recycling and reuse a more cost-effective choice for the general public.
Percentage recycling requirement	A law or rule that mandates the recycling of a certain percentage of the waste stream.
Material recycling requirement	A law or regulation requiring the recycling of specified waste items.
Deposit/Advanced disposal fee (ADF)/ Rebate	A law or ordinance requiring the public to pay for waste disposal prior to the development of waste (generally at the time that the building permit is applied for). If documentation is provided that the material is recycled, this cost is refunded.
Government waste recycling requirement	A legislation or rule requiring all government construction activities that produce waste (including C&D debris) to recycle or divert some of that garbage from landfills.
Government recycling purchasing requirement	A regulation or rule that forces government entities to purchase recycled-content items.
Business development	Investments granted by the government to enterprises to aid in the development of recycling.
Education	The government should make educational initiatives to raise recycling knowledge,

.Name	Description
	particularly for C&D waste.
Recycling Goal	Legislation requiring a certain percentage of waste to be recycled.
Green Building	A piece of law or a policy that stimulates green construction in the area.
Salvage requirement	An obligation for demolition contractors to post notice of impending demolition so that anyone might recover components from the structure.

(Source: Cochran ― Construction and demolishing debris recycling: methods, markets, and policy, 2006)

2.15 Overcoming Barriers

Education is required to overcome the barriers to reuse/recycling by promoting the programs that are available to provide information and resources for decreasing product landfilling. According to CIB Publication (2014) growing the market for reused materials, increasing the use of Canadian building demolition guides, encouraging the preparation of demolition/dismantling plans that all contractors or subcontractors will be expected to follow, expanding the Extended Producer Responsibility (EPR) program, which requires material manufacturers to take back waste materials, improve zero waste initiatives to reduce the amount of waste that is landfilled, use an integrated design process to communicate waste-reduction techniques, and requiring building rating systems certification to raise waste-reduction awareness are advised to address barriers to construction and demolishing recycling.

2.16 Hollow Concrete Blocks

Hollow Concrete Block (HCB) is manufactured into molds, to achieve the required physical strength and dimensions to requirements and standards. They are produced as:

A. Load bearing walls (Class A & B)
B. Non load bearing walls (Class C)

2.16.1 Classes and dimensions of Hollow Concrete Blocks

Ethiopian standards ESC D3.301 and MoWUD: 2001 hollow concrete block shall confirm three classes depending on their strength, as Class A, B and C.

Class A: Class A blocks must have a density of 900-1200 kg/m3 and be used for load bearing wall construction above or below ground level in damp proof course, in external walls that may or may not be covered with weather-protective coating, and for internal walls, according to Ethiopian standards.

Class B: According to the Ethiopian standard, these are used for load bearing wall construction above ground level in damp proof course in exterior walls that are treated with suitable weather-protective coating, and their density should be between 900 and 1200 kg/m3, whereas the Indian standard IS: 2185 (Part I) – 1979 recommended a minimum density within the range of 1000-1500 kg/m3.

Class C: This class is for non-load bearing inner walls and exterior panels walls in steel or reinforced concrete framed construction that are protected from the elements by rendering or other effective treatment and have a density of 600 to 900 kg/m3.

2.16.2 The production process of hollow concrete blocks

There are two major activities in the production of hollow concrete blocks (HCBs): one is linked to raw materials, and the other is related to the manufacturing process. Both procedures must be attended to in order to manufacture high-quality HCB (ES 596:2001). If proper care is not taken with materials, their quality, and handling mechanisms, poor quality HCB products may result, even if the manufacturing procedure is correct.

The production process of HCB involves the following major steps;

- Batching or proportioning of ingredients
- Mixing
- Compacting/Vibrating
- Curing

All materials must meet the standards before production can commence. The purpose of this laboratory test is to see if hollow concrete blocks made from recycled hollow concrete blocks meet Ethiopian standards. For the compression test, six full-sized samples from 4000 blocks will be taken. The unit is defined as the maximum load in Newton divided by the unit's gross cross-sectional area in square millimeters, with the nearest 0.1 N/mm2 findings reported separately for each unit and as an average for the six units (M. N. Anosike and A. A. Oyebade,2012).

Table 2.4 The nominal dimensions of HCB according to standard specification of building and road materials construction design S.C Addis Ababa

Thickness (t) in mm	Height(h) in mm	Length(l) in mm	Face sheld (d) in mm	Web (e) in mm	Max unit weight(kg/m3)
100	200	400	20	20	1200
150	200	400	25	25	1200
200	200	400	30	25	1200
250	200	400	35	30	1200
300	200	400	40	30	1200

2.16.3. Batching /Proportioning

Proportioning is the process of determining the appropriate amounts of raw materials required to manufacture HCB of the desired quality under specified mixing, putting, and curing conditions.

The combined aggregate content in the concrete mix used to make hollow blocks should not be more than 6 parts by volume of Portland cement for class C HCB and not more than 4 parts by volume of Portland cement for class B and A HCB, according to Ethiopian Standard specifications (Addis Ababa condominium housing projects HCB production training manual). The water cement ratio of 0.7 by weight basis according to EBCS -2

2.16.4. Mixing

The goal of thoroughly mixing the ingredient aggregates, cement, and water is for the cement-water paste to completely cover the aggregates' surface. All of the raw elements, including water, are collected in a concrete mixer, which is rotated for around 12 minutes. Within 30 minutes, the prepared mix should be removed from the mixer and consumed.

Machine mixing is necessary for large-scale concrete projects and for optimum workability so that the concrete may be placed quickly and without waste. Concrete mixers are used to mix concrete with coarse materials. According to (Claudia etal,.2006) Machine mixing procedure:

- Quantity measurement of each ingredient is the first step;
- Then add the aggregates and some amount of water, then the cement, then the sand;
- After mixing thoroughly add the rest of the measured water until the right consistency is achieved;
- Clean the concrete mixer thoroughly on completion after discharge of every batch

To prepare a concrete hollow block with high quality, which can be used for walls of houses, the mix ratio should be: 1 part good quality cement + 2 parts clean river sand + 3 parts rough gravel + sufficient water Keep in mind that for building houses always best quality blocks are to be used as the safety of families moving into the houses (Claudia etal,.2006). According the manual prepared for training HCB producers for condominium building projects for class B blocks 1 part of cement + 1 part sand + 1 part of red ash + 1 part 00 aggregate + 1 part 01 aggregate. For class C 1part cement + 2 sand + 3 part red ash + 0.5 part 00 aggregate + 0.5 part 01 aggregate. The HCB samples that is experimented on this thesis uses the smashed HCB as the course aggregate instead of the other ingredients (red ash, 00agregate).

2.16.5 Compacting/ Vibrating

The goal of compacting is to completely fill all air pockets with concrete while preventing free water movement through the concrete. Excessive compaction can lead to the creation of water pockets or layers with higher water content, lowering the product's quality. For manufacturing cement concrete hollow blocks, semi-automatic vibrating table machines are commonly utilized. An automatic vibrating unit, a lever-operated up-and-down metallic mould box, and a stripper head housed in a frame work make up the machine. A wooden pallet is kept on the machine's vibrating platform. The mold box is placed on the pallet and lowered. The concrete mix is poured into the mold and smoothed out uniformly. The concrete settles down the mold as a result of the motorized vibrating.

The mold level is then scraped with more concrete. The stripper head is positioned over the mould and brought into contact with the leveled material. Vibration causes the concrete to collapse to its lowest point. The mold box is then lifted using the lever. The molded hollow blocks on the pallet are removed, and the process is restarted with a new pallet. The machine can accommodate interchangeable molds for creating hollow blocks of various sizes.

2.16.6. Curing

Curing is one of the most crucial steps in the manufacturing process. Curing is used to replenish evaporating water using the sun and/or air. Water is also required for the hydration process, which is a chemical reaction that sets / hardens the mortar. Once the HCBs have been dropped on the floor, they must be kept moist and shielded from the sun. According to Indian standards, this could take up to 24 hours under a shelter away from the heat and winds. The hollow blocks are then cured for at least 21 days in a curing yard to allow complete shrinkage. When the hollow blocks are cured in a water tank, the water should be changed every four days at the very least. The first three days provide the highest strength gains, with lasting effects lasting up to 10 to 14 days. The better the product, the longer the curing time allowed. The blocks must not be utilized for at least one month following production to allow for initial shrinkage before being installed in the wall.

2.17 Summary of Literature Review

Ethiopia's construction industry is expanding quickly as a result of the country's rapid urbanization and the need for more affordable housing for its citizens. This activity produces a lot of building construction and demolition waste, which are typically dumped in landfills and have an adverse effect on the environment and the economy. One of the practical ways to lessen environmental damage and make construction sustainable is by reducing the reliance on natural and non-renewable resources is to recycle building and demolition debris.

In order to identify the gap, the literature research includes a survey of papers and thesis on building construction and demolition waste recycling. Studies have revealed that not all materials purchased and brought to sites are used for their intended purposes and occasionally wind up being wasted. Previous research has shown that material waste has a significant impact on both the construction project and the environment. Reduce, reuse, and recycle have essentially become the recommended practices when trying to manage waste because zero waste in the building business is not feasible. However, because the building sector consumes a lot of raw materials, waste management requires careful thought and attention.

Therefore, construction industry stakeholders can prevent excessive waste from being generated on construction sites by reducing and reusing. There are also numerous studies on the impact of recycling and reusing as part of a strategy to minimize material waste on construction projects. Different gaps were found in each examination of literature on recycling building and demolition waste. The critical gap was trying to find literature review on recycling in Ethiopia. As such this research is necessary to know the gap in major construction and demolishing waste and develop an appropriate waste management practice that will set out procedures to fill the knowledge gaps mentioned above.

CHAPTER THREE

3. RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

Research plays a critical role in resolving a variety of operational and strategic issues. This chapter's major purpose is to detail the research approach used. It explains the methodology used, as well as the data-gathering methods and tools used, and the analysis techniques employed. By raising awareness about the relevance of building construction and demolition waste recycling, this research will offer knowledge toward solving problems for stakeholders. A review of the literature on the subject was conducted first, based on the description of the problem. Following the literature review, the research employs both observation and survey data gathering methods in a number of public and private building construction and demolishing in Addis Ababa. Stakeholders were asked to complete and answer questionnaires and interviews for this purpose. Lastly, laboratory tests were conducted on the HCB of class A, class B, and class C if it can fulfill the standards.

3.2 The research type

The sort of research used in this study is exploratory research. An exploratory sort of research, among the numerous types of research, aids in filling a gap in a certain area of knowledge that may be undervalued and evolving. And when there aren't enough literature materials on the subject under investigation, this form of research is required (Leavy, 2017). As a result, this research is exploratory in nature, as there is a gap in our country's literature that this study attempts to fill.

3.3 The Research Design

The design was created using a combination of a thorough analysis of literature on selected building construction and demolition waste recycling in Addis Ababa. To fulfill the research aims, questions were designed using information acquired from literature and building construction and demolition waste recycling in Addis Ababa. The approach utilized in constructing the framework of research is known as research design, and its major goal is to successfully answer research questions in order to satisfy the research objectives (Leavy, 2017). It refers to the most common ways of gathering evidence, such as surveys, interviews, experiments, observations, and records of materials, as well as combinations of these.

This research uses a combination of literature review, survey questionnaire and interview, and laboratory experiment to identify the density and compressive strength of HCB. A review of numerous pieces of literature provides an in-depth understanding of recycling building construction and demolition waste materials, as well as the benefits of recycling. A questionnaire survey is done for stakeholders in the construction industry, to determine the amount of understanding about building construction and demolition waste recycling. It also seeks to learn about existing recycling of building construction and demolition practices. In order to acquire complete data from a large number of construction stakeholders in a short period of time, a questionnaire survey was chosen. Laboratory tests were also conducted on class A, class B, and class C HCBs to test the compressive strength and density.

3.4 Research Sample Selection

Sampling is the process of selecting a subset of a group or population with the goal of gathering data in order to draw conclusions in a study, and the sample chosen must accurately represent construction and demolition waste recycling and be dependable. The advantage of population sampling is that it saves time and money while also ensuring that the data collected is more accurate (Khan, 2008).

Sampling method for contractors

Distribution of the questionnaire survey focused only on companies that are Grade 1 contractors registered under the ministry of urban development and construction. The study will be limited to Grade 1 contractors that are based in Addis Ababa. Grade 1 contractors were chosen because these contractors participate in large-scale and complex projects (next to foreign contractors) which can benefit from the recycling of construction and demolishing waste recycling.

According to the 'Ministry of Urban Development and Construction Bureau' the numbers of construction companies with Grade 1 qualifications in Ethiopia are 133 but since this study focuses on contractors based in Addis Ababa the total population size will be 119.

Slovin's formula is used to calculate the sample size given the total population size and a margin of error.

$n = \frac{N}{(1+Ne2)}$ --------Slovin, E. (1960)

Where

n is the number of samples

N is a total population

e is the margin of error

With a total population size of 119 and a margin of error of 10%, the sample size will be 54. Though the sample size was calculated to be 54, the researcher believed to distribute 60 questionnaires to avoid the effect of unanswered questionnaires on the research. After the sample size has been determined 60 questionnaires were prepared for those 60 companies (sample size). Stratified random sampling was used to distribute the questionnaire, 15 questionnaires to project managers, 15 questionnaires to construction engineers, 15 questionnaires to site engineers, and 15 questionnaires to office engineers.

Table 3.1 Questionnaire response rate

No	**Different strata based on Job Description**	**Questionnaires distributed**	**Number of respondents**	**Respondent rate**
1	Project Engineer	15	12	80%
2	Construction Engineer	15	15	100%
3	Site Engineer	15	15	100%
4	Office Engineer	15	14	93%
Total		60	56	

Sampling method for HCB manufacturers

Information was requested to get the number of hollow concrete manufacturing enterprises from Job, Enterprise, and Industry Development Office. According to the office, only 1 HCB manufacturer was found in the Yeka sub-city and 1 HCB manufacturer in the Bole sub-city. But in the pilot study, the researcher has come across more than the number stated by the office. As such the researcher chose to carry out the sampling method with a convenient sampling method since the total population of HCB manufacturers was not certain. The convenient sampling was done with the ease of accessibility. As a result, the questionnaires were distributed to 10 HCB manufacturers with a production capacity of 6000 per day; 6 at the Yeka sub-city and 4 at the Bole sub-city.

3.5 Data analysis

Following the completion of the questionnaire survey, the results were coded and entered into SPSS. To provide a descriptive image of the collected data, an analysis was done. The quantitative information gathered from the questionnaire analysis was analyzed using straightforward percentages and frequency.

All other categories of respondents' interviews and open-ended data have yielded qualitative data that needed to be manually analyzed. To do this, respondents' opinions were summarized, and these summaries were then supported by valid quotations that accurately captured the respondents' opinions and data from documentary sources.

Laboratory tests were observed for compressive strength and density of class A, class B, and class C HCBs that were manufactured by replacing 50% of the coarse aggregate using recycled hollow concrete block. The analysis is divided into topics based on the research questions that were used to drive the entire investigation and are provided in the next chapter.

CHAPTER FOUR

4. RESULT AND DISCUSSION

This chapter presents a discussion on data collected through the questionnaires and test results of laboratory experiments. It entails analyzing and interpreting data in accordance with the literature review and research question which will help come to conclusions and recommendations about building construction and demolishing waste recycling.

The main interests of the questionnaire surveys were to assess the awareness and practice about building construction and demolishing waste recycling. With a total population size of 119 and a margin of error of 10%, the sample size will be 54. Though the sample size was calculated to be 54, the researcher believed to distribute 60 questionnaires to avoid the effect of unanswered questionnaires on the research. As such 60 questionnaires were distributed and 56 were responded to. The distribution was made according to the availability of the representatives. Finally, the required data were collected as per the questions presented to the respondents and analyzed.

The quantitative data gathered from the questionnaire analysis was analyzed using straightforward percentages and frequency. All other categories of respondents' interviews and responses/opinions to open-ended data have yielded qualitative data and were summarized.

4.1 Data analysis for contractors

4.1.1 General information of participants

For the set of data collected to obtain the current awareness and practice about building construction and demolishing waste recycling, a total of 60 questionnaires were distributed and among these 60 the 56 were responded to. From the 56 collected data's 21.4% of the respondents are site engineers, 28.5% of the respondents are construction engineers, 26.7% of the respondents are office engineers and 23.2% of the respondents are project managers.

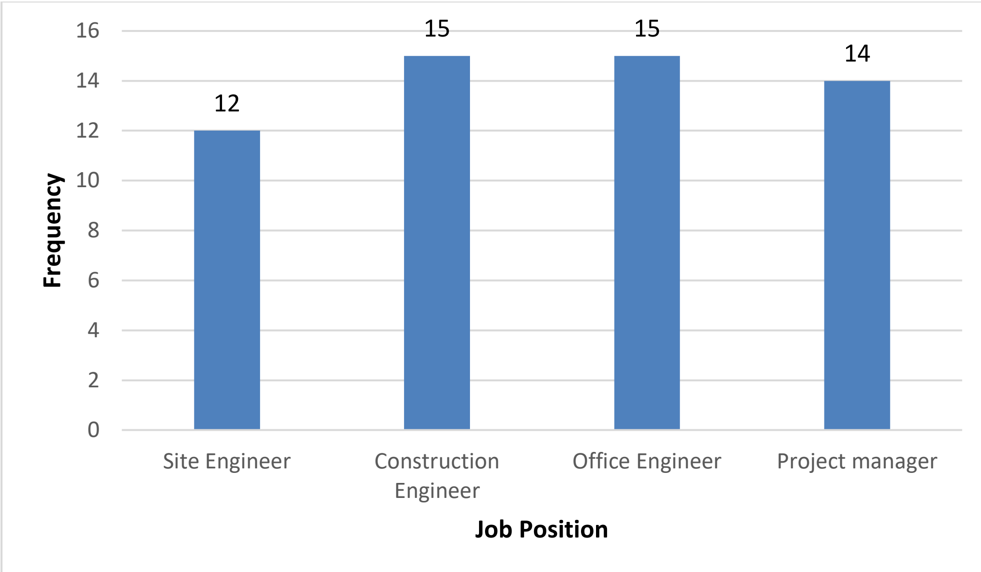


Figure 4.1 Respondent's position on site

4.1.2 Experience of respondents

The following table shows the experience of respondents in the construction industry. As shown in the table, of the total 57 respondents, 15 or 26.3 percent have 2 to 5 years of work experience in the construction sector, 14 or 24.6 percent have 5 to 10 years of work experience in the construction sector, 14 or 24.6 percent have 10 to 15 years of work experience in the construction sector, and 14 or 24.6 percent have 15 to 20 years of work experience.

Table 4.1 Experience of respondents

Years of experience	Number of respondents	Percent	Valid Percent	Cumulative Percent
2-5 years	15	26.3	26.3	26.3
5-10 years	14	24.6	24.6	50.9
10-15years	14	24.6	24.6	75.4
15-20 years	14	24.6	24.6	100.0
Total	57	100.0	100.0	

4.1.3 Most wasted construction materials

In this part of the questionnaire respondents evaluated the most wasted materials based on their experience. According to the respondent's hollow concrete block is the most wasted taking 30%, and cement 26% and sand 11% take the second and third rank as being the most wasted. The finding of the current study is close to the finding of the study done in Addis Ababa, 2017 with the title of "Assessment and Quantification of Construction material waste in building construction" by Hayat Jemal, where HCB amounts to 34.3% of the material wastage followed by cement which is 29.3%. Reinforcement bar and sand (fine aggregate) account for15.3% and 12.7% respectively. Gravel contributes to the least amount of waste, which is less than 8.3%

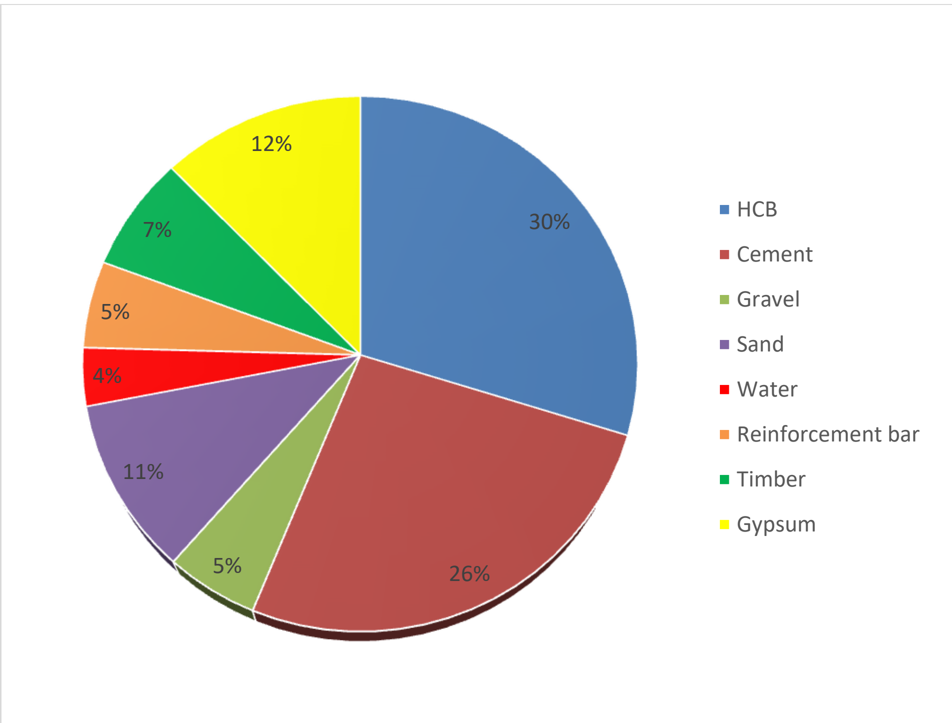


Figure 4.2 Most wasted material

4.1.4 Way of disposing construction or demolishing waste in the company

The respondents were asked to describe how their companies handled construction and demolition waste once the project was completed. They were given four options, these are as a fill material, reusing, fly tipping or recycling. 16% of the participants said they use the waste materials as a fill material while the 42% said they reuse the waste materials from construction and demolishing. 39% of the respondent said they fly tip the waste and 4% said they recycle building construction and demolishing waste. In the study of recycling construction and demolition waste as an integrated solid waste management technique in the Kenyan construction industry, Komu L (2016) from the collected data 26% of the respondents said as a fill material, 21% said they reuse and recycling, and 52% said disposing into open dumping site.

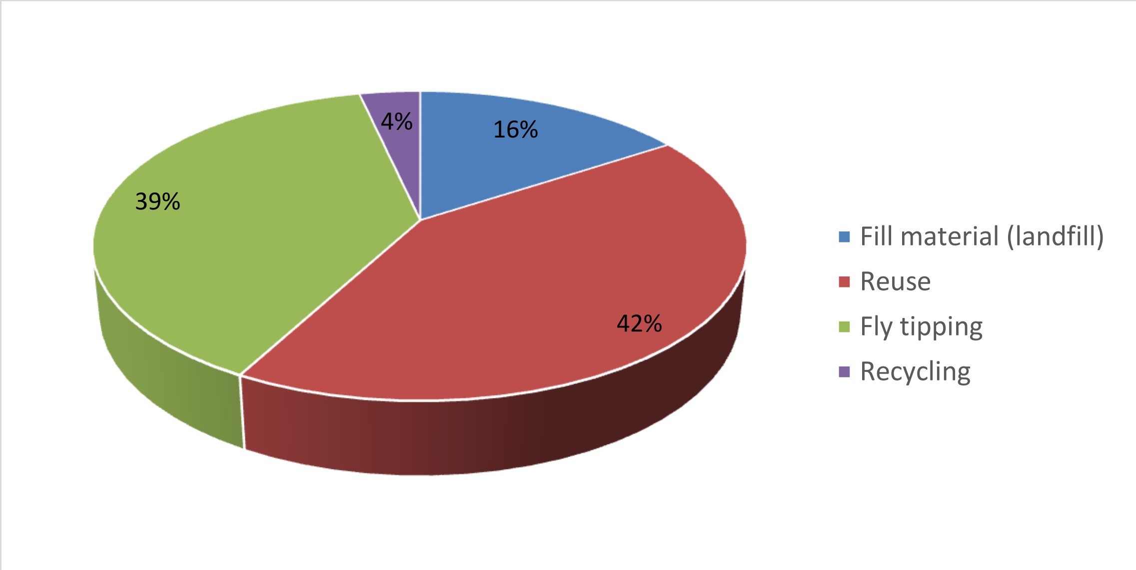


Figure 4.3 Building construction and demolishing waste disposal method

4.1.5 Separate disposal containers for different type of waste

This section discussed the need of separate disposal containers for different types of wastes at the site. 20% of the respondents claimed they have separate disposal containers for different types of waste and the rest 80% said they don't have a separate container. According to the study made in Kenya, 2016 "The study of recycling construction and demolition waste as an integrated solid waste management technique in the Kenyan construction industry" only 5% of the contractors who replied to the questionnaires sorted the material before recycling. 94% of the contractors, failed to separate the concrete waste. (C.S. Poon et al. 2001) on their study found that for construction waste, the most applicable on-site sorting method is to have refuse chutes set up for each building block for debris collection, enabling separation of non-inert materials from inert materials at the source of waste generation.

4.1.6 Construction waste management

This section discussed construction waste management plans before the start of any project; while in the discussion of waste management, 8.8% of the respondents agreed to having construction waste management plan before the start of the project and the remaining 91.2% do not have waste management plan. On the study made on Assessment and quantification of construction material waste in building construction in Addis Ababa, (Hayat, 2017), 60% of the respondents claimed that they don't have site management plans what so ever in their construction site and 30% said they carry out site waste management plans. Contrary to this data 48.1% of the respondents agreed to practicing site management and the remaining 51.9% stated they don't exercise waste management. It was understood from the respondents' explanation that they manage according to their day to day activity and the corresponding mitigation is taken then after. Despite the fact that each building and demolition project is unique, all stakeholders participating in the process should think about waste management initially from waste separation to disposal method.

4.1.7 Respondent's perception towards reuse and recycling

Although waste reduction and reuse are the preferred ways of waste management, recycling is pursued as a realistic waste management approach when reuse and reduction are not achievable. Almost 85% of the respondents have positive perception towards reuse and recycling but as they have claimed, the lack of recycling facilities has made it difficult for them to consider recycling as a waste management method.

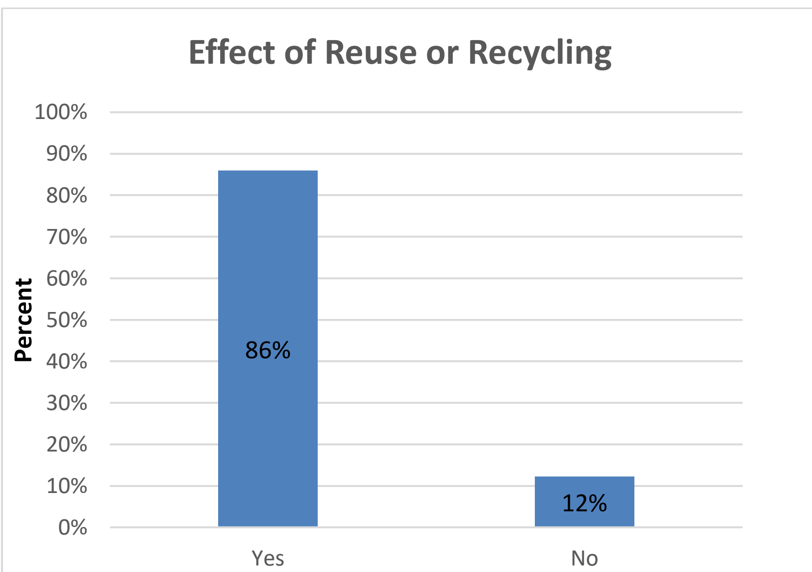


Figure 4.4 Perception towards reuse and recycling

4.1.8 Reuse of construction waste materials

As for the data collected on the reuse of construction waste materials, 81.8% of the respondents approved to reusing construction waste materials and the remaining 18.2% do not reuse construction waste materials on site. According to the respondents most of the materials they reuse are nail, wires and timbers.

4.1.9 Experience of reusing waste materials during construction

According to the questionnaire distributed the percentage of cement being reused during construction is 2.6%, nails being reused is 53.2%, HCB being reused is 2.6%, gravel being reused is 2.6%, wires being reused is 15.6%, ceramic tiles being reused is 2.6%, masonry stones being reused 2.6%, granite being reused 3.8%, reinforcement bars being reused 9.1% and marble being reused 5.2%.

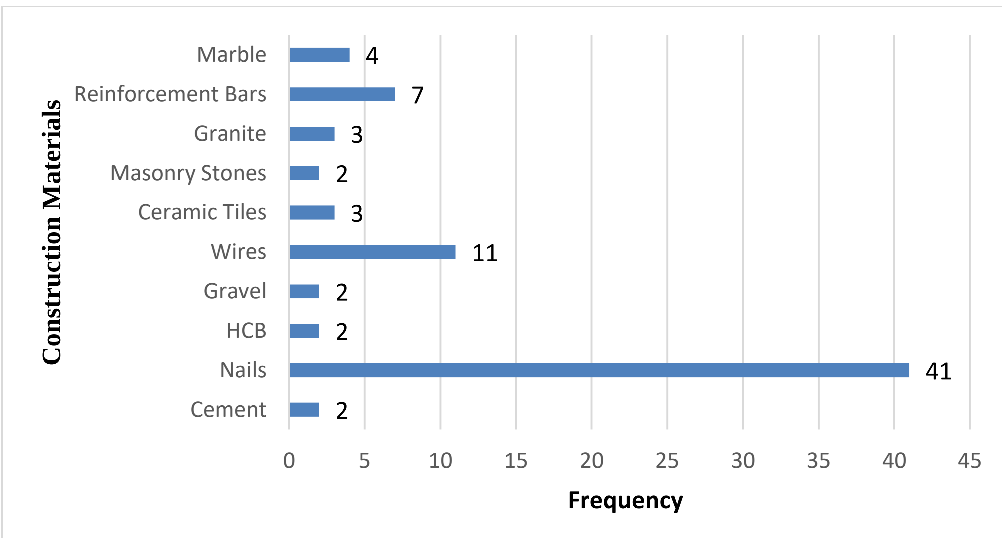


Figure 4.5 Reusing waste materials during construction

4.1.10 Limitations of building construction and demolishing waste recycling

Major variables that prevent construction and demolition waste from being recycled are lack of recycling factories, lack of incentives to motivate you to recycle waste, lack of demand from the owner or investor side on the building construction and demolishing waste recycling and reuse and Lack of support from government. There are a number of challenges that affect the building construction and demolishing waste recycling; 8.8% of the respondents think it is due to the high cost and labor intensiveness in separating building construction and demolishing waste, 13.2 of the respondent stated it is due to high cost for transportation between jobsites and waste diversion facilities, 11.7% of the respondents said due to lack of recycling factories, 8.3% of the respondents said due to lack of incentives to motivate you to recycle waste, 8.8% of the respondents think it is due to difficulty to install and maintain reusing and recycling facilities, 6.3% of the respondents said due to cost for waste diversion is higher than traditional landfilling, 6.3% of the respondents think it is difficult to establish a recycling plan for an individual project, 7.8% of the respondents said it is due to the limited application of these recycled products, 7.8% of the respondents think that it is due to lack of balance between demand and supply, 7.3% of the respondents think that it is due to lack of demand from the owner or investor side on the building construction and demolishing waste, 8.8% of the respondents think that it is due to lack of support from the government and 4.9% of the respondents think it is due to lack of compelling government Policy on building construction and demolishing waste recycling. Percentage is higher than 100% because respondents have selected more than one answer. According to Patrick et al. (1999) the inconsistency of C&D waste, the effort and equipment required to evaluate and separate the materials, the lack of or distance from recycling facilities, fluctuations in the market for recycle materials, and environmental regulations governing certain types of recyclable materials are the primary constraints on the operation of construction and demolishing waste recycling which relates to the current finding.

Table 4.2 Limitations of building construction and demolishing waste recycling

Limitations of building construction and demolishing waste recycling	**Responses**	
	N	**%**
High cost and labor intensiveness in separating building construction and demolishing waste	18	8.8%
High cost for transportation between jobsites and waste diversion facilities	27	13.2%
Lack of recycling factories	24	11.7%
Lack of incentives to motivate you to recycle waste	17	8.3%
Difficult to install and maintain recycling and reuse machine (e.g. Crushers)	18	8.8%
The cost for waste diversion is higher than traditional landfilling	13	6.3%

Difficult to establish a recycling plan for an individual project	13	6.3%
Limited applications for recycled products	16	7.8%
Lack of balance between demand and supply in the recycling and reuse market	16	7.8%
Lack of demand from the owner or investor side on the building construction and demolishing waste recycling and reuse	15	7.3%
Lack of support from government	18	8.8%
Lack of Compelling government Policy on building construction and demolishing waste recycling	10	4.9%
Total	205	100.0%

4.1.11 Effect of reusing or recycling on quality or time

Quality is defined as the standard of something as measured against other things of a similar kind. On this regard 61.8% of the respondents said that recycled materials don't have a negative effect on the quality and time of a construction but 38.2% claim it has a negative effect. Those who believe that products made from recycled construction and demolition debris are of high quality are also those who believe that reclaimed waste products are of high quality. Those who stated that they would not employ recycled items in their projects also believed that reclaimed waste products were of poor quality.

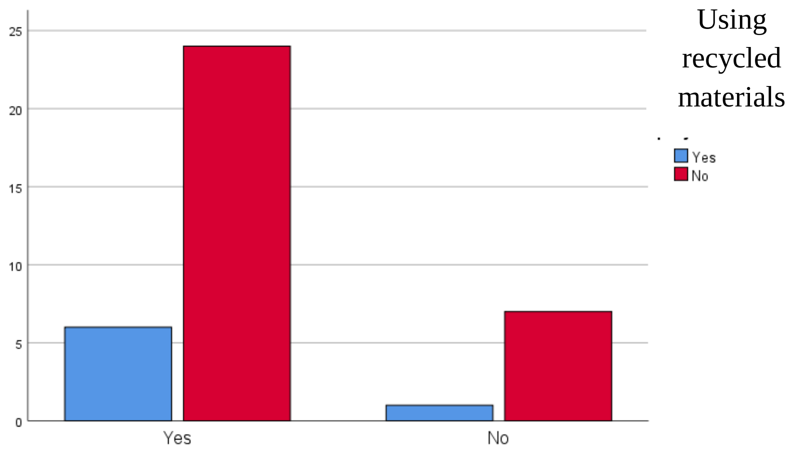


Figure 4.6 Effect of reusing or recycling on quality or time

4.2 Data analysis for HCB manufacturers

Since the total population of hollow concrete block manufacturers was not certain 10 hollow concrete block manufacturer were chosen by convenient sampling method to distribute the questionnaires. 10 questionnaires were distributed amongst hollow concrete manufacturers that produced more than 6000 HCB per day. These manufacturers use what is commonly known as Turkish machine. As most of the respondents stated the probability of hollow concrete blocks being damaged during construction meaning mostly after 24hrs of setting is 2 pieces out of one batch; one batch produced being 20 pieces. The minimum production per day, if there is power is 4000; this means that 10% or 400 pieces will be damaged per day, which is high in number. These hollow concrete blocks are damaged while moving them to the place where they will be cured. Recycling the 400 pieces will have significant impact on the material consumption. As all respondents replied the damaged blocks are then mixed with the fresh mix to produce a new batch of hollow concrete blocks. As the respondents have explained using these blocks will not have a negative impact because the block already contains cement, aggregate and sand which will be helpful for the next batch to attain its strength quickly.

4.3 Experimental Analysis

The three HCB manufacturing enterprises that were chosen to do the experiment are YGBZ, Ghion and KSH hollow concrete manufacturing enterprises.

The HCB waste was collected from construction site for class C and from HCB manufacturing enterprises for class A and class B. The hollow concrete blocks waste material were crushed into smaller pieces. The crushed HCBs passed through 10 mm sieve, since the net thickness of a block is 30 mm. A total number of 120 samples, with 6 batches each containing 20 samples were casted to get HCBs with normal mix proportion and with 50% replacement of the coarse aggregate. Out of these, 6 samples were chosen from each batch randomly as per ESC D3.301, MoWUD:2001, BATCODA. The mix proportion is as per ESC D3.301: 1:4 for class A, 1:5 for class B and 1:6 for class C.

Table 4.3 Mix proportion for HCB (ESC D3.301)

Class	**Proportions by volume of**				
	Sand	**Gravel 00**	**Gravel 01**	**Red ash or pumice**	**Cement**
A	2	1	1		1
	2	1		1	1
B	2	1	2		1
	2	1		2	1
C	3	1	2		1
	3	1		2	1

Composition of material to cast 20 HCBS of Class A with normal mix:

- Cement: 75 kg
- Fine Aggregate: 150 kg
- Coarse Aggregate: 150 kg
- Slump: 50mm
- Water: 38L

Composition of material to cast 20 HCBS of Class A with 50% replacement of course aggregate with recycled HCB

- Cement: 75 kg
- Fine Aggregate: 150 kg
- Coarse Aggregate: 75kg
- Slump: 50mm
- Recycled Coarse Aggregate : 75 kg
- Water 38 L

Composition of material to cast 20 HCBS of Class B with normal mix:

- Cement:60 kg
- Fine Aggregate: 120 kg
- Coarse Aggregate: 180 kg
- Slump: 50mm
- Water: 30L

Composition of material to cast 20 HCBS of Class B with 50% replacement of course aggregate with recycled HCB

- Cement: 60 kg
- Fine Aggregate: 120 kg
- Coarse Aggregate: 90 kg
- Recycled Coarse Aggregate: 90 kg
- Slump: 50mm
- Water: 30 L

Composition of material to cast 20 HCBS of Class C with normal mix:

- Cement: 27 kg
- Fine Aggregate: 81 kg
- Coarse Aggregate: 81 kg
- Slump: 50mm
- Water: 14 L

Composition of material to cast 20 HCBS of Class C with 50% replacement of course aggregate with recycled HCB

- Cement: 27 kg
- Fine Aggregate: 81 kg
- Coarse Aggregate: 41 kg
- Recycled Coarse Aggregate: 40kg
- Slump: 50mm
- Water: 14 kg

Concrete blocks are made using four main processes: batching, mixing, compacting/vibrating, drying and curing. The dry ingredients are placed in a mixer and mixed for several minutes under dry state. A small amount of water is added step by step to the mixer after the dry elements have been combined. The consistency of the mixture should be such that it can adhere in the hand without showing any free water. The mixture is then put into the molding machine. Lastly the HCBS are cured for 28 days.

The following tests have been conducted on the recycled HCB

- Block density
- Compressive strength

4.3.1 Block Density

The block density of HCB can be calculated as

$$\text{Density} = \frac{\text{Mass of HCB in kg}}{\text{Volume of HCB in cm3}} \times 10^6 \text{ Kg/m}^3$$

It is noted from the results that the densities of the hollow concrete blocks with the normal mix and with the 50% replacement have similar results.

Table 4.4 Density of class A HCB with normal mix

Class A						
Specimen No.	**1**	**2**	**3**	**4**	**5**	**6**
Mass kg	20.12	20.45	20.35	20.25	19.23	21.33
Volume m^3	0.016	0.016	0.016	0.016	0.016	0.016
Density kg/m^3	1257.50	1278.13	1271.88	1265.63	1201.88	1333.13
Average Density kg/m3	1268.02					

Table 4.5 Density of class A HCB with 50% replacement of coarse aggregate

Class A						
Specimen No.	**1**	**2**	**3**	**4**	**5**	**6**
Mass kg	19.61	20.1	19.88	19.93	20.82	20.06
Volume m^3	0.016	0.016	0.016	0.016	0.016	0.016
Density kg/m^3	1225.63	1256.25	1242.50	1245.63	1301.25	1253.75
Average Density kg/m3	1254.17					

Table 4.6 Density of class B HCB with normal mix

Class B						
Specimen No.	**1**	**2**	**3**	**4**	**5**	**6**
Mass kg	18.94	18.12	19.1	18.56	18.98	19.22
Volume m^3	0.016	0.016	0.016	0.016	0.016	0.016
Density kg/m^3	1183.75	1132.50	1193.75	1160.00	1186.25	1201.25
Average Density kg/m3	1176.25					

Table 4.7 Density of class B HCB with 50% replacement of coarse aggregate

Class B						
Specimen No.	**1**	**2**	**3**	**4**	**5**	**6**
Mass kg	18.07	17.53	18.16	17.21	18.09	18.51
Volume m^3	0.016	0.016	0.016	0.016	0.016	0.016
Density kg/m^3	1129.38	1095.63	1135.00	1075.63	1130.63	1156.88
Average Density kg/m3	1120.52					

Table 4.8 Density of class C HCB with normal mix

Class C						
Specimen No.	**1**	**2**	**3**	**4**	**5**	**6**
Mass kg	10.23	10.11	9.89	10.42	9.12	9.35
Volume m^3	0.012	0.012	0.012	0.012	0.012	0.012
Density kg/m^3	852.50	842.50	824.17	868.33	760.00	779.17
Average Density kg/m3	821.11					

Table 4.9 Density of class C HCB with 50% replacement of coarse aggregate

Class C						
Sample No.	**1**	**2**	**3**	**4**	**5**	**6**
Mass kg	9.62	9.55	9.32	9	9.35	9.18
Volume m^3	0.012	0.012	0.012	0.012	0.012	0.012
Density kg/m^3	801.67	795.83	776.67	750.00	779.17	765.00
Average Density kg/m3	778.06					

4.3.2 Compressive strength

Six samples were chosen from each batch randomly as per ESC D3.301, to check the compressive strength of the hollow concrete blocks. The samples were tested at the age of 28 days. Mortar was applied to the surface of the HCBs so that they have a smooth surface and uniform load distribution when the load is applied. After the mortar was applied, the HCBs were kept for 2 days to dry. The load was applied with a uniform rate of $5N/cm^2$ per second and a maximum load to failure was measured, at which point the specimen breaks. The compressive strength of HCBS with normal mix and with 50% replacement of the coarse aggregate are shown in the tables below. According to ESC D3.301 and MoWUD:2001 the minimum compressive strength for Class A HCB is $38kg/cm^2$ and for Class B HCB it is $32kg/cm^2$ and for Class C it is $18kg/cm^2$. From the results below the compressive strength for the hollow concrete blocks fulfill the standard of ESC D3.301.


Table 4.10 28 days compressive strength of Class A HCB with normal mix

Class A									
	Dimensions								
Specimen No.	**L in mm**	**H in mm**	**T in mm**	**Mass (Kg)**	**Weight (N)**	**Area (cm2)**	**Unit weight (kg/m3)**	**Failure Load(KN)**	**Compressive strength (MPa)**
1	400	200	200	20.12	197.38	800	1257.50	448	5.60
2	400	200	200	20.45	200.61	800	1278.13	409	5.11
3	400	200	200	20.35	199.63	800	1271.88	459	5.73
4	400	200	200	20.25	198.65	800	1265.63	438	5.47
5	400	200	200	19.23	188.65	800	1201.88	401	5.01
6	400	200	200	21.33	209.25	800	1333.13	483	6.03
									5.40

Table 4.11 28 day compressive strength of class A HCB with 50% replacement of coarse aggregate

Class A									
	Dimensions								
Specimen No.	**L in mm**	**H in mm**	**T in mm**	**Mass (Kg)**	**Weight (N)**	**Area (cm2)**	**Unit weight (kg/m3)**	**Failure Load(KN)**	**Compressive strength (MPa)**
1	400	200	200	19.61	192.37	800	1225.63	444	5.55

2	400	200	200	20.10	197.18	800	1256.25	410	5.12
3	400	200	200	19.88	195.02	800	1242.50	465	5.81
4	400	200	200	19.93	195.51	800	1245.63	504	6.30
5	400	200	200	20.82	204.24	800	1301.25	443	5.53
6	400	200	200	20.06	196.79	800	1253.75	383	4.78
									5.51

Table 4.12 28 days compressive strength of Class B HCB with normal mix

Class B									
	Dimensions								
Specimen No.	L in mm	H in mm	T in mm	Mass (Kg)	Weight (N)	Area (cm2)	Unit weight (kg/m3)	Failure Load(KN)	Compressive strength (**MPa**)
1	400	200	200	18.94	185.80	800	1183.75	436	5.45
2	400	200	200	18.12	177.76	800	1132.50	411	5.13
3	400	200	200	19.1	187.37	800	1193.75	442	5.52
4	400	200	200	18.56	182.07	800	1160.00	435	5.43
5	400	200	200	18.98	186.19	800	1186.25	475	5.93
6	400	200	200	19.22	188.55	800	1201.25	489	6.11
									5.60

Table 4.13 28 day compressive strength of class B HCB with 50% replacement of coarse aggregate

Class B									
	Dimensions								
Specimen No.	**L in mm**	**H in mm**	**T in mm**	**Mass (Kg)**	**Weight (N)**	**Area (cm2)**	**Unit weight (kg/m3)**	**Failure Load(KN)**	**Compressive strength (MPa)**
1	400	200	200	18.07	177.22	800	1129.06	424	5.30
2	400	200	200	17.53	171.97	800	1095.63	248	3.10
3	400	200	200	18.16	178.10	800	1134.69	234	2.92
4	400	200	200	17.21	168.78	800	1075.31	298	3.72
5	400	200	200	18.09	177.41	800	1130.31	358	4.47
6	400	200	200	18.51	181.53	800	1156.56	391	4.88
									4.06

Table 4.14 28 days compressive strength of Class C HCB with normal mix

Class C									
	Dimensions								
Specimen No.	**L in mm**	**H in mm**	**T in mm**	**Mass (Kg)**	**Weight (N)**	**Area (cm2)**	**Unit weight (kg/m3)**	**Failure Load(KN)**	**Compressive strength (MPa)**
1	400	200	150	10.23	100.36	600	852.50	220	3.67
2	400	200	150	10.11	99.18	600	842.50	209	3.48
3	400	200	150	9.89	97.02	600	824.17	187	3.12
4	400	200	150	10.42	102.22	600	868.33	240	4.00
5	400	200	150	9.12	89.47	600	760.00	175	2.92
6	400	200	150	9.35	91.72	600	779.17	201	3.35
									3.42

Table 4.15 28 days compressive strength of Class C HCB with 50% replacement of coarse aggregate

Class C									
	Dimensions								
Specimen No.	**L in mm**	**H in mm**	**T in mm**	**Mass (Kg)**	**Weight (N)**	**Area (cm2)**	**Unit weight (kg/m3)**	**Failure Load(KN)**	**Compressive strength (MPa)**
1	400	200	150	9.62	94.32	600	801.25	190	3.17
2	400	200	150	9.55	93.69	600	795.83	189	3.15
3	400	200	150	9.32	91.38	600	776.25	216	3.60
4	400	200	150	9.00	88.29	600	750.00	156	2.60
5	400	200	150	9.35	91.72	600	779.17	212	3.53
6	400	200	150	9.18	90.06	600	765.00	193	3.22
									3.21

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The main objective of this research was to asses current practices of building construction and demolishing waste recycling on selected buildings in Addis Ababa and recommend best practices The questionnaire survey was conducted to evaluate the awareness in recycling of stakeholders in the construction sector i.e Contractors and HCB manufacturers currently located in Addis Ababa. Laboratory experiment of HCB was also conducted as testing the major waste material from the surveyed questionnaire was the third objective of the research. The reason why the awareness of HCB manufacturers was needed is because HCB was found to be the most wasted material during the survey on the selected buildings. So knowing the awareness scale of the HCB manufacturers is important to facilitate the recycling of HCB.

The survey results showed that the practice of reuse and recycling is very small. As most respondents stated reuse and recycling is also limited to the reuse of particularly nails and timber. According to the questionnaire, the main reasons why recycling is not being practiced are as follows:

- **Lack of awareness on building construction and demolishing waste management**

Though most of the respondents have positive thinking towards recycling it is an unclear subject when it comes to which items are to be recycled, how it should be recycled or when it should be recycled.

- **Lack of awareness on the advantage of recycling waste materials and recycling facilities**

The second reason for not taking recycling as a disposing option is that most respondents believed that recycled materials loss their original property when recycled as such they have no importance to their originally intended purpose. Long-term sustainable solution for construction waste management in the construction industry depends on increasing adequate awareness and promoting reusing and recycling of waste materials.

- **Lack of government policy**

As was discussed on the literature review, the policies or proclamations in our country is limited to suggesting how solid wastes should be managed. There are no policy that obliges stakeholders to dispose construction and demolishing waste in certain manner. From the response of the respondent it was understood that due to the lack of regulations that forces them to recycle waste materials they found disposing construction and demolishing waste with other solid waste materials easier.

It is also concluded that using 50% replacement of recycled hollow concrete blocks as coarse aggregate of all classes attain the standard compressive strength of normal or ordinary hollow concrete blocks. Using recycled coarse aggregate from hollow concrete block waste can help reduce disposal to the landfill. It will also help in reduction of natural aggregate use.

5.2 Recommendation

Based on the result of this research the following measures are assumed to have an impact on improving building construction and demolishing waste recycling in the construction industry.

- Awareness should be created among stakeholders on the importance and effectiveness of building construction and demolishing waste recycling: Creating the know how of recycling and its technology to every stakeholder in the construction industry will clearly solve the vague impression that is behind the concept recycling. If trainings and other awareness creating methods are implemented while on the planning stage of a given project, all parties that are participating will have a clear vision on how to dispose the waste that arises during the construction or demolishing phase.
- Government should have a clear legislation on recycling with a strict implementation technique: this could be done by introducing laws that prohibits the disposal of waste materials that can be recycled, lowering the cost of recycling in order to make recycling more cost effective and increasing the cost of naturally occurring construction materials are some of the ways to bring waste up for recycle.
- Government should encourage stakeholders to recycle so that investors can see recycling plants as a possible business: for startup, practicing the use of recycled materials on

governmental projects to show the effectiveness of recycled construction and demolishing materials can bring the attention of investors due to demand that will arise in the area.

5.2.1 Recommendation for future research

- Further studies should be made on the physical and chemical properties of the recycled hollow concrete blocks
- Research should be carried out on the economic feasibility of recycling plant
- Increased percentage replacement of recycled hollow concrete block should also be studied

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Appendix A

Questionnaire for contractors

ADDIS ABABA UNIVERSITY

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

CONSTRUCTION AND DEMOLITION WASTE RECYCLING IN ADDIS ABABA

Part 1: General Question

1. Name of the company

____

2. Grade of the company

____

3. Type of the Construction project involved in

☐ Residential Building Construction ☐ Specialized Industrial

☐ Institutional and Commercial Building Construction ☐ Infrastructure and Heavy

4. What is your job position?

☐ Site Engineer ☐ Office Engineer

☐ Construction Engineer ☐ Project manager

Consulting side

5. How long have you been working in the construction sector?

- ☐ 0-2 years
- ☐ 2-5 years
- ☐ 5-10 years
- ☐ 10-15years
- ☐ 15-20 years
- ☐ 20-30 Years

Part 2: Waste

1. How often do you dispose construction waste?

- ☐ Daily
- ☐ Weekly
- ☐ Monthly
- ☐ other

2. Do you have separate disposal containers for different type of wastes?

- ☐ Yes
- ☐ No

3. What type of construction work generates high waste?

____

____

4. What is the most wasted construction material?

____

____

Part 3: Waste Management

1. Do you practice construction waste management in your company?

- ☐ Yes
- ☐ No

2. Does your company have construction waste management plan before starting a project?

- ☐ Yes
- ☐ No

3. If the answer for he above question is yes what kind of construction waste management plans do you practice?

____

____

____

____

4. What Kind of construction waste management procedure does your company follow?

____

____

5. Do you believe construction waste management help in reducing wastage if applied properly?

☐ Yes ☐ No ☐ Maybe

6. Does your company organize construction waste management trainings?

☐ Yes ☐ No

Part 4: Recycling and reusing Waste materials

Section One

1. Does your company reuse construction waste materials on site?

☐ Yes ☐ No

2. What type of construction waste material do you reuse?

☐ Cement ☐ Gravel ☐ Masonry Stones ☐ Reinforcement Bars
☐ Nails ☐ Wires ☐ Granite ☐ Marble
☐ HCB ☐ Ceramic Tiles
Other

____

____

3. How do you re-use the material you chose on Q.#2, do you reuse the construction waste material for the original intended purpose or do you use it for another purpose?

____

____

____

____

4. Does recycling or reusing has a positive effect on quality, cost and time of construction work?

☐ Yes ☐ No

5. Does recycling or reusing has a negative effect on quality and time of construction work?

☐ Yes ☐ No

6. What is the major way of disposing construction or demolishing waste in the company?

☐ Fill material (landfill) ☐ Reuse ☐ Fly tipping ☐ Recycling

Other____

7. Have you participated in any projects involving building construction and demolishing waste recycling in the past?

☐ Yes ☐ No

8. If your answer is yes for the above question please specify type of construction material.

10. In your opinion, what are the benefits of building construction and demolishing waste recycling?

☐ Saving space from landfills
☐ Lowering project budget
☐ Saving natural materials
☐ Saving transportation cost
☐ Enhancing company competitiveness

Other____

11. What are the limitations of construction and demolition waste recycling?

☐ High cost and labor intensiveness in separating building construction and demolishing waste
☐ High cost for transportation between jobsites and waste diversion facilities
☐ Lack of recycling factories
☐ Lack of incentives to motivate you to recycle waste
☐ Difficult to install and maintain recycling and reuse machine (e.g. Crushers)
☐ The cost for waste diversion is higher than traditional landfilling
☐ Difficult to establish a recycling plan for an individual project
☐ Limited applications for recycled products
☐ Lack of balance between demand and supply in the recycling and reuse market
☐ Lack of demand from the owner or investor side on the building construction and
☐ demolishing waste recycling and reuse
☐ Lack of support from government
☐ Lack of Compelling government Policy on building construction and demolishing waste recycling

Others____

12 Has your organization used any of the following approaches to reduce construction waste in the past?

- ☐ Using standard dimensions.
- ☐ Using computer-assisted design processes.
- ☐ Making sub-contractors responsible for their own waste (no dumpster at site).
- ☐ In bid documents and subcontracts, include standards for waste reduction, reuse, or recycling.
- ☐ Provide subcontractors/employees with incentives for waste reduction, reuse, or recycling.
- ☐ Make use of several construction methods (e.g., wall penalization, ICFs or SIPs, etc.)
- ☐ Burn waste on site.
- ☐ Grind waste on site.

13. Do you feel that the government has laid down efficient strategies to ensure contractors recycle construction and demolition waste?

☐ Yes ☐ No

14. What is the most reused material on site?

___

___

___

15. Do you think recycled products from construction and demolition waste is of low quality? If yes why?

___

___

___

16. Is there a demand for construction waste materials from outside of the site? If yes please provide which material it is?

___

___

___

17. Would you use recycled material products into your projects?

☐ Yes ☐ No

18. Why would you use recycling of construction and demolition waste as a solid waste management technique?

☐ It conserves environment

- ☐ It saves costs
- ☐ It is cheap compared to other solid waste management techniques
- ☐ It would be an additional business venture
- ☐ It is a legal requirement
- ☐ It would give my firm a competitive edge
- ☐ No, my firm cannot recycle construction and demolition waste

19. Do any of your subcontractors haul their own waste?

☐ Yes ☐ No

20. If "yes," please select the appropriate subcontractor:

☐ Cabinets ☐ Flooring/Carpet ☐ Roofing Framing ☐ Painter
☐ Electrician ☐ Plumber ☐ HVAC ☐ Drywall

State other

____

____

21. Do you believe recycling building construction and demolishing waste to be economically feasible for private companies?

☐ Yes ☐ No

22. If you recycle now or in the future, what would motivate you to do so??

- ☐ Immediate cost reduction
- ☐ Long-term cost reductions (recycling may cost the same or a little more now, but I believe it will save me money in the near future)
- ☐ Materials should not be buried in landfills if they may be reused.)
- ☐ Some homebuyers desire building waste to be repurposed.
- ☐ Personal and corporate societal/environmental responsibility

Other:

____

____

____

____

23. Do you believe that the Ethiopian government has put enough emphasis on the need for increased recycling in C&D waste?

☐ Yes ☐ No ☐ others

24. In your personal opinion, explain the need for mandatory government policy with regards to building construction and demolishing waste recycling in Addis Ababa

☐ Yes ☐ No

If you answer to the previous question is "No", explain how important the need for building construction and demolishing waste recycling is in Addis Ababa.

____

____

____

25. What are the actions expected from private construction companies to increase building construction and demolishing waste recycling in Addis Ababa

____

____

____

26. What do recommend on recycling construction and demolishing recycling?

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Appendix B

Questionnaire for HCB manufacturers

ADDIS ABABA UNIVERSITY

Addis Ababa Institute of Technology

School of Civil and Environmental Engineering

CONSTRUCTION AND DEMOLITION WASTE RECYCLING IN ADDIS ABABA

1. What type of mixer do you use to produce HCB?
2. What amount of HCB do you produce in a day?
3. How many of the HCB produced gets broken and/or damaged daily?
4. Do you recycle and/or reuse the broken or damaged HCB for production?
5. If your answer is yes for the above question, what is the major advantage of recycling HCB?
6. If you do not recycle and/or reuse the broken and or damaged, what is the reason?
   A. It adds to the initial production cost
   B. Prolongs production time
   C. The products becomes of low quality
   D. We are not in the position to reuse and or recycle
7. How to you dispose the broken and/or damaged products?