



**STUDY ON MATERIAL WASTAGE OF 40/60 CONDOMINIUM CONSTRUCTION
SITES**

**BY
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LIST OF ABBREVIATIONS

AAU	Addis Ababa University
BC	Building Contractors
C&D	Construction and Demolition wastes
ETB	Ethiopian Currency (Birr)
GC	General Contractors
HCB	Hollow Concrete Block
Kg	Kilo Gram
MSE	Micro and Small Scale Enterprise
OPC	Ordinary Portland Cement
Pcs	Pieces
Qtl	Quintal
RW	Relative Weight
SHDE	Saving Houses Development Enterprise
SWMP	Site Waste Management Plan

ABSTRACT

Most of the times, the actual percentage of waste generation is much higher than initially assumed, causing the additional cost of the project. Therefore, minimizing materials waste in the construction projects could yield great cost savings and profit increment. A Literature review was carried out to identify major construction materials waste causes and minimization measures being used in the construction industry. Consequently, a structured questionnaire survey was conducted to identify the effect of client material supplying in the generation of waste, causes of waste, levels of contribution of measures to waste minimization and to what extent the same measures are practiced on 40/60 condominium construction sites. Beside, an effort has been made to estimate the amount of materials waste analytically and site observations were undertaken to understand the problem very well. The survey focused on the four most dominant materials in terms of influencing the project costs which are concrete, mortar, reinforcement bar and hollow concrete block. The variables were then ranked in their order of importance based on the response of the consultants and contractors. Finally, based on the findings of this research, possible solutions are recommended to improve the generation of excessive material wastes in 40/60 condominium projects.

Keywords: *40/60 condominium sites, Causes of materials waste, Construction materials waste, Waste minimization measures*

1. INTRODUCTION

1.1 Background

The growth of Ethiopian economy and population has brought a significant increase in the construction industry, especially in Addis Ababa. Besides, building projects are becoming progressively larger and more complex in terms of physical size and cost. Due to this, the building industry is using a considerable amount of material resources. On the other hand, if the life cycle of the materials on site is closely examined, it is generally known that there is a relatively large portion of the materials being wasted because of different reasons at building sites (Getachew, 2009; Mulualem, Negatu and Tedla, 2012).

Since some degrees of waste materials are inevitable in the construction process, all estimators allow wastage factors in pricing a bill of quantities. Over the years, experience has shown, however, that unless controlling measures are implemented, wastage may frequently exceed often by a larger margin than the figure allowed in the tender document (Al-Moghany, 2006; Bossink and Brouwers, 1996).

As construction is a locomotive sector of the national economy, waste in the construction industry affects the overall national economy. It is important, therefore, to explore measures contributing to construction material waste minimization and assess the level of practice of such measures by the construction industry since cost reduction arising from minimization of waste materials is a direct benefit to all stakeholders.

Waste in the construction industry has been the subject of several research projects around the world in recent years. Many of them have focused on the environmental damage coming from materials waste in the process of construction. On the other hand, there have been some studies concerned with the economic aspect of waste in the construction industry.

In 1996, Bossink and Brouwers carried out an intense study in the Netherlands; with a concern of the measurement and prevention of construction waste, based on sustainability requirements stated by Dutch environmental policies. Accordingly, Bossink and Brouwers (1996) estimated

1–10% by weight of the purchased construction materials leave the sites of residential projects as waste in Dutch. Similarly, based on a study of 86 housing projects in the Gaza strip, Al-Moghany (2006) came up with an estimation of the material loss resulting from direct and indirect wastes were about 3.6–11%, which were significantly higher than the values that were normally allowed.

Likewise, there have been a number of studies mostly concerned with the economic aspect of waste in the construction industry. Skoyles (1987) undertook one of the most extensive studies regarding economic aspect of material waste. He monitored materials waste on 114 building sites, concluding that a considerable amount of waste can be reduced by adopting relatively simple prevention procedures. Storage and handling were identified as major causes of waste. Most problems of materials wastage appeared at building sites are associated with flaws in the management system and very little with the lack of qualified workers (Skoyles, 1987).

In our country, there were thesis studies undertaken at undergraduate and postgraduate level on the material waste control. A research conducted by Getachew Araya (2009) for his Master's thesis on wastage of materials in building construction sites of Addis Ababa, is amongst these academic works. In his survey; questionnaires were spread to 72 respondents and the result showed that 100 % of the respondents strongly agreed upon the existence of material wastage. According to his study, the top three sources of material wastage in building construction are operational, material handling and design respectively (Getachew, 2009).

In addition, other study at undergraduate level also pointed out the existence of wastage at the construction site of condominiums and different building projects (Mulualem, Negatu and Tedla, 2012). But these studies do not exhaustively worked out the approximate wastage level, the side effect and minimization techniques of materials wastage on condominium sites.

However, to solve the housing problem, which is one of the major problems in Addis Ababa; the city administration has been working on affordable housing projects for the last ten years and starting from 2013 new affordable housing scheme by all levels of the city dwellers launched. These are 10/90, 20/80 and 40/60 percent payment schemes from the lower income to the middle

income residents of the city. Therefore, in-depth investigation is vital to identify current condominium building construction materials wastage reduction techniques and the side effect of poor waste reduction practice on the project cost.

The construction sites selected for this study are 40/60 condominium housing construction sites which is introduced by the government to address the residents that are able to pay a larger amount than the previous condominiums. This housing is for citizens who can make a down payment of 40% of the home price before acquiring their house and the remaining 60% after obtaining the home.

This thesis research measure the actual levels of material waste occurring on 40/60 condominium construction sites and compare the measured waste with theoretical material waste quantities that has been determined before the projects commencement. Besides, it studies the effect of client material supplying in the generation of waste, causes of waste, level of contribution of waste minimization measures to waste reduction and to what degree the same measures are practice at the sites. Finally, based on the data gathered, the research will draw conclusion and suggest how materials waste could be reduced at 40/60 condominium construction sites.

1.2 Statement of Problem

It is known that there are some degrees of unavoidable wastes in the building construction process. Due to this, all estimators allow wastage factors in pricing a bill of quantities which is used to increase materials quantity to ensure enough materials are procured to complete the work realistically. But in most Addis Ababa condominium construction sites, the actual materials waste quantity is far higher than the nominal figures assumed by the companies in their cost estimate. However, much of these waste are avoidable (Getachew, 2009; Mulualem, Negatu and Tedla, 2012).

i.e. Actual material usage on site > Theoretical material usage + additional wastage allowance

Since the cost of materials account a great percentage of the total cost of construction projects, construction materials waste has an impact in the overall project cost. This comprises mainly the cost of transporting and disposing of site waste and the material procurement cost. This leads to

raise the following basic questions regarding material wastage at condominiums construction sites.

1. Does client material supplying on these projects increase the amount of material wastage?
2. What are the major causes of materials waste at the construction sites of condominiums?
3. What is the actual level of materials wastage occurring on the sites and its cost effect in the projects?
4. What are the levels of contribution of some waste minimization measures to waste reduction, and the level of practice of such measures in the condominiums construction sites?

To sum up, wastage reduction needs serious consideration and due attention since the construction industry consumes large amount of raw materials and the city administration is building and planning to build large amount of condominium houses. Therefore, this thesis aimed to provide an insight related to materials wastage at construction sites of 40/60 condominiums.

1.3 Objective of the Study

General Objective

The general objective of this study is to investigate ways of minimizing materials wastage in the 40/60 condominium construction sites by assessing the causes, its extent and effect in the project cost.

Specific Objectives

Specifically, this thesis will address the following points

- ❖ Assess the effects of client material supplying in the waste generation on the sites
- ❖ Identify the main causes of construction materials waste at the sites
- ❖ Estimate the percentage of materials wastage and investigate the side effect on the cost of the project
- ❖ Evaluate levels of contribution of waste minimization measures to waste reduction and levels of practice of same measures in the 40/60 condominium construction sites
- ❖ Forward recommendations which would help to minimize materials waste in the 40/60 condominium construction projects based on the findings of the study

1.4 Methodology

The study objectives were achieved by employing the method outlined below.

1. Different literature review was carried out on materials wastage in building sites with a main focus of prior research works.
2. Data gathering was conducted through field observations, questionnaire survey and documents evaluation on the defined issues of the research theme.
3. The collected data was analyzed and discussed.
4. Finally, based on the findings of the data analysis conclusion is drawn and recommendation on materials waste reduction practice in 40/60 condominium projects has been given.

1.5 Scope of the Study

In Addis Ababa, the capital city of Ethiopia, the building construction sector is growing rapidly. Besides that the ongoing and planned condominium construction projects are much greater than other cities. Therefore, for this study Addis Ababa condominium construction projects undertaken by government; in particular 40/60 condominium are considered. The rationale of this is the project cost of 40/60 condominium is relatively huge and therefore, the side effect of material wastage on the total project cost can be seen easily.

The concept of wastage is very broad; it is not only about materials wastage but it's beyond that. However, only materials waste is considered in this study since the materials cost covers a great percentage of the project cost.

In addition, even though improvement in all kinds of construction materials wastage is necessary, due to resource limitation this research is only undertaken on major building materials used in condominium construction namely, concrete, mortar, reinforcement bar and hollow concrete block. These materials are selected as they accounted the great percentage of the total cost of materials.

2. WASTE IN THE CONSTRUCTION PROJECT

2.1 Concept of Construction Waste

2.1.1 Definition of Construction Waste

Various researchers and experts define waste in different ways. Formoso et al. (2002) defined waste as any losses produced by activities that generate direct or indirect costs but do not add value to the product from the point of view of the client. According to the new production philosophy, waste should be understood as any inefficiency that results in the use of equipment, materials, labour, or capital in larger quantities than those considered as necessary in the production process (Koskela, 1992). Furthermore, Koskela (1992) describes waste includes both the incidence of material losses and the execution of unnecessary work, which generates additional costs but do not add value to the product. In other words, waste in construction is not only focused on the quantity of waste of materials on-site, but also related to several activities such as overproduction, waiting time, material handling, processing, inventories and movement of workers.

Both Formoso et al. (2002) and Koskela (1992) describes waste as a loss created through activities, but do not add value to the construction progress rather adds cost. So drawing from the views expressed above, the definition of construction waste to be used in this study is any losses in material, time and monetary result of activities but do not add value or progress to the construction.

2.1.2 Construction Waste Categories

Besides a clear understanding of the general concept of waste, it is helpful to use a classification of waste in different categories, in order to understand the wide range of possible corrective actions related to its prevention. Construction waste can be categorized into two: material waste and time waste (Al-Moghany, 2006; Ekanayake and Ofori, 2000).

Wasted time is understood as the time that is perceived by the skilled workers as useless, or as a wastes use of time. The most common reasons for occurrence of time waste are: shortage of labour, unskilled or unproductive workers, the indecisiveness of clients, accidents on site, the conflict between sub-contractors, poor work flow layout, shortage of materials and inclement weather (Bo Terji, 2010). Time is unnecessarily wasted due to reordering, re-delivery, waiting

and handling of additional material. Therefore, time waste can be viewed as the extra amount of time needed for reordering, re-delivery, waiting and handling of additional material which will lower productivity, delay completion time, raise labour and machinery costs, and bring on extra overhead costs, and hence reduce profit (Formoso et al, 1999).

The other type of waste in construction projects is materials waste. Studies in different countries have shown that not all materials procured and delivered to sites are used for the purposes for which they are ordered because of a number of reasons and become wasted (Bossink and Brouwers, 1996; Sagoe, 2011; Al-Moghany, 2006).

2.2 Construction Materials Waste

According to Ekanayake and Ofori (2000) construction material waste is defined as any material apart from earth materials, which needs to be transported elsewhere from the construction site or used on the site itself other than the intended specific purpose of the project due to damage, excess or non-use. The above definition gives more emphasis on the excess, damage or nonuse materials used in the construction of building component which don't add any value to the building and needs to be transported from the site or used for another purpose.

For many people the notion of material waste is directly associated with the debris removed from the site and disposed of in landfills. The main reason for this relatively narrow view of waste is the fact that it is relatively easy to see and measure.

However, other researchers define material waste as “the difference between the value of materials delivered and accepted on site and those properly used on specified and accurately measured in the work, after deducting the cost saving of substituted materials transferred elsewhere, in which unnecessary cost and time may be incurred by materials wastage” (Enshansi, 1996; McDonald and Smithers, 1997; Pheng and Meng, 1997).

Therefore, the construction materials wastage definition used in this study is excess of materials used than required quantities and the construction materials hauled away generated in the construction site that couldn't be useful for the intended construction.

The extent of wastage varies from site to site. Sites that have high levels of wastage generally have a poor standard of material control. The site conditions are another factor that affects waste generated on the sites. Levels of waste at muddy sites are comparatively higher compared to clean and well – drain sites. Other factors such as the size of project, design of the building and method of construction also contribute to difference in waste levels. If the waste level of materials for a particular project is high relative to that of other sites, the performance level would be comparatively lower (Enshansi, 1996).

2.2.1 Classification of Construction Materials Waste

Construction materials waste can be classified based on nature and losses; these are elaborated and discussed below:

2.2.1.1 Based on Nature

According to Formoso et al, (1999) waste can be classified by nature as unavoidable and avoidable waste in construction projects. It is the wastage that costs more than what is saved if tried to prevent. There is a certain limit up to which, waste of materials can be prevented. Beyond that limit, any action taken to prevent waste will not be viable, as the cost of saving will surpass the value of materials saved. Thus, natural waste is allowed in the tenders. The amount of allowable waste is subjective to the cost effectiveness of the approaches used to manage it (Formoso et al, 1999).

Avoidable waste is when the cost of waste is significantly higher than the cost to prevent it. Such kind of waste represents the waste amount beyond the acceptable level in the site. Therefore, these wastages could be controlled by implementing different waste minimization measures (Formoso et al, 1999).

2.2.1.2 Based on Loss

Skoyles and Skoyles (1987) make a distinction between construction materials waste as direct and indirect waste. Waste that can be prevented and which involves the actual loss or removal and replacement of material is called direct waste. Direct waste consists of a complete loss of materials, due to the fact that they are irreparably damaged or simply lost.

In this case, the wastage usually needs to be removed from the site. Therefore, the cost of direct waste does not end up in the cost of material, but followed with the cost of removing and disposing. Thus, by preventing direct waste straight forward financial benefits can be obtained. Direct waste can occur at any stage of the construction process before the delivery of material to the site and after incorporating the materials at the building (Formoso et al, 2002).

Forms of direct waste (Skoyles and Skoyles, 1987)

- a. **Delivery waste:** -losses during the transportation of materials to the site, unloading and placing in addition to the initial storage. Eg. Bricks, glassing
- b. **Cutting and conventional waste:-** cutting materials into various sizes and uneconomical shapes. Eg formwork, tiles, reinforcement bars
- c. **Fixing waste:-** dropped, spoiled or discarded materials during fixing. Eg. Bricks, roof tiles
- d. **Application and residual waste:-** hardening of the excess materials in containers and cans. Eg. Paint, mortar.
- e. **Criminal waste:-** theft and vandalism eg tiles, cement bags
- f. **Management waste:-** lack of supervision or incorrect decisions of the management. Eg. Throwing away excess material
- g. **Waste due to wrong usage:-** wrong selection of materials. Eg. Rejection of inferior quality marbles, tiles

Indirect waste occurs when materials are not physically lost; causing only a monetary loss, for example, waste due to concrete slab thickness larger than specified by the structural design. Indirect waste arises principally from the substitution of materials, from use of materials in excess of quantities allowable under the contract, from errors, waste caused by over allocation, where materials are applied in superior quantity of those indicated or not clearly defined in contract documents, and waste caused by negligence, where materials are used in addition to the amount required by the contract due to the construction contractor's own negligence. A large part of these wastes have been hidden, and it has not been perceived as actionable (Skoyles and Skoyles, 1987; Formoso et al, 2002).

Forms of indirect waste (Skoyles and Skoyles, 1987)

- a. **Substitution waste:-** substitution of materials at work, which will incur losses to either to the contractor or client. Eg use of 20cm HCB in place of 10 cm HCB
- b. **Production and operational waste:-** where materials are used in excess of those indicated or not clearly defined in the contract document. Eg. Additional concrete in trenches, use of excess plaster to rectify uneven surface
- c. **Negligence waste:-** site errors because of the condemned work or use of additional material. Eg over excavation of foundation resulting in the use of additional concrete.

2.2.2. Magnitude of Material Waste in the Building Construction Project

2.2.2.1 Material Usage Standard in Building Construction Project

Generally, the materials cost of a project is conceptualized during the inception stage by using past experience while contracting the quantities of work involved in a project are detailed in the contract bill of quantities. These are derived from the design and drawings. But there is inherent material wastage associated with all types of materials. For example the actual requirements of concrete for the floor slab of a building may be 2% more than the theoretical quantities measured from the drawing, as certain wastage does occur while placing concrete especially, due to inaccuracies in leveling of formwork. This waste factor is used to increase material quantity to ensure that enough material is procured to realistically complete the work and allow bulk discount purchase.

This wastage of materials is generally expressed as a percentage of the materials calculated theoretically from the quantities of work involved, and are termed as “standard wastage”. The total quantity of materials to be provisioned should cater for the standard wastage by increasing the theoretical quantity, proportionately (Chitkara, 2004).

$$\text{Actually needed quantity} = \text{Theoretical quantity} \times \frac{(100 + \text{Standard wastage } \%)}{100} \dots\dots\dots [\text{Eq. 2.1}]$$

It may be noted here that standard wastage caters for wastage during utilization only for causes considered beyond control at the site. This standard wastage of construction materials depends upon many variables such as the nature of work, method of application and type of materials

used. However, such allowances are often traditionally assigning and their accuracy or base rarely challenged. Rather, the standard wastage best be specified from the experience of contractors and its value is different for different materials. Good record keeping on previous work performance and by systematically comparing the current situation with similar performance in the past, a probable outcome can be predicted (Chitkara, 2004).

2.2.2.2 Measuring of Construction Material Waste

Waste quantification is a primary requirement for the waste minimization process. In addition to the fact that recording and measuring waste is a prerequisite to its management, knowing how much waste generated can also be used as a benchmarking tool against other projects cost estimation and cost overrun control.

Since the quantities produced are difficult to estimate and variable in composition, distinct measurement procedures are necessary for each of them. Some studies have been conducted in different countries to gain insight in the percentage of generated waste during construction operation for specific materials.

According to Bossink and Brouwers (1996), a research conducted in the Netherlands that was concerned with the measurement and prevention of construction waste, materials waste in construction studied in building projects in three views:

1. Construction waste of a specific material as percentage of total construction waste,
2. Construction waste of a specific material as percentage of its total amount,
3. Cost of construction waste of a specific material as percentage of total waste costs.

These methods are all illustrative of the level of waste generated and they can be used simultaneously. Amount of material waste generated in the projects found out by calculating the difference between the final estimated quantities and actual consumption.

$$\text{Wastage quantity (in \%)} = \frac{(M_p - M_u)}{M_p} \times 100\% \dots\dots\dots [\text{Eq. 2.2}]$$

Where: M_p is the purchased material; and

M_u is actual needed material

2.2.3 Causes of Construction Materials Wastage

To be able to reduce the amount of construction waste, the question occurs as to what the main causes of the generation. By identifying the main causes, construction industry players can avoid excessive waste generated. Construction waste originates from various sources in the whole process of implementing a construction project due to one or a combination of many causes.

Material waste can be categorized according to its source; namely the stage in which the root causes of waste occurs. Different studies in different countries identify these sources which cause building material waste. Bossink and Brouwers (1996) organized the sources of waste during the construction process as: design, procurement, materials handling, operation and residual.

In addition, in Singapore, Ekanayake and Ofori (2000) organized the sources of construction waste under four categories: design, operations, material handling and procurement. Further, the most common causes of construction waste were identified from past researches by Sasitharan Nagapan (2011). His study, conducted on causative factors of construction waste existing in construction field activities. The causes of construction waste are matrix and found that 63 waste factors existed in construction activities. The waste causes were grouped into seven categories: Design, Handling, Worker, Management, Site condition, Procurement and External. In this research the sources which cause waste on site were identified after a review of the literature, and placed in seven major categories.

1. Design
2. Procurement
3. Handling and storage
4. Operation
5. Site management
6. Supervision
7. Others

It is assumed that the importance of these categories will vary not only from project situation to project situation but also from material to material. For example, it is more likely that concrete waste rather than dimensional lumber waste will be created by design error. However, those wastes that are created can usually be attributed to short comings in one of the following areas:

Table 2.1 Causes of material wastage in building construction projects

Source	Cause
Design and Documentation	Lack of attention paid to dimensional coordination of products
	Design changes and revision
	Ambiguities, mistakes, and inconsistencies in drawings and specification
Procurement	Poor quality of materials
	Poorly schedule to procurement
	Mistakes on quantity surveys
	Purchased materials that do not comply with the specification
Handling and Storage	Improper handling of materials
	Double handling of materials
	Overloading of transport equipment (beyond its capacity)
	Improper storage of materials on site
Operation	Rework (chiseling, complete removal and rework...etc.)
	Using an excessive quantity of materials than required
	Using an incorrect type of material
	Damage to work done by other trade (like electrical & sanitary installation)
	Poor workmanship
Site management	Poor qualification of subcontractor's
	Scarcity of Equipment
	Untidy construction site
Site Supervision	Poor qualification of consultant engineer's staff assigned on the site
	Delay in performing inspection and testing by the consultant Engineer
	Poor coordination and communication between the consultant engineer, contractor and client
	Slow response from the consultant engineer to contractor inquiries
Others	Weather condition
	Theft

2.2.3.1 Design

The best opportunities for improving materials resource efficiency in construction projects occur during the design stage. Inadequacy of design and specification and lack of standard manufactured sizes are just some of the waste contributory factors. Design changes are common as a result of owner demands or requests to meet changing requirements and preferences. Changes in design decisions while construction is in progress can result in demolition, surplus and redundant materials, demoralization of labour force and reduction of quality of products and in extreme cases, turnover of construction personnel.

Besides, considerable waste is often incurred as a result of design information being incomplete when construction is to begin. There are always cases that the design specifications do not agree with the practical material dimensions causing large amounts of material wastage during construction. If detailed technical information about the construction materials or construction process can be taken into account by the designers, a significant amount of waste can be avoided (Sasitharan, Ismail and Asmi, 2012).

2.2.3.2 Procurement of Building Materials

Errors in ordering and shipping can cause materials wastes in the building construction projects. Procurement mistakes can result in one of three material conditions: over shipment, under shipment, or mis-shipment. They are usually caused by miscommunication either within the builder's organization or between the builder and the vendor (Bossink and Brouwers, 1996).

An enormous amount of waste stems from procurement errors. Ordering errors like ordering significantly more or less will interrupt the pre-planned flow of materials, thus causing deliveries made to redundant and result in additional handling with all its related costs (Sago, 2011).

2.2.3.3 Handling and Storage

Wrong materials storage and poor handling are key factor for physical waste generation in the building projects. Improper handling, may occur at the work site, or before the material arrives at the site. That is, the material may be damaged during fabrication, packaging, loading, or delivery. At the site, construction materials may be damaged due to unnecessary handling or

improper storage without appropriate protection. For example, many construction materials are subject to deterioration and bio-degradation due to environmental impacts. Besides, excessive stocks are subject to damage, deterioration, theft and vandalism (Al-Moghany, 2006).

Proper handling of materials is dependent on planning, particularly on clear and uninterrupted access from the place of storage to the place of usage, inclusive of provision of temporary roads and appropriate equipment (Sasitharan, Ismail and Asmi, 2012).

2.2.3.4 Operation

Operation is one of the major causes for waste generation accepted by many researches. Improper operation procedures are often resulting in high materials wastage. But, raw materials should be fully utilized avoiding wastage. Operational errors like rework, damage to work done by other trade, poor workmanship, using excessive quantity of materials than required are all due to negligence and carelessness or incapability of operatives (Sasitharan, Ismail and Asmi, 2012).

2.2.3.5 Site Management

Construction management is about planning, coordinating and controlling everything involved in the construction project. Poor planning which is due to lack of planning skills of the management staff lead to the generation of physical waste in building projects. Furthermore, incorrect planning and selection of equipment also cause the work to stop. Thus, proper planning and controlling is the key function that should be used effectively in eliminating material wastage (Sasitharan, Ismail and Asmi, 2012).

2.2.3.6 Site Supervision

Professional construction supervision specifically tailored to safeguard the successful completion of a construction project. Construction site supervision services can be complemented by compressive quality control services. This guarantees the materials used, all equipment's and systems are of good quality, function well and confirm to the standard. Checking and approving all these helps to reduce material wastage on the site (Al-Moghany, 2006).

2.2.3.7 Others

These wastes may result from a wide variety of sources. This can be due to weather conditions, theft and accident. To reduce material wastage from such causes avoids placing washable materials at steep slope or near drain and providing security guard at the construction site are advisable (Sasitharan, Ismail and Asmi, 2012).

2.2.4 Impact of Material Wastage on Building Construction Project Performance

Construction site waste management and minimization has great potential to contribute to construction industry performance improvement in addition to waste management problem caused by the construction sector. Wastage of materials in construction projects has an impact on quality of works, project cost, working time, safety and health of the workers (Sagoe, 2011). These impacts of material wastage described in detail below.

2.2.4.1 Effect on Quality of Work

Quality is one of the critical factors in the success of construction projects. Quality problems are considerable in all phases of construction. Achieving good waste minimization on construction projects helps to reduce the quantities of construction waste sent to landfill. Since most of the causes of material wastage are the causes for quality problem in construction projects, minimizing material wastage has a role in the improvement of quality of work. For example, the problem related to labour such as lack of skilled labour, a mistake by the workers, rework, etc. are the causes for material wastage and poor quality of work. Consequently, resolving these causes of materials wastage result also in achieving good quality of work (Sagoe, 2011).

2.2.4.2 Effect on Cost of Project

Construction material wastage significantly affects the total cost of a project. The true cost of material waste consists of direct and indirect costs. Direct cost consists of the purchase price of the material that ended up as waste and indirect costs consist of:

- (i) Cost of transporting the waste off-site
- (ii) Missed opportunity of not reclaiming reusable and recyclable material.
- (iii) Lost time in terms of labour and management time.
- (iv) Loss of ability to win contracts based on bad waste history

A construction company can thus be profitable by reducing the amount of waste it needs to dispose of. Due to this the construction materials wastage has significant influence on the overall project cost (Sagoe, 2011).

2.2.4.3 Effect on Work Time

The total time of construction project is usually specified prior to the commencement of construction. But construction projects are known to experience time delays due to various reasons. Material waste has a direct impact on the productivity and completion time of project which results in loss of a significant amount of revenue (Sagoe, 2011).

The occurrence of material wastage in construction projects results in an unnecessary works like waste handling processes which are non-value adding activities to the project. These non-value adding activities consume a high percentage of overall working time and effort without adding value thus resulting in delay. Therefore, effective minimization of material wastage in construction project results in the avoidance of unnecessary works (Bo Terji, 2010).

2.2.4.4 Effect on Safety of Workers of a Project

Another material wastage effect on the building project is lack of safety and health on the workers. Decreasing the amount of waste on site and managing more effectively what remains will lead to cleaner and safer sites. For instance high winds might lift unclear debris such as iron sheeting into the air which could be a potential threat to people (Al-Moghany, 2006). Good waste management on site, which includes, for example, encouraging your workers to think about where they place their waste, will also result in a better site image. More importantly, it could also lead to improved health and safety as there are likely to be fewer accidents if material waste is minimized. This can be achieved by providing:

- Safe access to people and vehicles on site that they can reach the allotted workplace
- Walkway which are free from obstructions of waste materials
- Tidy sites and storing materials in safe places and ensuring that all projecting nails are hammered down flat or removed completely
- Proper arrangement for gathering and disposing off waste materials

2.2.5 Construction Materials Waste Minimization

Waste minimization is one of the most effective approaches to respond to the waste problem in the construction industry. Waste minimization is defined by the Environmental Protection Agency of USA (2000) as “any method that reduces the volume or toxicity of a waste that requires disposal”. Poon and Jaillon (2004) also studied how to reduce building waste at construction sites in Hong Kong, and defined waste minimization as “any technique, process or activity which avoids, eliminates or reduces waste at its source or allows re-use or recycling of the waste”. In both sense waste minimization is a method that reduces the amount of waste generated on site.

2.2.5.1 Benefits of Construction Materials Waste Minimization

The consideration of waste minimization on the construction projects can create mainly financial and environmental benefits.

a. Financial benefit

For economic reasons people in the construction industry need to have an insight into the financial consequences of construction waste. Substantial savings could be obtained by reducing the amount of construction waste (Begum et al, 2006). The financial benefit gained by waste minimization appreciated over a short term or long-term period. This financial benefit comes from:

- Reduced purchase quantity of raw materials by waste minimization
- Reduced transportation costs for waste materials (less transportation because of less material wasted).
- Reduced disposal costs of waste materials. Less waste generated means less waste taken to landfill, which will reduce landfill fees for disposal.
- Long term benefits through reduction of the occurrence of delay, poor quality, health and safety problem on the building sites. Due to this the company will get higher profit.

According to Al-Moghany (2006), sending building materials to landfill is like throwing money away. This is because it is already paid for the material, paid someone to deliver it and then paid someone to collect it and throw it away. However, this argument could be necessarily true when the cost of waste is significantly higher than the cost to prevent it.

b. Environmental benefit

The large volume of waste in the construction industry contributes to the rapid depletion of natural resources and production of high volumes of air pollution (Formoso et al, 1999). The Environmental benefit is crucial because of its role in the improvement of the planet's atmosphere; taking into consideration the next generation's environment. Waste minimization can provide environmental benefits, which are important to be considered due to the alarming situation of materials waste on construction sites. The environmental benefit comes from (Sagoe, 2011):

- Minimized amounts of waste disposed of at landfills, which therefore extend the lifespan of landfills and reduced environmental effects as a result of disposal, e.g. noise, pollution.
- Reduces the production of green house gas emissions and other pollutants by reducing the need to extract raw materials and ship new materials long distances.
- When material ends up as waste it has the potential to be reused thereby minimizing its impact on the environment through less processing.

c. Increased image of the company

The ability to demonstrate good waste management could differentiate one contractor from the competitors. A clear waste management policy which includes effective recovery and recycling of resources could enhance the reputation of a contractor and give the superiority when tendering for new projects (Narimah, 2008).

d. Other benefits

- Increased site safety
- Increased work efficiency
- Creates employment opportunities and economic activities in recycling industries.

2.2.5.2 Construction Materials Waste Minimization Strategy on Building Construction Sites

Waste minimization is a shared responsibility between all parties of the construction process from the client down to the contractor. The best strategies of construction materials waste minimization identified from past research and discussed below.

a. Design for offsite construction

Off-site construction refers to structures built at a different location than the location of use. Off-site construction occurs in a manufacturing plant specifically designed for this type of process. Off-site processes have been proved to decrease waste by optimizing cutting patterns and schedules. Its application also has the potential to significantly change operations on site, reducing the amount of trades and site activities and changing the construction process into one of a rapid assembly of parts that can provide many environmental, commercial and social benefits, including (Shen, Tam and Drew, 2004; Andrew and Richard, 2004):

- Reduce construction related transport and movements;
- Improved workmanship quality and reducing on site errors and re-work, which themselves cause considerable amount of waste on site
- Improved health and safety on site through avoidance of accidents and
- Reduce construction timescales and improved program

b. Standardization of design

Standardization means to design items with generally accepted and uniform procedures, dimensions or materials. Standardization has the potential to dramatically reduce the current production of construction waste. This is by designing the building size and space to eliminate unnecessary elements, and to reduce off-cuts resulting from the construction process. Standardization of design in building construction ensures compatibility between market supply and specification. For example, by designing room areas and ceiling heights in multiples of standard material sizes a substantial reduction in off-cuts can be achieved (Shen, Tam and Drew, 2004; Andrew and Richard, 2004).

c. Proper detailing during design

This is perhaps one of the most crucial skills needed in the building design process. This is because the nature and quality of detailing in the design document contribute to how the building is built, what it will look like, what it will cost, and how long it may take to build. Thus, design document should be specified in precise and brief ways so that the contractor can avoid excessive material ordering and estimate properly the possible amount of waste to be generated (Faniran and Caban, 1998; Andrew and Richard, 2004).

d. Correct material planning and ordering

Creating an effective schedule of material ordering, fabrication and delivery of all building materials and components helps to reduce material wastage (Che, Ahmad, Abd and Kasim, 1999). Precise scheduling in building construction enables

- Purchasing raw materials that are just sufficient
- Just-in time delivery of materials, reducing potential for damages
- Good coordination between store and construction personnel to avoid over ordering
- Gives enough time for checking materials supplied for right qualities and volumes

e. Just-in-time delivery strategy

Just in time delivery strategy is arranging deliveries to match work stages in order to avoid materials being stored on site longer than necessary. Implementing just-in-time delivery strategy in the construction projects ensure materials arrive on site when they are needed, thereby avoiding damage while stored on site and additional mobilization of materials. Besides, it reduces the potential for over-ordering materials on several projects (Narimah, 2008; Andrew and Richard, 2004).

f. Proper storage and handling of materials

Once what materials need for the project established, there should be work on how those materials will be received and stored on the site. The site manager should plan in advance suitable storage space to protect materials degradation or damage from weathering or moisture (Dennis, 2002). There should be a strategy in place which makes the best use of a central storage area with procedures for moving materials to the workplace as moving materials increases the risk of damage. Top tips for materials storage on construction projects (Dennis, 2002):

- Designating storage areas for plant, materials, waste, flammable substances separately
- Stored materials shall not spread in an uncontrolled manner on footpaths and other walkways. Further materials do not store where they could obstruct access routes or where they could interfere with emergency escape;
- All storage areas should be tidy, even in the site itself;
- Storage areas should be safe, secure and weatherproof (where required)
- Excess vegetation should be controlled

The use of proper equipment for material handling and advance planning for minimizing multiple handling will result in direct cost reduction and time savings. Careful handling of materials reduces risk of wastage of materials on site. This will begin with the provision of suitable vehicles or delivery plants for transporting material from the storage area in the workplace so as to make the damage to the minimum. In addition, avoid double handling that the points of unloading should be the final position of stacking area (Poon et al. and Jaillon, 2004).

g. Improved the skill of the workforce

The construction industry, especially in our country, it is labor-intensive. Thus, the skill and perception of workers influence its progress. It is argued that the causes of construction waste are directly or indirectly affected by the skills of the personnel involved in the construction industry (Andrew and Richard, 2004). As a result, training is absolutely required that the contractor train employees and subcontractors on material wastage minimization practices. In addition, conducting the following methods on the construction sites helps to reduce the amount of material waste due to the ability and perception of the workforce (Al-Moghany, 2006).

- Periodic monitoring to ensure compliance
- Commending employees that adhere well to site policy and offer advice to those that are not meeting the requirements
- Motivating workers by establishing targets and offering bonuses or incentives
- Conducting regular meetings to reinforce effective practices

h. Using low waste building technology

Buildings are usually constructed by the conventional cast in-situ method. But material wastage can be minimized in buildings construction project through the use of the following technologies and practices described below.

Drywall partition

Dry wall is a system of factory made wall panels. It replaces the traditional brick and block walls. It has a number of advantages. It requires less labour and skill for installation, and provides better product qualities and higher flexibilities for future layout changes. Full height panels are assembled and conduits can be easily installed through its tubular spaces with minimal cutting, jointing and patching. The surface of the panel can be easily finished with a thin coat of

skim plaster in place of the thick cement sand plaster in traditional block walls. Hence, much less wet trade work is involved in the assembly process and less construction waste is generated at the end (Poon et al. 2003).

Precast concrete element

The Precast concrete system is commonly applied to beams, facades and staircases. These precast elements may be cast in a factory or cast at the site. In precast concrete construction the materials can be better utilized and wastage can be kept to a minimum because its effectiveness in replacing traditional wet-trade practices (Tam, Vivian, John and William, 2005).

Machinery sprayed plaster

Machine sprayed plaster now replaces traditional cement mortar in developed countries building projects. The major difference between the mechanized plaster and the traditional cement mortar is that the former is mixed and applied mechanically whilst the latter is applied and trowelled smoothly by hand. The use of mechanized spraying has the merits of high productivity, low labour demand and less waste (Poon et al. 2003).

i. Develop site waste minimization plan (SWMP)

A site waste minimization plan is a simple checklist that provides the contractor with information about (WRAP, 2007);

- The waste streams
- Decisions to be made respective volumes of waste generated
- To enable strategic reuse and recycle options and
- disposal options

In addition, site waste management plan is generally effective if there is a waste manager with overall responsibility. The waste manager should be given power to:

- Select his waste team
- With the help of his team instruct, oversee, record and feedback on day-to-day waste practice
- Delegate responsibility to sub-contractors where necessary and
- Coordinate with suppliers, service providers and sub-contractors to prioritize waste prevention and salvage on site.

2.2.5.3 Construction Materials Wastage Minimization Hierarchy

Three main waste minimization strategies used in construction projects. These are reduction; reuse and recycling collectively called the “3Rs” (Ayarkwa and Adinyira, n.d; NSCC, 2007).

a. Reduction

Reduction is defined as any activity that reduces or eliminates the generation of waste at the source, usually within the process. Therefore, Waste reduction or source reduction, means preventing the creation of the waste in the first place (Begum et al., 2006). The biggest opportunity to impact on waste generation through prevention principles is at (Dennis, 2002):

Design:- through design for waste reduction, i.e. the design stage will provide plans and specify materials that are prefabricated, recyclable and low waste building technologies.

Operations:- through clear communication of the designer to the project team to avoid unnecessary waste through errors and redo.

Procurement: - through the engagement of suppliers in delivering quality materials and through take back agreements for unused materials.

Reduction is at the highest preference on the construction waste minimization hierarchy; it has the most positive environmental impact due to the action having a direct effect. Many design and job site practices can significantly reduce waste and cost of materials while requiring only slight modifications of procedures.

b. Reuse

Reuse means to utilize articles from the waste stream again for a similar or different purpose without changing the form or properties of the article. This includes scrap generated on site and used materials. Reuse extends resource supplies and reduces energy and pollution even more than recycling (Begum et al., 2006). When reusing materials, the contractor should ensure that the material is of suitable quality and fit for the intended use.

c. Recycling

Recycling is a process where the separation of a waste from a waste stream for further use and the processing of that separated material as a product or a raw material. According to Ekanayake and Ofori (2000), recycling waste materials is a very important environmental management tool

for achieving sustainable development. Recycling, as a minimization strategy generally, requires more technological innovation than those of reduction and reuse, as the process typically requires the modification of materials through remanufacture. On the other hand, recycling waste without properly based scientific research and development can result in environmental problems greater than the waste itself (Begum et al., 2006).

It is important to understand the principles of waste minimization. The figure below illustrates the waste minimization hierarchy.

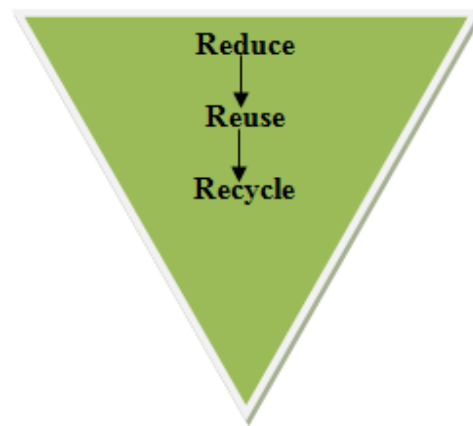


Figure 2.1 Waste minimization hierarchy
Source (Waitakere City Council's, 2008)

As Figure 2.1 above shows recycling is actually the last option after rethinking to reduce the amount of waste produced and reusing waste that are produced. Minimization of waste at source should be given the highest priority when developing strategies for waste minimization. This is because, conceptually, it makes more sense to avoid or minimize the generation of waste than to develop extensive schemes for treating waste. Reusing and recycling do not avoid the generation of waste rather reduce the volume of waste material to be disposed of and discharged into the environment, thereby allowing waste materials to be put to beneficial use.

However, the successful development of new materials or components using waste as raw material is a complex and a multidisciplinary task regarding technical, environmental, financial, marketing, legal and social aspects (Waitakere City Council's, 2008).

2.2.5.4 Factors Affecting Recovering of Construction Waste Materials

The choice of what and how construction waste materials can be recovered depends on many factors, including the type of project, space on the building site, the existence of markets for materials, the cost-effectiveness of recovery, the time allowed for the project, and the experience of the contractors (Al-Moghany, 2006).

i. Space on the building site

Materials recovery is often easiest if the building site is spacious enough to allow on-site sorting of materials. Having separate containers for each type of materials can reduce contamination.

ii. Materials markets

While it is possible to reuse and /or recycle many of the waste materials generated on site, the feasibility will depend on the market conditions for each type of material. Contractors can maximize recovery by taking advantage of all available markets for recovered materials.

iii. Cost-effectiveness

Hauling and disposal costs, the value of recovered materials, and labor costs contribute to whether materials recovery is more or less cost-effective than disposing of materials. Recovery of low value materials may be cost-effective if disposal costs are high and removal and sorting are not labor intensive. The labor cost incurred to remove items for reuse may be offset by savings from both the avoided costs of purchasing new materials and avoided disposal costs.

iv. Project timeline

Source separation of materials for reusing and recycling can take more time than disposing of all the generated wastes and often projects are on a tight schedule due to different reasons. Contractors can maximize materials recovery in the time allowed by planning ahead. If necessary, contractors can focus waste reduction efforts on off-site source separation and recycling.

v. Contractor experience

Contractors well experienced in recovery methods and local markets may be able to recover more materials than contractors unfamiliar with reuse and recovery techniques.

2.2.5.5 Best International Practice on Building Materials Wastage Minimization

While construction and demolition wastes are usually grouped together under the title “C&D waste” in many countries in the world, the minimization strategy also undergone for waste of both processes. Throughout the construction cycle, and especially at the end of a structure’s life, large quantities of material waste are produced. The increasing problems associated with construction and demolish waste have led to a complete rethinking in some of the industrialized countries. The current tendency in several industrialized countries is to view wastes as resources or by-products, which become new products that can be used for a variety of useful purposes (Begum et al., 2006; Zebau, Simona, Weisleder and David, 2006). This is because a large proportion of the waste produced on construction sites is recoverable for reuse and recycling.

a. Experience from Germany

Construction and demolition waste management in Germany is a mature and well integrated sub industry within the broader German construction market. In 2002, German construction and demolition activity generated 214 Megatons of waste composed two thirds of excavated material, nearly another third of building and road demolition waste and a smaller fraction of mixed construction site waste. Despite these high numbers, only 15% of these materials were disposed of in landfills, while the remaining 85% was recovered and reused in further applications or recycled (Zebau, Simona, Weisleder and David, 2006).

Germany’s high material and waste disposal costs favor the economics of recovering, reusing and recycling as much construction and demolition waste as possible. Additionally, strong waste management systems have long been required by laws and regulations at all levels of government in order to minimize the impact of construction and demolition waste in the waste stream. More recent versions of these regulations focus on the complete material cycle, working towards a closed loop substance cycle in construction and demolition.

This combination of regulatory pushes from the government and economic pulls from the market have helped Germany establish an effective construction and demolition waste management infrastructure. The disposal of waste is only permitted when recycling is much more expensive

or impossible and the waste is unavoidable. In Germany the following major construction materials are commonly recovered.

Table 2.2 Key construction materials reuse and recycle in Germany

No.	Material	Ways of minimization	
1	Concrete	Reuse	Some concrete can be reused with little processing:
			a) Pre-fabricated elements
			b) Concrete Block (once cleaned of mortar and finishes)
		Recycling	Primarily in road construction as underlay and drainage material. Ideally, recycled concrete could be used as aggregate in new concrete
2	Brick	Reusing	Bricks can be re-used directly.
		Recycling	Crushed brick can be used as
			a) Base fills in the construction of roads.
			b) Primary road surface material on unpaved roads in rural areas.
			c) Crushed stone replacement or low density concrete aggregate.
3	Wood	Reusing	Direct use when free of pollutants in addition the common reuse option for wood recovered from construction and demolition recycling is for fuel.
		Recycling	A number of engineered wood products can be produced from chipped wood material. These products include fiberboard, oriented strand board, and particleboard. The wood chips are formed into boards by various pressing methods and adhesives.
4	Steel	Reusing	Direct reuse when free of damage.
		Recycling	Directly ready for smelting if segregated and free of hazardous materials
5	Tiles	Reusing	Direct reuse when free of damage
		Recycling	Similar to brick and concrete crushed recycled ceramic tiles is used in road construction.

Furthermore, waste management practices have been integrated into mainstream architectural and engineering education and practice. Architects and engineers designing and constructing buildings are obliged to consider the entire life cycle of materials, from production, to removal and reuse or recycling, of components they install in buildings. Construction material manufacturers are responsible for ensuring that their products are designed in such a way as to reduce wastage (eg. different lengths of floor boards to reduce cutoffs), facilitate recovery after usage, work towards making them recyclable and make them environmentally compatible with post recovery applications.

Building owners, developers and engineers and architects are responsible for integrating a waste management strategy in their construction plan. This includes the use of recyclable building materials. Despite this, in order to insure the substitutability of recycled materials for new materials, a quality assurance system has been established in Germany. The government has established strict codes to which recycled material must conform in order to be reused in further applications. These codes give recyclers and contractors clear indications about what can and cannot be done with a particular material.

b. Experience from Australia

A number of states, including Victoria, South Australia and Western Australia, have 'towards zero' waste strategy documents. The strategies set state wide targets for waste reduction, resource recovery and littering (Chris and Emily, 2013).

Many local councils require waste management plans before granting development consent. They usually require the builder or designer to estimate the total waste stream volumes from both demolition and new construction. In addition, nominate the means of disposal, including the recycling contractor, recycling waste station or landfill site. The site plan is often required to show waste storage facilities on site during construction and provide a schedule for delivery or pickup.

The time and cost of waste plan preparation is usually recouped through reductions in waste disposal costs or dividends from the sale of salvaged resources. The following list demonstrates some reuse and recycle options in Australia.

Steel — Electric arc furnaces produce reinforcing bar, mesh and sections from 100% steel scrap. Conventional blast furnaces can incorporate up to 30% steel scrap.

Aluminum — Aluminum is 100% recyclable;

Timber — most timber (except treated timber) can be reprocessed into horticultural mulch. A particle board manufacturer in Australia is developing a recycling facility that requires little or no pretreatment of the waste.

Concrete — un-set concrete can be ‘washed’ out at the plant to remove the cement. Sand and stone can be reused. Set concrete can be crushed and recycled as aggregate for new concrete or road base and fill. Rapidly developing markets for this product mean the material is now in demand and disposal costs are significantly reduced.

Glass — most glass is recycled in Australia. Construction glass must be separated from other glass such as drink bottles. Glass may be cut and reused or recycled as aggregate for concrete.

Bricks and Blocks — these materials can be reused where appropriate or crushed on site with portable crushing plants and used as aggregate in concrete production.

2.3 Literature Review Summary

Generally, there is inherent material wastage associated with all types of materials. Due to this all estimators allow wastage factors in pricing a bill of quantities. But the actual material waste is far higher than the nominal figures assumed by the companies in their cost estimate. Thus, the literature review involves critical review of published literatures related to construction materials waste so that to identify the gap and bring the important concept for this thesis.

Studies have shown that not all materials procured and delivered to sites are used for the purposes for which they are ordered because of a number of reasons and become wasted. Previous studies have demonstrated that material wastage has a large effect on the financial

performance of construction projects. Besides, managing building materials waste can in fact achieve higher construction productivity, save on time and improve safety while disposal of extra waste takes extra time and resources that may slow down the progress of construction.

Construction waste originates from various sources in the whole process of implementing a construction project due to one or a combination of many causes. Various researches across the world have been undertaken in order to know the causes and factors that lead to material waste in construction projects. This is because in order to reduce the amount of construction waste, the question occurs as to what are the main causes.

Therefore, by identifying the main causes, construction industry players can avoid excessive waste generated on construction sites. In addition, there are different studies on effect of material wastage reduction and minimizing strategy, including reusing and recycling on construction projects.

From each of the literature reviews on construction waste minimization, different gaps were identified. The critical gaps identified from these studies are lack of quantified data on construction material waste quantities and the large discrepancy between the percentage of material waste allowed and actually wasted materials on site. On the other hand, wastage control needs serious consideration and due attention since the construction industry consumes large amount of raw material.

Therefore, this research is necessary in order to develop an appropriate construction waste minimization practice that will set out procedures to fill the knowledge gaps mentioned above. To fill this gap, 25 potential causes leading to construction materials wastage and 16 possible wastage minimization strategies were identified from literature review and forms the bases on which the questionnaire has been developed.

An effective and proper construction waste minimization should in the first place be able to identify waste types and categories, predicting the waste quantity, establish causes and origins of these wastes and providing waste reduction strategies in order to effectively reduce the waste amount of construction sites.

3. RESEARCH METHDOLOGY

3.1 Introduction

The research methodology gives justification in the choice of methods used to achieve the objective of the study which is specified at the beginning. Further, it gives the research population, sample size and statistical tools used for data analysis. With this background, statistical results obtained from the data's discussed in chapter four.

3.2 Research Design

The strategy followed in this research was first started with problem identification which has been done through unstructured literature review, archival study and informal discussion with colleagues and professionals in the sector and then the research design were formulated. Then data and information sources were determined based on the formulated research design.

On the basis of the data and information sources the research instruments were decided and available documentary sources relevant to the research were reviewed. The review includes books and journal.

Finally, after an in-depth review of literature, a questionnaire was designed and distributed to contractors and consultants to get their opinion based on their experience. Upon obtaining the desired data, checking and sorting of data has been done. The data's were then analyzed for extracting the information obtained through the overall research work. This was followed by thorough discussions in order to draw a conclusion and to forward recommendations based on the findings of the study.

A descriptive and exploratory survey design was used in this study. It was attempted to collect data from the relevant population (consulting firms and contractors) to evaluate their perception on the issues of material wastage in 40/60 condominium housing construction projects.

3.3 Source of Data and Research Instrument

Multiple evidences approach was used for data collection. These are questionnaire survey, observations made on site and case study by analyzing different documents.

A questionnaire survey was selected as the research instrument owing to its suitability to the level of information required, cost and time limitations and the high number of participants. The questionnaire form, which was accompanied by a covering letter, consisted four parts. Basically, the questions were structured or closed type questions. But, in view of obtaining as much information as possible, participants were encouraged to give additional information or comments on the open spaces provided under each question.

The first part sought information about the respondents' profile and the second part assess the effect of client material supplying on materials waste generation. In the third part, participants were asked to rate causes for materials wastage on their specific site. The respondents were requested to rank these causes in order of importance. The rating values of 5, 4, 3, 2, and 1 were assigned to the options major significant waste cause, significant waste cause, neutral, insignificant waste cause and not a waste cause respectively in obtaining the respondents' perception of the causes leading to construction material waste generation.

The fourth and last part of the questionnaire contained questions focused on construction materials wastage minimization but it is different for the two groups of respondents. The common question for both group of respondent's asses their perception on how the measures identified from literature contribute to materials waste minimization and the level of practice of these measures on their site.

For each waste minimization measure, the respondents were asked to score the level of contribution to waste minimization on a scale of 1 to 5 where 1= 'very low', 2= 'low', 3= 'Medium', 4= 'High' and 5= 'Very high'. The respondents were further asked to score each measures according to the level of practice in their organization on a scale of 1 to 5 where 1= 'Not practical', 2= 'Not practiced', 3= 'Practiced', 4= 'Frequently practiced' and 5= 'Most frequently practiced'.

Additionally, for the construction supervision consultants it asks two questions first about their practice during a design revision period regarding material wastage and the second is about their current site supervisor's assignment.

Observations made on site have helped me to see the actual condition on the site and is used to countercheck the reliability of the questionnaire response. The data's of the case study gathered from drawings of the buildings and material requesting form of contractor. The analysis of the data from these documents carried out mainly to obtain the approximate percentage of material wastage.

3.4 Research Population and Sampling

The construction sites selected for this study are 40/60 condominium housing construction sites. Currently the city administration has formed an independent office responsible for this specific project, Addis Ababa City Administration Saving Houses Development Enterprise (SHDE). As the figure from this office shows, there are 11 sites currently under construction on 40/60 scheme. The detail of research population is given in Table 3.1 below.

Source (Saving Houses Development Enterprise /SHDE/) May, 2015

Table 3.1 Study population data

No.	Project name	Total		Above third floor	
		Number of blocks	Number of Contractors	Number of blocks	Number of Contractors
1	Sengatera	5	5	5	5
2	Crown	14	7	14	7
3	Ehil Neged	6	3	6	3
4	Asko	11	5	3	2
5	Hintsa Akrobi	8	4	8	4
6	Bole Bulbula	28	14	7	4
7	Meri Loque	14	7	8	4
8	Bole Hayat 1	14	7	8	4
9	Bole Hayat 2	37	16	4	2
10	Bole Hayat 3	41	18	4	2
11	Bole Hayat 4	40	12	1	1
Total		218	98	68	38

Since the total population of the research is small, undergoing study on all of the population is safe. Therefore, the questionnaire is distributed in all these 11 sites. However, collecting the primary data from construction schemes who haven't reached third floor will not ensure data collected is fair and correct, and will not allow accurate conclusions to be drawn about material wastage. Thus, it considers only the contractors who have reached above the third floor on all 11 sites.

The target population for the data collected using the questionnaires consisted of construction supervision consultants and construction contractors. Professionals included in this study are those that have direct involvement in the construction process. The contractor professionals included were project managers and site Engineers. On the construction supervisors side the survey included resident engineers and site supervisors.

3.5 Method of Data Analysis

The analysis was done using Microsoft Excel and the responses assigned to each question by the respondents were entered and consequently the responses from 25 supervisors and 56 contractor's questionnaires were subjected to statistical analysis for further insight. The following statistical techniques which are grouped under various headings were then employed to analyze the data collected from the survey.

Frequency tables and descriptive statistics were constructed to display results with respect to each of the questions of general information and effect of client material supplying. Whereas the contribution of each of the causes to material wastage generation and minimization strategies for each of the selected materials was examined and the ranking of the attributes in terms of their criticality as perceived by the respondents was done by the use of relative weight (RW).

The relative weight (RW) for each of the causes of material wastage and minimization measures computed using the following expression.

$$RW = \frac{\sum (fxS)}{N} \dots\dots\dots [Eq. 3.1]$$

Where: RW = Relative weight

f = Frequency of response for each score

S= Score given to each causes/strategies (1to 5)

N= Total number of responses for each causes/ measures

Recognizing the difference in perceptions of the consultants and contractors, there was also the need to further ascertain if consultants' perceptions were statistically different from the contractors' perception. This leads to the use of Spearman's-rank correlation coefficient test. It has an advantage of not requiring the assumption of normality and or homogeneity of variances.

The Spearman (rho) rank correlation coefficient for any two groups of ranking is given by the following formula.

$$\text{Rho (rcal)} = 1 - \frac{6 \times (\sum di^2)}{N(N^2 - 1)} \text{-----[Eq. 3.2]}$$

Where: Rho (rcal) – Spearman rank correlation coefficient

di – Difference between ranks given by two respondents for each variable

N – Number of pairs of values in the data set

4. STUDY RESULTS AND DISCUSSION

4.1 Introduction

This chapter aims to display the results of this study. The quantitative research findings are outlined in table, different types of charts and text form. Each result was discussed in short, however; certain results were followed by a more in-depth discussion.

Two different questionnaires were administered, one for construction supervisors and the other for the contractors. The questionnaires comprised of four parts of both groups of respondents as the study aimed to do a thorough research investigation.

The total number of distributed questionnaires in this study consisted of one hundred thirty eight, but collected responses were only eighty six. Out of the returned questionnaires, five were rejected for the analysis due to many unreplied questions observed in the questionnaire contained therein. Table 4.1 below shows the response rate of the questionnaire.

Table 4.1 Response rate of the questionnaire

No	Stakeholder	Questionnaire distributed		Returned questionnaire		Failed questionnaire		Analyzed questionnaire	
		No.	(%)	No.	(%)	No.	(%)	No.	(%)
1	Supervisors	40	28.99	27	19.57	2	1.45	25	18.12
2	Contractors	98	71.01	59	42.75	3	2.17	56	40.58
Total		138	100	86	62.32	5	3.62	81	58.7

The numbers were determined on the basis of the available Engineers employed by the contractors and consultants on the sites and the time available for conducting the research work.

4.2 Description of Respondents

4.2.1 Classification of Organization

All the construction supervision organizations in the surveyed sites are category one consultant. The data in Table 4.2 shows the classification of surveyed contractors. Class 1 contractors constitute 29 (51.79%); those in class 2 were 20 (35.71%) and 7 (12.50%) were in class 3.

Table 4.2 Classification of contracting companies

Company classification	No.	Percentage (%)	Cumulative	
			Number	Percentage (%)
GC - 1	7	12.5	29	51.79
BC - 1	22	39.29		
GC - 2	8	14.29	20	35.71
BC - 2	12	21.43		
BC - 3	7	12.5	7	12.5
Total	56	100	56	100

4.2.2 Distribution of Respondents' Position on the Site

The distribution of respondents' position for both construction supervision consultants and contractors is shown in Table 4.3. It illustrates that 24 (42.86%) of respondent's occupation for the contracting companies are project manager, 2 (3.57%) vice-project manager and 30 (53.57%) site engineer.

In the same manner on the consultants side 5 (20.00%) resident engineer and 20 (80.00%) site supervisors. Thus, all respondents are the responsible body about the construction practice in their project than any other person. Therefore, they are expected to give reliable information.

Table 4.3 Respondents' position on the site

Respondents	Position on the site					Total
	Contractors			Consultants		
	Project manager	Assistant Project manager	Site Engineer	Resident Engineer	Site supervisors	
No.	24	2	30	5	20	81
Percentage (%)	42.86	3.57	53.57	20	80	200

4.2.3. Respondents Educational Background

Table 4.4 illustrates the level of education of respondents. From the total 81 questionnaires analyzed, 8 (9.88%) of the respondents had MSc, 63 (77.78%) hold a BSc. Degree while 10 (12.35%) of them had a diploma. This result in the level of education indicate that site personnel were qualified enough to give reliable information by understanding each of the questions of the questionnaire about construction materials waste produce on site and how it could be minimized.

Table 4.4 Educational background of respondents

Educational background	Contractor		Supervisors		Total	
	No.	Percentage (%)	No.	Percentage (%)	No.	Percentage (%)
MSc	4	7.14	4	16	8	9.88
BSc	49	87.5	14	56	63	77.78
Diploma	3	5.36	7	28	10	12.35
Total	56	100	25	100	81	100

4.2.4 Respondent's Experience

Table 4.5 below shows the respondent's years of experience, the highest years of experience in the construction industry is between 3 and 5 years, whereas in the condominium housing construction is 1 to 3 years.

Table 4.5 Respondent's experience

Experience in years	Contractor		Supervisors		Total		
	No.	Percentage (%)	No.	Percentage (%)	No.	Percentage (%)	
Experience in the construction industry	<1	5	8.93	1	4	6	7.41
	1 – 3	14	25.00	4	16	18	22.22
	3 – 5	21	37.50	12	48	33	40.74
	5 – 10	11	19.64	8	32	19	23.46
	10 - 15	3	5.36	0	0	3	3.70
	15 - 20	2	3.57	0	0	2	2.47
	> 20	0	0.00	0	0	0	0.00
	Total	56	100	25	100	81	100
Experience in the Condominium housing construction	<1	20	35.71	4	16	24	29.63
	1 – 3	25	44.64	12	48	37	45.68
	3 – 5	9	16.07	7	28	16	19.75
	5 - 8	1	1.79	1	4	2	2.47
	8 -10	1	1.79	1	4	2	2.47
	>10	0	0.00	0	0	0	0.00
	Total	56	100	25	100	81	100

4.3 Effect of Client Material Supplying on Material Wastage Generation

This part was aimed at evaluating the effect of providing construction material by the client on waste generation at these condominium building sites. From the results, the perception of consultants and contractors about its effect is similar. Figure 4.1 shows the distribution of the response of the two groups of respondents on the effect of client material supplying.

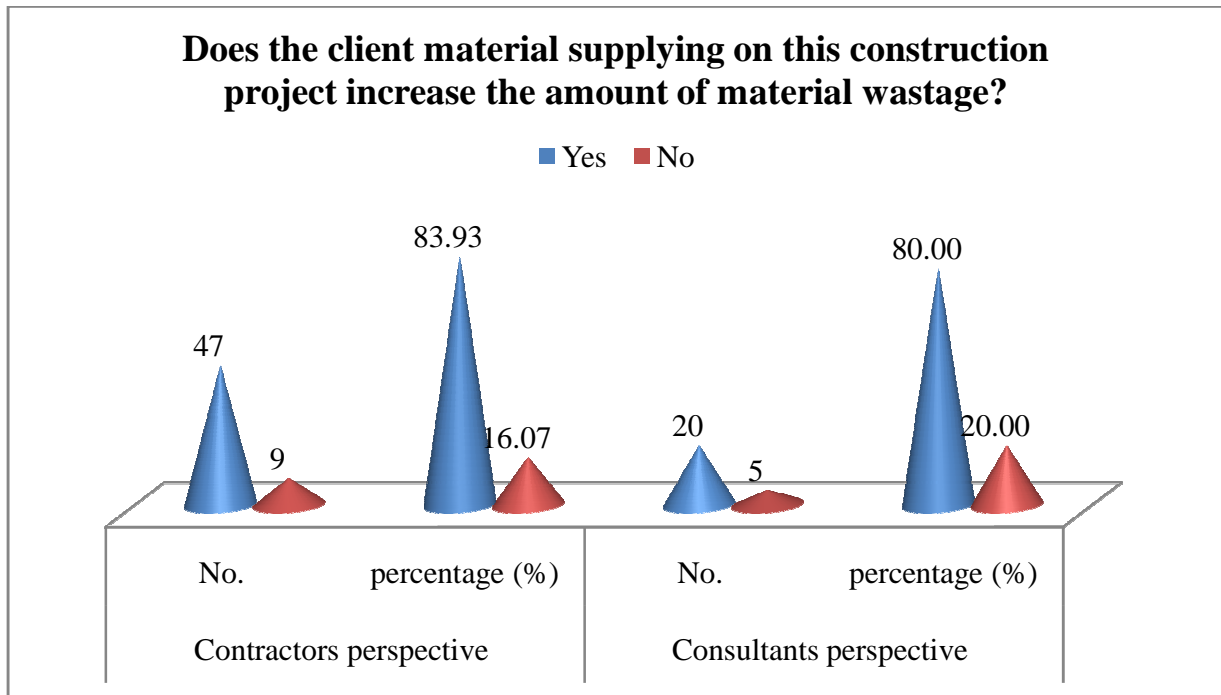


Figure 4.1 Response on the effect of client material supplying

It has been found that 47 (83.93%) of contracting companies and 20 (80%) of the consultants have agreed to client material supplying at their site increase the amount of material wastage. The reason for this increasing effect of client material supplying also has been assessed by this study.

In this regard also the contractors and the consultants give 70.21% and 63.16% percentage for the reason that because the client doesn't deliver good quality material. The details of the result of both groups of respondents presented in Figure 4.2 below.

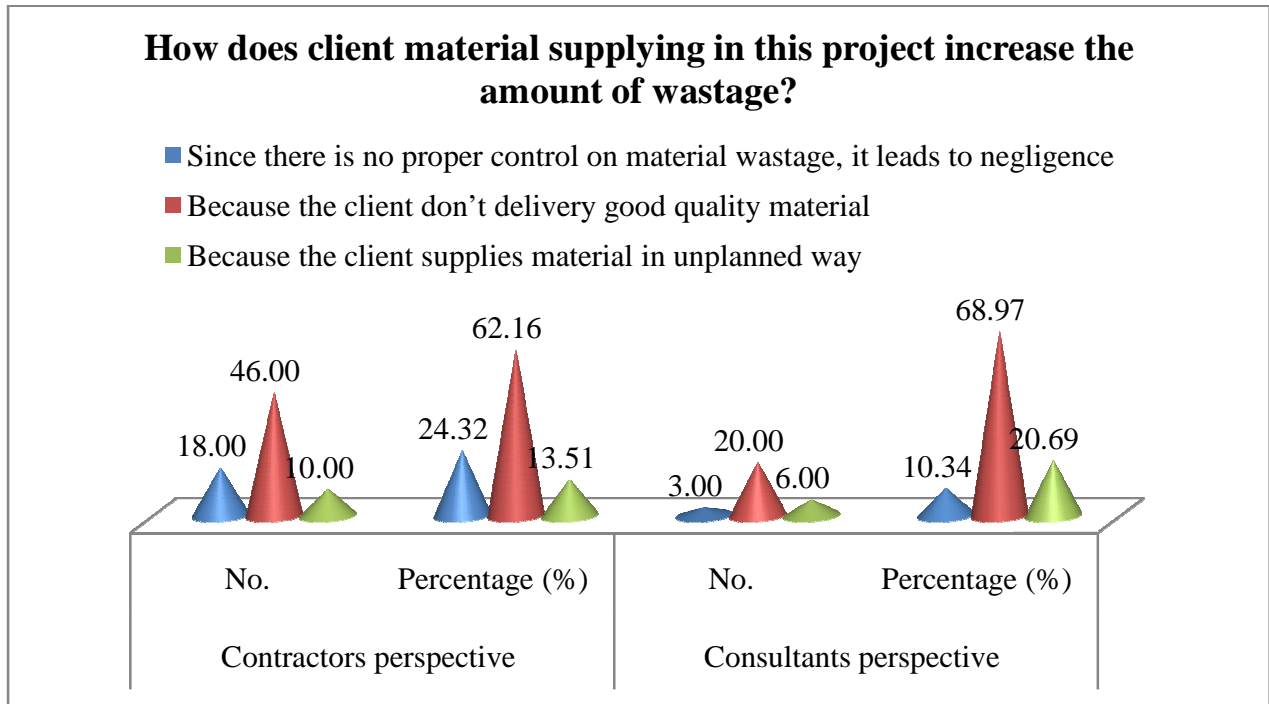


Figure 4.2 Reason for the wastage increasing effect of client material supplying

According to the contractors since there is no proper control on material wastage, it leads to negligence has the second highest response while client supplies material in unplanned way has the least percentage of response. Contrary to the response of contractors, consultants give the least response to since there is no proper control on material wastage, it leads to negligence.

This implies that the most important reason for the generation of material wastage at 40/60 condominium construction because of client material supplying is due to quality problem with the materials deliver to the sites. However, this finding is only applicable of the materials that the client provides. This is because in practical situations at 40/60 condominium construction sites, concrete and mortar are not supplied by the client.

4.4 Causes of Material Wastage

In this part the result of causes of material wastage that are gathered from questionnaire survey and site observation are presented and discussed. This gives a good indication on which activities need to be focused for each material in order to reduce waste.

The questionnaire of this study considered 25 causes of materials waste in construction, and those causes were categorized into seven sources as mentioned before, namely, design and documentation; procurement; storage and handling; operation; site management; site supervisor and others. Questionnaires were designed to measure the level of their contribution to the selected material waste generation in the sites.

For each material this study surveyed the data for the major categories of waste and top five causes of waste presented and discussed. Causes with relative mean value of 3.0 and above under each category indicate that they have significant effects on waste generation thus they consider as waste causing factors.

As discussed earlier in section 3.5 having established the perceptions of the consultants and contractors differently, there was also a need to further ascertain if consultants' perceptions were statistically different from the contractors' perception. This leads to the use of Spearman rank correlation coefficients.

Respondent's response tested for correlation using Spearman rank correlation coefficients, to see if there is difference in ranking between two groups of respondents. Accordingly, when the responses of the professionals (consultants and contractors) on the causes of waste in the surveyed materials compared, except for concrete the results showed no significant difference at the 5% significance level. Hence, the result of causes of concrete waste presents separately while the result of the rest materials was presented collectively.

Table 4.6 Spearman's rank correlation coefficients for causes of waste

Material	$Rho (r_{cal}) = 1 - \frac{6(\sum di^2)}{N(N^2-1)}$	A Critical value of r (Appendix B)
Concrete	0.19	0.409
Mortar	0.81	0.409
Reinforcement bar	0.62	0.409
Hollow concrete block	0.87	0.409

Finally, the results of site observation also presented for each material under the result of a questionnaire survey.

4.4.1 Causes of Concrete Wastage

Since the responses of the contractors and consultants on the level of contribution of waste causes for the generation of concrete waste showed a significant difference at 5% significance level, the data are presented separately.

a. Major categories of waste

Table 4.7 illustrates the relative mean and ranking of each category of waste for concrete by both groups of respondents.

Table 4.7 Relative weight and ranking of waste cause categories for concrete

Category	Contractor		Consultant	
	RW	Rank	RW	Rank
Design and Documentation	3.97	1	3.15	4
Procurement	2.85	6	3.00	5
Handling and storage	3.36	5	3.78	3
Operation	3.51	4	4.32	1
Site management	3.52	3	3.87	2
Site supervision	3.76	2	2.84	7
Others	2.13	7	2.86	6

The top three sources of waste category, according to consultants are operation, site management and handling and storage on the sites. Whereas according to the contractors, design, site supervision and site management contribute highly to the generation of concrete waste on the sites.

The results show that both groups of respondents have different opinions on the category of concrete waste. Even if the contractors identified design as the first source of waste, the consultants identified operation as the first source of waste for concrete, which is placed on the fourth position in the ranking of the contractors. The consultants further consider site supervision activities have nothing to do with the wastage of materials yet the contractors thought that it is the second in concrete waste causing. In my opinion the difference in this responding result from the consequential effect, which is directly related to who is responsible.

b. Level of contribution of the waste causes for the generation of waste

The mean and rank of each cause of the concrete waste which are greater than 3.0 according to the contractors and consultants perspective are presented in the Table 4.8 and Table 4.9 respectively.

Table 4.8 Relative weight and ranking of concrete waste causes - views of contractors

Cause	Source	RW	Rank
Design changes and revision	Design	4.41	1
Damage to work done by other trade (like electrical & sanitary installation)	Operation	4.18	2
Rework (chiseling, complete removal and rework...etc.)	Operation	4.16	3
Delay in performing inspection and testing by the consultant Engineer	Site Supervision	4.00	4
Ambiguities, mistakes, and inconsistencies in drawings and specification	Design	3.96	5
Untidy construction site	Site management	3.95	6
Overloading of transport equipment (beyond its capacity)	Handling and Storage	3.91	7
Poor coordination and communication between the consultant engineer, contractor and client	Site Supervision	3.80	8
Poor qualification of consultant engineer's staff assigned on the site	Site Supervision	3.64	9
Slow response from the consultant engineer to contractor inquiries	Site Supervision	3.61	10
Lack of attention paid to dimensional coordination of products	Design	3.54	11
Poor qualification of subcontractor's	Site management	3.52	12
Using excessive quantity of materials than required	Operation	3.50	13
Double handling of materials	Handling and Storage	3.48	14
Mistakes in quantity surveys	Procurement	3.45	15
Improper handling of materials	Handling and Storage	3.16	16
Poor workmanship	Operation	3.13	17
Scarcity of Equipment	Site management	3.09	18

Table 4.9 Relative weight and ranking of concrete waste causes - view of consultants

Cause	Source	RW	Rank
Poor workmanship	Operation	4.56	1
Overloading of transport equipment (beyond its capacity)	Handling and Storage	4.52	2
Damage to work done by other trade (like electrical & sanitary installation)	Operation	4.48	3
Rework (chiseling, complete removal and rework...etc.)	Operation	4.32	4
Using excessive quantity of materials than required	Operation	4.24	5
Improper handling of materials	Handling and Storage	4.20	6
Scarcity of Equipment	Site management	4.12	7
Design changes and revision	Design	3.96	8
Mistakes in quantity surveys	Procurement	3.88	9
Untidy construction site	Site management	3.84	10
Double handling of materials	Handling and Storage	3.80	11
Using incorrect type of material	Operation	3.76	12
Poor qualification of subcontractor's	Site management	3.64	13
Theft	Others	3.52	14
Slow response from the consultant engineer to contractor inquires	Site Supervision	3.44	15
Poor quality of materials	Procurement	3.32	16
Ambiguities, mistakes, and inconsistencies in drawings and specification	Design	3.16	17
Delay in performing inspection and testing by the consultant Engineer	Site Supervision	3.08	18

Both the contractors and consultants consider 18 causes out of the 25 causes as having contribution in the concrete waste generation on their sites. But, poor workmanship, overloading

of transport equipment and using an excessive quantity of materials than required didn't consider by the contractors as top five concrete waste causing factors in their site. While in site supervisor opinion design change and revisions, delay in performing inspections and testing by the consulting engineer and ambiguities, mistakes, and inconsistencies in the drawings and specification didn't consider as a top five concrete waste cause.

However, in both groups of respondents rework and damage to work done by other trade placed on the top five positions. This indicates that these two factors contribute significantly in the generation of concrete waste.

Rework may be a result of their inefficiency, inexperience, or inadequate supervision. The other basic cause of this result is damage to work done by other trades which results from poor planning that work already fixed may be damaged by others.

During my site visit I have also witnessed some of these factors in the sites. Figure 4.3 below shows bulg beam due to poor workmanship during casting of concrete and in fixing formwork these results in a surplus of concrete that is not useful.



Figure 4.3 Budg beam

In most of the sites deviations in the dimensions of cast-in-place structural elements are noticeable cause of concrete waste. Figure 4.4 also shows budg shear wall in one of the sites of 40/60 condominium construction projects.



Figure 4.4 Budg shear wall

Besides, during my site visit, some waste of concrete was also observed during transportation operations on site. Mostly related to the use of inadequate equipment and overloading of the transporting equipment's.



Figure 4.5 Result of improper way of transporting concrete

Figure 4.5 shows the result of improper way of transporting concrete which is made during transporting concrete from the mixer to the place of casting. This was due to overloading of the transport equipment and using inappropriate equipment.

4.4.2 Causes of Mortar Wastage

Since comparison of the ranks of all the causes of mortar waste showed no significant differences between the responses of the contractors and the consultants at 5% significance level, responses of the two groups of respondents pooled together and presented below.

a. Major categories of waste

The relative mean and rank of response of respondents for each of the categories which causes mortar waste are presented in Table 4.10 below.

Table 4.10 Relative weight and ranking of waste cause categories for mortar

Category	Contractor		Consultant		Total	
	RW	Rank	RW	Rank	RW	Rank
Design and Documentation	3.13	5	3.23	4	3.18	4
Procurement	2.92	6	3.15	5	3.03	6
Handling and storage	3.55	2	3.74	2	3.65	3
Operation	3.47	3	3.94	1	3.71	2
Site management	3.76	1	3.71	3	3.73	1
Site supervision	3.25	4	3.09	6	3.17	5
Others	2.21	7	2.18	7	2.19	7

The survey data on causes of mortar revealed that the site management category is the major causes of mortar waste with relative mean of 3.73, while the lowest mean 3.03 is in a procurement group with a ranking of sixth position.

b. Level of contribution of the waste causes for the generation of waste

16 out of 25 (64 %) of the pre-selected causes turned out to be waste attributes for mortar in these sites when statically analysis done on the response of the contractors and consultants. The mean and rank of each cause of mortar waste is presented in Table 4.11 in a descending order of total result.

Table 4.11 Relative weight and ranking of mortar waste causes

Cause	Source	Contractor		Consultant		Total	
		RW	Rank	RW	Rank	RW	Rank
Double handling of materials	Handling and Storage	4.34	1	4.28	3	4.31	1
Rework (chiseling, complete removal and rework...etc.)	Operation	4.29	2	3.96	5	4.12	2
Poor workmanship	Operation	3.55	9	4.48	2	4.02	3
Damage to work done by other trade (like electrical & sanitary installation)	Operation	4.09	3	3.92	6	4	4
Using excessive quantity of materials than required	Operation	3.3	14	4.68	1	3.99	5
Poor qualification of subcontractor's	Site management	4.07	4	3.88	7	3.98	6
Overloading of transport equipment (beyond its capacity)	Handling and Storage	3.68	8	4.04	4	3.86	7
Design changes and revision	Design	3.77	7	3.84	8	3.8	8
Scarcity of Equipment	Site management	3.84	5	3.6	13	3.72	9
Poor coordination and communication between the consultant engineer, contractor and client	Site Supervision	3.82	6	3.52	14	3.67	10
Ambiguities, mistakes, and inconsistencies in drawings and specification	Design	3.52	10	3.8	9	3.66	11
Improper handling of materials	Handling and Storage	3.43	11	3.76	10	3.59	12
Mistakes in quantity surveys	Procurement	3.36	13	3.68	11	3.52	13
Untidy construction site	Site management	3.38	12	3.64	12	3.51	14
Poor qualification of consultant engineer's staff assigned on the site	Site Supervision	3.16	15	3.32	16	3.24	15
Poor quality of materials	Procurement	2.73	20	3.48	15	3.11	16

It indicates that the highest five causes are double handling of materials, rework, poor workmanship, damage to work done by other trade and using an excessive quantity of material than required with relative mean of 4.31, 4.12, 4.02, 4.00 and 3.99 respectively. It has been noticed that untidy construction site, poor qualification of consultant engineers staff assigned at the site and poor quality of material are the lowest three factors that cause mortar waste with relative mean of 3.51, 3.24 and 3.11.

Double handling of materials was ranked in the first position. Multiple handling of the same batch of mortar mostly related to site layout problems that is the lack of properly planned pathways.

As the results in Table 4.11 showed poor workmanship was ranked in the third position. Poor workmanship may result from lack of trades' skills which lead to waste. For example, in mortar wastage it results from deviations in the given thickness. In addition, damage to work done by other trades was ranked in the fourth position. This problem results from inadequate planning and supervision. Ekanayake and Ofori (2000) revealed that damage to work done caused by subsequent trades was considered the main cause of waste in the operating group. The same was revealed by Bossink and Brouwers (1996).

The results in Table 4.11 additionally showed that using excessive quantities of materials than required is in the fifth position. This problem might result from inadequate supervision and insufficient information about the quantities of material on the part of the contractor. In addition, this might also happen due to the need of excessive thickness of plaster to cover the problem of the deviations in the dimensions of structural elements.

During site visits some of these results have also been noticed. Plastering waste was primarily due to the method of application. In all of the sites plastering work undergone by the traditional method which leads to lost during applying. Therefore, mixing of excessive quantities of materials in order to compensate the leftover mixed plaster is needed.



Figure 4.6 Mortar lost during application

As Figure 4.6 above shows these remainder quantities of mortar are left as waste when the crew moves to the next work.

Another source of mortar waste observed on the site is using mortar in different ways to cover construction defects in the buildings. This could be damage to work done by electrical or sanitary installation, after fixing doors and windows and any other defects.



Figure 4.7 Plastering work for covering defect after fixing window frame

Such kind of wastes results from rework and improper planning during construction, i.e. redoing due to poor performance.

The other cause of waste for mortar observed during site observation is the double handling of the mixed mortar because of mixing in unsuitable place and inadequate planning. Besides, due to an inappropriate way of transportation it spills during its transport around the building sites.



Figure 4.8 Inappropriate ways of transporting mortar

4.4.3 Causes of Reinforcement Bar Wastage

The results of the responses of the respondents on the causes of reinforcement bar are statically analyzed and summarized in the Table 4.12 and 4.13. Since there is no difference in the response of two groups of respondents on the causes of reinforcement bar wastage as shown by the result of Spearman's rank correlation coefficient test, all the data's presented here are collectively.

a. Major categories of waste

The study revealed that the major waste categories for reinforcement bar are mostly from the design, site management and procurement categories. Table 4.12 indicates the aggregate percentages of the relative mean and ranks of reinforcement bar waste categories.

Table 4.12 Relative weight and ranking of waste cause categories for reinforcement bar

Category	Contractor		Consultant		Total	
	RW	Rank	RW	Rank	RW	Rank
Design and Documentation	4.11	1	4.20	1	4.15	1
Procurement	3.18	3	3.27	3	3.23	3
Handling and storage	2.73	6	2.75	5	2.74	6
Operation	2.69	7	2.73	7	2.71	7
Site management	3.17	4	3.35	2	3.26	2
Site supervision	3.33	2	2.82	4	3.08	4
Others	2.79	5	2.74	6	2.77	5

As the table illustrates, there is high gap between the relative scores of design category and site management category which are the first and second waste causing category in reinforcement bar. This indicates that the basic cause of waste for reinforcement bar is design category. Therefore, to reduce waste in reinforcement working first at the design stage is best for 40/60 condominiums housing construction projects.

b. Level of contribution of the waste causes for the generation of waste

The analysis of reinforcement bar waste causes shown that, 48% of the pre-selected causes turned out to be waste causes for reinforcement bar. The mean and rank of each factor of the steel reinforcement waste is presented in Table 4.13 in a descending order of the total result.

As observed from the Table 4.13 lack of attention paid to dimensional coordination of products, design changes and revisions and ambiguities, mistakes, and inconsistencies in drawings and specification which are the first three significant waste causes are all from the design category.

Table 4.13 Relative weight and ranking of reinforcement bar waste causes

Cause	Source	Contractor		Consultant		Total	
		RW	Rank	RW	Rank	RW	Rank
Lack of attention paid to dimensional coordination of products	Design	4.23	1	4.16	3	4.2	1
Design changes and revision	Design	3.98	4	4.4	1	4.19	2
Ambiguities, mistakes, and inconsistencies in drawings and specification	Design	4.11	2	4.04	5	4.07	3
Mistakes on quantity surveys	Procurement	3.7	6	4.08	4	3.89	4
Poorly schedule to procurement	Procurement	3.46	9	4.2	2	3.83	5

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Untidy construction site	Site management	3.57	8	3.96	6	3.77	6
Poor workmanship	Operation	2.91	14	3.84	7	3.38	7
Slow response from the consultant engineer to contractor inquiries	Site Supervision	4	3	2.72	17	3.36	8
Improper storage of materials on site	Handling and Storage	2.93	13	3.68	8	3.3	9
Poor coordination and communication between the consulting engineer, contractor and client	Site Supervision	3.59	7	2.84	12	3.21	10
Poor qualification of subcontractor's	Site management	3.13	10	3.2	9	3.16	11
Improper handling of materials	Handling and Storage	3.71	5	2.52	20	3.12	12

The respondents consider that conversion waste from cutting uneconomical shapes in reinforcement bars as the most significant contributor to this material waste. This problem results from insufficient consideration made during the design stage for optimized cutting of bars. Ekanayake and Ofori (2000) mentioned in their study, lack of attention paid to modular coordination of products was the most significant contributors to site waste.

Design changes ranked in the second position with relative mean value 4.19. These problems arise because of the last minutes client requirement or due to unavailability of one size of bars in the market and the need for substitution with another type during the construction activities.

The results in Table 4.13 showed that mistakes in quantity surveys ranked in the fourth position for reinforcement bar wastage. This might be because of the structural design was poor in terms of detailing or inefficiency of quantity surveyor.

In most of the sites it was common to look short unusable pieces of reinforcement bars which are produced during cutting and bending of the bars. This indicates the structural design was poor in terms of standardization causing waste due to non-optimized cutting of bars.



Figure 4.9 Unusable pieces of reinforcement bars

Besides on most of the sites I have also observed poorly stored reinforcement bars which results in large disorganized stocks.



Figure 4.10 Large disorganized stocks of reinforcement bar

Due to the wrong storage in reinforcement bars, large disorganized stocks formulated which often leads to substitution of these materials by another.

4.4.4 Causes of Hollow Concrete Block Wastage

When the responses of the contractors and consultants compared on the causes of hollow concrete block waste, the results showed no significant difference at the 5% significance level. Hence, all the data were pooled together.

a. Major categories of waste

Table 4.14 below illustrates the major waste cause category for HCB in 40/60 condominium building construction projects, based on the responses of construction supervisors and contractors.

Table 4.14 Relative weight and ranking of waste categories for hollow concrete block

Source	Contractor		Consultant		Total	
	RW	Rank	RW	Rank	RW	Rank
Design and Documentation	3.89	2	3.64	3	3.76	2
Procurement	3.71	3	3.60	4	3.66	3
Handling and storage	4.09	1	4.40	1	4.24	1
Operation	3.49	4	3.49	5	3.49	5
Site management	3.45	5	3.64	2	3.55	4
Site supervision	3.18	6	2.97	6	3.08	6
Others	2.37	7	2.34	7	2.37	7

The result showed that handling and storage category were ranked in the first position with relative mean value of 4.24 followed by design category by relative mean value of 3.76. Procurement category ranked in third position with a mean value of 3.66 while site management, operation and site supervision main waste category of wastes were ranked fourth, fifth and sixth position with a mean value of 3.55, 3.49 and 3.08 respectively.

Handling and storage exhibit a more significant effect on an HCB waste generation among the major categories because of the effect of inappropriate storage on the site. Besides, it is also due to improper handling and double handling of the blocks on the sites.

b. Level of contribution of the waste causes for the generation of waste

The relative mean values of the causes for hollow concrete block wastage in the sites are presented in Table 4.15 with the corresponding ranks in a descending order of the total result. From the analysis, 60% of the pre-selected causes turned out to be waste causes for hollow concrete blocks.

Five main reasons pointed out from the result of hollow concrete block waste are poor quality of materials, improper storage of materials on site, improper handling of materials, lack of attention paid to dimensional coordination of products and poor workmanship with relative mean values of 4.62, 4.53, 4.40, 4.31 and 4.28 respectively. Bossink and Brouwers (1996), in their study revealed that choice of low quality products are the main cause of construction waste.

Table 4.15 Relative weight and ranking of hollow concrete block waste causes

Cause	Source	Contractor		Consultant		Total	
		RW	Rank	RW	Rank	RW	Rank
Poor quality of materials	Procurement	4.61	1	4.64	2	4.62	1
Improper storage of materials on site	Handling and Storage	4.34	3	4.72	1	4.53	2
Improper handling of materials	Handling and Storage	4.20	5	4.6	3	4.40	3
Lack of attention paid to dimensional coordination of products	Design	4.38	2	4.24	7	4.31	4
Poor workmanship	Operation	4.07	10	4.48	4	4.28	5
Damage to work done by other trade (like electrical & sanitary installation)	Operation	4.09	9	4.36	6	4.22	6
Double handling of materials	Handling and Storage	4.18	6	4.08	9	4.13	7
Poorly schedule to procurement	Procurement	4.16	7	4.04	10	4.10	8
Design changes and revision	Design	4.21	4	3.96	11	4.09	9
Poor qualification of subcontractor's	Site management	3.57	14	4.44	5	4.01	10
Rework (chiseling, complete removal and rework...etc.)	Operation	4.14	8	3.84	12	3.99	11
Overloading of transport equipment (beyond its capacity)	Handling and Storage	3.64	13	4.2	8	3.92	12
Poor coordination and communication between the consulting engineer, contractor and client	Site Supervision	3.91	11	3.68	14	3.80	13
Untidy construction site	Site management	3.73	12	3.84	12	3.79	14
Slow response from the consultant engineer to contractor inquiries	Site Supervision	3.38	15	2.84	17	3.11	15

Inappropriate storage of HCB in which the material put in unsuitable place on site leads to damage. Such waste was mostly related to site layout problem and the carelessness of the workers.

The results in Table 4.15 showed that improper handling of materials was ranked in the third position. Such waste was mostly related to inadequate equipment for transportation. Besides,

Lack of attention paid to dimensional coordination of products cause is mainly due to design problem in considerations of the dimensions of the standard HCB sizes. Therefore, certain type of masonry bonds, especially in doors and windows create much waste at the building sites, since they require blocks to be cut.

The site visit also confirms the above results in Table 4.15. During the time of the site visit, fairly in most of the site blocks were stored in improper way which leads to breakage and damage. Figure 4.11 shows some of the ways in which blocks are wrongly stored on site.



Figure 4.11 Improper storage of HCB

As Figure 4.11 shows the blocks are not placed in a level space and over stacked. This kind of over-stacking in the storage area could lead to breakages. Besides, since it is not put on a level ground tends to tilt and push the other blocks to fall down.

The other cause of HCB waste observed on the sites is wrong methods of handling. Figure 4.12 show typical way of handling HCB in most of the sites. This material is brittle and must be

handled with due care. However, this kind of manual handling leads to cracking of the blocks and finally it breaks downs.



Figure 4.12 Improper handling of HCB

Besides, as in the case of mortar, multiple handling of the same HCB, due to intermediate stocks along the process flow was observed at many sites. Insufficient planning of the site layout and lack of sufficient storage on the site is the principal reasons for wastage of HCB due to multiple handling.

Figure 4.13 shows HCB stored outside of the site due to lack of sufficient area inside the site. Then these HCB will be transported to the site when some area is found to place it. Finally, it will also move to its actual needed location. Therefore, these HCB moves at list three times.



Figure 4.13 HCB stored outside the site

Besides, in almost all of the sites it is common to look significant quantity of damaged concrete block left on site. This might be because of the quality problem. However, some of these damaged blocks were of large sizes that could have been suitable for reuse. Figure 4.14 below shows lots of damaged hollow concrete blocks dumped as a backfill.



Figure 4.14 Damaged HCB

These materials are forgotten and taken as a backfill. A solution would be to gather the materials when the job is moving on or else to set up a central storage area for the materials which were cut off and remained unused and consequently ended up as waste. Finally reusing and recycling of these materials in order to reduce the material wastage and consequently the financial loss.

4.5 Level of Contribution and Level of Practice of Waste Minimization Measures

In this part the result of the questionnaire survey on the views of contractors and consultants on waste minimization measures presented. The results of the survey provide evidence on the level of contribution and the level of practice of sixteen waste minimization measures in the 40/60 condominium construction sites. Like that of the causes of wastage, in this part also respondents' response tested for correlation using Spearman rank correlation coefficients to see if there is difference in ranking between the consultants and contractors.

Table 4.16 Spearman's rank correlation coefficient for the level of contribution of waste minimization measures

Material	$Rho (r_{cal}) = 1 - \frac{(6(\sum d_i^2))}{(N(N^2-1))}$	A Critical value of r (Appendix B)
Concrete	0.79	0.506
Mortar	0.89	0.506
Reinforcement bar	0.74	0.506
Hollow concrete block	0.89	0.506

Table 4.17 Spearman's rank correlation coefficients for level of practice of waste minimization measures

Material	$Rho (r_{cal}) = 1 - \frac{(6(\sum d_i^2))}{(N(N^2-1))}$	A Critical value of r (Appendix B)
Concrete	0.68	0.506
Mortar	0.71	0.506
Reinforcement bar	0.76	0.506
Hollow concrete block	0.67	0.506

The result of correlation tests in Table 4.16 and Table 4.17 shows no significant difference between the ranks of the respondents for all the materials surveyed in both levels of contribution and level of practice of minimization measures. Thus, the responses of both groups of respondents were combined for the descriptive analysis.

The 16 waste minimization measures were further categorized into three levels of contribution and practice to waste reduction: high, medium and low. High level of contribution and practice comprised those measures with relative mean score of 4.0 and above. Medium level of contribution and practice comprised measures with the relative mean value of between 3.0 and 3.99 and low level comprised those below 3.0 relative mean scores.

This is because a relative weight of less than 3 means the respondents does not agree that the measure have a contribution in the waste reduction or practiced in the sites. Further, relative weight above 4 means that higher contribution and frequently practiced.

4.5.1 Concrete

Statically analysis of the minimization measures revealed that 13 out of 16 pre-selected measures have medium to high contribution to reducing concrete wastage on 40/60 condominium construction sites. Table 4.18 shows empirical evidence on the levels of contribution of the various measures to concrete waste minimization.

Table 4.18 Level of contribution of measures for concrete waste minimization

Level of contribution	Method	Contractor		Consultant		Overall	
		RW	Rank	RW	Rank	RW	Rank
High	Correct material planning and ordering	4.21	3	4.52	1	4.37	1
	Careful handling and usage of tools and equipment on site	4.48	1	4.16	7	4.32	2
	Using low waste building technologies like ready mix and machine spray plastering	4.23	2	4.40	3	4.32	3
	Design for off-site construction	4.09	5	4.48	2	4.28	4
	Minimizing design changes	4.16	4	4.24	5	4.20	5
	Proper storage and handling of materials	3.93	8	4.28	4	4.10	6
	Improving the skill of the work force by giving training	3.91	9	4.20	6	4.06	7
	Developing waste management plan and hiring site waste manager	4.05	6	4.00	8	4.03	8

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Medium	Use of waste aware sub-contractor and right equipment	3.95	7	3.76	11	3.85	9
	Improving the coordination between contractor and consultant Engineer	3.84	11	3.80	10	3.82	10
	Use of quality materials	3.86	10	3.64	13	3.75	11
	Proper detailing during preparation of drawings and specification	3.80	12	3.68	12	3.74	12
	Just in time, material delivery	3.07	14	3.84	9	3.46	13
Low	Standardization of Design	2.61	16	2.80	14	2.70	14
	Recycling of some waste materials	2.68	15	2.72	15	2.70	15
	Reuse of waste materials on site	3.18	13	2.08	16	2.63	16

Eight measures were categorized as high level contributors to waste reduction, with relative mean values of more than 4.0. Whereas the response of respondents on the level of practice of waste minimization measures for reducing concrete wastage revealed that 8 out of the same 16 measures turned out to be practiced at medium level on the sites.

Table 4.19 Level of practice of waste minimization measures for concrete

Level of practice	Method	Contractor		Consultant		Overall	
		RW	Rank	RW	Rank	RW	Rank
Medium	Use of quality materials	3.73	1	3.6	2	3.67	1
	Proper detailing during preparation of drawings and specification	2.89	7	3.96	1	3.43	2
	Design for off-site construction	3.09	6	3.28	3	3.18	3
	Careful handling and usage of tools and equipment on site	3.52	2	2.76	8	3.14	4
	Improving the coordination between contractor and consultant Engineer	2.86	8	3.24	4	3.05	5
	Just in time, material delivery	3.21	5	2.8	7	3.01	6
	Correct material planning and ordering	3.25	4	2.76	8	3.01	7
	Proper storage and handling of materials	3.29	3	2.72	10	3.00	8

Low	Minimizing design changes	2.54	9	3.04	5	2.79	9
	Standardization of Design	2.20	11	2.88	6	2.54	10
	Use of waste aware sub-contractor and right equipment	2.48	10	2.4	11	2.44	11
	Using low waste building technologies like ready mix and machine spray plastering	1.84	13	2.24	12	2.04	12
	Developing a waste management plan and hiring site waste manager	1.91	12	2.12	14	2.02	13
	Reuse of waste materials on site	1.79	14	2.16	13	1.97	14
	Improving the skill of the workforce by giving training	1.77	15	1.8	16	1.78	15
	Recycling of some waste materials	1.45	16	2	15	1.72	16

Even though none of the high contributing measures practiced highly on the sites, correct material planning and ordering, careful handling and usage of tools and equipment on site, design for off-site construction and proper storage and handling of materials measures practiced on medium level.

The results further show that from the highest contributing factors using low waste building technologies, improving the skill of the workforce by giving training, minimizing design changes and developing waste management plans and hiring site waste manager practiced at a lower level on the sites according to the survey result. Not only these measures, but also use of waste aware sub-contractor and right equipment not practiced from the medium contributing measures.

4.5.2 Mortar

As Table 4.20 below shows apart from proper detailing during preparation of drawings and specification, standardization of design, recycling of some waste materials and re-use of waste materials on site all the other measures evaluated by the contractors and consultants have either medium or high level of contribution to minimize mortar waste in 40/60 condominium construction sites.

Table 4.20 Level of contribution of measures for mortar waste minimization

Level of contribution	Method	Contractor		Consultant		Overall	
		RW	Rank	RW	Rank	RW	Rank
High	Using low waste building technologies like ready mix and machine spray plastering	3.88	3	4.6	1	4.24	1
	Use of waste aware sub-contractor and right equipment	4.23	1	4.08	4	4.16	2
	Correct material planning and ordering	3.82	4	4.32	2	4.07	3
	Careful handling and usage of tools and equipment on site	3.91	2	4.16	3	4.04	4
Medium	Improving the skill of the work force by giving training	3.63	8	4.04	5	3.83	5
	Design for offsite construction	3.64	7	4	6	3.82	6
	Developing waste management plan and hiring site waste manager	3.77	6	3.76	7	3.76	7
	Proper storage and handling of materials	3.8	5	3.6	9	3.7	8
	Just in time material delivery	3.13	12	3.64	8	3.38	9
	Use of quality materials	3.18	10	3.52	10	3.35	10
	Minimizing design changes	3.39	9	3.08	12	3.24	11
	Improving the coordination between contractor and consultant Engineer	3.18	10	3.24	11	3.21	12
Low	Proper detailing during preparation of drawings and specification	2.86	13	2.88	13	2.87	13
	Standardization of Design	2.82	14	2.8	15	2.81	14
	Recycling of some waste materials	2.61	15	2.88	13	2.74	15
	Re-use of waste materials on site	2.23	16	2.6	16	2.42	16

However, from the 16 waste minimization measures only seven of them turned out to be practiced at medium level on the surveyed sites in which six of them have medium to high level of contribution. The level of practices of waste minimization measures for mortar in the 40/60 condominium sites according to the response of the contractors and consultants is shown in Table 4.21.

Table 4.21 Level of practice of waste minimization measures for mortar

Level of practice	Method	Contractor		Consultant		Overall	
		RW	Rank	RW	Rank	RW	Rank
Medium	Use of quality materials	3.63	1	3.6	1	3.61	1
	Proper detailing during preparation of drawings and specification	2.80	8	3.52	2	3.16	2
	Improving the coordination between contractor and consultant Engineer	3.11	6	3.16	3	3.13	3
	Proper storage and handling of materials	3.32	2	2.88	6	3.10	4
	Careful handling and usage of tools and equipment on site	3.29	4	2.76	7	3.02	5
	Correct material planning and ordering	3.30	3	2.72	9	3.01	6
	Just in time material delivery	3.25	5	2.72	9	2.99	7
Low	Design for offsite construction	2.89	7	3.04	4	2.97	8
	Standardization of Design	2.61	10	2.76	7	2.68	9
	Minimizing design changes	2.63	9	2.68	11	2.65	10
	Re-use of waste materials on site	2.02	12	3	5	2.51	11
	Use of waste aware sub-contractor and right equipment	2.48	11	2.44	12	2.46	12
	Developing waste management plan and hiring site waste manager	2.00	13	2	14	2.00	13
	Using low waste building technologies like ready mix and machine spray plastering	1.82	15	2.04	13	1.93	14
	Improving the skill of the work force by giving training	1.84	14	1.96	15	1.90	15
	Recycling of some waste materials	1.77	16	1.88	16	1.82	16

The above two tables demonstrate that from those with high level of contribution to mortar waste minimization only careful handling and usage of tools and equipment on site and correct material planning and ordering practiced in the sites at medium level. The rest highly contributing measures for minimizing mortar waste in the sites i.e. use of waste aware sub-contractor and right equipment and using low waste building technologies have low level of practice on the sites.

The respondents also indicated that from the medium contributing factors design for off-site construction, minimizing design changes, developing waste management plans and hiring site waste manager and improving the skill of the workforce by giving training have a low level of practice on the sites.

4.5.3 Reinforcement Bar

All the minimization measures have a contribution for reducing reinforcement bar wastage based on the statically analysis of the response of contractors and consultants. For each of the minimization measures the level of contribution illustrated in the Table 4.22 and Table 4.23 below.

Table 4.22 Level of contribution of measures for reinforcement bar waste minimization

Level of contribution	Method	Contractor		Consultant		Overall	
		RW	Rank	RW	Rank	RW	Rank
High	Standardization of Design	4.21	3	4.76	1	4.49	1
	Minimizing design changes	4.30	2	4.52	2	4.41	2
	Proper detailing during preparation of drawings and specification	4.43	1	4.36	3	4.39	3
	Proper storage and handling of materials	3.82	9	4.20	4	4.01	4
Medium	Correct material planning and ordering	4.18	4	3.76	11	3.97	5
	Just in time, material delivery	4.05	5	3.84	9	3.95	6
	Improving the coordination between contractor and consultant Engineer	3.96	6	3.92	7	3.94	7
	Developing a waste management plan and hiring site waste manager	3.71	12	4.08	5	3.90	8
	Use of waste aware sub-contractor and right equipment	3.79	10	4.00	6	3.89	9
	Reuse of waste materials on site	3.86	8	3.88	8	3.87	10
	Recycling of some waste materials	3.91	7	3.80	10	3.86	11
	Design for off-site construction	3.73	11	3.72	12	3.73	12
	Improving the skill of the workforce by giving training	3.61	14	3.68	13	3.64	13
	Use of quality materials	3.66	13	3.60	15	3.63	14
	Using low waste building technologies like ready mix and machine spray plastering	2.79	15	3.64	14	3.21	15
Careful handling and usage of tools and equipment on site	2.64	16	3.44	16	3.04	16	

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The highly contributing measures are observed to be measures that can directly result in minimization of wastage of reinforcement bar. Most of the measures in this category were also categorized as medium contributors to waste minimization.

The analysis of the response of respondents on the level of practice of waste minimization measures for reducing reinforcement bar wastage revealed that 7 out of the 16 pre-selected strategies turned out to be practiced on the sites. The relative mean and rank of level of practice of the various measures for minimizing reinforcement bar wastage based on the response of the contractors and consultants are shown in Table 4.23.

Table 4.23 Level of practice of waste minimization measures for rebar

Level of practice	Method	Contractor		Consultant		Overall	
		RW	Rank	RW	Rank	RW	Rank
Medium	Use of quality materials	3.68	1	3.56	1	3.62	1
	Correct material planning and ordering	3.14	3	3.16	5	3.15	2
	Design for off-site construction	3.04	5	3.24	3	3.14	3
	Proper detailing during preparation of drawings and specification	2.75	9	3.44	2	3.10	4
	Careful handling and usage of tools and equipment on site	3.11	4	3.08	6	3.09	5
	Improving the coordination between contractor and consultant Engineer	2.95	7	3.2	4	3.07	6
	Proper storage and handling of materials	3.30	2	2.8	9	3.05	7
Low	Minimizing design changes	2.77	8	3	7	2.88	8
	Reuse of waste materials on site	2.98	6	2.76	10	2.87	9
	Standardization of Design	2.63	11	2.96	8	2.79	10
	Just in time, material delivery	2.70	10	2.64	12	2.67	11
	Use of waste aware sub-contractor and right equipment	2.41	12	2.72	11	2.57	12
	Recycling of some waste materials	1.77	16	2.24	13	2.00	13
	Developing a waste management plan and hiring site waste manager	1.98	13	2	15	1.99	14
	Using low waste building technologies like ready mix and machine spray plastering	1.84	14	2.04	14	1.94	15
	Improving the skill of the workforce by giving training	1.82	15	1.88	16	1.85	16

The result points that proper detailing during preparation of drawings and specification and proper storage and handling which contribute highly in minimization of reinforcement bar waste practice at medium level on the sites. But the rest two measures which have high contribution for minimization of reinforcement bar waste have a low level of practice on the site.

Further the result also shows most of the measures which have medium level of contribution in reinforcement bar waste minimization i.e. re-use of waste materials on site, just in time material delivery, use of waste aware sub-contractor and right equipment, recycling of some waste materials, developing waste management plan and hiring site waste manager, using low waste building technologies and improving the skill of the workforce by giving training have low level of practice on the sites.

4.5.4 Hollow Concrete Block

Table 4.24 shows the result of the level of contribution of the selected sixteen construction material waste minimization measures for reducing HCB waste. The statically analysis of the minimization measures revealed that 15 out of the 16 pre-selected minimization measures have high and medium level of contribution for reducing HCB wastage on the sites.

Table 4.24 Level of contribution of measures for HCB waste minimization

Level of contribution	Method	Contractor		Consultant		Overall	
		RW	Rank	RW	Rank	RW	Rank
High	Use of quality materials	4.43	1	4.44	1	4.43	1
	Proper storage and handling of materials	4.30	4	4.32	2	4.31	2
	Just in time, material delivery	4.38	3	4.24	3	4.31	3
	Minimizing design changes	4.41	2	4.12	5	4.27	4
	Standardization of Design	4.23	5	4.20	4	4.22	5
	Correct material planning and ordering	4.21	6	4.08	6	4.15	6
	Improving the skill of the workforce by giving training	4.04	7	4.00	7	4.02	7

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Medium	Use of waste aware sub-contractor and right equipment	3.86	9	3.92	9	3.89	8
	Developing a waste management plan and hiring site waste manager	3.93	8	3.80	11	3.86	9
	Careful handling and usage of tools and equipment on site	3.75	12	3.96	8	3.86	10
	Improving the coordination between contractor and consultant Engineer	3.77	11	3.80	11	3.78	11
	Recycling of some waste materials	3.50	13	3.92	9	3.71	12
	Proper detailing during preparation of drawings and specification	3.84	10	3.44	14	3.64	13
	Using low waste building technologies like ready mix and machine spray plastering	3.13	14	3.76	13	3.44	14
	Reuse of waste materials on site	3.13	14	3.40	15	3.26	15
Low	Design for off-site construction	2.59	16	2.92	16	2.75	16

However, the analysis of the response of respondents on the level of practice of the same measures reveals that 6 out of 16 pre-selected measures turned out to be practiced on the sites for reducing HCB wastage at medium level. The details of the result presented in Table 4.25.

Table 4.25 Level of practice of waste minimization measures for HCB

Level of practice	Method	Contractor		Consultant		Overall	
		RW	Rank	RW	Rank	RW	Rank
Medium	Correct material planning and ordering	3.34	1	3.44	2	3.39	1
	Proper detailing during preparation of drawings and specification	2.91	6	3.56	1	3.24	2
	Careful handling and usage of tools and equipment on site	3.14	3	3.16	3	3.15	3
	Use of waste aware sub-contractor and right equipment	3.18	2	2.88	6	3.03	4
	Design for off-site construction	3.04	5	3	5	3.02	5
	Improving the coordination between contractor and consultant Engineer	2.91	6	3.12	4	3.02	6

Low	Proper storage and handling of materials	3.11	4	2.56	11	2.83	7
	Use of quality materials	2.77	9	2.68	9	2.72	8
	Standardization of Design	2.57	11	2.72	7	2.65	9
	Minimizing design changes	2.61	10	2.64	10	2.62	10
	Just in time material delivery	2.54	12	2.44	13	2.49	11
	Reuse of waste materials on site	2.80	8	2.12	14	2.46	12
	Developing a waste management plan and hiring site waste manager	1.96	15	2.72	7	2.34	13
	Improving the skill of the workforce by giving training	1.98	14	2.48	12	2.23	14
	Using low waste building technologies like ready mix and machine spray plastering	2.00	13	2.04	16	2.02	15
	Recycling of some waste materials	1.70	16	2.08	15	1.89	16

All these six waste minimization measures practiced on the site are under a medium level of practice. Further, we can also see that correct material planning and ordering contribution in minimizing wastage was high, but it is practiced at medium level according to the response of contractors and consultants.

In addition, from the low practiced measures, use of quality materials, proper storage and handling of materials, just in time material delivery, minimizing design changes, standardization of design and improving the skill of the workforce by giving training should be practiced at the highest level since this measure has higher contribution in minimizing HCB waste on the sites of 40/60 condominium construction.

In addition to the current medium practiced minimization measures, developing waste management plans and hiring a site waste manager, recycling of some waste materials, using low waste building technologies and re-use of waste materials on site should also be practiced on the site to minimize HCB waste.

Moreover, from the aggregate result of waste minimization measures on the four materials twelve measures selected as having a high contribution in minimizing waste on the site according to the respondents.

From Table 4.26 it can be easily seen that the highest level of practice of these waste minimization measures can significantly reduce the waste of concrete, mortar, reinforcement bar and HCB on 40/60 condominium sites. However, reusing and recycling of waste are not selected as highly waste minimization measure in any of the materials.

Table 4.26 Summary of selected highly significant waste minimization measures

Selected highly significant waste minimization measures	Useful in minimizing
Correct material planning and ordering	Concrete, Mortar and HCB
Careful handling and usage of tools and equipment on site	Concrete and Mortar
Using low waste building technologies like ready mix and machine spray plastering	Concrete and Mortar
Minimizing design changes	Concrete, Reinforcement bar and HCB
Proper storage and handling of materials	Concrete, Reinforcement bar and HCB
Improving the skill of the workforce by giving training	Concrete and HCB
Standardization of Design	Reinforcement bar and HCB
Design for off-site construction	Concrete
Developing a waste management plan and hiring site waste manager	Concrete
Proper detailing during preparation of drawings and specification	Reinforcement bar
Use of quality materials	HCB
Just in time, material delivery	HCB

Further, in order to get an insight on the role of the construction supervision consultants regarding material wastage reduction three additional questions were asked for them in the questionnaire. In the first question, respondents were requested to indicate what strategies were employed to reduce material wastage during design revision period. The second and the third questions assess about their site supervisors assignment on each specific site.

Figure 4.15 shows the percentage of the waste minimization strategies adopted by respondents during design revision. All of the respondents undergo at least correcting detailing problems on the design drawing during a design revision period. However, the result indicated that dimensional coordination and standardization and material selection to reduce waste are not widely practiced as a waste minimization strategy by the consulting firms during design revision period.

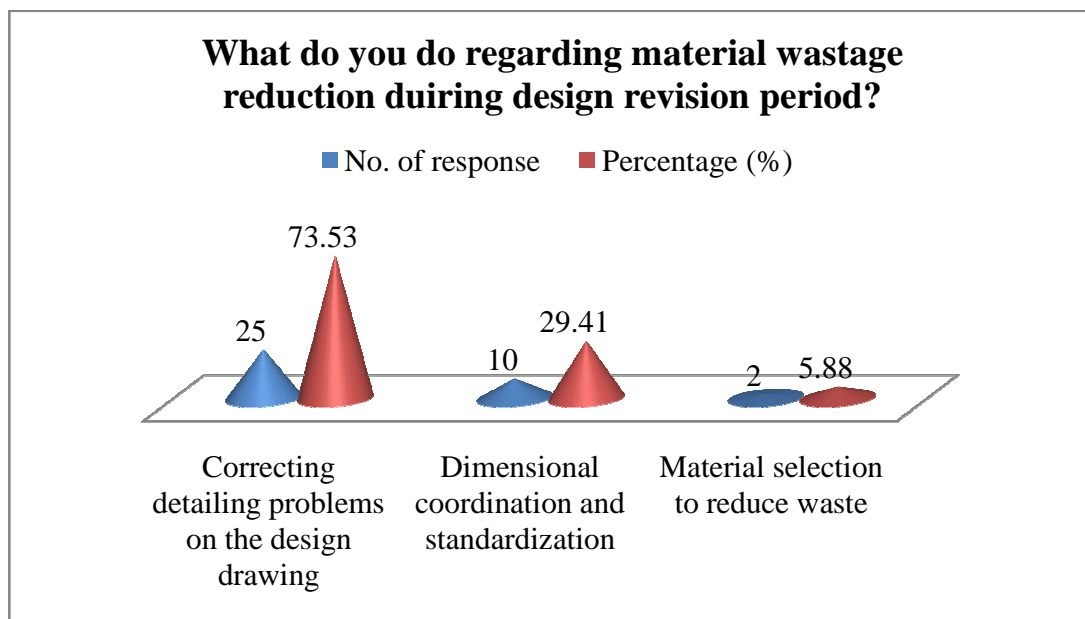


Figure 4.15 Strategies employed during design revision by consultants

The study further assesses the number of site supervisors from the construction supervisor's side in each site. It is interesting to note that none of the respondents indicate that there is one site supervisor for one block rather it is between two to four blocks for one site supervisors. Figure 4.16 below shows the number and percentage of site supervisor's assignment from the total 11 sites surveyed.

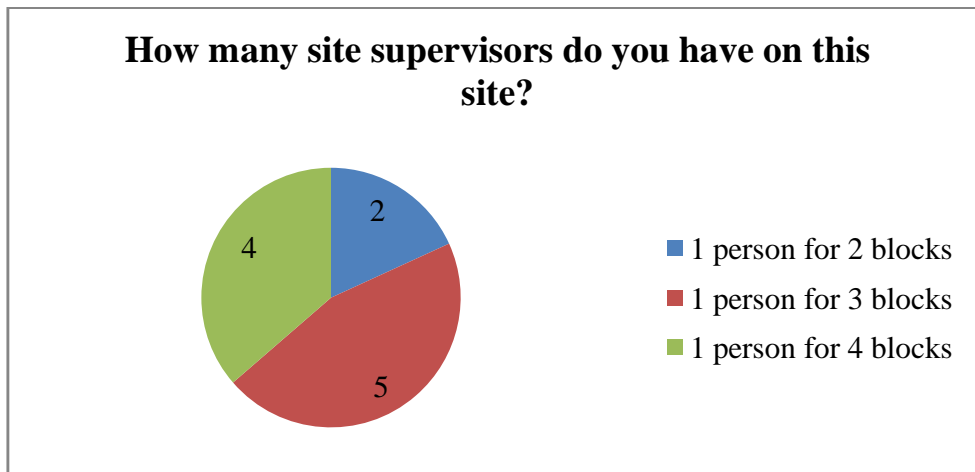


Figure 4.16 Number of site supervisors on the sites

On five (45.45%) of the sites the supervision consultants' respondents indicate that they had 1 person to three blocks assignment of site supervisors. This is closely followed by 1 person to four blocks assignment. This result portrays that almost three fourth of the sites have 1 site supervisor for more than 3 blocks which increases the incidence of materials wastes.

Moreover, the respondents were asked to describe their perception on the assignment of site supervisors in their specific site. Accordingly, the majority of respondents believe that the site supervisor's assignment is enough because the blocks are identical. Table 4.27 below shows the details of this result.

Table 4.27 Perception of consultants on the number of site supervisors

Do you think that this site supervisor's assignment is enough for this project?		
Answer	No.	Percentage (%)
Yes, because assigning more than the above number of site supervisors is not necessary	1.00	4.00
Yes, because the blocks are identical	15.00	60.00
No, but we have lack of site supervisors	9.00	36.00
Total	25.00	100.00

However, this is somewhat wrong perception that even if the blocks are identical, they are constructed by different contractors and with different employees. Therefore, it is important to give emphasis or considerations to different parameters of these building projects in allocating the number of site supervisors in order to monitor and control every activity on the site for reducing the generation of waste materials.

4. 6. Case Study

The aim of this case study is to illustrate the extent of construction material wastage, reuse and recycling practice and its cost effect. Two sites are chosen to show the actual levels of material wastage occurring on sites. The basic information about the projects is tabulated in Table 4.28 below.

Table 4.28 Case study projects basic information

Project detail	Site A	Site B
Type of construction	40/60 condominium housing construction	40/60 condominium housing construction
Typology of the blocks	2B+G+12	B+G+9
No of blocks on the site	5	14
Total cost per block	20,678,244.56	14,847,821.25

In this case study the quantity of waste estimated only for concrete (OPC cement and coarse aggregate), reinforcement bar and hollow concrete block. Estimating the quantity of mortar wastage however, couldn't be possible. This is because the amount of waste generated in these sites found out by calculating the difference between the needed quantity of materials and actual quantities of the materials taken by the contractors during the course of construction of the buildings. However, only these two sites are at the finishing stage and there is no project completed totally till now.

The data's for estimating this waste amount taken from the design drawings and material requesting forms of each of the blocks on the site. Therefore, data's are collected from these documents to get the planned and actual quantity of material used for each block respectively. Finally, the results compared against the 5% material wastage allowance included in the contract document and the reusing and recycling practice on the produced waste materials also assessed at these sites. Besides, its side effect on the project cost also calculated.

4.6.1 Comparison of Theoretical and Actual Percentage of Wastage

In this part the quantities of material waste produced during the construction of these new buildings presented before reuse and recycling. There is a significant difference between the theoretical and actual quantities of cement, coarse aggregate, reinforcement bar and HCB used in the two case study sites. Table 4.29 gives average quantity and percentage of wastage of these materials for the two 40/60 condominium building projects.

Table 4.29 Average quantity and the percentage of waste generated on the case study sites

Material		Unit	Average wastage on each site				
			Site A		Site B		
			Quantity	Percentage	Quantity	Percentage	
Cement (OPC)		Qut	1,915.00	8.90	1,549.77	11.53	
Coarse Aggregate		m ³	550.60	11.59	399.45	14.18	
Hollow Concrete Block	Slab Block	22cm	Pcs	5,598.00	10.07	10,4956.00	20.26
		16cm	Pcs	2,228.00	20.10	1,137.00	14.57
	Wall Block	20cm	Pcs	6,677.00	10.35	9,990	18.31
		10cm	Pcs	11,134.00	12.55	8,732.00	13.81
Reinforcement Bar		φ6	Kg			7,348.57	19.03
		φ8	Kg	317.19	0.64	5,346.11	7.50
		φ10	Kg	11,930.00	7.99	26,539.88	14.72
		φ12	Kg	14,915.38	12.01	24,705.71	11.53
		φ14	Kg	5,125.61	4.00	14,847.62	7.22
		φ16	Kg	5,216.83	3.60	11,561.19	8.82
		φ20	Kg	3,142.93	1.87	1,237.55	0.35
		φ24	Kg	0	0		

The result in Table 4.29 indicates that the largest source of waste in both sites is HCB. Four times larger than the allowable percentage of wastage are noticed for 16cm and 22cm high slab block in site A and B respectively. Whereas, the smallest percentage of wastage noticed in φ24 and φ20 reinforcement bar for site A and site B respectively, which are almost within the allowable limit of wastage.

There is also a variation in waste percentage of the two sites for the same material. For instance, the wastage of 22cm high slab block at site B is almost two times higher than at site A. This may be due to the firm’s experience and technological development among the contractors in the site.

Furthermore, a large variation of wastage was also found at a single site for different building materials. For instance, in site B the wastage of reinforcement bar for $\phi 6$ is 19.03 %, which is more than three times of $\phi 20$ percentages of wastage. This possibly reflects the non-standardized building structures resulting in the much cut off for $\phi 6$ reinforcement bar that generate higher levels of material wastage.

Similarly the waste percentage of 16 cm high slab block is two times of 22 cm high slab block in site A. Generally, this variation in the percentage of wastage from site to site and from material to material indicates the possibility of improvement in this wide range of materials waste.

4.6.2 Reused and Recycled Construction Waste Materials

All the four selected building materials in this study are reusable and recyclable. However, the only material reused and planned to be recycled on the sites is reinforcement bar. On the rest of the three materials, i.e. concrete, mortar and HCB nothing practiced yet regarding reusing and recycling. Table 4.30 shows the amount of reinforcement bar collected from each of the two case study sites up to now. However, they haven’t finished the collection process and there are remaining wasted reinforcement bars on the sites.

Table 4.30 Percentage of reinforcement bar collected for recycling

Site	Unit	Total Reinforcement bar Waste	Collected Reinforcement bar	
			Quantity	Percentage
A	Ton	201.28	106.92	53.12
B	Ton	457.93	117.60	25.68

The availability of the market for recycling reinforcement bar could be a good motive for recycling of this material. Reinforcement bar by far is the most expensive material; due to this it is highly profitable. The reason for not recycling the rest of the materials may be due to unavailability of the technologies, market and lack of experience.

Even if recycling of these materials was not possible there should be at least a proper way of reusing HCB on these sites. However, in none of the sites reusing of this material practiced. This might be due to the negligence of the parties involved in the construction.

4.6.3 Effect on the Total Project Cost

Table 4.31 presents the result of cost incurred due to excessive material usage in the two sites in which the case study undergone.

Table 4.31 Estimated cost of materials waste on the case study sites

No.	Material		Unit	Unit price	Average cost of waste				
					Site A		Site B		
					Excess Quantity	Total Cost	Excess Quantity	Total Cost	
1	Cement (OPC)		Qut	274.61	9,575.00	2,629,390.75	21,696.80	5,958,158.25	
2	Coarse Aggregate		m ³	330.00	2,753.00	908,490.00	5,592.34	1,845,472.20	
3	Hollow Concrete block	Slab	22cm	Pcs	9.80	27,990.00	274,302.00	146,939.00	1,440,002.20
		Block	16cm	Pcs	9.25	11,141.00	103,054.25	15,921.00	147,269.25
		Wall	20cm	Pcs	8.35	33,385.00	278,764.75	139,856.00	1,167,797.60
		Block	10cm	Pcs	4.68	55,671.00	260,540.28	122,247.00	572,115.96
4	Reinforcement bar		φ6	Kg	21.94			36,742.85	806,138.19
			φ8	Kg	21.94	1,585.94	34,795.42	26,730.54	586,468.14
			φ10	Kg	21.94	59,650.01	1,308,721.23	132,699.42	2,911,425.17
			φ12	Kg	21.94	74,576.92	1,636,217.63	123,528.55	2,710,216.34
			φ14	Kg	21.94	25,628.07	562,279.79	74,238.09	1,628,783.65
			φ16	Kg	21.94	26,084.14	572,286.05	57,805.93	1,268,262.15
			φ20	Kg	23.02	15,714.65	361,751.28	6,187.77	142,442.44
			φ24	Kg	23.02	0.00	0.00		
Total					8,930,593.42		21,184,552.42		
Average cost incurs per block (ETB)					1,786,118.68		1,513,182.25		
Cost effect per block (%)					8.64		10.19		

Study on Material Wastage of 40/60 Condominium Construction Sites

The cost of waste incurred, on average in these two sites is 9.4 % of the total cost, ranging from 8.64 % at site A to 10.19 % at site B. This indicates that minimization of material waste in the construction projects would therefore lead to substantial saving on the purchasing cost of building materials, in addition to savings on dumping costs. This cost impact estimated only based on the pure material purchasing cost, it doesn't include storage cost, transportation cost and disposal cost.

However, as discussed above in these two sites the client collected reinforcement bar in order to sell it to a steel factory at a price of 7 ETB/Kg. The cost saving found by selling these amounts of reinforcement bar from the two sites is shown in the table below.

Table 4.32 Cost saving by recycling of reinforcement bar

Site	Unit Rate (ETB/Kg)	Total Cost Incurred (ETB)	Collected Reinforcement bar (Kg)	Cost Benefit from the Collected Rebar (ETB)	Cost Benefit of Collected Rebar from Total Cost Incurred (%)
A	7.00	8,930,593.42	201,280.55	1,408,963.85	15.78
B	7.00	21,184,551.54	457,933.15	3,205,532.05	15.13
Total				4,614,495.90	

Even though all the reinforcement bars wasted on the sites was not collected, by recycling only this material up to 15% of the total cost of the waste materials assessed in this study could be saved.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The general objective of this study is to investigate ways of minimizing materials wastage in the 40/60 condominium construction sites by assessing the causes, its extent and effect on the project cost. Therefore, based on the results obtained, the following major conclusions have been made in accordance with the objectives of this thesis research.

1. The results of the case study demonstrate that the level of materials waste in 40/60 condominium construction projects is fairly high in all of the assessed construction materials. The survey result also reveals that cost effect extent up to 10 % of the project cost. Therefore, if proper waste minimization measures are devised, this amount of costs can be saved potentially, so as to increase the profit for the contractors by this extent.
2. Client material supplying in the construction of 40/60 condominiums has increased the generation of material waste. According to the majority of the respondents, this was happening by delivering of poor quality materials, particularly for the materials provided by the client.
3. The major causes of concrete waste differ for the two groups of respondents. The reason behind the difference in the result of responding by the two groups of respondents may be due to not to be responsible since concrete uses in larger quantity in these construction sites. However, both groups of respondents indicate that rework and damage to the work done by other trade are amongst the top five major causes of concrete wastage in the sites. Likewise, the result obtained indicates that double handling, rework, poor workmanship, damage to work done and using excessive quantities of materials than required are the top five signifying causes of mortar waste in 40/60 condominium construction sites. For reinforcement bar, the study has revealed that waste generated on site is directly related to design process. The top five causes of hollow concrete block wastage found to be poor quality materials, improper storage of materials, improper handling of materials, lack of attention paid to dimensional coordination and poor workmanship respectively.

4. Moreover, this study also provided empirical evidences on the levels of contribution and the levels of practice of waste minimization measures for each of the above four materials in 40/60 condominium construction sites. It has shown that for all of the four materials measures which have a high level of contribution in the minimization of waste are not practiced on the basis of their level of significance on the sites.
5. From the result of the questionnaire survey, it is unveiled that the allocation of site supervisors to the respective projects is not well considered to see the adequacy. Besides, it shows poor performance of the construction supervisors in standardization and modularization of design during a design revision period. This, consequently, results generation of a lot of waste, especially in reinforcement bar and hollow concrete blocks.

5.2 Recommendation

Based on the findings of this study, the following recommendations are forwarded in order to minimize material wastage at 40/60 condominium construction sites.

1. To minimize wastage happened due to design problem in 40/60 condominium construction sites, practicing highly off-site construction by adopting different technologies like prefabrication and precast units, proper detailing during designing, coordinating dimensions between materials and the design, and planning ahead to minimize design changes are sensible mechanisms.
2. Make sure the quality of materials delivered on the site is as stated in the specification and construction supervisors and contractors on the site shall start refusing to accept substandard material.
3. Material ordering practice needs to be improved in order to reduce waste comes from excessive quantity of material used that could be addressed by introducing just in time material delivery system, especially for hollow concrete block.

4. Storage facility on the sites needs to be improved by planning the details of material delivery and their storage space on site. Besides, all workers shall practice careful handling and usage of tools in all courses of the construction process.
5. Contractors need to develop waste management plans and to hire site waste manger to address material wastage problem and to enjoy the likely benefit. In addition, they shall start providing short term and long term trainings and workshops for the workers.
6. Devise good site controlling strategy to ensure adequate material planning and ordering, on-site material handling and storage which are helpful for controlling excessive material wastage. In order to facilitate this, supervisors should also give emphasis to different parameters of these building projects in allocating the site supervisors so as to make easy the site controlling and supervision work.

This study with its limitation has investigated material wastage in 40/60 condominium building projects in Addis Ababa. Nevertheless, the following issues are identified and suggested for future studies.

- ❖ Development of an empirical model for predicting waste quantities in the condominium construction sites.
- ❖ Assessing the quality of hollow concrete blocks delivered to condominium sites by using laboratory tests.
- ❖ Study on feasibility of reusing and recycling as minimizing measures of construction materials waste in condominium construction projects.
- ❖ Further investigation on material wastage of other types of buildings like commercial, industrial and school building projects.

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APPENDIX

Appendix A Questionnaire for the Consultants

QUESTIONNAIRE
FOR 40/60 CONDOMINIUM CONSTRUCTION PROJECT
CONSTRUCTION SUPERVISION CONSULTANTS

Study on Material Wastage Reduction Practice in Addis Ababa
Condominium Housing Construction Sites: Case Study of 40/60
Condominiums

Dear respondent, the aim of this questionnaire is to obtain necessary data for the partial fulfillment of an MSc thesis in Construction Technology and Management at Addis Ababa University. The objective of this thesis is to study material wastage reduction practice on 40/60 Condominium housing construction sites. Therefore, you are kindly requested to contribute to this research work by completing this questionnaire. The identity of the respondent and that of the company you represent shall remain confidential and all data's found from the survey will only be used for an academic purpose. I would like to extend my gratitude for taking your precious time to respond to this questionnaire. If you have any inquiry please contact through the following addresses.

Eskedar Girma

Post Graduate Student at A.A University, School of Civil and Environmental Engineering,
Construction technology and management stream.

Email: eskedarcivil@gmail.com

Part One: General Information

1. Classification of your organization _____

2. Your position on this site

Project Coordinator

Resident Engineer

Site Supervisor

If other, please specify _____

3. Educational Background

Graduate (MSC)

Undergraduate (BSC)

Diploma

If other, please specify _____

4. Years of experience in the construction industry

< 1 year

1 - 3 years

3 - 5 years

5 - 10 years

10 – 15 years

15 - 20 years

> 20 years

5. Years of experience in the condominium construction site

<1 year

1-3 years

3 – 5 years

5-8 years

8-10 years

>10 years

Part Two: Perception on the Effect of Client Material Supplying

6. Does the client material supplying on this construction project increase the amount of material wastage?

Yes

No

7. If your answer for question number 6 is yes, how does it increase the amount of wastage?

(You can choose more than one answer)

Since there is no proper control on material wastage, it leads to negligence

Because the client don't delivery good quality material

Because the client supplies material in unplanned way

Please specify if there are any other possible reasons of increasing the amount of material wastage due to client material supplying in your 40/60 condominium construction site.

Part Three: Causes of Material Waste

Below are possible causes of building construction material waste. Rank on a scale of 1-5 which of these waste causes contributes highly to the generation of waste on site.

No.	Effects' degree in the generation of waste
1	Not a waste cause
2	Insignificant waste cause
3	Quite a waste cause
4	Significant waste cause
5	Major waste cause

Source	Cause	Concrete					Mortar					Reinforcement bar					Hollow concrete block				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Design and documentation	Lack of attention paid to dimensional coordination of products																				
	Design changes and revision																				
	Ambiguities, mistakes, and inconsistencies in drawings and specification																				
Procurement	Poor quality of materials																				
	Poorly schedule to procurement																				
	Mistakes in quantity surveys																				
	Purchased materials that do not comply with specification																				
Handling and Storage	Improper handling of materials																				
	Double handling																				
	Overloading of transport equipment (beyond its capacity)																				
	Improper storage of materials on site																				

Study on Material Wastage of 40/60 Condominium Construction Sites

Source	Cause	Concrete					Mortar					Reinforcement bar					Hollow concrete block				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Operation	Rework (chiseling, complete removal and rework...etc.)																				
	Using excessive quantity of materials than required																				
	Using incorrect type of material																				
	Damage to work done by other trade (like electrical & sanitary installation)																				
	Poor workmanship																				
Site management	Poor qualification of subcontractor's																				
	Scarcity of Equipment																				
	Untidy construction site																				
Site Supervision	Poor qualification of consultant engineer's staff assigned on the site																				
	Delay in performing inspection and testing by the consultant Engineer																				
	Poor coordination and communication between the consultant engineer, contractor and client																				
	Slow response from the consultant engineer to contractor inquiries																				
Others	Weather condition																				
	Theft																				

Please specify if there are any other possible causes of material waste in your 40/60 condominium construction site.

Part Four: Waste Minimization Measures

4.1 Below are possible strategies that contribute to the minimization of material wastes in building construction projects. Rank on a scale of 1-5 first the level of contribution of these strategies for minimization of material wastage in 40/60 condominium construction sites. Secondly, rank the level of practice of these strategies on your site.

Level of contribution	
1	Very low contribution
2	Low contribution
3	Medium contribution
4	High contribution
5	Very high contribution

Level of practice	
1	Not practical
2	Not practiced
3	Practiced
4	Frequently practiced
5	Most frequently practiced

Study on Material Wastage of 40/60 Condominium Construction Sites

Please specify if there are other waste minimization strategies that could have significant contribution in material waste reduction in 40/60 condominium construction projects.

Please specify if any other waste minimization strategy practiced in your site

4.2 What do you do regarding material wastage reduction during design revision period? (you can choose more than one answer)

- Correcting detailing problems on the design drawing
- Material selection to reduce waste
- Dimensional coordination and standardization

If other please specify

4.3 How many site supervisors do you have on this site?

- 1 person for 1 block 1 person for 2 blocks 1 person for 3 blocks
- 1 person for 4 blocks 1 person for more than 5 blocks

4.4 Do you think that this site supervisor's assignment is enough for this project?

Yes, because assigning more than the above number of site supervisors is not necessary

Yes, because the blocks are identical

No, but we have lack of site supervisors

If other please specify

Thank you for your cooperation!

Appendix B Questionnaire for the Contractors

QUESTIONNAIRE
FOR 40/60 CONDOMINIUM CONSTRUCTION PROJECT
CONTRACTORS

Study on Material Wastage Reduction Practice in Addis Ababa
Condominium Housing Construction Sites: Case Study of 40/60
Condominiums

Dear respondent, the aim of this questionnaire is to obtain necessary data for the partial fulfillment of an MSc thesis in Construction Technology and Management at Addis Ababa University. The objective of this thesis is to study material wastage reduction practice on 40/60 condominium housing construction sites. Therefore, you are kindly requested to contribute to this research work by completing this questionnaire. The identity of the respondent and that of the company you represent shall remain confidential and all data's found from the survey will only be used for an academic purpose. I would like to extend my gratitude for taking your precious time to respond to this questionnaire. If you have any inquiry please contact through the following addresses.

Eskedar Girma

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Part One: General Information

1. Classification of your organization _____

2. Your position on this site

Projects manager Assistant Project Manager Site Engineer

If other, please specify _____

3. Educational Background

Graduate (MSC) Undergraduate (BSC)
 Diploma If other, please specify _____

4. Years of experience in the construction industry

< 1 year 1 - 3 years 3 - 5 years 5 - 10 years
 10 - 15 years 15 - 20 years > 20 years

5. Years of experience in the condominium construction site

<1 year 1-3 years 3 - 5 years
 5-8 years 8-10 years >10 years

Part Two: Perception on the Effect of Client Material Supplying

6. Does the client material supplying on this construction project increase the amount of material wastage?

Yes No

7. If your answer for question number 6 is yes, how does it increase the amount of wastage?

(You can choose more than one answer)

- Since there is no proper control on material wastage, it leads to negligence
- Because the client don't delivery good quality material
- Because the client supplies material in unplanned way

Please specify if there are any other possible reasons of increasing the amount of material wastage due to client material supplying in your 40/60 condominium construction site.

Part Three: Causes of Material Waste

Below are possible causes of building construction material waste. Rank on a scale of 1-5 which of these waste causes contributes highly to the generation of waste on site.

No.	Effects' degree in the generation of waste
1	Not a waste cause
2	Insignificant waste cause
3	Quite a waste cause
4	Significant waste cause
5	Major waste cause

Source	Cause	Concrete					Mortar					Reinforcement bar					Hollow concrete block				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Design and documentation	Lack of attention paid to dimensional coordination of products																				
	Design changes and revision																				
	Ambiguities, mistakes, and inconsistencies in drawings and specification																				
Procurement	Poor quality of materials																				
	Poorly schedule to procurement																				
	Mistakes in quantity surveys																				
	Purchased materials that do not comply with specification																				
Handling and Storage	Improper handling of materials																				
	Double handling																				
	Overloading of transport equipment (beyond its capacity)																				
	Improper storage of materials on site																				

Study on Material Wastage of 40/60 Condominium Construction Sites

Source	Cause	Concrete					Mortar					Reinforcement bar					Hollow concrete block				
		1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
Operation	Rework (chiseling, complete removal and rework...etc.)																				
	Using excessive quantity of materials than required																				
	Using incorrect type of material																				
	Damage to work done by other trade (like electrical & sanitary installation)																				
	Poor workmanship																				
Site management	Poor qualification of subcontractor's																				
	Scarcity of Equipment																				
	Untidy construction site																				
Site Supervision	Poor qualification of consultant engineer's staff assigned on the site																				
	Delay in performing inspection and testing by the consultant Engineer																				
	Poor coordination and communication between the consultant engineer, contactor and client																				
	Slow response from the consultant engineer to contractor inquiries																				
Others	Weather condition																				
	Theft																				

Study on Material Wastage of 40/60 Condominium Construction Sites

Please specify if there are any other possible causes of material waste in your 40/60 condominium construction site.

Part Four: Waste Minimization Measures

Below are possible strategies that contribute to the minimization of material wastes in building construction projects. Rank on a scale of 1-5 first the level of contribution of these strategies for minimization of material wastage in 40/60 condominium construction sites. Secondly, rank the level of practice of these strategies on your site.

Level of contribution	
1	Very low contribution
2	Low contribution
3	Medium contribution
4	High contribution
5	Very high contribution

Level of practice	
1	Not practical
2	Not practiced
3	Practiced
4	Frequently practiced
5	Most frequently practiced

Study on Material Wastage of 40/60 Condominium Construction Sites

Please specify if there are other waste minimization strategies that could have significant contribution in material waste reduction in 40/60 condominium construction projects.

Please specify if any other waste minimization strategy practiced in your site

Thank you for your cooperation!

Appendix C Response and Computation of Relative Weight and Rank

Consultants response on part 1 and part 2 (General information and Perception on the effect of client material supplying)

Respondents	Questions						
	Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	1	3	2	1	1	2	
2	1	3	3	4	3	1	1
3	1	2	2	4	4	1	1
4	1	3	2	3	1	1	1
5	1	2	1	4	2	2	
6	1	3	3	4	3	1	1
7	1	3	2	2	2	1	1 3
8	1	2	2	4	3	1	1 3
9	1	3	1	4	2	1	1
10	1	3	1	2	2	2	
11	1	2	2	3	2	1	1
12	1	3	2	3	2	1	1 3
13	1	3	2	2	1	1	1
14	1	2	2	3	2	2	
15	1	3	2	2	2	1	1 3
16	1	3	2	3	1	1	1 3
17	1	3	3	4	3	2	
18	1	3	3	3	3	1	1
19	1	3	3	3	3	1	1
20	1	3	3	4	5	1	1 2
21	1	3	2	3	2	1	1
22	1	3	1	3	2	1	1
23	1	3	2	3	2	1	1
24	1	3	2	3	2	1	1 2 3
25	1	3	3	3	3	1	1 2

Note

For Question Two

- 1 Project Coordinator
- 2 Resident Engineer
- 3 Site Supervisor

For Question Three

- 1 Graduate (MSC)
- 2 Undergraduate (BSC)
- 3 Diploma

For Question Four

- 1 < 1 year
- 2 1 - 3 years
- 3 3 - 5 years
- 4 5 - 10 years
- 5 10 - 15 years
- 6 15 - 20 years

For Question Five

- 1 < 1 year
- 2 1 - 3 years
- 3 3 - 5 years
- 4 5-8 years
- 5 8-10 years
- 6 >10 years

For Question Six

- 1 Yes
- 2 No

For Question Seven

- 1 Since there is no proper control on material wastage, it leads to negligence
- 2 Because the client don't delivery good quality material
- 3 Because the client supplies material in unplanned way

Contractors response on part 1 and part 2 (General information and Perception on the effect of client material supplying)

Respondents	Questions						
	Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	2	3	2	3	2	1	1 2 3
2	3	1	1	6	5	1	2
3	3	3	2	3	2	2	
4	3	3	1	3	2	1	2
5	3	3	2	2	2	1	1 2
6	4	1	2	4	4	1	1 2
7	1	3	2	4	3	1	2
8	2	3	2	4	2	1	2 3
9	1	1	2	4	1	1	2
10	2	3	2	2	2	2	
11	2	3	3	3	3	1	2
12	2	1	2	1	1	1	1 2
13	2	3	3	3	3	1	1 2
14	2	3	2	3	2	1	1 2
15	2	3	2	2	2	1	1 2 3
16	2	1	2	3	2	1	1 2
17	2	3	2	3	2	2	
18	2	3	2	3	2	1	2
19	2	1	2	2	2	1	1 2
20	2	3	2	1	1	1	2
21	1	3	3	4	3	1	2 3
22	1	1	2	4	2	1	2
23	1	3	2	3	1	1	2 3
24	1	1	2	2	2	2	
25	2	1	2	3	1	1	2 3
26	2	3	2	2	2	1	1 2
27	2	1	2	3	2	1	2
28	2	3	2	1	1	1	2
29	2	2	2	4	1	2	
30	2	1	2	3	1	1	2

Note

For Question One

- 1 GC 1 4 BC 2
- 2 BC 1 5 BC 3
- 3 GC 2

For Question Two

- 1 Projects Manager
- 2 Assistant Project Manager
- 3 Site Engineer

For Question Three

- 1 Graduate (MSC)
- 2 Undergraduate (BSC)
- 3 Diploma

For Question Four

- 1 < 1 year 4 5 - 10 years
- 2 1 - 3 years 5 10 - 15 years
- 3 3 - 5 years 6 15 - 20 years

For Question Five

- 1 < 1 year 4 5-8 years
- 2 1 - 3 years 5 8-10 years
- 3 3 - 5 years 6 >10 years

For Question Six

- 1 Yes
- 2 No

For Question Seven

- 1 Since there is no proper control on material wastage, it leads to negligence
- 2 Because the client don't delivery good quality material
- 3 Because the client supplies material in unplanned way

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31	2	1	1	4	3	1	2
32	2	3	2	2	1	1	2
33	2	1	2	6	3	1	3
34	1	2	2	4	1	1	2
35	4	1	2	3	1	1	2
36	3	1	1	5	3	1	1
							2
37	4	3	2	1	1	1	2
38	4	1	2	3	1	1	2
39	4	3	2	2	1	2	
40	4	3	2	1	1	1	1
							2
41	3	3	2	2	1	1	1
							2
42	4	1	2	3	1	1	1
							2
43	3	3	2	3	2	1	2
44	3	1	2	5	3	2	
45	5	3	2	3	2	1	1
							2
46	4	3	2	2	1	1	1
							2
47	4	1	2	5	3	1	2
48	4	3	2	2	1	1	2
49	4	1	2	4	2	2	
50	4	3	2	3	1	1	1
							2
51	5	1	2	4	2	2	
52	5	1	2	2	2	1	2
							3
53	5	3	2	3	2	1	2
54	5	1	2	2	2	1	2
							3
55	5	3	2	3	2	1	2
							3
56	5	1	2	2	2	1	1
							2

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Consultants Response on Part 3 (Causes of Material Wastage)

Respondents	Causes of Concrete Waste																									
	Question																									
	No.	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2
1	5	2	3	4	5	4	5	5	4	4	4	4	4	4	1	3	4	5	5	2	3	4	1	4	1	3
2	4	3	4	2	1	4	1	4	1	3	2	4	5	3	5	4	3	2	5	3	2	1	3	4	4	
3	4	3	2	5	3	3	1	5	2	3	1	4	3	2	5	4	3	5	5	3	3	2	3	2	2	
4	5	2	4	4	1	4	4	5	4	4	4	5	4		4	4	5	4	2	1	4	1	4	1	4	
5	4	4	4	2	1	4	4	5	3	5	4	5	4	4	4	5	4	4	4	4	4	5	4	4	4	
6	2	2	3	4	3	2	3	5	4	4	3	5	4	4	4	4	4	5	2	4	4	2	4	4	5	
7	4	3	3	5	4	4	5	3	5	5	3	4	4	4	3	4	5	5	4	4	3	4	4	2	3	
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9	4	2	3	4	1	3	2	1	4	5	4	4	5	5	4	4	1	4	5	2	2	1	3	3	5	
10	4	2	3	5	4	4	4	4	3	5	3	5	5	5	5	5	3	4	1	4	4	3	5	2	3	
11	5	2	4	4		5	3	4	3	5	3	5	5	5	5	5	4	2	3	3	4	2	5	2	4	
12	5	4	3	5	3	4	3	5	2	5	3	5	5	5	5	5	5	4	4	2	4	2	4	3	2	
13	2	2	2	5	1	3	2	2	4	5	1	4	5	4	5	4	1	2	3	2	2	1	3	1	3	
14	4	2	3	2	1	4		5	4	5	2	4	5	5	5	5	3	5	5	3	3		3	2	4	
15	4	2	3	2	1	4	1	5	5	5	2	4	5	5	5	5	3	5	5	3	3	1	3	2	5	
16	5	2	3	2	2	4	1	5	5	5	2	5	4	5	4	5	5	5	4	4	3	3	4	1	4	
17	4	2	3	2	1	5	1	5	5	5	2	4	5		5	5	3	5	5	3	3	1	3	2	1	
18	3	2	3	1	2	4	5	1	3	1		2	1	3	4	4	1	2	2	1	1	1	1	1	2	
19	3	3	3	4	4	3	4	4	4	5	3	5	4	4	5	5	4	1	5	2	3	4	3	3	4	
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21	4	2	3	2	1	4	1	5	5	5	2	4	5	5	5	5	3	5	5	3	3	1	3	2	3	
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23	5	2	3	5	5	5	5	5	5	5	5	4	5	4	5	5	5	5	4	4	4	2	4	3	4	
24	4	2	3	2	1	4	1	5	5	5	2	4	5	5	5	5	3	5	5	3	3	1	3	2	5	
25	5	2	3	2	2	4	1	5	5	5	2	4	4	5	4	5	5	5	4	4	3	3	4	3	3	

Respondents	Causes of Mortar Waste																									
	Question																									
	No.	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2
1	1	2	4	4	5	4	3	4	1	4	4	4	4	4	4	4	2	2	3	4	3	2	3		2	
2	3	3	4	2	3	4	2	4	3	2	2	4	4	2	3	4	3	4	2	3	4	2	3	2	4	2
3	2	2	2	5	2	5	2	4	3	5	2	3	5	3	4	5	4	4	2	3	2	3	3	2	2	
4	1	2	4	4	5	4	3	4	5	4	4	3	4	3	5	4	2	2	3	4	3	2	3	1	1	
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6	2	4	4	4	3	3	3	4	4	5	3	4	5	3	4	4	4	2	2	4	4	5	3	4	1	
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12	2	4	5	3	3	5	2	4	5	5	1	4	5	2	5	5	5	5	5	3	3	4	3	2	1	
13	1	4	2	5		2	2	2	5	2		4	4	1	2	4	4	3	4	3	2	2	2	1	1	
14	2	5	4	3	3	4	2	4	5	5	2	5	5	3	5	5	5	4	5	3	3	4	3	2	1	
15	2	4	4	3	3	4	2	4	5	5	2	5	5	3	5	5	5	5	5	3	3	4	3	2	1	
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17	2	5	4	3	3	4	2	4	5	5	2	5	5	3	5	5	5	3	5	3	3	4	3	2	1	
18	2	1	4	1	3	3	2	3	1	1	1	2	3	1	1	2	1	2	1	1		1	2	1		
19	2	4	3	4	5	5	4	3	5	2	5	4	5	4	4	5	5	5	4	3	3	1	2	3	4	
20	4	5	3	5	2	4	3	5	5	4	4	4	5	2	5	5	4	3	3	3	3	4	3	2	1	
21	4	4	3	5	2	4	2	5	5	5	4	4	5	3	5	5	5	4	4	5	4	5	3	2	1	
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24	2	5	4	3	3	4	2	4	5	5	2	5	5	3	5	4	5	4	4	3	3	4	3	2	1	
25	2	5	5	2	2	4	3	4	5	5	2	4	5		4	4	4	4	5	4	3	5	4	3	2	

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Respondents	Causes of Re bar Waste																								
	Question																								
	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2
1	4	3	4	4	5	4	2	2	4	4	1	4	3	2	1	4	2	2	4	4	3	2	2	3	3
2	4	2	4	2	4	5	2	3	1	1	3	2	2	3	2	2	2	3	3	2	2	2	1	3	2
3	5	5	3	5	4	4	3	2	5	4	3	4	2	2	2	4	3	3	1	2	2	3	4	2	2
4	4	4	4	5	5	5	3	1	3	1	5	4	5	2	2	4	3	2	4	4	3	2	2	2	3
5	4	4	4	2	3	4	3	4	4	3	5	5	5	4	2	5	3	3	3	4	4	4	4	4	5
6	3	4	4	3	5	3	2	3	3	3	3	2	4	3	3	2	2	3	4	5	5	5	5	3	3
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10	4	5	3	3	5	4	3	2	5	1	4	3	3	4	3	3	2	3	5	5	5	2	2	1	4
11	5	4	4	4	4	2	3	5	1	3	5	4	4	2	2	4	4	3	5	5	4	3	1	4	2
12	5	5	5	3	5	5	2	2	3	4	5	5	5	1	1	5	5	5	4	4	4	2	2	4	3
13	1	4	4	1	5	2	2	2	1	1	4	1	2	1	2	2	1	1	5	3	1	1	1	3	2
14	5	5	4	1	4	5	2	3	1	1	1	2	2	2	1	4	4	3	5	2	1	3	4	3	1
15	5	5	4	1	4	5	2	2	1	1	1	2	2	5	2	4	4	3	5	2	1	3	4	5	3
16	4	5	5	2	3	4	1	2	2	2	5	1	1	3	1	5	2	1	4	2	3	4	5	3	2
17	5	5	4	1	4	5	2	1	1	1	1	2	2	4	4	4	4	3	5	2	1	3	4	2	3
18	3	4	3	2	3	4	2	3	1	1	5	1	1	1	2	1	2	1	4	1	1	1	1	1	1
19	3	4	3	3	5	4	3	2	3	2	3	4	4	4	2	5	5	5	4	3	3	1	1	3	2
20	4	4	5	2	5	4	5	3	4	3	5	2	2	2	2	4	4	3	4	2	1	2	4	4	3
21	5	5	5	3	4	4	5	4	5	3	5	4	3	1	3	5	5	5	4	5	5	5	5	4	3
22	4	5	5	2	3	4	1	2	2	2	5	1	1	2	1	5	3	1	4	2	3	4	2	2	2
23	5	5	5	3	5	5	3	3	5	1	5	5	5	3	3	5	5	5	4	4	4	4	1	1	3
24	5	5	4	1	4	5	2	2	1	1	1	2	2	1	3	4	4	3	5	2	1	3	1	4	3
25	4	5	5	2	3	4	1	5	2	2	5	1	1	2	5	2	1	4	2	3	4	3	4	4	5

Respondents	Causes of HCB Waste																								
	Question																								
	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2
1	4	4	4	5	5	4	4	5	5	5	5	3	3	3	4	4	5	1	4	4	3	2	2	3	3
2	4	2	4	3	5	3	2	3	4	1	5	5	4	2	5	4	4	3	4	2	1	4	2	1	2
3	5	5	3	2	4	3	2	5	5	5	5	2	2	2	5	5	5	3	4	2	1	4	2	1	2
4	4	4	4	5	5	2	3	4	5	5	5	3	3	5	4	4	5	1	4	4	3	2	2	3	2
5	4	4	4	5	4	3	4	2	4	3	4	3	3	4	4	5	3	4	4	4	4	4	4	4	5
6	4	4	5	5	4	2	3	5	5	5	4	5	3	4	2	4	5	3	2	4	4	5	5	3	2
7	4	1	1	5	4	4	5	4	4	5	5	4	3	2	4	5	5	2	5	3	5	4	4	5	4
8	4	3	3	4	2	2	4	5	2	4	4	4	4	1	5	2	2	1	3	1	1	2	2	5	1
9	5	4	2	5	5	5	5	5	4	5	5	2	1	3	5	5	5	1	4	5	2	4	2	2	1
10	5	5	3	5	2	3	3	4	4	5	5	2	3	3	1	5	5	2	1	2	4	3	4	2	4
11	4	4	1	5	2	2	5	5	4	2	4	4	3	3	3	4	4	3	4	4	4	4	3	2	2
12	4	3	4	5	5	3	5	5	3	5	5	3	2	3	5	4	5	3	5	2	4	4	2	4	5
13	3	2	2	5	2	2	2	5	5	4	5	4	2	1	4	5	4	4	2	3	2	2	2	1	1
14	5	5	2	5	5	2	2	5	4	5	5	5	2	2	5	5	5	3	4	2	1	4	2	1	2
15	5	5	2	5	5	2	2	5	4	5	5	3	2	2	5	5	5	3	4	2	1	4	2	1	2
16	4	5	4	5	4	3	1	5	5	5	5	5	5	3	5	5	4	4	5	4	2	5	4	2	2
17	5	5	2	5	5	3	2	5	4	5	5	5	2	2	5	5	5	3	4	2	1	4	2	1	2
18	5	3	1	3	4	2	1	4	1	3	4	2	1	5	4	1	2	5	3	1	1	1	1	1	1
19	3	2	2	4	3	4	3	4	4	4	5	4	3	2	5	5	5	3	3	3	3	2	2	3	4
20	4	4	3	5	4	4	5	5	4	3	4	5	1	3	5	5	4	2	5	4	2	5	4	2	2
21	4	5	3	5	4	2	5	5	4	3	4	4	2	2	4	5	5	3	5	4	4	4	4	1	2
22	4	5	2	5	4	3	1	5	5	5	5	5	1	3	5	5	4	4	5	3	2	5	4	2	2
23	4	5	1	5	5	5	5	5	4	3	5	4	3	4	5	5	4	4	3	2	3	5	4	5	3
24	5	5	2	5	5	4	2	5	4	5	5	5	2	2	5	5	5	3	4	2	1	4	2	5	2
25	4	5	4	5	4	4	1	5	5	5	5	5	1	2	5	5	4	4	5	4	2	5	4	2	2

Note 5 Major waste cause 4 Significant waste cause 3 Quite a waste cause 2 Insignificant waste cause 1 Not a waste cause No response

Computation of Relative Weight and Rank for the Consultant's Response on Part 3

Concrete																										
Group	Design			Procurement				Handling and Storage				Operation					Site management			Site Supervision				Others		
Cause	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2	
Frequency of scoring (f)	1	1	0	0	1	10	0	9	2	1	1	2	0	1	1	0	0	3	1	1	3	2	12	2	6	1
	2	2	17	2	10	6	1	2	2	3	0	10	1	1	2	0	0	0	4	4	4	3	5	0	11	3
	3	2	4	17	1	3	5	3	1	5	2	6	0	1	2	2	1	9	0	2	9	11	4	10	5	7
	4	12	3	6	6	3	15	5	4	7	4	5	14	10	7	9	9	4	6	9	9	9	2	11	3	10
	5	8	0	0	7	2	4	5	16	9	18	1	10	12	11	14	15	9	14	9	0	0	1	2	0	4
$\Sigma(f^*s)$	99	58	79	83	53	97	67	105	95	113	65	108	106	94	112	114	91	103	96	74	77	47	86	55	88	
RW	3.96	2.32	3.16	3.32	2.12	3.88	2.68	4.2	3.8	4.52	2.6	4.32	4.24	3.76	4.48	4.56	3.64	4.12	3.84	2.96	3.08	1.88	3.44	2.2	3.52	
Rank	8	22	17	16	24	9	20	6	11	2	21	4	5	12	3	1	13	7	10	19	18	25	15	23	14	

Mortar																										
Group	Design			Procurement				Handling and Storage				Operation					Site management			Site Supervision				Others		
Cause	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2	
Frequency of scoring (f)	1	4	1	1	1	1	1	0	1	2	1	2	0	0	5	2	0	1	1	1	2	1	2	0	3	12
	2	15	4	2	5	8	2	11	1	0	5	10	1	0	3	2	1	3	4	4	0	5	4	7	11	8
	3	3	2	4	7	10	4	10	4	3	1	3	4	1	11	2	1	2	4	6	13	14	4	14	4	0
	4	2	9	12	5	1	15	2	16	4	3	4	15	6	2	9	8	11	11	6	8	3	9	3	3	3
	5	0	9	6	7	4	3	1	3	16	15	5	5	18	3	10	15	8	5	8	2	1	6	0	3	1
$\Sigma(f^*s)$	51	96	95	87	71	92	65	94	107	101	72	99	117	67	98	112	97	90	91	83	70	88	68	64	45	
RW	2.04	3.84	3.8	3.48	2.84	3.68	2.6	3.76	4.28	4.04	2.88	3.96	4.68	2.68	3.92	4.48	3.88	3.6	3.64	3.32	2.8	3.52	2.72	2.56	1.8	
Rank	24	8	9	15	18	11	22	10	3	4	17	5	1	21	6	2	7	13	12	16	19	14	20	23	25	

Re bar																										
Group	Design			Procurement				Handling and Storage				Operation					Site management			Site Supervision				Others		
Cause	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2	
Frequency of scoring (f)	1	1	0	0	6	0	0	3	2	9	10	5	5	5	5	7	2	1	5	2	1	8	4	8	3	2
	2	0	1	1	8	0	2	12	11	4	5	1	8	8	9	11	3	8	2	0	12	2	6	5	5	7
	3	4	1	4	6	5	2	7	7	4	6	4	2	4	5	5	1	5	13	2	3	7	7	1	7	11
	4	9	10	13	3	10	13	0	2	4	3	2	7	4	5	1	10	7	1	14	5	4	6	8	8	3
	5	11	13	7	2	10	8	2	2	4	1	13	3	4	0	0	9	4	4	7	4	4	2	3	1	1
$\Sigma(f^*s)$	104	110	101	62	105	102	58	63	65	55	92	70	69	58	48	96	80	72	99	74	69	71	68	71	66	
RW	4.16	4.4	4.04	2.48	4.2	4.08	2.32	2.52	2.6	2.2	3.68	2.8	2.76	2.32	1.92	3.84	3.2	2.88	3.96	2.96	2.76	2.84	2.72	2.84	2.64	
Rank	3	1	5	21	2	4	22	20	19	24	8	14	15	22	25	7	9	11	6	10	15	12	17	12	18	

HCB																										
Group	Design			Procurement				Handling and Storage				Operation					Site management			Site Supervision				Others		
Cause	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2	
Frequency of scoring (f)	1	0	1	4	0	0	0	4	0	1	1	0	0	5	2	1	1	0	4	1	2	8	1	1	8	4
	2	0	3	8	1	4	9	7	1	1	1	0	4	8	10	1	1	2	3	2	9	6	5	13	7	14
	3	2	3	5	2	1	8	4	1	1	5	0	5	9	8	1	0	0	12	4	4	4	1	1	4	2
	4	15	7	7	2	10	6	3	5	14	3	7	7	2	3	7	6	8	5	11	9	6	12	9	2	3
	5	8	11	1	20	10	1	6	18	8	15	18	9	0	1	15	17	15	0	7	1	1	6	1	3	2
$\Sigma(f^*s)$	106	99	68	116	101	71	72	115	102	105	118	96	56	63	109	112	111	66	96	73	61	92	71	57	60	
RW	4.24	3.96	2.72	4.64	4.04	2.84	2.88	4.60	4.08	4.20	4.72	3.84	2.24	2.52	4.36	4.48	4.44	2.64	3.84	2.92	2.44	3.68	2.84	2.28	2.40	
Rank	7	11	19	2	10	17	16	3	9	8	1	12	25	21	6	4	5	20	12	15	22	14	17	24	23	

Study on Material Wastage of 40/60 Condominium Construction Sites

Contractors Response on Part 3 (Causes of Material Wastage)

Respondents	Causes of Concrete Waste																									
	Question																									
	No.	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2
1	2	3	2	4	1	4	1	3	1	5	1	5	1	1	2	1	1	1	4	2	1	4	2	3	1	
2	3	4	4	3	2	3	4	3	2	2	5	1	5	5	5	3	5	5	3	4	5	3	3	4	2	
3	3	5	5	1	2	4	1	2	2	5	2	5	4	1	5	4	3	3	5	4	5	4	4	2	1	
4	2	4	5	4	4	4	4	2	3	2	5	5	2	2	4	3	4	3	5	4	3	4	2	3	1	
5	2	4	4	4	2	5	2	3	2	4	2	4	5	2	2	4	4	2	2	4	4	5	4	2	2	
6	4	5	4	5	3	1	5	3	3	4	5	5	4	5	5	4	4	3	5	4	5	5	3	5	1	
7	4	4	2	2	2	2	2	2	2	2	2	4	2	2	4	2	4	2	2	4	2	4	2	2	2	
8	1	4	4	4	1	2	1	3	2	4	3	4	4	4	4	1	1	4	3	3	1	3	2	1	1	
9	4	5	3	4	3	3	3	3	4	5	4	4	4	3	4	4	3	4	4	5	4	5	4	4	2	
10	4	4	3	4	3	3	5	4	4	4	3	3	5	4	4	3	4	5	4	2	5	3	5	4	2	
11	2	3	2	3	5	1	1	3	3	4	5	2	4	2	2	2	2	4	3	5	4	2	2	5	1	
12	4	5	5	2	2	4	1	5	4	5	2	5	4	1	5	4	3	3	5	4	5	4	5	2	1	
13	3	5	5	2	2	4	1	4	2	4	2	5	4	5	5	4	5	3	5	5	5	5	4	2	3	
14	3	5	5	4	4	2	4	4	4	4	2	5	2	2	5	2	3	2	3	2	3	2	3	2	5	
15	2	5	2	5	2	2	2	4	4	4	4	2	4	2	2	2	2	4	2	2	2	4	2	2	1	
16	1	4	3	1	3	1	5	3	4	3	2	3	5	1	4	4	2	5	1	4	5	4	1	1	1	
17	4	5	5	1	2	4	1	5	4	5	2	5	4	5	4	5	4	3	3	5	4	5	4	5	2	
18	5	5	5	2	2	4	1	1	4	4	2	5	4	5	5	4	5	3	5	5	5	5	4	2	3	
19	1	2	3	2	1	1	4	2	1	1	1	4	2	1	2	1	1	1	4	3	1	4	3	2	1	
20	4	4	3	4	3	3	5	5	3	3	3	2	4	2	4	2	3	3	2	3	3	3	3	3	2	
21	5	5	5	2	2	4	1	3	4	4	2	5	4	5	5	4	5	3	5	5	5	5	4	2	3	
22	4	5	5	1	2	4	1	1	4	5	2	5	4	1	5	4	3	3	5	4	5	4	5	2	1	
23	3	5	4	3	3	4	4	4	3	5	4	5	5	3	3	2	5	4	3	3	4	4	4	4	1	
24	5	5	5	5	5	5	5	2	5	4	5	4	4	5	5	4	5	4	5	5	5	5	5	2	2	
25	2	3	3	2	2	3	1	3	1	4	3	2	2	3	3	4	2	1	2	3	4	2	2	2	2	
26	2	4	2	4	3	5	3	4	3	5	4	5	4	5	2	3	4	3	2	3	2	2	3	1	2	1
27	5	5	3	4	4	3	3	3	5	3	4	5	3	3	4	5	3	5	4	1	3	1	5	4	3	
28	4	5	5	1	2	4	1	1	4	5	2	5	4	1	5	4	3	3	5	4	5	4	5	2	1	
29	5	4	3	3	5	3	3	1	4	5	3	2	1	1	3	1	1	1	1	3	1	4	1	4	1	
30	3	3	1	3	5	3	1	3	4	1	2	4	1	1	4	1	3	1	3	4	1	3	4	4	1	
31	3	4	3	5	2	2	1	4	2	2	4	3	4	1	4	2	3	2	4	4	4	1	2	1	2	
32	4	5	5	5	4	5	5	4	5	4	3	5	3	4	5	1	5	2	5	4	4	4	3	5	4	
33	4	5	4	1	3	4	3	4	4	4	1	4	4	2	4	4	5	3	5	1	5	1	5	4	1	
34	1	5	2	4	5	2	2	4	2	5	5	5	1	4	2	5	2	4	2	4	5	4	2	1	1	
35	4	5	4	1	2	4	1	4	4	5	2	5	3	1	4	2	3	2	5	4	3	4	4	2	2	
36	4	2	3	3	4	3	5	3	3	5	3	3	3	3	3	4	3	4	3	5	4	4	4	4	2	
37	1	3	3	2	3	1	1	3	3	1	3	3	2	1	2	4	3	3	4	3	3	1	3	3	3	
38	4	5	5	1	2	4	1	5	4	5	2	5	4	1	5	4	3	3	5	4	5	4	5	2	1	
39	5	5	5	2	2	4	1	3	4	4	2	5	4	5	5	4	5	3	5	5	5	5	4	2	3	
40	4	5	5	1	2	4	1	4	4	5	2	5	4	1	5	4	3	3	5	4	5	4	5	2	1	
41	5	5	5	5	5	5	5	3	5	4	5	4	4	5	5	4	5	4	5	5	5	5	5	2	2	
42	4	5	5	1	2	4	1	3	4	5	2	5	4	1	5	4	3	3	5	4	5	4	5	2	1	
43	4	5	4	4	2	2	5	4	3	4	5	4	4	5	4	4	4	4	5	2	4	2	4	5	2	
44	4	4	4	4	4	4	1	4	4	4	4	4	1	1	4	1	1	4	3	5	4	4	1	1	1	
45	4	5	3	4	2	2	3	4	4	5	2	4	4	3	5	4	5	4	3	3	5	4	4	3	1	
46	4	4	5	5	2	5	5	3	4	3	5	5	3	5	5	3	5	3	4	3	5	5	2	1	1	
47	4	5	5	1	2	4	1	2	4	5	2	5	4	1	5	4	3	3	5	4	5	4	5	2	1	
48	1	1	2	1	1	2	1	4	1	3	1	1	1	1	1	1	1	2	1	1	1	1	1	1	1	
49	5	5	5	4	2	4	5	4	4	4	4	4	4	5	5	4	5	4	3	2	4	4	5	4	1	
50	5	5	5	2	2	4	1	3	4	4	2	5	4	5	5	4	5	3	5	5	5	5	4	2	3	
51	5	5	5	5	5	5	5	2	5	4	5	4	4	5	5	4	5	4	5	5	5	5	5	2	2	
52	5	5	5	2	2	4	1	3	4	4	2	5	4	5	5	4	5	3	5	5	5	5	4	2	3	
53	5	5	5	5	5	5	5	3	5	4	5	4	5	5	5	4	5	4	5	5	5	5	5	2	2	
54	4	5	5	1	2	4	1	5	4	5	2	5	4	1	5	4	3	3	5	4	5	4	5	2	1	
55	5	5	5	2	2	4	1	3	4	4	2	5	4	5	5	4	5	3	5	5	5	5	4	2	3	
56	4	5	5	1	2	4	1	2	4	5	2	5	4	1	5	4	3	3	5	4	5	4	5	2	1	

Study on Material Wastage of 40/60 Condominium Construction Sites

Respondents	Causes of Mortar Waste																								
	Question																								
	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2
1	2	4	2	1	1	4	1	1	3	5	4	4	2	1	5	4	4	3	2	1	1	1	1	3	1
2	3	3	2	4	1	3	4	2	4	2	1	5	3	4	4	1	5	3	5	5	5	5	2	3	5
3	1	4	4	2	2	4	1	4	5	4	1	5	4	1	5	5	5	5	4	4	3	5	4	3	1
4	3	4	4	5	4	4	4	4	4	4	4	4	2	2	2	4	4	4	2	3	3	3	2	2	1
5	1	5	4	2	2	5	2	2	4	4	4	2	4	2	4	2	4	4	2	4	3	4	5	4	2
6	5	5	4	5	3	1	1	4	4	5	4	5	3	5	4	4	4	4	4	4	4	5	4	4	1
7	2	4	4	4	2	2	2	2	5	4	2	4	2	2	2	3	4	2	4	2	2	2	2	3	1
8	1	3	3	3	1	3	1	2	4	4	4	4	2	1	4	1	4	1	1	4	1	4	1	2	1
9	3	5	4	2	3	3	2	2	2	4	2	4	4	3	5	1	3	3	4	2	4	4	2	3	2
10	4	2	1	3	3	2	3	4	4	3	4	5	3	4	3	3	3	4	3	3	4	4	4	3	1
11		5	5	2	2	2	1	3	3	2	3	4	2	2	2	3	2	2	2	2	4	4	4	2	1
12	1	4	4	2	2	4	1	4	5	4	1	5	4	1	5	5	5	5	4	4	3	5	4	3	1
13	2	5	5	2	2	4	5	4	5	5	2	5	4	1	5	5	5	4	4	4	3	5	4	3	2
14	2	2	2	2	4	2	4	4	5	4	5	5	3	2	4	2	5	5	3	2	2	3	2	4	3
15	2	4	2	5	2	2	2	4	5	2	4	4	2	2	2	2	2	2	2	2	4	4	4	2	1
16	4	0	4	2	4	2	5	5	4	3	1	4		1	4	1	2	3	3	4	1	1	1	3	1
17	1	4	4	2	2	4	1	4	5	4	1	5	5	1	5	5	5	5	4	4	3	5	4	3	1
18	2	5	5	2	2	4	5	4	5	5	2	5	4	1	5	5	5	4	4	4	3	5	4	3	2
19	2	5	3			1	5	1	2	2	1	2	2	1	4	1	1	2	2	2	2	2	3	1	1
20	2	3	2	3	3	3	5	2	3	2	4	3	3	2	2	3	3	3	3	3	2	2	1	2	2
21	2	5	5	2	2	4	5	4	5	5	2	5	4	1	5	5	5	4	4	4	3	5	2	3	2
22	1	4	4	2	2	4	1	4	5	4	1	5	3	1	5	5	5	5	4	4	3	5	4	3	1
23	4	3	3	4	4	4	5	3	5	5	5	3	4	3	5	3	5	4	3	2	4	4	2	1	1
24	2	5	5	5	5	4	5	4	5	3	5	5	4	5	4	5	5	5	4	4	4	5	3	3	4
25	2	2	2	1	2	3	1	1	4	3	2	3	2	2	5	1	3	3	2	3	2	3	2	2	2
26	2	3	4	4	3	5	2	2	2	5	2	4	1	2	4	2	2	2	2	3	3	2	2	3	1
27	2	1	1	4	4	3	3	5	5	3	5	4	3	3	3	5	3	4	5	4	4	3	3	3	3
28	1	4	4	2	2	4	1	4	5	4	1	5	4	1	5	5	5	5	4	4	3	5	4	3	1
29	4	4	3	3	5	3	3	4	4	2	3	3	1	1	5	1	1	3	5	1	1	1	1	1	1
30	4	4	4	3	4	4	3	3	4	2	3	5	3		3	3	5	1	5	1	1	1	1		1
31	1	1	4	2	2	2	1	2	4	2	5	4	2	1	2	1	3	3	2	2	2	4	4	3	2
32	5	4	4	3	4	5	5	5	5	5	5	5	3	4	4	5	5	5	4	1	2	3	2	4	4
33	5	1	1	1	3	4	3	5	5	3		4	5	2	4	4	5	4	3	4	3	4	4	4	1
34	2	4	2	2	1	0	2	4	4	5	4	4	5	1	5	1	5	2	1	2	2	3	4	4	1
35		4	5	2	2	4	1	4	5	4	2	4	5	1	5	5	4	5	4	2	2	5	3	2	1
36	1	5	5	3	4	3	5	3	2	4	3	3	3	3	4	3	3	3	4	4	3	4	3	2	2
37	3	1	3	4	4	1	4	4	4	3	3	2	4	2	3	3	4	1	2	4	4	4	3	3	3
38	1	4	4	2	2	4	1	4	5	4	1	5	3	1	5	5	5	5	4	4	3	5	4	3	1
39	2	5	5	2	2	4	5	4	5	5	1	5	4	1	5	5	5	4	4	4	3	5	4	3	1
40	1	4	4	2	2	4	1	4	5	4	1	5	3	1	5	5	5	5	4	4	3	5	4	3	1
41	2	5	5	5	5	4	5	4	5	3	5	5	4	5	4	5	5	5	4	4	4	5	4	2	4
42	1	4	4	2	2	4	1	4	5	4	1	5	5	1	5	5	5	5	4	4	3	5	4	3	1
43	5	2	2	5	2	2	5	3	5	4	4	4	4	5	4	5	4	4	4	4	4	4	4	3	2
44	1	4	1	1	4	4	1	4	4	1	4	4	1	1	4	1	4	4	1	1	1	1	1	2	1
45	2	4	2	2	3	2	3	1	5	4	4	4	3	4	3	3	3	3	3	3	4	3	3	3	1
46	1	5	3	5	2	5	5	4	4	5	5	5	2	5	3	4	5	5	3	3	3	5	3	2	2
47	1	4	4	2	2	4	1	4	5	4	1	5	5	1	5	5	5	5	4	4	3	5	4	3	1
48	1	1	1	1	1	2	1	1	1	1	1	1	2	1	2	1	2	3	1	1	1	1	1	1	1
49	4	4	2	4	2	4	5	4	5	4	4	5	5	5	4	3	5	5	5	4	4	4	4	4	1
50	2	5	5	2	2	4	5	4	5	5	2	5	4	1	5	5	5	4	4	4	3	5	4	3	2
51	2	5	5	5	5	4	5	4	5	3	5	5	4	5	4	5	5	5	4	4	4	5	4	5	4
52	2	5	5	2	2	4	5	4	5	5	2	5	4	1	5	5	5	4	4	4	3	5	3	3	2
53	2	5	5	5	5	4	5	4	5	3	5	5	4	5	4	5	5	5	4	4	4	5	4	2	4
54	1	4	4	2	2	4	1	4	5	4	1	5	5	1	5	5	5	5	4	4	3	5	2	3	1
55	2	5	5	2	2	4	5	4	5	5	2	5	4	1	5	5	5	4	4	4	3	5	4	2	2
56	1	4	4	2	2	4	1	4	5	4	1	5	5	1	5	5	5	5	4	4	3	5	4	3	1

Study on Material Wastage of 40/60 Condominium Construction Sites

Respondents	Causes of Reinforcement Bar Waste																								
	Question																								
	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1	O2
1	3	2	2	1	4	2	5	4	1	2	2	5	1	1	1	1	1	2	2	2	2	3	2	3	1
2	5	3	2	5	4	4	5	5	2	2	2	1	2	5	2	2	5	2	3	5	5	5	4	3	2
3	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	2	3	4	4	2	4	5	2	4
4	3	4	4	2	5	3	3	2	0	2	3	3	5	2	2	4	2	3	2	3	3	2	4	2	1
5	5	5	4	3	5	5	2	4	3	3	4	4	4	2	4	2	5	5	5	5	3	5	4	3	4
6	5	5	4	5	3	1	2	4	4	4	4	5	4	4	4	1	4	3	4	4	3	4	5	2	4
7	5	4	4	3	3	2	2	3	2	3	4	4	2	2	2	4	4	3	4	2	2	2	2	4	4
8	4	3	3	3	3	2	2	1	5	5	1	1	4	3	4	4	1	4	1	1	4	4	1	1	1
9	3	3	3	2	4	4	3	3	2	2	3	3	3	2	3	2	2	4	4	2	2	5	4	3	2
10	3	4	4	4	4	4	4	3	3	1	3	1	3	4	1	4	3	2	3	2	3	3	3	3	4
11	5	2	5	4	5	1	1	2	3	3	3	2	2	2	2	2	2	4	2	2	4	4	4	2	1
12	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	2	3	4	4	2	5	5	3	3
13	4	5	5	2	3	4	1	5	2	2	2	1	1	4	1	1	2	1	4	2	3	4	4	2	4
14	4	4	4	2	4	4	3	2	2	2	3	3	4	4	4	3	2	2	2	4	2	4	4	3	2
15	5	4	2	2	3	2	2	4	2	2	4	2	2	2	2	2	2	2	2	2	4	4	4	4	2
16	4	5	3	3	5	5	2	5	3	1	3	3	3	1	5	2	1	2	5	5	5	5	5	2	3
17	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	2	3	4	4	2	4	5	4	4
18	4	5	5	2	3	4	1	5	2	2	2	5	5	4	1	1	2	1	4	2	3	4	5	4	4
19	4	4	3	1	5	1	4	1	1	1	1	2	1	2	1	1	1	1	2	2	2	3	2	1	1
20	5	3	2	2	3	1	4	1	1	1	1	2	3	2	2	5	4	2	2	1	3	2	4	1	1
21	4	5	5	2	3	4	1	5	2	2	3	1	1	4	1	1	2	1	4	2	3	4	5	4	4
22	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	2	3	4	4	2	4	5	4	4
23	4	4	5	3	4	5	3	4	5	3	5	5	3	3	5	4	5	4	4	2	4	4	4	1	1
24	4	5	5	4	5	5	5	5	5	1	5	5	5	2	4	2	5	5	5	4	4	4	5	3	3
25	3	4	1	1	2	3	1	2	1	1	3	3	3	2	4	3	4	2	2	3	2	2	3	2	2
26	4	3	5	4	4	5	3	3	2	5	3	2	2	2	3	3	2	1	2	3	3	2	2	2	1
27	5	5	3	4	4	4	3	4	3	3	3	3	3	3	5	4	5	3	5	4	3	3	3	3	2
28	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	2	3	4	4	2	4	5	4	4
29	3	4	3	3	5	3	3	2	4	1	4	2	3	1	5	3	3	1	5	1	1	3	1	1	1
30	3	4	3	2	3	3	4	3	2	3	2	1	1	1	1	3	3	4	4	1	5	3	1	1	1
31	4	3	4	1	4	1	1	5	2	1	4	3	4	1	2	4	4	2	3	2	2	4	4	2	4
32	5	4	4	1	4	5	1	3	1	1	3	3	5	4	1	2	3	3	4	1	2	3	4	4	4
33	3	2	5	1	3	4	3	4	2	3	4	1	1	3	2	4	4	4	1	4	2	2	4	3	3
34	5	4	2	2	0	1	1	2	2	1	4	1	1	1	3	2	4	3	3	2	2	4	4	1	2
35	3	3	4	3	3	3	3	4	2	1	1	1	2	4	3	3	3	3	4	2	2	3	3	4	2
36	4	4	5	2	4	3	1	3	4	3	2	3	3	3	5	3	3	4	4	4	3	3	4	4	2
37	5	1	3	4	4	3	4	3	4	3	4	2	3	2	2	2	5	5	3	4	4	3	4	3	3
38	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	4	3	4	4	2	4	5	2	3
39	4	5	5	2	3	4	1	5	2	2	5	1	1	4	1	2	4	1	4	2	3	4	5	2	2
40	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	2	3	4	4	2	4	5	4	4
41	4	5	5	5	5	5	5	5	5	1	5	5	5	2	4	2	5	5	5	4	4	4	5	3	3
42	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	4	3	4	4	2	4	5	4	4
43	5	5	5	5	3	2	1	4	3	5	5	1	4	5	1	4	4	3	4	4	3	5	5	4	2
44	4	4	5	4	4	4	4	4	2	1	4	1	4	1	4	4	4	1	4	1	4	1	4	1	2
45	3	3	4	2	2	2	1	5	2	2	3	3	4	4	3	3	4	3	4	4	3	4	3	3	3
46	5	5	3	5	2	5	5	5	4	4	4	5	5	2	3	5	5	2	3	3	3	3	5	4	4
47	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	2	3	4	4	2	4	5	4	4
48	3	3	3	3	2	3	4	1	1	1	2	1	1	1	1	1	2	2	1	2	2	1	1	5	2
49	4	4	4	4	2	4	5	4	4	3	5	4	5	5	4	5	5	5	5	4	4	4	4	4	2
50	4	5	5	2	3	4	1	5	2	2	5	1	1	4	1	5	4	1	4	2	3	4	5	3	3
51	4	5	5	5	5	5	5	5	5	1	5	5	5	2	4	5	5	5	5	4	4	4	5	3	3
52	4	5	5	2	3	4	1	5	2	2	5	1	1	4	1	5	2	1	4	2	3	4	5	4	4
53	4	5	5	5	5	5	5	5	5	1	5	5	5	2	4	5	5	5	5	4	4	4	5	3	3
54	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	2	3	4	4	2	4	5	4	4
55	4	5	5	2	3	4	1	5	2	2	5	1	1	4	1	5	2	1	4	2	3	4	5	4	4
56	5	4	5	3	3	5	3	4	2	1	1	1	2	4	3	3	2	3	4	4	2	4	5	4	4

Study on Material Wastage of 40/60 Condominium Construction Sites

Respondents	Causes of HCB Waste																								
	Question																								
	No.	D1	D2	D3	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O4	O5	SM1	SM2	SM3	SS1	SS2	SS3	SS4	O1
1	4	4	2	1	4	3	1	4	1	1	5	4	4	1	4	2	4	2	2	2	2	2	3	3	1
2	3	4	3	4	3	4	4	2	4	3	4	3	2	4	2	3	5	2	3	3	4	5	5	4	2
3	5	5	3	5	5	4	3	5	5	4	5	3	1	3	5	4	4	3	5	3	2	5	3	2	3
4	5	3	3	5	2	3	3	2	5	5	5	4	5	4	2	4	2	3	2	3	3	3	3	2	1
5	4	5	2	2	3	2	2	4	4	2	4	4	4	2	4	2	4	4	4	3	1	4	5	4	3
6	4	5	2	5	4	1	5	4	4	4	4	4	4	5	4	5	4	3	4	3	3	5	4	4	2
7	4	5	4	4	4	2	2	5	3	2	4	4	1	3	4	4	4	3	4	4	2	5	3	2	3
8	4	2	5	5	4	3	3	4	1	5	3	4	4	1	4	4	1	5	1	1	4	1	4	1	1
9	4	3	5	5	4	3	4	4	4	4	4	5	3	3	4	2	2	2	4	2	2	4	4	3	2
10	3	4	3	5	2	3	2	2	4	1	4	2	1	4	2	5	3	3	3	2	4	3	3	2	3
11	5	5	5	5	3	1	3	3	5	5	5	3	4	5	3	5	5	3	4	3	4	4	5	2	2
12	5	5	3	5	5	4	3	5	5	4	5	4	1	3	5	4	4	3	5	2	2	5	4	2	3
13	5	5	4	5	5	4	1	5	5	5	5	5	1	3	4	5	4	4	5	1	2	5	4	2	2
14	5	5	3	5	4	2	2	4	5	5	5	5	3	2	4	5	4	2	2	2	2	3	2	4	3
15	4	4	2	5	2	2	2	2	5	4	5	4	2	2	2	4	2	4	2	2	4	4	4	2	2
16	5	5	3	5	5	2	5	5	3	5	3	5	5	5	5	5	2	3	5	5	5	5	5	1	5
17	5	5	3	5	5	3	3	5	5	4	5	4	1	3	5	4	4	3	5	4	2	5	3	2	3
18	5	4	4	5	5	3	1	5	5	5	5	5	1	3	5	5	4	4	5	4	2	5	4	2	2
19	4	3	3	5	4	2	4	4	4	1	4	3	1	1	4	4	1	1	1	5	5	1	2	1	1
20	4	5	3	5	4	1	4	4	3	1	5	4	1	1	4	4	1	1	1	1	1	1	2	5	1
21	5	4	4	5	5	2	1	5	5	5	5	5	1	3	5	5	4	4	5	4	2	5	4	2	2
22	5	5	3	5	5	3	3	5	5	4	5	4	1	3	5	4	4	3	5	4	2	5	3	2	3
23	5	3	4	4	5	4	3	5	3	5	3	5	3	3	4	4	4	4	3	2	3	4	3	1	1
24	3	4	4	5	5	5	5	5	4	3	4	5	3	5	5	5	4	4	3	4	3	5	4	5	3
25	4	2	1	4	3	3	1	3	4	1	4	3	3	2	3	2	4	2	2	3	1	3	1	2	2
26	4	2	5	4	5	5	3	5	4	2	4	3	2	2	4	4	2	1	2	3	3	2	2	2	5
27	5	5	2	5	3	4	4	3	5	5	5	5	3	3	3	4	4	3	5	4	4	3	3	3	5
28	5	5	3	5	5	4	3	5	5	4	5	4	1	3	5	4	4	3	5	4	2	5	3	2	3
29	3	5	2	2	5	3	3	5	4	1	4	4	3	1	5	3	1	1	5	1	1	1	1	1	1
30	3	3	4	5	1	1	3	1	4	5	4	4	1	1	1	4	3	3	3	1	1	1	1	1	1
31	5	2	4	5	1	1	1	2	2	1	2	4	2	1	2	4	3	2	2	2	3	4	4	2	2
32	5	3	4	5	5	5	5	5	5	5	5	5	5	4	5	5	5	3	5	1	2	4	3	4	4
33	5	5	1	5	4	4	3	4	5	4	5	5	4	2	4	5	5	5	4	4	2	4	4	5	1
34	5	4	4	5	5	4	1	5	5	5	5	4	2	1	5	5	4	3	5	2	2	2	4	1	1
35	2	5	3	5	5	4	3	5	4	2	4	2	1	3	5	4	4	2	5	1	1	3	2	2	2
36	3	5	2	3	4	3	5	4	3	3	3	3	3	3	4	3	3	3	4	4	4	4	3	2	2
37	4	3	3	3	2	2	4	2	4	2	4	4	2	2	2	2	4	4	2	3	3	3	3	3	3
38	5	5	3	5	5	2	3	5	5	4	5	4	1	3	5	4	4	3	5	4	2	5	3	2	3
39	5	4	4	5	5	4	1	5	5	5	5	5	1	3	5	5	4	4	5	4	2	5	4	2	2
40	5	5	3	5	5	4	3	5	5	4	5	4	1	3	4	4	4	3	5	4	2	5	3	2	3
41	4	4	2	5	5	5	5	5	4	3	4	5	3	5	4	5	4	4	3	4	3	5	4	5	3
42	5	5	3	5	5	4	3	5	5	4	5	4	1	3	5	4	4	3	5	4	2	5	3	2	3
43	5	5	2	5	4	2	5	4	3	5	3	5	3	5	4	4	4	4	5	4	4	4	4	2	2
44	4	4	1	4	4	4	4	4	5	4	5	4	4	4	4	4	4	1	1	1	4	4	4	4	1
45	4	4	4	4	4	4	1	4	2	4	2	4	3	3	4	3	3	4	3	3	3	3	3	4	4
46	5	5	3	5	3	5	5	3	4	4	4	4	5	5	3	5	5	2	3	3	3	5	5	3	2
47	5	5	3	5	5	4	3	5	5	4	5	4	1	3	5	4	4	3	5	4	2	5	3	2	3
48	4	5	1	5	4	1	4	4	3	3	3	3	1	1	4	1	1	1	1	2	2	1	3	1	1
49	4	4	2	4	4	2	5	4	4	3	4	5	5	5	4	5	5	5	5	4	4	4	4	4	0
50	5	4	3	5	5	3	1	5	5	5	5	5	1	3	5	5	4	4	5	4	2	5	4	2	2
51	3	4	2	5	5	2	5	5	4	3	4	5	3	5	5	5	4	4	3	4	3	5	4	5	3
52	5	4	4	5	5	4	1	5	5	5	5	5	1	3	5	5	4	4	5	4	2	5	4	2	2
53	4	4	4	5	5	3	5	5	4	4	4	5	3	5	5	5	4	4	3	4	3	5	4	5	3
54	5	5	3	5	5	2	3	5	5	4	5	4	1	3	5	4	4	3	5	4	2	5	3	2	3
55	5	4	4	5	5	4	1	5	5	5	5	5	1	3	5	5	4	4	5	4	2	5	4	2	2
56	5	5	3	5	5	4	3	5	5	4	5	4	1	3	5	4	4	3	5	4	2	5	3	2	3

Note 5 Major waste cause 4 Significant waste cause 3 Quite a waste cause 2 Insignificant waste cause 1 Not a waste cause No response

Study on Material Wastage of 40/60 Condominium Construction Sites

Computation of Relative Weight and Rank for the Contractors Response on part 3

Group	Design			Procurement				Handling and Storage				Operation				Site management			Site Supervision				Others			
Cause	D1	D3	D4	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O5	O6	SM2	SM3	SM5	SS1	SS2	SS3	SS4	O1	O3	
Frequency of scoring (f)	1	6	1	1	14	4	5	28	4	4	3	4	2	5	21	1	8	6	4	4	3	6	5	5	6	29
	2	7	2	7	11	29	8	4	9	7	5	25	4	7	9	6	10	4	9	4	9	2	3	9	31	15
	3	7	5	12	6	9	9	6	22	9	5	7	6	5	6	4	6	20	25	11	8	7	6	7	5	9
	4	23	13	9	15	6	25	5	16	30	24	8	15	33	2	16	31	7	14	9	21	12	26	17	10	1
	5	13	35	27	9	7	9	13	5	6	19	11	29	6	16	29	1	19	4	28	15	29	16	18	4	1
$\Sigma(f^s)$	198	247	222	159	148	193	139	177	195	219	162	233	196	145	234	175	197	173	221	204	224	213	202	143	95	
RW	3.54	4.41	3.96	2.84	2.64	3.45	2.48	3.16	3.48	3.91	2.89	4.16	3.5	2.59	4.18	3.13	3.52	3.09	3.95	3.64	4	3.8	3.61	2.55	1.7	
Rank	11	1	5	20	21	15	24	16	14	7	19	3	13	22	2	17	12	18	6	9	4	8	10	23	25	

Mortar																										
Group	Design			Procurement				Handling and Storage				Operation				Site management			Site Supervision				Others			
Cause	D1	D3	D4	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O5	O6	SM2	SM3	SM5	SS1	SS2	SS3	SS4	O1	O3	
Frequency of scoring (f)	1	18	6	5	5	4	20	5	1	2	16	1	3	28	0	11	3	2	4	7	6	7	7	5	33	
	2	22	4	10	27	28	10	6	8	4	8	11	3	11	7	4	5	6	10	10	9	4	12	12	14	
	3	4	5	6	7	7	8	6	5	3	10	5	5	13	4	6	10	8	11	8	7	24	7	9	30	3
	4	6	23	21	7	10	30	4	34	15	22	13	17	19	4	18	5	9	17	29	31	16	12	27	7	5
	5	4	18	14	9	5	4	20	4	33	14	10	30	9	8	25	26	31	20	5	1	1	26	1	1	1
$\Sigma(f^s)$	118	211	197	153	147	188	166	192	243	206	155	240	185	118	229	199	228	215	189	177	165	214	171	152	95	
RW	2.11	3.77	3.52	2.73	2.63	3.36	2.96	3.43	4.34	3.68	2.77	4.29	3.3	2.11	4.09	3.55	4.07	3.84	3.38	3.16	2.95	3.82	3.05	2.71	1.7	
Rank	23	7	10	20	22	13	17	11	1	8	19	2	14	23	3	9	4	5	12	15	18	6	16	21	25	

Reinforcement Bar																										
Group	Design			Procurement				Handling and Storage				Operation				Site management			Site Supervision				Others			
Cause	D1	D3	D4	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O5	O6	SM2	SM3	SM5	SS1	SS2	SS3	SS4	O1	O3	
Frequency of scoring (f)	1	0	1	1	6	1	6	15	4	7	27	15	27	12	8	14	7	4	11	3	6	1	2	4	8	10
	2	0	3	5	16	5	6	6	6	31	14	7	7	17	16	9	12	21	10	9	19	23	6	4	11	14
	3	11	9	10	19	27	8	20	8	6	10	12	10	10	5	17	19	6	20	6	4	18	11	5	16	11
	4	21	26	11	8	13	15	7	22	6	2	11	3	8	24	11	10	14	8	29	24	11	31	18	20	21
	5	24	17	29	7	10	21	7	16	5	2	11	8	8	3	5	7	11	7	9	3	2	6	25	0	0
$\Sigma(f^s)$	237	223	230	162	194	207	150	208	136	103	164	123	148	166	152	163	175	158	200	167	155	201	224	158	155	
RW	4.23	3.98	4.11	2.89	3.46	3.7	2.68	3.71	2.43	1.84	2.93	2.2	2.64	2.96	2.71	2.91	3.13	2.82	3.57	2.98	2.77	3.59	4	2.82	2.77	
Rank	1	4	2	15	9	6	21	5	23	25	13	24	22	12	20	14	10	16	8	11	18	7	3	16	18	

HCB																										
Group	Design			Procurement				Handling and Storage				Operation				Site management			Site Supervision				Others			
Cause	D1	D3	D4	P1	P2	P3	P4	H1	H2	H3	H4	O1	O2	O3	O5	O6	SM2	SM3	SM5	SS1	SS2	SS3	SS4	O1	O3	
Frequency of scoring (f)	1	0	0	4	1	2	6	12	1	2	7	0	0	25	9	1	1	5	6	5	8	6	6	3	8	13
	2	1	4	11	2	4	13	5	6	2	5	2	2	6	7	6	5	5	8	8	10	26	3	5	29	18
	3	7	7	22	2	6	13	20	4	7	7	6	8	13	25	4	4	5	22	10	11	12	8	21	5	20
	4	18	18	15	8	15	19	8	15	18	19	19	26	6	5	21	25	35	17	7	25	10	12	22	8	2
	5	30	27	4	43	29	5	11	30	27	18	29	20	5	9	24	21	6	3	26	1	1	27	5	5	2
$\Sigma(f^s)$	245	236	172	258	233	172	169	235	234	204	243	232	125	163	229	228	200	171	209	166	139	219	189	138	127	
RW	4.38	4.21	3.07	4.61	4.16	3.07	3.02	4.2	4.18	3.64	4.34	4.14	2.23	2.91	4.09	4.07	3.57	3.05	3.73	2.96	2.48	3.91	3.38	2.46	2.27	
Rank	2	4	16	1	7	16	19	5	6	13	3	8	25	21	9	10	14	18	12	20	22	11	15	23	24	

Study on Material Wastage of 40/60 Condominium Construction Sites

Consultants Response on Part 4 (Waste Minimization Measures)

Level of contribution of waste minimization measures

Respondents	Concrete															
	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16
1	4	3	3	5	4	5	5	5	5	4	4	5	3	4	1	2
2	5	4	4	4	3	4	4	4	4	4	2	5	4	3		
3	4	2	3	4	4	4	5	5	5	5	5	4	4	4	1	4
4	4	3	4	5	2	5	5	5	5	4	4	5	4	4	2	4
5	5	5	5	5	4	5	5	3	5	5	5	5	5	5	4	4
6	5	3	3	4	4	4	4	4	2	4	1	4	4	4	3	2
7	5	2	5	5	5	5	4	4	4	4	4	5	4	5	2	2
8	4	2	2	4	1	4	1	2	4	5	2	3	3	2	1	
9	3	5	3	2	3	4	2	5	3	1	2	5	1	4	1	1
10	4	4	5	3	5	4	4	5	3	2	2	5	5	4	5	2
11	4	3	4	2	5	4	4	3	3	5	5	4	4	3	2	2
12	5	2	3	5	3	5	5	5	5	5	5	5	4	4	3	2
13	2	2	3	5	5	5	2	3	4	3	4	4	2	1	4	4
14	5	3	4	4	4	5	5	5	3	5	5	4	4	4	1	4
15	5		4	5	3	5	5	5	5	5	5	5	4	4	3	2
16	5	3	4	4	4	5	5	5	3	5	5	4	4	4	1	4
17	5	2	4	5	3	5	5	5	5	5	5	5	4	4	2	2
18	4	1	2	4	3	2	2	2	1	3	1	3	4	4	1	3
19	5	2	5	5	4	4	4	3	4	4	5	5	4	4	3	4
20	5	3	4	4	4	5	5	5	3	5	5	4	4	4	1	4
21	4	4	3	4	4	4	3	4	4	2	4	4	3	4	4	4
22	5	3	4	4	4	5	5	5	3	5	5	4	4	4	1	4
23	5	3	3	5	3	5	5	5	5	5	5	4	4	4	2	2
24	5	3	4	4	4	5	5	5	3	5	5	4	4	4	1	4
25	5	3	4	5	3	5	5	5	5	5	5	5	4	4	3	2

Respondents	Mortar															
	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16
1	4	2	3	3	3	5	3	4	3	4	2	3	5	3	5	4
2	4	3	4	4	4	5	4	3	3	3	3	4	4	4	1	3
3	5	2	3	3	2	4	3	3	2	4	5	5	3	2	1	2
4	4	3	4	3	3	5	4	4	4	4	4	5	5	3	5	4
5	3	2	3	3	3	5	4	3	5	5	3	5	5	4	5	4
6	4	1	4	3	3	4	4	2	4	4	4	4	4	3	3	2
7	4	3	2	4	3	4	4	4	3	4	3	4	5	3	5	3
8	5	1	1	2	2	3	5	5	4	3	1	5	4	4	1	1
9	4	3	3	2	3	3	5	3	2	4	3	5	5	3	1	
10	5	4	1	2	5	5	4	3	3	3	4	4	4	4	5	4
11	3		4	3	4		4	4	4	5	4	4	3	3	1	2
12	4	3	3	3	4	4	3	4	3	4	5	5	4	2	4	3
13	3	5	4	2	3	4	3	4	4	4	2	4	3	2	4	4
14	3	4	2	5	4	5	5	3	4	5	4	5	4	3		3
15	4	3	3	3	4	4	5	4	4	3	3	5	4	4	4	4
16	5	4	3	3	4	5	3	3	4	5	4	5	4	3	1	3
17	4	3	4	3	4	5	5	4	3	4	4	5	4	3	2	2
18	4	3	1	2	2	5	3	4	4	3	2	5	5	1	2	3
19	3	3	3	5	4	5	4	5	5	4	5	4	4	5	4	4
20	5	2	2	2	4	5	5	3	5	5	5	5	4	3	1	3
21	4	2	4	4	4	4	4	4	4	3	4	4	3	4	3	3
22	3	4	4	4	4	5	5	4	4	5	5	5	4	3	1	3
23	4	3	2	3	4	4	5	3	3	4	5	5	4	4	3	3
24	5	4	2	4	4	5	5	3	4	4	5	5	4	3	1	3
25	4	3	3	2	4	5	5	4	3	5	5	5	4	5	2	2

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Respondents	Reinforcement Bar															
	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16
1	5	5	5	4	4	4	4	4	4	3	3	4	5	5	5	4
2	1	4	4	5	4	3	4	5	4	2	4	1	4	4	4	4
3	3	4	4	5	2	4	2	5	3	2	4	3	4	4	2	4
4	5	5	5	2	5	5	5	4	5	3	3	5	5	4	4	3
5	3	5	5	5	5	5	5	5	4	5	5	4	4	5	5	4
6	2	4	4	5	3	3	4	4	4	1	4	3	4	2	4	4
7	4	5	5	5	5	5	4	5	5	4	4	5	5	4	4	4
8	1	3	1	4	1	3	3	2	2	2	5	1	1	1	3	5
9	1	5	3	4	3	5	1	5	2	2	1	2	3	5	4	3
10	4	5	4	4	4	4	4	4	3	2	2	3	5	3	5	5
11	1	5	5	5	4	3	4	5	3	5	5	4	5	3	4	3
12	5	5	5	5	3	4	3	5	5	5	5	4	3	4	3	5
13	5	5	5	4	3	1	2	2	4	5	4	3	5	2	4	3
14	5	5	5	5	4	3	4	4	2	4	5	5	5	5	4	3
15	4	5	5	5	3	5	3	5	5	5	5	4	3	5	3	5
16	5	5	5	5	4	3	4	4	4	4	5	5	5	5	4	3
17	5	5	5	5	3	5	3	5	5	5	5	4	3	5	3	5
18	2	5	1	2	3	3	2	1	1	2	2	3	2	1	5	4
19	4	5	4	5	5	4	4	5	5	5	4	4	4	2	4	1
20	4	5	5	5	4	3	4	4	4	4	5	5	5	5	4	3
21	5	4	4	4	4	4	3	4	4	4	4	2	4	4	3	4
22	5	5	5	5	4	3	4	4	4	4	5	4	5	5	4	3
23	5	5	5	5	3	5	3	5	5	5	5	4	3	5	3	5
24	4	5	5	5	4	3	4	4	4	4	5	3	5	5	4	3
25	5	5	5	5	3	4	3	5	5	5	5	4	3	5	5	5

Respondents	HCB															
	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16
1	2	5	4	3	5	3	5	5	4	5	5	5	4	4	3	3
2	1	4	5	3	3	4	3	2	3	2	4	2	4	3	4	3
3	2	5	2	3	3	4	3	2	3	4	2	2	3	3	4	2
4	2	5	3	3	5	3	4	5	4	4	4	5	5	4	3	5
5	4	4	2	5	5	5	4	5	5	5	5	5	3	5	3	3
6	3	4	4	5	5	4	4	4	5	2	4	1	2	3	4	4
7	5	5	5	5	5	5	4	5	4	4	4	4	5	5	4	5
8	1	5	4	5	5	4	3	3	4	4	4	1	4	1	3	1
9	2	3	4	5	5	4	4	2	5	2	5	2	3	3	3	3
10	5	5	3	4	4	4	4	3	3	2	2	4	5	5	5	5
11	2	5	2	4	4	4	4	4	4	5	5	4	4	4	3	3
12	4	4	3	4	5	5	4	5	4	5	4	4	4	4	4	5
13	4	5	3	2	2	1	5	5	5	5	4	2	5	3	3	5
14	2	5	4	5	5	4	4	5	5	4	4	5	2	4	3	5
15	4	3	5	4	5	5	5	5	4	5	5	4	5	4	4	5
16	2	5	4	5	5	4	4	5	5	4	4	5	4	4	3	5
17	4	3	5	4	5	5	5	5	4	5	4	4	4	4	4	5
18	2	1	4	2	1	4	1	4	3	1	1	5	3	4	2	2
19	4	4	3	5	5	4	4	5	5	5	4	4	5	3	4	4
20	2	5	2	5	5	4	4	5	5	5	4	5	5	4	3	4
21	4	4	4	4	4	4	4	4	4	4	4	4	4	3	3	4
22	2	5	4	5	5	4	4	5	5	4	4	5	5	4	3	4
23	4	3	2	4	5	5	5	5	4	5	5	4	4	4	4	5
24	2	5	3	5	5	4	4	5	5	4	4	5	3	4	3	3
25	4	3	2	4	5	5	4	5	4	5	5	4	5	4	4	5

Note 1 Very low contribution 3 Medium contribution 5 Very high contribution
 2 Low contribution 4 High contribution No response

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Current level of practice of waste minimization measures

Respondents	Concrete															
	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16
1	5	3	5	3	4	3	3	3	4	1	5	5	3	5	4	4
2	4	5	5	5	5	3	3	2	4	2	4	4	4	3	3	2
3	4	5	5	5	4	4	4	3	5	5	5	4	2	3	2	3
4	5	3	5	3	4	3	4	3	4	2	2	5	3	4	5	4
5	3	4	5	5	4	4	4	3	4	2	3	3	3	4	2	2
6	4	4	3	4	3	3	3	4	3	2	3	4	3	3	2	2
7	3	3	4	3	4	4	3	3	3	2	2	2	3	3	3	3
8	1	1	2	3	3	3	4	2	1	1	1	2	3	4	1	1
9	3	3	4	3	5	3	3	3	3	2	2	3	2	4	2	2
10	5	5	5	4	4	3	2	3	3	1	1	2	3	3	3	2
11	3	5	5	4	3	3	3	2	2	2	2	1	3	3	3	2
12	2	1	4	2	3	2	2	3	3	1	1	1	1	3	2	2
13	3	5	4	4	4	3	3	2	3	1	1	1	2	4	2	1
14	4	3	4	2	4	3	3	2	2	2	2	2	3	4	1	1
15	2	1	4	2	3	2	2	3	3	1	1	1	1	2	2	2
16	4	3	4	2	4	3	3	3	2	2	2	2	3	4	1	1
17	2	4	4	2	3	2	3	3	1	1	1	1	1	2	2	2
18	5	1	1	4	2	3	1	2	1	2	4	1	1	1	1	1
19	1	2	2	2	2	2	2	2	1	1	1	1	2	2	2	2
20	4	3	4	2	4	3	3	3	2	2	2	2	3	4	1	1
21	3	4	4	4	4	2	2	4	4	4	2	3	3	4	4	4
22	4	3	4	2	4	3	3	2	2	2	2	2	3	4	1	1
23	2	1	4	2	3	2	2	3	3	1	1	1	1	2	2	2
24	4	3	4	2	4	3	3	2	2	2	2	2	3	4	1	1
25	2	1	4	2	3	2	2	3	3	1	1	1	1	2	2	2

Respondents	Mortar															
	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16
1	3	3	4	2	4	3	3	4	3	2	4	3	4	4	4	4
2	4	2	4	3	5	3	4	3	3	2	5	4	4	4	3	2
3	4	4	4	3	3	3	3	3	2	2	2	4	4	4	3	2
4	3	3	4	2	4	4	3	2	2	3	4	3	4	4	4	4
5	3	4	4	4	4	4	4	3	3	3	2	3	3	4	3	2
6	4	4	3	4	3	4	3	4	3	2	3	4	3	3	4	2
7	3	3	4	3	4	3	3	3	3	3	2	2	3	3	3	3
8	1	1	2	3	3	3	4	4	2	1	1	2	3	2	3	1
9	3	3	4	3	5	3	3	2	3	2	3	1	2	4	2	2
10	5	5	5	4	4	2	3	2	3	2	2	2	3	3	3	3
11	1	5	5	4	3	3	3	3	3	2	2	1	2	3	3	1
12	2	1	2	2	3	2	2	3	3	1	1	1	1	2	4	1
13	3	4	4	4	4	3	3	4	3	1	1	1	2	3	2	1
14	4	3	4	2	4	3	3	2	2	2	2	2	2	4	3	1
15	2	1	2	2	3	2	3	3	3	1	1	1	1	2	2	1
16	4	3	4	2	4	2	3	2	2	2	2	2	2	4	3	1
17	2	1	2	2	3	2	3	2	3	1	1	1	1	2	3	1
18	5	2	5	2	3	2	2	3	2	4	2	2	4	2	2	4
19	1	2	2	2	2	2	2	2	2	1	1	1	2	2	3	2
20	4	3	4	2	4	3	2	3	4	2	2	2	2	4	3	1
21	3	4	4	4	4	2	2	4	4	4	1	3	3	4	4	4
22	4	3	4	2	4	3	3	2	4	2	2	2	2	4	3	1
23	2	1	2	2	3	2	2	3	3	1	1	1	1	2	3	1
24	4	3	4	2	4	3	3	3	2	2	2	2	2	4	2	1
25	2	1	2	2	3	2	3	3	1	1	1	1	1	2	3	1

Computation of Relative Weight and Rank for the Consultant's Response on Part 4 (Waste Minimization Measures)

Level of contribution of waste minimization measures

Concrete																	
Question	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16	
Frequency of scoring (f)	1	0	1	0	0	1	0	1	0	1	1	2	0	1	1	10	1
	2	1	7	2	2	1	1	3	2	1	2	4	0	1	1	5	10
	3	1	11	8	1	8	0	1	4	8	2	0	2	3	2	5	1
	4	8	3	11	11	11	9	6	4	6	6	5	11	18	19	3	11
	5	15	2	4	11	4	15	14	15	9	14	14	12	2	2	1	0
$\Sigma(f*s)$	112	70	92	106	91	113	104	107	96	105	100	110	94	95	52	68	
RW	4.48	2.8	3.68	4.24	3.64	4.52	4.16	4.28	3.84	4.2	4	4.4	3.76	3.8	2.08	2.72	
Rank	2	14	12	5	13	1	7	4	9	6	8	3	11	10	16	15	

Mortar																	
Question	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16	
Frequency of scoring (f)	1	0	2	3	0	0	0	0	0	0	1	0	0	1	9	1	
	2	0	5	5	7	3	0	0	1	2	0	3	0	0	3	3	5
	3	6	11	9	11	7	2	6	10	8	6	5	1	4	12	3	11
	4	13	5	8	5	14	8	9	12	12	12	8	8	15	7	4	7
	5	6	1	0	2	1	14	10	2	3	7	8	16	6	2	5	0
$\Sigma(f*s)$	100	70	72	77	88	108	104	90	91	101	94	115	102	81	65	72	
RW	4	2.8	2.88	3.08	3.52	4.32	4.16	3.6	3.64	4.04	3.76	4.6	4.08	3.24	2.6	2.88	
Rank	6	15	13	12	10	2	3	9	8	5	7	1	4	11	16	13	

Reinforcement Bar																	
Question	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16	
Frequency of scoring (f)	1	4	0	2	0	1	1	1	1	1	1	2	1	2	0	1	
	2	2	0	0	2	1	0	3	2	3	6	3	1	1	3	1	0
	3	2	1	1	0	9	10	7	0	3	2	2	6	6	2	6	9
	4	6	4	6	6	10	7	12	10	10	7	6	11	6	6	13	8
	5	11	20	16	17	4	7	2	12	8	9	13	5	11	12	5	7
$\Sigma(f*s)$	93	119	109	113	90	94	86	105	96	92	102	91	100	98	97	95	
RW	3.72	4.76	4.36	4.52	3.6	3.76	3.44	4.2	3.84	3.68	4.08	3.64	4	3.92	3.88	3.8	
Rank	12	1	3	2	15	11	16	4	9	13	5	14	6	7	8	10	

HCB																	
Question	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16	
Frequency of scoring (f)	1	2	1	0	0	1	1	1	0	0	1	1	2	0	1	0	1
	2	11	0	6	2	1	0	0	3	0	4	2	3	3	0	1	2
	3	1	5	6	4	2	2	3	2	4	0	0	0	4	6	14	6
	4	9	6	9	8	3	15	16	4	11	9	15	9	10	14	9	5
	5	2	13	4	11	18	7	5	16	10	11	6	10	8	4	1	11
$\Sigma(f*s)$	73	105	86	103	111	102	99	108	106	100	95	94	98	95	85	98	
RW	2.92	4.2	3.44	4.12	4.44	4.08	3.96	4.32	4.24	4	3.8	3.76	3.92	3.8	3.4	3.92	
Rank	16	4	14	5	1	6	8	2	3	7	11	13	9	11	15	9	

Current level of practice of waste minimization measures

Concrete																	
Question	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16	
Frequency of scoring (f)	1	2	6	1	0	0	0	1	0	3	10	9	9	6	1	7	8
	2	5	1	2	11	2	6	8	9	6	13	10	8	4	5	11	12
	3	6	9	1	5	8	15	12	14	10	0	2	3	14	7	4	2
	4	8	3	14	6	13	3	4	2	5	1	2	3	1	11	2	3
	5	4	5	7	3	2	0	0	0	1	1	2	2	0	1	1	0
$\Sigma(f*s)$	82	72	99	76	90	69	69	68	70	45	53	56	60	81	54	50	
RW	3.28	2.88	3.96	3.04	3.6	2.76	2.76	2.72	2.8	1.8	2.12	2.24	2.4	3.24	2.16	2	
Rank	3	6	1	5	2	8	8	10	7	16	14	12	11	4	13	15	

Mortar																	
Question	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16	
Frequency of scoring (f)	1	3	6	0	0	0	0	0	0	8	9	9	5	0	0	13	
	2	5	3	7	14	1	10	6	8	7	12	11	9	9	8	5	6
	3	7	9	1	5	10	12	15	12	14	3	2	4	6	5	15	2
	4	8	5	14	6	12	3	3	5	3	2	2	3	5	12	5	4
	5	2	2	3	0	2	0	0	0	0	0	1	0	0	0	0	0
$\Sigma(f*s)$	76	69	88	67	90	68	69	72	68	49	50	51	61	79	75	47	
RW	3.04	2.76	3.52	2.68	3.6	2.72	2.76	2.88	2.72	1.96	2	2.04	2.44	3.16	3	1.88	
Rank	4	7	2	11	1	9	7	6	9	15	14	13	12	3	5	16	

Reinforcement Bar																	
Question	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16	
Frequency of scoring (f)	1	1	5	0	0	0	0	1	0	0	8	9	10	5	0	3	6
	2	6	1	3	13	2	7	6	13	11	13	9	7	4	8	4	9
	3	7	12	9	3	9	8	10	6	9	3	5	6	12	5	15	6
	4	8	4	12	5	12	9	6	4	3	1	2	1	1	11	2	1
	5	3	3	1	4	2	1	2	2	1	0	0	1	3	1	1	2
$\Sigma(f*s)$	81	74	86	75	89	79	77	70	66	47	50	51	68	80	69	56	
RW	3.24	2.96	3.44	3	3.56	3.16	3.08	2.8	2.64	1.88	2	2.04	2.72	3.2	2.76	2.24	
Rank	3	8	2	7	1	5	6	9	12	16	15	14	11	4	10	13	

HCB																	
Question	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16	
Frequency of scoring (f)	1	0	0	2	1	0	0	0	1	0	4	2	9	3	0	4	5
	2	3	9	2	10	12	1	8	11	13	4	13	10	10	8	16	15
	3	19	11	6	11	9	13	8	11	9	15	5	3	4	6	3	3
	4	3	3	10	3	4	10	6	2	2	0	0	2	3	11	2	2
	5	0	1	5	0	0	1	3	0	0	1	5	1	5	0	0	0
$\Sigma(f*s)$	75	68	89	66	67	86	79	64	61	62	68	51	72	78	53	52	
RW	3	2.72	3.56	2.64	2.68	3.44	3.16	2.56	2.44	2.48	2.72	2.04	2.88	3.12	2.12	2.08	
Rank	5	7	1	10	9	2	3	11	13	12	7	16	6	4	14	15	

Response of Consultants on the Additional questions

Respondents	Question		
	4.2	4.3	4.4
1	1	4	3
2	1 3	4	3
3	1	4	3
4	1	4	3
5	1	2	2
6	1 2	3	2
7	1 2	3	2
8	1	3	2
9	1	2	2
10	1 3	3	2
11	1 2	3	2
12	1 2	3	3
13	1	3	2
14	1 2	3	2
15	1 2	3	2
16	1 2	3	3
17	1	4	3
18	1	4	3
19	1	4	2
20	1 2	4	2
21	1 2	4	3
22	1	3	2
23	1	3	2
24	1	4	2
25	1	4	1

Note

For Question 4.2

- 1 Correcting detailing problems on the design drawing
- 2 Material selection to reduce waste
- 3 Dimensional coordination and standardization

For Question 4.3

- 1 1 person for 1 block
- 2 1 person for 2 blocks
- 3 1 person for 3 blocks
- 4 1 person for 4 blocks

For Question 4.4

- 1 Yes, because assigning more than the above number of site supervisors is not necessary
- 2 Yes, because the blocks are identical
- 3 No, but we have lack of site supervisors

Contractors Response on Part 4 (Waste Minimization Measures)

Study on Material Wastage of 40/60 Condominium Construction Sites

Level of contribution of waste minimization measures

Respondents	Concrete															
	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16
1	4	1	3	5	3	1	3	1	1	5	1	5	5	5	2	4
2	4	2	4	4	3	5	5	3	4	2	3	4	4	3	3	1
3	4	2	4	4	4	5	5	5	1	4	5	5	3	4	3	1
4	4	4	4	4	4	4	4	3	4	2	4	4	5	5	4	4
5	4	3	4	4	5	5	5	4	1	5	5	5	3	4	3	1
6	5	3	3	4	4	5	5	5	5	4	4	5	5	5	3	3
7	4	4	4	4	4	4	5	4	3	3	3	3	3	4	4	4
8	1	1	3	4	5	5	5	1	4	5	1	1	3	1	1	1
9	3	3	3	4	3	3	3	3	3	4	3	4	4	4	3	3
10	5	2	4	5	4	4	5	4	3	4	3	5	5	5	4	4
11	5	3	5	5	4	5	4	3	3	5	4	5	5	5	1	1
12	4	3	4	4	4	5	5	5	1	4	5	5	3	4	3	1
13	5	4	4	5	4	5	5	4	5	5	5	5	5	4	5	5
14	3	2	3	2	2	3	3	3	3	3	3	2	3	2	2	2
15	3	2	3	2	3	2	3	3	3	4	3	2	3	3	1	1
16	5	2	5	4	3	5	5	3	5	5	5	4	4	5	1	2
17	4	2	4	4	5	5	5	4	1	5	5	5	3	4	3	1
18	5	4	4	5	4	5	5	5	5	3	5	5	5	4	5	5
19	4	3	2	4	2	2	4	2	5	4	2	2	5	2	1	3
20	5	2	3	5	3	3	4	4	4	3	2	5	5	2	2	2
21	4	3	4	4	4	5	5	5	1	5	5	5	3	4	3	1
22	4	4	4	4	4	5	5	5	1	4	5	5	3	4	3	1
23	3	5	5	5	5	5	4	4	3	5	5	5	5	4	5	5
24	5	5	4	5	4	5	5	5	5	4	5	5	5	4	5	5
25	4	2	4	4	3	2	5	3	3	4	2	3	5	5	3	1
26	3	2	4	4	4	2	4	3	3	3	3	3	5	4	2	4
27	5	2	5	5	5	5	5	5	5	5	5	5	5	5	4	4
28	4	2	4	4	4	5	5	5	1	4	5	5	3	4	3	1
29	4	3	4	3	5	5	4	3	5	3	5	3	4	5	4	4
30	4	3	4	4	4	2	5	2	2	4	1	3	3	4	1	2
31	4	1	4	5	4	1	4	2	4	5	5	3	5	3	1	1
32	1	3	3	4	4	5	3	5	1	3	5	3	2	4	3	4
33	4	2	4	5	5	5	5	5	3	5	5	5	5	3	5	4
34	4	1	4	4	4	5	5	5	1	4	5	5	3	4	3	1
35	1	1	3	4	2	4	5	3	5	4	1	4	4	3	5	1
36	3	3	3	3	3	3	4	4	3	5	3	3	3	3	3	3
37	4	1	2	3	2	4	2	1	4	3	4	3	1	3	2	2
38	5	2	4	4	4	5	5	5	1	4	5	5	3	4	3	1
39	5	3	4	5	4	5	5	5	5	3	5	5	5	4	5	5
40	5	2	4	4	4	5	5	5	1	4	5	5	3	4	3	1
41	5	3	4	5	5	5	5	5	5	3	5	5	5	4	5	5
42	5		4	4	4	5	5	5	1	4	5	5	3	2	3	1
43	4	4	4	5	4	4	5	2	5	5	4	5	5	5	4	4
44	2	2	4	4	4	4	4	4	4	4	2	4	5	4	4	4
45	3	4	3	4	3	3	3	4	5	4	3	4	3	4	2	3
46	5	4	5	5	5	4	5	5	1	5	5	5	5	5	1	3
47	5	2	4	4	4	5	5	5	1	4	5	5	3	4	3	
48	4	4	3	1	4	3	1	1	1	2	4	1	2	1	3	3
49	4	4	4	4	4	4	5	5	5	4	4	4	5	5	4	4
50	5	2	4	5	4	5	5	5	5	3	5	5	5	4	5	5
51	5	3	4	4	4	5	5	5	1	4	5	5	3	4	3	1
52	5	2	4	5	4	5	5	5	5	3	5	5	5	4	5	5
53	5	3	4	5	4	5	5	5	5	3	5	5	5	4	5	5
54	5	2	4	4	4	5	5	5	1	4	5	5	3	4	3	1
55	5	2	4	5	4	5	5	5	5	3	5	5	5	4	5	5
56	5	3	4	4	4	5	5	5	1	4	5	5	3	4	3	1

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Respondents	Mortar															
	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16
1	1	2	2	3	2	1	3	4	4	1	5	5	5	3	4	1
2	4	3	2	3	1	3	4	4	5	4	4	5	3	4	1	1
3	5	4	3	4	3	5	2	3	3	5	4	4	5	3	1	3
4	2	2	2	3	4	5	4	5	3	4	4	4	4	4	2	3
5	4	1	3	4	1	5	3	3	4	5	4	4	5	4	1	3
6	3	2	2	4	5	5	4	5	4	4	5	5	5	3	3	3
7	4	3	3	2	3	4	4	3	3	4	3	3	4	4	2	3
8	1	4	4	1	1	1	4	4	4	2	5	2	3	3	1	1
9	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
10	4	3	3	4	4	4	3	5	4	3	5	4	5	4	3	3
11	3	2	2	2	3	4	4	3	3	4	5	5	5	3	1	1
12	5	4	2	4	2	3	3	3	4	4	4	4	5	4	1	3
13	4	3	3	3	4	4	4	3	3	3	5	4	5	3	2	2
14	3	3	2	2	3	2	3	3	3	3	3	2	2	3	2	2
15	3	3	2	3	3	2	4	4	4	3	4	4	2	3	1	1
16	3	2	3	3	1	3	4	3	3	3	3	5	5	3	3	1
17	3	4	3	4	2	4	5	3	4	2	4	4	5	2	1	3
18	4	3	3	3	5	4	4	5	3	5	3	4	5	3	4	3
19	2	2	2	2	2	3	4	5	4	2	4	2	2	2	3	1
20	2	2	2	2	3	3	3	5	3	3	5	3	3	3	3	3
21	5	2	3	4	3	5	4	3	4	4	4	4	5	3	1	3
22	4	3	4	4	4	4	4	3	3	5	4	4	5	4	1	3
23	4	2	2	5	5	5	4	5	4	4	3	5	5	3	4	3
24	4	3	4	4	5	5	3	5	3	3	5	4	5	4	3	4
25	3	4	2	3	2	2	4	5	3	2	4	5	4	4	1	1
26	4	2	3	4	2	2	3	3	3	3	3	4	3	4	4	2
27	4	3	2	2	4	4	4	5	3	4	4	4	5	3	4	4
28	5	2	4	4	2	5	3	3	2	3	4	4	5	3	1	3
29	3	3	3	4	5	5	5	4	3	5	4	3	3	2	4	4
30	2	4	4	4	2	2	3	3	2	2	4	4	3	3	2	2
31	2	2	3	3	1	1	4	5	4	1	4	5	3	2	1	1
32	5	3	4	4	5	3	3	2	3	2	1	4	3	3	4	3
33	5	2	2	2	5	4	4	2	2	3	2	2	5	3	4	3
34	4	3	4	4	5	5	3	5	4	4	5	4	5	2	3	4
35	3	4	4	2	4	1	3	5	4	1	3	3	2	3	2	3
36	3	3	3	4	3	5	4	3	3	3	4	3	4	4	1	3
37	1	3	3	2	4	1	4	1	5	4	3	4	3	2	2	2
38	5	4	3	4	3	5	5	3	1	5	4	4	5	3	1	3
39	4	3	2	4	3	5	4	5	2	5	5	4	5	3	3	4
40	5	4	3	3	2	5	4	3	1	5	4	4	5	2	1	3
41	4	3	4	3	5	5	5	5	3	4	3	4	5	3	3	4
42	5	2	3	4	2	5	5	3	1	4	4	4	5	2	3	3
43	5	2	3	4	4	4	5	5	3	4	3	5	5	4	3	2
44	4	4	4	4	2	2	4	5	4	2	4	4	4	4	2	3
45	3	2	3	3	2	4	4	2	3	1	4	3	4	3	2	2
46	5	2	3	5	4	4	5	5	1	5	3	5	5	5	3	1
47	5	4	4	4	5	5	5	3	1	5	4	4	5	4	1	3
48	1	2	3	3	4	5	5	2	1	4	1	1	1	3	3	3
49	3	4	4	4	3	4	5	5	5	4	3	5	4	4	4	4
50	4	3	4	4	3	5	4	5	5	5	4	4	5	4	2	3
51	5	3	2	3	4	5	4	3	1	5	4	4	5	3	1	3
52	4	3	3	4	3	5	4	5	5	5	3	4	5	2	3	4
53	4	3	3	4	2	5	4	5	5	5	4	4	5	3	3	2
54	5	2	2	4	5	5	4	3	1	5	4	4	5	3	1	3
55	4	3	2	4	4	5	5	5	5	5	3	4	5	4	4	3
56	5	4	3	4	3	5	4	3	1	5	4	4	5	3	1	3

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Respondents	Reinforcement Bar															
	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16
1	4	5	5	5	3	5	1	3	2	2	1	1	4	2	5	3
2	3	5	4	4	5	5	3	4	5	4	3	3	3	3	2	2
3	4	3	5	5	3	4	2	4	4	2	3	2	5	4	5	5
4	4	5	4	4	4	4	2	4	5	4	4	5	4	4	2	4
5	4	3	5	5	3	4	3	4	4	4	5	2	5	4	5	5
6	4	5	4	5	5	5	1	3	5	5	4	5	3	5	3	4
7	4	4	4	3	3	4	4	4	4	4	3	4	3	3	3	3
8	1	5	4	3	5	4	1	5	1	3	2	1	3	3	3	1
9	3	4	4	4	3	3	3	3	4	3	3	3	3	3	4	3
10	4	5	5	5	3	5	4	4	4	4	3	3	4	4	4	4
11	4	5	5	5	4	5	3	5	5	3	4	5	1	3	5	3
12	4	3	5	5	3	4	2	4	4	4	3	2	5	4	5	5
13	5	5	5	5	5	5	3	3	5	5	5	3	4	5	3	5
14	4	4	4	4	4	4	3	3	3	4	4	2	2	4	4	2
15	3	3	2	2	3	3	3	3	3	2	3	1	3	3	3	1
16	4	5	5	5	5	5	3	5	5	3	2	2	3	5	5	3
17	4	3	5	5	3	4	5	4	4	4	5	2	5	4	5	5
18	5	5	5	5	5	5	3	3	5	3	3	3	4	5	3	5
19	4	5	3	3	4	3	2	2	2	1	3	3	3	4	2	4
20	3	5	3	3	2	5	2	5	3	4	3	4	2	3	2	3
21	5	3	5	5	3	4	4	4	4	2	5	2	5	4	5	5
22	4	4	5	5	3	4	3	4	4	4	4	2	5	4	5	5
23	5	5	5	4	3	5	4	5	5	5	5	5	5	5	3	5
24	4	5	5	5	5	5	3	3	5	5	5	3	4	5	3	5
25	5	5	4	4	5	4	3	4	5	2	2	3	1	3	4	1
26	4	5	3	4	4	3	2	4	4	2	2	3	4	3	3	2
27	5	5	5	5	5	5	2	5	5	5	5	4	4	5	5	4
28	4	3	5	5	3	4	3	4	4	4	4	2	5	4	5	5
29	4	4	4	3	4	4	3	4	4	5	5	5	3	5	3	3
30	3	3	4	3	2	3	2	4	2	3	1	2	3	2	4	2
31	1	5	5	3	4	4	2	5	5	1	1	1	1	4	5	4
32	4	5	4	3	3	3	5	3	4	3	4	3	4	4	3	4
33	4	4	3	2	4	4	2	5	3	4	2	5	5	5	4	5
34	3	5	5	5	3	5	5	3	5	2	5	3	4	5	3	5
35	2	5	3	4	5	4	3	3	4	4	1	1	4	3	4	1
36	4	3	3	3	4	3	3	4	3	3	3	2	5	3	3	5
37	2	2	3	3	3	3	1	2	3	4	4	1	2	4	3	3
38	4	3	5	5	3	4	4	4	4	4	5	2	5	4	5	5
39	3	5	5	5	4	5	2	3	5	5	5	3	4	5	3	5
40	4	4	5	5	3	4	3	4	4	4	4	2	5	4	5	5
41	3	5	5	5	5	5	2	5	5	5	5	3	4	5	3	5
42	4	3	5	5	3	4	2	4	4	4	5	2	5	4	5	5
43	4	5	5	4	5	5	3	4	5	4	4	4	4	5	5	4
44	4	5	4	4	4	4	2	4	4	4	2	2	4	4	4	4
45	3	3	4	4	2	3	3	3	3	3	1	4	2	2	4	4
46	5	5	5	5	4	5	2	5	5	4	5	4	3	4	5	1
47	4	3	5	5	3	4	3	4	4	4	5	2	5	4	5	5
48	4	3	4	4	1	1	2	3	1	3	4	3	3	1	3	3
49	4	5	4	4	3	5	3	4	5	3	4	4	4	5	4	4
50	3	5	5	5	5	5	2	3	5	5	5	3	4	5	3	5
51	4	3	5	5	3	4	2	4	4	4	5	2	5	4	5	5
52	3	5	5	5	5	5	2	5	5	2	5	3	4	5	3	5
53	3	5	5	5	3	5	3	3	5	5	5	3	4	5	3	5
54	4	3	5	5	3	4	2	4	4	4	5	2	5	4	5	5
55	4	5	5	5	5	5	1	3	5	5	5	3	4	5	3	5
56	4	3	5	5	3	4	2	4	4	4	5	2	5	4	5	5

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Respondents	HCB															
	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16
1	4	5	5	3	5	2	3	5	2	3	1	1	5	3	1	3
2	2	3	3	4	5	5	4	5	4	5	3	2	3	4	3	2
3	1	5	3	5	5	5	3	4	5	3	5	3	4	4	3	4
4	4	4	4	4	5	5	4	5	4	4	4	5	5	4	2	4
5	1	5	3	5	5	5	3	4	5	3	5	3	5	4	3	4
6	3	5	3	5	5	5	5	5	5	5	4	5	4	3	3	4
7	3	4	4	4	4	4	3	3	3	4	3	4	4	4	4	3
8	2	5	3	5	5	2	3	5	5	5	4	3	3	3	1	2
9	3	5	3	4	5	3	4	3	5	3	3	3	3	4	3	3
10	4	4	5	5	5	4	5	5	4	4	3	3	4	4	4	4
11	1	5	5	5	5	5	4	5	3	5	4	5	4	5	3	2
12	1	5	3	5	5	5	3	4	5	4	5	3	5	4	3	4
13	4	4	5	5	5	5	5	5	4	5	5	4	4	4	4	5
14	2	4	4	3	3	3	3	4	3	3	3	2	5	3	3	2
15	3	5	2	3	3	3	3	5	3	3	3	1	3	3	3	1
16	2	5	5	5	5	5	5	5	5	5	5	2	4	5	3	2
17	1	5	3	5	5	5	3	4	5	3	5	3	4	4	3	4
18	4	3	5	5	5	5	5	4	4	5	5	4	3	4	4	5
19	3	3	5	3	4	2	4	5	5	4	3	3	5	2	3	5
20	3	4	5	3	4	2	4	5	5	3	3	2	4	2	4	3
21	1	5	3	5	5	5	3	5	5	3	5	3	5	4	3	4
22	1	5	3	5	5	5	3	5	5	3	4	3	4	4	3	4
23	5	5	5	5	5	5	3	4	5	5	3	5	5	5	4	4
24	4	3	5	5	5	4	5	4	4	5	5	4	3	4	4	5
25	1	4	4	4	5	5	5	3	3	4	2	3	5	4	3	3
26	4	4	3	3	1	4	4	3	5	3	3	2	3	4	2	2
27	4	5	5	5	5	5	5	5	5	5	4	4	5	5	5	4
28	1	5	3	5	5	3	3	4	5	4	4	3	4	4	3	4
29	2	3	3	4	3	3	4	3	5	5	5	5	4	4	3	2
30	2	4	4	3	3	3	2	5	3	3	2	2	3	3	2	3
31	5	5	5	4	5	5	4	5	4	2	1	1	3	5	2	2
32	4	3	4	3	2	4	3	3	5	4	5	3	4	3	3	4
33	2	4	4	5	1	4	3	4	5	2	3	3	4	5	2	2
34	4	5	5	5	5	5	5	4	4	5	5	4	3	4	4	5
35	1	4	4	3	3	3	2	3	5	5	1	1	5	2	3	2
36	3	3	3	3	3	3	4	3	3	5	3	3	3	3	3	3
37	2	4	2	3	1	3	3	5	4	4	4	1	4	2	1	3
38	1	5	3	5	5	5	3	4	5	3	5	3	4	4	3	4
39	4	3	5	5	5	5	5	5	4	5	4	4	3	4	4	5
40	1	5	3	5	5	5	3	4	5	4	5	3	4	4	3	4
41	4	3	5	5	5	4	5	4	4	5	4	4	3	4	4	5
42	1	5	3	5	5	5	3	4	5	4	5	3	4	4	3	4
43	4	5	5	5	5	5	5	5	5	4	4	4	4	4	3	4
44	4	4	4	4	5	4	4	5	4	4	2	2	4	4	4	4
45	4	3	2	3	3	3	2	4	5	3	3	3	4	1	4	2
46	3	5	5	5	5	5	5	5	5	4	5	4	5	5	5	1
47	1	5	3	5	5	5	3	4	5	5	5	3	4	4	3	4
48	3	2	1	4	5	1	1	5	3	5	4	2	4	3	1	3
49	4	4	4	5	5	5	5	4	5	4	4	4	4	4	3	4
50	4	3	5	5	5	5	5	4	4	5	5	4	3	4	4	5
51	1	5	3	5	5	5	3	4	5	3	5	3	4	4	3	4
52	4	5	5	5	5	5	5	4	4	5	5	4	3	4	4	3
53	4	3	5	5	5	5	5	4	4	4	5	4	3	4	4	5
54	1	5	3	5	5	5	3	4	5	4	5	3	4	4	3	4
55	4	3	5	5	5	5	5	5	4	5	5	4	3	4	4	5
56	1	5	3	5	5	5	3	5	5	4	5	3	4	4	3	4

Note 1 Very low contribution 3 Medium contribution 5 Very high contribution
 2 Low contribution 4 High contribution No response

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Current level of practice of waste minimization measures

Respondents	Concrete															
	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16
1	3	1	3	3	5	5	4	5	3	2	1	1	4	3	5	2
2	4	4	4	3	4	3	5	5	4	5	1	2	4	3	1	2
3	3	2	2	2	4	3	5	3	2	1	2	2	3	3	1	1
4	3	2	4	2	3	2	4	3	3	2	2	2	1	2	2	1
5	3	2	2	2	4	3	5	3	3	1	2	2	3	4	1	1
6	3	2	2	5	4	4	4	5	4	1	2	1	1	3	1	1
7	4	2	4	3	4	2	4	4	3	4	4	2	2	3	2	2
8	3	5	3	4	4	3	3	3	2	1	2	4	1	3	1	1
9	3	3	3	2	3	3	5	3	3	2	1	2	2	2	2	2
10	3	2	2	3	4	3	3	3	3	1	1	2	2	2	1	1
11	5	5	4	4	5	4	5	4	3	2	4	3	3	3	1	1
12	3	2	2	2	4	3	3	3	2	1	2	2	3	3	1	1
13	2	1	4	2	3	2	4	3	3	1	1	1	1	2	2	2
14	3	3	3	2	3	2	2	4	2	2	2	2	2	3	2	2
15	3	3	2	2	3	3	3	3	3	2	3	1	3	3	3	1
16	5	2	2	5	4	5	5	5	5	5	5	1	4	3	2	1
17	3	2	2	2	4	3	3	3	4	1	2	2	3	3	1	1
18	2	1	4	2	3	2	5	3	3	1	1	1	1	2	2	2
19	3	1	3	3	4	2	3	4	3	3	1	2	2	3	3	1
20	3	3	3	2	3	3	3	3	4	2	2	3	3	2	3	3
21	3	2	2	2	4	3	4	3	5	1	2	2	3	2	1	1
22	3	2	2	2	4	3	4	3	4	1	2	2	3	4	1	1
23	3	2	1	2	3	4	5	3	3	3	1	1	1	3	1	1
24	2	1	4	2	3	2	4	3	3	1	1	1	1	2	2	2
25	4	2	3	4	5	5	5	4	3	2	2	2	3	3	1	1
26	4	4	4	4	5	4	4	3	3	2	4	2	4	3	4	2
27	5	4	3	4	4	4	4	3	3	2	2	2	3	5	1	1
28	3	2	2	2	4	3	3	3	5	1	2	2	3	4	1	1
29	4	5	4	3	5	4	2	2	2	1	3	3	1	3	1	1
30	4	4	4	3	3	2	3	4	3	1	2	2	3	3	2	1
31	3	2	5	3	4	4	4	4	4	1	1	1	1	3	1	1
32	3	5	4	3	2	4	3	2	3	2	2	1	3	4	5	5
33	2	3	3	3	4	2	2	4	3	1	2	2	2	3	4	2
34	3	1	2	2	3	2	3	2	2	2	2	2	3	2	1	1
35	4	4	3	3	4	3	4	5	3	4	1	1	2	2	1	1
36	3	3	3	2	3	3	4	3	3	3	3	3	3	3	3	3
37	2	2	2	2	5	4	1	2	1	1	1	1	3	1	2	1
38	3	2	2	2	4	3	3	3	2	1	2	2	3	4	1	1
39	2	1	4	2	3	5	2	3	3	1	1	1	1	2	2	2
40	3	2	2	2	4	3	5	3	2	1	2	2	3	4	1	1
41	2	1	4	2	3	4	2	3	3	1	1	1	1	2	2	2
42	3	2	2	2	4	3	3	3	2	1	2	2	3	4	1	1
43	2	1	3	2	5	4	5	2	5	2	1	1	2	2	2	1
44	4	2	4	2	2	4	4	4	4	4	2	2	4	1	1	1
45	4	2	4	3	4	3	2	3	5	2	1	4	5	3	1	2
46	5	1	3	2	5	5	5	5	4	4	5	4	5	5	3	1
47	3	2	2	2	4	3	3	3	4	1	2	2	3	4	1	1
48	2	1	2	2	3	5	5	2	3	2	2	1	3	1	1	1
49	4	2	4	4	4	4	4	4	4	3	2	3	3	3	4	3
50	2	1	4	2	3	5	2	3	3	1	1	1	1	2	2	2
51	3	2	2	2	4	3	3	3	4	1	2	2	3	4	1	1
52	2	1	1	2	3	2	2	3	3	1	1	1	1	2	2	2
53	2	1	2	2	3	2	2	3	3	1	1	1	1	2	2	2
54	3	2	2	2	4	3	3	3	4	1	2	2	3	4	1	1
55	2	1	4	2	3	2	2	3	3	1	1	1	1	2	2	2
56	3	2	2	2	4	3	3	3	4	1	2	2	3	4	1	1

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Respondents	Mortar															
	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16
1	1	5	5	5	5	5	3	5	2	2	1	1	4	3	5	3
2	3	4	4	4	4	4	4	4	4	4	1	2	3	4	3	1
3	4	2	2	2	4	3	3	3	3	1	2	2	3	3	1	1
4	2	2	4	2	1	2	3	3	3	2	2	2	1	3	2	1
5	4	2	2	2	4	3	3	3	2	1	2	2	3	3	1	1
6	4	2	2	5	4	4	4	4	4	1	2	1	1	3	1	1
7	4	2	2	3	4	4	4	3	3	1	2	2	2	3	2	2
8	4	5	3	3	3	3	3	4	2	4	1	1	1	3	5	5
9	2	3	3	3	3	3	3	3	2	2	2	2	2	3	2	2
10	2	2	2	3	4	3	3	3	3	1	1	2	2	3	1	1
11	3	5	5	4	4	4	2	3	3	2	4	3	3	5	1	1
12	4	2	2	2	4	3	3	3	2	1	2	2	3	3	1	1
13	2	1	2	2	3	4	3	3	3	1	1	1	1	2	2	2
14	3	3	2	2	3	3	3	4	3	2	2	2	2	3	2	2
15	3	3	2	2	3	3	3	3	3	2	3	2	3	3	1	1
16	3	5	5	5	4	4	5	5	5	5	5	1	3	5	2	1
17	4	2	2	2	4	3	3	3	4	1	2	2	3	3	1	1
18	2	1	2	2	3	4	2	3	3	1	1	1	1	2	2	2
19	1	1	3	3	4	3	4	4	3	2	1	2	2	3	3	2
20	2	2	3	2	3	3	3	3	3	2	3	2	3	2	2	3
21	4	2	2	2	4	3	3	3	3	1	2	2	3	3	1	1
22	4	2	2	2	4	3	3	3	2	1	2	2	3	3	1	1
23	1	2	1	2	3	4	3	3	3	3	1	1	1	3	1	1
24	2	1	2	2	3	2	3	3	3	1	1	1	1	2	2	2
25	2	3	3	4	5	5	4	4	3	2	2	2	3	4	1	1
26	3	3	3	4	4	5	4	4	4	3	3	2	4	4	4	2
27	5	5	5	4	4	4	4	3	3	2	2	2	3	5	1	1
28	4	2	2	2	4	3	3	3	4	1	2	2	3	3	1	1
29	4	5	4	5	4	4	2	3	3	1	3	3	1	4	1	1
30	2	4	4	2	3	2	3	4	3	1	2	2	3	4	2	1
31	2	5	5	3	4	5	4	4	4	1	1	1	1	3	1	1
32	4	3	4	3	2	4	3	3	3	2	2	1	3	3	4	3
33	3	3	2	3	5	3	2	2	4	4	4	2	4	4	5	5
34	2	1	2	2	3	2	3	3	3	1	1	1	1	2	2	2
35	2	4	3	2	4	4	4	5	5	4	1	1	2	4	2	2
36	3	3	3	3	3	3	4	3	3	3	3	3	3	3	3	3
37	1	3	3	3	1	3	3	2	4	2	2	1	3	3	3	2
38	4	2	2	2	4	3	3	3	2	1	2	2	3	3	1	1
39	2	1	2	2	3	2	4	3	3	1	1	1	1	2	2	2
40	4	2	2	2	4	3	3	3	4	1	2	2	3	3	1	1
41	2	1	2	2	3	2	4	3	3	1	1	1	1	2	2	2
42	4	2	2	2	4	3	3	3	2	1	2	2	3	3	1	1
43	5	5	5	2	5	5	5	5	5	4	4	4	4	4	4	4
44	1	4	4	4	5	4	4	4	4	4	2	2	4	4	4	4
45	3	2	4	1	4	3	3	2	3	2	3	4	4	3	3	3
46	5	5	5	5	5	5	5	5	4	4	5	4	5	5	3	1
47	4	2	2	2	4	3	3	3	4	1	2	2	3	3	1	1
48	1	1	2	2	3	4	4	3	3	2	2	1	4	2	1	1
49	3	4	4	4	4	4	4	4	4	3	2	3	3	4	4	3
50	2	1	2	2	3	2	2	3	3	1	1	1	1	2	2	2
51	4	2	2	2	4	3	3	3	4	1	2	2	3	3	1	1
52	2	1	2	2	3	2	3	3	3	1	1	1	1	2	2	2
53	2	1	2	2	3	2	2	3	3	1	1	1	1	2	2	2
54	4	2	2	2	4	3	3	3	4	1	2	2	3	3	1	1
55	2	1	2	2	3	2	4	3	3	1	1	1	1	2	2	2
56	4	2	2	2	4	3	3	3	4	1	2	2	3	3	1	1

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Respondents	Reinforcement Bar															
	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16
1	5	5	3	5	5	1	3	5	2	2	1	1	4	3	1	1
2	5	4	3	4	4	4	5	4	3	3	1	2	3	4	3	2
3	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
4	2	2	3	2	1	2	3	4	2	2	2	2	1	3	2	1
5	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
6	3	2	5	5	4	4	4	2	4	1	2	1	1	3	4	3
7	2	3	4	3	4	3	3	4	3	4	4	2	1	2	4	2
8	1	3	4	4	4	3	4	3	4	1	2	1	1	3	2	1
9	2	3	2	3	4	3	2	3	2	2	2	2	2	3	3	2
10	1	2	3	3	4	3	3	2	3	1	1	2	2	3	2	1
11	2	5	4	4	5	4	3	5	3	3	4	3	3	5	3	2
12	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
13	3	1	2	2	3	2	2	4	2	1	1	1	1	2	2	2
14	2	5	3	4	4	4	3	4	3	3	3	2	2	3	3	2
15	3	3	3	2	3	3	3	2	3	2	3	1	3	3	3	1
16	3	5	3	5	4	5	5	5	5	5	5	2	3	1	3	1
17	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
18	3	1	2	2	3	2	2	4	2	1	1	1	1	2	2	2
19	3	1	3	3	4	2	3	3	3	2	1	2	2	3	1	5
20	2	2	3	3	2	3	2	3	4	3	2	2	3	2	2	3
21	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
22	4	2	2	2	4	3	3	2	2	1	2	2	3	3	4	1
23	1	2	3	2	3	4	3	1	3	3	1	1	1	3	1	1
24	3	1	2	2	3	2	2	4	2	1	1	1	1	2	2	2
25	1	4	4	4	5	5	5	3	3	2	2	3	3	4	3	1
26	4	2	3	4	4	4	4	4	3	2	3	3	4	4	3	2
27	3	5	3	4	4	4	4	5	3	2	2	3	3	5	5	3
28	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
29	1	4	3	4	4	5	1	4	2	1	3	1	1	4	5	
30	2	4	3	2	3	2	4	4	2	1	2	2	4	4	2	2
31	1	5	4	3	4	5	4	5	4	1	1	1	1	3	2	1
32	4	3	3	3	5	5	3	5	4	2	2	1	3	3	4	5
33	4	1	3	2	2	5	3	4	5	1	1	3	1	1	2	4
34	3	1	2	2	3	2	2	4	2	1	1	1	1	2	2	2
35	2	4	4	3	5	3	5	3	4	5	1	1	2	4	3	1
36	4	3	3	3	3	3	4	3	3	3	3	2	3	3	3	1
37	2	4	1	4	1	2	1	4	2	2	2	1	2	2	1	1
38	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
39	3	1	2	2	3	2	2	4		1	1	1	1	2	2	2
40	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
41	3	1	2	2	3	2	2	4	2	1	1	1	1	2	2	2
42	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
43	4	5	2	2	5	5	5	5	5	4	4	4	4	4	5	4
44	4	4	2	4	5	4	4	4	4	4	2	2	4	4	1	4
45	3	2	3	2	3	3	5	2	4	1	1	4	3	3	4	3
46	3	5	2	5	5	5	5	5	2	4	5	4	5	5	5	1
47	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
48	1	3	3	2	3	2	2	3	4	3	3	1	4	2	3	1
49	4	4	2	4	4	4	4	4	4	3	2	3	3	4	3	3
50	3	1	2	2	3	2	2	4	2	1	1	1	1	2	2	2
51	4	2	1	2	4	3	3	2	2	1	2	2	3	3	4	1
52	3	1	2	2	3	2	2	4	2	1	1	1	1	2	2	2
53	3	1	2	2	3	2	2	4	2	1	1	1	1	2	2	2
54	4	2	3	2	4	3	3	2	2	1	2	2	3	3	4	1
55	3	1	2	2	3	2	2	4	2	1	1	1	1	2	2	2
56	4	2	1	2	4	3	3	2	2	1	2	2	3	3	4	1

Study on Material Wastage of 40/60 Condominium Construction Sites

Respondents	HCB															
	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16
1	3	5	3	5	3	4	5	4	2	2	1	1	5	3	5	2
2	4	4	3	3	3	2	4	4	2	4	2	2	3	3	3	1
3	4	2	3	2	2	3	3	3	2	1	2	2	2	3	3	1
4	2	2	2	2	1	3	3	3	2	2	2	2	4	4	4	1
5	4	2	3	2	2	3	3	3	2	1	2	2	2	2	3	1
6	4	2	3	5	4	4	5	4	4	1	2	1	2	3	4	1
7	4	3	3	3	4	5	3	4	4	3	4	2	4	2	3	2
8	4	2	1	4	2	3	3	3	1	1	2	4	2	3	5	1
9	2	3	2	3	2	4	2	2	2	2	2	2	3	2	2	2
10	2	2	3	3	4	3	3	3	3	1	1	2	2	3	3	1
11	3	5	2	4	4	3	4	4	3	3	4	3	5	2	4	1
12	4	2	3	2	2	4	3	3	2	2	2	2	2	3	4	1
13	2	1	2	2	3	4	3	2	2	2	1	1	4	2	3	2
14	3	4	4	3	3	3	2	2	2	2	2	2	3	3	3	2
15	3	3	3	2	3	5	3	3	3	2	3	1	2	3	4	1
16	3	4	2	4	2	3	4	4	4	4	4	3	4	4	3	2
17	4	2	3	2	2	3	3	3	2	1	2	2	2	3	3	1
18	3	1	2	2	3	4	3	2	2	2	1	1	4	2	3	2
19	3	1	2	3	2	5	3	3	3	2	1	2	3	3	4	3
20	2	3	3	2	3	5	3	2	2	3	3	2	3	3	3	3
21	4	2	3	2	2	4	3	3	2	1	2	2	2	3	4	1
22	4	2	3	2	2	3	3	3	2	1	2	2	2	3	4	1
23	1	2	4	2	3	5	3	3	3	3	1	5	1	3	3	1
24	2	1	2	2	3	4	3	2	2	2	1	1	4	2	2	2
25	3	4	5	4	5	3	4	5	3	2	2	3	3	4	1	1
26	2	3	4	2	1	3	3	4	3	2	2	2	3	4	4	2
27	5	5	4	4	3	3	3	4	3	2	2	3	5	5	3	3
28	4	2	3	2	2	3	3	3	2	1	2	2	2	3	2	1
29	3	1	2	2	4	5	1	5	2	1	3	1	4	4	1	1
30	2	4	2	2	3	5	2	3	3	2	2	2	4	3	3	1
31	2	5	5	3	4	4	4	4	4	1	1	1	5	3	1	1
32	4	4	4	3	2	3	3	3	5	2	2	2	4	3	2	3
33	4	3	5	4	2	3	4	5	3	3	1	3	3	2	2	4
34	2	1	2	2	3	3	3	2	2	2	1	1	4	2	2	2
35	3	4	3	3	2	4	4	3	4	4	1	1	4	3	4	1
36	3	3	3	2	3	3	3	4	3	3	3	3	3	3	3	3
37	1	3	2	3	1	5	1	1	3	3	3	1	3	2	2	2
38	4	2	3	2	2	3	3	3	2	1	2	2	2	3	2	1
39	2	1	2	2	3	4	3	2	2	2	1	1	4	2	2	2
40	4	2	3	2	2	3	3	3	2	1	2	2	2	3	2	1
41	2	1	2	2	3	1	3	2	2	2	1	1	4	2	2	2
42	4	2	3	2	2	3	3	3	2	1	2	2	2	3	2	1
43	5	5	5	2	5	4	5	5	5	4	4	4	5	4	4	4
44	1	4	4	4	5	4	4	4	4	4	2	2	4	4	4	4
45	3	3	2	1	3	3	2	3	1	1	1	4	3	3	3	3
46	5	5	5	5	5	5	5	5	2	4	5	4	5	5	3	1
47	4	2	3	2	2	3	3	3	2	1	2	2	2	3	2	1
48	1	1	2	2	2	4	2	2	4	2	2	1	2	2	1	1
49	3	4	4	4	4	3	4	4	4	3	2	3	4	4	4	2
50	2	1	2	2	3	1	3	2	2	2	1	1	4	2	2	2
51	4	2	3	2	2	3	3	3	2	1	2	2	2	3	2	1
52	2	1	2	2	3	1	3	2	2	2	1	1	4	2	2	2
53	2	1	2	2	3	1	3	2	2	2	1	1	4	2	2	2
54	4	2	3	2	2	2	3	3	2	1	2	2	2	3	2	1
55	2	1	2	2	3	1	3	2	2	2	1	1	4	2	2	2
56	4	2	3	2	2	2	3	3	2	1	2	2	2	3	2	1

Computation of Relative Weight and Rank for the Contractors Response on part 4 (Waste Minimization Measures)

Level of contribution of waste minimization measures

Concrete																	
Question	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16	
Frequency of scoring (f)	1	3	6	0	1	0	2	1	4	19	0	4	2	1	2	8	21
	2	1	21	2	2	4	5	1	4	1	3	4	3	2	4	6	5
	3	7	16	12	3	9	6	6	11	11	14	9	9	22	7	22	7
	4	22	10	37	31	34	9	10	10	7	24	7	8	5	31	8	12
	5	23	2	5	19	9	34	38	27	18	15	32	34	26	12	12	10
$\Sigma(f*s)$	229	146	213	233	216	236	251	220	172	219	227	237	221	215	178	150	
RW	4.09	2.61	3.8	4.16	3.86	4.21	4.48	3.93	3.07	3.91	4.05	4.23	3.95	3.84	3.18	2.68	
Rank	5	16	12	4	10	3	1	8	14	9	6	2	7	11	13	15	

Mortar																	
Question	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16	
Frequency of scoring (f)	1	4	1	0	1	5	5	0	1	9	4	2	1	1	0	20	10
	2	5	18	18	9	13	6	1	4	4	7	1	4	4	9	10	7
	3	13	23	24	15	16	7	14	23	21	12	15	7	10	29	15	30
	4	19	13	13	29	11	14	30	5	15	16	28	33	7	17	10	8
	5	15	0	0	2	11	24	11	23	7	17	10	11	34	1	0	0
$\Sigma(f*s)$	204	158	160	190	178	214	219	213	175	203	211	217	237	178	125	146	
RW	3.64	2.82	2.86	3.39	3.18	3.82	3.91	3.8	3.13	3.63	3.77	3.88	4.23	3.18	2.23	2.61	
Rank	7	14	13	9	10	4	2	5	12	8	6	3	1	10	16	15	

Reinforcement Bar																	
Question	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16	
Frequency of scoring (f)	1	2	0	0	0	1	1	5	0	2	2	5	6	3	1	0	5
	2	2	1	1	2	3	0	21	2	3	8	6	19	4	3	4	4
	3	12	17	7	10	25	9	22	17	7	11	11	18	12	11	21	9
	4	33	7	15	13	12	24	5	26	22	24	12	7	20	23	10	11
	5	7	31	33	31	15	22	3	11	22	11	22	6	17	18	21	27
$\Sigma(f*s)$	209	236	248	241	205	234	148	214	227	202	208	156	212	222	216	219	
RW	3.73	4.21	4.43	4.3	3.66	4.18	2.64	3.82	4.05	3.61	3.71	2.79	3.79	3.96	3.86	3.91	
Rank	11	3	1	2	13	4	16	9	5	14	12	15	10	6	8	7	

HCB																	
Question	BP1	BP2	BP3	BP4	BP5	BP6	BP7	BP8	BP9	BP10	BP11	BP12	BP13	BP14	BP15	BP16	
Frequency of scoring (f)	1	17	0	1	0	3	1	1	0	0	0	3	5	0	1	4	2
	2	8	1	3	0	1	4	3	0	1	2	3	8	0	4	5	11
	3	9	13	21	12	7	10	23	8	8	15	13	23	16	9	29	10
	4	20	14	10	9	3	8	11	23	16	18	13	15	27	35	16	23
	5	1	28	21	35	42	33	18	25	31	21	24	5	12	7	2	10
$\Sigma(f*s)$	145	237	215	247	248	236	210	241	245	226	220	175	216	211	175	196	
RW	2.59	4.23	3.84	4.41	4.43	4.21	3.75	4.3	4.38	4.04	3.93	3.13	3.86	3.77	3.13	3.5	
Rank	16	5	10	2	1	6	12	4	3	7	8	14	9	11	14	13	

Current level of practice of waste minimization measures

Concrete																	
Question	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16	
Frequency of scoring (f)	1	0	15	2	0	0	0	1	0	1	31	20	20	15	3	29	35
	2	13	25	22	36	2	13	10	6	9	15	28	28	8	17	17	16
	3	29	6	13	12	19	23	17	34	28	4	3	5	26	23	5	3
	4	10	5	18	6	27	13	15	10	13	4	3	3	5	11	3	0
	5	4	4	1	2	8	7	13	6	5	2	2	0	2	2	2	1
$\Sigma(f*s)$	173	123	162	142	209	182	197	184	180	99	107	103	139	160	100	81	
RW	3.09	2.2	2.89	2.54	3.73	3.25	3.52	3.29	3.21	1.77	1.91	1.84	2.48	2.86	1.79	1.45	
Rank	6	11	7	9	1	4	2	3	5	15	12	13	10	8	14	16	

Mortar																	
Question	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16	
Frequency of scoring (f)	1	5	12	1	1	2	0	0	0	0	30	18	20	16	0	24	29
	2	18	21	31	33	1	10	6	3	8	14	27	29	6	12	18	17
	3	10	9	9	9	19	25	31	37	29	4	6	4	26	30	6	6
	4	19	5	8	7	28	15	16	11	16	7	3	3	7	10	5	2
	5	3	9	7	5	6	6	3	5	3	1	2	0	1	4	3	2
$\Sigma(f*s)$	162	146	157	147	203	185	184	186	182	103	112	102	139	174	113	99	
RW	2.89	2.61	2.8	2.63	3.63	3.3	3.29	3.32	3.25	1.84	2	1.82	2.48	3.11	2.02	1.77	
Rank	7	10	8	9	1	3	4	2	5	14	13	15	11	6	12	16	

Reinforcement Bar																	
Question	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16	
Frequency of scoring (f)	1	7	12	3	0	2	1	2	1	0	32	19	21	17	2	5	28
	2	9	21	16	32	2	15	13	18	30	10	26	26	7	14	17	17
	3	17	7	30	9	16	23	25	8	12	8	6	6	25	28	12	5
	4	21	8	6	11	28	9	9	21	10	4	3	3	6	9	18	3
	5	2	8	1	4	8	8	7	8	3	2	2	0	1	3	4	2
$\Sigma(f*s)$	170	147	154	155	206	176	174	185	151	102	111	103	135	165	167	99	
RW	3.04	2.63	2.75	2.77	3.68	3.14	3.11	3.3	2.7	1.82	1.98	1.84	2.41	2.95	2.98	1.77	
Rank	5	11	9	8	1	3	4	2	10	15	13	14	12	7	6	16	

HCB																	
Question	CP1	CP2	CP3	CP4	CP5	CP6	CP7	CP8	CP9	CP10	CP11	CP12	CP13	CP14	CP15	CP16	
Frequency of scoring (f)	1	4	13	1	1	3	5	2	1	2	19	18	18	1	0	4	29
	2	16	19	20	34	22	3	5	14	32	22	28	26	19	17	20	18
	3	13	9	23	10	20	25	36	24	11	8	5	7	11	29	17	6
	4	20	9	7	8	7	14	9	12	8	6	4	4	19	8	13	3
	5	3	6	5	3	4	9	4	5	2	0	1	1	6	2	2	0
$\Sigma(f*s)$	170	144	163	146	155	187	176	174	141	111	110	112	178	163	157	95	
RW	3.04	2.57	2.91	2.61	2.77	3.34	3.14	3.11	2.52	1.98	1.96	2	3.18	2.91	2.8	1.7	
Rank	5	11	6	10	9	1	3	4	12	14	15	13	2	6	8	16	

Appendix D Critical Values of Spearman's Rank Correlation Coefficients

Number of subjects (data set)	Level of significance for one tailed test			
	0.05	0.025	0.01	0.005
	Level of significance for two tailed test			
	0.1	0.05	0.02	0.01
5	0.9	1	1	
6	0.829	0.886	0.943	1
7	0.714	0.786	0.893	0.929
8	0.643	0.738	0.833	0.881
9	0.6	0.683	0.783	0.833
10	0.564	0.648	0.746	0.794
12	0.506	0.591	0.712	0.777
14	0.456	0.544	0.645	0.715
16	0.425	0.506	0.601	0.665
18	0.399	0.475	0.564	0.625
20	0.377	0.45	0.534	0.591
22	0.359	0.428	0.508	0.562
24	0.343	0.409	0.485	0.537
26	0.329	0.392	0.465	0.515
28	0.317	0.377	0.448	0.496
30	0.306	0.364	0.432	0.478