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Assessment on selected prefabricated wall construction practices as an alternative materials and technology in the Ethiopian housing sector

A thesis submitted to the school of graduate studies of Addis Ababa University in partial fulfilment of the requirement for the degree of Master of Science in Construction Technology and Management

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LIST OF ABBREVIATIONS

HCB: Hollow concrete block

SCC: Self compacting concrete

ACI: American concrete institute

LWC: Light weight concrete

OPC: Ordinary Portland cement

GGBS: Ground granulated blast furnace slag

CMU: Concrete masonry unit

LECA: Lightweight expanded clay aggregate

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ABSTRACT

Provision of affordable housing to citizens is one of the biggest concerns of governments all across the world. The cost of housing in cities of Ethiopia is very high that it is impossible for most city to afford a quality house. The government is trying to provide affordable houses with good quality and in short period of time. But the houses provided by the government are mostly substandard and timely completion of housing projects has been a challenge.

This research is about prefabricated wall construction materials and about the significance of implementing alternative prefabricated wall construction materials in the Ethiopian housing construction sector. The thesis discusses five selected wall construction materials, their property and suitability for the housing construction.

The research briefly describes five selected wall construction materials, hollow concrete block, Agrostone panel, gypsum board, and Styrofoam concrete and light weight concrete by explaining about the properties and advantages of the materials for the housing construction sector.

The research goes on to explore the housing construction sector of Ethiopia for the perception and extent of using prefabricated wall construction materials. Furthermore the research includes experimental analysis to examine the physical properties of alternative prefabricated wall construction materials and also conduct a brief preliminary cost analysis of the wall construction materials.

The findings from questionnaire, and cost analysis shows that hollow concrete block is the most cost effective material and the most available wall construction material. The other materials can be explored for their other attributes like timely finish, better quality, aesthetic and ease of transportation.

Key words: Prefabricated wall making materials, Hollow concrete blocks, Agrostone, Styrofoam, Gypsum board, Light weight concrete

CHAPTER 1: INTRODUCTION

1.1 Background

Housing is one of the three basic needs of human beings. Provision of affordable housing is an urgent issue for urban development in Ethiopia. Future national competitiveness and economic success will depend on the comparative efficiency of cities. Because housing is the work force goes at night, the quantity, quality, availability and affordability of housing becomes a key component in national economic competitiveness (Kalpana Gopalan, 2015), (Kapumulla, 2018).

In the absolute sense the basic human need for shelter defines the housing problem in terms of quantity and quality: is there enough housing to go round, and is it of a satisfactory standard? The answers to both questions are contingent upon wider social and cultural factors but quantity and quality are essential components of the housing problem (Malpass & Murie, 1999)

Affordable housing provisions are essential for a country at a national level, the city level, as well as the individual level. Cities are engines of economic growth, and housing that can be afforded by the median wage-earner is a pre-requisite for the city to attract and retain the labour force required to ensure its economic success. Affordable housing is one of the indicators of balanced growth in a country (Kalpana Gopalan, 2015)

The land cost in Ethiopia is extremely high that makes is very difficult for majority of urban dwellers to buy a quality house since most dwellers of cities in Ethiopia are middle and low income communities. So people turn their face to the government to provide affordable housing. According to the Growth and Transformation Plan of Ethiopia, 750,000 houses will be constructed and transferred by the year 2019. (National planning commission, 2016).

But the construction of residential buildings by conventional materials and traditional methods is very slow relative to the high demand for housing. Conventional materials are building materials that are widely accepted and are commonly being used in most construction sites. Currently in most building construction projects the basic building elements are constructed using cast in situ concrete. And the construction method is traditional that is characterized by low quality and cost and time overrun.

The cost of cement and other construction materials is increasing which results in the increase of construction cost. These factors make affording a house impossible for the middle and low

income communities that live in the city slum.. Alternative solutions have to be thought to rectify such problems and minimize the burden of the community (Tadege, 2007).

Cost is not the only factor while dealing with affordable housing time should also be considered. The rapid increase of housing demand requires construction of large number of houses in short time. The need for systematic use of precast elements in construction arises from the need of fast-paced construction of standard quality (Chane, 2017).

Prefabricated construction has long been recognized internationally to have numerous advantages that benefit the majority of participating parties in the construction process. It is also recommended as key vehicle in emphasizing efficient construction within developed construction industries (Li, 2014).

Various methods could be implemented to mitigate the ever increasing cost of construction and make housing affordable for low and middle income city dwellers without compromising the quality, function and strength of the building which also should be time saving because cost effective housing is a relative concept and has more to do with budgeting and seeks to reduce construction cost through better management, appropriate use of local materials, skills and technology without sacrificing the performance and structure life (Tiwari P, 1999).

One of the methods used to alleviate the problem is prefabricated construction also termed as offsite construction reduces the time spent on site drastically since most of the activities are performed inside closed environment within a factory. The building elements or panels produced in the controlled condition of the factory can be inspected for stringent quality check measures, proper supervision of materials and workmanship resulting in improved quality and a better product (Nanyama & Anil Sawhneyb, 2017).

1.2 Wall construction materials

Walls are vertical constructions of a building that enclose, separate, and protect its interior spaces. They may be loadbearing structures of homogeneous or composite construction designed to support imposed loads from floors and roofs, or consist of a framework of columns and beams with nonstructural panels attached to or filling in between them (Ching, 2014). Therefore walls are one of the major elements of a building.

The major cost of construction is incurred on building materials and most of these building materials are cement products. In the case of low cost housing, building materials account for 70-75 % of the total cost of construction and 30% of the overall building cost is for wall construction (Tadege, 2007). Therefore the cost of wall construction material selection and construction method significantly affects the overall cost of building construction.

In the Ethiopian housing new construction technologies used for the program are based on a concrete pillar and slab system and also Agrostone board is applied in terms of minimizing the carpenter work concrete, reinforcement bar and others but still now huge amount of cement and gravel are used on the construction site and hollow blocks are applied to as a wall and floor structures. But, the cost of housing units, time management and quality of those houses is not far from problem (Kebede, 2013).

Alternative wall construction materials and construction methods should be assessed and put into practice to make the housing construction effective and efficient. Use of prefabricated wall construction materials can be a valuable alternative because of the various advantages it has over the traditional way of wall construction.

1.3 Problem statement

Provision of affordable housing is an urgent issue in the fast growing urbanization of Ethiopia. In order to tackle the existing and future need of housing the construction of housing should be fast and of an affordable cost for the low and middle income community. In light of this the city administration launched the Addis Ababa Grand Housing Program to provide low cost housing in short period of time. But most of the projects couldn't be finished in the planned time because of improper use and wastage of both material and technology, shortage of skilled man power and construction materials (Cherenet & Sewnet, 2012).

The housing projects planned by the government to reduce the cost and time of buildings widely used Hollow Concrete Blocks (HCB) for both internal and external wall. Due to the scarcity and escalating cost of cement using cement products had caused a challenge to execute the housing projects according to the cost and time schedule (Taffese, 2012).

But in most public construction projects the quality of HCB is poor and do not confirm with the standard set (Kahsay, 2014). Therefore there is a need to make the construction of wall

cost efficient. In order to achieve this objective using alternative cost efficient wall making materials and methods is needed.

The alternative wall construction materials should solve the existing problem of quality, cost and construction time. Therefore the alternative wall making materials and methods should be well studied in terms of their availability, economic viability, construction method and time.

Prefabricated wall construction materials are known to have an advantage of better quality, cost efficiency, fast construction time and lower operational cost than cast in situ construction (Davea, et al., 2016). Hence the extent of application of prefabricated wall construction materials in Ethiopian housing sector should be studied for the provision of affordable houses for the majority of city dwellers.

1.4 Research questions

The primary research question of the study is

- The suitability of alternative prefabricated wall materials towards provision of affordable houses.

Specifically the research attempts to answer the following questions.

- What is the extent of use of prefabricated wall making materials as an alternative wall construction material?
- What is the perception of stakeholders in the construction industry towards using prefabricated wall construction materials?
- What is the economic viability of using alternative prefabricated wall materials in the Ethiopian housing construction sector?

1.5 Objective of the study

The major objective of the research is to study the suitability of alternative prefabricated wall materials towards the provision of affordable houses in Ethiopian housing construction sector.

1.6 Specific objectives

- To assess the current extent of using alternative prefabricated wall making materials in the Ethiopian housing construction industry.
- To study the perception towards using prefabricated wall making materials by the major stakeholders in the construction industry.
- To conduct cost analysis of the selected prefabricated wall making materials for the housing sector.

1.7 Significance of the study

In providing the solution for the pressing challenge of providing adequate housing for the majority middle and low income city dwellers cost, quality and time are the major factors. The houses should be of affordable cost, good quality and delivered in time. To achieve these goals the government should take the lead in exploiting all the alternative options to come up with the best solution. This is basically because most of the housing construction in cities are undertaken by the government.

It is found that cost-effective and alternative construction technologies, which apart from reducing construction cost by the reduction of quantity of building materials through improved and innovative techniques, can play a great role in providing better housing methods and protecting the environment (Tam, 2011).

The study assess selected prefabricated wall making materials and conducts economic analysis for the selected prefabricated wall making materials. The study is significant in pointing the advantage of the selected prefabricated wall making materials in order to achieve the affordability issue in the construction of houses. It also assess the knowledge gap in the housing construction in order to implement alternative wall making materials.

The research gives insight for government housing policy makers about the perception on prefabricated wall construction materials in the attempt to provide affordable housing for low and middle income majority of city dwellers. The research also benefits the construction stakeholders on the economic viability of application of various prefabricated wall construction materials.

1.8 Scope and limitation of the study

There are many prefabricated wall making materials used in the construction sector throughout the world where assessing all of them in one study will be impossible. The focus

of this research is only on prefabricated wall making materials used as internal partition selected on the basis of material availability, familiarity to the current construction industry. These materials are Hollow concrete blocks, Agrostone panel, gypsum board, light weight concrete and Styrofoam concrete.

The study is limited to the following wall making materials, and it has tried to study their properties, construction methods, and their respective economic viability. The materials are selected because they are prefabricated and used as a wall making material in the housing sector.

- Hollow Concrete Blocks (HCB)
- Agrostone
- Gypsum board
- Light weight concrete
- Styrofoam concrete

HCB is a partially prefabricated wall making material used in most building constructions in Ethiopia as a wall making material and it is widely used as an interior and exterior wall material. (Cherenet & Sewnet, 2012). Agrostone panel is a low cost prefabricated partition wall material used in housing projects and it is made of locally available materials (Taffese, 2012). This research will assess their effectiveness and sustainability.

Light weight concrete is concrete with density range of approximately 300 to a maximum of 2000 kg/m^3 (Aisswarya, 2018). The significant reduction in the concrete density is useful because it reduces the dead load which makes it easier for handling and construction (Baradiya, et al., 2018).

Gypsum is used in the construction industry of Ethiopia mainly as a decorative element. But in other countries like the USA and other European countries Gypsum is also used as a wall partition material for fast housing projects (Gypsum Association, 1974). So given the need for rapid construction of houses, studying the material as an alternative wall making material is beneficial.

Styrofoam concrete is made from a mixture of cement, sand and Styrofoam aggregate. Styrofoam is mostly used as the packaging tool for various industries like food and electronics and after use it is disposed as a waste (Mohd Hilton Ahmad, 2015). Studying this

material for wall material will be beneficiary as it is light weight and also uses recycled waste which is bad for environment.

The housing construction sector of Addis Ababa city is selected to carry out the study. The rationale behind this is Addis Ababa is the country's capital and biggest city in addition the number of housing projects in the city is much greater than any other city in Ethiopia.

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The United Nation Development Goals sets to ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums by 2030 (UNITED NATIONS, 2015). In the provision of housing, one has to deal with the human needs that primarily involve the use of natural resources such as land, water, energy, materials, etc., as well as human resources, like laborers, experts with skills and knowledge (Rika Kisnarini, 2015).

Sustainable development is all about improving and sustaining an existing structure over a period of time. Therefore sustainable housing relates with the capability of housing delivery system that enhance and support sustainable development for the collective well-being of the society living in a particular place (Muhammad, et al., 2015). Housing affordability is defined as the payment of a house without having suffering in other aspects of basic needs of a household (Stone, 2004). Affordable housing in the Ethiopian context means housing affordable by low and middle income majority.

However in Ethiopia the down payment and the continuous payments required for the houses built by the government are so high that the low income community can't afford it (UN-HABITAT, 2011). A 30% income standard the most commonly used and accepted measure in many countries but this number varies from 25% to 40% in some countries (Robinson & Grant M. Scobie, 2006). In Addis Ababa about 80% of the population makes less than 126 USD a month and the monthly pay back of small size of condominium houses requires 66% of the salary which is unaffordable for low income society (Woundimagegnehu, 2014).

Recently the definition of low cost housing has been under debate; low cost housing may be defined as a provision of housing which caters to the requirements of lots among their financial gain capabilities, while not sacrificing the strength, performance and lifetime of the structure (I. Michael Raj, 2018).

In the construction industry a project is called successful when the project is delivered with the required quality standard, on the scheduled time and within the budget allocation. To achieve these goals costs should be managed effectively. Clients rightly expect that the final cost of their projects should not exceed the approved budget, and indeed for some, cost certainty may be their main priority (Cunningham, 2017).

2.2 Housing in Addis Ababa

Addis Ababa is one of the fastest growing cities in Africa. The population of the city has nearly doubled every decade for the past few decades and Addis Ababa's population is currently estimated to be above 4 million, which is a 17% share of Ethiopia's total urban population, and this number will continues to rise reaching 12 million in 2024 (Tigabu & Semu., 2008).

Regarding the demand side, it is fairly strong and continuously growing overtime, one million houses are to be demanded, of which the 400,000 houses are highly desired along with the sever housing problems. This is due to the fact that almost all the factors that affect demand, such as population, urbanization and economic growth are positively affecting. Hence, the concerned bodies have to consider each of them and take the following suggestions in combination (Zerayehu Sime Eshete, 2015).

An estimated 70–80 percent of the urban population lives in what might be considered slums. Around 80 percent of dwellings in urban areas are made from wood and mud (also known as chika construction). The main drivers of the urban housing shortage are low incomes, insufficient supply of serviced land, and requirements that housing units meet unrealistically high and costly standards (World Bank, 2015).

There is a considerable housing and related land management problems in Addis Ababa. The main cause of these problems are high cost of construction, scarcity of construction materials, lack of knowledge in construction techniques, growth of population, shortage of fund for large scale housing program. Utilizing low cost housing technology is expected to reduce cost, increase productivity and improve quality. As technology improves, building cost will be reduced and the quality and durability of the houses constructed may be achieved. Besides that, it will respond to the demands of the lower and middle class by building affordable houses (GTZ, AAHDPO, 2005).

Housing inadequacy is largely felt at the level of low and middle income and more so with a continuous rise in the cost of construction at all levels. This necessitates the use of appropriate and cost-effective technologies in house construction. Because the leading type of housing construction system in Ethiopia which is a conventional system couldn't be compatible with an increasing rate of housing providers and this created a negative impact on housing construction such as long-time construction, material wastage, rising cost, high embedded energy and so on (Kebede, 2013).

With increasing demand and higher rental prices today, a significant proportion of the people in Addis Ababa shares shelters that are of less quality and without relevant facilities (UN Habitat, 2017). While the Integrated Housing Development Program (IHDP) has the laudable aim of targeting the low-income sector of the population, unfortunately experience has shown that the low-incomes are not benefiting from the IHDP due to inability to afford the initial down payment and monthly service payments. In general, the current IHDP housing construction systems do not match the housing demand and supply due to cost, speed, and quality for the targeted group.

The population growth in Addis Ababa is very fast due to the migration of people from different parts of the country. This population growth will put further and continued challenges and pressure on the city administration to provide efficient and affordable basic services and housing in sufficient quantities. To do so would require a doubling of the city capacity in urban planning, management and effective implementation, supported by strong political leadership from the top (UN Habitat, 2017)

2.3 The need for alternative wall construction material

Wall is the largest component in the building, so if the wall has a light weight it can affect the overall weight of the building as it covers large area in a building (Wibowo, 2017). Walls are one of a building major systems used to separate entities and enclose spaces. They serve aesthetic purposes, provide privacy, and bar, or at least restrict, passage of people or other moving objects, water, air, sound, heat and also often light (Merritt & Ricketts, 2001).

In general any vertical member whose length and height are both much larger than the thickness may be treated as a wall. Walls subjected to vertical loads are called load bearing walls. Walls that support their own weight, such as panel or enclosure walls, are called non load-bearing walls (Merritt & Ricketts, 2001).

Non-bearing reinforced-concrete walls, frequently classified as panels, partitions, or cross walls, may be precast or cast in place. In most applications for non-bearing walls, stresses are low and alternative materials, such as unreinforced masonry, when supported by beams above grade, or panels of other materials, can be used. Consequently, unless aesthetic requirements dictate reinforced concrete, low-stressed panels of reinforced concrete must be designed for maximum economy (Merritt & Ricketts, 2001).

Partition walls are important building elements and have a great importance in the overall life-cycle impacts of a building. A partition wall is a thin element built to divide the indoor space into rooms or other compartments. Additionally, it is used to enable more effective space organization and to improve comfort and safety (Mateus & Sara Neiva a, 2013).

Partition wall should be carefully chosen to meet certain performance requirements that relates to structural strength, fire proofing capacity, durability, and sound isolation. A partition may be constructed with steel or wood studs as a framed faced with plastered or gypsum board. Alternatively it could be constructed with concrete blocks of structural tiles (Allen & Iano, 2009). In developing countries people use different types of walling materials for their homes majorly for three probable reasons – cost of material, durability and aesthetics. These factors are what people basically base their selection of walling materials for their houses on (Adewale, et al., 2018).

Hollow Concrete Block is the most common wall making material in Ethiopian construction (Joro, 2015). It is an alternative wall and floor making material, used for construction of walls using hollow concrete block and for construction of ribbed slab using filler blocks. Those blocks are used for construction of walls and ribbed slabs and follow the same procedure of production.

The manufacture of hollow concrete blocks requires constant monitoring to produce blocks that have the required properties such as shape, appearance, texture and color and apparent density, water absorption and compressive strength. Masonry construction of structures offers many advantages over traditional wood framing, including increased strength, fire resistance and insulation value. Traditionally, masonry construction techniques involved taking masonry units, typically manufactured cement, sand, water & aggregate, “buttering” the units with mortar, typically mixed from cement, sand water and lime, and stacking the buttered units to form a number of courses (Mohammad Vekas Wani, 2018).

In a data collected from Addis Ababa condominium housing project technical staffs from client side, contractors and consultants, one of the major type of defect is uneven wall finish. And usually residential buildings are the one which experienced most of the defects due to poor workmanship. Poor workmanship on plastering and rendering, block work and metal work was pointed out (Dires, 2016).

In public building projects lack of onsite materials control, poor handling of materials, lack storage of materials near of construction site, insufficient instructions about handling & wrong handling of materials, using excessive quantities of materials more than the required & purchased materials that don't comply with specification are the factors that cause material wastage in construction sites (Joro, 2015).

The result of improper handling and managing materials on site during construction process will influence the total project cost, time and the quality. The costs of materials management may range from 30-80% of the total construction costs depending on the type of construction. However, the total cost accounted 50-60% of construction projects is for construction materials and equipment (Narimah Kasim, 2013). Therefore the selection of wall construction materials becomes very important as the issues of affordable housing in terms of quality and quantity poses a challenge in developing economies (Adewale, et al., 2018)

2.4 Selection criteria for wall construction materials

It is well understood that materials play an important role in engineering design. Material selection is one of the most challenging issues in the design and development of products, and it is also critical for the success and competitiveness of the manufacturing organizations (Uğura & Baykan, 2016).

Construction material selection is a complex process subjective to and determined by several requirements, decision, and considerations of building material options. Various parties are involved in the decision making of construction materials including client, civil engineer, consultants, contractors, and government department responsible for building legislation (Akadiri, 2018).

The required design working life, the period of a structure to be used for the intended purpose with anticipated maintenance but without a major repair, for building structures and other common structures is 50 years (Ministry of Works and Urban Development, 1995).

Technology selection in house building is cost driven because the other criteria including time and quality are interpreted in financial terms (Pan, et al., 2012). The most important factor in wall material selection for decision makers is cost followed by fire resistance, heat insulation and sound insulation (Uğura & Baykan, 2016). Time and cost savings are the most important indicators to achieve the efficient construction and quality and safety of construction are also important performance indicators of construction (Nourbakhsh, et al., 2012).

The factors used to measure the selection of building materials are client's demand, overall cost, climatic compliance and maintenance demand. Empirical results indicate that maintenance demand is the most important factor that determines the selection of materials and cost of the materials plays a prominent role in the decision process (Akadiri, 2018).

Durability is the ability of a product to perform the required function over its lifetime without excessive maintenance or repair the choice of construction materials is dependent on various factors and durability and the structural strength and to stay safe for the building life span is one of the major factors that affect material selection (Saud, et al., 2019), (Domone & illston, 2010).

The time that takes the material to be constructed and assembled on site is one of the factors that influence the selection of construction material selection (Domone & illston, 2010). The time saving ability of a construction material is one of the properties that makes it smart construction material (Dogne & Choudhary, 2014). The availability of construction material is also one of the major criteria for the selection of construction material (Domone & illston, 2010).

A wide range of construction materials are available in the market. The proper selection of construction materials to be used in a particular construction project depends on the following factors (Jemal, 2017).

- Strength
- Availability
- Durability
- Workability
- Ease of transportation

- Cost of material and construction
- Aesthetics
- Resistance to fire

2.5 Prefabricated wall making materials

Prefabrication of building components using large panel technology was first developed in the mid 1960's to allow rapid construction of buildings at a moderate cost. The popularity of this method stems from cost savings by mass production of standardised building elements and reduction of labour costs (Zhao & Riffat, 2007).

Nowadays construction development has been augmented fast with the introducing of new systems and methods of construction and new technologies. Precast concrete revolution is being used broadly by several countries in the world, which is a standout between the qualities of precast concrete systems. There has a specific characteristic of the precast concrete. Site space, Quality, Speed and Site refuse are some of them. In ancient history ancestors used pre-cast concrete and other construction blocks for the aqueducts, culverts, and tunnels (Kapumulla, 2018).

Some of the advantages of Prefabrication building components are (Kymmell, 2007)

- Prefabricated components speed up construction time, resulting in lower labor costs
- Prefabrication allows for year-round construction.
- There are less wasted materials than in site-built construction
- Worker safety and comfort level are higher than in site-built construction.
- In most cases, Prefabrication drastically reduces construction time and cost, and allows construction to take place regardless of environmental conditions.
- Prefabricated buildings can be designed for virtually any use, but are ideally suited to operations requiring temporary structures, short construction time, and relatively inexpensive construction costs (Kymmell, 2007).

Various materials can be used for the construction of walls, these include Hollow Concrete Blocks, rammed earth, bricks, hollow clay blocks, concrete, and modular panels of different size and materials. And the use of large panels made of low density materials has been increasingly used throughout the world for the construction of modular walls (Zhao & Riffat, 2007).

Prefabrication of building elements and cost efficient management system is one of the bases for the housing development program of Addis Ababa. And the prefabricated elements include Hollow Concrete Blocks, U-shaped blocks, precast beams and precast lintels. Therefore HCB became the most commonly used wall material in the housing construction sector (Low cost housing technical manual, 2005). The other material widely used as partition wall construction for housing is Agrostone panel which is made of agricultural/industrial wastes and/or natural minerals as a filler, magnesium-based chemicals as a binder and fiberglass as reinforcement (Taffese, 2012).

The construction of walls using HCB in most construction projects is characterised by various quality issues starting from the production stage to the finishing. The materials used for the production of HCB i.e. aggregate, cement and water, usually don't meet the specification standard (Kahsay, 2014).

The material wastage in public projects of Addis Ababa is more than 11% and the main causes are reworks that don't comply with drawing and specifications, rework due to worker's mistakes, cutting uneconomical shapes on HCB, ordering of materials that don't fulfil project requirements defined on design documents, and inappropriate storage leading to damage or deterioration (Joro, 2015).

In the Hollow Concrete Block construction overproduction or production of a quantity greater than required or earlier than necessary, conversion waste from cutting uneconomical shapes, poor quality of materials, over ordering or under ordering due to mistake in quantity surveys, damage during transportation & poor schedule during procurement the materials are other important causes of materials waste arising from storage and handling (Joro, 2015) (Kahsay, 2014).

Off-site manufacturing has the potential of improving housing delivery in terms of speed, quantity and quality. In addition, it is recognised that off-site manufacturing typically requires fewer trade operatives compared to traditional method of construction. As such, the problem of skills shortage could be more readily managed with the adoption of off-site manufacturing (James, et al., 2014).

The Building industrialization also could maximize the improvement of the quality of components and assembly precision, and effectively reduce the roof leaks, wall cracks, quality defects of wall and window such as cold air infiltration, so the architectural quality

and accuracy can be improved significantly. Factory production and on-site assembling of prefabricated components can help in the reduction of labour and also beneficial for site management. Building industrialization transfer most of the operation to production line, saving construction cost and schedule greatly (Shijun Sun, 2015).

2.6 Hollow concrete blocks

A Hollow concrete block (HCB) is primarily used as a building material in the construction of walls. It is sometimes called a concrete masonry unit (CMU). A concrete block is one of several precast concrete products used in construction. The term precast refers to the fact that the blocks are formed and hardened before they are brought to the job site (Thorat, et al., 2015). HCB is a machine-formed masonry building unit composed of cement, aggregates, and water (Merritt & Ricketts, 2001).

Hollow concrete blocks (HCB) and bricks, now a days, are becoming very popular. These blocks are being widely used in construction of residential buildings, factories and multi-storied buildings. These hollow blocks are commonly used in compound walls due to their low cost. These hollow blocks are more useful due to their lightweight and ease of ventilation. The blocks and bricks are made out of mixture of cement, sand and stone chips (Thorat, et al., 2015).

Hollow concrete block production starts from selection and proportioning of raw materials such as aggregates, cement and water. Next, production process will be continued; it composed of batching, mixing, compaction (vibration), curing and drying. Finally, those hollow concrete blocks must complied with the requirements stated in the recommended standards in terms of dimension, density, water absorption, linear shrinkage and compressive strength by testing on sample of blocks. And the number of sampled blocks and selection procedures should follow right procedure which is stated in the recommended standard. (Kahsay, 2014).

Being light in weight HCBs provide economy in design of sub-structure due to reduction of the loads and the cavity of blocks helps achieving insulation of walls and provides energy saving for all times. Hollowness results in sound insulation. If the HCBs are engineered properly then they help obtaining dimensional accuracy and high finishing quality and having cost competitiveness (Thorat, et al., 2015).

Hollow Concrete Block (HCB), cement product, which is the most widely used building materials in the Country has been utilized for both internal and external wall construction (Taffese, 2012).

The compressive strength of HCB at 28 days according to the Ethiopian standard is presented as follows.

Table 2.2: Comprehensive strength of hollow concrete blocks at 28 days (Kahsay, 2014)

Type of HCB	Class	Minimum compressive strength (N/mm^2)	
		Average of 6 units	Individual units
Load bearing	A	5.5	5.0
	B	4.5	4.0
	C	3.5	3.0
Non load bearing	D	2.0	1.8

2.7 Agrostone panel

Agrostone panel is composed of agricultural/industrial wastes and/or lightweight natural minerals as fillers magnesium-based chemicals as a binder and fiberglass as reinforcement (Taffese, 2012).

Fillers for Agrostone panel production can be agricultural products and/or lightweight natural minerals like pumice and diatomite. Addis Ababa Agrostone production center uses an agricultural product, bagasse which is available from a number of inland sugar factories. Addis Ababa Agrostone production center also partly uses lightweight natural minerals such as pumice and diatomite as fillers. It uses Magnesium Oxychloride Cement (MOC), also known as Sorel cement as a binder (Taffese, 2012).

Agrostone panel has several benefits compared to conventional building materials. One of the major benefits of the product is its low-cost production. This in turn contributes towards reducing housing construction costs. Agrostone panel nearly reduces the cost of the wall

construction by half compared with the conventional hollow concrete block walls (Taffese, 2012).

Unlike the traditional building materials, Agrostone panel do not require cement plastering for finishing work which demands considerable amount of cement (Taffese, 2012). The construction technologies used for the housing program are based on a concrete pillar and slab system and Agrostone board is applied for internal wall partition material in terms of minimizing the carpenter work concrete, reinforcement bar and others (Kebede, 2013).

Type of products mostly produced by Agrostone production center are Agrostone panels, reliefs, and doors. The reliefs include roman colons, roofing materials, wallboards, corner lists etc. The length of the panels can vary to a maximum of 3.5m and there are 10cm and 20cm thick boards. The 10cm thick hollow partition board is the common product (Kebede, 2013)

2.8 Gypsum board

Gypsum is a naturally occurring mineral resource found in many areas in the world and is mined just like any other mineral. It crystalline mineral of calcium sulphate with chemically bound water which aids it's resistance to fire. It has a hardness definition of 2 on the Mohs scale of mineral hardness (D & Amusan Lekan M, 2014).

Gypsum board consists of a core of set gypsum surfaced with specifically manufactured paper firmly bonded to the core. It is designed to be used without addition of plaster for walls, ceilings, or partitions and provides a surface suitable to receive either paint or paper. It is extensively used in ''drywall'' construction, where plaster is eliminated (Merritt & Ricketts, 2001).

The Gypsum Physical properties according to (Gypsum Association, 2007)

1. Color: white, yellow, gray, red, orange, black, if not pure
2. Specific gravity: 2.31 to 2.35 g / cm3 / g / cm3 water 25oC
3. Hard pearly especially surface.
4. Form minerals: crystalline, fibrous and massive.
5. Shine like silk
6. The low conductivity

7. System is monoclinic crystalline.

Gypsum board is the generic name for a family of sheet products consisting of the main core of unburnt and coated with a paper on its surface. This is the terminology chosen for gypsum sheet products are designed to be used as wall, ceiling or ceiling and have the ability to be decorated. Strength gypsum board directly proportional to the thickness. Gypsum is formed under conditions of various purity and varying thickness (Gypsum Association, 1980)

Gypsum is the first salt due to evaporation of sea water followed by anhydrite and halite, when salinity is growing. As evaporates minerals, gypsum precipitate shaped layer of sedimentary rocks of limestone, red shale, sandstone, clay and rock salt, and often shaped lens deposition in sedimentary rock units (Lailan Ni'mah, 2016).

Gypsum has been employed as construction material since 17th century. During that time, gypsum was used as ornamental element for building decoration. At the end of 19th century, gypsum was incorporated to civil architecture as construction material and as interior decoration element due to the production of laminated plasterboard which soon became indispensable for its low cost, easy installation, lightness and versatility (Torre & Luis Tapia, 2018).

Gypsum plasterboard systems are very fast to erect and provide huge labour saving and flexibility in construction. Globally, gypsum drywall systems are used as a replacement of brick and mortar construction. In the developed world, the building solutions are fairly advanced from a performance point of view as the construction practices have evolved over a period of time (Mr. Dhiren K. Paghdar, 2013).

Gypsum board product consists of a core of set gypsum surfaced with specifically manufactured paper firmly bonded to the core. It is designed to be used without addition of plaster for walls, ceilings, or partitions and provides a surface suitable to receive either paint or paper. Gypsum board is extensively used in ''drywall'' construction, where plaster is eliminated (Merritt & Ricketts, 2001).

In the home building industry, drywalls have demonstrated to be the most preferable solution worldwide. Between the main advantages of these panels, there is their low fabrication cost which is according to their materials and production volumes. One of these materials is gypsum which has been employed as construction material since 17^{th} century (José de la Torre, 2018)

Dry wall construction has the following advantages as compared to convention wall construction: (Allen & Iano, 2009)

- Light weight concrete results in – 8 to 10 times lighter than conventional systems like Brick / Block work.
- Faster construction – Five to eight times faster.
- Superior acoustics performance in terms of insulation with insulation rating up to 74 dB.
- Tested and certified systems to give between ½ – 4 hour fire ratings.
- Smooth finish, aesthetically beautiful crack free surfaces.
- Flexibility in terms of modifications and refurbishment at some point in time.
- Green and recyclable product (Mr. Dhiren K. Paghdar, 2013)
- It is installed with minimal labour by semiskilled workers and can be fashioned into surfaces that range from smooth to heavily textured.
- It is light in weight compared to many other materials
- It is a durable material

It is the least expensive of all interior wall and ceiling finishing materials

2.9 Light weight concrete

The LWC density ranges from 650 Kg/m3 to 1850 Kg/m3 as compared to 1800 kg/m3 to 2400Kg/m3 for conventional brick and concrete respectively. Despite millions of tiny air filled cells, it is strong and durable. They are excellent in acoustic performance, earthquake resistant, good insulation, workability, long life span due to termite and fire resistance, weather proof and, material savings, low modulus of elasticity (0.5%– 0.75%) than that of the normal concrete and therefore they are more pronounced to deflection (Singh, 2016).

The principle techniques used for producing lightweight concrete can be summarized as follows

1) Omitting the finer fraction of normal weight aggregate to create air-filled voids using a process pioneered by Wimpey in the UK in 1924 (no-fibes concrete).
2) Including bubbles of as in a cement paste or mortar matrix to form a cellular structure containing approximately 30-50 per cent voids (aerated or formed concrete)

3) Replacing, either wholly or partially, natural aggregates in a concrete mix with aggregates containing a large proportion of voids (lightweight aggregate concretes) (Aisswarya, 2018).

Light weight concrete, having low density has various benefits the low density of concrete reduces the dead load of the structure which in turn helps in the faster construction progress. The other advantage is decreased weight of a building on the foundation is an important factor, in case of weak soil. Floors and walls if made up of LWC will result in cost efficient construction (Mulgund & Kulkarni, 2018).

Achievements in modern concrete technology have led to the introduction of light-weight concrete (LWC) and self-compacting concrete (SCC) as structure mass reducing and workable materials. LWC which is well recognised in the construction industry as opposed to SCC is an excellent solution for decreasing the dead load of the structure, while SCC is a modern material which facilitates the pouring and removal of construction problems. In recent years, some efforts have been made to combine the advantages of these two types of concrete in one package called light-weight self-compacting concrete (Vakhshouri & Nejadi, 2016).

Aerated light weight concrete or also known as cellular concrete is a light weight building material that has been aerated to reduce its density before to the setting of Portland cement in the formation. The light weight concrete offers not only low density, they also possess superior insulation and acoustic performance, fire resistant properties as well as relatively high strength with dimensional stability (Lim Sheau Hooi, 2017).

The light weight concrete can be used to make wall partitions. Prefabricated unit, floating platform and many other applications in building and construction that require low load application. The main material used to produce light weight concrete are Ordinary Portland cement (OPC), water, sand, lime, gypsum, ground granulated blast furnace slag (GGBS) and aluminium powder (Lim Sheau Hooi, 2017).

Cellular Light Weight Concrete is a versatile material which is made up of cement, fly ash and protein based foam. Basically it is a material which is currently is being used for walling purpose. Cellular Light Weight Concrete gives better sound insulation, thermal insulation, durable, lightweight, uniform size & shape, reduce permeability (Chandel & Sakale, 2016). The greater part of cellular concrete production has been in the form of building blocks, wall

panel, because of their lightness in weight can be very much larger in size than the building bricks, effect economics both in handling and in construction (Baradiya, et al., 2018).

2.6.1 Classification of Light Weight Concrete

No-fines concrete

It is a mix of cement, water and coarse aggregate with fines (sand) omitted. This result in each particle of coarse aggregate is coated with a layer (up to about 1.3mm) of cement paste which bonds it to adjacent particles in point to point contact to leave interstitial voids. In non-fines aggregate concrete the voids are interconnected to produce a porous open textured concrete the reduced density, strength and shrinkage. Maximum aggregate size can range from 7 to 75mm but is usually from 10 to 20 mm. For normal weight aggregates, aggregate/cement ratios from 6 to 10 produce densities of between 1200 and 1900 kg/m3.

Aerated and foamed concrete

Aerated concrete containing intentionally entertained voids in the hardened cement paste or mortar matrix to form a cellulose structure of low density are known as aerated cellular, gas, foamed or foam concretes. They are divided into two principle types namely aerated and foamed. The air can be introduced into a mortar or concrete mix using two principle methods. First, using first using foam generator and second, a synthetic or protein based foam producing admixture mixed with other constituents in a normal mixer or high-shear mixer. The resulting bubbles in the hardened concrete should be discrete and usual bubble size is between 0.1 and 1mm. (Aisswarya, 2018).

Table 2.1: Properties of light weight concrete

Properties	Class and type		
	I Structural	II Structural/ Insulating	III Structural
Compressive Strength (MPa)	>15	>3.5	>0.5
Coefficient of thermal expansion (W/Mk)	-	<0.75	<0.3
Approximate density (Kg/m3)	1600-2000	<1600	<1450

Natural light weight aggregate include Pumice, diatomite, scoria, volcanic, sawdust, rice husk. Artificial aggregates include artificial cinders, coke breeze, foamed slag, thermacoal beads, lightweight expanded clay aggregate.

Light weight concrete can be made from LECA as coarse aggregate. They are light enough and their lightness is due to the porosity present in the material by heating the clay to the temperature of 1300 degrees. In the heating process, the wet clay starts to expand by having porous inside and hence the LECA becomes light in weight (Aisswarya, 2018)

2.6.2 Need for development of lightweight concrete

a) Low Density: It can be used to reduce the self-weight of structure.
b) Compressive Strength: It can be effectively use in structural components.
c) Low Thermal Conductivity Concrete: The lower thermal conductivity of LECA provides less heat loss. LECA has 4 times the R-Value of typical sand and gravel aggregate concrete. This significant R-Value increase both slow heat transfer and eliminates or reduces moisture condensation on walls and ceilings.
d) Workability, Appearance, Acoustics: Workability particularly in nailing, sawing and drilling, Acoustic ranges are high.
e) The repairing and strengthening processes are aims to improve the performance of the concrete members, restore and increase the strength and stiffness of the concrete, improve the appearance of the concrete surface, increase water tightness, prevent access of corrosive materials to the reinforcing, and improve the overall durability of the concrete members.

2.10 Styrofoam

Styrofoam was widely used for food and manufacturing production equipment as packaging tools to absorb vibration during handling and transportation process. After this process, the Styrofoam used to protect the equipment normally serves as disposal waste. It is estimated that it produced large amount of wastes as it is abundantly used in the market. Due to its lightweight characteristics, it has potential to serve as aggregates replacement of coarse-aggregates. In concrete pre-cast industry, this requires smaller and cheap handling and transportation process (Mohd Hilton Ahmad, 2015).

Styrofoam is popular to be used as a good thermal insulation material in building construction. Commonly, Styrofoam for delivering process was shaped according to the delivering item’s shape. Normally after delivering process, it commonly treated as waste product and it seldom to be recycled as a new Styrofoam as it is not economical to be

reproduced. Styrofoam aggregate has a closed cell structure consisting essentially of 98% air. Styrofoam concrete is made from a mixture of cement, sand and Styrofoam aggregate. By using different volumes of waste Styrofoam incorporated with fly ash, a range of densities and also compressive strength can be obtained (Mohd Hilton Ahmad, 2015).

Styrofoam has hydrophobic characteristics, non-absorbent, good insulation properties and closed cellular aggregates may have the potential to be developed as good commercial lightweight aggregates (M. H. Ahmad, 2008).

The advantages of using Styrofoam as aerated lightweight concrete and fly ash usage forming materials is addressed to find an eco-building material that has benefits:

1) The use of waste materials will reduce the cost of manufacture and improve the value of industrial waste.
2) Earthquake loads that work will be smaller because the weight of the structure is reduced, so that the structure will be safe and suitable for residential buildings in the earthquake area. The pores allow the Styrofoam used as vibration and noise absorber.

2.11 Summary of literature

The literature review covered the housing need in the country's capital city and the issue of affordability. Then it discusses the selected prefabricated wall making materials in terms of their property, construction method and advantage of their application.

During conducting the literature review the researcher found out that there are very small documents about the wall construction materials widely used by the housing sector and in the construction sector in general. Therefor the references mostly used on the current Ethiopian practice on wall construction materials are thesis documents.

Agrostone panel is a widely used partition wall material in the housing sector specifically in the government housing projects. But there are almost no documents on the detail production method, properties and handling of the material. The documents on the practicality and economic feasibility of the material is also scarce and the available documents have very little to discuss the issues on the material.

Light weight concrete panel is a new practice as a wall construction material for the country. The material needs to be assessed for the practicality and applicability in the Ethiopian

construction sector. The literature addressed the definition and few physical properties of the material. Styrofoam is also a new practice for the Ethiopian building construction sector. Its physical properties and application in buildings are discussed in the literature review.

CHAPTER 3: METHODOLOGY

3.1 Introduction

In this chapter the research design and methodology used in acquiring the necessary information to achieve the research objectives are discussed. The chapter specifically explains the research type and design, used for conducting the research.

This research starts with identification of problem on the use of prefabricated wall making material followed by literature review which assesses the housing need in Addis Ababa and the need to use prefabricated wall making materials. The literature review also discusses the selected prefabricated wall making materials with their properties and advantage. Finally it gives critical analysis about the literature gap about the conventional wall construction materials.

After the literature review is conducted the research goes into assessing the current practice of using prefabricated wall construction materials using the research techniques discussed in the next sections.

3.2 Research type

Type of research is defined based on the purpose of the research. The exploratory research type is used in conducting this research. From the various types of researches an exploratory type of research helps to fill a gap in the certain area of knowledge which might be understated and emerging. And this type of research is needed where there are no enough literature documents about the topic under the study (Leavy, 2017). Therefore this study is an exploratory type of research that attempts to assess the practice of prefabricated wall making materials in Ethiopian housing construction sector.

3.3 Research design

Research design is the approach used in building the structure of a research and its main purpose is to answer the research questions to meet the research objectives effectively (Leavy, 2017). It refers to the basic methods of collecting evidence: surveys, interviews, experiments, observations, archival data and combination of these. This section explains the research design used for conducting this research (Vogt, et al., 2012).

This research uses the combination of archival data, survey questionnaire and interview to collect the data necessary to achieve the objectives. It also uses laboratory experiment to identify the physical properties of the wall materials selected in the research.

Desk study is conducted to identify the necessity of prefabricated wall making materials and the advantage it has over the conventional method of wall construction. Review of various literature gives in depth knowledge of housing need in the county, the need of prefabricated wall construction materials and the advantages of using these materials for the housing construction industry. In addition to this it analyses the selected prefabricated wall construction materials in terms of their properties and advantages in the housing sector.

Questionnaire survey is conducted for various stakeholders of the construction industry focusing on the housing sector in pursuit of the extent of the use of prefabricated wall construction materials among the major stakeholders of the construction industry specifically the housing sector. It also aims in finding the current practice of wall construction methods and material selection. Questionnaire survey is selected to collect comprehensive data from the large number of construction stakeholders in a short period of time.

3.4 Research population

The study population for this research includes various stakeholders of the construction sector. For the set of data collected about the current practice of prefabricated wall construction materials the population is:

- General contractors and building contractors
- Consulting/ architectural design firms
- Public client representatives
- Construction material suppliers

General contractors, consulting/ architectural design firms and real estate companies are selected to collect data on the wall making materials mostly used for housing construction and what selection criteria is used in deciding the materials. So the study aims at finding the knowledge and assess the practice of selecting prefabricated wall making materials.

3.5 Population sampling method

Sampling is the selection of part of a group or a population with the aim of collecting data to draw conclusion in conducting a research and the selected sample must represent the

population well and it should be reliable. Advantage of population sampling is that it saves time and cost and also the data collected is of a better accuracy (Khan, 2008). The population sampling method used in carrying out this research is the systematic sampling method because the method is easier to execute than the other sampling methods.

Systematic sampling proceeds by picking up one element after a predetermined time depending on the sampling ratio. For example if one wants sample size of ***n*** from a population of size ***N*** the sampling ratio would be:

n/ N……Eq. 3.1

where

n= sample size

N= total population

Then after deciding where to start from among the first few population the selection repeats every ***n/ N*** until it reaches the intended sample size.

The main population of this research are contractors, consultants and client representatives currently involved in the construction of Addis Ababa housing projects prefabricated wall material suppliers.

CHAPTER 4: DATA ANALYSIS

This chapter discusses and reports the survey findings of the research. After the questionnaire survey was carried out, statistical analysis were undertaken on the responses using SPSS software.

The main objective behind the questionnaire survey was to assess the awareness about prefabricated wall construction materials from stakeholders in the housing construction sector. In order to achieve this objective questionnaire was distributed among contractors, consultants and client representatives currently working in housing construction projects. For the collection of data the Project 13 also known as Lideta and Bole 20/80 Housing projects was selected. The projects are selected randomly from the 18 project offices under the Housing Development Corporation. The projects are located at Bole Arabsa 20/80 housing construction site.

Semi structured interview was conducted with prefabricated wall production plants found in Addis Ababa with the objective of gaining additional knowledge on the use of prefabricated wall construction materials. The interview also aimed at finding preliminary cost of prefabricated wall construction materials.

4.1 Questionnaire analysis

4.1.1 Questionnaire response rate

For the set of data collected to obtain the current awareness about the use of prefabricated wall making materials, a total of 50 questionnaires were distributed. The number of the questionnaires is limited to 50 because the researcher believed it would represent the population and would be effective to collect and analyse the data within the time given. 15 questionnaires were given to client representatives, 18 for contractors and 17 for consultants currently working on the condominium building site. The distribution was made according to the availability of the representatives.

Table 4.1: Questionnaire response rate

No	Respondents	Questionnaire distributed	Returned questionnaire	Percent
1	Client representatives	15	9	60%
2	Contractors	18	13	72.2%
3	Consultants	17	12	70.5%

4	Total	50	34	68%

4.1.2 Background of respondents

Table 4.2: Field of specialization of respondents

No	Field of specialization	Number	Percent
1	Civil engineering	18	52.9
2	Construction technology and management	10	29.9
3	Water engineering	2	5.8
4	Building construction	1	2.9
5	Architecture	1	2.9
6	Housing development	1	2.9

Table 4.3: Educational level of respondents

No	Educational level	Number	Percent
1	Diploma	1	2.9
2	BSc	18	88.2
3	MSc	1	8.8

4.1.3 Respondents position on site

The following table presents the position of contractors, consultants and client representatives on the housing project.

Table 4.4 Respondents position on site

Client			Consultant			Contractor		
Position	No	Percent	Position	No	Percent	Position	No	Percent
Site engineer	3	33.3	Site supervisor	11	91.6	Project manager	4	28.57
Junior officer	2	22.2	Plan and budget officer	1	8.3	Site manager	1	14.28
Senior officer	2	22.2				Site engineer	8	57.14

Department head	2	22.2						
Total	9	100		12	100		13	100

4.1.4 Respondents work experience

Table 4.5 presents the work experience of respondents in the construction industry and in the housing construction sector specifically.

Table 4.5 respondents experience in construction engineering and housing

Experience in construction industry			Experience in housing		
Year	No	Percent	Year	No	Percent
< 5 years	11	55	< 5 years	18	90
5-10 years	8	40	5-10 years	2	10
>10 years	1	5			
Total	20	100		20	100

4.2 Perception towards prefabricated wall construction materials

4.2.1 Advantage of prefabricated wall construction materials

In this part the perception of questionnaire respondents towards the use of prefabricated wall construction materials is discussed. Respondents evaluated the practice of the current wall construction materials based on the criteria of cost efficiency, time management quality, durability, material availability and ease of construction. When asked about the advantage of prefabricated wall making materials 11.7% of respondents replied that prefabricated wall making materials are not advantageous for the Ethiopian housing construction sector. 79.5% of respondents agreed that using prefabricated wall construction materials is advantageous for the Ethiopian housing construction sector and 8.8% had a neutral opinion about the issue.

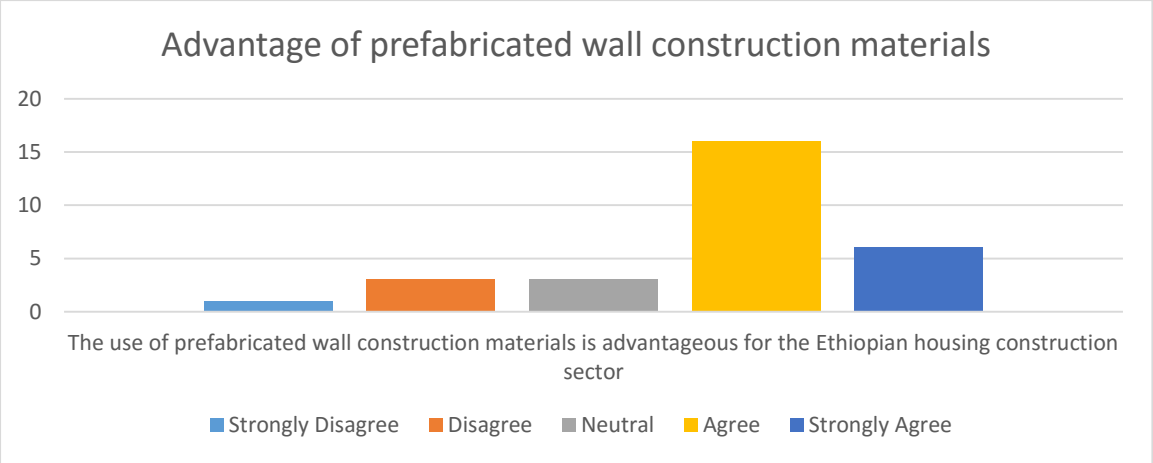

Figure 1: Advantage of prefabricated wall construction materials

4.2.2 Cost of wall making materials

When asked if the conventional wall construction materials used in the housing sector of Ethiopia are cost efficient, 44.1% of respondents replied they disagree from which 14.7% strongly disagree and 29.4% disagree. 8.8% of respondents had neutral opinion about the cost efficiency of the current wall construction materials. 47% of respondents believe the current wall construction materials are cost efficient. For the cost comparison with the conventional wall making materials in the housing sector the and use of prefabricated wall construction materials, 20.6% of respondents disagree, 29.4% of respondents had a neutral opinion and 50% of respondents agree that prefabricated wall construction materials are cost effective.

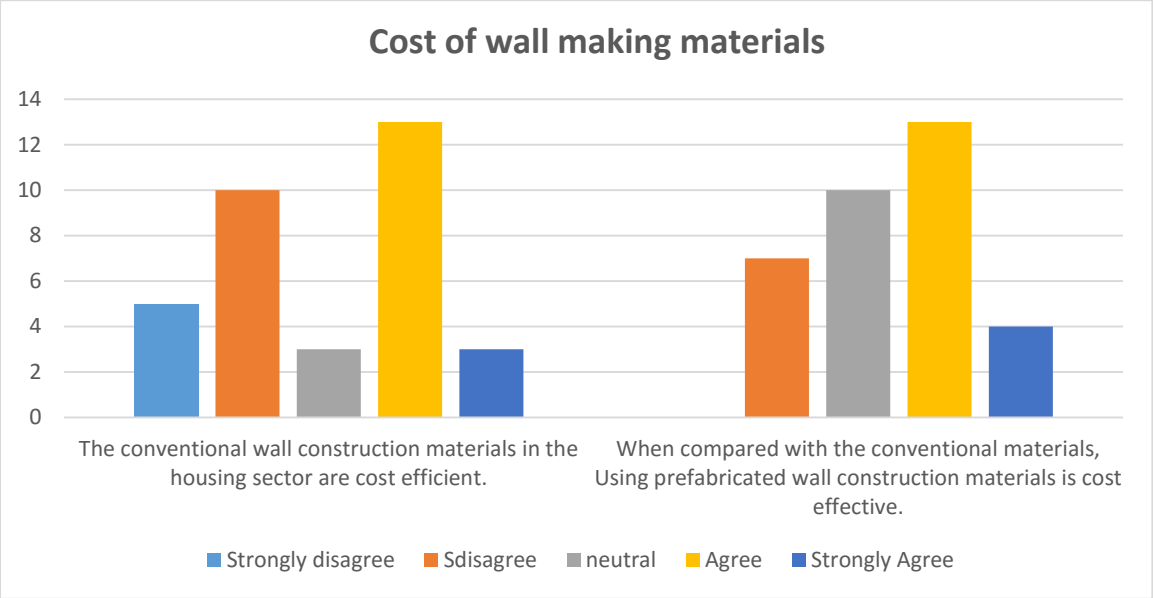

Figure 2: Cost of wall making materials

4.2.3 Construction time

This section discussed the time to finish the construction of walls using conventional wall making materials was in question and 52.9% of the participants responded that the conventional wall making materials are not time efficient. 20.6% of respondents had a neutral opinion 26.5% believe the conventional wall making materials are time efficient.

The following section discussed the time of construction using prefabricated wall construction materials, 85.3% of the respondents agreed with the time efficiency of prefabricated wall construction materials. And 14.7% of the respondents had a neutral opinion.

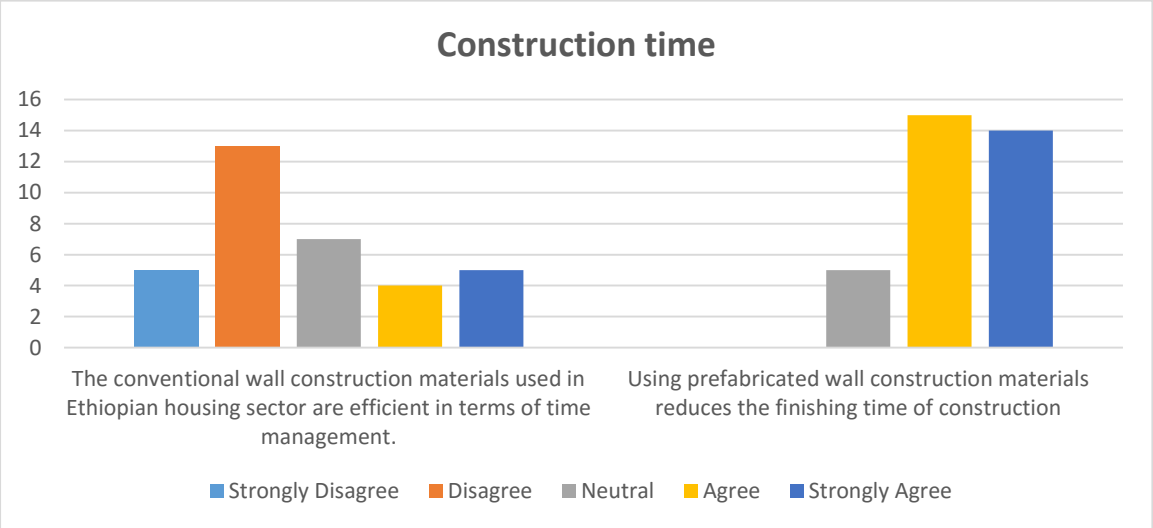

Figure 3: Construction time

4.2.4 Quality of construction

In the discussion about the quality of conventional wall construction materials 58.8% of the respondents think the quality of the conventional wall making materials used in the housing sector are not to the appropriate standard. 26.5% of the respondents had a neutral opinion on the quality of the conventional wall construction materials and 14.7% of the respondents believe the conventional wall making materials are up to the appropriate standard.

Compared to the conventional wall making materials the quality of prefabricated wall construction materials was questioned. 17.7% of the respondents believe that prefabricated materials have less quality compared with the conventional wall construction materials. And 61.8% of the respondents said that prefabricated wall making materials are better in quality

compared with the conventional wall making materials. And 20.6% of respondents have a neutral opinion on the quality of prefabricated wall construction materials.

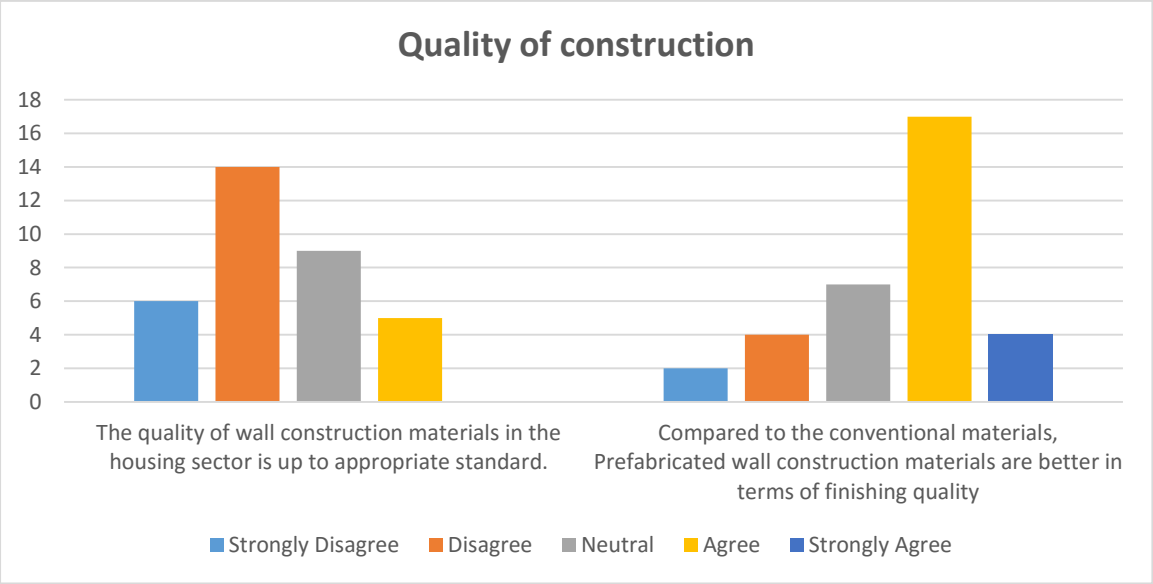

Figure 4: Quality of construction

4.2.5 Durability of material

Durability is usually defined as the ability of a material to perform for a long time (Bomberg, 2017). On this regard the durability of prefabricated wall construction materials 23.5% of the respondents believe prefabricated wall construction materials are not better than the conventional wall construction materials. 20.6% of the respondents have a neutral opinion on the durability aspect of the prefabricated wall making materials and 55.8% of respondents replied that prefabricated wall construction materials are better in durability compared with the conventional materials.

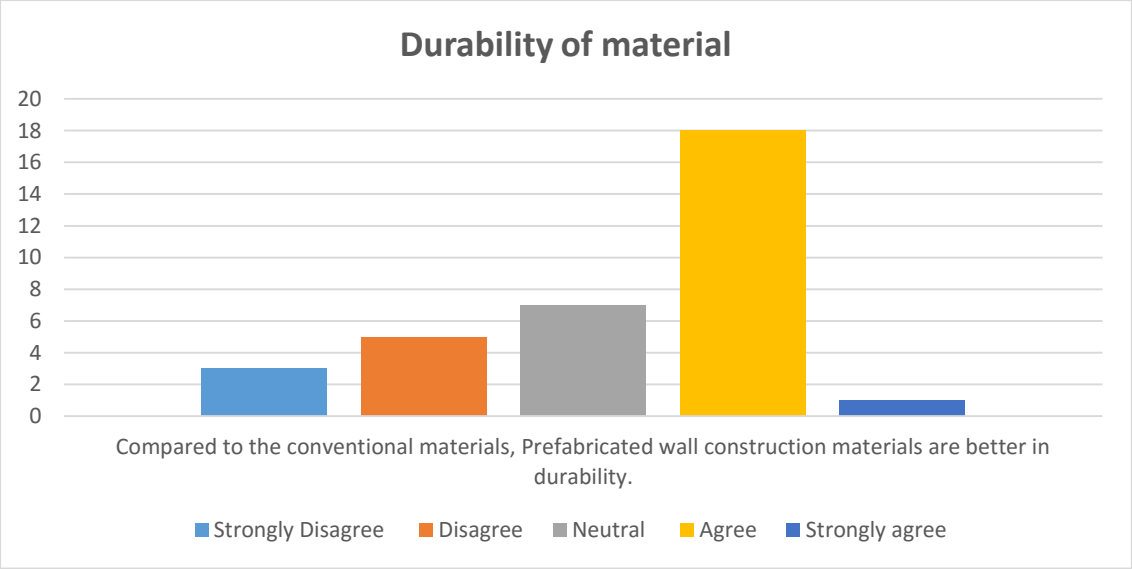

Figure 5: Durability of materials

4.2.6 Material availability

In the data collected on the material availability of prefabricated wall construction materials, 29.4% of the respondents replied that prefabricated wall making materials are not available compared to the conventional wall making materials. In this issue 17.6% of respondents held a neutral opinion and 52.9% of respondents replied that prefabricated wall making materials are more available than the conventional wall making materials in the housing sector.

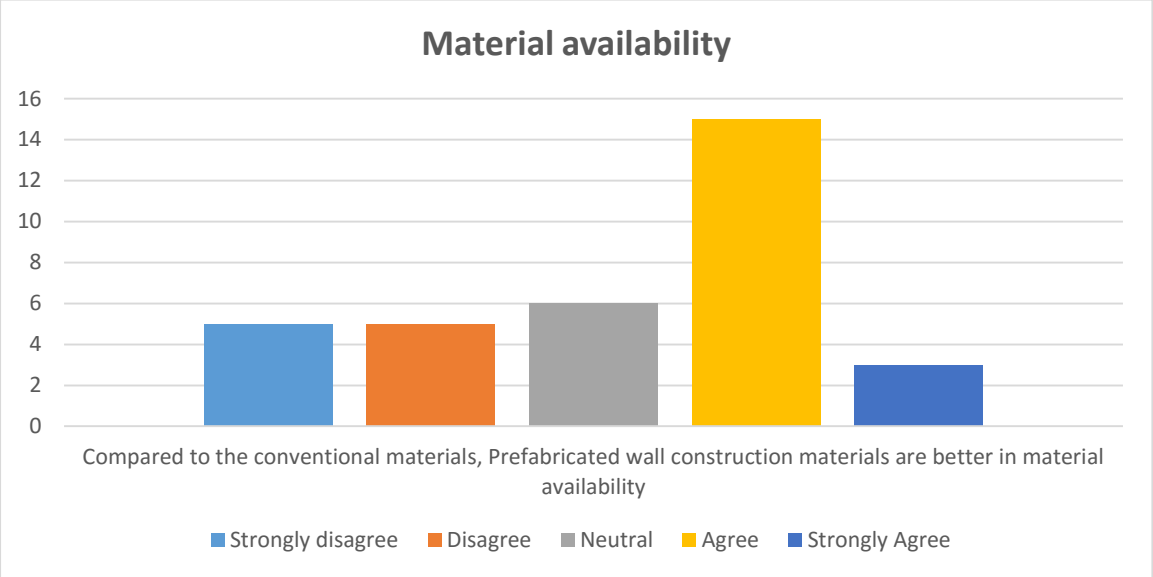

Figure 6: Material availability

4.2.7 Ease of construction

For the set of data collected on the ease of construction of prefabricated wall construction materials, 14.7% of respondents replied that the conventional wall construction materials are easier to construct and 20.6% of respondents had a neutral opinion. 64.7% of the respondents replied that prefabricated wall construction materials are easier to construct compared with the conventional wall construction materials.

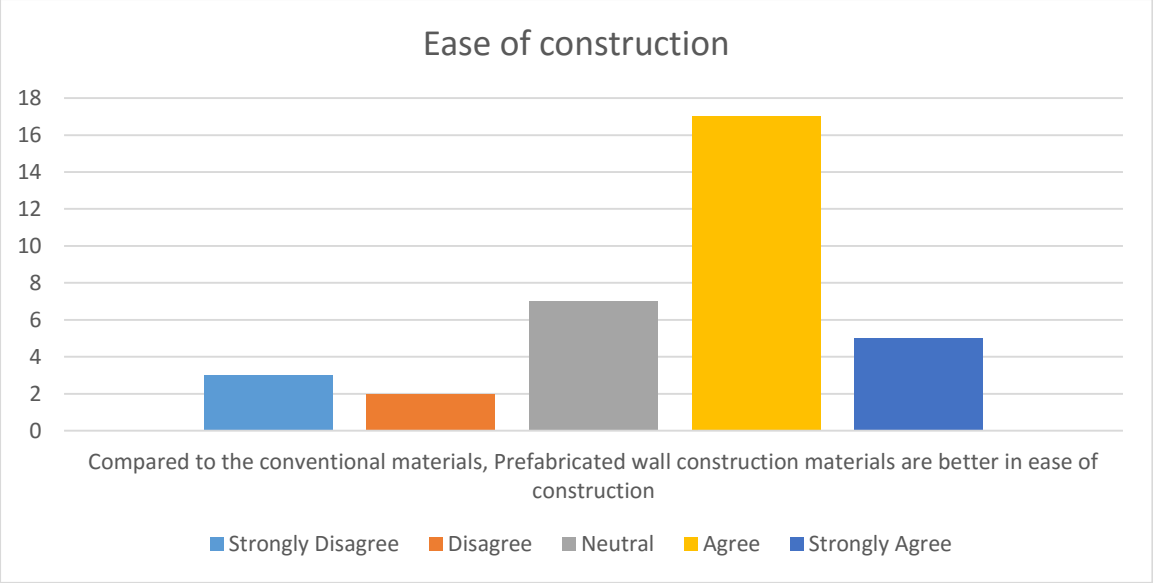

Figure 7: Ease of construction

4.2.8 Attributes of wall making materials

This section presents the response of participants on the attributes of the five selected wall making materials based on their experience in the housing construction sector. And the data presented are the opinions of the respondents of questionnaire.

The Relative Importance Index (RII) is used to rank the attributes of the wall construction materials (Nourbakhsh, et al., 2012).

$$RII = \frac{\sum_{i=1}^{5} Wixi}{\sum_{i=0}^{5} xi} \quad \text{.....Eq. 4.1}$$

Where

i= Response category index= 1,2,3,4 and 5 for poor, fair, good, very good and excellent respectively.

W_i = the weight assigned for i^{th} response= 1, 2, 3, 4, 5

X_i = frequency of the i^{th} response

According to the data collected HCB ranked the highest in cost efficiency followed by Agrostone and Styrofoam concrete. LWC rand gypsum board ranked 3rd and 4th in cost of the wall making material. Agrostone has the highest rank in time of construction followed by gypsum board, Styrofoam concrete, LWC and HCB ranking 2nd to 5th respectively.

For material availability HCB ranked 1st followed by LWC, and gypsum board. Styrofoam concrete and Agrostone panel ranked 4th and 5th respectively. For the aesthetics gypsum board ranked to be the highest followed by Styrofoam concrete and LWC. HCB and Agrostone panel are the least aesthetically pleasing materials according to the respondents.

LWC ranked to be the most durable wall making material in the data collected followed by gypsum board. HCB and Styrofoam ranked 3rd and 4th where Agrostone is the least durable wall construction material compared with the others. For ease of transportation Styrofoam concrete ranked the highest followed by gypsum board, Agrostone and HCB. LWC is the most difficult material to transport compared with the selected wall making materials.

The workability of HCB ranked the highest followed by Agrostone and LWC. Gypsum board and Styrofoam concrete ranked 4th and 5th respectively.

Hollow concrete block

Table 4.6: Attributes of hollow concrete block

HOLLOW CONCRETE BLOCKS	Poor		Fair		Good		Very good		Excellent		RII
	No	%	No	%	No	%	No	%	No	%	
Cost efficiency	0	0	9	26.5	17	50	6	17.6	2	5.9	0.8
Time of construction	6	17.6	10	29.4	10	29.4	5	14.7	3	8.8	0.5352
Material availability	0	0	5	14.7	13	38.2	11	32.4	5	14.7	0.6941
Aesthetics	2	5.9	4	11.8	20	58.8	7	20.6	1	2.9	0.6058
Durability	6	17.6	2	5.9	18	52.9	6	17.6	2	5.9	0.5764
Transportation	6	17.6	6	17.6	10	29.4	10	29.4	2	5.9	0.5764
Workability	0	0	2	5.9	23	67.6	6	17.6	3	8.8	0.6588

Fire resistance	0	0	2	5.9	20	58.8	9	26.5	3	8.8	0.6764

According to the respondents view of the attributes of HCB cost efficiency ranks 1st with RII value 0.8 material availability is second with 0.6941 RII and fire resistance stands 3rd with RII of 0.6764

Agrostone panel

Table 4.7: Attributes of Agrostone panel

AGROSTONE PANEL	Poor		Fair		Good		Very good		Excellent		RII
	No	%	No	%	No	%	No	%	No	%	
Cost efficiency	1	2.9	3	8.8	16	47.1	5	14.1	4	11.8	0.6275
Time of construction	0	0	6	17.6	8	23.5	13	38.2	2	5.9	0.7310
Material availability	14	41.2	6	17.6	4	11.8	5	14.7	0	0	0.4
Aesthetics	18	52.9	4	11.8	5	14.7	2	5.9	0	0	0.3379
Durability	16	47.1	7	20.6	5	14.7	1	2.9	0	0	0.3448
Transportation	5	14.7	2	5.9	11	32.4	10	29.4	1	2.9	0.6
Workability	1	2.9	3	8.8	16	47.1	6	17.6	3	8.8	0.6482
Fire resistance	10	29.4	6	17.6	6	17.6	5	14.7	2	5.9	0.5517

The number of respondents about the attributes of Agrostone panel is 29 because 5 respondents are not at all familiar with Agrostone panel. According to the respondents view of the attributes of Agrostone panel time of construction ranks 1st with RII value 0.7310 workability is second with 0.6482 RII and cost efficiency stands 3rd with RII of 0.6275 value.

Gypsum board

Table 4.8: Attributes of gypsum board

GYPSUM BOARD	Poor		Fair		Good		Very Good		Excellent		RII
	No	%	No	%	No	%	No	%	No	%	
Cost efficiency	3	10.3	14	48.3	9	31	3	10.3	0	0	0.4827
Time of	3	10.3	2	6.9	12	41.4	9	31	3	10.3	0.6482

construction											
Material availability	4	13.8	3	10.3	13	44.8	6	20.7	3	10.3	0.6068
Aesthetics	1	3.4	2	6.9	6	20.7	11	37.9	9	31	0.7724
Durability	5	17.2	4	13.8	13	44.8	3	10.3	4	13.8	0.5793
Transportation	3	10.3	1	3.4	12	41.4	11	37.9	2	6.9	0.6551
Workability	0	0	5	17.2	8	27.9	13	44.8	3	10.3	0.6068
Fire resistance	6	20.7	4	13.8	10	34.5	6	20.7	3	10.3	0.5724

The number of respondents for the attribute of gypsum board is 29 because 5 respondents of the questionnaire not at all familiar with the material in question. For the attributes RII value of gypsum board aesthetics has the highest rank with 0.7724 value and transportation ranks 2nd with 0.6551 RII value. Time of construction stands third with RII value of 0.6482.

Styrofoam

Table 4.9: Attributes of Styrofoam

STYROFOAM	Poor		Fair		Good		Very Good		Excellent		RII
	No	%	No	%	No	%	No	%	No	%	
Cost efficiency	1	4	3	12	16	64	4	16	1	4	0.608
Time of construction	1	4	5	20	12	48	5	20	2	8	0.616
Material availability	4	16	7	28	11	44	3	12	1	4	0.544
Aesthetics	3	12	6	24	6	24	10	40	2	8	0.712
Durability	5	20	7	28	4	16	9	36	1	4	0.576
Transportation	2	8	4	16	12	48	7	28	3	12	0.712
Workability	1	4	3	12	18	72	3	12	0	0	0.584
Fire resistance	12	48	7	28	5	20	1	4	0	0	0.36

The number of participants who responded to the attributes of Styrofoam is 25. The rest of the participants are not at all familiar with the wall making material. Aesthetics and transportation ranked the highest in the RII value of Styrofoam 0.712 value. Time of

construction and cost efficiency ranked 2nd and 3rd with RII values 0.616 and 0.608 RII values respectively.

Light weight concrete

Table 4.10: Attributes of light weight concrete

LIGHT WEIGHT CONCRETE	Poor		Fair		Good		Very Good		Excellent		RII
	No	%	No	%	No	%	No	%	No	%	
Cost efficiency	2	7.1	9	32.1	13	46.4	3	10.7	1	3.6	0.5428
Time of construction	3	10.7	7	25	14	50	3	10.7	1	3.6	0.5428
Material availability	2	7.1	4	14.3	14	50	6	21.4	2	7.1	0.6142
Aesthetics	2	7.1	1	3.6	12	42.9	10	35.7	3	10.7	0.6785
Durability	1	3.6	2	7.1	8	28.6	9	32.1	8	28.6	0.75
Transportation	3	10.7	8	28.6	12	42.9	2	7.1	3	10.7	0.5571
Workability	2	7.1	3	10.7	14	50	6	21.4	3	10.7	0.6357
Fire resistance	0	0	2	7.1	10	35.7	6	21.4	10	35.7	0.7714

The number of respondents that are familiar with light weight concrete were 28. According to the data collected for the attribute of light weight concrete fire resistance ranked 1st with score of 0.7714 value. Durability and aesthetics ranked 2nd and 3rd with RII values of 0.75 and 0.6785.

4.2.9 Challenges affecting the application of prefabricated wall construction materials

There are a number of challenges that affect the adaptation of prefabricated construction in various countries. Shortage of skills, shortage of expert personnel that can design and manage building construction, higher cost of prefabricated materials negative perception towards prefabrication, lack of government incentives, directives and promotion and transportation limitation of prefabricated elements are the limitations of prefabricated buildings encountered in various parts of the world (El-Abidi1 & Ghazalia, 2015).

Towards the adaption of prefabricated construction systems most professionals in the building construction industry decided that lack of skilled man power, lack of design and

engineering, limited number of suppliers of technologies, lack of designers commitment limited knowledge and understanding about prefabrication, lack of local technological advancement and un-trust the quality and safety of components were the challenges for adapting modular construction in Ethiopian construction industry. Massive transportation requirement and high initial cost of materials are also challenges for the application of prefabrication in Ethiopia (Geleta, 2019).

Respondents were asked to state the influence of challenges affecting the application of prefabricated wall construction materials. The gathered data was analysed using relative importance index to determine the factors affecting application of prefabricated wall construction materials. In this section a five point Likert scale was used to analyse the data for ranking of factors. The highest influential factor was selected using the RII value.

Table 4.11: Challenges affecting the application of prefabricated wall making materials

Challenges/factors	NI		SI		I		VI		EI	
	No	%	No	%	N0	%	N0	%	N0	%
Lack of technical assistance and Technological development	2	5.9	2	5.9	13	38.2	11	32.4	6	17.6
Lack of awareness among stakeholders	0	0	2	5.9	12	35.3	13	38.2	7	20.6
High cost of alternative materials	0	0	3	8.8	13	38.2	16	47.1	2	5.9
Transport cost of raw materials for production	0	0	6	17.6	10	29.4	10	29.4	8	23.5
Shortage of skilled man power	0	0	4	11.8	11	32.4	12	35.3	7	20.6
Lack of technology for production	0	0	4	11.8	12	35.3	9	26.5	9	26.5
Poor performance of finished products	0	0	4	11.8	11	32.4	10	29.4	9	26.5
Lack of adequate	0	0	3	8.8	15	44.1	10	29.4	6	17.6

researches on Alternative wall construction Materials										

Lack of commitment from the government bodies and lack of financial support from the government are also mentioned as factors that affect the application of prefabricated wall construction materials.

Table 4.12: RII value of challenges affecting the application of prefabricated technology

Challenges/factors	RII value	Rank
Lack of technology for production	0.6985	1
Lack of awareness among stakeholders	0.6838	2
Poor performance of finished products	0.6764	3
Shortage of skilled man power	0.6617	4
Transport cost of raw materials for production	0.6470	5
Lack of adequate researches on Alternative wall construction Materials	0.6397	6
Lack of technical assistance and Technological development	0.625	7
High cost of alternative materials	0.625	7

According to the RII value of the respondents review lack of technology for production ranked the highest in the factors affecting the application of prefabricated wall construction materials with RII value of 0.6985. Lack of awareness among stakeholders ranks second with RII value of 0.6838 and poor performance of finished prefabricated products is the third ranking with RII value of 0.6764.

4.3 Preliminary cost analysis of wall construction materials

The cost analysis of the selected wall making materials per cubic meter is presented in this section. The price and rates of HCB was obtained from materials suppliers and contractors. The rates of Agrostone and gypsum board were found from the material manufacturers and suppliers by conducting semi structured interview.

Table: 4.13: Cost of different wall making materials

Item	Description	Unit	Rate	Amount (Birr)
Hollow Concrete Blocks	Class 1 Hollow Concrete Blocks,	m^2	160	160
	2 coats of plaster in cement, lime and sand with gypsum plaster as third coats having 20mm thickness. Inclusive of benefits, travel subsides and cost of overtime related to targeted output	m^2	190	190 **350**
Agrostone panel	60 cm width and 15 cm thickness Agrostone panel	m^2	210	210
	Installation, wastage, transporting, handling, labour including benefits, travel subsides and cost of overtime related to targeted output.	m^2	120	120 **330**
Gypsum board	10 cm thickness 66 cm width and 51cm height Prefabricated Gypsum board	m^2	250	250
	Installation, wastage, transporting, handling, labour including benefits, travel subsides and cost of overtime related to targeted output.	m^2	150	150 **400**

The local cost of Styrofoam and light weight concrete are not included in this cost analysis because the materials are not being used in the Ethiopian building industry.

But the current prices of Styrofoam concrete prefabricated wall were obtained from alibaba.com. The reason behind the selection of the website is because it is believed that it has no affiliation to any particular supplier, sales agent or manufacturer which is proved by the number of suppliers that post their product on the website. For Styrofoam concrete

prefabricated panel to obtain the representative price value the first 10 results on the website that fit the required specification were taken and the mean price value of Styrofoam was calculated.

The average cost of prefabricated Styrofoam concrete wall on alibaba.com is USD16.85 (589.925 ETB).

4.4 Experimental analysis

This section of the study discusses the results of experiments done on the light weight concrete and Styrofoam concrete. The mix design of the concrete was carried out as per the ACI Mix Design Method. The compressive strengths of Styrofoam concrete and light weight concrete were compared with a C15 normal concrete and HCB which is made according to the local standard.

The concrete was required to have a compressive strength of 25Mpa at 28 days. The samples were prepared using locally available materials. The slump of the concrete is 50 mm and the maximum size of aggregate is 25mm.

For the normal concrete with 25MPa at 28 days the concrete material properties are as follows

- Cement:
    - Dangote OPC
- Water/ cement ratio= 0.5 according to ACI 211.1
- Coarse aggregate:
    - Specific gravity= 2.69
    - Water absorption= 1.315%
    - Unit weight= 1635.6 kg/m^3
    - Nominal maximum size of aggregate= 25mm
- Fine aggregate:
    - FM=3.04
- Slump= 50mm

The mix design calculation was made according to the ACI 211 method. And the amount of each ingredient used to cast three cubes with 0.15m^3 cubes was

- Water: 2.04 kg

- Cement: 5.67 kg
- Coarse aggregate: 13.47 kg
- Fine aggregate: 9.52 kg

The required concrete strength in 28 days is calculated as follows according to ACI 318.

$$f'_{cr} = f'_c + 1.345 \quad \text{Eq. 4.2}$$

For Styrofoam concrete all the above material properties were used except the coarse aggregate.

The proportioning for the Styrofoam concrete was as follows.

- Water: 2.49 kg
- Cement: 5.67 kg
- Coarse aggregate: 6.73 kg
- Fine aggregate: 9.52 kg
- Styrofoam: 0.09 kg

For the concrete made with Styrofoam the half of the weight of coarse aggregate was replaced by Styrofoam as a coarse aggregate. The maximum size of Styrofoam used was 25 mm.

Tapping the concrete by metal rod was used as a compaction method to avoid the floating of Styrofoam particles due to the light weight.

For light weight concrete the properties of concrete materials used for the normal weight concrete was used but half the weight of coarse aggregate was replaced by pumice.

The proportion of ingredients for the light weight concrete to cast three cubes was:

- Water: 2.49 kg
- Cement: 5.67 kg
- Coarse aggregate: 6.73 kg
- Fine aggregate: 9.52 kg
- Pumice: 2.4 kg

Summary of test results

The compressive strength test results showed that LWC made of pumice and Styrofoam concrete made from 50% replacement of aggregate has lighter weight compared with the concrete made with 100% aggregate and the compressive strength results showed that the materials can be used as a non-load bearing wall construction materials.

Table 4.14: 7 day compressive strength of normal concrete

Specimen no	Dimensions (cm)			Area (cm^2)	Failure load (KN)	Compressive strength (MPa)	Weight (gm)
	L	W	H				
1	15.0	15.0	15.0	225.0	357.26	15.87	8102
2	15.0	15.0	15.0	225.0	383.38	17.03	8103
3	15.0	15.0	15.0	225.0	377.75	16.78	8094

The average 7 day compressive strength of concrete is 16.56 and the 28 day compressive strength will be 27.6 MPa.

Table 4.15: 7 day compressive strength of light weight concrete with Styrofoam

Specimen no	Dimensions (cm)			Area (cm^2)	Failure load (KN)	Compressive strength (MPa)	Weight (gm)
	L	W	H				
1	15.0	15.0	15.0	225.0	233.0	10.35	6442
2	15.0	15.0	15.0	225.0	303.6	13.49	6319
3	15.0	15.0	15.0	225.0	271.3	12.05	5646

The average 7 day compressive strength is 11.96MPa and the 28 day strength will be 19.93 MPa. Because of the light weight they have the Styrofoam particles float on the surface during normal vibration for compaction. Therefore the compaction was made by tapping rod.

Table 4.16: 7 day compressive strength of light weight concrete with pumice

Specimen no	Dimensions (cm)			Area (cm^2)	Failure load (KN)	Compressive strength (MPa)	Weight (gm)
	L	W	H				
1	15.0	15.0	15.0	225.0	327.0	14.53	6838
2	15.0	15.0	15.0	225.0	366.2	16.27	6833

3	15.0	15.0	15.0	225.0	354.7	15.74	6593

The average 7 day compressive strength is 15.51MPa. Since concrete gains 60% of its strength on the 7th day, by improvising the 28 day strength will be 25.85 MPa.

Material strength tests for gypsum board is not applicable in this country because there are no testing facilities for gypsum board but a typical compressive strength of 50*50mm or 100*100mm samples cut from across the full board width conditioned for at least 24 hours and tested in compressive strength machines is presented as follows.

Table 4.17 Compressive strength of gypsum board

Thickness mm	Board type	Compressive strength MPa
7.9	MH gypsum board	2.75
12.7	Regular gypsum board	2.4
15.9	Type x gypsum board	2.75

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The main objective of this research was to study the suitability of alternative prefabricated wall materials towards the provision of affordable houses in Ethiopian housing construction sector. The questionnaire survey was conducted to assess the perception of major stakeholders in the housing construction sector i.e. client representatives, contractors and consultants currently working in housing projects of Addis Ababa. The summary of the findings is discussed below.

- The study has concluded that the use of prefabricated wall construction materials is advantageous for Ethiopian housing construction sector. Compared with the conventional wall construction materials using prefabricated wall construction materials for housing construction reduces the construction finishing time and the use of prefabricated wall materials is better in ease of construction and finishing quality.
- According to the questionnaire analysis the three most influential challenges that affect the application of prefabricated wall construction materials in Ethiopia are
    - Lack of technology for production
    - Lack of awareness among stakeholders
    - Poor performance of finished products
- Styrofoam concrete and light weight concrete could be used as an alternative wall construction materials because they meet the standard for non-load bearing wall construction. The compressive strength of Styrofoam concrete and light weight concrete made with pumice meets the standard for non-load bearing wall construction since it exceeds 15MPa.
- The questionnaire analysis revealed that the from conventional wall construction materials used in the housing construction sector HCB is cost effective and most available material. But the potential of the other materials should also be assessed because they have a promising attributes to be used as an alternative wall construction materials and improve the overall performance of housing construction sector.

5.2 Recommendations

Based on the research results and findings it is recommended that if following measures are taken it will improve the application of prefabricated wall construction on the Ethiopian housing construction sector.

- Government policy should be developed to support the application of prefabrication of wall construction and direction should be given to ensure quality of the prefabricated materials. And the developed policy should also include financial support for parties willing to introduce prefabricated wall construction materials and a platform to improve the link between universities and researchers should be provided to study the feasibility of new prefabricated wall construction materials.
- Awareness should be created among stakeholders through
    - Universities and technical schools should focus on creating and adopting prefabricated technologies that are applicable for the Ethiopian housing construction sector.
    - Including prefabricated construction materials and technologies in the curriculum of universities an encourage students to come up with researches and ideas that can be applicable and feasible for the Ethiopian housing construction sector.
    - Technical and knowledge support for major stakeholders and suppliers on the construction sector.
    - Researches should be carried out on the cost analysis and economic feasibility of various prefabricated wall construction materials.
- The existing prefabricated wall materials should be reevaluated for their cost, quality and time efficiency. This measure should include
    - The reexamining the quality of Agrostone panel to find out the source of problems in the material and reengineer the product so that it could be utilized on the proper manner.
    - The material availability for Agrostone panel should be well studied

  - Conducting subsequent studies and quality checks with the production and construction of Agrostone panel construction.
  - The cost, quality and time efficiency of HCB should also be studied in relation to other prefabricated wall construction materials.

- Gypsum board wall construction should be considered as one of the wall construction materials used in the housing construction sector and the properties of the material should be studied for the effective application of gypsum including the raw material availability and economic analysis for provision the technical and knowledge support

- Light weight concrete and Styrofoam concrete as prefabricated wall construction material should be considered for the wall construction materials and the different types of light weight concrete should be utilized as an alternative wall construction material for housing projects.

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ANNEX 1

Dear Participant

At present, I am working on a research titled "***Prefabricated Wall Construction Practices as an Alternative Materials and Technology in The Ethiopian Housing Sector"*** as a partial fulfilment of the requirements for the degree of Master of Science (MSc) in Construction Technology and Management at Addis Ababa University, Institute of Technology and my thesis advisor is Dr. Denamo Addissie.

The main objective of the research is **to study the suitability of alternative prefabricated wall materials towards the provision of affordable houses in Ethiopian housing construction sector**. To meet this research objective, it is necessary to have the opinion of contractors, client and consultants currently working on the scheme project and hence you are one of the stakeholders recruited to respond this questionnaire.

Accuracy in answering the questions included in the questionnaire is necessary to have reliable output of the data analysis. Moreover, your immediate response helps to finish the research timely. I confirm that your response will be kept confidential and will be used only for the purpose of this research.

I would like to extend my gratefulness for your time and willingness to fill out this research instrument.

Looking forward to your soonest response
With Regards,

Mishame Desalegn

If you have any question or look for clarification on the questionnaire, please contact me on
Tel: +251 916 15 21 03 or E-mail:-mishamedesalegn@gmail.com

Part one:

Background Information about participants

1. What is your education level?

   Diploma ☐ BSC ☐ MSC ☐ PHD ☐

2. Your field of specialization

   Civil engineering ☐ Construction management ☐

   Architecture ☐ Other ☐ Please specify _____

3. What is the type of organization you are working in now?

   Client ☐ Consultant ☐ Contractor ☐

4. What is your position in the organization?

   _____

5. Current role on the project

   _____

6. What is your work experience in Building Construction?

   0 – 5 years ☐ 5 – 10 years ☐ More than 10 Years ☐

7. What is your work experience in condominium housing construction?

   0 – 5 years ☐ 5 – 10 years ☐ More than 10 Years ☐

Part two: Extent of using prefabricated wall construction materials

1. What are the wall construction materials prominently used in the **housing sector**? List below

   _____

   _____

   _____

   _____

   _____

   _____

2. Is using prefabricated wall construction materials advantageous for Ethiopian housing sector?

   Yes ☐ No ☐

   State your reason

3. On a scale of one to five, one being the highest score evaluate the advantage of prefabricated wall construction materials in terms of cost time and quality of construction. (To answer this question put X in the appropriate box below)
   Strongly Agree (SA) = 5; Agree (A) =4; Neutral (N) = 3; Disagree (DA) = 2; Strongly Disagree (SD) =1

   Conventional materials are building materials that are widely accepted and are commonly being used in most construction sites.

No	Evaluation statements	SA	A	N	DA	SD
1	The conventional wall construction materials in the housing sector are cost efficient.					
2	The conventional wall construction materials used in Ethiopian housing sector are efficient in terms of time management.					
3	The quality of wall construction materials in the housing sector is up to appropriate standard.					
4	The use of prefabricated wall construction materials is advantageous for the Ethiopian housing construction sector					

5	When compared with the conventional materials, Using prefabricated wall construction materials is cost effective.					
6	Using prefabricated wall construction materials reduces the finishing time of construction.					
7	Compared to the conventional materials, Prefabricated wall construction materials are better in terms of finishing quality.					
8	Compared to the conventional materials, Prefabricated wall construction materials are better in durability.					
9	Compared to the conventional materials, Prefabricated wall construction materials are better in material availability					
10	Compared to the conventional materials, Prefabricated wall construction materials are better in ease of construction.					

4. On the scale of one to four, four being the highest score, **how familiar** are you with the following prefabricated wall construction materials? (To answer this question put X in the appropriate box below)

No	Wall construction material	Not at all familiar	Slightly familiar	Moderately familiar	Very familiar
1	Hollow concrete block				
2	Agrostone panel				
3	Gypsum board				
4	Styrofoam				
5	Light weight concrete				

5. On a scale of one to five, five being the highest score, based on your experience label attributes of the following prefabricated wall construction materials for housing construction. (Put X in the appropriate box below)

I. Hollow concrete block

No	Material properties	Poor	Fair	Good	Very good	Excellent
1	Cost efficiency					
2	Time of construction					
3	Material availability					
4	Aesthetics					
5	Durability					
6	Ease of transportation to construction site					
7	Workability					
8	Fire resistance					

II. Agrostone panel

No	Material properties	Poor	Fair	Good	Very good	Excellent
1	Cost efficiency					
2	Time of construction					
3	Material availability					
4	Aesthetics					
5	Durability					
6	Ease of transportation to construction site					
7	Workability					
8	Fire resistance					

III. Gypsum board

No	Material properties	Poor	Fair	Good	Very good	Excellent
1	Cost efficiency					
2	Time of construction					
3	Material availability					
4	Aesthetics					
5	Durability					

6	Ease of transportation to construction site					
7	Workability					
8	Fire resistance					

IV. Styrofoam

No	Material properties	Poor	Fair	Good	Very good	Excellent
1	Cost efficiency					
2	Time of construction					
3	Material availability					
4	Aesthetics					
5	Durability					
6	Ease of transportation to construction site					
7	Workability					
8	Fire resistance					

V. Light weight concrete

No	Material properties	Poor	Fair	Good	Very good	Excellent
1	Cost efficiency					
2	Time of construction					
3	Material availability					
4	Aesthetics					
5	Durability					
6	Ease of transportation to construction site					
7	Workability					
8	Fire resistance					

6. On the scale of one to five, five being the highest score, state the Level of Influence of the challenges/factors affecting the application of prefabricated wall construction materials.
   Extremely Influential (EI) =5; Very Influential (VI) = 4; Influential (I) = 3; Slightly Influential (SI) =2; Not at all Influential (NI) = 1

	Challenges/ factors	EI	VI	I	SI	NI
1	Lack of technical assistance and Technological development					
2	Lack of awareness among stakeholders					
3	High cost of alternative materials					
4	Transport cost of raw materials for production					
5	Shortage of skilled man power					
6	Lack of technology for production					
7	Poor performance of finished products					
8	Lack of adequate researches on Alternative wall construction materials					
9	Other factors • • • • • • •					

Thank you for your time!

ANNEX II

List of contractors and consultants from which the data was collected.

1. Contractors

No	Contractor name	Construction site
1	Getachew Haylu	Lideta
2	Kelkilew Tadesse	Lideta
3	Fanaye Rudolfo	Lideta
4	Alemayehu Bahiru	Lideta
5	Brehanu Handero	Lideta
6	Yohanes Dessie	Lideta
7	Samueal Fekire	Lideta
8	Abadi	Lideta
9	SB & YG Construction	Lideta
10	Fontenina Construction	Lideta
11	Onex Stone	Lideta
12	Sabhe B.C/Amanu Andualem G .C	Lideta
13	Sabhe B.C/Eliyas Bekele B.C	Lideta
14	Sabhe B.C/Tefera Solomon G. C	Lideta
15	Helen Fetene	Lideta
16	Lemlem Berhe	Lideta
17	Akalu Argaw	Lideta
18	G. K. M	Lideta
19	Nahm Sultan	Lideta
20	G/Meskel	Lideta
21	Abebech Girma	Lideta
22	Yit Con.Yibrah Tsfahuegn	Lideta
23	Kibrom Girmay	Lideta
24	Mason Construction	Lideta
25	Temesgen Tefera	Lideta
26	Brehailu Kinfe	Lideta
27	Miruts Construction	Lideta
28	Nued Construction	Lideta
29	Milky Construction	Lideta
30	Masaw Construction	Lideta
31	Mulush Construction	Lideta
32	Glb Construction	Lideta
33	Siyum Dawud	Lideta
34	Beabcon	Lideta
35	Keberom Girmay	Lideta
36	Goytom Desta	Lideta
37	Abdulahi Mohammed	Lideta
38	Samson G/Sellasie	Lideta
39	Kh Enjineering	Lideta

40	Serja Construction	Bole
41	Mesfen Semere	Bole
42	Tesfaye Abebe G/Maryam	Bole
43	Mulugeta Abebe Tarekegn	Bole
44	Abun Construction	Bole
45	Abrham Yosef	Bole
46	Tilahun Mekete Zewedie	Bole
47	Yifredew Abreham	Bole
48	Esayas Endale Fetene	Bole
49	Bruk Kebede H/Mariam	Bole
50	Bruh Tesfa	Bole
51	Yared Mekonenn	Bole
52	Solomon Gedeye Hailu	Bole
53	Nebiyu Worku	Bole
54	Yohannes Bantiregu	Bole
55	Abreham Amanuel Desalegn	Bole
56	Tsegaye Megersa	Bole
57	Jafar Kasim Hasen	Bole
58	Tadele Berhe G/Yohanes	Bole
59	C.I.G Int.Trading	Bole
60	Kaleb Teka Berhe(Romadi)	Bole
61	Muhaba Reshid	Bole
62	Negasi Abay Tekilay	Bole
63	Yetebarek Telahun Yimere	Bole
64	Eliyas Reda Zoweda	Bole
65	Kibrom Desta G.C	Bole
66	Tesfaye Brihe	Bole
67	Yetwins Construction P.L.C	Bole
68	Nejib Adem Hassen	Bole
69	G/Medhin Teka Abera	Bole
70	Asbo Construction & Machenery Rent	Bole
71	Ojulu Addaye Gnybare	Bole
72	Melaku Atsebeh	Bole
73	Yonas Alemu	Bole
74	G.T Drago Plc	Bole

2. Consultants

Consultant name	**Number of blocks**	**Resident engineers**	**Site supervisors**	**Coordinator**
Image consulting	84	2	20	1
Beles consulting	80	2	24	1