ADDIS ABABA SCIENCE AND TECHNOLOGY

UNIVERSITY

EFFICIENCY AND APPLICATION OF ALTERNATIVE LOW COST CONSTRUCTION TECHNOLOGIES IN BUILDING PROJECTS: THE CASE OF ADDIS ABABA

By

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(Construction Technology and Management)

To

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Approval Page

This is to certify that the thesis prepared by Mr. Kefyalew Agergzat entitled "Efficiency and Application of Alternative Low Cost Construction Technologies in Building Projects: In The Case of Addis Ababa and submitted in fulfillment of the requirements for the Degree of Master of Science complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Declaration by Student

Here with I declare that, this thesis prepared for the partial fulfillment of the requirements for MSc. degree in Construction Technology and Management entitled “Efficiency and Application of Alternative Low Cost Construction Technologies in Building Projects: in the Case of Addis Ababa” prepared with my own effort except for secondary sources which have been acknowledged, as listed in the bibliography. I have made it independently with the close advice and guidance of my advisor.

Kefyalew Agergzat

Signature ——————————————

Date ————————————————

Acknowledgment

I would like to first thank God the almighty, for granting me the opportunity to do this research. The completion of this thesis involved kindly contribution, support and encouragement of many people. I am indebted to all who encouraged me in the process and give me the courage when I was really in need. It is a pleasant aspect that I have now the opportunity to express my gratitude for them. I am greatly indebted to my Advisor Kasi Rakha (Dr.), for all her guidance, insightful comments, patience, and encouragement throughout the process of the research. Without him, this project could not have the present form. I would like to express my greatest gratitude to Ethiopian Roads Authority for providing me the sponsorship. Special thanks extended to Mr. Henok Abera (construction materials cost inventory Head) for proved access to got material cost from construction bureau.

Abstract

Economic factors have influence the construction industry dramatically in recent years and in many parts of the world, construction materials are scarce and expensive. The people live in Addis Ababa city suffer for an increasing shortage of house. Low-income group of people live in the city are incapable to modify and construct new home by using conventional construction materials technologies due to the costs of materials. Government efforts to eliminate the problem have not been successful due to materials cost escalation and other factor. Many researchers are searching for low-cost materials as a substitute or alternative for the present situation, but these technologies are not applying in building construction sectors. To study the reason behind why these alternative low cost materials technologies are not applying in the building sectors, the study assessed efficient and application alternative low cost construction technologies in building sectors. To assessed this study, the study utilized both primary (Performa questionnaires, interview, observation and content analysis) and secondary (literature reviews) data. Descriptive statistics used to analyze the collected data. This study finds that alternative low cost materials technologies are sustainable in the building sectors. The raw materials are locally readily available. The amount of energy conceptions are low when compere to conventional building technologies. The costs of alternative building technologies are reasonable. By combining alternative materials technologies with conventional building materials technologies for different components of the building, the overall cost and total project duration decrease by 13.14% and 20.53% respectively. Unluckily the biggest challenge facing the wide spread use of alternative low-cost construction technologies in building sectors today is primarily not sustainability but largely due to lack of governmental support, lack of promotion about the technologies, lack of standards and specifications, and also lack of information by the general public about the technologies.

In General, alternative low cost technologies are sustainable, quite economical, durable and safe in low-rise building construction.

Key word: Application, Efficiency, Low-cost, Sustainable, Technologies,

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Abbreviations

CSEB = = = = = = = = == Cement Stabilized Earth Block

MWUD = = = = = = = ==Ministry of Work and Urban Development

ACTS = = = = = = = = ==Alternative Construction Technologies

CSEB = = = = = = = = ==Compressed Stabilized Earth Blocks

CEBS = = = = = = = = ==Compressed Earth Blocks

ISO = = = = = = = = = ==International Organization for Standardization

PVC = = = = = = = = ===Polyvinyl Chloride

E.C = = = = = = = = = ==Ethiopian Calendar

ALCCT = = = = = = = ==Alternative Low-cost Construction Technologies

CHAPTER ONE

1. INTRODUCTION

1.1. Background

The construction sector comprises establishments primarily engaged in the construction of buildings or engineering projects (e.g., highways and utility systems). Establishments primarily engaged in the preparation of sites for new construction. Over the last five, or so decades, developing countries in particular have experienced phenomenal growth of urban areas partly due to policies that have tended to favor urbanization as an engine of rapid development (Duranton, 2008). Residential construction practices, technologies, and resources must conform to local building authority regulations and codes of practice. Cost of construction on per square meter (or per square foot) basis for houses can vary dramatically based on site conditions, local regulations, economies of scale (custom designed homes are often more expensive to build) and the availability of skilled tradespeople. The present rate of construction in developing countries according to is generally sufficient to meet the needs of only 10% of the net increase in population per year. This is partly due to the unavailability and the soaring costs of conventional building materials. As this shortage of building is becoming worse, more efforts are being made to develop cheap, serviceable and energy efficient construction materials for the construction of affordable sustainable buildings (Baba Shehu Waziri et al. 2013).

Adequate shelter is one of the most important basic human needs. Currently, the majority of developing countries faced with a problem of providing adequate and affordable housing in sufficient numbers. In the last few decades, shelter conditions have been worsening: resources have remained scarce, housing demand has risen and the urgency to provide immediate practical solutions has become more sensitive (Vinu Prakash, 2016). The World Bank identified 152 developing countries as of the year 2007, of which it reported one in three people are without adequate shelter. The stakeholders should be working to lower the statistic through the provision of low-cost, sustainable building materials and technologies while recognizing the ‘Adequate Shelter for All’ agenda, committing to, “Access to safe and healthy shelter and basic services recognized as essential to a person’s physical, psychological, social and economic well-being (un-habitat, 2008). For providing low-cost housing, we must rely on locally available raw materials (Satprem Maïni, 2013)

Constructions in Ethiopia are ancient phenomena. Ancient time the people of Ethiopia constructed their home from locally available materials such as stone mud, timber, grass and ash. During this ancient period, very impressive construction ware constructed. Lalibela rock hewon church, Aksum Awolt, Fassil Jegol Gubbi, Harar Gubbi those are historical evidence from ancient Ethiopian construction. Most of these constructions constructed by using locally available materials technology and they are still impressive and liable. In modern Ethiopian construction, the construction sector increase dramatically. Most construction are constructing by using stone, timber, concrete, brick and steel. Now day the industries stick on these materials. The cost of this materials increase day to day and cover half and above cost of construction. The building materials account for approximately 60% of the total building costs. Housing and Building Research Institute (HABRI) accentuates the above sentiment and states that the building materials cost can sometimes account for as much as 75% of the cost of a low-cost house (Edwin K. Kaburu, 2017). Other construction materials that are readily available in the country not applied for the construction industries due to low innovation and adaptation culture.

Traditionally, most rural houses have built with little or no cash expenditure. Earth undoubtedly the oldest building material known. Even though building with earth once fell out of popularity when the modern building materials and methods were discover, but then it gains its revival time following the energy crisis. Moreover, growing concern and interest about environmental and ecological issue globally also increased the used of earth as a building material (Fetra Venny Riza et al. 2010). However, this is no longer the case owing to rapid population growth and the diminishing sources of local building materials. The trend now is to buy building materials - local and imported. The situation are further compounded by the simple fact that people have less time for building activities and have even tended to forget their traditional building skills. The situation is indeed bleaker in the urban centers, with respect to provision for adequate housing (Malpenzi & Mayo, 1987). Using locally available and/or produced building materials for housing can reduce the buildings cost and impact on the environment. However, in developing countries, where there is a need for low cost building materials for housing (Jijo James et al. 2016).

1.2. Statement of the Problem

Construction industries are one of the most booming industries in the world. These industries are mainly an urban based which is concerned with preparation and construction of real estate properties. Building construction is one of real estate properties in this industry. Building construction project consume different resource (material, time, labour and equipment). In this sector building construction material cost, cover more than half of the total cost of building. In the last five-year Ethiopia building construction, sector increase dramatically. However, the construction method and alternative low cost construction technology innovation and adaptation are poor in the country. Around 2000-2004 E.C some researchers conduct researches on alternative low cost construction technology in the country. Nevertheless, these technologies not applied in building construction sector. The people live in Addis Ababa city suffer for an increasing shortage of housing. Government efforts to eliminate the problem have not been successful due to material cost escalation and other factor. Since 2003 E.C Addis Ababa city government regulate the city master plan. Following Addis Ababa city master plan, the government of the city regulates building proclamation. The building proclamation promote to the city residence. According to the proclamation stakeholders (city residents, investors, shareholders) who need to construct the building in the city the building rise (floor height) must be greater than one story for residence building, two story and above for commercial and mixed building. In addition, the building height determine by location of the site .This regulation provide other challenge for the city residents, because in the city most people live low quality house, and they are low-income group. Those low-income group of people incapable to modify and construct new home by using conventional construction technologies with respect to regulation which the city government regulate in different year. To integrate the housing demand of the people in the city with different building regulation we must assess efficiency and applicable alternative low cost construction technologies in building sectors.

1.3. Objective

1.3.1. General Objective

- To assess efficiency and application of alternative low cost construction technologies in building sectors.

1.3.2. Specific Objective

- To analyze cost comparison of alternative low cost technologies with conventional construction technologies.
- To analyze time comparison of alternative low cost technologies with conventional construction technologies
- To study sustainability of alternative low cost construction technologies.
- To identify the barriers to adapt low cost construction technologies in building projects.
- To propose the possible solution to adapt alternative low cost construction technologies in building sector.

1.4. Research Questions

- Are low cost construction technologies efficient in building projects?
- What are the applications of alternative low cost construction technologies in building projects?
- What are the barriers to adapt low cost construction technologies in building projects?
- What requirements will need to innovate and adapt alternative low cost construction technologies?
- What are the possible solutions to adapt low cost construction technologies in building projects?
- Are low cost construction technologies reducing the total cost of building?

1.5. Significant of the Study

This study will have the following significant

- Create awareness on the benefit of alternative low cost construction technologies in building projects among stakeholders.

- Promote knowledge on new alternative low cost construction technologies in building sector.
- Increase the acceptability of alternative low cost construction technologies in the city
- Provide cost wise method of construction using low cost construction technologies.

1.6. Scope of the Study

This study was focus on alternative low cost construction technologies in the application of building projects. The study was carryout within Addis Ababa city in Ethiopia. The city selects for the study because it has the highest need of affordable building and housing; which is a subsequent of rural urban migration. The city also has largest number of buildings where some alternative building materials and technologies have used. The scope has restricted to alternative low cost technologies only, but not advanced costly technologies.

1.7. Organization of the Thesis

This thesis organized to have five chapters presented the first chapter serves as an introduction, setting out the problems and the manner in which these were address. It provides insight into the nature of the topic and issues relating to alternative low cost building technologies. The second chapter serves as the literature review section of the Thesis. The chapter provides an in depth study of alternative low cost and conventional building technologies. The third chapter presents the methodology used for conducting this research. The fourth chapter presents the responses on the investigation of Efficiency and application of alternative low cost construction technologies in building projects the results of the study and discusses the implications thereof and the fifth chapter presents the conclusions and relevant recommendations of the study

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Introduction

The construction sector is responsible for building new houses, apartments, factories, offices and schools. It also builds roads, bridges, ports, railroads, sewers and tunnels, among many other things. In addition, it maintains and repairs all of those structures and produces the basic materials such as concrete that used to make them. The industry's significance is due not only to the fact that it provides the buildings and infrastructure on which virtually every other sector depends, but to the fact that it is such a sizeable sector in its own right (OECD, 2008).The construction industry is an economic investment and its relationship with economic development is well posited (Myers, 2013). According to Baris Der-Petrossian and Erik Johansson (2000), the construction sector provides the direct means to the development and expansion of economic activities and is, at the same time, a major consumer of physical and natural resources and a polluter of the environment). According to k.k. Chitkara (1998), construction as an industry comprises six to nine percent of the gross domestic product of developed countries. Large-scale construction requires collaboration across multiple disciplines. Different professionals are participating in the construction projects. Those involved with the design and execution must consider zoning requirements, environmental impact of the job, scheduling, budgeting, construction-site safety, availability and transportation of building materials, logistics, inconvenience to the public caused by construction delays and bidding.

Large construction projects sometimes referred to as megaprojects. However, while the construction industry is remarkably stable over the long term, it is also remarkably unstable in the short term, especially during periods of economic adjustment. When the economy contracts, the construction industry contracts earlier and more quickly; and when the economy recovers the construction industry starts its recovery later, though it grows at a faster pace (Sharon Szymanski, 2008). Regarding to the economical implication of construction industry we emphasize that irrespective of the position one takes regarding the relationship of the construction industry to economic growth, it does not in any way invalidate the importance of the construction industry in regards to providing the necessary infrastructures that stimulate economic development. As such, the industry is required for national development. It argued that for a country to have meaningful and sustained development, it urgently requires that it indigenize its construction industry, because if the construction industry is inefficient, it will be difficult for such a country to attain meaningful development (A.L. Olanrewaju and A.R. Abdul Aziz, 2015).

2.2. Construction in Ethiopia

According to Tadesse AYALEW et al. (2015), the construction industry in Ethiopia has been developing tremendously since 2001. GDP contribution of the industry has been raised to 5.6% and approaches to the sub Saharan average (6%). Meanwhile, the Gross Domestic Capital Formation (GDCF), which was about 60 percent in 1996/97, has reached nearly 75% in 2002/03. Beyond its contribution to the nation, the industry is also the sixth major contributor of the content infrastructure stock following South Africa, Egypt, Morocco, Algeria and Nigeria. Since then, the country has been implementing significant number of programs/projects, which include the University Capacity Building Program (UCBP), the housing development program and the road sector programs among others. Regarding to Alem Tesfahunegn (2003) Ethiopian government has developed several strategies and programs aimed at alleviating housing shortage. These include settlement up grading, site and service schemes, tenant purchase, encouraging owner building and institutional provision of housing to employees. To meet this, need the government should revise the national housing policy and encourage development of low-cost materials technology and its dissemination. The government should ensure the housing finance made available to developers and homebuilders.

According to Bengt Hjort and Teferis Sendabo (2005), the concept “Sustainable low-cost housing” is not new in Ethiopia. Several attempts have made, and some are still being made, to introduce new, sustainable, low-cost house building technologies. However, the full-scale housing program not established from the outset. It emerged from the government’s preliminary exploration of more effective and affordable housing construction techniques in the late 1990s. Ethiopia found the German government as a partner and signed a bilateral agreement for technical assistance in 1999.Working with Germany's official development agency 'German Technical Cooperation' (GTZ), the collaboration's aim was to develop a "simple technology to promote housing Construction. The LCH technology's main measures to reduce costs and increase efficiency consisted of designing a new and cheaper hollow block size; creating columns without formwork by inserting reinforcement inside the hollow blocks, combining both strip and slab foundations, and introducing a pre-fabricated formwork-free slab system using beams and hollow blocks (Sascha Delz, 2016). The construction industry consists of deferent types and size of firms. These operate in the deferent sub markets characterizing the construction industry. Construction firms must be registered and licensed in order to undertake any construction work in Ethiopia. The firms classified according to size, expertise and financial capability by the ministry of work and urban development (MWUD) (Alem Tesfahunegn, 2003).

2.3. Building Construction

The building industry is a vital element of any economy but has a significant impact on the environment. By virtue of its size, construction is one of the largest users of energy, material resources, and water, and it is a formidable polluter. In response to these impacts, there is growing consensus among organizations committed to environmental performance targets that appropriate strategies and actions are needed to make building activities more sustainable (Peter O. Akadiri, 2012). With respect to significant influence of the building industry, the sustainable building approach has a high potential to make a valuable contribution to sustainable development. Sustainability is a broad and complex concept, which has grown to be one of the major issues in the building industry. The idea of sustainability involves enhancing the quality of life, thus allowing people to live in a healthy environment, with improved social, economic and environmental conditions. A sustainable project designed, built, renovated, operated or reused in an ecological and resource efficient manner. It should meet a number of certain objectives: resource and energy efficiency; CO2 and GHG emissions reduction; pollution prevention; mitigation of noise; improved indoor air quality; harmonization with the environment. An ideal project should be inexpensive to build, last forever with modest maintenance, but return completely to the earth when abandoned (Bainbridge, 2004). Building industry practitioners have begun to pay attention to controlling and correcting the environmental damage due to their activities. Architects, designers, engineers and others involved in the building process have a unique opportunity to reduce environmental impact through the implementation of sustainability objectives at the design development stage of a building project. While current sustainability initiatives, strategies and processes focus on wider global aspirations and strategic objectives, they are noticeably weak in addressing micro-level (project specific level) integrated decision-making (Kumaraswamy, 2006).

According to Bengt Hjort and Kristian Widen (2015), the traditional way to construct a residential building in Ethiopia is to use a frame of wood in the walls. The wall frame later on covered with clay mixed with straw. This traditional technology has advantages. The technology is well known and accepted and materials can many times obtain locally. Residential buildings which gives a good indoor climate and that are reasonably durable can built with this technology. The traditional technology is very "timber-consuming." Regarding the current de-forestation in Ethiopia and the resulting timber shortage, now and in the future, it seems clear that an alternative technology must use. According to UN-Habitat (2009), the building and construction industry considered a major contributor to climate change and a key player in sustainable development with the potential significantly affect the environment in both positive and negative terms.

2.4. Construction Technologies

According to Jerry Magutu (2015), appropriate technology are started taking root, four main attitudes are identifiable: Rejection of the concept, acceptance of the idea in principle, active involvement in knowledge, mobilization and experimentation, and willingness to apply the concept as a normal part of construction business administration and community activity. More effort is required to bring appropriate technology at par with conventional technology. Low cost building materials for housing are not been sufficiently institutionalized, unlike conventional technology whose dissemination has largely been effected through commercial organizations and the profit mechanism. In addition, there has been insufficient emphasis on the development of support structures, political and economic backing and the implementation machinery hence a constraint that is highly inhibitive to the process of dissemination and full embracing of the technology.

The provision of support structures and infrastructure for the dissemination of low-cost building materials for housing has been a responsibility of a number of actors in form of government agencies. According to Peter Njoroge Ngigi (2016), a global initiative to promote sustainability in building construction has resulted in a myriad of choices in construction products and technologies for homebuilders and homeowners. However, limited information is available to enable decision making for optimal integration of these technologies based on building performance requirements and individual priorities.

2.5. Application of Construction Technologies

According to Shimeles Kebede (2013), the Benefit of alternative construction technology such as prefabrication, modularization, bamboo, stabilized earth block, compressed earth block processes on the housing building project. These approaches have greatly contributed to the improvement of the construction industry in terms of construction duration, construction costs, product performance, onsite safety, productivity, customization, and environmental issues. According to David Kvarnström (2014), Development of innovative, cost saving technologies ware initiated during the 70s, but little has changed in the actual practice of the construction sector. Conventional building materials, as concrete and quarry stones, are still dominating the sector, providing insufficient alternatives for low-income households. Locally produced building materials, such as stabilized soil blocks (SSBs), may have an abundant supply of raw material, create more job opportunities, require less skill, capital and means of production, are more economically and environmentally sustainable, and use smaller amounts of imported products. In many developing countries, building material compose the main part of the total cost in residential housing construction projects.

According to Jerry Magutu (2015), the common objective construction technology has been the lowering of construction costs, especially about housing to make it affordable to a majority of people who are predominantly in the low-income cadre. The potential beneficiaries of the appropriate technology are invariably draw from economically weaker sections of society, who have very limited purchasing power to afford houses that are constructed with conventional building materials and technologies. Seeking to include all the benefits of the alternative technologies may enhance the performance of the many different building systems. Using a prioritization scheme, one can begin this sizeable effort by focusing on the building components that have the most impact on cost and time consumption. Asserts that such an approach would entail focusing on the large construction elements constitute a building for instance the walling system. In addition, the implementation of innovative technologies poses greater risks and potential negative impacts for the contractors in terms of technological uncertainty, construction costs and schedule delays (Peter Njoroge Ngigi, 2016). In most countries the common problem that affecting the choice of innovated (alternative) materials and technologies are availability/suitability of raw materials; availability of skilled labour; scale of construction; Cost variation with conventional materials; availability of adequate power for production of components (Shimeles Kebede, 2013)

2.6. Conventional Building Technologies

2.6.1. Hollow Concrete Block

According to Building Materials & Technology Promotion Council (2013), Hollow concrete blocks are becoming very popular. These blocks are being widely used in construction of residential buildings, factories and multi-storied buildings. These hollow blocks commonly used in compound walls due to its low cost. Expensive as there is a requirement of graded sand and large quantity of cement i.e. 12–17% by weight. Vibrating table is required to settle the mix. To compress the material a heavy lid slammed many times. Hollow concrete blocks are replacements of stone and convectional bricks. They are easy to place, and lighter than convectional bricks. Hollow blocks construction provides facilities for concealing electrical conduit, water and soil pipes. It saves cement in masonry work, bringing down cost of construction considerably. Most concrete blocks have one or more hollow cavities, and their sides may be cast smooth or with a design. According to Ali Haider Jasvi1 and D.K. Bera (2015), in demand by different department like housing board, PWD, forest department, road transportation. Standard size of hollow brick is 400x200x100mm, 400x200x150mm, 400x200x200mm. These blocks have a compressive strength of 39–147KN/m. Uses are interior and exterior walls, retaining walls, compound walls.

2.6.2. Concrete Technologies

Concrete is most widely used and versatile construction material possessing several advantages over steel and other constructions materials. It is difficult to point out another material of constructions which is as versatile as concrete. It is the material choice where strength, permanence, durability. Impermeability, fire resistance and abrasion resistance are required. It is so closed associated with every human activity that it touches every human being in his day-to-day living (Joshua Amarnath D. et al. 2015). Concrete is an essential material with a worldwide estimated consumption of between 21 and 31 billion tons of concrete in 2006, concrete is the second most consumed substance on Earth after water. A world without concrete is almost inconceivable. Concrete made from coarse aggregates (gravel or crushed stone), fine aggregates (sand), water, cement and admixtures. These constituents are mostly available locally and in virtually unlimited quantities. Primary materials can replace by aggregates made from recycled concrete. Waste materials from other industries can used to produce additions like fly ash, slag and silica fumes. Concrete is one of the more sustainable building materials when both the energy consumed during its manufacture and its inherent properties in-use are taken into account (ASBI, 2009).

Reinforced concrete is one of the most widely used modern building materials. Concrete became very popular after the invention of Portland cement in 19th century; however, its limited tension resistance prevented its wide use in building construction. To overcome this weakness, steel bars embedded in concrete to form a composite material called reinforced concrete. Developments in the modern reinforced concrete design and construction practice were pioneer by European engineers in the late 19th century. Now, reinforced concrete extensively used in a wide variety of engineering applications (e.g., buildings, bridges, dams). The worldwide use of reinforced concrete construction stems from the wide availability of reinforcing steel as well as the concrete ingredients. The extensive use of reinforced concrete construction, especially in developing countries, due to its relatively low cost compared to other materials such as steel. Frequently, reinforced concrete construction used in regions of high seismic (ozcebe 2007).

Concrete structure is an important characteristic of environmental temperature changes will only cause the interface to the strain is small in the reinforced concrete member. The compressive strength of concrete is large but the tensile strength is smaller, by plane pure shear, concrete principal tensile stress and shear and forms a 45-degree angle, and the principal stress and the principal tensile stress of orthogonal (Wei Wu 2015). For more than 200 years, concrete accepted for its long-lasting and dependable nature. In addition to durability and dependability, concrete also has superior energy performance, is flexible in design, affordable. It can expect that concrete will need to increase industrialization and urbanization while protecting the environment (Milwaukee Journal Sentinel 2006). The concrete industry should consider recycling industrial by-products such as fly ash safely and economically. When industrial by-products replace cement, even up to 70%, in concrete, the environmental impact improves along with the energy efficiency and durability of concrete (Naik et al. 2003).

Sustainable concrete structures and infrastructure, the concrete industry can develop a sustainable future for generations to come. Furthermore, buildings that are constructing to be both durable and environmentally friendly often lead to higher productivity because the buildings generally lead to better air quality and therefore higher productivity. The cement and concrete industries could contribute to meeting the goals and objectives of the 1997 Kyoto Protocol UNFCCC COP9 Rep. 2004". Among other things, the Kyoto Protocol requires meeting a target of reduction in GHGs to the 1990 level. It is estimated that about 28 billion t of CO2 were emitted worldwide in 2004 United Nations 2007", with significant portions emitted by the United States 22%", China 18%", E.U. 11%", Russia 6%", India 5%", and Japan 5%". Those involved with the manufacture of Portland cement would have a huge impact on the sustainable development of the concrete industry as a whole, because in 2004 cement production contributed about 7% of worldwide GHGs primarily CO2"; or, about 2 billion t of GHGs (Tarun R. Naik and F. ASCE,2008).

Any future taxes on GHG emission would have noticeable and noteworthy economic impact on the price of cement. A number of characteristics apply to innovative concrete products. First, by produced precast or cast-in-place reinforced concrete elements those made with Portland cement and pozzolanic materials that include renewable components, recycled components, or both. Second, innovative concrete products are constructing to enhance the performance of concrete elements, which may also contain recycled concrete as aggregates. High performance materials intended to reduce cross sections and the volume of concrete produced. They are also intended to increase the durability of concrete structures to minimize the maintenance needs of the concrete construction and limit the amount of nonrenewable special repair materials that need to be used in maintaining the concrete (Coppola et al. 2004). Concrete producers are creating sustainable solutions for many market sectors, including agriculture and construction. In agriculture, integrated waste management solutions developed that convert manure into biogas, nutrient rich fertilizer, and reusable water. Industrial, commercial, and institutional buildings are being constructed so that they are more energy efficient have better air quality, and necessitate less maintenance (McDonough, 1992).

The Pre-cast construction includes those buildings where the majority of structural components are standardized and produced in plants in a location away from the building, and then transported to the site for assembly. These components manufactured by industrial methods based on mass production in order to build a large number of buildings in a short time at low cost. Many countries used various pre-cast building systems during the second half of the 20th century to provide low-income housing for the growing urban population (Shehdeh M.S. Ghannam, 2012).

2.6.3. Glass Technologies

Glass is an ancient building material, which facilitated penetration of light into buildings. Once it used exclusively for windowpanes, whereas nowadays there are examples of structures made of glass only. Apart from the traditional non-bearing application in engineering, it progressively used for construction of bearing elements. The adequate choice of the glass type can largely improve the energy efficiency of the building. There are a great number of glasses in use today, depending on its purpose, and the application potential is larger. Apart from its traditional role, the glass progressively used as a structural, load bearing material (Jelena Savić et al. 2013).

Using glass manipulated for use specifically as floors, is a major benefit because of its durability and ease of replacement. Some designers choose to design walkways with glass instead of acrylic or a polycarbonate member because of how well it withstands wear. An acrylic covering would have to replace much more often. Although it is long lasting, glass panels will still occasionally need replaced. Depending on the method of installation, it is possible that replacement of broken or otherwise damaged pieces can do in a short amount of time. Using glass planks that supported by a grid-type frame, it is even possible to change panels in a matter of a few minutes (Rachel Lynn White, 2007).

2.6.4. Stone

Natural stone has been used both as a loadbearing structures as non-loadbearing facing stone either in the form of a thing facade masonry of facade board supported by bearers. It is also possible to attach natural stone. stone facades of buildings have traditionally been constructed as solid stone structures with natural stone and brick so that an exterior natural stone cladding was attached to directly to load-bearing an insulating massive brick wall with mortar (ENPI CBC, 2007). Stone masonry is a traditional form of construction practiced for centuries in the regions where stone is locally available. It found in old historic centers, often in buildings of cultural and historical significance, and in developing countries where it represents affordable and cost-effective housing construction. This construction type is present in earthquake-prone regions of the world, such as Mediterranean Europe and North Africa, the Middle East, India, Nepal, and other parts of Asia. Stone masonry construction generally shows very poor seismic performance. Poor quality of mortar is the main reason for the low tensile strength of rubble stone masonry. Due to their large thickness, stone masonry walls are rather heavy and induce significant seismic forces (Marjana Lutman, 2015).

Restoration targets, such as castles, fortifications and stone churches make up a significant share of the natural stone construction volume. The durability of natural stone structures affected not only by the stone material used but also by the structural solutions and other materials used in the structures, such as the sealant. The climatic conditions of the construction site also have a great effect on the durability of the structures (ENPI CBC 2007 - 2013).

Although not very insulated, native stone can provide extreme structural capabilities and longevity of materials and finished structure. Most stone used for construction is set in cementations mortar. Stone can provide foundations and structural elements such as arches for infill walls of indigenous material, thus reducing the need for concrete and wood. Like adobe, stone has a passive solar gain capacity due to its thermal mass that allows a stone structure to moderate interior temperatures. Stone itself has a low R-value and high conductivity, so should use judiciously on exterior walls where insulation is desirable. Depending on the desired effect, stone can collected or cut. Collected native stone is economical and requires no processing- perfect for use in landscaping, for retaining walls and durable patios (Center for Resourceful Building Technology, 1995).

Natural building stones have considered a valuable and essential part of the building industry. The constructions and monuments that have created bear witness to extraordinary technical and artistic achievements. In the last several decades, new technologies have led to considerable advances in the excavation and further processing of natural building stones. The possibilities offered by modern design for creating aesthetic interiors and exterior façades have led to a greater demand in recent years. The forecast for net production has arisen from a continuous production increase, whereby the production volume doubled every 10 years (Montani, 2003). Until 2008, economic crises led to a drop in stone production by approximately 40 %. These changes in economic growth bring into question the sustainability of economical stone quarrying and processing (Mosch, 2009).

The joint system plays an important role. The system describes all planar elements that dissect the rock body into individual blocks known as in-situ blocks (Lu and Latham, 1999). According to Mosch (2009), three basic quality grades can differentiate in general for natural building stones: (1) individual blocks, (2) gravestone sector, and (3) building industry. The highest requirements placed on the individual blocks, which used, for example, in sculptures. A complete homogeneity in color and decor or even special individual needs of the ultimate buyer has guaranteed, whereby a very high price reached in general. In the gravestone sector, a flawless petrography and structural formation of the stone is generally expected. The third grade encompasses all the qualities that are Appling in the building industry. A further classification corresponding to the physical and technical construction properties of the materials is possible, which ultimately can used to determine potential areas of application for the stone. Over the ages, exploitation methods of natural building stones have changed significantly. Stone tools also used, but later replaced by metal tools such as chisels and hammers in the exploitation (Shadmon, 1989).

2.6.5. Timber Technologies

Timber for construction is one of the many forest products used around the world. It used in buildings both large and small. While there are limitless possible designs, and construction based in both engineering and cultural practice, timber has a high strength to weight ratio, and used most efficiently in structures where it is carrying a lot of its own self-weight. In many areas of the world, building codes trump engineering, so heights are limited well below what is possible in timber. (Michael H. Ramage et al. 2017). The timber frame walls panels with doors and window frames built into panel openings manufactured on site or pre-manufactured in panels and then raised and fitted onto the floor platform of the building. (Justin Haselau, 2013).

The density of wood determined mainly by the amount of wood substance per unit volume and the moisture content. The higher the proportion of wood substance is the greater the density and the higher the mechanical properties. Mean values for the density of softwoods and hardwoods range from about 400 to 650 kg/m3 and 500 to 1200 kg/ m3, respectively. Wood of high density tends to shrink and swell more with changes in moisture content than wood of low density. The shear strength characterized by three types of failure, namely, shear parallel to grain, shear perpendicular to grain and rolling shear. In shear parallel to grain, the failure mode is quasi-brittle with shear strengths of about 5 to 12 MPa. For a given magnitude of load, the strength of a timber member reduced as the duration of the load increases. This loss of strength may be as high as 40%, which basically means the long-term strength for permanent loads such as self-weight or dead loads is only about 60% of that for the timber when it is first loaded in a structure (A.M. Harte, 2009).

Timber was the first material used for bridge construction and the oldest known bridges go back to 600 BC. The bridge known, as Caesar's Bridge across the Rhine believed built under the direction of Vitruvius. In 1570, Andrea Palladio published an illustration of a timber trussed bridge spanning 30 m over the Cismone River in north-east Italy, which was constructed around 1550 AD The timber has been turned in to many uses during the ancient days such as buildings with fine decorations, elephant carts bridges, forts, agricultural tools etc. (Nandana Abeysuriya, 2011). Very hard wood used for doors and window frames because of its natural resistance to insect attack. Plywood and particleboards used mainly for furniture. Timber is easy to form, saw, nail and fit; even with simple hand tools. Timber is natural and renewable. It has a high strength to weight ratio and is easy to work with, making it especially useful where only basic technology and procedures are available (Apu, 2003).

The advantages of timber as a building material include availability, workability, and environmental sustainability, flexibility of space arrangement, dry construction, industrial production and comparative cost effectiveness (Gregory, 1984; Nolan 1994 and Whitelaw, 1990). Environmental sustainability recognizes that human activity over time and the health of the environment are interdependent and that environmental health has necessary social, political and economic determinants. Probably the most significant environmental benefit of timber is its renewability and biodegradability (Yomi Michael D. Adedeji and Prof. Olu Ola Ogunsote, 2005). It has low manufacturing process energy and benign air emissions (Townsend and Wagner, 2000). Timber is an excellent insulator against hot or cold weather. The old “log-house” remains a model for minimum energy consumption in buildings (Ogunsote, 1993).

Low cost housing perceived as cheap and low-quality housing. Even low-income earners do not want to see to be living in cheap or substandard houses. Timber readily attacked by insects, fungi and vermin. The insects that attack timber include beetles, termites and marine borers. Subterranean and dry-wood termites in particular feed on cellulose found in timber (Ezeji, 1984). Timber also attacked by both destructive and nondestructive fungi. Destructive fungi cause wet rot and dry rot when the moisture content of timber is above 20%. Timber ignites at 250°C to 300°C and chars about 1mm at 900°C to 1200°C for average species (Oyetola, 2001). The charcoal that form on the outside retards combustion and large solid sections can survive longer in a fire than steel members of equivalent strength can. The competitive challenges posed by modern architecture encourage the development of timber constructions (Natterer, 2001).

The approach to the optimization of the whole-life cost of a timber building focusing mostly on its mechanical, structural and energy subsystems for a life cycle of 20 years. Another parameter that examined is the effect of the fuzziness of the design temperature inside a building on its life cycle cost. The total life cycle cost of a specific system is dependent on the system's most critical components. These components can identified through the examination of the system's life cycle stages, which -in the case of construction projects- are mainly the raw material acquisition stage and construction stage (initial cost), the operation/maintenance stage and the waste management stage that also co-estimates the remaining costs at the end of the system's expected life cycle. In the same manner that the environmental impact of the life cycle can quantified and measured, the economic cost of the same system can estimated on a similar basis. In the latter case, the aim of the analysis is the calculation of the cost associated with the life cycle of the examined system or life cycle cost (D.N. Kaziolasa et al. 2015).

2.7. Alternative Low Cost Construction Technologies

Various research organizations have made notable contributions to developing cost effective technologies such as fly ash bricks, sand lime bricks, cellular concrete, dry hydrated lime pozzolona and rice husk ash pozzolana as binding agent, which are not only cost effective and eco-friendly as most of them are produced from industrial wastes (Ham Singh O., 2011). Scarcity of urgent demand of low cost building, environmental concern due to the extensive exploitation of natural resources, shortage of fund and skilled labor these and other challenges are suggesting that the research for alternative construction technological option. Alternative construction technology can be creating job opportunities for unemployed or underemployed skilled and unskilled workers living in poverty. They can also have multiplier effects by creating income-earning opportunities for people involved in other housing-related micro- and small enterprises, including home-based enterprises. In addition, cost comparisons of building using these alternative materials and technologies suggest that they have the potential to enable a 30-50 percent reduction in building costs (Un-Habitat, 2006).

2.7.1. Compressed Stabilized Earth Block (CSEB)

Compressed stabilized earth block (CSEB) is a manufactured construction material formed in a mechanical press that forms a compressed block out of an appropriate mix of dry inorganic soil, non-expansive clay, aggregate, and sometimes a small amount of cement. CSEB compressed in many different shapes, sizes and forms from plain blocks to hollow interlocking blocks for earthquake safety, U blocks for ring beams, coping blocks for the rooftop and even tiles for the floor (Baba Shehu Waziri, 2013). Stabilized soil technology offers an alternative in the sector where this poses environmental degradation. The main raw material, soil, is cheap, and the cement proportion is relatively small. The products can be produced on site, and possibly facilitating work opportunities, by using interlocking stabilized soil for walling, which require less mortar work and are fast to lay, compared to quarry stones. Apart from economic and environmental benefits, the technique is favorable in many other aspects as well, such as availability, versatility and simplicity (David Kvarnström, 2014).

The production process has a significant influence on the quality and performance of soil blocks and the curing phase is essential for the blocks ‘future strength and durability. The soil should have a combined silt and clay content (percentage passing the 0,075 mm sieve) no greater than 20% and a particle size distribution bounded by that of a medium gravel and a fine sand is desirable (Jamie Goggins et al. 2012). The selection of a stabilizer will depend on the quality of the soil and the project’s requirements. Cement is preferable for sandy soils to achieve greater strength quickly. Lime is better for very clayey soil but takes longer to harden and to produce strong blocks. Interlocking blocks using the Hydra-form machine produced from sandy soil with clay content of between 5 and 20%, and a silt content of between 5 and 25%. Generally, soil with lower clay and silt proportions, below 10%, will be difficult to handle when it removed from the machine. Conversely, soil with a higher clay and silt content, above about 35%-40%, will need to blend with sandy soil to ensure its suitability. (United nation industrial development organization, 2016).

Production of CSEB required moderate to low skilled worker since the CSEB manufacture is very simple. It only takes three stages process which are: soil preparation, mix compression and the curing. Curing method in CSEB production usually took advantage from natural humid where bricks could have stacked immediately after compression but the strength gain over time. It is important to prevent rapid drying out hence the brick is moist cured under polythene sheet in the open air (humid atmosphere where air relative humidity >70% is the best condition in order to assure a maximum hydration of the used stabilizer) for about 28 days if used cement as a stabilizer (Fetra

Venny Riza et al., 2010). The stabilized soil block production process is techniques consisting of mixing at least 5 per cent cement (less than that of normal bricks) or lime stabilizer with soil and a minimal amount of water (and possibly waterproofing agents). The blocks are compressed using steel hand press machines or mechanical presses machines to produce good quality blocks (UN-Habitat, 2012). The compressive strength of compressed stabilized earth building blocks (that is, the amount of pressure can resist without collapsing) depends upon the soil type, type and amount of stabilizer and the compaction pressure used to form the block. Maximum strengths (described in MN/m2) obtained by proper mixing of suitable materials and proper compacting and curing (Sadek Deboucha and Roslan Hashim, 2010)

Compressed Stabilized Earth Blocks (CSEB) offer a number of advantages that includes increased utilization of local material and reducing the cost of transportation as the production is in situ, makes quality housing available to more people, and generates local economy rather than spending for import materials. Other advantages are faster and easier construction method resulting in the lesser requirement of skilled labors, good strength, insulation and thermal properties, less carbon emission and embodied energy in the production phase, create extremely low level of waste and cause no direct environmental pollution during the whole life cycle. (Baba Shehu Waziri, 2013)

2.7.2. Compressed Remedy Earth Blocks (CEBs)

Over the years, a building constructed of compressed earth blocks exposed to the elements affected by rainwater and due to the ageing of these blocks surface cracks will appear. This will result in water penetration and a build-up of moisture to a critical level. Compressive strength decreases with increasing moisture content and once it reaches its critical moisture content it is likely to fail. Minimal moisture content will result in better strength, water resistance and durability of the blocks. Actual destructive action of moisture once the block penetrated is the dissolution and softening of loose particles and the pore pressure generated will result in a disruptive internal stress. Therefore, the capacity of the block to resist the disruptive action of moisture will differentiate the life span of the earth block (J. M. Irwan et al. 2016). The technology that has become widespread in the new system of re-invented buildings is the Compressed Earth Blocks that makes unbaked earth blocks. Unlike the native adobe block, which is a mixture of earth, water and distinct cultural additives molded to desired shape with the hand. Compressed earth block supplemented in very small amounts (Iwuagwu Ben Ugochukwu and Iwuagwu Ben Chioma M., 2015).

In contexts where the building tradition already relies heavily on the use of small masonry elements (fired bricks, stone' sand-cement blocks), the compressed earth block is very easily assimilated and forms an additional technological resource serving the socio-economic development of the building sector (Hubert Guillaud, 2003). Architectural characteristics are similar in most countries: the rectangular plan, single door, and small lateral windows are predominant. Quality of construction in urban areas is generally superior to that in rural areas. The foundation, if present, is made of medium to- large stones joined with mud or coarse mortar. Walls made with adobe blocks joined with mud mortar. Roof covering may be corrugated zinc sheets or clay tiles, depending on the economic situation of the owner and the cultural inclinations of the region (Marcial Blondet and Gladys Villa Garcia M., 2007).

The compressive strength of rammed earth can be up to 4.3 MPa. This is less than that of a similar thickness of concrete, but more than strong enough for use in domestic buildings. Indeed, properly built rammed earth can withstand loads for thousands of years, as many still-standing ancient structures around the world attest. Rammed earth using re-bar, wood or bamboo reinforcement can prevent failure caused by earthquakes or heavy storms (Sruthi G S., 2013). Earth as mud bricks, has been used in building construction for thousands of years and approximately 30% of the world's present population still live in earthen shelters. Mud brick used extensively for building construction around the world, particularly in extreme hot, dry desert climates like that of most Arabian countries. In these countries, mud bricks made by blending mud and water together into a goopy mixture.

Traditionally straw is add to improve tensile strength and may prevent mud bricks from cracking. The mud brick is then Mud bricks have several advantages over other conventional building materials, e.g., concrete masonry. These advantages include: a very minimal manufacturing process; skilled labor is not necessary; mud is available from natural resources; inexpensive construction materials; and mud structures are able to perform satisfactorily under hot environmental conditions. However, there are many disadvantages in using mud bricks as building materials. These include mud brick may tend to erode under rain impact; absorption of water causes swelling of mud brick, while evaporation of water from the mud brick gives rise to shrinkage and cracking; and mud brick is a relatively fragile material, which cannot resist earthquake hazards (Farraj Al-Ajmi, 2016).

Exterior rammed earth walls are massive, usually with a 2-3-foot thickness that provides thermal mass and stability. Bond or collar beams and reinforcing rods are required to provide reinforcement and stability to the walling process is mechanized can take less time to erect than blocks. Some builders provide a skilled crew to erect rammed earth buildings. The cost of labor for the crew, or the cost of the equipment used in mechanized rammed earth processes, can make this method of building one of the most expensive of the indigenous technologies (Center for Resourceful Building Technology April, 1995).

2.7.3. Bamboo Technologies

Bamboo is highly versatile resource and widely available needs to adopt as an engineering material for construction of houses and other buildings. In order to propagate these for wider application, awareness and confidence building amongst professionals and householders is required (Building Materials and Technology Promotion Council, 2010). This material had been using for construction even from early times. It used as Technical and Non-Technical ways. For building the houses our ancestors used Bamboo as basic material. Because of its high strength to weight, ratio Bamboo fibers have better modulus of elasticity than any other natural material. The longer is the fiber the higher it gives the tensile strength.

Addition of Bamboo fibers to the concrete elevates the mechanical strength and tensile strength. It has low specific weight too. (BINDU M., 2016). Bamboo is both a decorative and a structural member. For shelter purposes bamboo culms between 60 to 100 mm diameters generally adopted, which means that most of the bamboo spices available are within this range. Bamboo is widely used as a basic timber for rural housing. It used as poles, purlins, trusses, rafters, mats for wall/ceilings/roof, frame of doors & windows and fence posts, especially in tropical countries. (O.A. Nwoke, 2015).

In construction sector, bamboo used to make all the components of building both structural and non-structural. Traditionally bamboo culms used for constructing housing in rural community, scaffolding and for constructing footbridges (Cansa, 2016). Bamboos being lightweight, pliable and yet very strong, can be brought into multiple uses. Bamboo mixed with wood and other materials used in building houses. Besides these multiple benefits of bamboo, they used mostly in luxury condominiums. Use of bamboo in housing however, has some disadvantages, as it is a non-dimensional material and does not often come with uniform shape, size and age. As well if bamboos not treated well then they are highly vulnerable to fungus and termite attacks. Even considering the above-mentioned disadvantages there is a great opportunity to promote bamboo for the construction of houses as the entire above problems can solved by converting or processing bamboo into engineered panels (Ar. Vidya and Ar. Radha, 2016).

Bamboos are Occur and Distributed in different part of Ethiopia. According to Ensermu Kelbessa et al. (2000), there are 130,000 hectares of highland and more that 480,000 hectares of lowland bamboo in the country.

distribution of lowland bamboo in Ethiopia	
Region	Local areas
Southern Nations, Nationalities and Peoples Regional State	Gamo Gaelebena Hamer Baco Bench & Maji Majina Goldiya
Gambela	Gambela
Oromiya	Gimbi Guten Kelem Leka
Amhara	Hinde Chilga

	Wegera
Tigray	Shire
Benishangul Gumuz	Assosa Bambesi Begi Demi Guba Dibate Kamashi Pawae

(Source: Eastern Africa Bamboo Project, 2010)

(Source: Yigardu Mulatu et al. (2016***))***

2.7.4. Bagasse Technologies

Bagasse mainly used as a burning raw material in the sugar cane mill furnaces. The low caloric power of bagasse makes this a low efficiency process. There exists an excellent opportunity in fabricating bagasse based composites towards a wide array of applications in building and construction such boards and blocks as reconstituted wood, flooring tiles etc. Value added novel applications of natural fibers and bagasse-based composites would not go in a long way in improving the quality of life of people engaged in bagasse cultivation, but would also ensure international market for cheaper substitution (Deepak Verma, 2012). It is possible to produce high-strength concrete with the combination of the finely ground bagasse ash. Interestingly, concrete containing up to 30% of SCBA exhibits compressive strength in the range of 65.6 MPa–68.6 MPa (28 days), which is relatively greater than that of the control concrete. It also noted that the incorporation of SCBA significantly improves the resistance to chloride penetration of concrete (Rukzon & Chindaprasirt, 2012).

It can utilized as sand replacement in mortars and concretes as, perhaps surprisingly; the samples of mortar produced with 20% and 30% of SCBA in place of sand can enhance the relative compressive strength (Sales & Lima, 2010). Hence, it has been successfully proven that it could be used as partial admixture in concrete, self-compacting concrete (Cordeiro et al. 2008), high-strength concrete and lime mortars with limestone powder or calcium carbide residue as a mixture (Rattana shotinunt et al. 2013). Production of particleboard panels with sugarcane bagasse may be able to satisfy the growing demand in the wood panel industry for raw materials. Furthermore, the production of particleboard panels with sugarcane bagasse may allow the industry to expand, reduce the use of timber (and thereby, reduce the pressure on forests), and reduce the costs of panel production; these properties have the potential to make such boards very competitive (Stefânia Lima Oliveira et al. 2016).

Bagasse-PVC Boards uses sugarcane bagasse and PVC as binder. PVC is the most widely used resin in making different articles for building applications such as door shutters, sanitary fixtures, pipes, cables, cabinets, etc. due to its inherent self-extinguishing characteristic and affordable cost. Bagasse-Cement Boards and Panels the product is eco-friendly and the process utilizes sugar cane bagasse and ordinary Portland cement. The physic-mechanical behavior of the developed building board passes most of the requirements of general purposes high density board and is cost effective too (Ar. Vidya and Ar. Radha, 2016).

2.7.5. Straw Bale Technologies

Today straw bale construction often utilizes bales as insulated infill in a post and beam or timber frame structural wall. The framing members bear the weight of the roof and provide wall structure. Straw is an annually renewable waste product of grain production. Using straw for insulation avoids the resource and energy consumption that the production of most modern insulations demands. Often, baling straw avoids disposal by burning in the field, a common practice that adds C02 and particulates to the atmosphere. Straw bale buildings have built with nonprofessional labor for a fraction of the building cost of conventional professional stick framing. Custom straw bale buildings can also be costlier than average conventional construction (Ali Haider Jasvi1, D.K. Bera, 2015). straw bale construction structures as a low cost alternative for building highly insulating walls are built by creating a frame (out of wood, usually) and stacking bales of straw as if they were cement bricks in order to create walls. These straw bales are then, plastered over on both the inside and outside of the bale to create walls that are strong and insulated. Using straw as wall material can save up to 50 percent off the cost of traditional wall materials. The primary attractiveness of the process is 50 percent less energy use required to heat homes, saving on energy bills. Straw bale structures with walls made out of these bales are also great at providing sound and thermal insulation. (Justin Haselau, 2013).

Straw compressed with low technology tools into bales with a density of more than 90 kg/m^3. It acquires special properties as a building material by its compactness and insulating capacity. A straw bale suitable for building is a compressed block of cereal straw, mainly wheat, rye or rice, pressed with a density higher than 80kg / m^3 and a relative humidity less than 18%. Straw has a very similar chemical structure and physical properties like wood. Bales, allow us to create walls that can be bearing and provided with mortar coatings (clay, lime, gypsum), comply with all expectations applicable to a wall in conventional building and contribute significantly to the thermal insulation. The plastered walls of straw bales have passed all kinds of tests for resistance to fire, demonstrating its optimal resistance (Germany RF90, USA RF120) Thermal conductivity of straw bales the is between 0,0337 y 0,086 W/mk. Straw bale building has been institutionalized in Europe. In Germany and Austria there is an official certification for the straw bale as a building material, France a leading European country with nearly 3,000 buildings, is working with professional Rules for straw building (Lopez Altuna Alejandro and Iborra Lucas Milagr, 2016).

There are two primary forms of straw bale construction, load bearing and non-load bearing. In non-load bearing straw bale construction, the bales serve primarily as in-fill insulation, although their function as a mesh to hold plaster gives another significant benefit. In load bearing structures, the weight of the roof and lateral shear pressures actually carried by the bales and the plaster that encase them. Two string bales are used which is considered best suited for non-load-bearing application while three string bales are thus more appropriate for load bearing application (Adeola A. ADEDEJI. and Jimoh A. BELLO, 2011). Straw bales are tightly packed and covered with a skin of cement render. Fire cannot burn without oxygen, and the dense walls provide a nearly airless environment, so the fire resistance of compacted straw is very good. A test of a plastered wall panel showed a two-hour fire resistance, and an unplaster bale wall had a 30-minute resistance.

Straw bale walls should not exceed moisture content of 15%. Protecting bale walls with an appropriate foundation, generous roof overhangs, intact & well maintained guttering, porches and verandahs and suitable render materials are the most effective ways to avoid direct rain exposure, splash back, and resulting moisture damage to the walls. Well-applied, intact, properly maintained and breathable render will also protect the straw bales from moisture damage. (Mohamed Salah Gharib Elsayed, 2008). Sustainable building projects and straw bale building is readily recognized as a sustainable building method. Generally, there is some reluctance to accept nonstandard 'alternative building methods by building officials. Bales of recycled materials as paper, pasteboard, waxed cardboard, crushed plastics, whole tires used carpeting have also used or currently explored for building). Basic straw-bales are produced on farms and referred to as "field-bales". The ASTM E-119 fire resistance test for plastered straw-bale wall assemblies in 1993 passed for a 2-hour firewall assembly. In this test, a gas flame blows on one side of the wall at approximately 2000 degree Fahrenheit (1100 degrees Celsius) while the temperature of the other side of the wall is continuously measured. The results of this test had no burn-through and a maximum temperature rise of 60 degrees Fahrenheit (33.3 degrees Celsius.) (en.wikibooks.org., 2013).

2.7.6. Agro-stone

Agro-stone panel is composed of agricultural/industrial wastes and/or lightweight natural minerals as fillers, magnesium-based chemicals as a binder and fiberglass as reinforcement. The technology of Agro-stone panel production practiced in Asia and Latin America. All countries adopted the Agro-stone panel production technology based on the availability of the raw materials on their own countries. Likewise, Addis Ababa Agro-stone production center has adopted this technology based on locally available raw materials. Agro-stone 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. Agro-stone panel nearly reduces the cost of the wall construction by half compared with the conventional hollow concrete block walls (AAHDPO, 2007).

Unlike the traditional building materials, Agro stone panel do not require cement plastering for finishing work that demands considerable amount of cement. It does not also consume much water during construction. In addition, its production utilizes energy efficient and uncomplicated machinery that can operate by unskilled workers. All these makes the panel to be cost effective than the conventional ones. In another perspective, its lightweight property enables reduction of costs of building structures. Agro stone panel is also quite easy to assemble and cover large area of wall within short period of time, which in turn reduces the construction time. Its environmental friendly production as well as the above physical properties of the Agro-stone panel makes it better building materials than the conventional materials.

Agro-stone panels patented for internal partition and non-loading walls use. However, it used for external walls in number housing projects in Addis Ababa by treating with different finishing materials to protect from moisture attack. As the water absorption test carried out at MRTC reveled, the Agro-stone panels are poor to resist water. Hence, it requires careful surface water treatment in order to use it as an external wall. This incurs additional costs. The other observed problem is that metals become corrode when they are in contact with Agro-stone panel. One of the causes for this is the unreacted chloride ions in MOC since the binding chemicals cannot be reacted completely if the mix proportion is not correct enough. Agro-stone panel is an alternative low-cost eco-friendly building material that mainly uses agricultural/industrial wastes and/or natural minerals as raw materials. It reduces the cost of wall construction significantly while attaining the desired physical and mechanical properties. Comprehensive and flexural strength tests conducted and presented in this work. Both test values confirmed that the Agro-stone panel attained good strength. In addition, water absorption test performed and the result shows poor water resistance of the panel. Hence, further research needed to improve the properties of Agro stone panel as well as to further reduce the cost. One direction of the future research is finding alternative raw materials that can complement the existing materials (Woubishet Zewdu Taffese, 2012).

2.8. Barrier to Adapt Alternative Low-cost Construction Technologies

Many contractors, architects, and home owners today are concerned about the environment and interested in sustainable construction technologies, the perceived higher initial cost of innovative construction products and methods, and a lack of life cycle cost and benefit data present significant barriers in the implementation of such techniques (Peter Njoroge Ngigi, 2016). In many countries, standards for building and land subdivisions do not consider affordability issues and have general nature. Standard subdivisions often based on regulations of the pre-independence periods prescribing large plots and banning building next to plot boundaries. This results in large plot sizes and high infrastructure costs. Building standards are also high urging and encouraging needy groups to get involved in informal building activities.

These regulations and standards should adjust also in consideration of affordability criteria. The building code sets out building regulations and requirements. According to Iwuagwu Ben Ugochukwua et al. (2015) usually, earth, timber, straw, stone/rock and thatch constructed together with the simplest of tools and methods to build simple, live able dwellings. Although globalization has relegated them as being ‘primitive’, this ‘primitive’ classification comes partially from the building materials and their relatively low technological uses when compared to present day western (Architectural) construction techniques that result in skyscrapers. Present interpretations of sustainability have given them a new status as likely technologies for the contemporary world.

The housing policy of Ethiopia not strong in the past, several disorganized urban plans, designs, and construction methods are visible. To overcome these problems, research works on up grading low-income housing, proposing new low-cost housing projects, introducing new sanitation methods, use of local building materials and transfer of construction technology are still in progress. It is my belief that the outcome will be beneficial and applicable in the country to overcome the housing problems of the country (Alem Tesfahunegn, 2003). Innovations evolve in an economic, social, cultural and political space and influenced by the dimension of this space. Determinants of innovation vary between industry contexts, political contexts, national contexts etc. There may be differences in education, communication, business maturity etc. As learning is a central activity in innovation, and learning is a social activity, which involves interaction between people, it is important to have an infrastructure around the innovation project or innovation diffusion project that enable people to learn about it (Bengt Hjort and Kristian Widén, 2015).

2.9. Research Gaps

Considering alternative configurations would enrich the results with more insights on energy-savings opportunities. This is especially true for urban buildings, where regional typologies are the results of adaptation to specific contextual conditions. The different material options were based on current construction practice and viable alternatives according to the relevant literature. These assumptions may not be suitable for location-specific analyses that need to factor the local availability of materials, transportation distances, potentially different production processes and housing life due to specific contextual conditions. Carbon emissions and primary energy were selected for the analysis as they are key indicators for the environmental impact of buildings nevertheless, other impact categories, such as abiotic resources depletion and acidification potential, are expected to be significant for a massive market uptake for new housing and should be investigated in future research. Most study has not considered affordability, with the underlying assumption that this is largely a policy matter. Most studies assume all housing that need air condition to achieve thermal comfort has it. These assumptions are not applicable to current market conditions, but they do provide policy-makers with an estimate of aspirational costs and energy needs. This study has also not considered advance high-efficiency cooling technologies. The life cycle cost calculation does not attempt to estimate building costs comprehensively, but rather focuses on estimating the cost implications of particular technology and material choices. Land value, maintenance, disposal and other additional costs associated with securing against natural hazards. Total annual requirements for filling the alternative material technologies gaps are also strongly dependent on the amount of building unit assumed, and the feasibility of rolling out housing to close the gap. The political economy around the provision of housing upgrades, particularly related to multi-story buildings in urban areas, needs to be factored when translating different research results to actual policy.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1. Introduction

This chapter discusses the methodology that used in the study. It outlines the study design, target population, sampling procedure, methods of data collection, validity and reliability and data analysis methods as well as operationalization of variables. All these used in order to achieve the research objectives.

3.2. Research Design

Research design is the scheme, outline or plan that used to generate answers to research problems. This research problem studied using comparative research design. Comparative research type is use to address the stated specific objectives and research questions. Comparative research design is selected because the data obtained through schedule data collection, interview and content analysis will emanate from the nature of the specific objectives are require to compare the data collected about ALCCT and CCT in terms of application, efficiency, sustainability, cost, time and quality. Using the research design, this study focused on acquisition of quantitative and qualitative from a cross-section collected data.

3.3. Research Approach

Qualitative and quantitative research approaches are used because; mixed research approach is useful to capture the best of both qualitative and quantitative data. According to Johonson & Onwuegbuzie (2004), the mixed research approach can help to answer a broader and more complete range of research questions. Therefore, with this consideration the qualitative and quantitative approach will adopt for this study purpose.

3.4. The Data Utilized

The data for this research consists of two types, namely primary and secondary data explained as follow.

3.4.1. Primary Data

The primary data consists of information obtained from questionnaires and the responses conducted with targeted population. Those persons are in a position of authority to reflect on the actual situation, which enables proper and accurate comparisons to make. The aim was to design a simple, clear questionnaire with limited open-ended questions and using a series of check boxes. The assumption was that busy executives could easily complete the questionnaires. In the specific projected treatment of each problem, the data required was stated and in how the data was secure, the respondents did not have to disclose their identity when responding to the questionnaire. All the responses treated as strictly confidential.

3.4.2. Secondary Data

Mullins (1994) defines secondary data as "already published data collected for purposes other than the specific research at hand." The secondary data obtained through a review of existing material such as journal publications, dissertations, newspapers, unpublished theses, books, and internet and conference papers. Secondary data selected according to its relevance to the research. The main criterion for the selection of secondary data was that it had to be relevant to the particular sub-problems and to test hypotheses.

3.5. Sampling Techniques

According to Fellows and Liu (1997), sampling is necessary, it is almost impossible to examine the entire population. In order to obtain a good representation of the respondents, it is possible to use a sample of the population, which is much smaller than the total population, but sized and structured to be statistically representative. Clearly, the results from such sampling will not be the same as if the whole population consulted, but the result is adequate for the purpose for which the information is required. For this study, unrestricted random samplings were adapted.

3.6. Target Population

According to Borg and Gall (2009) target population as is a universal set of research of all members of actual or imaginary set of people, events or objects to which an investigator wishes to generalize the result. The target population of this study were the stakeholder which are directly and indirectly involve in building project while the study population will be government and non-governmental organization, contractors (project managers, site engineer), consultants (Supervising engineers, contract administrator), and building materials suppliers participating in building construction. Mugenda (2003) explained that the target population should have observable characteristics to which the study intends to generalize the result of the study. This definition assumes that the population is not homogeneous. The target population of the study was 103 as shown in Table

Table 3.1: list of respondents

respondent	Performa-questionaries' distributed	Number responded	% of total respondents
Site engineers, project managers	36	28	41.38
architects, structural engineers, contract administers, supervisors	45	40	36.78
Site inspectors	13	11	12.64
Construction Materials cost estimators	9	8	9.2
total	103	87	100

This represented a sample size of 103 of which 87 have responded. This is statistically reasonable response rate, as the size exceeds 50 percent as recommended.

3.7. Method of Analysis and Presentation

To meet the specific objectives of the study the data collected from both primary and secondary sources require rigorous analysis and interpretation that provide comprehensive and meaningful results. To achieve this end, the data that collected from primary and secondary source of data were analyzed using Descriptive statistics method. Counts or frequencies used to figure out how many times something occurred or how many responses fit into a particular category and the findings presented in a table and figure. The data from the completed Performa-questionnaires captured and summarized according to each question. A summary sheet, containing all the questions as listed in the Performa questionnaire, was completed based on the responses of each individual contractor, consultants and professional. The data gathered was statistically interpreted using mean, percentages and relationships were established which were used to write up the analysis.

To compere cost and time acquire to construct building by using conventional and alternative low cost technologies, a residential building taken. To comparing cost and time first, prepared plan and collect raw data from relevant construction company, then the amount of work and time require to complete the work are estimated. To analyze sustainability low cost technologies and barriers to adopt in building sector, sustainability and barrier analysis conducted.

Plan preparation: - plan preparation done for residential building to estimate the quantities of conventional technologies and alternative low cost construction technologies. Double story building takes to estimate the quantities.

Work estimation: - to find out the amount of materials require for the proposed residential building constructions; the amount of work estimated. The details of the materials that are using in the construction collected from construction companies. By getting these details, the study was estimate the quantities of the materials require.

Materials selection: - the cost of Building materials (i.e. conventional and low cost building materials) which used to construct the proposed building collected from similar project and Addis Ababa construction bureau.

Estimation of Project Duration: - the time require to construct the proposed residential building by using (conventional and mixed (conventional and alternative low cost technologies)) was calculated by dividing the amount of work to productivity of labor. The productivity of labor collected from Addis Ababa construction bureau. Time require to complete the proposed building was estimated using Critical Path method by MS project 2010 professional.

Cost Analysis: - the materials cost was collected form Addis Ababa construction bureau and Construction Company that are involves in the construction of building projects. The cost was analyzed in two ways, the first one was analysis by using Microsoft excel 2010, and the second was by using MS project 2010 professional.

Sustainability analysis: - the sustainability of the proposed alternative low cost building materials technologies analyzed by using respondent idea, content analysis and literature review.

Barrier analysis: - to analyzed barrier to adapt, innovate and develop in building sector 12 barrier were listed and distributed to the respondents, after collecting the respondent suggestion the barriers are ranked in the degree of their effects, and analyzed by calculating their mean using Microsoft excel 2010.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1. Introduction

This chapter presents analysis of the efficiency and application of alternative low cost technologies in building sector. It has systematically designed to evaluate data in order to relate to research method chosen for the study. The analysis of this study carried out on the data collected through Performa questionnaire, interviews, site observations and content analysis. The questionnaires distributed for Stakeholders those have better experience in the construction industry to get sufficient and relevant information. From the total number of sample questionnaire distributed (103 Performa questionnaires) 87 questionnaires collected from interested responsible construction industry professionals. The main statistics calculated in the data analysis are the mean, frequency scores and quantitative comparison approach.

4.2. Respondents

The target populations discussed above and here their respective profiles tabulated in the following manner. The profile of the respondents included their educational background, average year of work experiences.

Table 4.1 Respondents profile

Respondents	Educational level	Average year of experience	No of respondents that accepted questionnaire	No of respondents that returned questionnaire	No of respondents that not returned questionnaire
architects, structural engineers,	BSc., MSc.	5	36	28	8

contract administers, supervisors					
Site engineers, project managers	BSc., MSc.	4	45	40	5
Site inspectors	BSc., MSc.	6	13	11	2
Quantity surveyors	BSc.	3	9	8	1
Total			103	87	16

The average year of experience of the respondents in constructions were between 4 and 6 this implies that most of the respondents are experienced in construction industries, thus help to arrive at relevant result through obtaining relevant data.

4.3. General Awareness of Respondents about Alternative Low Cost Building Technologies

From the ancient period to until different types of low cost materials technologies used in hut and home construction for living purpose. Many constructions are constructed using low cost materials technologies. Now days these construction used of tourism purpose. Majority (94.25%) of the respondent stated that alternative low cost technologies are not new for Ethiopia, and the remaining 5.75% of the respondent agree that alternative low cost technologies are new for Ethiopia. Their reasons are most construction constructed using conventional technologies.

Table 4.2: awareness on ALCCT technologies

	frequency	percent	cumulative percent
yes	5	5.75	5.75
no	82	94.25	100.00
total	87		100.00

Regarding to 90.8% of the respondents their construction company is not familiar with alternative low cost construction technologies in the building sector. 9.2% of the respondents inform that their construction company is familiar on some types of alternative low cost building technologies (table 4.3). Those respondents described their company use agro-stone and hydra-form for technologies to construct condominiums building wall and temporary shelter home for immigrant.

Table 4.3 familiarity of construction companies on ALCCT

	frequency	percent	cumulative percent
yes	8	9.20	9.20
no	79	90.80	100
total	87		

Construction industry consumes different types of construction materials. In this day, material cost increase dramatically. Low-income group are incapable to construct their home using conventional material technologies. To solve this problem continues budget allocations are required to innovate and adopt low cost alternative technologies. Construction Company should play important role adapting alternative technologies. To adapt the technologies yearly budget are require. From table 4.4, 89.66% of the respondents inform that most of construction companies do not allocate budget to innovate and develop alternative low cost construction technologies. The other 10.34% of respondents agree there is budget allocation in their company to innovate and develop ALCCT. The respondents those are work in Addis Ababa construction bureau inform that their company allocate yearly budget to integrate low cost technologies to conventional technologies in the building sectors.

Table 4.4 awareness on budget allocation by construction companies

	frequency	percent	cumulative percent
yes	78	89.66	89.66
no	9	10.34	100.00
total	87		

The people live in Addis Ababa city most are living in low standard house. Majority (81.61%) of the respondents indicate that most of the people live in the city not easily construct and modify their home due to their low annual income and high cost of conventional construction materials. 18.39% of the respondents agree that the people of the city can construct and modify by using conventional material technologies (table 4.5).

Table 4.5: awareness on low income group

	frequency	percent	cumulative percent
yes	16	18.39	18.39
no	71	81.61	100
total	87		

Construction material producer and suppliers are playing important role by promoting and innovating low cost construction technologies to integrate in construction sectors. The adaption of alternative construction technologies depend on the quality of technologies and customers' acceptance. Competent producer and suppliers are required to continuous promotion and supply of alternative technologies. Table 4.6 show that, 93.10% of the respondents agree some companies in the city are produces some types of ALCCT and they are supply alternative low cost building technologies to customer. 6.9% of the respondent agrees that there is no any company to produce and supply ALCCT in the city.

Table 4.6 awareness on the company which is produce and supply ALCCT

	frequency	percent	cumulative percent
yes	81	93.10	93.10
no	6	6.90	100
total	87		

Construction sector in the city increase dramatically. This sector consumes different types of construction materials technologies. Most construction constructed using conventional material technologies. The stockholders those are live city familiars to these technologies.

Table 4.7 illustrate that, 87.36% of the respondent have no any information on the buildings which constructed by using ALCCT. In addition, 12.64% have information on the buildings that constructed by using low cost construction technologies.

Table 4.7 awareness on building which is constructed by using ALCCT

	frequency	percent	Cumulative percent
YES	11	12.64	12.64
NO	76	87.36	100
total	87		

4.4. Performance and Quality Related Issues about ALCCT

4.4.1. Cement Stabilized Compressed Earth Block

According to table 4.8 majority of the respondents agree that earthquake resistance of cement stabilized compressed earth block is low mean score 2.57. Mortar consumption of interlocking CSEB are moderate mean score 2.27. Due to vertical and horizontal shape of interlocking part of the blocks mortar consumptions is low. Compressive strength of the blocks are moderate mean score 2.26. The compressive strength of CSEB reduce due to poor quality of soil and type of compaction by controlling those factors, we can achieve good strength blocks. Tensile strength the blocks are very low by mean score 1.41, sound insulation is high by mean score 3.11, moisture resistance moderate by mean score 2.83 and thermal insulation high by mean score 3.31. As observed by Oti (2009), combination bricks made of cement stabilized earth blocks subjected up to 100 cycles 24 hours repeated of freezing and thawing got satisfaction result where only having maximum 1.9% weight loss at the end of the 100th cycles. According to his explanation the examination after the test showed no damaged occur of any type. According to ASTM 560 (freeze-thaw test), the result shows that SCEBs are durable.

Nicholas Edwards (2013) achieve 4.2 MPa average compressive strength of SCEB by mixing clay content of 12%, silt content of 12%, sand content of 68%, gravel content of 8%, cement content of 5%, and water absorption of 10.3%. According to ASTM 140, the average absorption of the test samples shall not be greater than 5% with no individual unit greater than 7%. The minimum Standard requirement for precast concrete masonry units is 2.8 MPa, so compressed earth blocks compare favorably to conventional masonry units. This two standards show that the results achieve by Nicholas Edwards (2013) about SCEBs, the blocks have good strength and low water absorption resistance capacity.

Table 4.8 Cement stabilized compressed earth block

Constraints	mean	Remark
earth quake resistant	2.57	low
Mortar consumption	2.72	moderate
Compressive strength of the block	2.67	moderate
Tensile strength	1.41	Very low
sound insulation	3.11	high
moisture-resistance	2.83	moderate
thermal insulation	3.13	high

4.4.2. Bamboo Technologies

Table 4.9 illustrate that most of the respondents agree that architectural aesthetics values of bamboos technologies are very high mean score 3.9. Earthquake resistance bamboos technologies are low mean score 2.59, compressive strength is high by mean score 3.09, tensile strength moderate by mean score 2.8. I Nyoman Sutarja (2017) conduct experimental investigation and achieve the average compressive and tensile strength of bamboo is roughly situated between 40 and 80 N/mm2, and around 160 N/mm2 which is twice to four times and 3 times higher than most conventional construction grade timbers respectively. The bending strength of most bamboo species varies between 50 and 150 N/mm2 and is on average twice as strong as most conventional structural timbers. The average yield strength was 129.17 MPa and the average elongation was 8.99%. The results stated that bamboo use as an alternative concrete reinforcement, especially the light and moderate structure. Vulnerability to fungus and termite attack is very low by mean score 2.16 and availability of raw materials are high mean score 3.89.

Table 4.9 Bamboo technologies

constraints	mean	remark
architectural aesthetics	3.9	Very high
earthquake resistant	2.59	low
Compressive strength	3.09	high
tensile strength	2.8	moderate
vulnerability to fungus and termite attacks	2.16	low
Availability raw materials	3.89	high

4.4.3. Remedy Earth Block

According to table 4.10 majority of the respondents agree that thermal insulation of remedy earth very high mean score 3.94. Moisture resistance very low by mean score 1.53 and earthquake resistance low mean score 2.2. Compressive strength low by mean score 2 and tensile strength is very low by mean score 1.7. Compressive strength decreases with increasing moisture content and once it reaches its critical moisture content it is likely to fail. Minimal moisture content will result in better strength, water resistance and durability of the blocks. Rammed earth using re-bar, wood or bamboo reinforcement can prevent failure caused by earthquakes or heavy storms

Table 4.10 Remedy earth block

constraints	mean	remark
Thermal insulation	3.94	Very high
moisture resistance	1.53	Very low
Earthquake resistance	2.2	low
Compressive strength	2	low
Tensile strength	1.7	Very low

4.4.4. Bagasse Technologies

Table 4.11 illustrate that most of the respondents are agree that fire resistance of bagasse's technologies is very low mean score 1.78. Compressive strength is moderate mean score 2.44. Moisture resistance moderate mean score 2.84 and availability of raw materials low mean score 2.08.

Table 4.11 Bagasse technologies

constraints	mean	remark
Fire resistance	1.78	Very low
Compressive strength	2.44	moderate
Moisture resistance	2.84	moderate
Availability of raw materials	2.08	low

4.4.5. Straw Bale Technologies

According to table 4.12 most of the respondents agree that moisture resistance capacity straw bale is moderate by mean score 2.8. Sound and thermal insulation are low by mean score 2.18. Fire resistance straw-bale is very low by mean score 1.37. According to en.wikibooks.org (2013), The ASTM E-119 fire resistance test for plastered straw-bale wall assemblies in 1993 passed for a 2-hour firewall assembly. In this test, a gas flame blows on one side of the wall at approximately 2000 degree Fahrenheit (1100 degrees Celsius) while the temperature of the other side of the wall is continuously measured. The results of this test had no burn-through and a maximum temperature rise of 60 degrees Fahrenheit (33.3 degrees Celsius.), and also According to fire safety tests conducted by the National Research Council of Canada, bale walls withstood temperatures up to 1,850 degrees for two hours. These result show that straw bale have good fire resistance capacity. Durability of straw bale is moderate mean score 2.47.

Table 4.12 Straw bale technologies

constraints	mean	remark
Moisture resistance	2.8	moderate
sound and thermal insulation	2.18	low
fire resistance	1.37	Very low
durability	2.47	moderate

4.4.6. Agro-stone

Table 4.13 show that most of the respondents agree that fire resistance capacity of agro-stone is moderate mean score 2.87. Simplicity of the panels to assemble is very high mean score 3.64. Moisture resistance is moderate mean score 2.56. Durability is high by mean score 3.08. Sound and thermal resistance is low mean score 2.76.

Table 4.13 Agro-stone

constraints	mean	remark
fire resistance	2.87	moderate
Simplicity of panel to assemble	3.64	Very high
moisture resistance	2.56	moderate
Durability	3.08	high
sound and thermal insulation	2.76	low

4.5. Cost Comparisons and Analysis

The cost of both conventional and alternative low cost materials technologies collected from Addis Ababa construction bureau and construction companies that have more experience in construction sectors. For each component of building available and mostly adapted conventional building material technologies costs were analyze. The cost of alternative low cost materials technologies collected from Addis Ababa construction bureau and small-scale enterprise that use low cost materials to produce output.

4.5.1. Cost of Alternative Foundation Material Technologies

Fired brick and basaltic stone used for building foundation work. According to figure 4.1, cost of fired brick less than the cost of basaltic stone by 45.7% per M^3. The cost brick include the cost of fire that used during burning of brick. The cost of building a foundation varies greatly depending not only on the type of foundation, but also on the location where the foundation has Bing built. The cost of a foundation fluctuates from region to region, and the overall cost of a particular foundation influenced by both the complexity of the job and availability of raw materials.

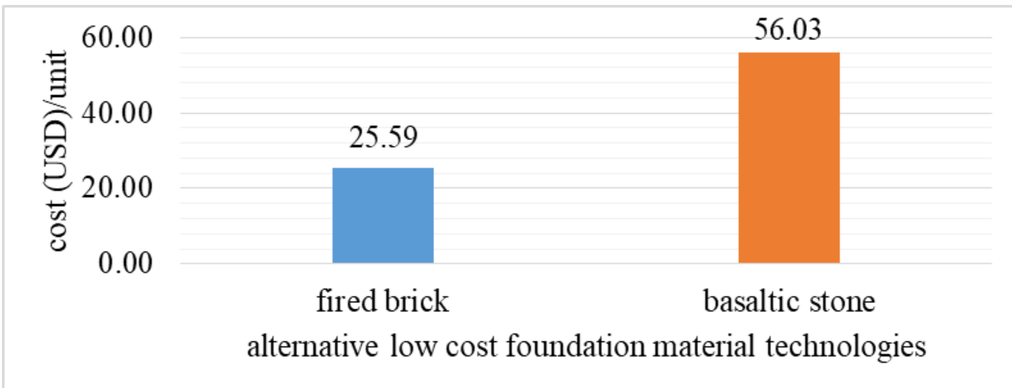


Figure 4.1: Cost of alternative foundation material technologies

4.5.2. Cost of Conventional Foundation Material Technologies

Different types of conventional materials technologies used for the construction of building foundation. Some of these are reinforced cement concrete and basaltic stone. The cost of Reinforced cement concrete foundation has high cost due to the cost of cement and reinforcement bar. The cost of basaltic stone masonry less than the cost of foundation that was construct by using reinforced cement concrete by 62.69%.

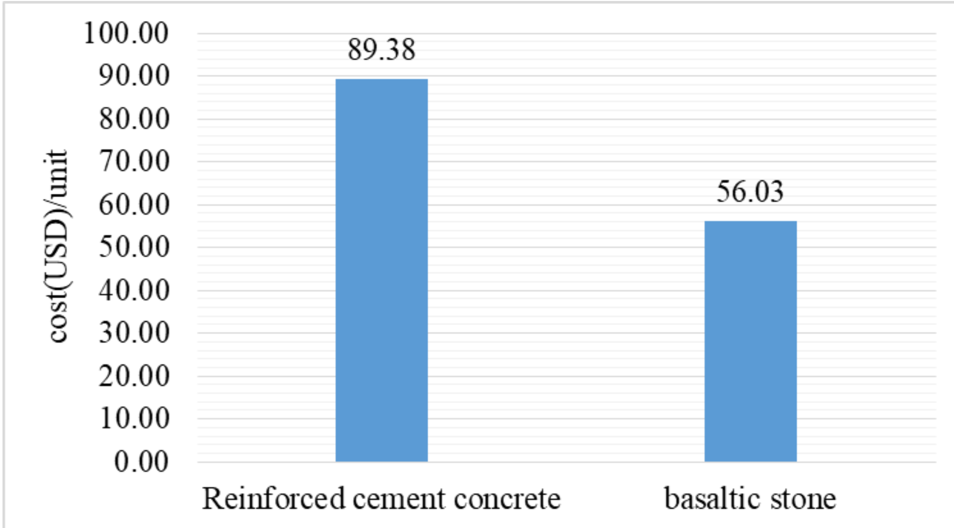


Figure 4.2: Cost of Conventional foundation material technologies

According to figure 4.1 and 4.2 the cost Alternative low cost foundation materials technologies have less than the cost of conventional foundation materials technologies. The average cost of conventional foundation material technologies greater than the average cost of alternative low cost foundation materials technologies by 45.7% per m^3.

4.5.3. Cost of Conventional Wall Materials Technologies

In conventional building construction, different types of materials technology used for wall construction. Costs of wall varied due to quality, availability and durability of materials technologies. According figure 4.3 MDF wall is the costliest wall types than other wall type and plywood wall is the cheapest type of wall than other. The cost of double brick wall by 67.7% cheapest than MDF wall. Cost of metal sheet wall by 56.4% lower than the cost of double brick wall. Cost of Glass wall by 10.86% less than the cost of metal sheet wall. Cost of single brick wall by 8.93% less than cost of glass wall. HCB class A (20cm) wall cost by 32.79% less than the cost of single brick wall. Cost of HCB class B (20cm) by 3.72% less than the cost of HCB class A (20cm). Cost of timber panel wall by 6.88% less than the cost of cost of HCB class B (20cm). Cost of HCB class C (20cm) by 18.98% less than the cost of timber panel wall. Cost of 22cm thick hydra-form wall by 15.07% less than the cost of HCB class C (20cm). Cost of HCB class C (15cm) by 0.16% less than the cost of 22cm thick hydra-form wall. cost of HCB class C (10cm) by 19.04% less than cost of HCB class C (15cm) wall and cost of chip-wood wall by

16.01% less than cost of HCB class c (10cm) wall, and the cost of plywood by 8.89% less that the cost of plywood per meter square.

The cost variation of these materials technologies come form due to materials technologies availability, method of construction, production cost process and quality of materials. Most MDF are import from other country. To construct MDF wall aluminum or other frame are should be used to erect the wall properly, this is increase the cost of MDF wall. The costs differences occur between HCB walls are due to CHB quality and size.

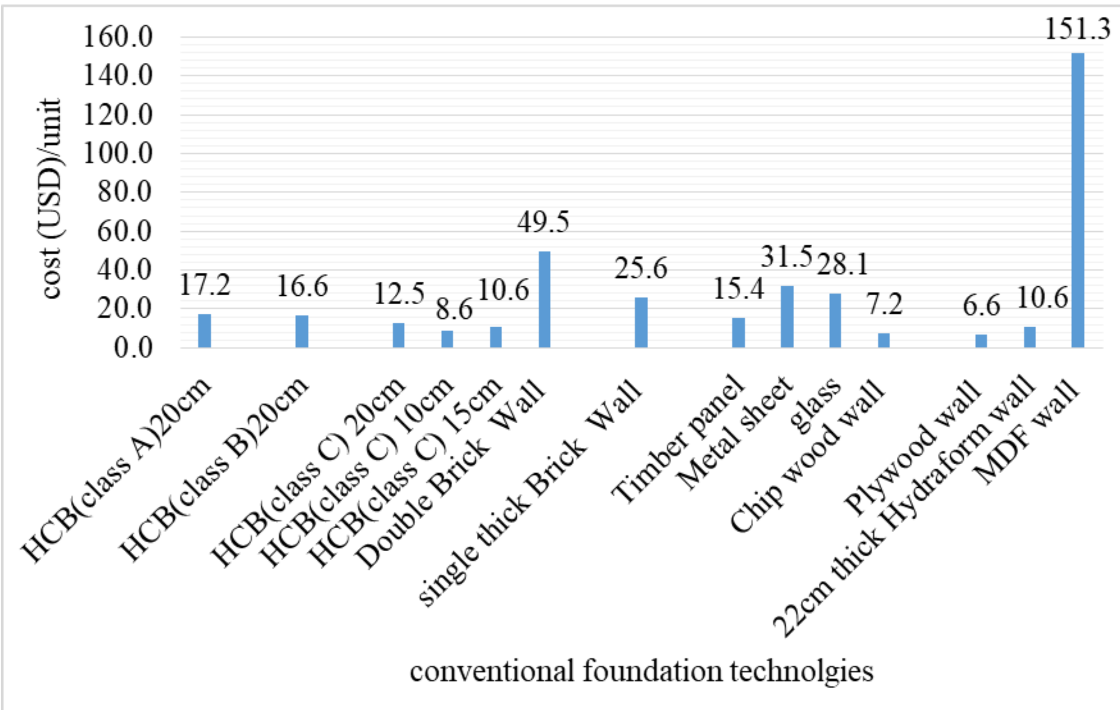


Figure 4.3: Cost of Conventional wall materials technologies

4.5.4. Cost of Alternative Wall Materials Technologies

According to figure 4.4, the cost of alternative wall is different. 40cm thick dressed stone wall type wall is costliest than other types of wall which is constructed using different low cost materials technology. Cost of bamboo panel wall by 62% less than the cost of 40cm thick dressed stone wall. Cost of mud wall with all woodwork by 21.2% less than the cost of bamboo panel wall. Cost of timber wall by 8.34% less than mud wall with woodwork. Cost of asbestos wall by 4.73% less than the cost of timber wall. Cost of stabilized compressed earth block wall by 12.28% less than the cost of asbestos wall. Cost of compressed earth block by 5.6% less that the cost of stabilized compressed earth block, and cost of agro-stone wall by 3.67% less than the cost of hydra-form wall.

The reasons of alternative wall material technologies costs are low, because of raw materials availability and simplicity of their construction method. Transportation and production cost of alternative wall materials are minimum.

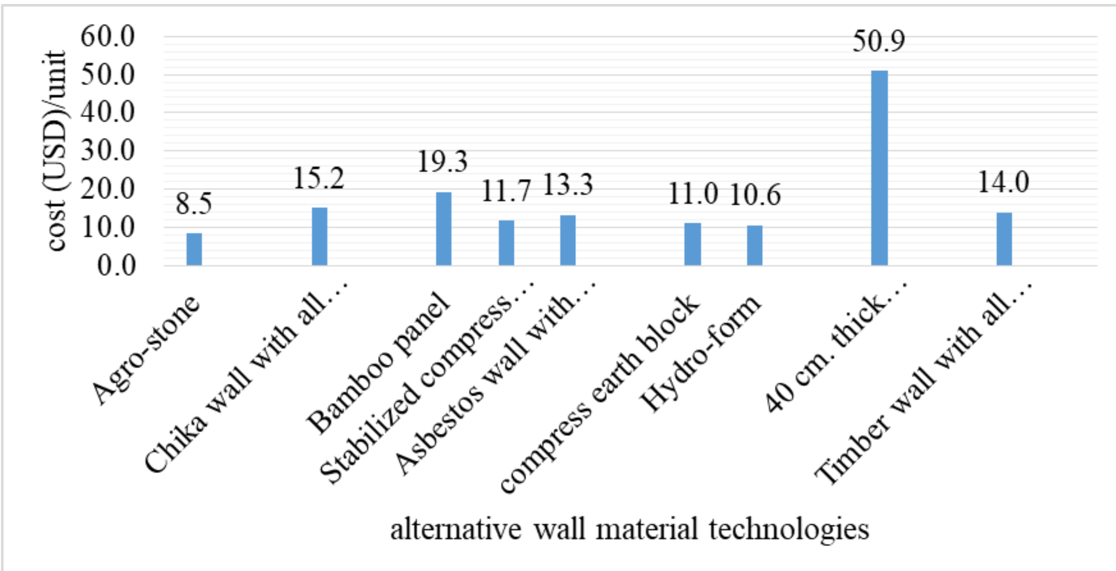


Figure 4.4: Cost of alternative wall materials technologies

Figure 4.3 and 4.4 shows that Average cost of the walls that constructed by using conventional material technologies are greater than the cost of walls constructed by using alternative low cost material technologies by 38.55%.

4.5.5. Cost of Conventional Slab Materials Technologies

The cost of conventional slab floor includes the delivery of slab materials and any material overages because of waste. It also includes labors, supplies such as building permit fees. As per the present market rates, average cost of concrete for a meter cube foot slab ranges between $89.38 and $102.74. The average cost of constructing floor slab depends on many variables such as thickness of slab, floor finish type and local labors rates. According to figure 4.5, the cost of metal sheet slab less than the cost of reinforced cement concrete slab by 64.7%. The cost of ribbed slab by 47.65% less than the cost of metal sheet slab. The cost of wood slab less than the cost ribbed slab by 6.55%. The cost of ribbed slab reduces due to the cost of hollow concrete blocks and labors cost. The labors that use during construction of ribbed slab less than the labors require to casting solid concrete slab.

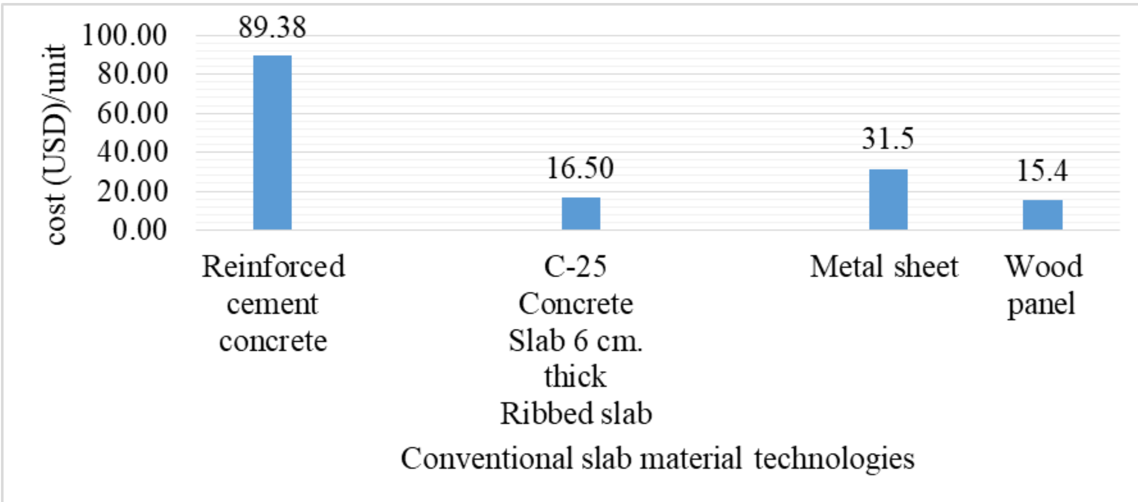


Figure 4.5: Cost of conventional Slab materials technologies

4.5.6. Cost of Alternative Slab Materials Technologies

The cost of cement stabilized compressed earth block slab less than the cost of bamboo slab by 25.21%. The production and transportation cost are minimum due to locally available of raw materials and no requirement of long distance transportation in to construction site. The labors require to install and to produce stabilized compressed earth block are semi-skilled and un-skill labors. These reduce labor cost, the labor cost decrease the cost of wall also decrease. The tools used to produce stabilized compressed earth block are simple. it also have role to reduce the cost.

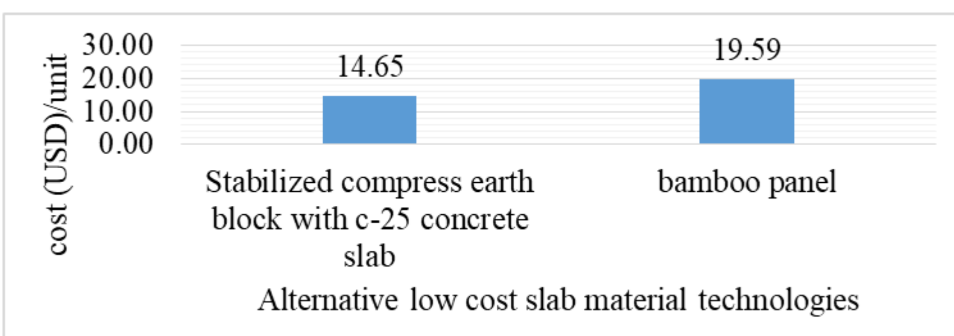


Figure 4.6 Cost of alternative slab materials technologies

Figure 4.5 and 4.6 illustrate that the average cost of slab constructed by alternative low cost construction materials technologies less than the cost of slab constructed by using conventional construction slab materials technologies by 55.19%.

4.5.7. Cost of Conventional Truss and Purlin Materials Technologies

According to figure 4.7, the average cost of different RHS size greater than the average cost eucalyptus wood purlin and truss by 73.95%. Most of RHS that used to in current construction are imported. The cost of this material increase when foreign currencies increase. Wooden trusses can be installing without the help of heavy construction machines. The construction of wooden truss can constructed using semi-skilled labors. Due to these the cost of timber tress are reasonable cost than RHS tress. When it comes to working on a construction site, wooden trusses do not use electrical energy to well the components of the truss, these also one of the reasons why cost of wood truss is low than the cost of RHS truss.

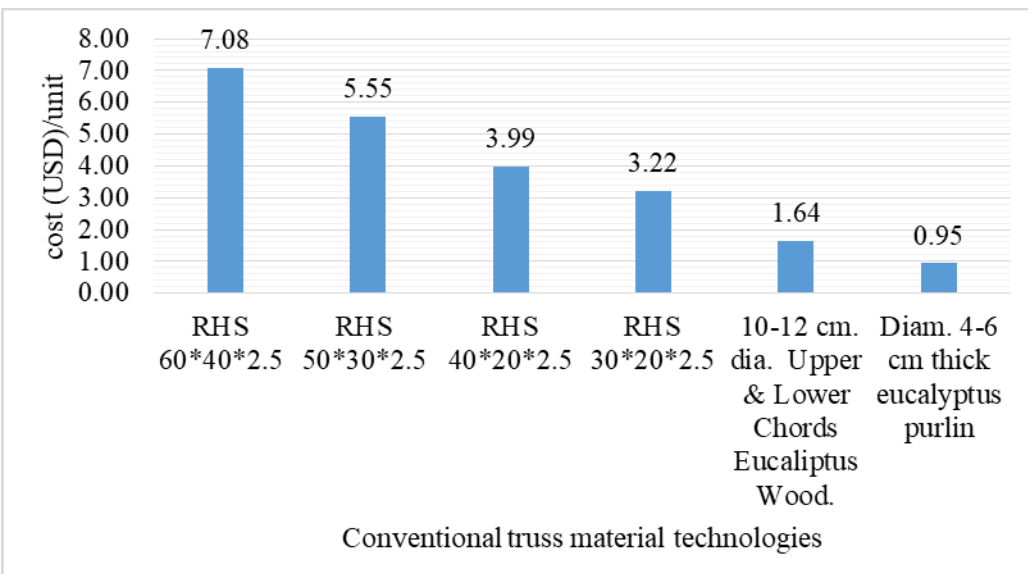


Figure 4.7: Cost of conventional truss and purlin materials technologies

4.5.8. Cost of Alternative Truss and Purlin Materials Technologies

The diameter of bamboo increase the cost also increases, the diameter decrease the cost also decrease this relationship show that the cost of bamboo depends on its diameter and quality. According to figure 4.8, the average cost of bamboo diameter 10-12 cm greater than the average cost of bamboo diameter 4-6 cm by 14.56%.

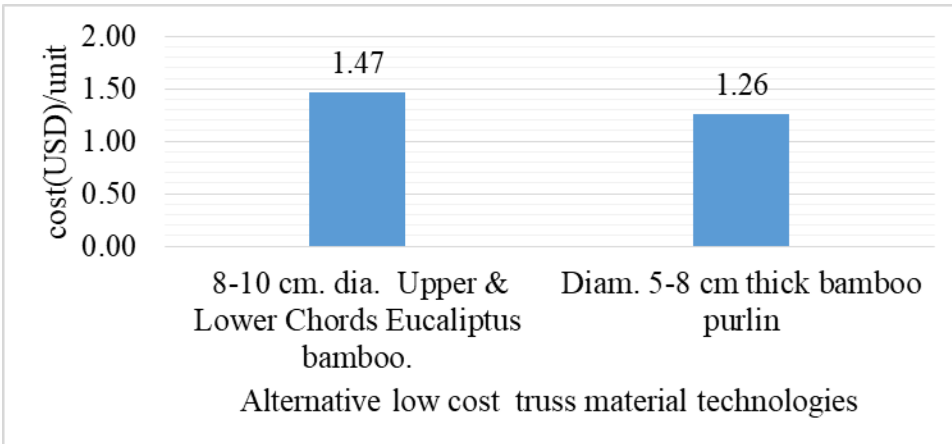


Figure 4.8 Cost of alternative truss and purlin materials technologies

Regarding to figure 4.7 and 4.8 the average cost of conventional truss and purlin greater than the average cost of purlin and truss made with alternative low cost materials technologies less than the average cost of purlin and truss made with conventional materials technologies by 27.17%.

4.5.9. Cost of Conventional Roof Cover Materials Technologies

According to the above figure, 4.9 reinforced cement concrete roofs are the most expensive than roof constructed by other conventional materials technologies. The cost of reinforced roof greater than the cost of metal sheet roof, G-28 CIS roofing and galvanized EGA 300 roof by 78.02%, 88.45% and 89.02% respectively. The cheapest available material was corrugated galvanized iron sheeting. This material, manufactured locally out of imported raw materials, was cheaper than products made entirely out of local materials.

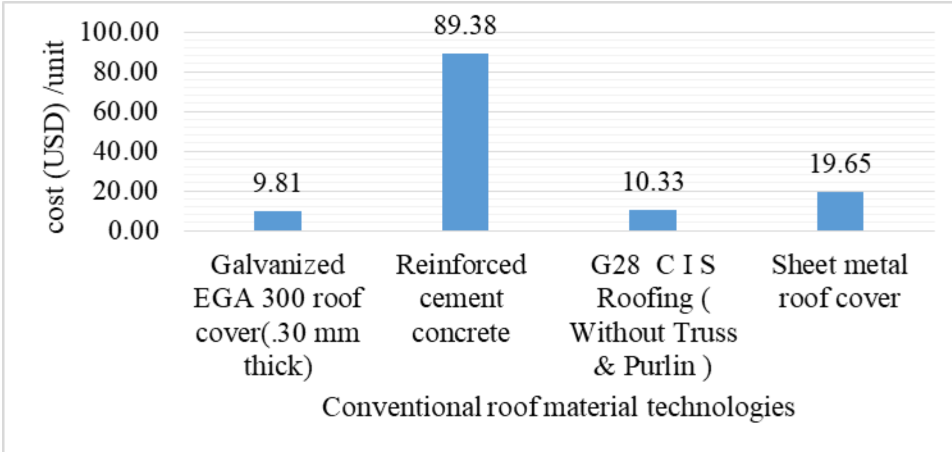


Figure 4.9: Conventional roof cover materials technologies

4.5.10. Cost of Alternative Roof Cover Materials Technologies

Based on the above figure 4.10 the cost of asbestos roof covers greater than the cost of straw bale (grass roof cover) by 53.69%. The relative cost of the various low-cost roof materials technologies has changed considerably due to international movement of raw material prices, increased cost of energy, and the introduction of locally manufactured roof materials technologies.

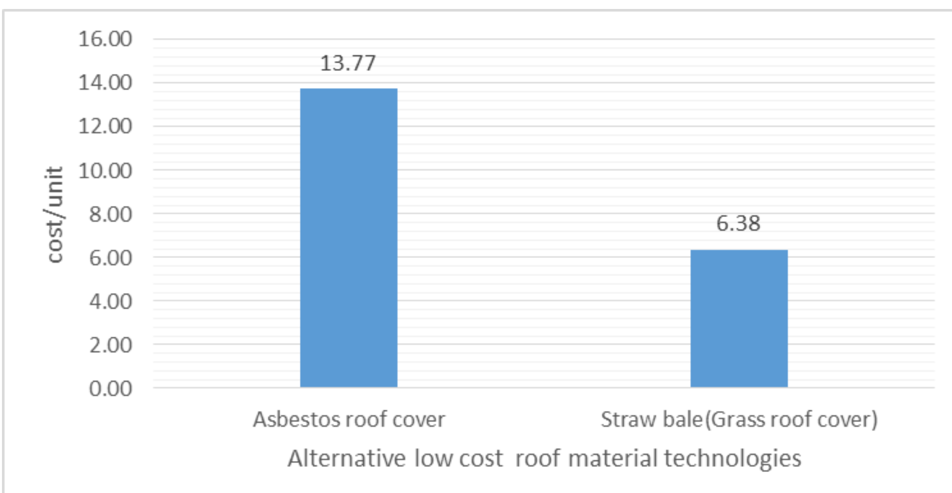


Figure 4.10: Cost of alternative roof cover materials technologies

Based on figure 4.9 and 4.10 the average cost of alternative low cost roof less than the average cost of conventional roof materials technologies by 68.81%.

4.5.11.Cost of Conventional Plastering Materials

The costs of cement plaster wall greater than the cost of gypsum plaster wall. Regarding to figure 4.11, costs of cement plaster wall greater than the cost of gypsum plaster walls by 73.7%. The cost of application of mortar varies with number of layers in which the mortar is applied. Thus, the cost of plastering depends on area to be plastering and number of layers of plaster to be Appling. The cost of other labors varies with the quantity of cement mortar to mix and number of layers of plasters to apply.

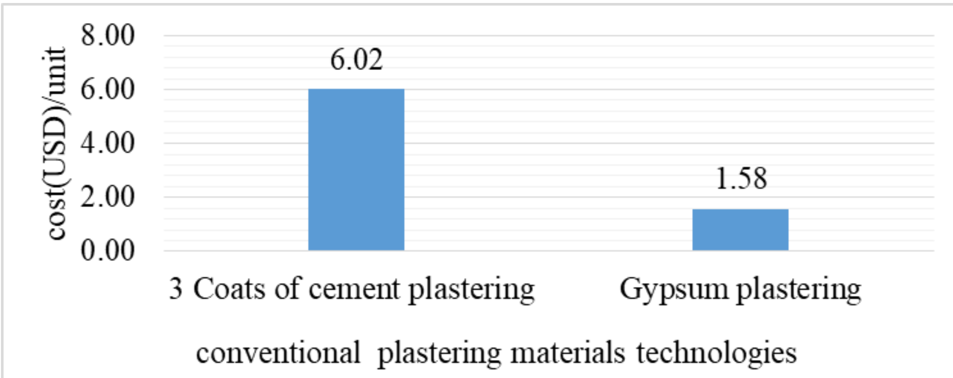


Figure 4.11 Cost of conventional Plastering material technologies

4.5.12.Cost of Alternative Wall Plastering Materials

The cost of plaster different depending on local labor costs and type of plaster however, the fact remains that in most cases, the plasterwork one of the most cost-incurred parts of the construction. From figure 4.12, the cost of non-erodible mud plaster walls less than the cost of lime plaster walls by 46.87.

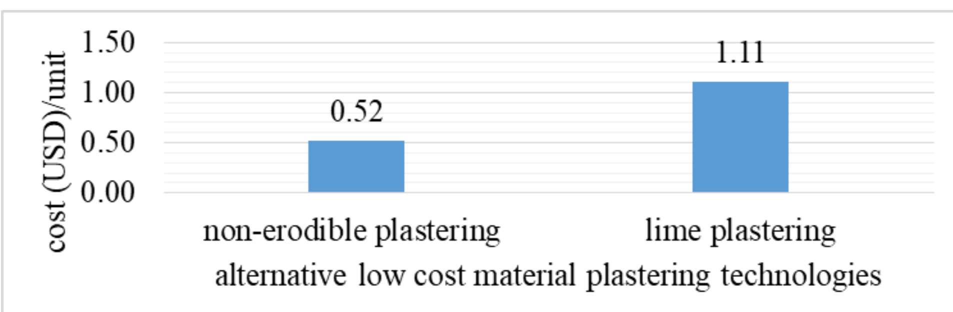


Figure 4.12: Cost of alternative plastering materials technologies

Regarding to figure 4.11 and 4.12, average cost of wall plastered by alternative low cost materials technologies less than the wall plastered by conventional wall technologies by 21.45%.

4.5.13.Cost of Conventional Flooring Materials Technologies

According to figure 4.13, the cost of marble flooring is higher than other type of flooring materials. Cost of 3cm thick marble floor by 18.04% greater than the cost of 2cm thick marble floor. Cost 2cm marble flooring higher by 18.07% the cost of 10mm thick polished granite flooring. Cost of 6 cm ceramic tile floor by 24.75% cheaper than the cost of 10 cm thick polish granite floor. Cost 30 mm thick terrazzo tile by 9.92% cheaper than the cost of 10 mm thick ceramic tile floor. Cost of 20 cm thick terrazzo tile 6.84% cheaper than the cost of 20 cm thick wood floor. Cost of 5 cm thick cement screed floor 48.21%, 61.5% and 71.7% cheaper than the cost 2cm thick PVC floor, 6mm thick ceramic floor and 20cm thick terrazzo tile floor respectively.

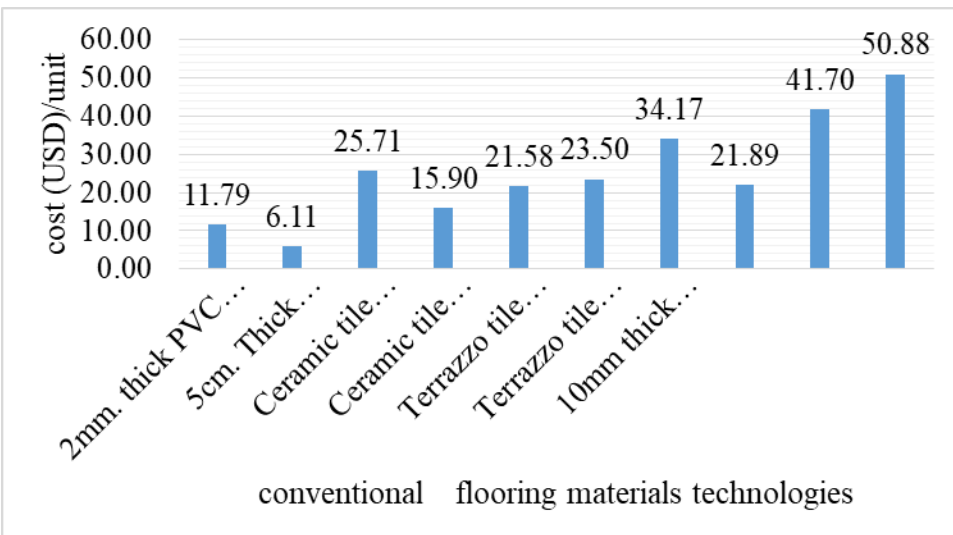


Figure 4.13: Cost of conventional Flooring materials technologies

4.5.14.Cost of Alternative Flooring Materials Technologies

The costs are per square foot of floor area for the basic building and additional costs for waste materials that differ from building to building. Building shape, floor area, design elements, materials used, and overall quality influence the basic floor cost. Based on figure 4.14, cost of 2mm thick plastic flooring less than the cost of 20 cm thick bamboo flooring by 24.17% per meter square.

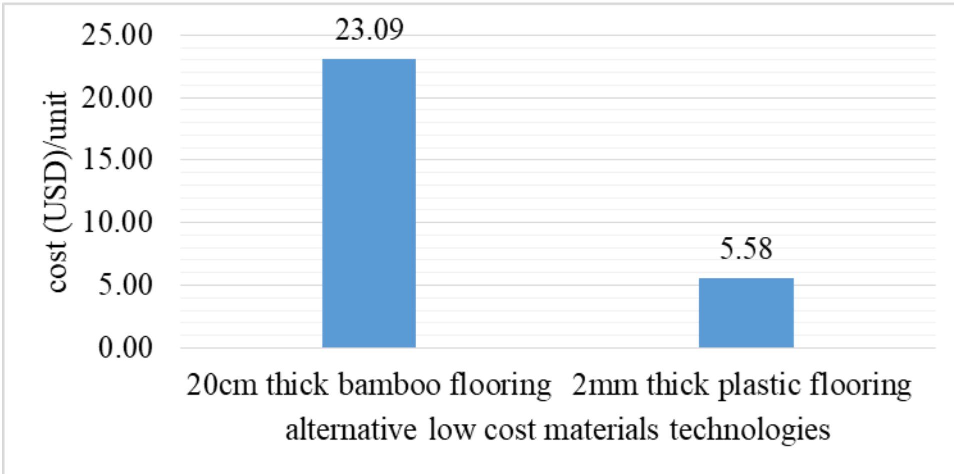


Figure 4.14: Cost of alternative flooring materials technologies

According to figure 4.13 and 4.14, the average cost of floor constructed using alternative low cost materials technologies less than the floor constructed using technologies by 3.34%.

4.5.15.Cost of Conventional Ceiling Materials Technologies

In building sector, different types of ceiling materials are used. The costs of those materials varied due to their quality, simplicity and nature to assemble them. According to figure 4.15 cost of plywood ceiling by 21.02% less than the cost of 8cm thick chip-wood ceiling cost of timber ceiling greater than the cost plywood by 21.58%, and the cost of PVC ceiling greater than the cost of plywood ceiling by 27.83%.

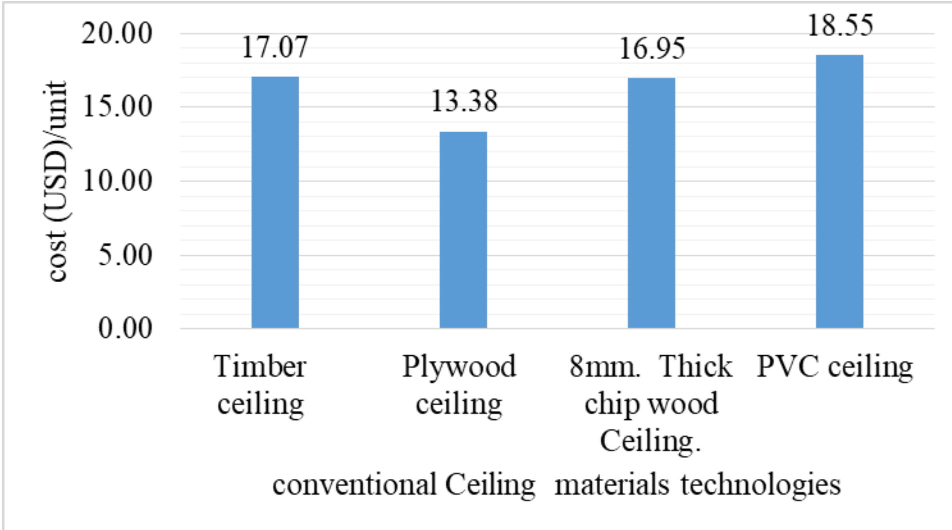


Figure 4.15: Cost of conventional Ceiling materials technologies

4.5.16.Cost of Alternative Ceiling Materials Technologies

Regarding to figure 4.16 the cost of plastic sack ceiling by 2.24% cheaper than the cost of rush ceiling, cost of rush ceiling by 0.17% cheaper than the cost of sack ceiling. The cost of sack ceiling by 1.84% cheaper than the cost of Abujedy ceiling and cost of Abujedy ceiling 0.34% cheaper than the cost of bamboo ceiling.

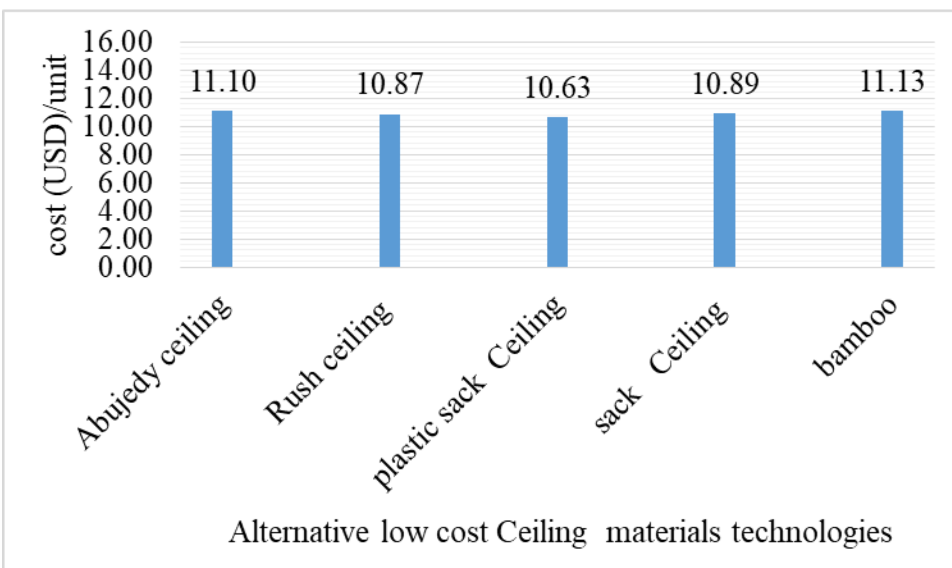


Figure 4.16: Cost of alternative ceiling materials technologies

According to figure 4.15 and 4.16, the average cost of ceiling constructed using alternative low cost ceiling technologies by 33.73% cheaper than the cost of ceiling constructed by convention materials technologies.

4.5.17.Cost of Conventional Doors Materials Technologies

Regarding to the figure 4.17 partial glazed metal door of 38LTZ by 1.78%, 63.76%, 75.56% and 79.46% cheaper than the cost of 3cmthick timber door, mahogany plywood smooth finished, flush antique MDF board wooden door and smooth MDF board made imported wooden door respectively.

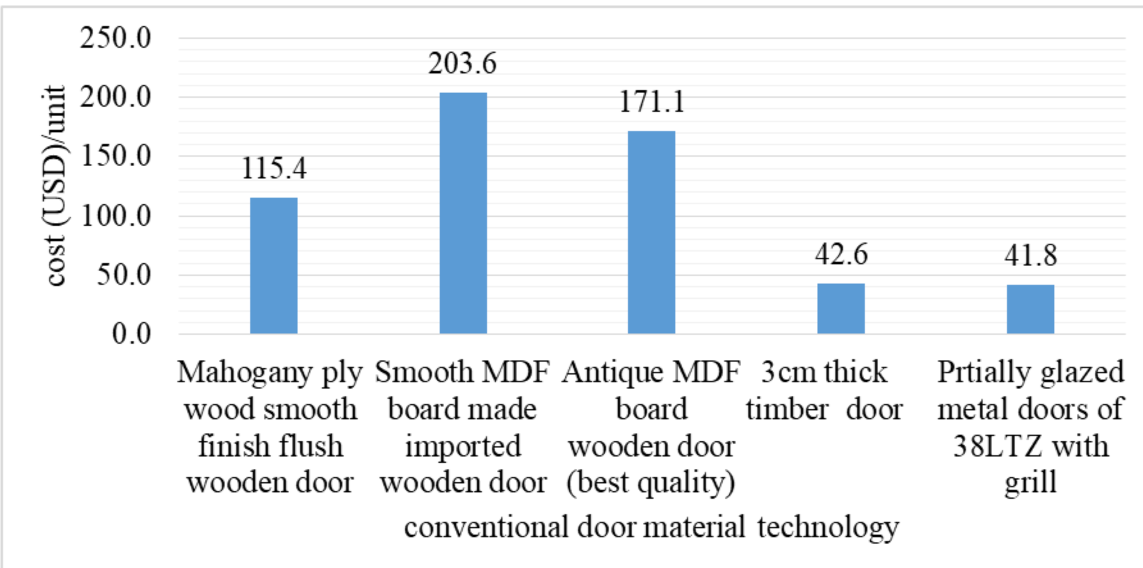


Figure 4.17: Cost of conventional Doors materials technologies

4.5.18.Cost of Alternative Doors Materials Technologies

The costs G-32 CIS door with all woodwork 9.37% expensive than the costs of timber door. The cost of door depends on the shape and size the door. Most decorative doors are require higher cost than normal door types.

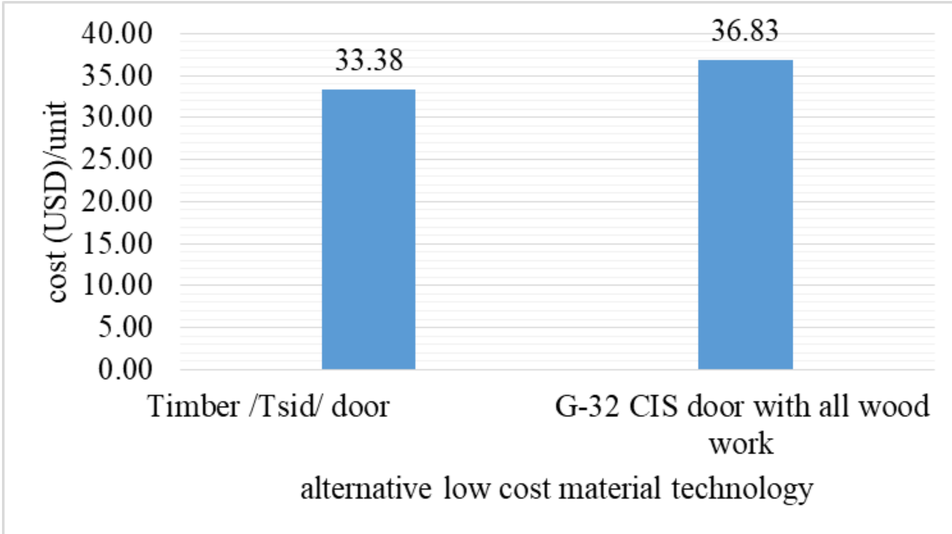


Figure 4.18: Cost of alternative doors materials technologies

Figure 4.17 and 4.18 show that, the average cost of door which made by using alternative low cost materials technologies by 69.45% cheaper than the cost of door which is made by conventional materials technologies.

The above discussions indicate that all possible conventional and alternative low cost materials technologies can apply to construct building. By considering the cost of material and external construction practice, the following plan was prepare. After preparing the plan the materials technologies were select based on their cost, time, quality and sustainability in the sector.

The following table illustrate that the cost of each section of the building components. During materials selection for the proposed residential building, content analysis conducting on the document comprises details of materials specification for residential building. The materials selected for this study are listed appendix “C” in MS schedule figure 4.26 and 4.27.

Table 4.14 total cost of the proposed residential building using conventional technologies

Task Name	Cost(USD)	Cumulative cost(USD)
PROJECT- RESIDENCE BUILDING		
DESCRIPTION		
Sub-structure		
Excavation & Earth Work	2,148.20	2,148.20
Masonry Work	3,028.40	5,176.60
Concrete Work	10,974.68	16,151.28
Super structure		
Concrete Work	11,869.78	28,021.06
Block work	5,568.77	33,589.83
Roofing	348.59	33,938.42
Carpentry and Joinery	3,108.00	37,046.42
metal Works	1,113.15	38,159.57
Plastering and Pointing	3,793.74	41,953.31
flooring	1,492.30	43,445.61
Painting	1,226.86	44,672.47
Glazing	182.37	44,854.84
Sanitary Installation	4,869.07	49,723.91
Electrical Installation	1,278.19	51,002.10

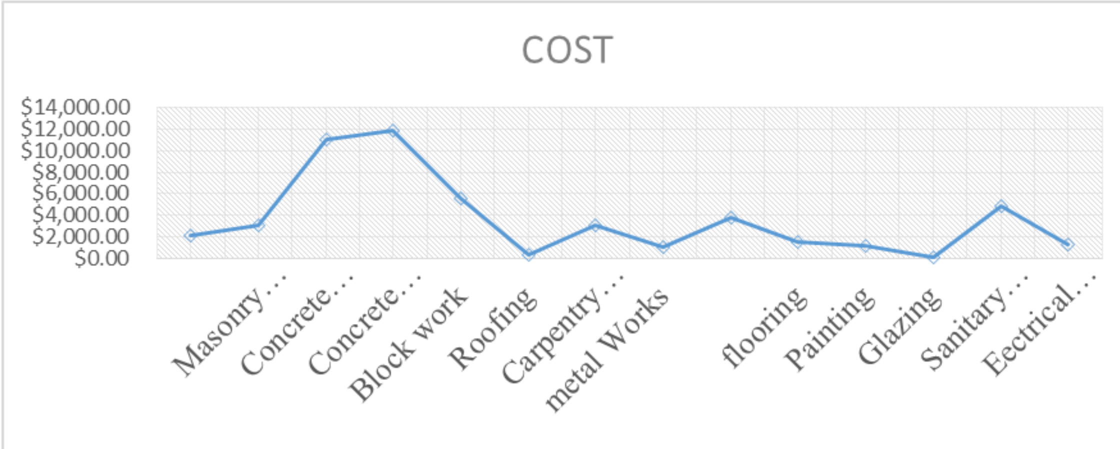


Figure 4.19: cost of each section of the proposed residential building

Figure 4.19 and 4.20 show that individual building component and cumulative cost of the proposed residential building. According to the figures cost of concrete and block work are higher than other works per unit cost. The results show that, great attention is requiring to substituting the components of the building construct using concrete and hollow concrete block. Most components of the building are construct using this materials technologies. The total cost of the building increase due to the cost of these technologies.

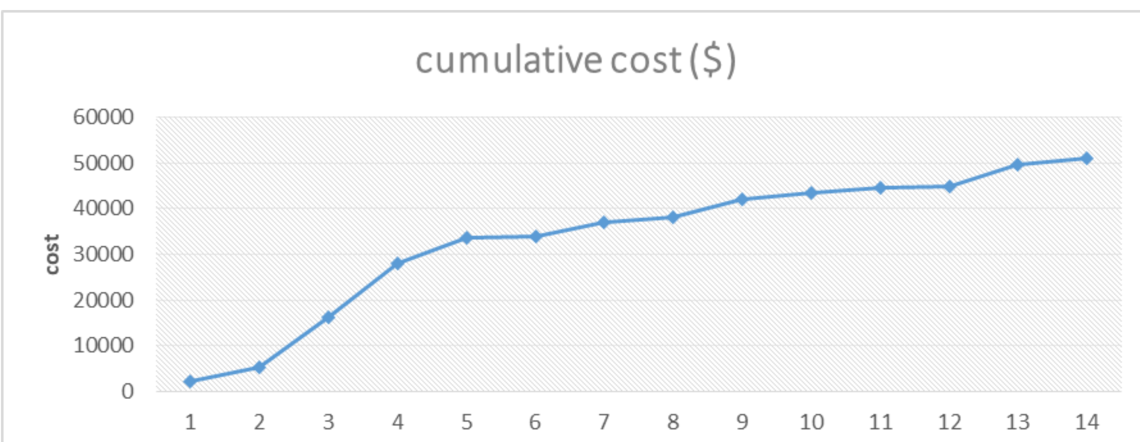


Figure 4.20 cumulative cost of the proposed residential building by using conventional technologies

Figure 4.21, 4.22 and table 14.13 show that individual building component and cumulative cost of the proposed residential building using both technologies. According to the figures and table by substituting conventional wall, roof, ceiling, window, door and purlin materials technologies by alternatives low cost technologies the cost of proposed building can reduce reasonably. The results show that, combination method is effective to reduce the cost of construction. Great attention is requiring to during construction, because of construction techniques are affect the overall cost of projects.

Table 4.15 the cost of proposed building by mixing conventional and alternative building technologies

Task Name	Cost(USD)	cumulative cost (USD)
PROJECT- RESIDENCE BUILDING		
DESCRIPTION		
Sub-structure		
Excavation & Earth Work	2,148.20	2,148.20
Masonry Work	3,028.40	5,176.60
Concrete Work	10,974.68	16,151.28
Super structure		
Concrete Work	11,869.78	28,021.06
Block work	3,369.76	31,390.82
Roof work	282.83	31,673.65
Carpentry and Joinery	2,730.71	34,404.36
Plastering and Pointing	1,770.48	36,174.84
flooring	819.19	36,994.03
Painting	636.96	37,630.99
Glazing	182.37	37,813.36
Sanitary Installation	4,869.07	42,682.43
Electrical Installation	1,278.19	43,960.62

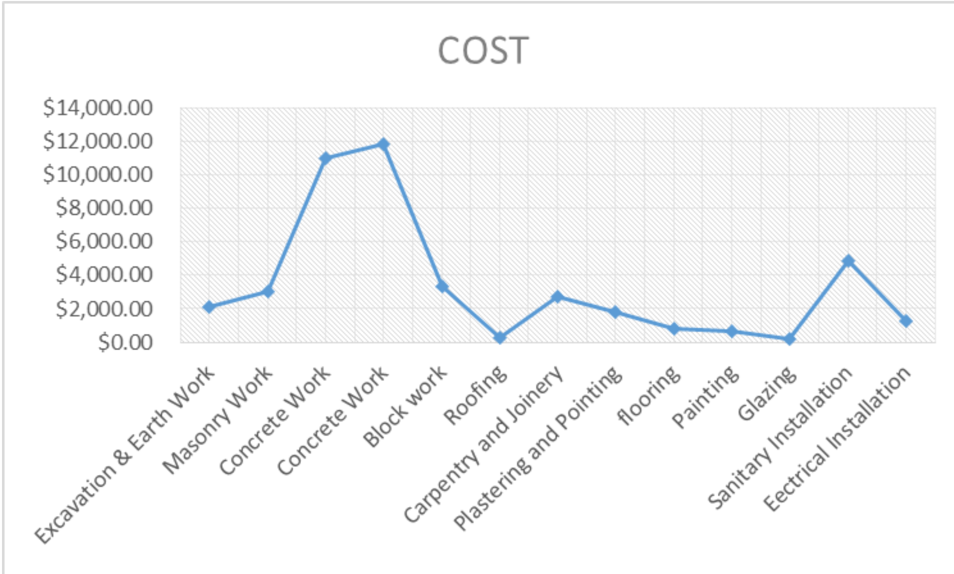


Figure 4.21 cost of different components of proposed residential building using ALCCT

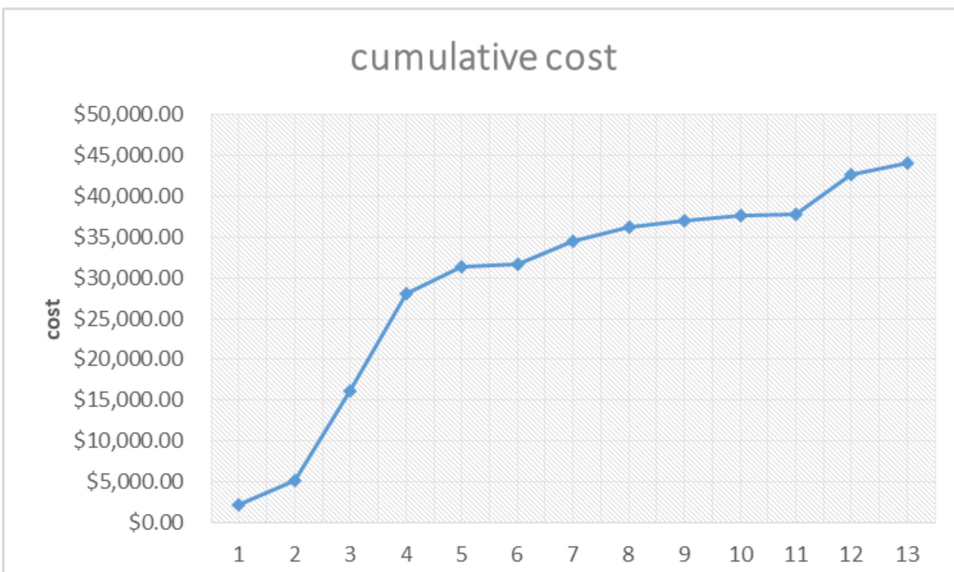


Figure 4.22 cumulative cost of the proposed residential building by combining alternative technologies with conventional building technologies

Building project consumes different types of resource. The cost of this resource depends of raw materials availability and quality. To reduce the cost of materials technologies several method and techniques are adapt from conceptual phase up to completion phase of the project. Figure 4.23 show that by combining alternative low cost building materials technologies with conventional building technologies, we can reduce the overall cost of the building project. In this assumption, except frame structure, sanitary and electrical portion of the building work, most the proposed residential building components assigned to be construct by mixing conventional and alternative low cost building technologies. The overall cost of the proposed building reduces from $ 51,002.10 in to $ 43,960.62. These amounts cover 13.81% less cost of integrated method of building technologies than conventional.

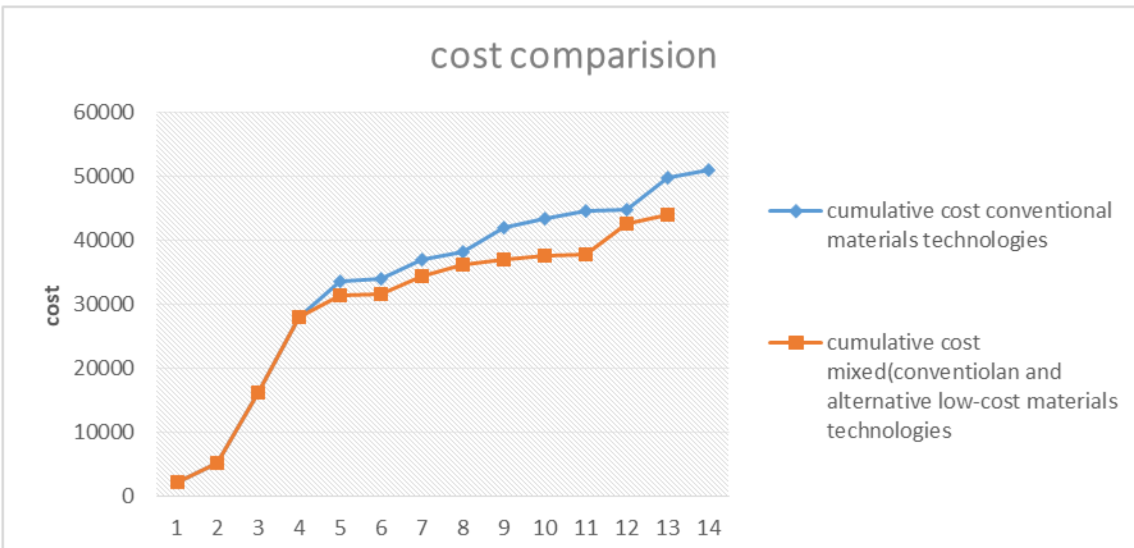
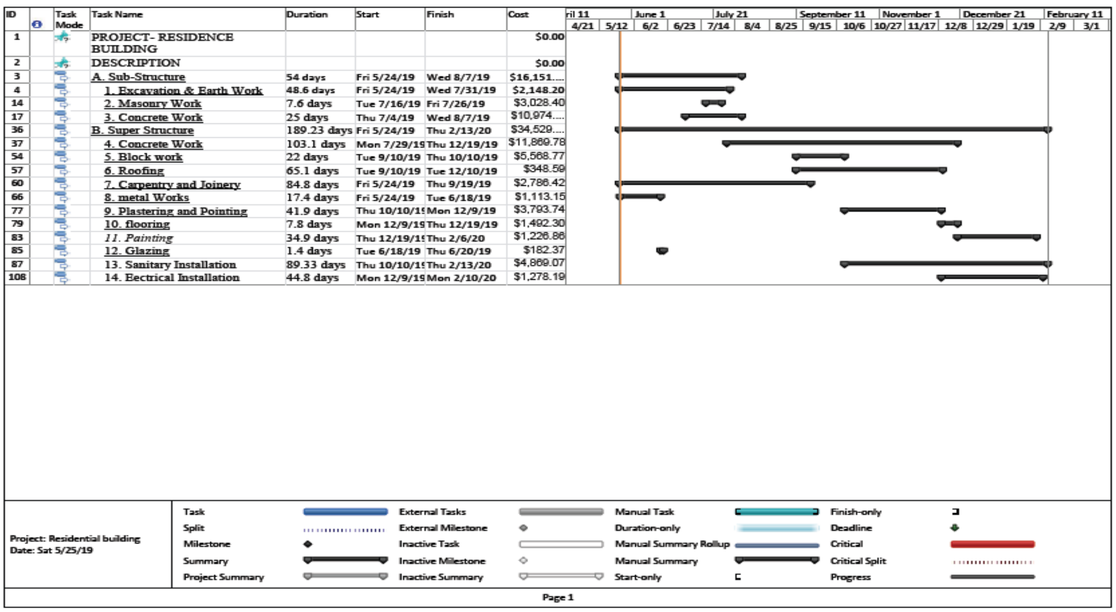


Figure 4.23: cumulative cost difference between alternative low cost materials technologies and conventional materials technologies.

4.6. Time Analysis

To determine the total time that require to complete Project estimate from total sum of working periods that characterize the time length of project work and are required to complete all the activities listed in the project schedule and all the components of the work breakdown structure, considering the allocation and consumption of all necessary human resources. For the proposed design, the project duration expressed in terms of working time units (days, weeks, months).

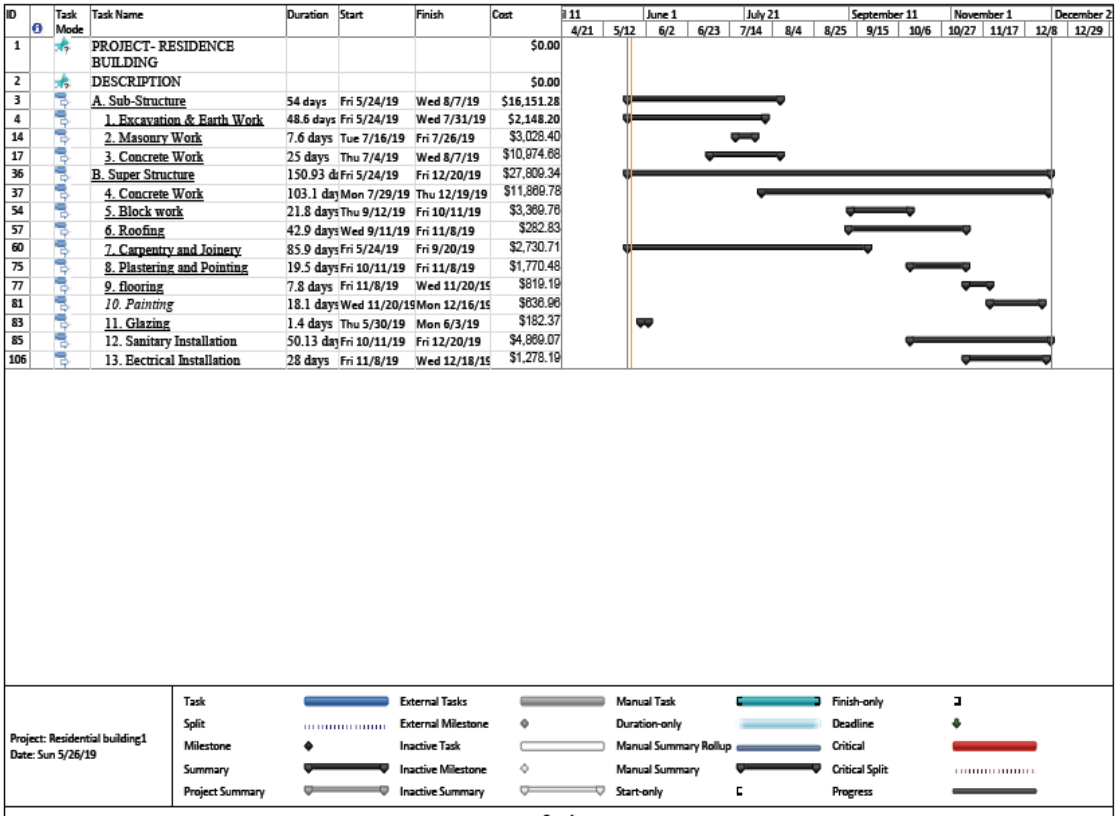
The project duration depend on labor productivity and complexity of the construction technologies. To increase labor productivity construction technologies and method of construction must be simple and easily understandable, and materials technologies are familiars to local labors. This assumption help to more efficiently complete tasks and produce better products. Project duration can often reduce by assigning more labor to project activities, but in this study to reduce project duration, locally available material technologies are propose. Local construction technologies and there construction methods are easy to adapt by local labor, this is one of the way to increase The project cost depends on project duration, the project duration increase the project cost similarly increase and the reverse is true.



ID	Task Name	Duration	Start	Finish	Cost
1	PROJECT- RESIDENCE BUILDING				$0.00
2	DESCRIPTION				$0.00
3	A. Sub-Structure	54 days	Fri 5/24/19	Wed 8/7/19	$16,151....
4	1. Excavation & Earth Work	48.6 days	Fri 5/24/19	Wed 7/31/19	$2,148.20
14	2. Masonry Work	7.6 days	Tue 7/16/19	Fri 7/26/19	$3,028.40
17	3. Concrete Work	25 days	Thu 7/4/19	Wed 8/7/19	$10,974....
36	B. Super Structure	189.23 days	Fri 5/24/19	Thu 2/13/20	$34,529....
37	4. Concrete Work	103.1 days	Mon 7/29/19	Thu 12/19/19	$11,869.78
54	5. Block work	22 days	Tue 9/10/19	Thu 10/10/19	$5,568.77
57	6. Roofing	65.1 days	Tue 9/10/19	Tue 12/10/19	$348.59
60	7. Carpentry and Joinery	84.8 days	Fri 5/24/19	Thu 9/19/19	$2,786.42
66	8. metal Works	17.4 days	Fri 5/24/19	Tue 6/18/19	$1,113.15
77	9. Plastering and Pointing	41.9 days	Thu 10/10/19	Mon 12/9/19	$3,793.74
79	10. flooring	7.8 days	Mon 12/9/19	Thu 12/19/19	$1,492.30
83	11. Painting	34.9 days	Thu 12/19/19	Thu 2/6/20	$1,226.86
85	12. Glazing	1.4 days	Tue 6/18/19	Thu 6/20/19	$182.37
87	13. Sanitary Installation	89.33 days	Thu 10/10/19	Thu 2/13/20	$4,869.07
108	14. Ectrical Installation	44.8 days	Mon 12/9/19	Mon 2/10/20	$1,278.19

Figure 4.24: time require to complete the project using conventional technologies

The above figure 4.24 show that time requires to completing the proposed residential building by using conventional building technologies. According to the figure total time require to complete the proposed building is 190 calendar days. The require days to execute each activities are calculated by dividing the total amount of work for individual activity to crew productivity per hour. To execute a certain task different crew composition are require. The productivity affected by the output of each crew. The total duration to complete the proposed building estimated by adding the time required to execute the critical activities.



ID		Task Mode	Task Name	Duration	Start	Finish	Cost
1			PROJECT- RESIDENCE BUILDING				$0.00
2			DESCRIPTION				$0.00
3			A. Sub-Structure	54 days	Fri 5/24/19	Wed 8/7/19	$16,151.28
4			1. Excavation & Earth Work	48.6 days	Fri 5/24/19	Wed 7/31/19	$2,148.20
14			2. Masonry Work	7.6 days	Tue 7/16/19	Fri 7/26/19	$3,028.40
17			3. Concrete Work	25 days	Thu 7/4/19	Wed 8/7/19	$10,974.68
36			B. Super Structure	150.93 d	Fri 5/24/19	Fri 12/20/19	$27,809.34
37			4. Concrete Work	103.1 day	Mon 7/29/19	Thu 12/19/19	$11,869.78
54			5. Block work	21.8 days	Thu 9/12/19	Fri 10/11/19	$3,369.76
57			6. Roofing	42.9 days	Wed 9/11/19	Fri 11/8/19	$282.83
60			7. Carpentry and Joinery	85.9 days	Fri 5/24/19	Fri 9/20/19	$2,730.71
75			8. Plastering and Pointing	19.5 days	Fri 10/11/19	Fri 11/8/19	$1,770.48
77			9. flooring	7.8 days	Fri 11/8/19	Wed 11/20/19	$819.19
81			*10. Painting*	18.1 days	Wed 11/20/19	Mon 12/16/19	$636.96
83			11. Glazing	1.4 days	Thu 5/30/19	Mon 6/3/19	$182.37
85			12. Sanitary Installation	50.13 day	Fri 10/11/19	Fri 12/20/19	$4,869.07
106			13. Bectrical Installation	28 days	Fri 11/8/19	Wed 12/18/19	$1,278.19

Figure 4.25: time require to complete the project using both alternative and conventional technologies

Figure 4.25 shows that time requires to completing sub-tasks of the proposed residential building by using conventional building technologies. According to the figure total time require to complete this proposed building is 151 calendar days. The duration determined using critical path method. The completion dates of the project depend on the critical activities. The critical activates delay the total project duration also delay. According figure C1 earthwork, concrete work, block work, carpentry work for purlin, plastering, floor work, painting PVC power cable installation are main critical activities. The main reasons to reduce the total estimated duration are external plastering and painting not require for stabilize compressed earth block due to its esthetics appearance, and instead of HCB for internal wall agro-stone panel are used. The time required constructing agro-stone panel less than the time require constructing HCB wall. Due to small units of HCB, construction of HCB wall takes longer time than agro-stone.

4.7. Sustainability of Alternative Low Cost Technologies in Building Sectors

The choice of construction materials has wide-reaching economic, environmental, and social consequence on any structure. Total cost of most structures depends greatly on the types of materials used. Energy consumption of any building has a significant relationship with the materials used for construction and the design of the building. Adaptability of some buildings by the society sometimes has bearing on the types of materials used. Sustainability of construction materials technologies measures due to the value of economic and social acceptance as well as impact on environment. From below discussion bamboo are the most sustainable alternative building material because the cost, quality and social acceptance high. And also environmental friendly material

The challenge for the construction industry is to re-engineer its entire process in order to reduce its impact on the environment. The material technologies used in construction sectors have several effects on the surrounding environment. Different materials technologies emit different amount of CO_2 to the environment. The sustainability of construction technologies depend on the amount of CO_2 emission to the environment. Table 4.16 shows that, 60.92% of the respondents agree that alternative low cost technologies are sustainable in the building sector. The remaining 39.08% of the respondents inform alternative low cost technologies are not sustainable in the sector. sustainable construction are all framed towards creating a healthy built environment through resource efficient and ecologically sound processes, preservation of ecosystems and maintenance of natural balance between development and carrying capacity of the sectors. Most of the respondents explain the following reasons why alternative low cost construction technologies are sustainability in building sector.

- Availability of raw materials
- Low energy consumptions
- Low carbon dioxide (co2) emission
- Low cost of raw materials
- Required semi-skilled and un skilled labors to produce

Table 4.16 sustainability of ALCCT

	frequency	percent	cumulative percent
yes	53	60.92	60.92
no	34	39.08	100
total	87		

The raw materials that used to produce alternative low cost technologies are readily available in the country. These technologies easily produce by using simple tool and semi-skill and un-skilled labors. To train labor on the construction method and techniques of alternative low cost technologies are easy because of the materials technologies are familiar for local labor.

4.7.1. Impact of building technologies on the environment

Tables 4.17 show that, 82.76% of the respondents agree that conventional building technologies have negative impact on the environmental, social and economic sectors. Remaining 17.24% of the respondents inform that ALCCT have negative impact on the environmental, social and economic sector. These respondents' arguments are disforestation and depletion of land when we use bamboo and earth soil for construction purposes. The choice of building materials technologies is of paramount importance. The use of naturally occurring materials in the construction process is good practice reflecting both the climatic diversity and the spatial distribution of resource endowments. Because of technological advancements, house construction currently reflects less availability of materials and their climatic suitability, but more the affordability of materials and the changing nature of building technology.

Table 4.17 the impact of building technologies on the environment

	frequency	percent	cumulative percent
conventional construction technologies	15	17.24	17.24
alternative low cost construction technologies	72	82.76	82.76
total	87		100.00

Alternative low cost technologies are environmental friendly. Carbon dioxide emission and energy consumption is low compere to conventional construction technologies. According to table 4.17.1 Adobe is indisputable the most environment friendly material. It releases zero carbon di oxide to the environment. Both cement-stabilized products (CSEB and HCB) cause a large carbon dioxide emission. A lot of carbon dioxide is release in the production of fired bricks. The release of carbon dioxide is almost nil in the production of Gypsum Stabilized Earth walls.

Table 4:17.1 the totals of the environmental computation (Source: Vroomen, 2007).

	Adobe	CSEB	Fired brick	Hollow concrete blocks (HCB)	Gypsum stabilized earth wall in sections	Gypsum stabilized earth massive blocks
Energy required (MJ/fu)	36	233	1026	390	191	161
Carbon dioxide emission (Kg/ fu)	0	55	118	98	2	1

4.7.2. Maintenance cost

The maintenance cost of building depends on the life cycle construction materials technology that used to construct the building. According to table 4.18, 52.87% of the respondents strongly agree the maintenance costs of alternative low cost building technologies are reasonable. Based on 27.59% of the respondents the maintenance costs of the buildings constructed by ALCCT are average. The other 13.79% of the respondent strongly disagree the maintenance cost of the building constructed by ALCCT are not minimum and remaining 5.75% disagree on the maintenance cost of the building constructed by using ALCCT is minimum.

Table 4.18 maintenance cost

	frequency	percent	cumulative percept
strongly agree	46	52.87	52.87
agree	24	27.59	80.46
disagree	12	13.79	94.25

strongly disagree	5	5.75	100
total	87		

4.7.3. Energy Consumption

To produce construction materials technologies different amount of energy are consuming. The amount of energy that use to produce construction materials technologies depend on materials technologies production process and complexity the raw materials combination process. Table 4.19 show that, 74.71% of the respondent agree low cost construction technologies production process consume less amount of energy compare from energy consume by conventional materials technologies production process. The remaining 25.29% of respondent are disagree that the consumptions of energy during the production of ALCCT is low. According to table 4.17.1 the energy requirement of Gypsum Stabilized Earth is about half of the energy requirements of HCB. The firing of bricks is a very energy consuming process and adobe block require the minimum energy than the other.

Table 4.19 energy consumption

	frequency	percent	cumulative percent
YES	65	74.71	74.71
NO	22	25.29	100
total	87		

4.7.4. Reusability and recyclability of ALCCT

Any construction projects have its own life cycle cost or design period. The life cycle of a certain construction project, depend on the quality and durability of the construction materials that used to construct the construction project. Table 4.20 shows that 85.06% of the respondents inform, low cost construction technologies are not reusable and recyclable. The remaining 14.94% of the respondent describe low cost materials technologies are recyclable and reusable.

Table 4.20 reusability and recyclability of ALCCT

	frequency	percent	cumulative percent
yes	13	14.94	14.94
no	74	85.06	100
total	87		

4.8. Barrier to Innovate and Adapt Alternative Low Cost Materials Technologies

Table 4.21 list of barriers

	barrier	mean	Rank
1	Poor Innovation diffusion	8.06	1
2	Lack of government support and recognition	7.82	2
3	Limitation of Finance or budget	6.51	3
4	Low profitability	6.47	4
5	Poor promotion of the technologies	6.45	5
6	Lack of Guideline, Standardization and manuals	6.2	6
7	Luck of Local Code and Regulation	6.16	7
8	Luck of Willingness to apply the concept	5.1	8
9	Low Customer Acceptance	5.09	9
10	Rejection of concept and Acceptance of idea in principle	5	10
11	High initial cost of innovative technologies	4.85	11
12	Poor Quality assurance and aesthetic value of materials	4.68	12

Poor innovation diffusion: -innovated construction technologies should be address to the user with reasonable time. According to the respondent's poor innovation diffusion ranked in the first stage by mean score 8.06. In the city (Addis Ababa) ALCCT innovation diffusions are very low, even if after innovation of low cost technologies, it takes longer time to integrate in the building sectors.

Lack of governmental support and recognition: - the above table 4.21 show that most of the respondents believed that lack of governmental support and recognition have great effect to innovate and develop ALCCT in the building sectors, and they ranked in the second stage mean score 7.82. In different institutes, (governmental and non-governmental) many researchers conducted research on ALCCT and got several results, but the government support and recognition ware very low.

Table 4.22 governmental attention on ALCCT

	frequency	percent	cumulative percent
strongly agree	4	4.60	4.60
agree	9	10.34	14.94
disagree	57	65.52	80.46
strongly disagree	17	19.54	100

Table 4.22 show that majority of the respondents 65.52% disagree the government Ethiopia give attention on alternative low cost technologies innovation, improvement and adaption in the building sector.19.54% of the respondents strongly disagree on the attention of government. Other 10.34% of the respondents agree on the government attention and 4.6% strongly agree the government give attention to innovate, improve and adapt ALCCT in building sector. Form the general perspective of the respondents' information the government of Ethiopia not gives attention on ALCCT significantly.

Limitation of finance/budget: - finance and budget are the prominent elements to innovate, develop and improvement of construction technologies. Without finance and budget allocation, any of construction technologies are not effective and sustainable, because to conduct innovative idea different types of inputs are use. This input requires some amount of money to process. According to the respondent's limitation of finance and budget ranched in the third stage mean score 6.51.

Low profitability: - regarding to the table 4.21, majority of respondent agrees that due to low profitability of ALCCT for producer and raw material suppliers ranked in the fourth stage mean score 6.47. From raw materials suppliers the products seller requires reasonable profit. The profits of most of ALCCT are low due to raw materials availability, less skilled labour requirement and easily constructability. Most companies that are produce construction materials technologies that consider high profit margin.

Poor promotion: - according to the respondent's poor promotion of ALCCT is ranked in the fifth stage by mean score 6.45. Promotion is play an important role in addressing of the information about construction technologies quality, cost, availability and durability of the technologies, and use provide method and technique how to apply in building sectors.

Table 4.23 promotion on ALCCT

	frequency	percent	cumulative percent
Very high	0	0	0
high	0	0	0
moderate	14	16.09	16.09
low	31	35.63	51.72
Very low	42	48.28	100

Promotion on particular construction technology is very important in announcing the technology to the customer/user. Regarding to table 4.23, majority respondents (48.28%) agree that promotion on the uses and application of ALCCT is very low. Other 35.63% of the respondent agree that there the promotion is low. The remaining 16.09% of the respondent inform the promotion is moderate.

Table 4.24 information availability

	frequency	percent	cumulative percent
Very high	0	0	0
high	4	4.60	4.60
low	22	25.29	29.89
Very low	61	70.11	100

According to table 4.24, majority of respondents (70.11%) of the respondents agree information availability is very low to enable decision making for optimal integration of alternative low cost technologies based on building performance requirement. Remaining 25.29% and 4.6% of the respondent describe the information availability is low and high respectively.

Lack of guidelines, standards and manuals: - regarding to table 4.21 majority of the respondents ranked lack of guidelines, standards and manuals in the sixth stage by mean score 6.2. In the county, there are no sufficient and abundant guidelines, standards and manuals to use and apply low cost construction technologies. Most of guidelines, standards and manuals that use in Ethiopia are emphasize and describe the project site safety aspects conventional technologies method, standard and techniques for applicability in the construction.

Lack of local code and regulation: - local code and regulation are very important to design building by using different types of construction materials technologies. To analyze materials technologies their load carrying capacity locally recognized code and regulation should be requiring. Table 4.21 show that, most the respondent ranked Lack of local code and regulation in the seventh stage by mean score 6.16.

Lack of willingness to apply the concept: - table 4.21 show that, majority of the respondents ranked Lack of willingness to apply the concept in eighth stage by mean score 5.1. Willingness to accept the concept of ALCCT use to apply technologies in construction industries, and play important role to diffuse and address the information to the user as well as other stakeholders those are directly and indirectly involve in the construction sectors.

Low customer acceptance: - supply and demand in construction industry must balance unless other ways there is no positive correlation between cost and construction technologies improvement in reasonable intervals. The demand of construction technologies high, the supply is low the cost of technologies increases and the demand is low the supply is high the cost of construction technologies is low. In the same manner the acceptance of ALCCT is low by customer/user the cost of construction technologies is low and the profit margin of the producer is low. Table 4.21 show that, majority of respondents ranked Low customer acceptance in the ninth stage by mean score 5.09.

Rejection of concept and idea in principle: -according to the respondents in the above table 4.21 Rejection of concept and idea in principle ranked in tenth stage by mean score 5. Idea and concept are the first accept by relevant governmental and non- governmental sectors is the first stage to innovate and develop ALCCT. In this stage, different types of scenario initiated for the future acts. Concept and idea refuse in this stage the proceeding acts cannot go on in the future.

High initial cost of innovation of technologies: - the cost to innovate construction technologies depend on the complexity of method and techniques, raw materials requirement and effort require from conceptual stage up to product. The effort, technique and method are easy, and raw materials use for input easily available and the cost are reasonable, the cost of innovation reasonable. According to the respondents High initial cost of innovation of technologies ranked in eleventh stage by mean score 4.8.

Poor quality assurance and aesthetic value of technologies: - quality aspect of construction materials technologies no compromise in the construction sectors. The quality of construction industry depends on materials technologies quality. Table 4.21 show that, most of respondents ranked Poor quality assurance and aesthetic value of technologies in the twelfth stage by mean score 4.68.

4.9. Possible Solutions to Integrate, Adapt, Innovate and Improve Alternative Low Cost Materials Technologies in Building Sectors

Different barriers that have impact to integrate, adapt, innovate and improve alternative low cost technologies in building sector were discuss in the above discussion. To solve those challenges remedy measures should be required. According to the respondents the following possible solution are proposed: -

- Integration/combination,
- Providing locally recognized code and standard,
- Continuous Governmental support,

- Create awareness among the stakeholders,
- Providing sample model/prototype,
- Comprise alternative construction materials technologies in the design,
- sharing experience from the countries that have experience on/in alternative low cost technologies,

Integration/combination:- by integrating alternative low cost technologies with conventional technologies, we can easily adopt the technologies in building sector. Different components of building (like wall, roof, floor, frame structure and ceiling) can construct by combining both alternative low cost and conventional material technologies. According to figure 4.25 by integrating alternative low cost with conventional technologies, the cost of building decrease by 13.14% and project completion date reduced by 20.53% respectively.

Providing local recognized code and standard: - to apply ALCCL in building sector there should be have locally recognized code and standards. After innovating alternative low cost technologies, the innovated technology should be complying with locally recognized code. Even if there is no locally, recognized code and standard the technologies must be integrate to the international code and standards. In addition to this, the technologies may not comply with the current international and local code and standards new code and standards should be conduct. Unless, alternative low cost technologies not apply in the building sectors.

Continuous Governmental support: - the government should be support to innovate, develop and integrate alternative low cost technologies in building sector. Most of the researchers face financial shortage during the time of conducting researches. The government should support the researchers ideally and financially. After the end of research result output and alternative low cost technologies innovated the government play important role to promote the technologies to address in to the users/customers.

Create awareness among the stakeholders: - Stakeholders are not aware of the whole range of low cost alternative building technologies and doubt their mental capacities to use them. Stakeholders those have knowledge and little understanding on alternative low cost alternative building technologies must contribute their knowledge to other. Governmental sectors and Private sectors those are interested in low-cost alternative building technologies should create awareness among other stakeholders to adopt the technologies.

Providing sample model/prototype: -to increase the acceptance of alternative low cost technologies by customer exemplary low cost building sample mode/ prototype should be constructing. The prototype create figurative image to the customers and new construction suppliers and producers. During model preparation different type of design approach will conducted. This is one of the methods to promote and integrate alternative low cost technologies in building sectors.

Comprise alternative construction materials technologies in the design: - to initiate technologies into the customers, the designers should include low cost technologies in the design. This situation plays irreplaceable result to promote alternative low cost technologies to the users.

Experience sharing: - some countries have experience on alternative low cost technologies in the building sector. The government of Ethiopia can share their experience to transfer these technologies.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

In chapter four, the results show that the existing alternative low-cost building technologies should be encouraged. In this study, alternate construction materials technologies were study and the potential of these materials to use as alternative building materials technologies brought out. Depending on the availability of the materials particularly in the city, these materials selected and should apply in building sectors. There should have been attempts at local levels to make use of agro-stone, bamboo, cement stabilized compressed earth block, remedy compressed earth block, natural fibers like bagasse and straw bale in building sector, but to use those technologies there lacks scientific precisions and proper techniques to be used precisely.

From the analysis, the study concludes that: -

Alternative low cost materials technologies improve cost-efficient building construction. By integrating conventional construction technologies with alternative low cost material technology like compressed stabilized earth block or hydro form, agro stone and likes have significant role in reduction the cost of building project. Alternative low cost technologies are cost efficient for low-rise building. Cost of alternative low cost construction technologies minimum to compere conventional building technologies. Their cost reduced by 13.14% to conventional building technologies. The cost reduces due to raw materials availabilities and easy production process.

By using alternative low cost building technologies, the project duration can be reducing. by integrating alternative low cost with conventional technologies, the cost of building project completion date reduced by 20.53% .The main reasons to reduce the total estimated duration are external plastering and painting not require for stabilize compressed earth block due to its esthetics appearance, and instead of HCB for internal wall agro-stone panel are used. The time required constructing agro- stone panel less than the time require constructing HCB wall.

Due to the weight of cement stabilized compressed earth block and compressed remedy earth block cannot use in high-rise building. Bamboos technologies, agro-stone panel and bagasse panel can use for high-rise building, because their weight is light than other. Most of alternative low cost technologies have low moisture resistance capacity; it not recommended using these technologies in moist area without moisture protection.

Alternative low cost technologies are sustainable in the building sector because the raw materials are locally available, the cost are reasonable, environmentally friendly (carbon dioxide emission is less). Application of bamboo in building sector extremely minimized wood consumption in the use of wood roof has negative effects on the environment, by using locally available bamboo materials can create positive environment. Alternative low cost construction technologies production processes consume less amount of energy compare from energy consume by conventional materials technologies production process.

Building design must consider all the design aspect, regulations and standard to provide the required function, service and expected economic life. In Ethiopian regulation, standards and code of building do not any give recognition of alternative low cost materials technologies. The code and standards of the country explain design consideration of building using conventional materials technologies. This facto greatly influence the adoption of alternative low cost materials technologies in building sector, and lack of governmental support and lack of awareness of stakeholder about alternative low cost technologies put its effect on adaption of these building materials technologies.

In General, alternative low cost building technologies are effective and efficient in building by combining to conventional building technologies.

5.2. Recommendations

The study recommend mainly for the stakeholder that directly involve in the building project and also governmental, non-governmental organization and designers those participate in the building design.

- All stakeholders should contribute the effort to adapt, innovate and improve alternative low cost materials technologies in the building sector.
- In order to be more effective, the adopted standards and specifications for these alternative building technologies have to be complemented by corresponding adjustments in building codes and regulations, tendering and contractual documents, and codes of practice.
- Ethiopian Governments must be the enabler in building cost reduction by subsidizing tax, zero rating or reducing tax for alternative building materials. Reducing materials costs and enticing local production would culminate in increased usage of ALCCTs, for both public and private stakeholders' participation that would eventually bring cost of housing delivery.
- The concerned stakeholder should sensitizing and education of the public through open forums, printed brochures, show houses, physical demonstrations of construction speeds, active public participation and other promotion methods.
- Suppliers, professionals and developers in the housing sectors hold and adopt alternative low cost building technologies to lead from the front.
- In the building design Consideration the designer should be consider basic design aspect about alternatives low cost materials technologies

5.3. Further research

There are needs for further research. This will help identify the many application and contributions of alternative low cost materials technologies in building sectors. similar research will be conducted at all level to analyze all the contributions of alternative low cost materials technologies in cost, time reduction as well as sustainable in the sector, and critical problems to adopt in construction projects. In addition to that, construction industry stakeholders were informing of the findings of this study in order for them to take an initiative to address these issues. The areas include:

i. Impacts of alternative low cost materials technologies in the construction industry as a whole in Ethiopia.
ii. Structural integrity of alternative low cost materials technologies with conventional technologies
iii. Ways to improve or promote alternative low cost materials technologies in building sectors.
iv. Construction techniques and approaches alternative materials technologies in building projects

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Appendix A

Performa questionnaires

Introduction

Dear sir/Madam

I am currently undertaking a Master of Science degree in construction Technology and management at Addis Ababa science and Technology University.

The objective of this preform questionaries' to assess efficiency and application of alternative low cost material technologies in building projects in the case of Addis Ababa. This title submitted for partial fulfillment of MSc degree in construction technology and management. The respondents asked to prepare themselves on the Performa questionaries' and to give their accurate information on both conventional and alternative material technologies, because the final result of this thesis will determined by information that you give to the researcher.

Profile of the respondents

1. Name ____________________________phone No_____________________
2. Organization/company ________________________
3. Job position ________________________________
4. Experience _________________________________
5. Educational statuses _________________________
6. Educational background_______________________

Addresses of the researcher

Email--------kfka20kefyalew@gmail.com

Phone ------------0912900752

Part one

For the following questions, the respondents ask to fill or thick their answer according to the intention of the questions.

1. Is there any budget allocation to innovate and develop low cost construction technology in your company?

   Yes ☐ No ☐

   If your answer is ‘’yes’’ how match money allocated in each budget year or average budget per year______________________________

   If your answer is ‘’No’’, why? ____

   ____

2. Do you agree the government of Ethiopia give attention on alternative low cost construction technologies innovation, improvement and adoption in the building sector?

   Strongly agree ☐ agree ☐ disagree ☐ strongly disagree ☐

3. In what degree the promotion did on the use and application of alternative low cost construction technologies in the building sector?

   Very high ☐ high ☐ moderate ☐ low ☐ very low ☐

4. In what degree the information's are available to enable decision making for optimal integration of alternative low cost technologies based on building performance requirement

   Very High ☐ high ☐ low ☐ very low ☐

5. Would you mind low cost building construction technologies are new for Ethiopia?

   Yes ☐ No ☐

6. Do you think most of people live in Addis Ababa city can construct new building or modify their home easily by using conventional building technologies (concrete, reinforcement, HCB)

   Yes ☐ No ☐

7. Which building construction technology have high environmental, social and economic negative impact

   Conventional building technologies ☐

   Alternative low cost building technologies ☐

Why ____?

8. Is there any institution that supplies low cost building technologies in the city?

   Yes ☐ No ☐

   If your answer is ''yes'' list, the name of the institutions and the technologies______________________________

9. Do you have any information a building that constructed by using low cost construction technologies in the city?

   Yes ☐ No ☐

   Where, and what types of building technologies?

   ____

10. Do you agree the maintenance costs of alternative low cost building material technologies are reasonable?

    Strongly agree ☐ agree ☐ disagree ☐ strongly disagree ☐

11. Are you thinking low cost construction technologies production process can reduce the amount of energy consumption that used to produce the technologies in the production site?

Yes ☐ No ☐

12. Do you think low cost construction technologies are reusable and recyclable after their service life cycle?

Yes ☐ no ☐

13. Please list the application of alternative low cost construction technologies in building sector.

_______________ _________________________

____________________ _________________________

14. would you mind your construction company is familiar with alternative low cost building technologies

Yes ☐ no ☐

If your answer is "yes", which types of alternative low cost construction technologies

____?

If your answer is "No", why it's not? _____________________

15. Do you think alternative low cost building construction technologies are sustainable in the sector?

Yes ☐ no ☐

If your answer yes, how_______________

If your answer is no, why_______________

16. Please list possible solution to adopt, innovate and develop alternative low cost Materials technologies in building sector.

____

____

____

____

In the following table different type of barriers are listed. The respondents asked to Rank the Barriers in terms of their priority that impact on alternative low cost building material technologies adaptation, innovation and development in building sectors.

S. No.	Barriers	Rank
1	Luck of Local Code and Regulation	
2	Poor Quality assurance and aesthetic value of materials	
3	*Poor promotion of the technologies*	
4	Lack of Guideline, Standards and manuals	
5	Limitation of Finance or budget	
6	Poor Innovation diffusion	
7	Low Customer Acceptance	
8	Lack of government support and recognition	
9	Low profitability	
10	Rejection of concept and Acceptance of idea in principle	
11	Luck of Willingness to apply the concept	
12	high initial cost of innovative technologies	

In the following table different types of alternative low cost building construction technologies are listed in the first column and there constraints in the second column please tick ✓ mark in the given score based on the degree of contribution for the given constraints.1 = very low, 2 = low, 3 = moderate, 4 = high, 5 = very high.

Alternative material technologies	Constraints	Score				
		1	2	3	4	5
Stabilized compress earth block	earth quake resistant					
	Mortar consumption					
	sound insulation					
	Water-resistance					
	thermal insulation					
Bamboo technologies (panel, post, Frame)	architectural aesthetics					
	earthquake resistant					
	vulnerability to fungus and termite attacks					
	Availability raw materials					
Remedy earth block	Thermal insulation					
	Water resistance					
	Earthquake resistance					
	labour and raw materials cost					

Bagasse panel technologies	Fire resistance					
	Compressive strength					
	Moisture resistance					
	Availability of raw materials					
Straw bale technologies	load-bearing capacity					
	Cost of construction					
	Maintenance cost					
	Moisture resistance					
	sound and thermal insulation					
	fire resistance					
Agro-stone technologies	fire resistance					
	Simplicity of panel to assemble					
	moisture resistance					
	Durability					
	sound and thermal insulation					

Part two

In the following table, different types of conventional and alternative low cost building construction technologies are listed. The purpose is to collect the cost of building materials from different construction company to assess cost comparison between conventional and low cost material technologies. The company asked to fill the exact cost of the given materials in which the materials listed in the table.

1. Conventional and Alternative low cost foundation material technologies

Conventional foundation material technologies	unit	Cost/ unit	Alternative low cost foundation material technologies	unit	Cost/ unit		In %
Reinforced cement concrete	M^3		stone	M^3			
			Fired brick	M^2 / M^3			

2. Conventional and Alternative low cost Wall material technologies

Conventional Wall material technologies			Alternative low cost wall material technologies				
HCB(class A)20cm	M^2		Agro-stone	M^2			
HCB(class B)20cm	M^2		Chika wall with all wood work /እንጨት በጭቃ ግድግዳ /	M^2			
HCB(class C) 20cm	M^2		Bamboo sheet/panel	M^2			
250mm. thick Double Brick Wall	M^2		Stabilized compress earth block	M^2			
120mm. thick Brick Wall	M^2		Asbestos wall with all wood work	M^2			
Timber panel	M^2		compress earth block	M^2			
Metal sheet							

glass	M^2		stone	M^3			
40 cm. thick Dressed Stone Masonry Wall One Side well dressed & the other plastered	M^2		Hydro-form	M^2			
Timber wall with all wood work	M^2						
Chip wood wall with all wood work	M^2						
Plywood wall with all wood work	M^2						
MDF wall with all wood work	M^2						

3. Conventional and Alternative low cost beam and column material technologies

Conventional beam and column material technologies			Alternative low cost beam and column material technologies				
Wood/timber			stone	M^3			
Reinforced cement concrete	M^3		bamboo				
metal			Fired brick	M^3			

4. Conventional and Alternative low cost slab material technologies

Conventional slab			Alternative low				

material technologies			cost slab material technologies				
Reinforced cement concrete	M^3		Stabilized compress earth block	M^2/ M^3			
C-25 Concrete Slab 6 cm. thick Ribbed slab (Mech. Mix) 1:2:3	M^3		bamboo panel	M^2			
Metal sheet							
Wood panel							

5. Conventional and Alternative low cost truss material technologies

Conventional truss material technologies			Alternative low cost truss material technologies				
steel			bamboo				
timber							

6. Conventional and Alternative low cost roof material technologies

Conventional roof material technologies			Alternative low cost roof material technologies				
Galvanized EGA 300 roof cover (0.30 mm thick)	M^2		Corrugated bamboo sheet				
Reinforced cement concrete	M^2		Asbestos roof cover	M^2			
glass	M^2		Straw bale(Grass roof cover)	M^2			
G28 C I S Roofing (	M^2						

Without Truss & Purlin)							
Sheet metal roof cover	M^2						

7. Conventional and Alternative low cost door and window frames and panels material technologies

Conventional door and window frames and panels material technologies			Alternative low cost door and window frames and panels material technologies				
timber			timber				
Metal/steel			bamboo				
Reinforced cement concrete			Agro stone frame and door and window				
Composite							
glass							
plastic							

8. conventional and Alternative low cost plastering materials technologies

FINISHING WORKS							
conventional plastering materials technologies			Alternative low cost plastering materials technologies				
3 Coats of cement plastering (1:3) (To internal wall and external wall)	M^2		Non erodible mud plaster				

Final Coat of Gypsum plastering external Vertical wall and Exposed column and beam	M^2						

9. conventional and Alternative low cost flooring materials technologies

conventional flooring materials technologies			Alternative low cost flooring materials technologies				
2mm. thick PVC flooring	M^2		Stabilized earth	M^2			
5cm. Thick cement screed flooring (without glass).	M^2		bamboo	M^2			
Ceramic tile flooring 10mm thick	M^2		Fired brick	M^2			
Ceramic tile flooring 6mm thick	M^2						
Terrazzo tile flooring (1:3) 30mm thick	M^2						
Terrazzo tile flooring (1:3) 20mm thick Marble Chips Flooring.	M^2						
10mm thick polished Granite flooring	M^2						
20mm Wood flooring	M^2						
2cm thick Marble	M^2						

flooring (1:3).							
3cm thick Marble flooring (1:3).	M^2						
10. conventional and Alternative low cost Ceiling materials technologies							
conventional Ceiling materials technologies			Alternative low cost Ceiling materials technologies				
Timber ceiling	M^2		Abujedy ceiling	M^2			
Purlin ceiling	M^2		Rush ceiling	M^2			
Plywood ceiling	M^2		Ceiling made with plastic sack	M^2			
8mm. Thick chip wood Ceiling.	M^2		Ceiling made with sack	M^2			
PVC ceiling	M^2		Bamboo sheet	M^2			

11. conventional and Alternative low cost truss & purlin materials technologies

conventional			Alternative low cost				
10-12 cm. dia. Upper & Lower Chords Eucalyptus Wood.	ml		bamboo	ml			
8-10 cm. dia. Vertical & Diagonal member eucalyptus Wood.	ml						
Diam. 6 cm thick	ml						

eucalyptus purlin							
50 X 70mm. Tid Wood Roof Purlin	ml						

12. conventional and Alternative low cost Doors and window materials technologies

Mahogany ply wood smooth finish flush wooden door Woyra ply wood smooth finish flush wooden door	m^2		Bamboo panel door and window	m^2			
Smooth MDF board made imported wooden door	m^2		Agro-stone door and window	m^2			
Antique MDF board wooden door (best quality)	m^2						
Solid wooden door (best quality)	m^2						
1cm thick timber door	m^2						
3cm thick timber door	m^2						
1cm thick timber window	m^2						
3cm thick timber window	m^2						
3cm thick timber window with glass	m^2						
G-32 CIS door with all wood work	m^2						
G-32 CIS window	m^2						

with all wood work							
Timber /Tsid/ door	m^2						
Timber /Tsid/ window	m^2						

APENDIX B

Collected data

1. Cost of Conventional and Alternative low cost foundation material technologies

   NB 1 USD = 29.2 ETB (Ethiopian birr)

Conventional foundation material technologies	unit	Cost/unit	Alternative low cost foundation material technologies	unit	Cost/unit

Reinforced cement concrete	M3	89.38	stone	M^3	56.03
Fired brick	M^3	25.59	Fired brick	M3	25.59

Table B1

2. Conventional and Alternative low cost Wall material technologies					
Conventional Wall material technologies	unit	cost/unit	Alternative low cost wall material technologies	unit	cost/unit
HCB(class A)20cm	M^2	17.20	Agro-stone	M^2	8.53
HCB(class B)20cm	M^2	16.56	Chika wall with all wood work	M^2	15.23
HCB(class C) 20cm	M^2	12.49	Bamboo sheet/panel	M^2	
250mm .thick Double Brick Wall	M^2	1447.25	Stabilized compress earth block	M^2	
120mm .thick Brick Wall	M^2	25.59	Asbestos wall with all wood work	M^2	13.30
Timber panel	M^2	15.42	compress earth block	M^2	
Metal sheet		31.52			
glass	M^2	28.10	stone	M^3	56.03
Chip wood wall with all wood work	M^2	7.20	Hydro-form	M^2	10.61

Plywood wall with all wood work	M^2	6.56	40 cm. thick Dressed Stone Masonry Wall one Side well dressed & the other plastered	M^2	50.92
MDF wall with all wood work	M^2	151.31	Timber wall with all wood work	M^2	13.96

Table B2

3. Conventional and Alternative low cost beam and column material technologies					
Conventional beam and column material technologies	unit	cost/unit	Alternative low cost beam and column material technologies	cost	cost/unit
Wood/timber			stone	M^3	56.03
Reinforced cement concrete	M^3	89.38	bamboo		
metal			Fired brick	M^3	3.07

Table B3

4. Conventional and Alternative low cost slab material technologies					
Conventional slab material technologies	unit	cost/unit	Alternative low cost slab material technologies	unit	cost/unit

Reinforced cement concrete	M^3	89.38	Stabilized compress earth block		
C-25 Concrete Slab 6 cm. thick Ribbed slab (Mech. Mix) 1:2:3	M^3	16.50	bamboo panel		
Metal sheet					
Wood panel					

Table B4

5. Conventional and Alternative low cost truss material technologies					
Conventional truss material technologies	unit	cost	Alternative low cost truss material technologies	unit	cost
10-12 cm. dia. Upper & Lower Chords Eucalyptus Wood.	mI	47.86	10-12 cm. dia. Upper & Lower Chords Eucaliptus bamboo.	mI	42.92
RHS 60*40*2.5	mI	206.8	Diam. 4-6 cm thick bamboo purlin	mI	36.67
RHS 50*30*2.5	mI	162			
RHS 40*20*2.5	mI	116.6			
RHS 30*20*2.5	mI	94.2			
Diam. 4-6 cm thick eucalyptus purlin	mI	27.62			

Table B5

6. Conventional and Alternative low cost roof material technologies					
Conventional roof material technologies	cost	cost/unit	Alternative low cost roof material	cost	cost/unit

			technologies		
Galvanized EGA 300 roof cover (0.30 mm thick)	M^2	9.81	Corrugated bamboo sheet		
Reinforced cement concrete	M^2	89.38	Asbestos roof cover	M^2	13.77
G28 C I S Roofing (Without Truss & Purlin)	M^2	10.33	Straw bale(Grass roof cover)	M^2	6.38
Sheet metal roof cover	M^2	19.65			

Table B6

7. conventional and Alternative low cost plastering materials technologies					
conventional plastering materials technologies	cost	cost/unit	Alternative low cost plastering materials technologies	unit	cost/unit
3 Coats of cement plastering (1:3) (To internal wall and external wall)	M^2	6.02	Non erodible mud plaster	M^2	15.2
Final Coat of Gypsum plastering external Vertical wall and Exposed column and beam	M^2	1.58	Lime plaster	M^2	32.45

Table B7

8. conventional and Alternative low cost flooring materials technologies					
conventional flooring materials technologies	unit	cost/unit	Alternative low cost	unit	cost/unit

			flooring materials technologies		
2mm. thick PVC flooring.	M^2	11.79	Stabilized earth	M^2	
5cm. Thick cement screed flooring (without glass).	M^2	6.11	bamboo	M^2	
Ceramic tile flooring 10mm thick	M^2	25.71	Fired brick	M^2	
Ceramic tile flooring 6mm thick	M^2	15.90			
Terrazzo tile flooring(1:3) 30mm thick	M^2	21.58			
Terrazzo tile flooring(1:3) 20mm thick	M^2	23.50			
Marble Chips Flooring.		7.09			
10mm thick polished Granite flooring	M^2	997.98			
20mm Wood flooring	M^2	639.50			
2cm thick Marble flooring (1:3).	M^2	1218.11			
3cm thick Marble flooring (1:3).	M^2	1486.18			

Table B8

9. conventional and Alternative low cost *Ceiling* materials technologies					
conventional *Ceiling* materials technologies	unit	cost/unit	**Alternative low cost Ceiling**	unit	cost/unit

			materials technologies		
Timber ceiling	M^2	17.07	Abujedy ceiling	M^2	11.10
Purlin ceiling/	M^2	15.47	Rush ceiling	M^2	10.87
Plywood ceiling /Compersato/	M^2	13.38	Ceiling made with plastic sack	M^2	10.63
8mm. Thick chip wood Ceiling.	M^2	16.95	Ceiling made with sack	M^2	10.89
PVC ceiling	M2	18.55			

Table B9

10. conventional and Alternative low cost truss & purlin materials technologies					
conventional truss and purlin	unit	cost/unit	Alternative low cost	unit	cost/unit
10-12 cm. dia. Upper & Lower Chords Eucalyptus Wood.	ml	1.64	10-12 cm. dia. Upper & Lower Chords bamboo.		
8-10 cm. dia. Vertical & Diagonal member eucalyptus Wood.	ml	1.51	8-10 cm. dia. Vertical & Diagonal member bamboo.		
Diam. 6 cm thick eucalyptus purlin	ml	0.95			

50 X 70mm. Tid Wood Roof Purlin	ml	2.47			

Table B10

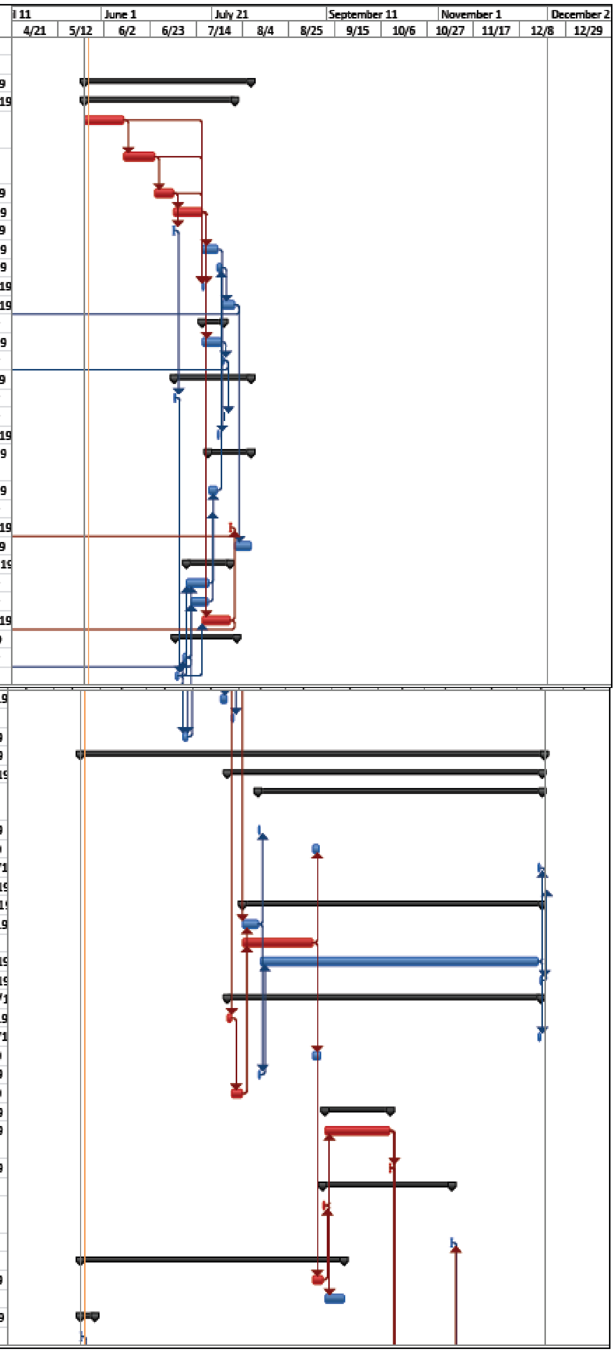
11. conventional and Alternative low cost Doors and window materials technologies					
conventional door and window	cost	cost/unit	alternative low cost door and window	unit	cost/unit
Mahogany ply wood smooth finish flush wooden door	m^2	115.404656	Bamboo panel door and window		
Antique MDF board wooden door (best quality)	m^2	171.087984			
Solid wooden door (best quality)	m^2	346.502568			
1cm thick timber door	m^2	33.3765834			
3cm thick timber door	m^2	1243.7			
1cm thick timber window	m^2	23.1311195			
3cm thick timber window	m^2	32.2529955			
3cm thick timber window with glass	m^2	53.564875			
G-32 CIS door with all wood work	m^2	36.826087			
G-32 CIS window with all wood work	m^2	34.0896953			
Timber /Tsid/ door	m^2	51.0314961			
Timber /Tsid/ window	m^2	38.2728518			

Table B11

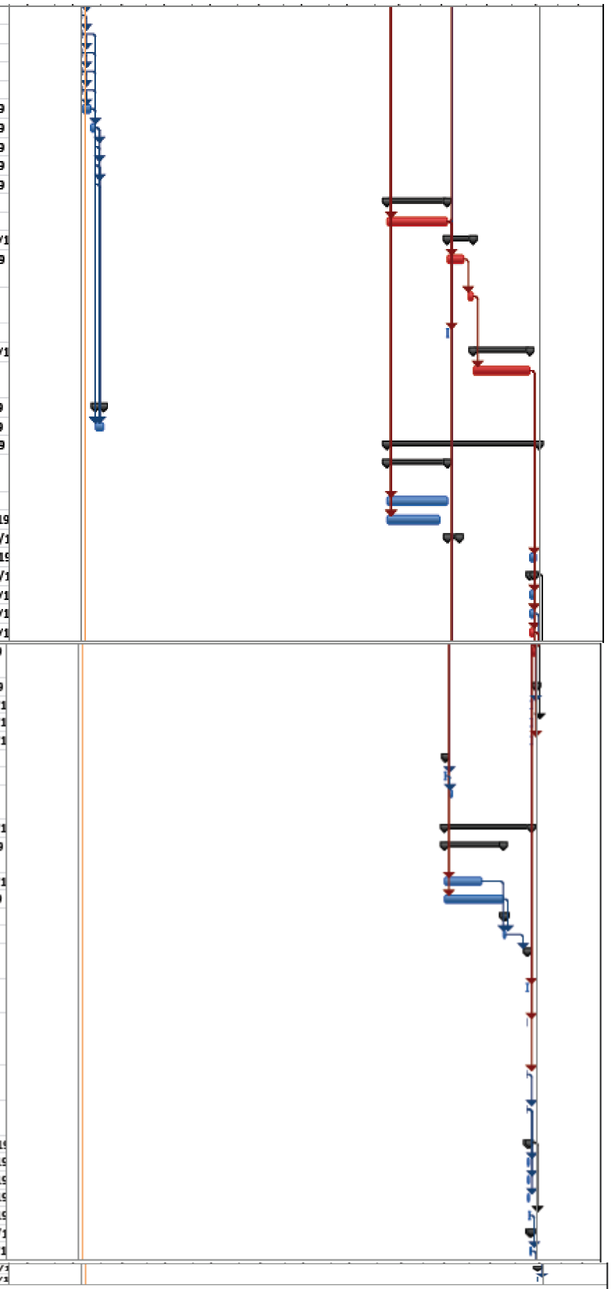
Appendix C

Duration estimation using professional MS project

ID	Task Name	Duration	Start	Finish
1	PROJECT- RESIDENCE BUILDING			
2	DESCRIPTION			
3	A. Sub-Structure	54 days	Fri 5/24/19	Wed 8/7/19
4	1. Excavation & Earth Work	48.6 days	Fri 5/24/19	Wed 7/31/19
5	Clear of the site to remove top soil to an average depth of 20 cm	12 days	Fri 5/24/19	Mon 6/10/19
6	Excavate in bulk to an average depth not exceeding 75cm	10 days	Tue 6/11/19	Mon 6/24/19
7	Excavate for isolated footings in ordinary soil	6.8 days	Tue 6/25/19	Wed 7/3/19
8	Trench excavation for foundation	9.1 days	Wed 7/3/19	Tue 7/16/19
9	Backfill around footings with selected soil	0.2 days	Wed 7/3/19	Wed 7/3/19
10	Ditto around masonry	5 days	Tue 7/16/19	Tue 7/23/19
11	Ditto under hard-core	2.7 days	Tue 7/23/19	Thu 7/25/19
12	cart away surplus excavated material and deposit	0.5 days	Tue 7/16/19	Wed 7/17/19
13	hard core 25cm thick basaltic or equivalent stone	3.8 days	Thu 7/25/19	Wed 7/31/19
14	2. Masonry Work	7.6 days	Tue 7/16/19	Fri 7/26/19
15	masonry foundation wall below NGL	6.3 days	Tue 7/16/19	Thu 7/25/19
16	masonry foundation wall above NGL	1.3 days	Thu 7/25/19	Fri 7/26/19
17	3. Concrete Work	25 days	Thu 7/4/19	Wed 8/7/19
18	5cm thick lean concrete	0.5 days	Thu 7/4/19	Thu 7/4/19
19	Ditto under grade beam	0.2 days	Fri 7/26/19	Fri 7/26/19
20	Ditto under masonary	0.3 days	Tue 7/23/19	Wed 7/24/19
21	**Concrete quality C-25 with 360kg of cement per meter cube of concrete**	**13.9 days**	Fri 7/19/19	Wed 8/7/19
22	In foundation footings pad	1.2 days	Fri 7/19/19	Tue 7/23/19
23	In foundation columns	0.1 days	Fri 7/19/19	Fri 7/19/19
24	In grade beams .	0.5 days	Mon 7/29/19	Mon 7/29/19
25	In ground floor slab	5.4 days	Wed 7/31/19	Wed 8/7/19
26	**Pformwork**	**13.7 day**	Tue 7/9/19	Mon 7/29/19
27	for footing pads	8.3 days	Tue 7/9/19	Fri 7/19/19
28	for foundation columns	5.3 days	Thu 7/11/19	Fri 7/19/19
29	In grade beams .	8.4 days	Tue 7/16/19	Mon 7/29/19
30	**Steel reinforcements**	**20.1 day**	Thu 7/4/19	Thu 8/1/19
31	16mm deformed bars	1.6 days	Mon 7/8/19	Tue 7/9/19
32	14mm deformed bars	1.5 days	Thu 7/4/19	Fri 7/5/19
33	12mm deformed bars	0.9 days	Fri 7/26/19	Mon 7/29/19
34	10mm deformed bars	1 day	Wed 7/31/19	Thu 8/1/19
35	8mm deformed bars	2.2 days	Tue 7/9/19	Thu 7/11/19
36	B. Super Structure	150.93 d	Fri 5/24/19	Fri 12/20/19
37	4. Concrete Work	103.1 day	Mon 7/29/19	Thu 12/19/19
38	**Concrete quality C-25, with 360kg of cement per meter cube of concrete**	**93.1 days**	Mon 8/12/19	Thu 12/19/19
39	In elevation columns	0.5 days	Mon 8/12/19	Tue 8/13/19
40	intermidate and Top tie beam	0.8 days	Fri 9/6/19	Mon 9/9/19
41	In 15cm thick solid slab and Roof slab	1 day	Tue 12/17/19	Wed 12/18/1
42	In stair case	0.2 days	Thu 12/19/19	Thu 12/19/19
43	**formwork**	**98.2 day**	Mon 8/5/19	Thu 12/19/1
44	In elevation columns	5.3 days	Mon 8/5/19	Mon 8/12/19
45	In beams and lintels	23.8 days	Mon 8/5/19	Fri 9/6/19
46	In 15cm thick suspended filer slab	90 days	Tue 8/13/19	Tue 12/17/19
47	In stair case	0.8 days	Wed 12/18/19	Thu 12/19/19
48	**Steel reinforcements**	**102.2 da**	Mon 7/29/19	Wed 12/18/1
49	16mm deformed bars	2 days	Mon 7/29/19	Wed 7/31/19
50	14mm deformed bars	1.1 days	Tue 12/17/19	Wed 12/18/1
51	12mm deformed bars	1.7 days	Fri 9/6/19	Mon 9/9/19
52	10mm deformed bars	1.1 days	Mon 8/12/19	Tue 8/13/19
53	8mm deformed bars	2.7 days	Wed 7/31/19	Mon 8/5/19
54	5. Block work	21.8 days	Thu 9/12/19	Fri 10/11/19
55	20cm thick Stabilized compress earth block for external wall	21.1 days	Thu 9/12/19	Fri 10/11/19
56	Ditto 10cm Agro-stone wall	0.7 days	Fri 10/11/19	Fri 10/11/19
57	6. Roofing	42.9 days	Wed 9/11/19	Fri 11/8/19
58	Supply and fix Straw bale(Grass roof cover) (20cm thick) on eucalyptusl truss & purlin.	1 day	Wed 9/11/19	Wed 9/11/19
59	Supply and fix Diam.10 cm PVC down pipe	0.6 days	Fri 11/8/19	Fri 11/8/19
60	7. Carpentry and Joinery	85.9 days	Fri 5/24/19	Fri 9/20/19
61	Supply and fix bamboo purlin	2.7 days	Fri 9/6/19	Tue 9/10/19
62	Supply and fix Rush ceiling	6.9 days	Thu 9/12/19	Fri 9/20/19
63	**Supply and fix flush type doors**	**4.61 day**	Fri 5/24/19	Thu 5/30/19
64	D1 size (900*2100)mm	0.2 days	Fri 5/24/19	Fri 5/24/19



65	D2 size (700*2100)cm	0.1 days	Fri 5/24/19	Fri 5/24/19
66	D3 (size=1150*2500)m	0.02 days	Fri 5/24/19	Fri 5/24/19
67	D4 (size=1220*2100)mm	0.02 days	Fri 5/24/19	Fri 5/24/19
68	W1(Size=2500*2500)mm	0.02 days	Fri 5/24/19	Fri 5/24/19
69	W2(Size=1500*1800)mm	0.05 days	Fri 5/24/19	Fri 5/24/19
70	W3(Size=180*160)mm	2.1 days	Fri 5/24/19	Tue 5/28/19
71	W4(Size=700*400)mm	1.8 days	Tue 5/28/19	Thu 5/30/19
72	W5(Size=1300*900)mm	0.1 days	Thu 5/30/19	Thu 5/30/19
73	W6(Size=1300*900)mm	0.1 days	Thu 5/30/19	Thu 5/30/19
74	W7(Size=800*600)mm	0.1 days	Thu 5/30/19	Thu 5/30/19
75	8. Plastering and Pointing	19.5 days	Fri 10/11/19	Fri 11/8/19
76	Apply 2 coats of plaster in cement-sand mortar	19.5 days	Fri 10/11/19	Fri 11/8/19
77	9. flooring	7.8 days	Fri 11/8/19	Wed 11/20/1
78	Supply 5cm. Thick cement screed flooring (without glass).	5.7 days	Fri 11/8/19	Fri 11/15/19
79	Supply and fix 10cm high ceramic tile skirting bonded by best type glue.	2.1 days	Mon 11/18/19	Wed 11/20/19
80	Supply and fix 6cm thickness ceramic window sill	0.6 days	Fri 11/8/19	Fri 11/8/19
81	*10. Painting*	18.1 days	Wed 11/20/19	Mon 12/16/1
82	Apply 3 coats of approved plastic paint to all internal plastered wall surfaces	18.1 days	Wed 11/20/19	Mon 12/16/19
83	11. Glazing	1.4 days	Thu 5/30/19	Mon 6/3/19
84	Supply and fix clear glass of 5mm thick.	1.4 days	Thu 5/30/19	Mon 6/3/19
85	12. Sanitary Installation	50.13 day	Fri 10/11/19	Fri 12/20/19
86	**Supply and install galvanized plastic pipes for cold and hot water**	19.8 days	Fri 10/11/19	Fri 11/8/19
87	f 15mm	19.8 days	Fri 10/11/19	Fri 11/8/19
88	f 20mm	16.2 days	Fri 10/11/19	Mon 11/4/19
89	**Supply and fix gate valves**	3.4 days	Fri 11/8/19	Wed 11/13/1
92	Supply and fix kitchen sink	3 days	Mon 12/16/19	Thu 12/19/19
93	**Supply and fix hand wash basins**	2 days	Mon 12/16/1	Wed 12/18/1
94	Size 500X400 mm	2 days	Mon 12/16/19	Wed 12/18/1
95	Supply and fix wash down water closets	2 days	Mon 12/16/19	Wed 12/18/1
96	Supply and fix shower tray	2 days	Mon 12/16/19	Wed 12/18/1
97	Supply and fix 60 ltr water heater complete with necessary accessories	2.7 days	Wed 12/18/19	Fri 12/20/19
98	**Supply and fix crystal glass mirror**	0.03 day	Fri 12/20/19	Fri 12/20/19
100	Supply and fix toilet paper holder	0.5 days	Wed 12/18/19	Wed 12/18/1
101	Supply and fix soap holder	0.5 days	Wed 12/18/19	Wed 12/18/1
102	Floor drain with smile trap	0.4 days	Wed 12/18/19	Wed 12/18/1
103	**Supply and fix vent caps**	0.1 days	Fri 11/8/19	Fri 11/8/19
104	f 100mm	0.1 days	Fri 11/8/19	Fri 11/8/19
105	Construct and mount 2m 3 effective capacity water tanks	1 day	Mon 11/11/19	Mon 11/11/19
106	13. Eectrical Installation	28 days	Fri 11/8/19	Wed 12/18/1
107	**Supply and install PVC sheathed power cable or wire**	19.2 days	Fri 11/8/19	Thu 12/5/19
108	3x4sq.mm	11.2 days	Fri 11/8/19	Mon 11/25/1
109	3x2.5 Sq.mm	19.2 days	Fri 11/8/19	Thu 12/5/19
110	**DISTRIBUTION BOARDS**	1 day	Thu 12/5/19	Fri 12/6/19
111	Surface/flash mounted main distribution board M	1 day	Thu 12/5/19	Fri 12/6/19
112	**Type of Light fitting or Approved Equivalent supplied,**	0.6 days	Mon 12/16/19	Mon 12/16/19
113	RZB 33705.009, Wall mounted Incandecent,60W, light fitting ,or approved	0.5 days	Mon 12/16/19	Mon 12/16/19
114	RZB 21641.002.Q WITH 1X75W STANDARD INCANDESCENT LAMP for bed rooms ,or approved equivelent	0.3 days	Mon 12/16/19	Mon 12/16/19
115	RZB 59251.002.Q + RZB 05-56150.Q ,for toilet light,	0.3 days	Mon 12/16/19	Mon 12/16/19
116	RZB 931042.002 OR EQUIVALENT for corridors and stair	0.3 days	Mon 12/16/19	Mon 12/16/19
117	**Switches: 10A, 250V light switch**	0.5 days	Mon 12/16/1	Tue 12/17/1
118	Sigle Pole,10A	0.3 days	Mon 12/16/19	Tue 12/17/19
119	Double Pole,10A	0.5 days	Mon 12/16/19	Tue 12/17/19
120	Two Way Switch	0.5 days	Mon 12/16/19	Tue 12/17/19
121	Flush mounted socket outlets	0.5 days	Tue 12/17/19	Tue 12/17/19
122	**TV System**	0.3 days	Tue 12/17/19	Wed 12/18/1
123	TV outlet:	0.3 days	Tue 12/17/19	Wed 12/18/1
124	**Earthing system**	0.2 days	Wed 12/18/1	Wed 12/18/1
125	Earthing system	0.2 days	Wed 12/18/19	Wed 12/18/1

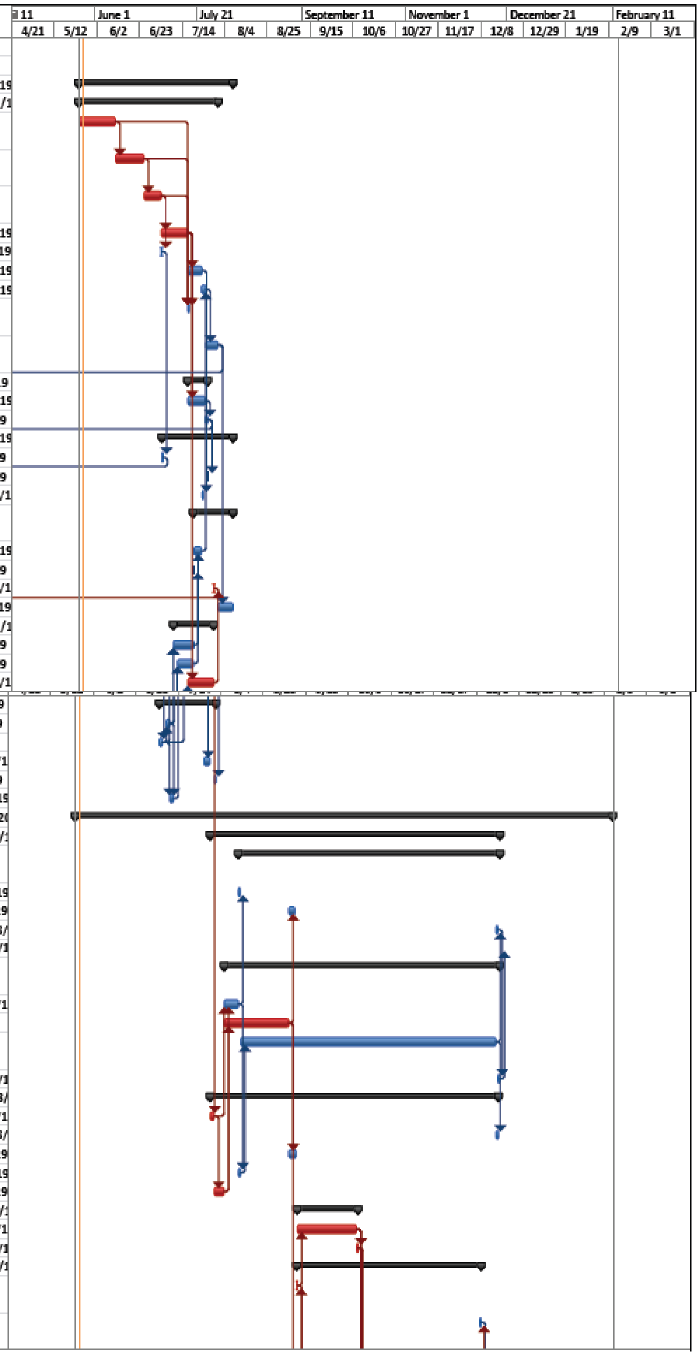


Project: Residential building11
Date: Sun 5/26/19

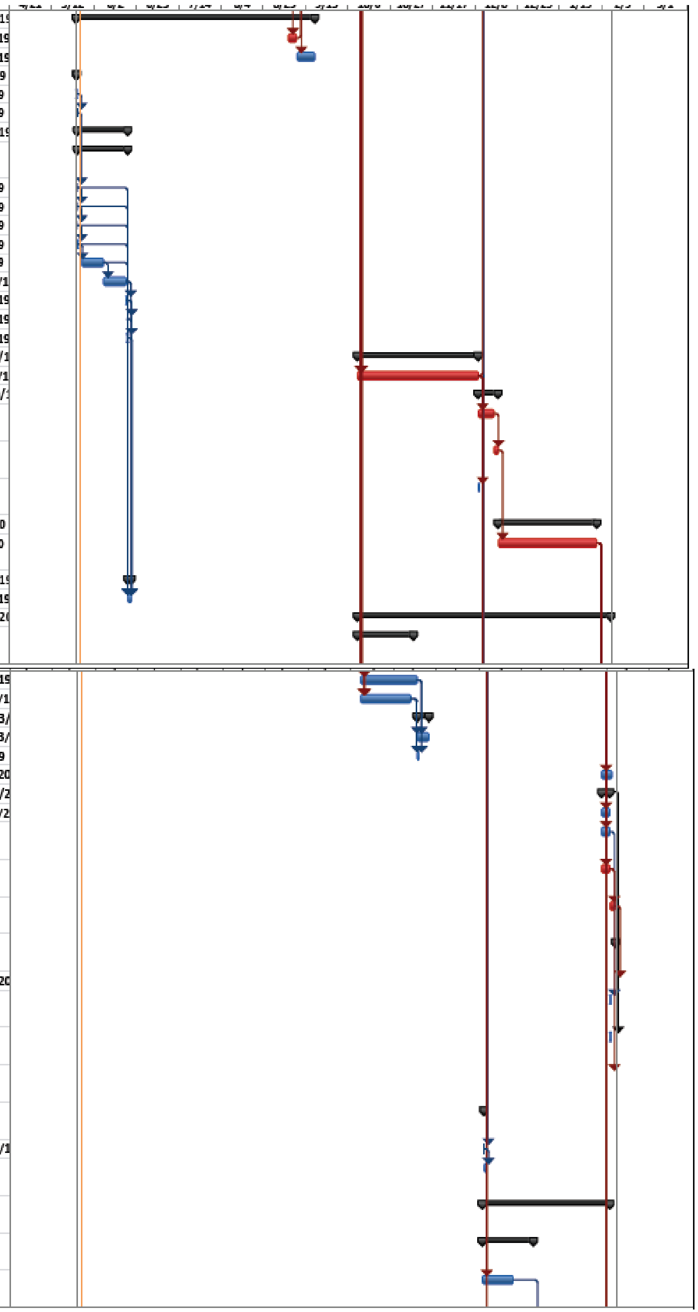
Task	External Tasks	Manual Task	Finish-only
Split	External Milestone	Duration-only	Deadline
Milestone	Inactive Task	Manual Summary Rollup	Critical
Summary	Inactive Milestone	Manual Summary	Critical Split
Project Summary	Inactive Summary	Start-only	Progress

Figure C1: time schedule for the proposed building using conventional building technologies

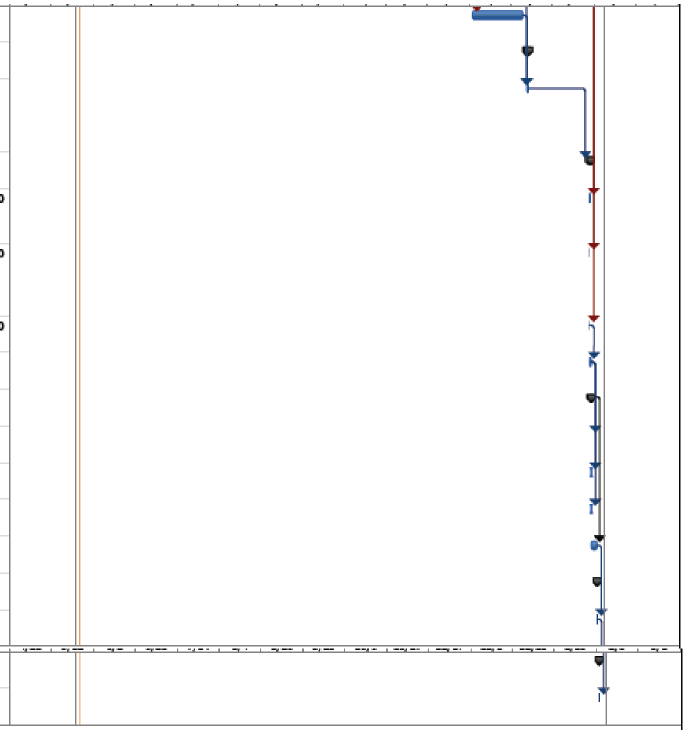
ID	Task Name	Duration	Start	Finish
1	**PROJECT- RESIDENCE BUILDING**			
2	**DESCRIPTION**			
3	**A. Sub-Structure**	54 days	Fri 5/24/19	Wed 8/7/19
4	**1. Excavation & Earth Work**	48.6 days	Fri 5/24/19	Wed 7/31/1
5	Clear of the site to remove top soil to an average depth of 20 cm	12 days	Fri 5/24/19	Mon 6/10/19
6	Excavate in bulk to an average depth not exceeding 75cm	10 days	Tue 6/11/19	Mon 6/24/19
7	Excavate for isolated footings in ordinary soil	6.8 days	Tue 6/25/19	Wed 7/3/19
8	Trench excavation for foundation	9.1 days	Wed 7/3/19	Tue 7/16/19
9	Backfill around footings with selected s	0.2 days	Wed 7/3/19	Wed 7/3/19
10	Ditto around masonry	5 days	Tue 7/16/19	Tue 7/23/19
11	Ditto under hard-core	2.7 days	Tue 7/23/19	Thu 7/25/19
12	cart away surplus excavated material and deposit	0.5 days	Tue 7/16/19	Wed 7/17/19
13	25cm thick basaltic or equivalent stone hard-core	3.8 days	Thu 7/25/19	Wed 7/31/19
14	**2. Masonry Work**	7.6 days	Tue 7/16/1!	Fri 7/26/19
15	masonry foundation wall below NGL	6.3 days	Tue 7/16/19	Thu 7/25/19
16	masonry foundation wall above NGL	1.3 days	Thu 7/25/19	Fri 7/26/19
17	**3. Concrete Work**	25 days	Thu 7/4/19	Wed 8/7/19
18	5cm thick lean concrete C-5	0.5 days	Thu 7/4/19	Thu 7/4/19
19	Ditto under grade beam	0.2 days	Fri 7/26/19	Fri 7/26/19
20	Ditto under masonary	0.3 days	Tue 7/23/19	Wed 7/24/1
21	**Concrete quality C-25 with 360kg of cement per meter cube of concrete**	13.9 days	Fri 7/19/19	Wed 8/7/19
22	In foundation footings pad	1.2 days	Fri 7/19/19	Tue 7/23/19
23	In foundation columns	0.1 days	Fri 7/19/19	Fri 7/19/19
24	In grade beams .	0.5 days	Mon 7/29/1	Mon 7/29/1
25	In ground floor slab	5.4 days	Wed 7/31/1	Wed 8/7/19
26	**formwork**	13.7 day:	Tue 7/9/19	Mon 7/29/1
27	for footing pads	8.3 days	Tue 7/9/19	Fri 7/19/19
28	for foundation columns	5.3 days	Thu 7/11/19	Fri 7/19/19
29	In grade beams .	8.4 days	Tue 7/16/19	Mon 7/29/1
30	**Steel reinforcements**	20.1 day:	Thu 7/4/19	Thu 8/1/19
31	16mm deformed bars	1.6 days	Mon 7/8/19	Tue 7/9/19
32	14mm deformed bars	1.5 days	Thu 7/4/19	Fri 7/5/19
33	12mm deformed bars	0.9 days	Fri 7/26/19	Mon 7/29/1
34	10mm deformed bars	1 day	Wed 7/31/1	Thu 8/1/19
35	8mm deformed bars	2.2 days	Tue 7/9/19	Thu 7/11/19
36	**B. Super Structure**	189.23 d:	Fri 5/24/19	Thu 2/13/20
37	**4. Concrete Work**	103.1 da	Mon 7/29/1	Thu 12/19/1
38	**Concrete quality C-25, with 360kg of cement per meter cube of concrete**	93.1 days	Mon 8/12/19	Thu 12/19/19
39	In elevation columns	0.5 days	Mon 8/12/1	Tue 8/13/19
40	intermidate and Top tie beam	0.8 days	Fri 9/6/19	Mon 9/9/19
41	In 15cm thick solid slab	1 day	Tue 12/17/1	Wed 12/18/
42	In stair case	0.2 days	Thu 12/19/1	Thu 12/19/1
43	**Provide, cut and fix in position sawn zigba formwork or equivalent**	98.2 days	Mon 8/5/19	Thu 12/19/19
44	In elevation columns	5.3 days	Mon 8/5/19	Mon 8/12/1
45	In beams and lintels	23.8 days	Mon 8/5/19	Fri 9/6/19
46	In 15cm thick suspended solid slab and Roof slab	90 days	Tue 8/13/19	Tue 12/17/19
47	In stair case	0.8 days	Wed 12/18/	Thu 12/19/1
48	**Steel reinforcements**	102.2 da	Mon 7/29/1	Wed 12/18/
49	16mm deformed bars	2 days	Mon 7/29/1	Wed 7/31/1
50	14mm deformed bars	1.1 days	Tue 12/17/1	Wed 12/18/
51	12mm deformed bars	1.7 days	Fri 9/6/19	Mon 9/9/19
52	10mm deformed bars	1.1 days	Mon 8/12/1	Tue 8/13/19
53	8mm deformed bars	2.7 days	Wed 7/31/1	Mon 8/5/19
54	**5. Block work**	22 days	Tue 9/10/1!	Thu 10/10/1
55	20cm thick HCB (class B) wall	21.1 days	Tue 9/10/19	Wed 10/9/1
56	Ditto 10cm HCB (class B) wall	0.9 days	Thu 10/10/1	Thu 10/10/1
57	**6. Roofing**	65.1 day:	Tue 9/10/1!	Tue 12/10/1
58	Supply and fix Galvanized EGA 300 roof cover	0.6 days	Tue 9/10/19	Tue 9/10/19
59	Supply and fix Diam.10 cm PVC down pipe	0.6 days	Mon 12/9/19	Tue 12/10/19



60	**7. Carpentry and Joinery**	**84.8 day**	Fri 5/24/19	Thu 9/19/19
61	purlin and truss	2 days	Fri 9/6/19	Tue 9/10/19
62	Supply and fix 6mm thick Plywood ceil	6.9 days	Tue 9/10/19	Thu 9/19/19
63	**Supply and fix flush type doors**	**0.5 days**	Fri 5/24/19	Fri 5/24/19
64	D1 size (900*2100)mm	0.4 days	Fri 5/24/19	Fri 5/24/19
65	D2 size (700*2100)cm	0.1 days	Fri 5/24/19	Fri 5/24/19
66	**8. metal Works**	**17.4 day**	Fri 5/24/19	Tue 6/18/19
67	**Supply and fix Partially glazed metal doors/windoow**	**17.4 days**	Fri 5/24/19	Tue 6/18/19
68	D3 (size=1150*2500)m	0.1 days	Fri 5/24/19	Fri 5/24/19
69	D4 (size=1220*2100)mm	0.1 days	Fri 5/24/19	Fri 5/24/19
70	W1(Size=2500*2500)mm	0.1 days	Fri 5/24/19	Fri 5/24/19
71	W2(Size=1500*1800)mm	0.2 days	Fri 5/24/19	Fri 5/24/19
72	W3(Size=180*160)mm	8.9 days	Mon 5/27/1	Thu 6/6/19
73	W4(Size=700*400)mm	7.1 days	Thu 6/6/19	Mon 6/17/1
74	W5(Size=1300*900)mm	0.2 days	Tue 6/18/19	Tue 6/18/19
75	W6(Size=1300*900)mm	0.2 days	Tue 6/18/19	Tue 6/18/19
76	W7(Size=800*600)mm	0.5 days	Tue 6/18/19	Tue 6/18/19
77	**9. Plastering and Pointing**	**41.9 day**	Thu 10/10/1	Mon 12/9/1
78	Apply 2 coats of plaster	41.9 days	Thu 10/10/1	Mon 12/9/1
79	**10. flooring**	**7.8 days**	Mon 12/9/1	Thu 12/19/1
80	Supply and fix 300x300x6mm approved type ceramic tile	5.7 days	Mon 12/9/19	Tue 12/17/19
81	Supply and fix 10cm high ceramic tile skirting	2.1 days	Tue 12/17/19	Thu 12/19/19
82	Supply and fix 6cm thickness ceramic window sill	0.6 days	Mon 12/9/19	Tue 12/10/19
83	***11. Painting***	**34.9 day**	Thu 12/19/1	Thu 2/6/20
84	Apply 3 coats of approved plastic paint to all internal plastered wall surfaces	34.9 days	Thu 12/19/19	Thu 2/6/20
85	**12. Glazing**	**1.4 days**	Tue 6/18/19	Thu 6/20/19
86	Supply and fix clear glass	1.4 days	Tue 6/18/19	Thu 6/20/19
87	**13. Sanitary Installation**	**89.33 da**	Thu 10/10/1	Thu 2/13/2
88	**Supply and install galvanized plastic pipes for cold and hot water**	**19.8 days**	Thu 10/10/19	Thu 11/7/19
89	f 15mm	19.8 days	Thu 10/10/1	Thu 11/7/19
90	f 20mm	16.2 days	Thu 10/10/1	Mon 11/4/1
91	**Supply and fix gate valves**	**3.4 days**	Thu 11/7/19	Wed 11/13/
92	f 15mm	3.4 days	Thu 11/7/19	Wed 11/13/
93	f 20mm	0.8 days	Thu 11/7/19	Fri 11/8/19
94	Supply and fix kitchen sink	3 days	Thu 2/6/20	Tue 2/11/20
95	**Supply and fix hand wash basins**	**2 days**	Thu 2/6/20	Mon 2/10/2
96	Size 500X400 mm	2 days	Thu 2/6/20	Mon 2/10/2
97	Supply and fix wash down water	2 days	Thu 2/6/20	Mon 2/10/20
98	Supply and fix shower tray	2 days	Thu 2/6/20	Mon 2/10/20
99	Supply and fix 60 ltr water heater complete with necessary accessories	2.7 days	Mon 2/10/20	Thu 2/13/20
100	**Supply and fix crystal glass mirror**	**0.03 days**	Thu 2/13/20	Thu 2/13/20
101	Size 500X400 mm.	0.03 days	Thu 2/13/20	Thu 2/13/20
102	Supply and fix toilet paper holder	0.5 days	Mon 2/10/20	Mon 2/10/20
103	Supply and fix soap holder	0.5 days	Mon 2/10/20	Mon 2/10/20
104	Floor drain with smile trap	0.4 days	Mon 2/10/20	Mon 2/10/20
105	**Supply and fix vent caps**	**0.1 days**	Tue 12/10/19	Tue 12/10/19
106	f 100mm	0.1 days	Tue 12/10/1	Tue 12/10/1
107	Construct and mount 2m 3 effective capacity water tanks	1 day	Tue 12/10/19	Wed 12/11/19
108	14. Eectrical Installation	44.8 days	Mon 12/9/19	Mon 2/10/20
109	**Supply and install PVC sheathed power cable or wire**	**19.2 days**	Mon 12/9/19	Fri 1/3/20
110	3x4sq.mm	11.2 days	Mon 12/9/19	Tue 12/24/19



111	3x2.5 Sq.mm	19.2 days	Mon 12/9/19	Fri 1/3/20
112	**DISTRIBUTION BOARDS**	**1 day**	Mon 1/6/20	Mon 1/6/20
113	Surface/flash mounted main distribution board MDB with locable door, bus bar rating 50A,1p, earthing lead and with all its	1 day	Mon 1/6/20	Mon 1/6/20
114	**Type of Light fitting**	**0.6 days**	Thu 2/6/20	Fri 2/7/20
115	RZB 33705.009, Wall mounted Incandescent,60W, light fitting ,or approved equivelent	0.5 days	Thu 2/6/20	Thu 2/6/20
116	RZB 21641.002.Q WITH 1X75W STANDARD INCANDESCENT LAMP for bed rooms ,or approved equivelent	0.3 days	Thu 2/6/20	Thu 2/6/20
117	RZB 59251.002.Q + RZB 05-56150.Q ,for toilet light,	0.3 days	Thu 2/6/20	Thu 2/6/20
118	RZB 931042.002 OR EQUIVALENT for corridors and	0.3 days	Thu 2/6/20	Fri 2/7/20
119	**Switches: 10A, 250V light switch, supplied, installed**	**0.5 days**	Fri 2/7/20	Fri 2/7/20
120	Sigle Pole,10A	0.3 days	Fri 2/7/20	Fri 2/7/20
121	Double Pole,10A	0.5 days	Fri 2/7/20	Fri 2/7/20
122	Two Way Switch	0.5 days	Fri 2/7/20	Fri 2/7/20
123	Flush mounted socket outlets	0.5 days	Fri 2/7/20	Mon 2/10/20
124	**TV System**	**0.3 days**	Mon 2/10/20	Mon 2/10/20
125	TV outlet	0.3 days	Mon 2/10/20	Mon 2/10/20
126	**Earthing system**	**0.2 days**	Mon 2/10/20	Mon 2/10/20
127	Earthing system	0.2 days	Mon 2/10/20	Mon 2/10/20



Project: Residential building
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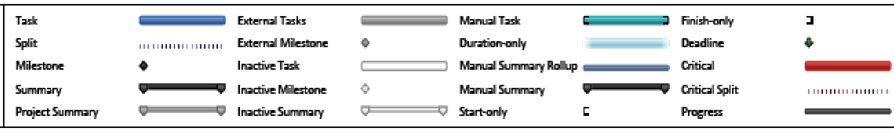

Figure C2: time schedule for the proposed building using conventional building technologies