ADDIS COLLEGE

APPLICATION OF MODERN FORMWORK SYSTEMS BUILDING CONSTRUCTION PROJECTS IN ADDIS ABABA CITY.

BY

TAMERAT SEYOUM

A Thesis submitted to the School of Graduate Studies of Addis College in Partial Fulfillment of the Requirement for the Degree of Master of Science in Construction Technology and Management

Jun, 2023

Addis Ababa, Ethiopia

Addis College School of Graduate Studies

Department of Construction Technology and Management Stream

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Declaration

I the researcher of this study, Tamrat Seyoum declare that this final project work entitled "APPLICATION OF MODERN FORMWORK SYSTEMS BUILDING CONSTRUCTION PROJECTS IN ADDIS ABABA CITY" represents my own work with the guidance and suggestions of my advisor and it is conducted for the partial fulfillment of the requirement for the Degree of masters of Science in Construction Technology and Management and submitted to Addis Ababa College post Graduate Study program.

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ABSTRACT

The aim of the study is to Application of modern formwork systems building construction projects in Addis Ababa city. Formwork materials and workmanship standard are major factors that determine the quality of the ultimate concrete. Formwork has been used since the introduction of Portland cement and construction of concrete structures. It has remained a labor-intensive activity where most of the carpenters start off as daily laborers and finish up as formwork carpenters without any formal training especially in the Ethiopian construction industry. But nowadays due to globalization across the world, the construction industry has started focusing on new innovative ways of formwork construction and approaches to increase overall efficiency of the project. Formwork not only holds the concrete during its wet stage but has many other important functions in the activity of concreting. It becomes integral part in construction and the foremost important trade in the reinforced concrete construction works which leads and determines the smooth flow of all subsequent construction activities. Formwork types and the way they are erected and handled affect the quality of the concrete finish and also the economy. Good quality of formwork can contribute to good quality of concrete. On the other hand, bad formwork has often produced failures of minor as well as major magnitude leading to additional treatments. A descriptive and case study research design were employed and Questionnaires were distributed and the results from 36 respondents and observations in 3 projects sites for this research conducted in Addis Ababa, indicated that bad form joints, offsets, verticality problems and poor facing material are some of the evident that bad forms can potentially have on the surface of concrete and leads to additional treatments. Financial capacity of contractors is found the main factor that affect formwork selection which contributes to bad concrete surface finishing; and improper selection of form release agents together with poor workmanships have highly affected the reusability of plywood in the building construction sites in Addis Ababa. One of the root causes for poor formwork practices by some of the local contractors in Addis Ababa is, striving to compensate the low bid amount by low cost materials, for example, used oil which highly affects the formwork. Based on results, this research contributes on improving future formwork constructions in Ethiopia by creating awareness from current practices in Addis Ababa.

Keywords: Formwork, Current practice, reuse of formwork, form release agent, life-cycle.

CHAPTER ONE

1. Introduction

1.1 Background of the study

Construction is one of the important sectors in the world. Construction involves huge investment and plays an important role in growth of several other sectors in economy. In construction industry, formwork plays an important role. Formwork contributes a major part of cost in construction and gives shape to the fresh concrete and support the fresh concrete to gain its strength to carry on its own weight (Christine, 2004).

Formwork is temporary structure whose purpose is to provide support and containment for fresh concrete until it can support itself. It molds the concrete to the desired shape and size and controls its position and alignment. As the topic fast track construction is very vast, the scope of study is limited as far as this project is concerned. The scope of study of this is limited to certain areas in fast track construction techniques, as formwork systems. Formwork, which is the basic element in any construction project, is one of the aspects where new techniques can be implemented for cost cutting in long run. The formwork system plays a vital role in construction, and choosing the right formwork system can result in sustainable construction. The cost of formworks is much higher than we consider it in project cost; it is around 20-25% of the project cost (Edward, 2008).

Formworks were holds and supports wet concrete until it gets matured and they were a very vital element in concrete construction. In Ethiopia economy and introduction of multinationals and nations pride program for golden quadrilateral of the construction. In order to have speedy construction and timely completion of projects. Now days, low waste modern formwork systems for superstructure construction are commonly adopted.

Formwork cost 40 to 60% of structural work in construction. Formwork should have good quality in terms of strength, durability and rigidity and it should be safe to workers and concrete structures and should possess good efficiency in operation, easy to handle and should be economical. It should be strong enough to withstand the dead and live load. Therefore, choosing a correct application of modern formwork becomes essential in construction. Incorrect selection of formwork will lead to increase in cost and time overrun in construction project. Different types of formworks are available in construction. Among

which choosing an appropriate system of formwork is crucial factor in successful completion of project in term of time, cost, quantity, and safety (Awad, 1999).

Formwork system effects on the cost, time, and quality of project delivery (Kumathekar, 2007). Building construction industry in developing country like Ethiopia used basically two types of formwork systems; timber and steel. Due to long existence and preference by most local contractor timber formwork was the most dominant type of formwork used in the building construction industry of the country (Bereket, 2015).

In building construction, formwork is used for one purpose which to create the shape of structural elements such as beam, column, shear wall and stair cases. In actual work; by using formwork, we can mold the concrete mix to satisfy the desired shape of the building element (Edward, 2008). Formwork is used to provide temporary support for the concrete until it can stand on its own. This confirms that, the various types of formwork used in construction, which varies according to the type & needs of the project. Concrete is poured into formworks, which are commonly made of steel, wood, aluminum, prefabricated forms, etc. The key considerations influencing the choice of formwork for high-rise buildings are time, cost, and quality. As traditional formwork systems are being replaced by advanced ones, the need for the newly emerging type of formwork systems is increasing. These formwork systems must be strong enough to support loads, retain shape, and be free of leaks, and the material used for formwork must be inexpensive, readily available, and reusable. The advancement of technology, increase of population and the space limitation lead the way to construct high-rise buildings. By conventional method we required more time to complete, the project Formwork, operations are also risky, and workers are typically exposed to unsafe working conditions. Partial or total failure of concrete formwork is a major contributor to deaths, injuries, and property damages within the construction industry. Another common hazard occurs during stripping of formwork in which loose formwork elements fall on workers under the concrete slab being stripped.

The quality of the resulting concrete is affected by the quality of formwork materials and workmanship. Many concrete-related problems such as discoloration, stains, and dusting are attributed to concrete formwork. Also, some deformed concrete surfaces are due to deformed formwork systems caused by repetitive reuse and inadequate support of formwork.

Conventional formwork construction system in Ethiopia takes relatively longer time to strip and erect. The labor time for production and erecting of formworks is relatively longer. This will also add costs to the project as the contractor's productivity will be reduced. The quality of concrete surfaces is mostly not good as proper formworks are not designed and constructed accordingly. Either the concrete surfaces are chiseled or additional plastering is applied to rectify the poor appearance. Hence, the use of modern formworks, which solves the above problems in Ethiopia, is mandatory to have better concrete fulfilling the requirements.

1.2 Statement of the problem

In today 's building construction industry where the emergence of high rising buildings is increasing from day to day, old ways of construction and materials are replaced with newly innovated technologies to make the construction process safer, quality, economical and timely completed in different parts of the world. Concrete work is major in building construction which needs concern to produce quality surface finishing.

In general, a critical factor is defined as the factors which contributed to the ineffective result and achievement towards successful of building construction with considering of time, quality and cost. Building projects that are delivered within estimated cost, specified quality and time greatly satisfy client, contractor and consultant. However, almost all building projects in Ethiopia are not lucky to be delivered successfully to the client. Among main factors for the poor performance of the construction sector of Ethiopia was usage and practices of lower quality of formwork system (Bereket, 2015).

The quality of the concrete surface finish affected by the quality of formwork materials. Formwork materials which do not fulfill good quality criteria are commonly used with many repetitions. Hence, quality, cost, speed and safety are important aspects in the formwork and scaffolding operation. The speed of construction in the time of erecting and stripping of formwork and scaffolding material affect overall project progress.

The type of formwork and scaffolding in the construction sites was the key factor to determine the success of a building construction project in terms of economy, quality and safety of building construction projects.

Nowadays concrete structures with high quality of surface finish are produced in building construction projects, which in other words means requirement to additional treatments of concrete surface to rectify imperfections after removal of forms, has been minimized. But

most building projects in Ethiopia especially undertaken by local contractors are still in need of additional treatment to rectify defects such as bulging of concrete walls, offsets, rough and uneven concert surface, edges of structural elements not straight etc., by chiseling and plastering with mortar. Conventional ways of formwork construction have been practiced, where timber boards and steel panels are most widely used materials. Steel panels and timber boards are the most commonly used formwork materials in Ethiopia. The quality of concrete surfaces is mostly not good as proper formworks are not designed and constructed accordingly (Tarekegn, 2010). The other problem in Ethiopian building construction is that formwork takes relatively longer time to erect and strip. The type of formwork used and the way it is erected construction sites are among the key factors in determining the success of a construction project in terms of cost, quality, construction speed and safety of the projects (Wong, 2015). Usage and practices of low quality of formwork systems hence could result in poor appearance of concrete surface quality.

The existence of this modern formwork seems to be one of the problem solving in reducing the used of conventional formwork which was exposed to the additional site work in nature as well as to the construction waste that finally affected the time, cost and safety. Nevertheless, production of modern formwork with full of advantages seems not glowing enough when their application still not rapidly embracing.

Conventional formwork construction system in Ethiopia takes relatively longer time to strip and erect. The labor time for production and erecting of formworks is relatively longer. This will also add costs to the project as the contractor's productivity will be reduced. The quality of concrete surfaces is mostly not good as proper formworks are not designed and constructed accordingly. The concrete surfaces are either chiseled or additional plastering is applied to rectify the poor appearance. Hence, the use of modern formworks which solves the above problems in Ethiopia is very mandatory to have better concrete fulfilling the requirements. Therefore, this is to study and recommend suitable modern formwork systems which will alleviate the major problems of traditional formwork construction in Ethiopia.

1.3 Objectives of the Research

1.3.1 General objectives

The general objective of the study is to evaluate the application of modern formwork systems building construction projects in Addis Ababa city.

1.3.2 Specific objectives

More specifically the study employed to:

1) Analyze existing formwork systems and examine local construction inefficiencies attributed to failure to adopt modern formwork systems
2) Assess the advancement in formwork system applied in building construction in Addis Ababa, Ethiopia
3) To investigate the materials of the formwork and methods used in erecting the modern formwork systems in Addis Ababa Ethiopia.
4) To propose the mechanism of reducing cost by using modern formwork systems in local construction practices.
5) To recommend the best formwork system that fulfills the cost, quality and safety requirements to the Ethiopian construction industry.

1.4 Research Questions

The research answered the following questions:

1) What looks like of existing formwork systems and local construction inefficiencies attributed to failure to adopt modern formwork systems?
2) How the advancement in formwork system applied in building construction in Addis Ababa, Ethiopia
3) What are the materials of the formwork and methods used in erecting the modern formwork systems in Addis Ababa Ethiopia?
4) What looks like of advancement in formwork system applied in building construction in Addis Ababa, Ethiopia?
5) Which formwork system is best that fulfills the cost, quality and safety requirements to the Ethiopian construction industry?

1.5 Scope of the Study

The study is delimited in geographically, conceptually and methodologically:

Geographically the study assesses the construction which found only in Addis Ababa projects.

Conceptually the research focuses on the formwork systems for building projects. Formworks for precast concrete elements are out of the scope of this thesis. Only cast in situ concrete formworks are investigated. Different types of Walls, column, beam, slab, and special formwork systems such as self-climbing are investigated.

Methodologically the study is a sample survey. From the sample a conclusion was made for the whole population.

1.6 Significance of the Study

The research is believed to initiate the local contractors in using standard formwork systems. Local professionals can appreciate the modern formwork systems in this thesis, be motivated to design, and construct safe and economical formwork systems. The environmental effects of construction of formwork are also revealed through this research. Regulatory body such as Ministry of Works and Urban Development will be benefited in modifying the regulation of licensing of contractors or introducing methods of use of formworks for high-rise building.

The study on identification of critical factor and its difficulties for applying modern formwork; will assists the Ethiopian government to overcome the shortcomings. This can provide an alternative solution to enhancing the uses of modern formwork in the Ethiopian construction industry.

The research also was believed to be a basis for future studies who will do research in formwork and scaffolding. It initiates the local contractors to identify which type of formworks was better according to their cost, quality, time and safety in formwork and scaffolding system.

1.7 Limitation of the study

The study has got some limitations. One of the limitations were shortage of data. The study used a primary data from the constructors. Hence this time questionnaires were distributed to the respondents. Some respondents were unwilling to give their data. The others which

drawbacks the researcher was there was a limited time. Within these short periods of time, it was a challenge to accomplish those works.

1.8 Organization of The Thesis

The study is presented in to five chapters. The first chapter an introduction part which includes background of the study, statement of the problems, objective of the study, research questions, significance of the study, scope and limitation of the study were discussed. The second chapters which discusses about the related literature. The third chapter is about the methodology which includes research area, research design, approach, sampling, analysis techniques were discussed. The fourth chapters is result and discussions and the final chapter which is chapter five discusses about conclusion and recommendation is discussed

CHAPTER TWO

2. LITERATURE REVIEW

2.1 Concept of Formwork

A formwork is defined as a temporary structure or mold for the support of concrete while it is setting and gaining sufficient strength to be self-supporting. Formwork has a broader definition: it is the total system of support for freshly placed concrete including the mold or sheathing, which contacts the concrete, as well as all supporting members, hardware, and necessary bracing. Forms are essential to concrete construction. They mold concrete to the desired size and shape and control its position, alignment, and surface contour. Formwork is more than a mold. A temporary structure supports its own weight, the weight of the freshly placed concrete, construction loads such as materials, equipment, and workers, and other possible live loads during construction (Neville, 1994).

Different authors give definitions of formwork differently. For instance according to Hanna (1999) form and formwork have the same meaning. It is defined as a temporary structure whose purpose is to provide support and containment for fresh concrete until it can support itself. Other authors define formwork in relation to false work as temporary or permanent molds into which concrete or similar materials are poured. In addition, false work as the structural supports and bracing used to support all or part of the formwork or structure. In this thesis, the definition made by ACI will be used. That is formwork includes all supports, face materials, and form as face material only (ACI 318-05).

2.2 Formwork System

The type of formwork systems used is among the key factors determining the success of a construction project in terms of speed, quality, cost and safety of works. Therefore, selecting the formwork system, that is, making structural frames faster, simpler, and less costly to build, must begin in the earliest phase of the design efforts(Basher Alamin, 1999).Generally there are two board category of formwork system as horizontal and vertical formwork system; these are described in detail below.

2.2.1 Horizontal formwork system

Forming system that is used for horizontal concrete structures such as slab, beam, stair cases and foundation is referenced as horizontal formwork system. Generally, five horizontal formwork systems can be used to support different slab types. There are:

1) Conventional wood or metal formwork system

2) Flying/Table formwork system

3) Column-mounted shoring

4) Tunnel formwork system

5) Joist-slab formwork system

Horizontal formwork can be operated manually or by other power-lifted methods, thus formwork systems for horizontal concrete can also be classified into two main categories: hand-set systems and crane-set systems. Conventional wood or metal systems are classified as hand-set systems. In hand-set systems, different formwork elements can be handled by one or more laborers. Flying formwork systems, column–mounted shoring systems, and tunnel formworks are classified under crane-set systems. In crane-set systems, adequate crane services must be available to handle formwork component. (Awad S. Hanna 1999).

2.2.3 Vertical formwork system

Vertical formwork systems are those used to form the vertical supporting elements of the structure (i.e. columns, shear walls).Typical vertical formwork systems utilized in construction include conventional formwork, ganged forms, jumps forms, slip forms, and self-raising forms (Basher Alamin, 1999). Conventional vertical formwork system is all wood forming systems consists of sheathing made by plywood or lumber that retains concrete until it hardens or reaches adequate strength. This system is also known as job-built wood system. The sheathing is supported by vertical wood studs. The studs are supported by horizontal walls which also align the forms. Single or double horizontal walls are preferred to avoid drilling through single walls which reduces its loading carrying capacity. Ties are drilled through walls (single wale) or inserted between them (double wale) to resist the lateral pressure of plastic concrete (Hanna, 1999).

2.2.4 The selection criteria of formwork system

In the building construction projects with reinforced concrete structures, the selection of a formwork system suitable for field conditions is essential for the success of a project. The type of formwork used in the projects may be selected based on different criteria that influence discussion of the contractor. This subsection, discusses the guidelines on how to choose formwork, factors affecting the selection, economics involved in formwork.

Formwork systems are classified in many ways, according to size they are classified as small sized formwork and large sized formwork. According to location of use, it is classified as timber form and girder form, where timber is used for irregular frame structures and girder form and climb forms are used for wall and column structures, where aluminum form is used for repeated regular section. Based on materials of construction it is classified as timber, steel, aluminum and plastic formwork. According to nature of operation crane independent, crane dependent and tunnel type formwork system. There are different types of formworks available and are being used in the construction of reinforced concrete structure. A plywood form is the oldest type of the formwork used in the construction industry. This is used for small construction works. This method is more expensive in usage of labor, it is time consuming process, it is difficult to carry install and dismantle. It has very poor surface finishing. Steel formworks are fabricated of thin steel plates.

Different panels can be joined by clamps or bolts & nuts. These formworks are used in a place where reuse of shuttering is needed. These are stronger and durable. Aluminum formworks are made from high strength aluminum alloys. The panels are joined by pin of wedge arrangement system. These are light in weight and reuse of formwork is more. Installation and dismantling is very easy and have very good surface finish. Plastic formworks are very light in weight and can be installed easily and save time & money and are cost effective. The panels can be attached with each other with the help of locking handles. These are easier to clean and can be reused instantly and have good surface finish.

Selection of a formwork for a high rise building mainly depends on individual's experience or by the senior members of an organization and the availability of the formwork system. This type of selection may result in cost expensive or faculty selection. The owner of an organization aims to reduce the overall cost of the project with specified quality and safety. Since, formwork is a costly item in construction he must be involved in formwork selection system process. Designer should design the building in such a way that it should have a greater number of similar size structures so that formwork can be used repeatedly which will reduce the cost and increase the productivity.

Hanna, (1989) identified 38 factors influencing the selection of FWSs for building construction projects in the United States and categorized them into four groups based on expert opinion: building design, job specification, local conditions, and supporting organization.

Hanna and Sanvido, (1990) investigated the selection process for vertical FWSs utilizing the factors and FWS alternatives identified by Hanna (1989). The study by Hanna et al. (1992)

proposed a rule-based expert system to guide decision makers in selecting the most suitable FWS for building construction projects. In an expanded version of the previously developed rules and guidelines for selecting FWSs, Hanna, (1999) incorporated additional factors, such as labour productivity to the relevant literature. Proverbs et al. (1999) analyzed the importance levels of nine factors affecting FWS selection and the degree of association between each selection factor for contractors from the UK, France, and Germany. Most of the studies on the FWS selection problem from 1989 until 2012 considered the FWS selection criteria under the four main groups identified by Hanna. The widespread use of industrial FWSs in building construction projects across the world, as well as new technological advancements in formwork engineering.

2.2.5 Factors affecting horizontal formwork selection

Selecting the formwork system for cast-in-place reinforced concrete slabs is a critical decision that can affect cost, safety, quality, and speed of construction. Many factors must be considered for the proper selection of the formwork system (Awad S. Hanna, 1999). Among these are:

- Factors related to building architectural and structural design, which include slab type and building shape and size
- Factors related to project (job) specification, and schedule, which includes the speed of construction.
- Factors related to local conditions, which include area practices, weather conditions, and site characteristics.
- Factors related to the supporting organizations, which include available capital, hoisting equipment, home-office support, and availability of local or regional yard supporting facilities.

Depend on the nature of the project one or more groups of criteria can be used to select to the type of formwork used. Each major criteria group is also divided into several primary factors. Some factors may have high effect in the selection of a horizontal formwork but low effect in the selection of a vertical system. For example, span length of the slab may be very significant in selecting a horizontal system and may have slight effect in selecting a vertical formwork system. Also, some factors may be considered not at all. For example, the weather

condition may not be an effective factor in Ethiopia owing to the prevailing moderate climate throughout the entire four seasons of the year.

The following sections briefly define the terminology and explain how these factors affect the selection of the horizontal formwork system. All terminology and explanation are refereed from a concrete formwork systems based on Awad S. Hanna (1999).

i) Building Design:

Slab Type The construction cost of slabs is often more than half the cost of structural framing systems, except in extremely tall buildings. Therefore, selection of the slab formwork system deserves considerable attention to minimize cost. The selection of a formwork system should be made on the basis of the selected floor system that satisfies the structural loading conditions. Floor slabs in concrete buildings are classified into two basic types, one-way and two-way, based on the load distribution applied on the slab

ii) Building Shape

Special buildings such as industrial buildings and power plants usually have extensive electrical and mechanical requirements which do not lend themselves to any sophisticated formwork system. As a result, they should be constructed using the traditional formwork method. Some of the factors that enable the contractor to decide whether to use a formwork system or a traditional forming method are:

i. Variation of column and wall location

ii. Variation of beam depth and location

iii. Variation of story height

iv. Existence of block outs and openings for windows and doors

v. Extensive Heating, Ventilating, and Air Conditioning (HVAC) requirements

iii) Job Specification:

Speed of Construction The most important advantage of using a formwork system is the speed of construction. The speed of construction affects cost because it determines the time when the building will be available for use and also reduces the financial charges. The major factor that determines the speed of construction is the floor cycle time. In recent years, casting two floors per week in highrise buildings has been achieved, especially in metropolitan areas such as Hong Kong(Raymond W, 2001) . This fast floor cycle can only be achieved by using sophisticated formwork techniques such as flying forms and tunnel formwork which are capable of forming one story every two days.

iv) Local Conditions

The nature of the job, including local conditions, is one of the primary factors in formwork selection. Some of the factors that should be considered are explained below.

a) Area Practice

In geographic areas where the labor force is expensive and unskilled, the use of formwork ‘‘systems’’ can substantially reduce the cost. In areas where the labor force is inexpensive and skilled, a conventional formwork system is an economical alternative even if the building features are compatible with a sophisticated form- work system. As a result, some geographic areas use preassembled formwork systems because of the lack of inexpensive skilled labor force.

b) Site Characteristics

The building site itself may influence the selection of a suitable forming system, because of site limitations and accessibility for construction operations. The feasibility of using flying forms, for instance, is influenced by site characteristics, which include:

1. Accessibility to the site.
2. Availability of a fabrication area.
3. Surrounding area restrictions such as property lines, adjacent buildings, power lines, and busy streets. In open and unrestricted suburban sites, all forming systems are practical and some other considerations should be evaluated to determine the most efficient and cost-effective system. In downtown restricted sites, the only possible system may be ganged units that can be transferred from floor to floor.

v) Supporting organization

The major resource requirements that should be carefully evaluated when deciding upon a forming system are discussed below.

a. Available Capital (Cost)

The cost of concrete formwork is influenced by three factors:

i) Initial cost or fabrication cost, which includes the cost of transportation, materials, assembly, and erection.

ii) Potential reuse, which decreases the final total cost per square foot (or per square meter) of contact area.

2.2.6 Factors affecting Vertical formwork selection

Many of the factors that affect the selection of vertical formwork system for building are similar to those factors affecting the selection of horizontal formwork system. However, there are some factors that are particularly important to the selection of vertical formwork systems. For example, lateral pressure caused by plastic concrete on vertical formwork system depends on the floor height of the building, thus the floor height is very significant in selecting a vertical formwork system to show the effect of the factors those influence the selection of different type of vertical formwork system is presented below. This table was extracted from a Concrete Formwork System. These tables show the relationship between the factors affecting the selection of formwork systems and the different forming systems available for vertical concrete work. The table helps the formwork designer/selector to choose the appropriate vertical formwork system, thus contractor must first list all the known major components of the project and then compare them to the characteristics listed in table under each forming system. These tables can also be used by architects to make some minor adjustments in their design to accommodate the use of an efficient formwork system.

2.3 Requirements for Formworks

Requirements of a Good Formwork System: -

- Formwork is to be strong enough to withstand the dead and live loads, forces caused by ramming and vibration of concrete and other incidental loads imposed upon it during and after casting of concrete.
- Suitable arrangements should be there to avoid any settlement in the formwork either before or during the placing of concrete.
- Formwork should be of sufficient stiffness to avoid excessive deflection and joints should be tightly butted to avoid leakage of cement slurry.
- Formwork must be accurately set out so that the resulting concrete product is in a right place and is of correct shape and dimensions.
- Formwork surface is to be coated with suitable mould oil so that good concrete quality and surface finish can be achieved.
- Form panels and units should be so designed that their maximum size does not exceed and can be easily handled by hand or mechanical means. In addition, all formwork must also be designed and constructed to include facilities for

adjustments, leveling, easing, and striking without damage to the formwork or concrete.

- Ensure optimum stock of formwork for the size of work force, the specified time schedule, and flow of materials.

Cost, safety, speed, and quality are some of the requirements to be fulfilled by formworks. These requirements will be described in the following sub-sections.

2.3.1 Cost of formwork system

This is a vital factor for deciding formwork system as one must know the capital provision for formwork in the project. It is always beneficial to work out these details at the time of bid. Cost is influenced by three components;

a) Initial cost or make-up cost:

Includes; cost of transportation, materials, assembly and erection.

b) Reuse cost of formwork system:

The formwork system cost goes on reducing as we increase reuse of same. The re-use for traditional timber formwork is usually limited due to the durability of the plywood sheathing. The optimum number of uses for timber form usually ranges from 12 to 14. Thus, it is still sufficiently economical to use timber formwork for high-rise buildings at heights in accordance to the multiple of the usual re-used times. Although the metal form can be reused many times, the high initial cost of providing the form often discourages its selection, especially when there is no need to reuse them too many times, for example in a low-rise development. A careful balance between cost, speed, performance and the quality of output should be properly considered when making the selection.

c) Maintenance & storage cost:

It includes cost of stripping, repair, storage, etc. Formwork materials are a valuable asset of company, If proper care is taken during handling and storage, much return is obtained on the investment. Formwork needs to be handled correctly, maintained, repaired if necessary and finally, cleaned regularly.

Formwork is the largest cost component for a typical multistory reinforced concrete building. Formwork cost accounts for 40 to 60 percent of the cost of the concrete frame and for

approximately 10 percent of the total building cost in developed country. A large proportion of the cost of conventional formwork is related to formwork labor costs in developed country. Significant cost saving could be achieved by reducing labor costs.

The proportion of cost of formwork varies from country to country. The percentages stated above are valid for developed countries like Germany. The situation for developing country, Ethiopia, might be very different. The actual current proportion of the formwork cost in Ethiopia is established through this research and discussed in chapter four.

Formwork economy is achieved by considering four important factors:

i. Cost of form materials

ii. Ease of form fabrication

iii. Efficient use of forms — erecting and stripping

iv. Planning for maximum reuse to lower per use cost .

Formworks, which are easy to erect and strip, will reduce the overall completion of the project, which leads to early collection of revenues to be generated from the building or other structure. Such economic benefits are obtained if the formworks are modern and efficient. Maximum reuse is obtained if the formworks materials are durable and handled well. The traditional formworks, which need many blows of hammer to strike, will not be durable as the material is threatened. Hence innovative formworks, which can be easily striped, more durable, and reusable should be used to ensure formwork economy.

Many scenarios should be considered in achieving cost effective formworks. These include:

- ✓ Cost and feasibility of adapting materials on hand versus cost of buying or renting new materials
- ✓ Cost of a higher grade of material versus cost of lower grade of material plus labor to improve for required quality and use
- ✓ Selection of more expensive materials that provide greater durability and capability for reuse vs. less expensive materials that have a shorter use-life.
- ✓ Building on-site versus building in a central shop and shipping to site, (this depends on the site itself and space available, the size of project, the distance of shipping, etc.

2.3.2 Speed

Speed of construction is defined as the rate in which concrete building is raised and can be expressed in terms of number of floors erected per week or months. Speed of construction can be also measured in terms of inches or millimeters of concrete poured per hour. Formwork operations can control the pace of construction projects. Several levels of shores and re-shores carry the loads until the concrete gains enough strength to support its own weight and all other externally applied loads. Shores are vertical members that support recently built concrete that have not developed full design strength. On the other hand, re-shoring occurs when the original shoring is removed and replaced in such a manner as to avoid deflection of the cured concrete. Several floors may be blocked, preventing the progress of any other construction activities, if the formwork system is not efficient. Faster formwork cycle from erection to stripping would allow for faster removal of shoring and re-shoring and faster overall project progress the life cycle of formwork starts with the choosing of suitable formwork

The physical activities in the formwork life cycle are represented by these steps:

(i) Fabricate formwork;

(ii) Erect formwork; and

(iii) Remove formwork.

First appropriate formwork material is chosen and fabricated to get the desired shape and size. After that the elements will be erected, concrete will be casted and forms will be stripped. By providing additional shores (re-shore), it is possible to remove forms as early as possible. Finally, re-shores will be removed after concrete supports its weight and additional live loads.

2.3.3 Quality

Many concrete-related problems such as discoloration, stains, and dusting are attributed to concrete formwork. In addition, some deformed concrete surfaces are due to deformed formwork systems caused by repetitive reuse and inadequate support of formwork [7]. If the surface of the concrete is good, the cost of finishing to be applied on the surface will also be less. On the other hand, if concrete surfaces are of less quality, which results from poor

quality of formworks, cost of grinding and plastering will be higher. Therefore, formworks should fulfill the following quality requirements.

2.3.3.1 Strength

All components should be designed to cater for the most severe loads that are likely to be imposed on the formwork. To achieve this, the design should be done by a person competent in formwork design. Care should be taken to ensure that the design details are met and that the construction loads imposed on the formwork are within the limits designated by the designer. Sound materials should always be used. Reused material may be satisfactory, but should be checked regularly to ensure it is adequate for the job in the hand. The strength of each item of formwork material contributes to the overall safety of the temporary structure [4].

2.3.3.2 Stiffness, Accuracy and Water Tightness

Formwork should not bow, bulge, sag, or otherwise move in such a way that the completed concrete element is outside the tolerances imposed for the work. The formwork designers should detail the units to have adequate stiffness, but site personnel are responsible for ensuring that the correct, good quality materials are used in the proper manner. For example, plywood sheeting for general formwork use has a greater capacity in one direction than in the other. It should always be used in correct orientation.

In general, formwork should be built to accuracy greater than that desired in the finished concrete structure or element. All support structures should ensure that this accuracy is maintained until the concrete has hardened. The accuracy required might affect the selection of the material from which formwork is to be built as some materials may be finished to tighter tolerances than others might. All joints should be sealed to stop grout leaking from the formwork. Grout loss causes ragged edges, hydration staining and honeycombing, which in turn can affect strength, durability and appearance. Formwork materials, which have well defined engineering properties such flexural, compressive strength, are believed to fulfill the above requirements. Therefore, standard and modern systems of the formworks are preferred to fulfill those quality requirements.

2.3.4 Safety

Formwork operations are risky, and workers are typically exposed to unsafe working conditions. Partial or total failure of concrete formwork is a major contributor to deaths,

injuries, and property damages within the construction industry. Structural collapses and failures involving concrete structures account for 25 percent of all construction failures. More than 50 percent of concrete structure failure during construction is attributed to formwork failure though there is no proper documentation of the construction failure in Ethiopia, the percentage of collapses, which are caused by defects in formwork construction, is not less than the above figure. The possible health hazards related to formwork assembly, preparation and stripping are described in subsequent sections.

2.4 Causes of Formwork Failure

Formwork failures are the cause of many accidents and building failures that occur during concrete construction, usually when fresh concrete is being placed. Generally, some unexpected event causes one member to fail, then others become overloaded or misaligned and the entire formwork structure collapses.

The main causes of formwork failure are:

Faulty formwork structural design

Improper stripping and shore removal: Premature stripping of forms, premature removal of shores, and careless practices in re-shoring can produce catastrophic results.

Inadequate bracing: Inadequate cross bracing and horizontal bracing of shores is one of the factors most frequently involved in formwork accidents.

Vibration: This occurs when shores are displaced by the vibration caused by passing traffic, movement of workers & equipment and vibrating concrete.

Unstable soil under mudsills (A plank, frame, or small footing on the ground used as a base for a shore or post in formwork).Site drainage must be adequate to prevent a washout of soil supporting the mudsills.

Inadequate control of concrete placement: The temperature and rate of vertical placement of concrete are factors influencing the development of lateral pressures that act on the form shows the pressure distributions of concrete assuming it as fluid. If temperature drops in during construction operations, rate of concreting often has to be slowed down to prevent a buildup of lateral pressure overloading the forms. If this is not done, formwork failure may result. Temperature drop is major problem in developed country and may not be applicable to Ethiopian case. Failure to regulate properly the rate and order of placing concrete on horizontal surfaces or curved roofs may also produce unbalanced loadings and consequent failures of formwork.

Lack of attention to formwork details: Even when the basic formwork design is soundly conceived, small differences in assembly details may cause local weakness or overstress loading to form failure. This may be as simple as insufficient nailing, or failure to tighten the locking devices on metal shoring.

Contractors are generally responsible for stability and safety of concrete formwork. Contractors need to be guided by codes and regulations that regulate formwork safety. Contractors typically are trying to achieve fast removal of formwork elements without compromising the safety and integrity of structures. Proper planning of formworks will minimize the hazards associated with formwork preparation, assembly, and removal.

2.5 Current application of Formwork in Buildings

In today ‘s concrete construction, the type and systems of formwork used to mould fresh concrete plays significant role. It influences the quality of work, construction time, site safety and cost of the project. Different formwork systems provide a wide range of concrete construction solutions that can be chosen to suit the needs of a particular concrete structure. The selection of formwork types and design of the layout for building concrete structures are some of the most complex tasks in formwork construction, especially if the sheets are to be reused many times to form different concrete structural elements to take economic advantages.

2.6 Conventional Formwork

Conventional/ traditional Formwork the oldest formwork type which uses timber, bamboo, timber boards, timber props, masonry and carpentry Conventional formwork is the most traditional/oldest type of formwork used in the construction industry, which uses timber, bamboo, and carpentry or assembling to complete the concrete construction. It is a formwork type which is still being practiced and very much suitable for small houses or low-rise building construction projects, mostly two – three stories (Loganathan & Viswanathan, 2016). Although this type of formworks has advantages for low initial cost, low labor experience requirements and low weight, high floor cycle wastage, low reusability, poor finish, and high labor requirement are on the other hand, the disadvantages. This is the type of formwork where most of the carpenters started as daily laborers and takes longer time to assemble and erect. conventional formwork systems for slab and stair case.

2.7 Features of Traditional Formwork

Traditional formwork construction has been practiced for a long period of time since the introduction of Portland cement and suitable for small house or low rise building up to three stories till these days. the common features of traditional formwork as follows.

- Usually timber in the form of plywood, planking, batten and joist are used as the basic material
- Installation of the formwork is on a labor intensive basis. Human workers need to enter into every corner to perform the formwork installation works.
- The work operation is so designed to allow a single worker can handle his work basically by oneself. Size and weight of each formwork panel is so designed in the right combination to be moved and lifted for installation by a single worker Except for simple hand-tools, limited machinery is required in the installation process.
- Every work location requires care to be taken by human workers. Every small, difficult accessible and awkward shaped location can be taken care of by human worker
- Works are repeated from location to location or from floor to floor.
- For example, when workers completed the installation of formwork on the lower floor, they need to get up to the upper floor and repeated the works again though they are basically the same.

2.8 Modern Conventional Formwork

Modern conventional type of formwork is similar to the traditional slab formwork method but more advanced materials such as steel props and various types of jacks (U jacks, T jacks) are used as supports in the formwork instead of timber supports and ply wood sheets are used instead of timber planks on slab decks, beams and columns. These advanced materials can reuse for several times. The advantages of this type are low initial cost, low skilled labor requirement and can use in places where there are a lot of deviations in the structure.

Modern concrete technology has provided concrete mixes with properties which can be pumped with ease to the uppermost floors of tall buildings without clogging hoses and yet still give the properties required for strong, serviceable and durable building structures (SRIA, 2016). Modern concreting methods including the use of prefabricated reinforcement cages and precast concrete elements have enabled high rise structures to be built with

increasing speed. The 47-storey Telecom Corporate building in Melbourne was constructed in record time with an average floor to floor cycle in its office areas of only 3 days (SRIA, 2016).

"Reinforced concrete framing systems have been proven to be the most economical form of construction for medium- to high-rise buildings, in Australia" (SRIA, 2016). This can be attributed to the following:

- The fluid nature of reinforced concrete makes changes in structural dimension, shape and direction straightforward. Service penetrations through floor slabs, beams, walls and columns can be easily accommodated.
- It allows follow-up work from other trades such as building fit out to begin the minute formwork is removed.
- Reinforced concrete is fire-resistant, so there are no delays waiting for the structure to be fire-proofed.
- The Steel Reinforcement Institute of Australia's research has shown that reinforced concrete buildings will usually have a significantly reduced floor-to-floor height in comparison to structural steel buildings averaging 420mm less per floor.

Vertical forming systems are those used to form the vertical supporting elements of the structure (i.e. columns, walls). There are a number of different vertical forming systems used in the Australian high rise construction industry. These include: conventional, crane lifted platforms, slip forms, and jump forms (Peurifoy & Oberlender, 2011). Conventional forming systems rely on the site tower crane to lift prefabricated vertical wall forms into their pouring position on top of the concrete slab. The slab intern acts as a platform so that the wall form can be accessed by workers to align, secure the forms in place and fit reinforcing steel prior to the concrete pour. The most common procedure is to fasten a base plate to the slab with fasteners or concrete nails (ACI, 2005).

Slip forms place concrete by extrusion. The concrete is placed in the forms, which at the same time is being jacked vertically, extruding the concrete, in the shape of the form. The movement of the forms is slow enough for concrete to gain the strength to keep its shape and support its weight. Vertical slip forms are usually moved by jacks riding on smooth steel rods in the concrete. The continuous process is carried on, filling and moving the forms upward,

often 24 hours a day until the structure is complete. The working deck, concrete supply hoppers, and finishers platforms are carried by the moving formwork (ACI, 2005).

Jump forms are used where no floor is available on which to support the wall formwork, or most commonly in high-rise construction where the wall and columns proceed ahead of the floor slab. Jump forms use the same prefabricated vertical wall forms as a conventional system. The form is "cycled" that is, filled with concrete, stripped, and then jumped to the next level after the concrete is set (ACI, 2005). The jump forms provide built in working platforms to allow workers to access the forms, place reinforcing steel, pour the concrete and concrete finishing. Jump forms are electrically or hydraulically self-climbing. Used correctly they minimize the number of pieces to be handled by the site tower crane and simplify the task of resetting the wall forms which in turn saves considerable time. Crane lifted platforms are essentially the same as jump forms in that they proceed ahead of the floor slab and provide working platforms which simplify the task of resetting the forms. However, as the name suggests instead of being self-climbing like jump forms, they are lifted in between cycles by the site tower crane.

2.9 Ethiopian Formwork Construction Systems

2.9.1 Introduction

For many years reinforced concrete construction is predominantly followed in Ethiopia, thus the formwork plays a vital role in the Ethiopia construction. The most commonly used type of formwork systems are the traditional or conventional systems made of dressed lumber and fabricated at site during construction. They are also known as as-built formwork. Currently even for construction of wide variety of structures from small to medium sized projects, the conventional formwork systems are used. Quality, safety, and economy are the three objectives of formwork construction. The conventional formwork systems could account only for the economy aspects of form construction, thus the modern formwork systems known as Engineered or System Formwork Systems was developed later.

In Ethiopia, even if different types of formwork are available there is a lack of due consideration of cost, quality, time, and safety criteria on the selection of Formwork materials. In addition, care is not given on the off form finish. Formwork materials, which do not fulfill good quality criteria, are commonly used with many repetitions. There is misunderstanding on the costs difference while using good and poor quality formwork.

Forms should be accurately set, clean, tight, adequately braced, and constructed of or lined with materials that will instruct the desired of the form finish to the hardened concrete. Wood forms, unless oiled or otherwise treated with a form-release agent, should be moistened before placing concrete, otherwise they will absorb water from the concrete and swell. Forms should be made for removal with minimum damage to the concrete. With wood forms, use of too large or too many nails should be avoided to facilitate removal and reduce damage. For architectural concrete, the form-release agent should be a non-staining material ACI Committee 347 (1999).

The technology of formworks in Ethiopia is at an infant stage. This situation is attested through reviewing the construction practices of sites in all sub cities of Addis Ababa. Since the construction methods and materials used in all sub cities in particular and country in general is similar, representative sites in Addis Ababa are selected for review. As there are few literatures written on the formwork construction practices in our country, investigations from sites are considered as a review and presented in subsequent sections. Formwork construction practices for footing, column, slab and beam will be reviewed from quality, safety, and environment aspect.

2.9.2 Footing Pad and Foundation Column Construction Systems

Formworks for footing pads can be either timber or steel panel. The steel panels are joined using black wire and supported from back by timber (see figure 2.1).Incase of timber boards, the members are nailed together and supported from back in the same manner as that of steel panels. Formwork release agents, mainly burnt oil is usually applied on the panels and boards before placing of the formworks. Lean concrete is casted to form hard surface beneath the formworks, which minimizes the settlement of the forms.

Figure 2.1 Footing pad formwork construction system in Addis Ababa

Column forms can be either timber or steel like that of footings'. The members are oiled and tied together using timber yokes supported by diagonal props. Wooden ladder is provided as an access for concreting. The following picture is taken from one of the high rise buildings in Addis Ababa which is constructed by local grade one contractor.

Figure 2.2 Column formwork construction systems in Addis Ababa.

Spacing of yokes differs from contractor to contractor. Some provide very closely, which is not economical while others provide at relatively larger spacing, which is not safe. This might be due to the lack of guidelines for the formwork design. As the timber is used intensively for yokes, ladder and props, the construction system is not environmentally friendly unless rapid replacement of trees are made. The platform system for concreting is not suitable to properly consolidate concrete. Vibrators are sometimes inserted diagonally as the working condition is not suitable for labor. This will result in segregation of concrete. Moreover, failure of the ladder may occur while concreting which make unsafe working conditions for the workers.

2.9.3 Slab and Beam Formwork Construction Systems

Steel panels of different sizes such as for instance0.9m*2m, 1m*1m etc are used as forms for slab construction. Almost all contractors use wooden shores (see figure 2.3). A few contactors use steel in combination with wooden props. Some start to modify wooden props by providing metal shoes in which the props are inserted. This system will help them to easily remove the props. Few contractors in Addis Ababa have started to use modern formwork, Doka systems, for slab construction. It is possible to say that the current construction systems in Ethiopia are threatening the environment as mainly timber is deployed for slab and beam props. In most sites, the props are very closely spaced and make the circulation underneath difficult.

Figure 2.3 Slab formwork construction systems in Addis Ababa

Concerning beam formwork, the construction system is not different from others members. Timber boards and/or steel panels are used as sheeting material. Timber, mainly eucalyptus tree, props are used in Addis Ababa in particular and Ethiopia in general (see figure 2.4).The quality of concrete for beam and slab might be affected unless very experienced work force is employed in construction of beams and slab. The depth of the beam will be different at different points if all props for beam and slab are not precisely cut and placed. This problem is recurrent in most construction sites in Addis Ababa. More over the width of a particular beam might be different owing to the bulging of forms. Bulging may occur if the form ties are not properly designed. This phenomenon is also observed in most of our construction sites.

2.9.4 Advantages and Disadvantages of Traditional Formwork Systems

Conventional formwork systems especially wooden formworks have the following merits and demerits.

Some of the advantages such systems are:

1. *Flexibility*. Because the system is built piece by piece, it is virtually capable of forming any concrete shape. A complicated architectural design can be formed by this system.

2. *Economy*. This system is not economical in terms of labor productivity and material waste. However, the system may be economical for small projects with limited potential reuses. The system has the advantage of low makeup cost or initial cost. Application of Modern Formwork Systems in Ethiopia Also, for restricted site conditions, where storage areas are not available and the use of cranes is difficult, the conventional wood system might be the only feasible alternative.

3. *Availability*. Wood is a construction material that is available virtually anywhere. In areas where formwork suppliers are not available, a conventional wood system may be the only feasible alternative.

The major problems associated with conventional formwork systems are:

1. *Labor Intensive*. The conventional formwork system is a labor-intensive system and considered as demerit for developed country.

2. *High waste*. Erecting and dismantling conventional formwork is conducted piece by piece. This causes breaking of edges and deformation of wood. It is estimated that 5 percent waste is generated from a single use of formwork.

3. *Limited number of reuses*. Number of reuses is the key to an economical formwork construction. A limited number of reuses force the contractor to use several sets of formwork; this adds to the expense of formwork construction.

4. *Higher quality of labor force and supervision*. Conventional formwork systems work best with a high-quality labor force and adequate supervision. In areas with an unskilled or semiskilled labor force and minimal supervision, more sophisticated formwork systems are more appropriate.

5. *Limited spans*. Since dimension wood is low strength compared to that of aluminum and steel sections, it has limited use in applications where long spans are desired.

Since formwork systems in our country have the above limitations, it is the duty of stake holders in the construction industry to overcome the problems.

2.10 Classification of Formworks

Formwork can be classified according to a variety of categories; relating to the differences in sizes, the location of use, construction materials, nature of operation, or simply by the brand name of the products.

2.10.1 Classification According to Size

In practice, there are only two sizes for formwork; small-sized and large-sized. Any size, which is designed for operation by workers manually, is small-sized. The most common

small sized systems are made of timber and aluminum, and are usually in the form of small panels. There is seldom medium-sized formwork. In cases where large-sized formwork is used, the size of the form can be designed as large as practicable to reduce the amount of jointing and to minimize the amount of lift.

2.10.2 Classification According to Location of Use

Different elements in the structure of building have different design and performance requirements in the use of formwork. Accordingly, classification can be made as wall formwork, column formwork, beam formwork, and slab formwork.

2.10.3 Classification According to Nature of Operation

Formwork can be operated manually or by other power-lifted methods. Some systems are equipped with a certain degree of mobility to ease the erection and striking processes, or to allow horizontal movement using rollers, rails, or tracks. Timber and aluminum forms are among the manually operable types of formwork. They are designed and constructed in ways that they can be completely handled independently without the aid of any lifting appliances. However, it is labor intensive and is more appropriate to be used in simpler jobs. Power-lifted formwork can be of the self-climbing and crane-lifted types. Crane-lifted systems are usually in the form of large panels.

2.10.4 Classification According to Materials of Formwork

Before the final selection of the formwork material is made for a particular job, a number of factors should be considered, including size of the forms ,shape of the forms , surface finish required ,accuracy required ,number of re-uses required, handling methods proposed ,methods of compaction proposed, method of curing proposed and Safety.

Speed of the project and the capital available. The weighting given to each factor will vary from project to project. Thus, on small projects where multiple uses of formwork, elements are unlikely and a great deal of cutting and fitting may be required, timber sections may well be indicated. On major projects, where standardized components can be employed, and multiple re-use achieved, heavier steel sections may well be warranted. Modular units may be viable in such circumstances. The quality of the finish required and the overall cost of the formwork are likely to be the principal determinants.

Contractors in our country need to consider the above factors to have safe, quality, and economical formworks. Moreover, knowledge of all formwork materials is mandatory for the selection of best formwork system.

Many materials may be used for formwork. Plywood, steel, glass reinforced plastic, aluminum alloys, earth, precast concrete, particle board, hard board, gypsum board (for left-in-place sub grade forms), lumber, cardboard, rubber, polyvinyl chloride, and polystyrene are all used for forms and supporting formwork.Description of these materials is made in the following sections.

2.10.4.1 Steel Formwork

Steel is very strong and can be used repetitively without much damage done to the form. Steel forms are also in use in combination with timber. Steel sections are used in the fabrication of different formwork components, namely: steel panel forms, horizontal and vertical shores, steel pan and dome components used for joist and waffle slabs, and steel pipes for formwork bracing.Steel formwork has the advantages of very high reuse rates,very smooth surfaces are possible, strong, and fast to install in simple walls. Its disadvantages includes costs of 6-10 times plywood form, thicker the surface of the steel sheet, the greater the weight , Steel dents easily, Release agents are demanded as, if not used, cleaning labor will quickly overcome any economy gained by durable surfaces and Low versatility.

Figure 2.5 **Steel Formwork**

2.10.4.2 Aluminum Formwork

Aluminum has become an increasingly popular material for many formwork applications such as lightweight panels, joists, horizontal and vertical shoring, and aluminum trusses for flying forms. The popularity of aluminum stems from its lightweight, which reduces handling costs and offsets its higher initial material cost. When compared to steel panels, aluminum panels used for ganged forms weigh approximately 50 percent less. The major problem with aluminum forms is corrosion: Pure aluminum is attacked chemically by wet concrete. When aluminum is in contact with fresh concrete, a surface reaction does occur between the aluminum and the alkaline constituents of the concrete resulting in a slight superficial attack on the metal. Aluminum alloys have proven to be very successful in resisting corrosion.

Merits of aluminum formwork:

I. In contrast to most of the modern construction systems, which are machine and equipment oriented, the formwork does not depend upon heavy lifting equipment and can be handled by unskilled labors.

II. Fast construction is assured and is particularly suitable for large magnitude construction of respective nature at one project site.

III. Construction carried out by this system has exceptionally good quality with accurate dimensions for all openings to receive windows and doors, right angles at meeting points of wall to wall, wall to floor, wall to ceiling, etc., concrete surface finishes are good to receive painting directly without plaster.

IV. System components are durable and can be used several times without sacrificing the quality or correctness of dimensions and surface.

Figure 2.6 **Aluminum Formwork**

2.10.4.3 Plastic Formwork

Different companies innovate range of formwork products, which is aimed at completely revolutionizing the concreting procedure by saving time and resources, while providing a smooth finish that is nothing short of excellent. Geo-plast is one of such innovations. The products come in the form of Plastic panels that can be efficiently assembled into an airtight and minutely precise mould .Once the concrete is set, Geo-panels are effortlessly removed to reveal the finished structure. All Geopanel pieces can be comfortably assembled by just one person this enables concrete structures to be erected with minimal labor& tools. The necessity of cranes or other heavy lifting machinery is also eliminated. Furthermore, since all moulds are produced from ABS (acrylonitrile, butadiene, and styrene) Plastic they can be easily cleaned after use with just water and can be stored even in humid conditions. The following are some of the plastic column formworks.

Figure 2.7 **Plastic Formwork**

2.10.4.4 Timber Formwork

Timber, arguably the original building material, retains its prime importance within the construction industry because of its versatility, diversity, and aesthetic properties. About 20% of the earth's land mass is covered by forests, divided roughly two-thirds as hardwoods in temperate and tropical climates and one-third as softwoods within temperate and colder regions. Approximately a third of the annual worldwide timber harvest is used in construction, and the rest is consumed for paper production, as a fuel, or wasted during the logging process.

In Ethiopia, more than the figure stated for developed country is expected to be utilized for construction of structures. Almost all contractors use timber as false works and others, which indicates that the construction industry of Ethiopia highly utilizes timber.

Environmental issues, raised by the need to meet the current and future demands for timber, can only be resolved by sustainable forest developments. In temperate climate forests, clear cutting, in which an area is much stripped, followed by replanting, is the most economical, but the shelter wood method, involving a staged harvest over several years, ensures that replacement young trees become established as the mature ones are felled. The deforestation of certain tropical regions has allowed wind and rain to erode the thin topsoil, leaving in hospitable or desert conditions; furthermore, the overall reduction in world rain forest areas is

contributing significantly to the greenhouse effect by reducing the rate of extraction of carbon dioxide from the atmosphere.

Compared to the other major construction materials, timber as a renewable resource is environmentally acceptable. Trees require little energy for their conversion into usable timber, and young replacement trees are particularly efficient at absorbing carbon dioxide and releasing oxygen into the atmosphere. Temperate and tropical hardwoods, suitably managed, can be brought to maturity within a human lifespan; softwoods within half that period.

Timber can be best used for formwork if their replacement is promised. Otherwise, it is a threat to Ethiopia's environment in particular and global environment in general.

The advantages of timber formwork are:

a) Easy handling because it is light in weight

b) Easy to disassemble

c) Damaged parts can be replaced with new one

d) Very flexible

The disadvantages of timber formwork are:

a) Cannot be used for long period. They have limited re-use and can only be reused 5 or 6 times b) If the timber is dry, it will absorb moisture from wet concrete which could weaken the resultant concrete member.

c) Timber with high moisture content (more than 20 % moisture content) will shrink & cup, leading to open joints & leakage of grout.

Figure 2.8 **Timber Formwork**

2.10.4.5 Plywood Formwork

Plywood is used as sheathing that contacts concrete for job-built forms and prefabricated form panels. Since plywood comes in large, it saves forming time. Plywood is made by gluing together thin layers of wood, called veneer, under intense heat and pressure. The grain of each ply is laid at a right angle to the adjacent pieces. This process gives plywood extra strength and reduces shrinkage and swelling. Plywood has particular orientations that affect their strength. A weak position can be achieved when the grain (face grain) is parallel to the span of support. A stronger orientation is seen when the grain (face grain) is perpendicular to the span of support see figure below.

Figure 2.9 **Plywood Formwork**

2.11 Selection of Formworks in Ethiopia

Formwork systems are classified in many ways, according to size they are classified as small sized formwork and large sized formwork. According to location of use, it is classified as timber form and girder form, where timber is used for irregular frame structures, girder form, and climb forms are used for wall and column structures, where aluminum form is used for repeated regular section. Based on materials of construction it is classified as timber, steel, aluminum, and plastic formwork. According to nature of operation crane independent, crane dependent and tunnel type formwork system. There are different types of formwork available and are being used in the construction of reinforced concrete structure.

A plywood form is the oldest type of the formwork used in the construction industry. This is used for small construction works. This method is more expensive in usage of labor, it is time-consuming process, it is difficult to carry install and It has very poor surface finishing.

Steel formworks are fabricated of thin steel plates. Different panels can be joined by clamps or bolts & nuts. These formworks are used in a place where reuse of shuttering is needed. These are stronger and durable.

Aluminum formworks are made from high strength aluminum alloys. The panels are joined by pin of wedge arrangement system. These are light in weight and reuse of formwork is more. Installation and dismantling is very easy and have very good surface finish.

Plastic formworks are very light in weight, can be installed easily and save time & money, and are cost effective. The panels can be attached with each other with the help of locking handles. These are easier to clean and can be reused instantly and have good surface finish.

Selection of a formwork for a high-rise building mainly depends on individual's experience or by the senior members of an organization and the availability of the formwork system. This type of selection may result in cost expensive or faculty selection. The owner of an organization aims to reduce the overall cost of the project with specified quality and safety. Since, formwork is a costly item in construction he must be involved in formwork selection system process. Designer should design the building in such a way that it should have more number of similar size structures so that formwork can be used repeatedly which will reduce the cost and increase the productivity.

2.11.1 Building Design and Shape

The construction cost of slabs is often more than half the cost of structural framing systems, except in extremely tall buildings. Therefore, selection of the slab formwork system deserves considerable attention to minimize cost. The selection of a formwork system should be made based on the selected floor system that satisfies the structural loading conditions. Selection of the types of slab has an impact on the cost of formworks. For instance construction of two way slabs supported by the drop beams is relatively complex and more costly. Concerning building shape, for instance special buildings such as industrial buildings and power plants usually have extensive electrical and mechanical requirements, which do not lend themselves to any sophisticated formwork system. As a result, they should be constructed using the traditional formwork method.

Some of the shape factors that enable the contractor to decide whether to use a formwork system or a traditional forming method are:

• Variation of column and wall location

• Variation of beam depth and location

• Variation of story height

• Existence of openings for windows and doors . Designers play great role in minimizing the cost of formwork. Ease of construction should be considered besides safety, aesthetics, and other design requirements.

2.11.2 Job Specification

The most important advantage of using a modern formwork system is the speed of construction. The speed of construction affects cost because it determines the time when the building will be available for use and reduces the financial charges. The major factor that determines the speed of construction is the floor cycle time. In recent years, casting two floors or more per week in high-rise buildings has been achieved, especially in metropolitan areas. This fast floor cycle can only be achieved by using sophisticated formwork techniques such as flying forms and tunnel formwork, which are capable of forming one story every two days.

2.11.3 Local Conditions

The nature of the job, including local conditions, is one of the primary factors in formwork selection. Some of the factors that should be considered are explained below.

2.11.3.1 Area Practice

In geographic areas where the labor force is expensive and unskilled, the use of formwork ‘‘systems’’ can substantially reduce the cost. In areas where the labor force is inexpensive and skilled, a conventional formwork system is an economical alternative even if the building features are compatible with a sophisticated formwork system. As a result, some geographic areas use preassembled formwork systems because of the lack of inexpensive skilled labor force.

2.11.3.2 Site Characteristics

The building site itself may influence the selection of a suitable forming system, because of site limitations and accessibility for construction operations. The feasibility of using flying forms, for instance, is influenced by site characteristics, which include- Accessibility to the

site, Availability of a fabrication area and surrounding area restrictions such as property lines, adjacent buildings, power lines, and busy streets.

In open and unrestricted suburban sites, all forming systems are practical and some other considerations should be evaluated to determine the most efficient and cost-effective system. In downtown-restricted sites, the only possible system may be ganged units that can be transferred from floor to floor.

2.12 Removal of formwork

Formwork shall be so designed as to permit easy removal without resorting to hammering or levering against the surface of the concrete. The periods elapsing between the placing of the concrete and the striking of the formwork shall have regard to the following factors: - Concrete strength Stresses in the concrete during construction including for precast units any disturbance and handling stresses, curing, Subsequent surface treatment requirements. The presence of re-entrant angles requiring early removal of formwork to avoid thermal cracking.

The time shall be as approved by the Engineer-in-Charge after consideration of the loads likely to be imposed on the concrete and shall in any case be not less than the periods specified in the Code. Notwithstanding the foregoing the Contractor shall he held responsible for any damage arising from removal of formwork before the structure is capable of carrying its own weight and any incidental loading.

2.13 Ethiopian Standards Recommendations

The time between casting and removal of the formwork depends mainly on the strength development of the concrete and on the function of the formwork. In the absence of more accurate data, the following minimum periods are recommended:

Table 2.1 EBCS 2 Recommendation for Formwork Stripping Times

Form Work Type	Duration
non-load bearing parts of formwork (vertical formwork of beam; formwork for columns and walls)	18 hours
soffit form work to slabs	7 days
props to slabs	14 days
soffit formwork to beams	14 days
props to beams	21 days

2.14 ACI Recommendation

ACI's "Guide to Formwork for Concrete" (ACI 347R) recommends that engineer specified criteria based on strength gain is used to determine form removal time. In the absence of such criteria, the guide contains recommendations for the length of time that formwork should remain in place when the air temperature is above 10oC (Table 2.2). The time need not be consecutive, but it is the total time during which the temperature is above 10oC. When high early-strength cement is used, these times can be shortened. When air temperatures remain below 10^{o}C or retarding admixtures are used, these times should be lengthened. Unusually heavy construction loads may require longer times before form removal.

Table 2.2 ACI General Guidelines for Form Stripping Times [3]

Member	**Time**	
Walls	12hrs	
Columns	12hrs	
Sides of beams or Girders	12hrs	
Joist ,beam, or girder bottoms	Where design live loads are:	
	< dead load	>Dead load
Under 10ft(3m) clear span	7days	4days
10 to 20ft clear span	14days	7days
	21days	14days
One way floor slabs		
Under 10ft clear span	4 days	3 days
10 to 20ft clear span	7 days	4 days
Over 20ft clear span	10 days	7 days
Two way floor slabs	Contingent on reshores being placed immediately after stripping.	

2.15 Empirical Evidence

The building construction industry in Ethiopia has been massively developing in the past decades. Buildings of different purposes or infrastructure projects are being constructed in large amounts every year in cities of the country, especially in the capital Addis Ababa.

According to Wong (2015) formwork is one of the key factors that guarantee the success of these building construction projects in terms of quality, safety, cost and time. It contributes a most important part of cost in most of the building construction projects. The selection and effective use of formwork can lead to the success of a project. An appropriate formwork system is always cost and labor effective, suitable to handle, fulfilling requirements, and most significantly, it have to be safe to use all before, during and after concrete placement. Although the main purpose of formwork is molding or holding freshly placed concrete until it hardens and supports its own weight and to a specified shape, size and alignment, the continuous need of achieving better concrete surface features, construction time and cost minimizations, and safety makes the construction industry keep continuous improvements of formwork for concrete. The currently available formwork types are categorized into three major parts, namely, Conventional formwork which is oldest type and uses timber props, bamboo, and timber V planks etc., Modern Conventional formwork which is advanced conventional and uses steel props instead of timber, plywood and steel sheets instead of timber plank or panels, and System Formwork which is a modular or prefabricated type of formwork designed for advanced concrete features. The quality and surface appearance of the concrete structures is normally dedicated by the quality of formwork materials and systems. Using formwork materials with inferior quality usually leads to unsatisfactory result and defects which is the case in Ethiopia especially by local contractors (Amare, 2015). Failures to achieve the required results in concrete construction may cause additional treatments and elongated time frame which is false economy. Study on current formwork practices and trends in Ethiopian building construction industries: Case of selected contractors in Addis Ababa 2019 Selection of the formwork system which suits for cast in place reinforced concrete is a critical decision that can affect the whole construction process. With proper selection of formwork system then, cost of construction can be significantly brought down, quality of the concrete can be great, the project will be completed within stipulated time and injuries can be minimized

CHAPTER THREE
3. RESEARCH METHODOLOGY

3.1. Introduction

This chapter describes the methodology used in order to conduct the study. It describes the types of methods selected for data collection and analysis and the reasons for why these methods were chosen in comparison to the other alternative methods. The chapter consists of sections. The first two sections present the research approach and the survey design of the study. The third and fourth sections outline the sample and data related and date analysis and presentation also discussed in this chapter.

3.2. Research Design

The study used both descriptive and case study research. Descriptive research concerned with the assessment of attitudes, opinions, demographic information, conditions, and procedures (Creswell, 2012). The study used both descriptive and explanatory design. Descriptive research concerned with the assessment of attitudes, opinions, demographic information, conditions, and procedures (Creswell, 2012). The case study research design in order to do an in-depth inquiry regarding most effective application of modern formwork system for building project construction.

3.3. Research Approach

According to Creswell (2003) there are three approaches that are used in conducting a given research. These are quantitative, qualitative and mixed research approach. Quantitative research approach focuses primarily on the construction of quantitative data, and quantitative data is a systematic record that consists of numbers constructed by researcher utilizing the process of measurement and imposing structure (Kent, 2007). As per (Bryman and bell, 2007) the quantitative research approach employ measurement that can be quantifiable while qualitative cannot be measured. In mixed research approach inquirers draw liberally from both qualitative and quantitative assumptions (Creswell, 2009). Accordingly, a mixed research approach is used.

3.4. population of the study

According to Sekaran (2003), Target population is the population to which a researcher wants to generalize the results of the study. Population is the aggregate of all the elements that share some common set of characteristics and that comprise the universe for the purpose of the research problem. The population from which the sample actually was drawn and about which a conclusion was made and the study population is often more limited than the target

population (Getu and Tegbar, 2006). Therefore, population of the study are the study population to be considered in order to complete this research was surveying in different types of building in Addis Ababa. The study population was selected building construction in Addis Ababa city which includes from grade one up to grade five contractors.

3.5. Sampling Techniques and sample size determination

The study population to be considered in order to complete this research was surveying in different types of building in Addis Ababa. The study population was selected building construction in Addis Ababa city which includes from grade one up to grade five contractors. A non-probability purposive sampling method was employed to select the constructors

The sampling procedure was purposive sampling approach. Among all building construction projects, only ongoing construction projects were selected because observing the finishing surface and method of form working is vital for this study. According to the data gather from construction work there 5 ongoing building sites in Addis Ababa. From the selected construction projects 5 contractors' representative 3 consultant representative there are a total of 10 individuals per site were selected. Sampling was introduced with a view to making the research findings economical and accurate. The questioner was distributed to the contractor and consultants and filed survey was conducted. The research was conducted by using purposive sampling method. It was selected by some arbitrary method because it is known to be representative of the total population, or it is known that it produces well matched groups. The sampling was chosen purposively with regards to those contractors whose grade one up to grade five contractors. The reason is the contractor's grade one up to grade five and they are participating in large projects and they more experienced.

Since this research didn't consider sample only the target population was chosen judgmentally (Purposively). For that reason, the target population of the research are chosen based on the non-probability selection method of judgmental selection. Judgmental sampling method is preferred to collect comprehensive and reliable information from the sources having relevant knowledge and/or experience directly related to the subject of the study.

3.6 Data Source and Collection Instrument

The study used both primary and secondary sources . Primary data collection instruments used in this study were questionnaire and interview , whereas, among secondary method of data collection instrument various documents, literatures and reports were reviewed.

3.6.1 Questionnaire

Questionnaires will be prepared based on objectives of the project. Questionnaire survey will be collected from different sites and survey will be done. During collecting data, the factors considered during the selection of formwork for any project from various stakeholders will be collected. Both primary and secondary will be used to collect. The primary data is by observation & questionnaire survey.

The first part contained general information which includes name of the company, grade of the company and the respondent's position in the company. In the second part questions regarding which type of formwork system did they use, which formwork has more quality, which formwork is easy for stripping and erecting, which type of formwork materials use for the structural elements and the current cost of the formwork. The respondents were asked which type of modern formwork material is good according to their quality, cost and safety. The participants were requested to list out best formwork systems according to their quality, cost, safety and time.

3.6.2 Document Review

In this study, the project documents of the selected construction company in Addis Ababa, Ethiopia were be reviewed. On that, project description, project execution report, monitoring and evaluation reports including end year review documents were checked.

This is the method of collecting secondary data; it has advantages because the researcher is able to collect as much data as possible without limitation. The major sources of secondary data in this study included published books, journals, Papers and articles. Internet is another source where varieties of current materials were obtained which explains a lot about Project management in Health care sector.

3.7 Data Analysis Techniques

Data from questionnaires was analyzed through both descriptive and inferential statistics using SPSS software version 26 (Statistical Package for Social Science). The descriptive statistics (frequency distribution, percentile, minimum, maximum, mean and standard deviation) which helped the researcher to examined the effect of project management practices on project performance. The SPSS used to analyze the data obtained from primary sources. Specifically, descriptive statistics (mean, standard and deviation) and inferential statistics (correlation and regression analysis) were employed in this study.

Comparison was made based on the respondents' response for formwork steel and timber systems with regards to the cost of the formwork, concrete quality and speed of construction. The comparison was made by using bar and pie chart graphs under the three criteria and interpretation were given for each comparison made on site observation data. The qualitative and quantitative data that gathered from data collection process was analyzed by statistically and descriptive analysis method. The data has been analyzed to determine investigation on the effects of formwork and scaffolding types in building projects. The data was processed and analyzed in the form of table and graph. A descriptive method has been used for the analysis of the data which provides a general overview of the results in order to make interpretations and discussions based on the results. Evaluation was made based on the respondents' response for the application of formwork types in building projects with regards to the cost, concrete quality, safety and speed of construction.

3.8 Validity of the Instrument

Content validity involves the degree to which the study is measuring what it is supposed to measure. More simply, it focuses on the accuracy of the measurement (John et.al, 2007). All measures use to construct the instruments should have shown acceptable level of construct and content validity in previous studies and are used in this study with modification. Additionally, several measures were employed to ensure that the results are free from material errors from the design of the questionnaire. Such measures are clarity of instructions, clarity of the questions, the layout of the questionnaire and other comments.

3.9 Ethical considerations

According to Creswell (2012) "as the researchers' anticipate data collectors, they need to respect the participants and sites for the research''. In the study the researcher-maintained objectivity, courtesy and high professional standards through scientific process and no falsification, alteration or misrepresentation of data for biased or other purposes. The study conducted by considering ethical responsibility. This includes providing information to the respondents the purpose of the study and the use of the information as well. Information obtained held in strict confidentiality by the researcher. Respondents' anonymity was kept so that participants would feel free and safe to express their ideas.

CHAPTER FOUR

4. RESULT AND DISCUSSION

4.1 Introduction

This chapter presents the data analysis, the research findings or results, and based on the results the researcher gives discussion on the findings and also gives interpretation of the results. In order to present findings and discussions about the field observation evaluation was made for application of modern formwork system used in the building projects with respect to cost, concrete quality, safety and speed of construction; the researcher used different form of tables, qualitative and quantitative analysis were done. The data analysis intends to accomplish the objectives of the study and answer the research questions. The total number of questionnaires distributed were 60 questionnaires in order to collect data. The data collected from the respondents are presented and analyzed in this chapter. It focuses on result and discusses the result gathered from the respondents through questionnaire and field observation. Based on the gathered data from the respondents and field observation evaluation was made for application of modern formwork system used in the building projects with respect to cost, concrete quality, safety and speed of construction. This research has three objectives; to identify the types of modern formwork used in building construction, to determine the application of formwork in building construction and to compare the quality and cost of formwork used. There were thirty copies of questionnaires distributed to the targeted respondents consisting of different contractors that are involved in construction of building projects in Addis Ababa. The researcher managed to collect back 56 (93.3 %) useable questionnaires from the respondents. The collected questionnaires and their return rate are given in table. the total number of questionnaires distributed to the respondents were 58 questionnaires distributed in Addis Ababa for contractors, consultant and client.

Table 4.2 questionnaires distribution

NO	Purpose of project	Number of project	Loaction	% of response rate
1	Real State	2	Bole	95%
2	Apartemrnt	2	Megenana	93%
3	Office Project	1	mexico	94%

4.2 Response rate

As stated in the previous chapters of this paper, questionnaire was designed and distributed to a total of 60 constructors. From the total 60 questionnaires 4 were not filled and returned appropriately. Accordingly, 56 questionnaires were appropriately filled and returned which gives 93.33 % return rate.

Table 4-1: Response rate

Number of populations	Number of samples	Number of distributed questionnaires	No of respondents/ Contractor's staffs	Number of valid respondents/ contractor's staffs	Percent of valid respondents to No. of distributed questionnaires
60	60	60	56	56	**1.33**

4.3 General Information (Demographic data) of the Respondents

The first part of the questionnaire consists of items about the demographic information of the respondents. It covers the personal data of respondents, such as Sex, academic level, Age, marital status, and job types. The following tables, graphs and figures depicted for each demographic characteristic of the respondents. Respondents to the returned questionnaires have 2 years to 25 years of experiences in the construction industry in different positions as indicated in Table 4.2. 42% of the respondents, which is highest rate of Reponses, have a position of site engineers and they were the one to reply nearly for each of the questionnaire than anyone else. About half (50%) of the total respondents have 0-5 years of experience in construction industry while the remaining have more than 5 years on the field.

Table 4.2 profile of respondent

Gender	Male	36	64.3%
	Female	20	35.7%
Marital status of the Respondent	Single	5	8.9%
	Married	50	89.3%
	Divorced	0	1.79%
	Widowed	0	0%
Work position of the respondents	Owner	0	0.0%
	Project Manager	10	17.86%

	Office Engineer	20	35.71%
	Site Engineer	26	46.43%
Experience in Construction Industry	0 to 5	24	42.9%
	5 to 10	13	23.2%
	10-15	15	26.8%
	15 to 20	3	5.4%
	20 to 25	1	1.8%

4.3.1 Materials and methods of modern formwork

during assessing the materials and methods of applying modern formwork 54 respondents said timber is available formwork material, 2 respondents said steel formwork materials are most available in the country. According to the fig 4.2 57% of the respondents agreed that the most available formwork material is timber . the second available formwork material is steel formwork since 26% of respondent say so.

4.3.2 Identification of formwork materials used

According to the survey made in Addis Ababa, 70% of the respondents use combination of both steel panels and timber boards as formwork materials. These materials were used for casting concrete of almost all structural members such as column, beam, slab and wall About 5% of the respondents use steel, 20% use timber and 5% use yellow timber as formwork material. The summary of the results is shown in figure.

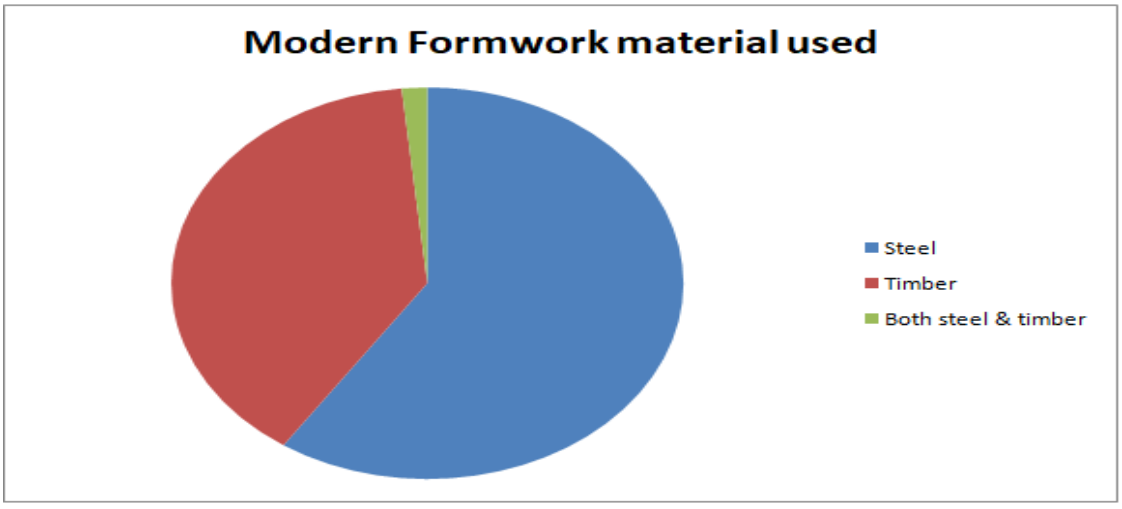

Figure 4.1: Formwork Materials Used by Contractors in Addis Ababa

According to construction formwork can be made out of timber, plywood and steel, used separately or in combination. Steel forms are used in situation where large numbers of re-use of the same forms are estimated. For small works, timber formwork proves useful. From the result Steel and timber were the most prominent formwork material in Addis Ababa. Steel formwork used in large projects with high rate of reuses and timbers used in small projects with low rate of reuses. Alternative formwork materials like aluminum, plastic and modern formwork systems are not adaptable. This is due to low financial capacity of the contractors. The higher grade contractors use yellow timber formwork. It is different from the conventional timber formwork system good for the quality of surface finish of concrete.

Figure 4.2 formwork materials uses in A.A

4.3.3 Formwork Selection Criteria Being Practiced Currently

One of the most important factors on the success of completion time and cost of many building projects is formwork practice. Results from questionnaires, observations in three sites and interviews, for the purpose of this research, from building construction projects in Addis Ababa indicated that the impact of formwork on the cost and duration of the projects is high. This indicates that proper selection of formwork to building projects can play a great role both to the owners of buildings and the contractors themselves. Because on time completion of projects helps the owners to take advantages of early usage of building structures and a one-time concrete finishing would make the contractors economically advantageous.

For the close ended question respondents were asked to rank amongst five major factors in formwork selection process, namely, cost, quality, speed of construction, safety and stock availability of materials, most of them ranked quality to fulfil the first priority as illustrated in Figure 4.3. Speed of construction took the least priority of these factors at the building construction project currently on progress in Addis Ababa. This part is aimed at knowing the priorities of main factors in formwork selection and practice at building construction projects in Addis Ababa. The rank is made by calculating

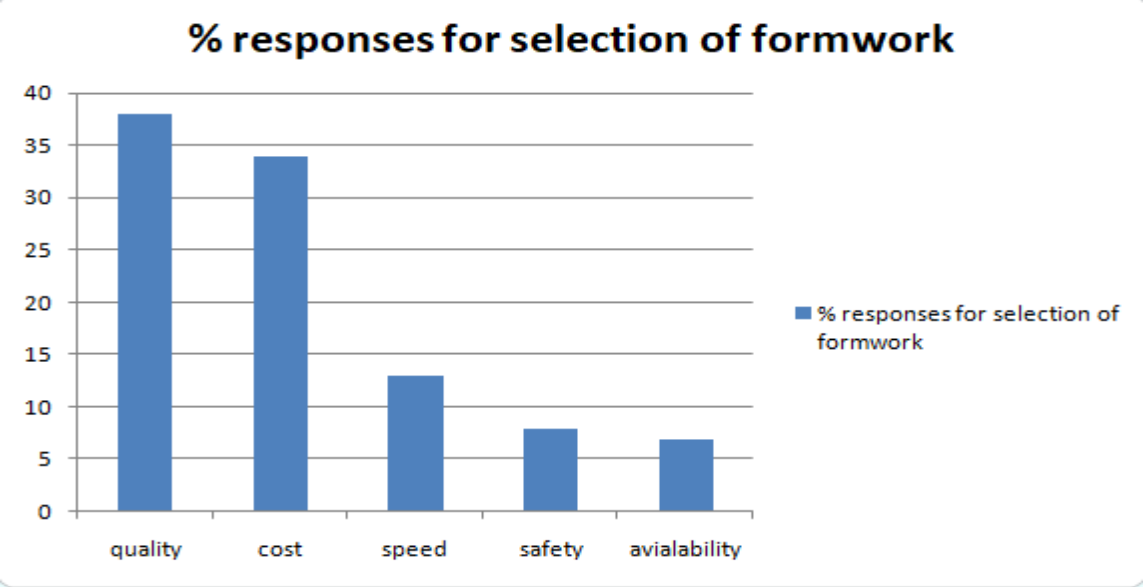

Figure 4.3 responses for selection of formwork

4.3.4 Sources of formwork material

According to the survey made, 52% of the respondents use owning (local market), 7% use owning (imported), 13% produced by company itself and 28% use rental. The higher grade contractors use their own formwork. This is due to the relatively higher financial capacity and

the lower grades use rental formwork system. The result summarized in figure 4.3.

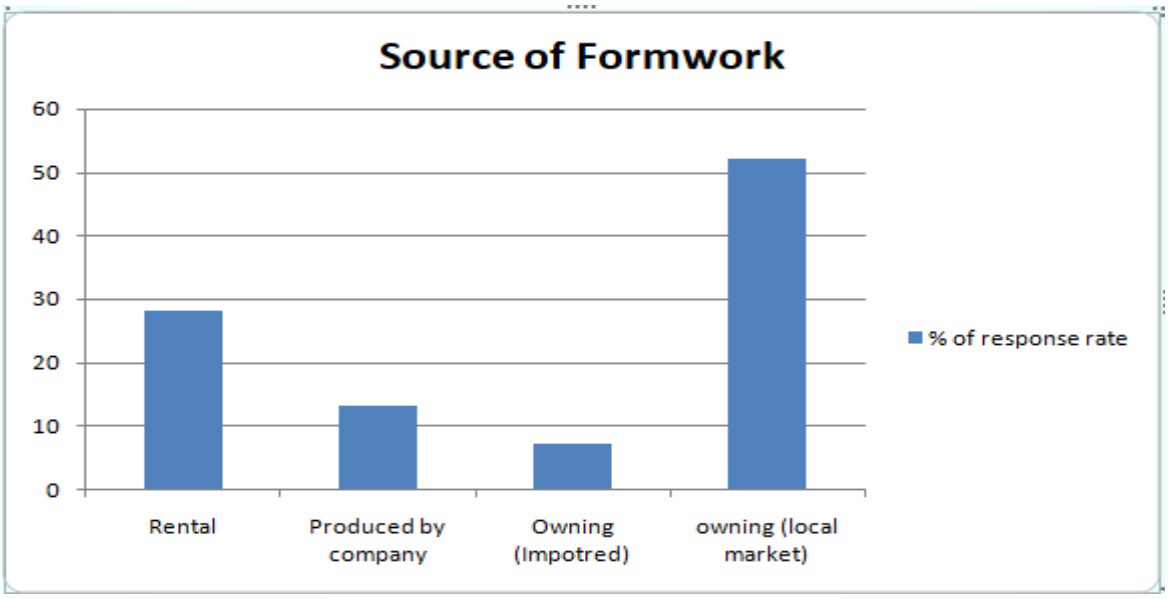

Figure 4.4 Response rate for source of formwork

4.3.5 Selection of formwork system for structural elements

In Addis Ababa the building contractors use either steel or timber formwork it depend on the structures. The respondent where asked to select timber, steel or combination of both formwork for different structural element of building such as beam, column, slab and wall. The analysis was made by using bar chart to show the respondent rate in figure 4.4.

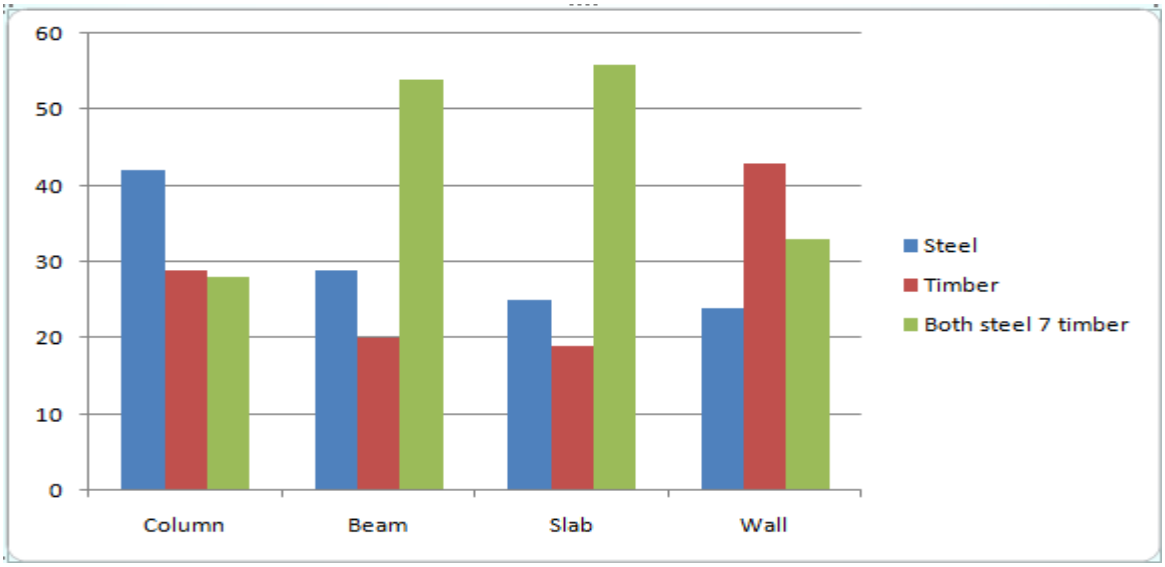

Figure 4.5: Response rate for selection of formwork for structural elements.

From the response rate for column 40% of the respondent use steel formwork, 30% use timber and 45% use combination. For beam 20% use steel, 17% use timber and 50% use combination. For slab 20% use steel, 21%. From the result columns formwork materials are

vary with their shapes, it casted by using either steel or timber formwork. For rounded shape of columns steel formwork more suitable than timber and for rectangular shaped columns steel or timber formworks are used. Also slab and beam are casted by using combination of both steel and timber formworks. Slabs require more amount of formwork material it covers large area from beam to beam. It supported by timber or steel vertical props. Beam formwork has prefabricated formwork sheeting parts (sheeting bottom and side sheeting panels). Wall formwork consists of vertically arranged upright timbers (formwork bearers) to which sheeting boards are nailed at the concrete side. Similar to beam formworks, the sheeting of column formworks are prefabricated according to the column dimensions from sheeting boards connected by cover straps.

4.3.6 The application of formwork in building construction

During construction the quality of the surface finish of the concrete is directly affected by the application of formwork materials, not only the surface finish but also the horizontal and vertical alignment and the shape of the structures also affected by the kind of formwork. The size, shape, smoothness of surface finish and alignment of the structural elements depend on the quality and accurate construction of the formwork. Steel formwork can be reused many times than timber formwork. Despite its high rate of use, the quality of the steel panels used by local contractors is not satisfactory. Dimensional accuracy includes size; shape and alignment of structural elements easily affect .The panels are not maintained well and the concrete surfaces casted using such formworks is not good for the surface finish.

4.3.7 Column formwork system in Addis Ababa

The column formworks are produced according to the column dimensions. Before placing the concrete the alignment should be checked for both steel and timber formwork. In field observation to erect the formwork first point the exact center of the column by using column spacer. Column spacer is part of the column formwork it’s used before erecting the column formwork to point the exact center of the column. The members are oiled for both steel and timber after that, tied together using timber yokes supported by diagonal props as shown in figure 4.5 and 4.6.

Figure 4.6: Column formwork construction systems using steel at bole site

After the formwork erection the vertical alignment is checked by using plumb bob. The plumb bobs are easily swing by wind loads instead of plum bob use stone on the string. The next step is measure by using meter in the upper, middle and lower outer part in two sides of the column formwork to the string after that check the vertical alignment. During the measurement the upper, middle and lower part should be equal but there might be errors 1mm to 2mm errors taken as due to wind load. The measurement results in the figure 4.5 upper part 19mm, in the middle 22mm and in the lower 21mm. In addition to this the measurement results in the figure 4.6 upper part 30mm, in the middle 31mm and in the lower 30mm. The formworks are disassembled until to get the correct vertical alignment. The joints are covered to prevent leakage. Therefore vertical alignments are checked before placing the concrete. From the result conclude that formwork affect the alignment of structural elements.

Figure 4.7 : Column formwork construction systems using timber at bole site

4.3.8 Beam and Slab formwork System in Addis Ababa

In application of modern or standard formwork very important to select the appropriate formwork kind for different structures. Concerning beam formwork, the construction system is not different from others members. Timber or steel panels are used as sheeting material. To check the horizontal alignment of beam and slab by using hand leveling. After erection of the formwork before placing the concrete alignment should be checked. Put the leveling instrument horizontally at both ends of the side formwork. The bubble of leveling should be at the center if the alignment is correct the bottom formwork is a horizontally placed formwork for the slab and beam. The side formwork is a vertical formwork for the slab at the beam side and prop/shore is the part of formwork which mainly for holding the bottom formwork in position. At the beam side the pope must be erected straight each other; it can check by using meter or string.

Figure 4.8: Slab and beam formwork bole site.

4.3.9 Application of steel formwork system on the concrete surface finish

After the vertical and horizontal alignment checking the concrete was placed. The formwork removed or striped by following EBCS standards. In figure 4.9 columns casted by using steel formwork and having size 50cm*30cm after 18hr the formwork removed or striped, check the column dimension using meter 52cm*33cm it has some variation from the actual size. So the formwork material has influence on the size of column Also discolorations on the surface finish of concrete due to the burned oils. However, to make stripping easier all the member of formwork oiled burned oils but steel formworks doesn't absorb oil like timber it requires more oil and caused discoloration on the concrete surface finish. There is some roughness on the edge of the column this is due to improper stripping of the formwork. These problems are caused due to lower quality of formwork material. Therefore to correct these problems it requires chiseling the concrete surface. Improper stripping of formwork has effect on concrete surface. To make stripping of formworks easier both steel and timber formworks should be oiled. But the release oil has effect on the concrete finishing surface. Timber formwork also requires chiseling but it requires slight chiseling compared to steel.

Figure 4.9: Column after stripping of steel formwork some roughness and discoloration on concrete surface at bole site.

4.3.10 Application of timber formwork on the concrete surface finish

Timber formwork removed or striped for column formwork the same as steel. As shown in figure 4.10 column having size 40cm*30cm after 18hr the formwork removed or striped, check the column dimension using meter 41cm*31cm it has some variation from the actual size. Timber with high moisture content (more than 20 % moisture content), wet concrete will shrink & cup leading to open joints & leakage of grout. Can't be used for long. Have limited re use. In addition to this timber formwork with high observation capacity affects the concrete strength and also discoloration of the concrete surface finish. Improper stripping of formwork has effect on concrete surface. To make stripping of formworks easier both steel and timber formworks should be oiled. But the release oil has effect on the concrete finishing surface. Timber formwork also requires chiseling but it requires slight chiseling compared to steel.

Figure 4.10: Column after stripping of timber formwork at megenagna site

4.3.11 Effect of chiseling on concrete surface

From the respondents rate chiseling the surface has an effect on the concrete structure yes or no question.

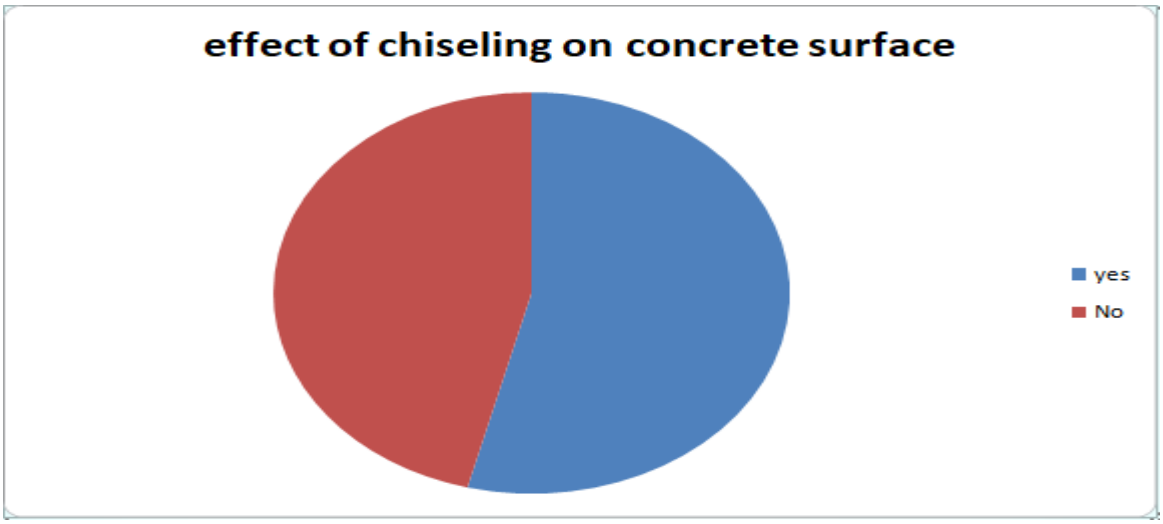

Figure 4.11: Respondents rate on chiseling concrete surface

According to the respondents rate the higher grade contractors prefer timber formwork is more accurate in the time of placing concrete mix, accuracy include size, shape and alignment of structural elements than steel formwork. The lower grade contractors prefer steel formwork were more accurate in the time of placing concrete mix than timber. Steel formwork can be re-used many times, the high initial cost of providing the form often discourages its selection, especially when there is no need to re-use them too many times, for

example in a low-rise development. In addition to that timber formwork can't be used . According to the survey data 100% of contractors say steel formwork reuses many times than timber formwork. From the survey made, steel formworks are used more than ten times without caring for its maintenance and cleaning also timber formwork were used four times. Most of the contractors clean the panels after the concrete was set on them. Cleaning method is done by adding water on set concrete and using sharp metals to release it. Such cleaning procedure affects the quality of panels.

4.3.12 Quality of concrete finish

The different points of related to concrete finish quality were raised on the questionnaires to be rated by the respondents. The quality of concrete finish is affected by the application of modern formwork. Type materials. Accordingly, among the total 56 respondents , 40 of them were strongly agree ,4 were is agree , and 3 of them were natural. Using steel formwork more repeatedly results poor quality of concrete finishes, incorrect alignment, bad joints , offsets , poor facing material .

4.3.13 Cost of form working in Addis Ababa

in assessing the cost of applying formwork materials, 26 (94%) respondents said that timber has lowest cost. Whereas 2 respondents (6%) said that coated plywood has the lowest cost an 2 of respondents steel has the lowest cost. other choices like plastic, ammonium, bamboo, precast formwork materials were not selected by any of the respondents as a cheapest formwork material. From the above research fining timber is the cheapest formwork material. As indicated in Table 4.3, financial capacity of the construction company is one of the leading factors that affect the selection of formwork for a specific building construction project in Addis Ababa. Formwork is the area that contractors can save costs, if selected and practiced properly. Flat slabs are currently preferable by most of the designers in Addis Ababa. These slabs have reduced the area and complexity of formwork; which in turn reduces costs and wastages of forms. This is because beams are casted in slabs and only soffit area is added to slab area. Form areas that would be required for both sides of beams are omitted, which reduces the cost of formwork. The other importance of flat slab is that it allows using the whole shuttering panels to all rooms with no cut requirements which plays great role to the formwork economy by reducing wastage. But the same factors that affect reusability of forms discussed in affect the cost of formwork currently practiced despite the advantages of flat slabs. According to the questionnaire survey and observations in some

building projects in the city, the minimum cost of formwork is 23% and 32% of concrete work by local and international contractors respectively. Construction of formwork involves considerable costs in terms of material, labor for assembling, erection and removal of. The average cost of forms including these costs are 950 Birr/m2 for plywood and 2200 Birr/m2 for steel sheets respectively. Table 4.9 indicates costs of forms currently used, up to 6 repetitions for plywood, which is maximum and 10 repetitions for steel sheets, which is nearly minimum in most of the sites.

Table 4.3 Cost of different formwork materials currently practiced and reuses

Number of reuses	Total unit cost of formwork	
	plywood	Steel sheet
1	950	2200
2	475	1100
3	316.67	733.33
4	237.5	550
5	190	440
6	158	366.67
7	-	314.28
8	-	275
9	-	244.4
10	-	220
Cost/m2	378	378

According to the respondents, the minimum number of uses for plywood and laminated board is 3 times. But plywood is used up to 6 times in some building projects sites while laminated board is up to 4 times. Steel sheets on the other hand, are said to be used for a minimum of 8 and more times depending on conditions of the project sites. Costs of formwork have gone down to 316.67Birr/m2 for plywood and after the minimum number of uses, i.e. 3 times for both as indicated in Table 4.9.. But those local contractors who are using plywood up 6 times could reduce the cost to 158 Birr/m2 compromising quality of the concrete surface finishing if forms are not cleaned and repaired properly. The cost of steel sheets can also be reduced 275 Birr/m2 and below after 8 repetitions, which is the minimum currently practiced number of uses. The contract amount currently practiced are 378 Birr/m2 for plywood considering the cost of materials, labors, form treatment oils and number of uses

4.3.14 Comparison of the quality, cost of steel and timber formwork

The formwork material plays a great role on the quality of concrete surface finish, size and dimension. According to the respondents rate timber formwork is more accurate in the time

of placing concrete mix, accuracy include size, shape and alignment of structural elements than steel formwork the result summary shown in figure 4.12.

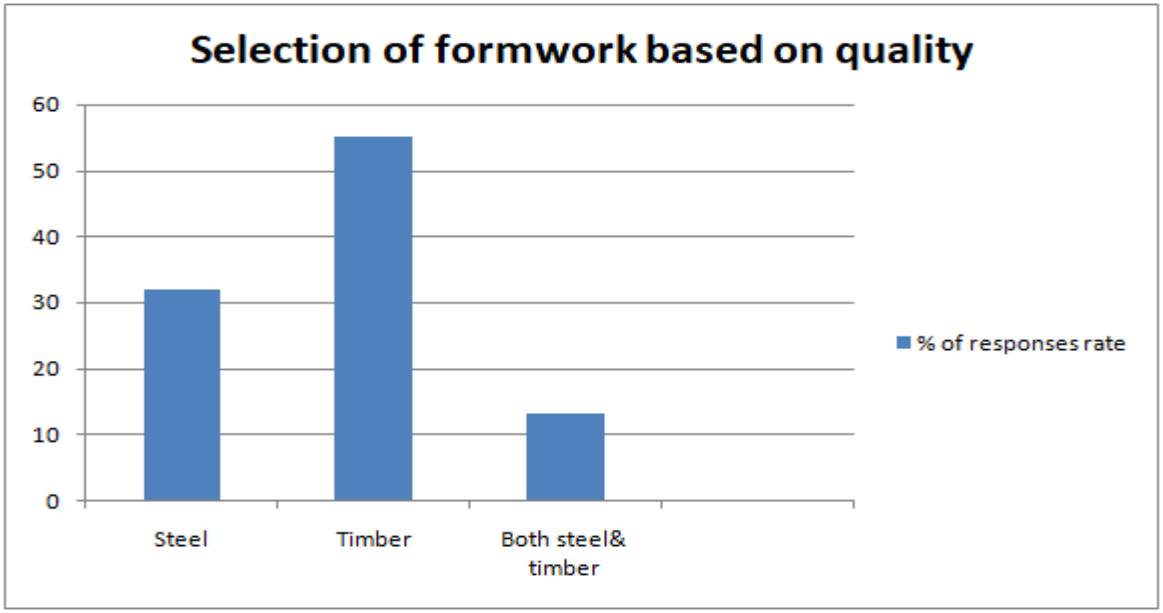

Figure 4.12: Response rate for selection of formwork based on Quality

According to the respondents rate the higher grade contractors prefer timber formwork is more accurate in the time of placing concrete mix, accuracy include size, shape and alignment of structural elements than steel formwork. The lower grade contractors prefer steel formwork were more accurate in the time of placing concrete mix than timber. However that Steel formwork can be re-used many times, the high initial cost of providing the form often discourages its selection, especially when there is no need to re-use them too many times, for example in a low-rise development. In addition to that timber formwork can't be used for long. Have limited re-use. According to the survey data 100% of contractors say steel formwork reuses many times than timber formwork. From the survey made, steel formworks are used more than ten times without caring for its maintenance and cleaning also timber formwork were used four times. Most of the contractors clean the panels after the concrete was set on them. Cleaning method is done by adding water on set concrete and using sharp metals to release it. Such cleaning procedure affects the quality of panels and subsequently quality of concrete surfaces. Improper storage of steel panels has also resulted in bending and rusting of the elements. Steel formwork has higher initial cost than timber and can be reuses many times for large projects but its quality may become lower and lower with high rate of reuses. Timber formwork can't be reused many times but for the quality of structures it is preferable. It is suitable for small projects. Timber formworks requires more

time for erection and stripping and the skilled man power if care should not take the timber become easily broken but steel formwork does not. The respondents rate for the quality, cost and speed of construction formwork system from steel and timber shown in figure. 4.13

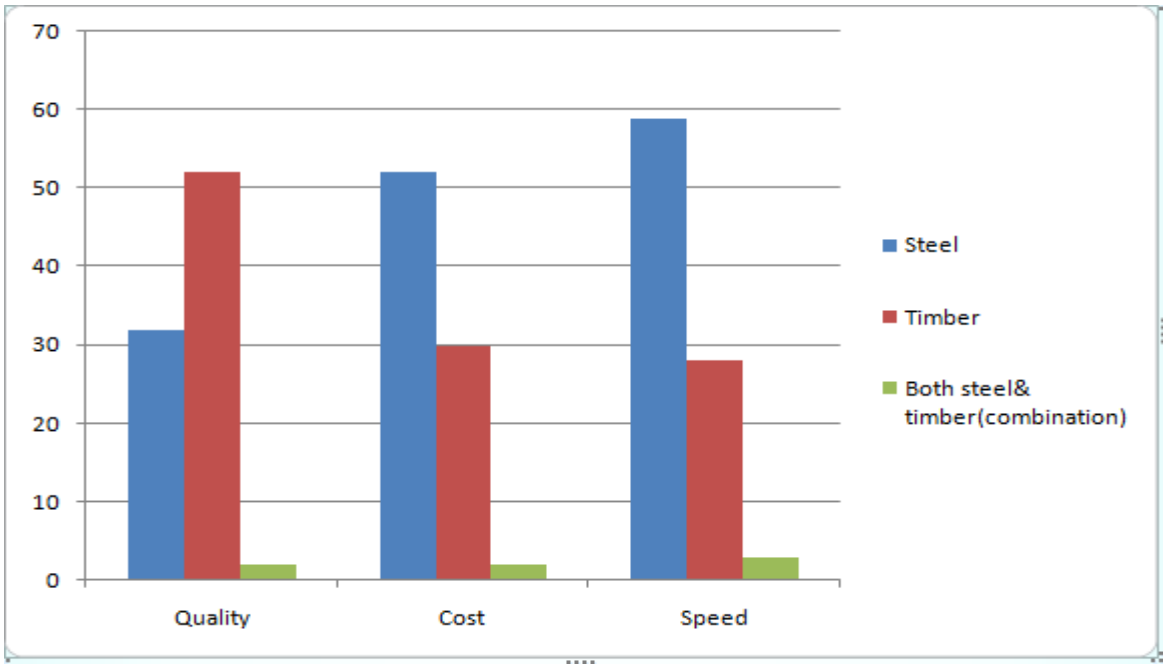

Figure 4.13: Response rate of Formwork quality, cost and speed

According to the respondents rate 52% of the respondents prefer for the quality of concrete timber formwork, 52% of the respondents prefer steel formwork in their cost and 59% of the respondents prefer steel has good speed of construction.

Remark that the timber bring used for formwork must satisfy the following requirements. It should be durable and treatable, have sufficient strength characteristics and light weight, it is economical for small construction jobs. It can easily be made into any shape or size. And it is easy for transporting purpose for in between sites. The kind of formwork material plays a greater role on the quality of finished concrete. The finished surface of concrete dimension, smoothness and regularity governed by the formwork type. Timber more suitable for small projects in addition to this majority of the contractor prefer for the smoothness of the concrete finished surface timber formwork.

Steel formwork is reused many times for large projects its high rate of use minimize the quality. The reuses are made without maintenance and cleaning of the formwork. Also lack of stock resulted in bending and rusting. Because of this all the above mentioned problems steel formwork has low quality than timber formwork. The speed of construction done by steel and timber formwork system, that means erection time and stripping time is steel formwork is

preferable than timber. During erecting and stripping time timber requires more care because it easily become broke .Therefore steel formwork take shorter time for erecting and stripping than timber formwork system. Steel formwork mostly used in large construction projects or in situations where large number of re-uses of the same shuttering is possible. It is Suitable for circular or curved shaped structures such as tanks, columns & also used for structures like sewer tunnel and retaining wall. Strong, durable & have longer life. Steel can be installed & dismantled with greater ease & speed resulting in saving in labor cost. No danger of formwork absorbing water from the concrete and minimizing honeycombing from the literature review and respondents rate according to quality, cost and speed of construction steel and timber formwork has their own merits and demerits. Summarized in the table Merits and Demerits of steel & timber formwork.

A modern formwork system is essential to meet the construction on well in time and at competitive rates. However the modern formwork system requires more price than conventional system. Hence costing of formwork for a particular project is very critical for the engineers. Considering the factors like the efficiency of formwork being linked to the succeeding & preceding activities, idling at sites and poor planning; the time-bound costing method ends up with higher formwork costs especially on materials for no fault of formwork.

Table 4.4 summary of merit and demerit formwork

Steel formwork	Timber formwork
Reuses many times	Less initial cost
Good speed of construction	Good for surface finish/Smoothness
Strong and able to carry heavy loads	Light in weight/ easy to transport
Higher initial cost	Shorte life
Lower quality for the surface finish	Easily broken

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The building construction industry of Addis Ababa used basically two types of application formwork systems, timber and steel. Good quality of formwork can contribute a great too good quality of concrete. The building surface finish, alignment, size and shape affected by the kind of formwork. The formwork material plays a major rule in the safety of workers and the structure. Based on the results and discussion; the following major conclusions have been derived and summarized in accordance with the objectives of the study. Steel and Timber boards are the most commonly used formwork materials in Addis Ababa.

Recently, an increase in economical reinforced concrete (reinforced concrete) structures has been conspicuous in Korea due to the development of structure technology and construction materials. In the tall building construction project with reinforced concrete structures, formwork represents a high percentage of construction cost and construction duration, and affects the subsequent processes, and thus the selection of a formwork system that is suitable for field conditions is an essential factor for project success. Decision-making on the selection of a formwork system, however, still depends on the experience and intuition of some working-level employees. In this regard, it is necessary to obtain tools that can scientifically and systematically support decision-making, given that more and more building construction projects have become bigger and taller. In this regard, this study proposed a formwork selection model. Having analyzed the results in previous chapter, the following conclusions were made:

As per the types of formwork categorized for this research, 58% of the¬ respondents are using modern conventional, 36% conventional and 6% system formworks.

Plywood is the most widely used formwork material by local while laminated¬ board is used by international contractors as form material.

From the respondents, 81% of revealed that formwork has great impact on cost¬ and duration of total project. The minimum costs of formwork according to this research, are 23% and 32% of the concrete structures, for local and international contractors respectively.

Corners of structural elements and surfaces at the form joints, through which¬ slurry leaks, are the most common imperfection areas by the local contractors. And hence chiseling and plastering these areas is necessarily required to make them straight, smooth and uniform.

Selection of formwork is highly affected by the financial capacity of the¬ contractors followed by availability of formwork material in the company and market.

One of the root causes for poor formwork practices by some of the local¬ contractors in Addis Ababa is, striving to compensate the low bid amount by low-cost materials, for example, used oil which highly affects the formwork.

Poor workmanship, shape of building structures and, selection and application of¬ improper form release agents are the most common practices which limit number of reusing forms and cause defects on the finishing surface of concrete.

From the analysis generally one can say that the cost of formwork that used in selected projects vary up to 30 % of the concrete frame

5.2. Suggestions

Based on the findings of the research, the following issues are recommended to steel and timber formwork.

- The government of Ethiopia should support local contractors in importing modern formwork systems free of duty and provide loans to contractors so that they can purchase the desired formworks. Long term loan with fair interest rate from both government and private banks will alleviate the liquidity problems of most contractors in owning new formwork systems.
- To keep its quality, it should be maintained after every reuse, clean it well, painting is applicable and stock in suitable place.
- To prevent or minimize deforestation steel formwork and scaffolding with longer life reuses more preferable.
- Regulatory bodies such as Ministry of Works and Urban Development should prepare standard specification which incorporates details of materials of formwork, appropriate release agents, stripping time, strength requirements for different structures etc. Minimum requirements which suit to Ethiopian case should be set by

such bodies. Modern formwork technology applied as substitute in place of conventional formwork system.

- To minimize formwork utilization prefabricated (precast) and modular construction was recommended.
- Many construction companies chisel the concrete surface for plastering and because of the quality of formwork. For plastering instead of chiseling rush coat is better. And also, through the use of modern formwork the cost of plastering and chiseling will be minimized.
- Regulatory body should include the use of standard/modern formworks as the requirement for licensing of at least higher grade contractors
- Formwork materials should be selected considering safety of both the concrete structures and labor.
- Contractors should consider cumulative cost savings from extended life of¬ formworks rather than initial costs which are minor compared to cost of concrete structures, for example burnt oil, which affects life of forms.
- Contractors should train the laborers to make them more effective and efficient for economical results.
- Government of Ethiopia should prepare concrete finishing standards and¬ checklists which will help to select suitable formwork materials and workmanship.
- Contractors should be able to design their formwork systems for the sake of safety of their workmen and third party. The design will also help them in achieving economy in formwork construction. For instance very closely spaced props in Ethiopian construction projects should be improved through designing of the formworks. This can be done by implementing new systems such as metal props whose properties are well known and easy to design.
- Associations such as Civil Engineering, Contractors and Construction Management should prepare guidelines on rental systems in Ethiopia. They should also encourage professionals to conduct further research on formworks and scaffolds systems in Ethiopia so that the problems in the construction industry will be alleviated.

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Appendix

Section 1: Respondent`s (personal) Information

1. Job position in the company:

Owner ☐ Project manager ☐ office engineer ☐ site engineer ☐ other ☐

2. Experience in construction industry:_____ years.

3. Experience in building construction:_____ years.

4. Number of building projects you have participated:_____

5.Name of the company_____

Section 2: Formwork

1. In your construction company, which type of formwork system did the company use? Mark on the boxes.

Steel formwork ☐ Timber formwork ☐

Combination of both ☐ neither of them ☐

Other formwork system ☐

please ☐

specify_____

_____

2. Which type of formwork material is more accurate in the time of placing concrete mix ☐ (accuracy include size, shape and alignment of structural elements) .Mark on the boxes.

Steel formwork ☐ Timber formwork ☐

Combination of both ☐ neither of them ☐

Other formwork system ☐

please ☐

specify_____

_____

3.What are the differences, if any, in the relative importance levels of formwork selection criteria according to the "professional title" of the construction professionals?

_____

4.What are the critical Formwork selection criteria in building construction projects?

_____

5.Please rank the following factors according to their priority in your formwork selection criteria from 1-5. Quality Cost Speed Safety stock availability of material

6. For the smoothness and regularity of concrete surface, what type of formwork system do you recommend for building construction? Mark on the boxes.

Steel formwork ☐ Timber formwork ☐

Combination of both ☐ neither of them ☐

Other formwork system please ☐

specify_____

_____

7. Do you think that chiseling the surface has an effect on the concrete structure? Yes _____ No ___

8.Which design codes (standards) have you commonly used in designing formwork for your building projects?

EBCS ☐ ACI ☐ BS ☐

Others, please specify_____

9. What type of formwork material is easy for erecting and stripping? Mark on the boxes.

Steel formwork ☐ Timber formwork ☐

neither of them ☐

Other formwork system please

specify_____

_____

10. Which type of formwork materials does your company use for the following structural elements? (Thick on the table for each structural element) .

Structural Element	Steel Formwork	Timber Formwork	Both Steel & Timber Formwork(Combination)
Column			
Beam			
Slab			
Wall			

11. Which type of formwork material is good according to their quality, cost and speed? Please rank the materials for their quality, cost and speed (1 for very good, 2 for good)

	Steel Formwork	Timber Formwork	Both Steel &Timber Formwork(Combination)
Quality			
Cost			
Speed			

12. Which type of formwork material has less cost including its labor cost? Please specify its cost coverage in percentage.

a. Steel_____

b. Timber_____

c. Other please specify

_____

_____

13. Please specify the reusability of your formwork. Describe the number of times you use before disposing of the form material. (Please fill the number in the table)

No.	***Form Material***	***No of reuses***
1	Steel	
2	Timber board	
3	plywood	
4	Aluminum	
5		
6		

14. What is the source of your formwork materials? (Please mark on the boxes you can mark more than one item. Owning (purchase from local market)

Rental

Produce by company itself

15. Which type of formwork material reuses many times? Mark on the boxes.

Steel formwork ☐ Timber formwork ☐

16. What is the current rental rate and purchase price for the following formwork materials?

Formwork material	Formwork sizes	Rental rate Per m2 per day	Purchase price per m2
Steel			
Timber			

17. Is there any support made by government in importing such formworks?

Yes------ No----------

18. From which formwork rental companies do you hire formworks? (please circle on the letter of your choice)

a. Local Companies ☐

b. International Companies(imported) ☐

c. Both ☐

19. Is there any contract document for the rental formwork? For instance, clauses related to damaged formwork, cleaning, maintenance during return, rental rate computation etc.(please tick in the boxes) Yes No Please, describe if you have different rental system_____

_____

_____

Setion 3 Formwork Construction Systems

1.Please choose the formwork systems that your company is using or specify other methods if any.(please write yes or no in the space provided)

i. Modern formwork Systems ☐

ii. Conventional formwork systems ☐

2. Please explain your reason, if you are not using modern formwork systems.

_____

_____

3. Which method of erecting and stripping formwork is used in your company?

(tick in the box)

Using labor only in transporting, erecting and stripping ☐

Using labor and Cranes in transporting, erecting and stripping ☐

Using labor and other hoisting equipments in transporting, erecting and stripping ☐

Please describe if there are other methods _____

_____

5. How long do you wait before stripping slab and beam soffit formworks? (please fill the average number in the space provided)

a. Slab (steel formwork casted with OPC cement) _____days

b. Slab (steel formwork casted with PPC cement) _____days

c. Slab (timber formwork casted with OPC cement) _____days

d. Slab (timber formwork casted with PPC cement) _____days

e. beam (steel formwork casted with OPC cement) _____days

f. beam (steel formwork casted with PPC cement) _____ days

g. Beam (timber formwork casted with OPC cement) _____days

h. Beam (timber formwork casted with PPC cement) _____days

Section 4.Design and Specification of Formworks

1. Have you ever designed the formworks for the applied loads? (please tick in the box) Yes No If yes, which design codes (standards) do you use?

EBCS ☐ ACI ☐ BS ☐ DIN ☐

specify if

other_____.

What is your opinion (if any) on the significance of formwork design? _____

_____

_____

2. Which type of props for slab and beam do you often use? Please rank in order of usage, if you use more than one material. That is (1 for highly used, 2 for less used etc.)

Wooden ☐

Steel ☐

Aluminum ☐

other, specify____

3. Which formwork materials are commonly specified by local consultants? Please rank the materials in order of specification (1 for most specified, 2 for less specified etc.)

1._____ 2._____ 3._____ 4._____

4. Are you satisfied with current formwork specifications by local consultants? Yes No If No ,what do you propose to improve it,_____

_____

_____

_____

5. Do consultants provide the design loads to the contractor? Yes_____ No_____

6. Do consultants provide the minimum strength of concrete, for beams and slabs in particular, before removal of formworks? Yes No

7. Is there any general specification of formworks made by the regulatory body (MWUD) which serves as guide? Yes No; if there are others, please list them

_____

_____