ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

COST, QUALITY AND SPEED COMPARISON OF STEEL AND TIMBER FORMWORK SYSTEM USED FOR BUILDING PROJECTS

(A CASE STUDY IN ADDIS ABABA)

BY

BEREKET AMARE SIDA

A thesis submitted to

The school of graduate studies of Addis Ababa University in partial fulfillment of the requirement for the degree of Master of Science in Construction Technology and Management

October 2015

ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

ADDIS ABABA INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

COST, QUALITY AND SPEED CIMPARISON OF STEEL AND TIMBER FORMWORK SYSTEM USED FOR BUILDING PROJECTS (A CASE STUDY IN ADDIS ABABA)

By Bereket Amare

Approved by Board of Examiners

Dr. Ephraim Senbetta
Advisor **Signature** **Date**

Prof.Dr.Eng Abebe Dinku
Internal Examiner **Signature** **Date**

Eng. Yebeltal Zewdu
External Examiner **Signature** **Date**

Mr. Fasil Tebeje
Chairman **Signature** **Date**

Acknowledgements

I would like to acknowledge different people and enterprises that have assisted me in realization of this research work. In particular, I wish to extend my gratitude and appreciation to my advisor Dr. Ephraim Senbetta, who had guide and advised me in this research work. I also extend my grateful acknowledgement to all my best friends and all relevant enterprises for their invaluable assistance and cooperation in conducting the data collection work and questionnaire during my research.

Last but not least, I thanked my families for their continuous moral support during study.

Contents

List of Tables

List of Figures

Abstract

The type of formwork system used is the key factor in determining the success of building construction project in terms of cost, quality, and speed. Completing the project with estimated cost, time and specified quality is the measure for successful deliverance of the project to client but almost all building projects in our country are not lucky to be delivered successfully to the client. The underlying problems include relatively high price than estimated cost, delay in construction and low quality of finished concrete. The type of formwork used can be mentioned for the poor performance of the construction sector of Ethiopia is usage and practices of inferior quality of formwork system. Pointing out the usage and practices of formwork system this research study the comparison of steel and timber formwork with regarding to cost, quality and time of completion of selected building construction projects in Addis Ababa.

The study was conducted by selecting thirty building projects from Addis Ababa that are under construction during the study period. The projects comprise different category of building such as office, commercial, apartment, multipurpose and hospital buildings. Questionnaires and interviews were conducted in the projects to get relevant data which helps to achieve the objectives of this thesis. Formwork rental companies and regulatory bodies in Addis Ababa were also interviewed.

The research finding indicated that the average meter square cost of steel formwork is higher than timber formwork the cost difference varies based on the type of structural element, for instance cost of steel beam formwork is 17.05% higher than timber beam formwork and for column steel formwork is 22.88% higher than timber formwork, Taking average the difference is steel formwork costs 16.96% higher than timber formwork. Regarding to the speed of construction the research finding indicated that the steel formwork construction gives faster phase of construction and concerning with the quality of finished concrete modern formwork system creates good surface concrete.

Keywords: Building Construction; Formwork; Cost; Quality; Speed; Concrete; Project Management; Project

Chapter 1 Introduction

1.0 Introduction

The interest of all stakeholders that are involved in the building construction industry is to get successfully completed project at the end. The current condition of defining successful construction project include the completion of the project within budgeted cost, allocated time, at the proper performance or specification and with minimum construction work injury. Thus managing successful building construction projects require addressing issues of cost, speed, quality and safety of construction.

Among many factors formwork systems are key factors in determining the success of a building construction project in terms of cost, speed, quality and safety of work. Selecting poor quality of formwork systems in aiming to minimize the cost of project will directly affect the speed and quality of construction through problems such as misalignment, misplacement or holding up other works causing serious interruption can result. Similarly aiming purely at speed often contradicts the achievement of other quality targets and budgeted cost of the projects. The quality of the resulting concrete is dictated by the quality of formwork materials and workmanship that affects the cost and speed of construction. The design and use of the right formwork system, as well as stipulation of an effective resource planning strategy to control and maximize the use of the formwork, are crucial to the overall success of a project.

1.1 Background

Almost all construction projects are undertaken having a predefined cost, completion time and quality. Common assessment of the success of construction projects is that they are delivered on time, to budget, to technical specification and meet client satisfaction. From the view point of cost, completion time and quality of the projects, the construction industry of Ethiopia is not at required level compared to the rest of the world. Among different factors that contribute to poor practices of construction industry of the country, the usage of inferior quality of formwork systems.

The building construction industry of the country used basically two types of formwork systems, timber and steel panel formwork systems. Due to long existence and preference by most local contractor timber formwork is the most dominant type of formwork used in the building construction industry of the country. However, due to the large scale of work, shortage of timber panel and involvement of foreign contractors in the construction industry steel panel and engineered wood formwork systems are being used in small scale in the building construction.

The debate between timber and steel formwork system for concrete element is one of the critical issues that has to be consider in current time because the construction sector of the country at booming rate of growth. Knowledge of the two formwork system may be helpful for contractors make decision which type of formwork system can be best for the specific project.

Low initial cost, high adaptability to complicated shape and with labour intensive method of construction traditional timber formwork can be best option for the contractor to reduce the cost of formwork. But with labour intensive method construction erection and dismantling this formwork requires enormous time which leads to delay of the projects and ultimately in increase cost of the projects. In addition to this repetitive use of traditional timber formwork worn out its form very rapidly which in turn create quality problems, such as deformed concrete surface and poorly finished concrete, which require additional cost for remedial measurement of finished concrete.

In another scenario steel formwork with longer life and more in number of reuse can be greater advantage than traditional timber formwork for the contractor. Steel panel can also be installed and dismantled with better ease and speed as compared to traditional timber panel formwork but they required higher initial cost to purchase or to rent. When concrete sections are large, equipment such as crane is needed to handle the steel panel which is unfortunate for most of the contractors in the country due to their limited capacity.

With above perspective this research work is intended to compare the cost, time and quality consideration in the utilization of timber and steel formwork in building construction industry of Ethiopia. The study will focus on building projects that are under construction in Addis Ababa. Thirty projects are selected randomly that represent the true nature of the construction industry of the country.

The research is provoked by the current rapid development of construction industry of the country. Rapid increase of the industry creates a need for cost effective, timely and high quality projects, which satisfy the stakeholders that are involved in the construction industry of the country. Thus in order to address the need of the construction industry of the country it is a wise decision to select the type of materials and method of construction for temporary works, formwork and scaffolding, which are important factors in determining the cost, completion time and quality of the projects. In addition to above stated reasons there is also no detailed study regarding to practices and usage of formwork system in our country. Therefore, this thesis tries to give the overall practices and usage of formwork system in the construction industry of the country with detail literature review.

1.2 Problem statement

Building projects that are delivered within estimated cost, specified quality and calculated time can greatly satisfy client, contractor and consultant and also the project can be said it is delivered in successful manner. But almost all building projects in our country are not lucky to be delivered successfully to the client (Fetene Nega, 2008). The underlying problems include relatively high price than estimated cost, delay in construction and low quality of finished concrete.

In my opinion, among main factors that can be mentioned for the poor performance of the construction sector of Ethiopia is usage and practices of inferior quality of formwork system. Different literature point out that type of formwork used in the construction sites is among the key factor in determining the success of a construction project in terms of cost, quality and construction speed of the projects. Pointing out the usage and practices of formwork system this research study the comparison of steel and timber formwork with regarding to cost, quality and time of completion of building construction projects in Addis Ababa. Brief description of the main problem and sub problem of the study is given below in table 1.

Table 1: Problem statement

Main Problem	**Timber formwork systems versus steel formwork systems, and which is truly better for the contractor?** This research will compare the two methods of formwork systems for building elements and attempt to provided comparison between steel formwork systems and timber formwork systems.
Sub Problems	**1. Which system will provide the best value for money to the contractor?** This will identify which system provides the best value for money for the thrifty contractor
	2. Which system ensures a better quality of finish concrete element? This will identify which system produces the most uniform, straight, smooth, flat and attractive concrete surface
	3. Which system provides faster speed of construction? 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. This will identify which system best for completing the project faster.

1.3 Objectives

The objective of this research work is following

- Cost wise comparison of timber and steel formwork system used for building projects.
- To compare quality of finished concrete made by timber and steel formwork system
- To compare the speed of construction of building projects that use timber and steel formwork system.

1.4 Scope and Study Area

The scope of this thesis is limited to the structural elements of building projects such as column, beam, slab, shear wall and stair that are casted in the construction site. In addition this research will be based on the comparison of two type of formwork for concrete elements. It will not be focused on the rivalry between two specific opposing systems, nor that between two different manufacturers. The purpose is not to prove that one product is superior to another, but rather to determine which systems, steel panel or timber panel, are superior.

The research was conducted in Addis Ababa for different category of building type such as apartment, office, multipurpose, condominium and hospital buildings. The study compromise different category of contractors, starting from grade 6 up to grade 1 contractor, involved in the construction of building projects.

1.5 Methodology

This research work was accomplished with a combination of the following research methods.

- Thorough and a detail literature review is conducted on books, codes of practices, specifications, magazines or newspapers and relevant websites to learn about the factors that influence the cost, completion time and quality of constructed projects with respect to usage of steel and timber formwork systems.
- Thirty building projects that are under construction in Addis Ababa are selected for case study. A simple random sampling technique is implemented to select these building construction projects.
- The primary data of this research is collected by survey data collection methods such as questionnaires, observation and personal interview
- Reviewing contract documents, specification and archival records taken as means of secondary data source for this research.

- The results will be presented in tabular and graphical forms and the analysis and discussions will also be made on the research findings both qualitatively and quantitatively.

1.5 Glossary of Terms

This glossary provides some basic definition for formwork terms used in this thesis. Definitions are taken from America Concrete Institute (ACI-347, 2009) and Formwork for Concrete book (Hurd, 2005)

FORM

-A temporary structure or mold for the support of concrete while it is setting and gaining sufficient strength to be self supporting, sometimes used interchangeably with formwork, but also used in a more restricted sense to indicate supporting members in direct contact with the freshly placed concrete.

FORMWORK

-Total System of support for freshly placed concrete, including the mold or sheathing that contacts the concrete and all supporting members, hardware, and necessary bracing.

FALSEWORK

-The temporary structure to support work in the process of construction, the discussion of concrete construction, the term may be used much the same as formwork to include shores or vertical posts, forms for beams or slabs, and lateral bracing.

SCAFFOLD

-A temporary elevated platform (supported suspended) and its supporting structure used for support workers, tools, and materials; adjustable metal scaffolding can be used for shoring in concrete work, provided its structure has the necessary load-carrying capacity and structural integrity

JOIST

A horizontal structural member supporting decks from sheathing; usually rests on stringers or ledgers.

BACKSHORE

-shore placed snugly under a concrete slab or structural members after the original forms and shores have been removed from a small area at a time, without allowing the slab or members to deflects and thus support its own weight or existing construction loads from above

PRESHORES

-Added shores placed snugly under selected panels of a deck forming system before any primary (original) shores are removed. Preshores and the panels they support remain in place until the remainder of the bay has stripped and backshored, a small area at a time.

RESHORES, RESHORING

Shores placed snugly under a concrete slab or other structural member after the original forms and shores have been removed from a large area, thus requiring a new slab or structural member to support its own weight and existing construction loads applied poor to installation of reshores.

SHEATHING

The material forming the contact faces of forms; also called lagging, sheeting.

SHORE

-Temporary vertical or inclined support for formwork and fresh concrete or for recently built structures which have not developed full design strength. Also called tom, prop, post, strut

SHORING

System of vertical or inclined supports for forms; may be wood or metal posts, scaffold-type frames, or various patented members.

STRINGER

-Horizontal structural member usually (in slab forming) supporting joists and resting on vertical supports.

Chapter 2 Literature Review

2.1 Introduction

The purpose of this chapter is carrying out a detail literature review about concrete formwork system and its influence on the cost, quality and speed of construction of building projects. A review of books, thesis, standards and relevant website are carried out to develop this chapter.

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 there are five horizontal formwork systems that 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)

Conventional wood or metal systems for horizontal concrete work are made of plywood, lumber, steel and aluminum sheathing for decking. Sheathing is supported by horizontal members called joists or runners. Joists are supported by another set of horizontal members perpendicular to the joists, called stringers. The stringers are supported by vertical members called shores. The shoring may be steel, aluminum, or wood; see figs. 2.1 and 2.2(Jensen, 1986).

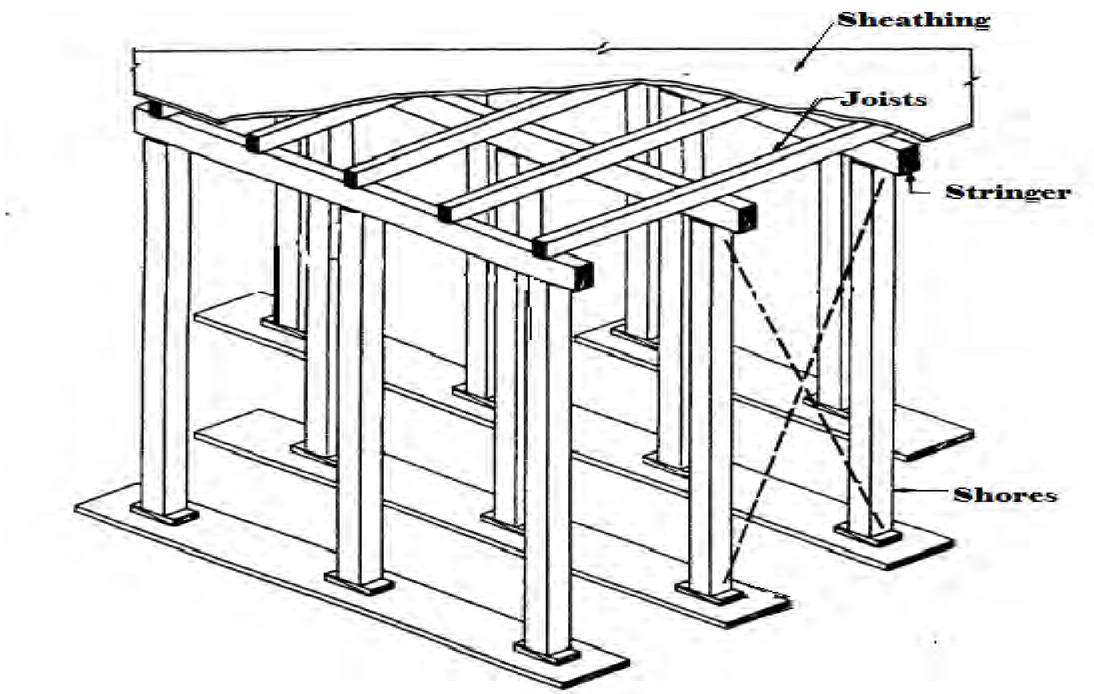

Fig.2.1 Conventional wood system (Hurd, 1995)

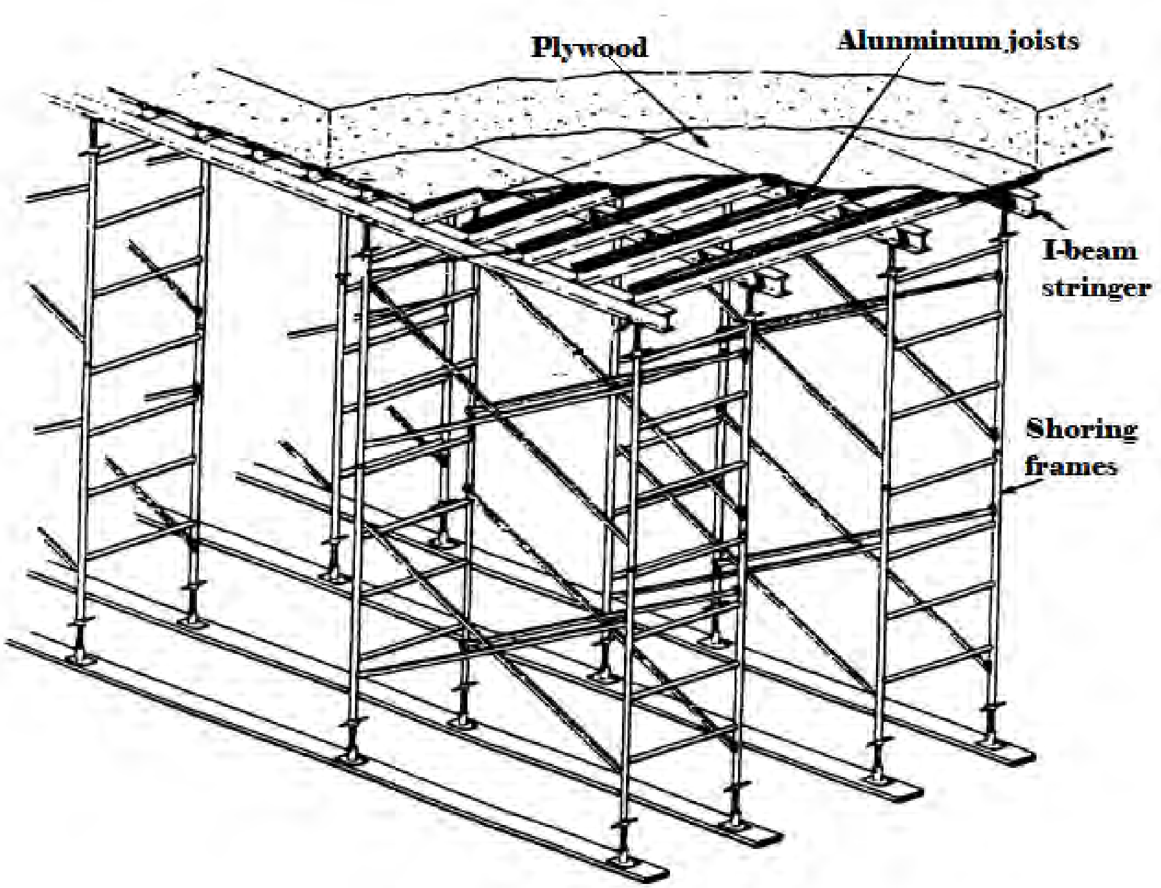

Fig. 2.2 Conventional Metal system (Ratay, 1996)

A table form/flying form is a large pre-assembled formwork and falsework unit, often forming a complete bay of suspended floor slab (Fig. 2.3). The assembled sections are either lifted per elevator or "flown" by crane from one story to the next.It offers mobility and quick installation for construction projects with regular plan layouts or long repetitive structures, so is highly suitable for flat slab, and beam and slab layouts. The use of these systems can greatly reduce the time and manual labor involved in setting and striking the formwork.Their advantages are best utilized by large area and simple structures (http://www.concretecentre.com/technical_information/, Accessed on 28 November, 2013)

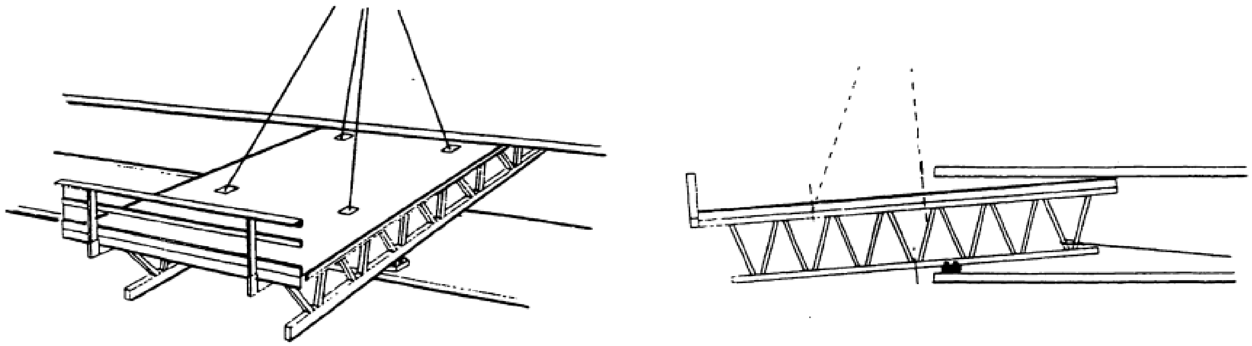

Fig.2.3 Flying/Table formwork system (Peurifoy and Oberlender, 1996)

Column-mounted shoring system is the term used for formwork panels supported by an up-and-down adjustable bracket jack system attached to already-cast concrete bearing walls or columns. The system consists of plywood decking which can be assumed on the ground or in place, once the form has been flown and set on the column (Fig.2.4). These systems were developed to employ concrete columns to support formwork for concrete slabs and thus eliminate any need for shoring and reshoring that may ultimately reduce the overall construction schedule(Awad S. Hanna, 1999).

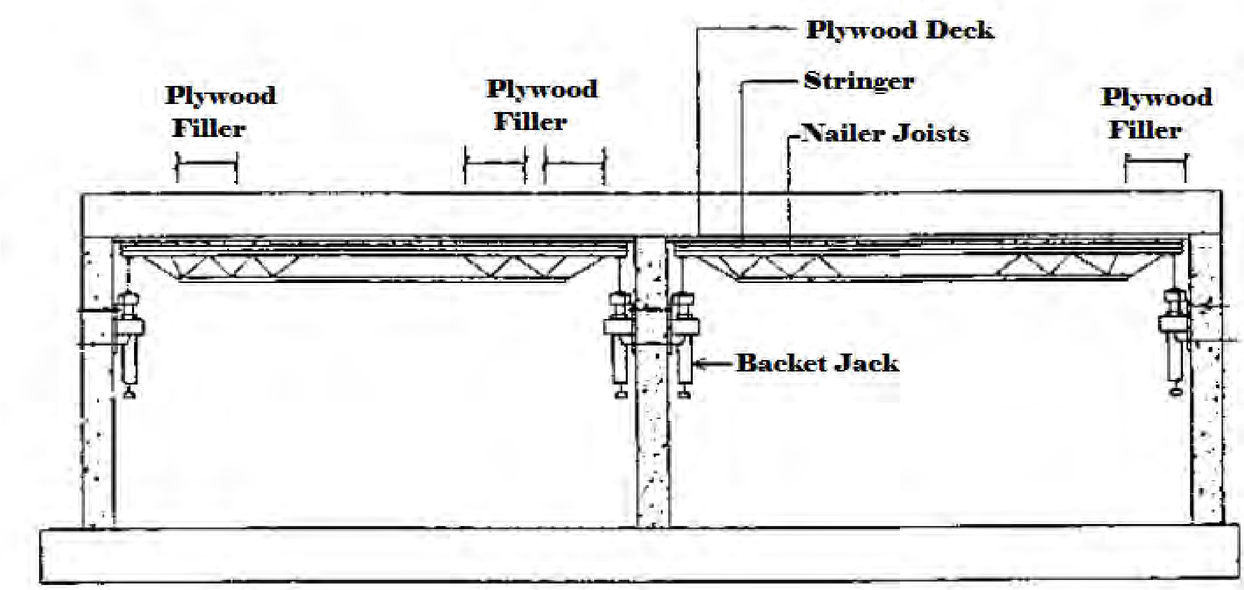

Fig.2.4 Column-Mounted formwork system (Awad S.Hanna,1999)

Tunnel formworks are factory made U-shaped or inverted L-shaped steel form system, which permit casting both slab and supporting walls at the same time (Fig 2.5). For stripping after the concrete has gained enough strength, the tunnels are collapsed or telescoped and moved to the next pour. For longer slab spans, the tunnel form may be made in two inverted L-shapes (Jensen, 1986).

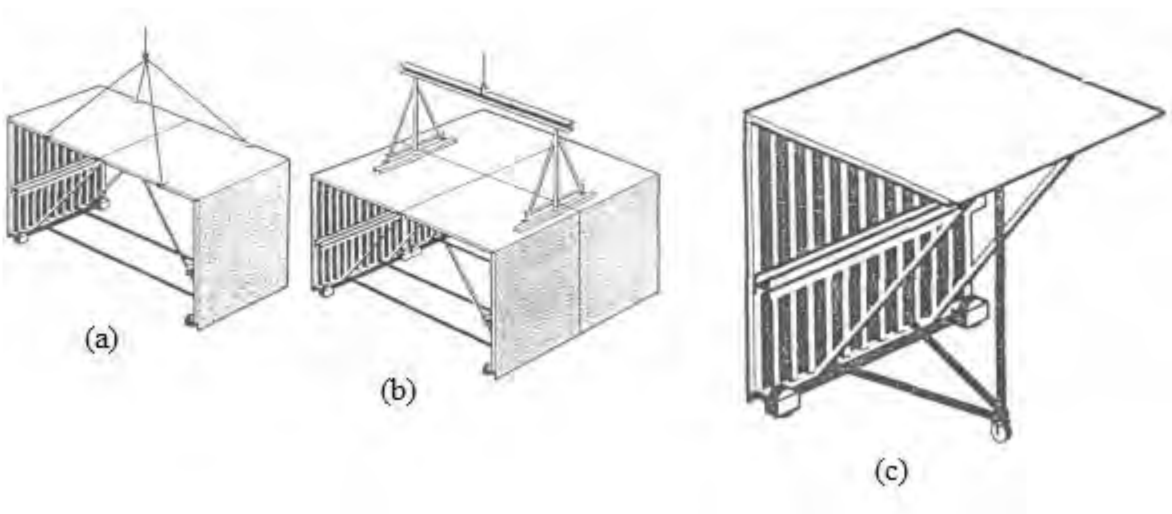

Fig 2.5 (a),(b) and (c) Tunnel formwork system (NurayBenli, 2005)

Concrete joist construction is a monolithic combination of regularly spaced joists arranged and a thin slab cast in place to form an integral unit with the beams, girders, and columns (Fig 2.6). When the joists are all parallel this is referred to as ribbed slab or one-way joist construction. If the joists intersect each other at right angles, it is two-way joists construction or waffle slab. These types of construction have been frequently formed with ready-made steel or other materials pans or domes of standard sizes. According to Hurd (1995), there are four different types of joists slab formwork system utilized in the construction industry. These are;

1. Nail down flange type can be placed, aligned, and nailed from the top side. Simplest to use, but does not generally provide architectural concrete surface.

2. Adjustable type has no flanges, provides smooth joists bottoms without flange marks. Pans can be removed without disturbing soffits and share supports.

3. Dome type used for two-way or waffle slabs. This kind of slab design may offer certain structural economies. Flanges are butted at joints, not lapped.

4. Slip-in type is based on the same form as the nail-down type, but uses soffit board between pans to form a smooth joist bottom. Like adjustable, pans can be removed without disturbing soffit supports.

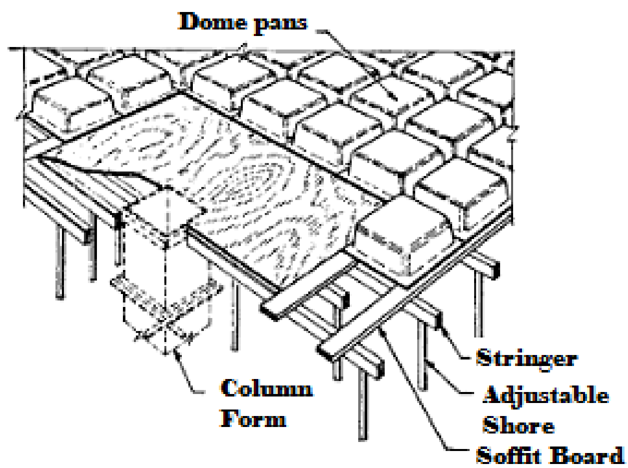

Fig 2.6 Two-way joist slab forming with prefabricated dome pans (Hurd, 1995)

2.2.2 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 (Fig. 2.7 a &b) 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 wales which also align the forms. Single or double horizontal wales are preferred to avoid drilling through single wales which reduces its loading carrying capacity. Ties are drilled through wales (single wale) or inserted between them (double wale) to resist the lateral pressure of plastic concrete (Hanna, 1999).

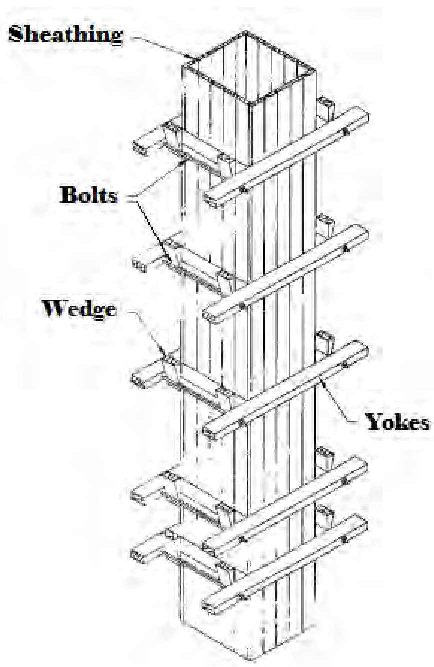

Fig 2.7(a) Column Formwork

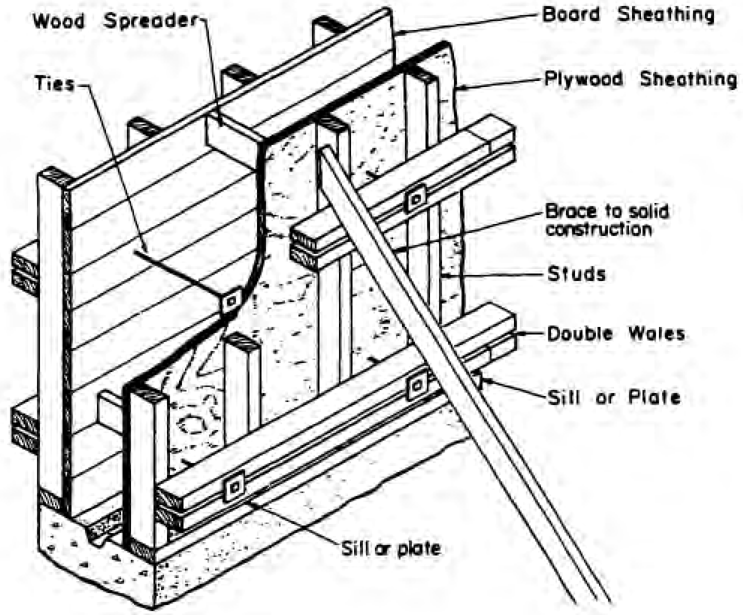

Fig 2.7(b) Wall Formwork

Fig 2.7 Conventional column and wall formwork (Hurd, 1995)

Gang forms are made of large panels joined together with special hardware and braced with strongbacks or special steel and aluminum frames (Fig 2.8). Gang forms can be made on site, rented, or purchased from formwork manufacturer. The advantages of manufactured forms over site made is that they are precise in dimension and can be reused a large number of times (Argaw Tarekegn, 2010).

Fig 2.8 Gang formwork system (WTF, Forming systems catalog, 2011)

Slip formwork is originally designed for curved structures such as bins, silos, and towers for which the conventional formwork systems are not suitable. However, slip forms are now used for variety of structures, including rectangular buildings, bridge piers, and canal lining. Slip form consist of inner and outer forms. Forms may be fabricated from wood or steel, and supported by strong vertical yokes. These yokes are tied together at the top to give the form sides the rigidity needed. The bottom ends of the form sheathing are slightly tapered to help make the form self-clearing. To provide a platform, form which workers may look after placing the concrete in the forms, a working platform is attached to the inner form and rides upward with it. At the same time a finisher's scaffold is suspended from the outer form so that workers can finish the newly extruded concrete as it emerges. Slip forms move continuously upward, drawn by jacks climbing on vertical steel jack rods. These are anchored at the base of the structure and embedded in the concrete below the forms. The jack may be hydraulic, electric, or pneumatic and are capable of producing form speed of up to 50cm/hr. concrete is placed into the form at the top end as it is drawn upward. The continuous process is carried on, filling and moving the forms upward, often 24 hours a day until the structure is complete. Concrete joint between lifts is to be carried out if the operation stopped. Fig 2.9 shows a schematic diagram of slip formwork (Smith and Andres, 1993).

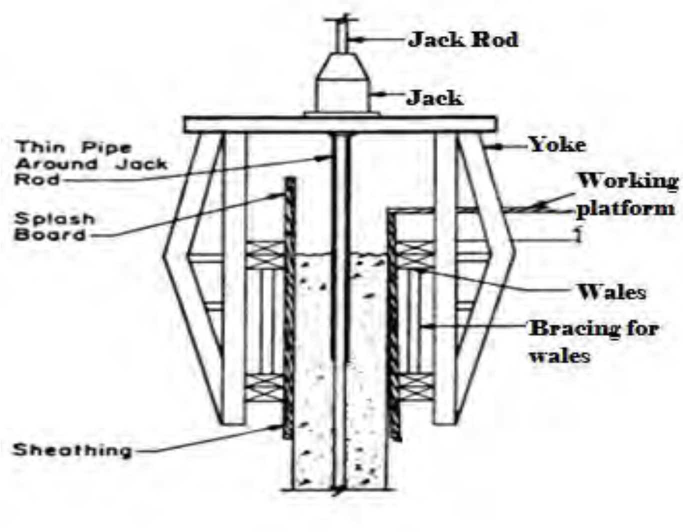

Fig 2.9 Typical slip formwork (UNITEC New Zealand applied technology, 2009)

Jump form systems are used where no floor available on which to support the wall formwork, or the wall and column proceed ahead of the floor. Generally, jump form systems comprise the formwork and working platform for cleaning/fixing of the formwork, steel fixing and concreting. The formwork supports itself on the concrete cast earlier so does not rely on support or access from other parts of the building or permanent works. Jump form, here taken to include systems often described as climbing form, is suitable for construction of multi-storey vertical concrete elements in high-rise structures, such as: Shear walls, Core wall, Lift shafts, Stair shafts, and Bridge pylons. These are constructed in a staged process. It is a highly productive system designed to increase speed and efficiency while minimizing labour and crane time. Systems are normally modular and can be joined to form long lengths to suit varying construction geometries (Fig 2.10).

Three types of jump forms are in general use:

I. Normal jump/climbing form – units are individually lifted off the structure and relocated at the next construction level using a crane. Crane availability is crucial.
II. Guided-climbing jump form – also uses a crane but offers greater safety and control during lifting as units remain anchored/guided by the structure.
III. Self-climbing jump form – does not require a crane as it climbs on rails up the building by means of hydraulic jacks (http://www.concrettecentrte.com/, Accessed on 5 December 2013).

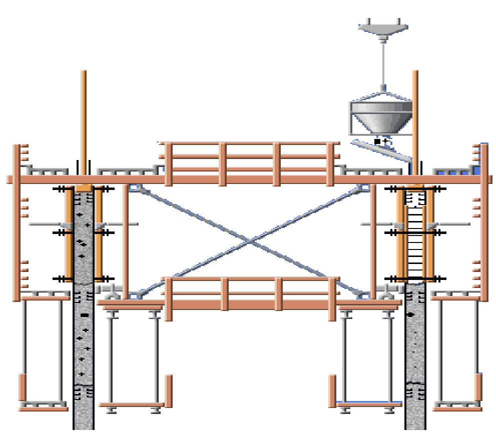

Fig 2.10. Jump Forming system (www. Cityu.edu.hk)

Self-raising forms retain all the basic characteristics of jump forms that is; unit lifts one lift at a time, with no movement of plastic surface contact areas of concrete relative to the forms. It is necessary to move the form laterally away from the placed concrete before they can be lifted to the next position and again moving them laterally back to the forming location once they have been lifted. They are not an extrusion-type forming system like slip form. The self –raising forms are more economical than jump forms because of the elimination of necessity for heavy use cranes and hand labor in the handing, stripping, and reinstallation of forms. The system consists of upper forms and lower lifters (self- raisers) (Fig.2.11). The lifters are attached to the wall already cast below the form (Ratay, 1996)

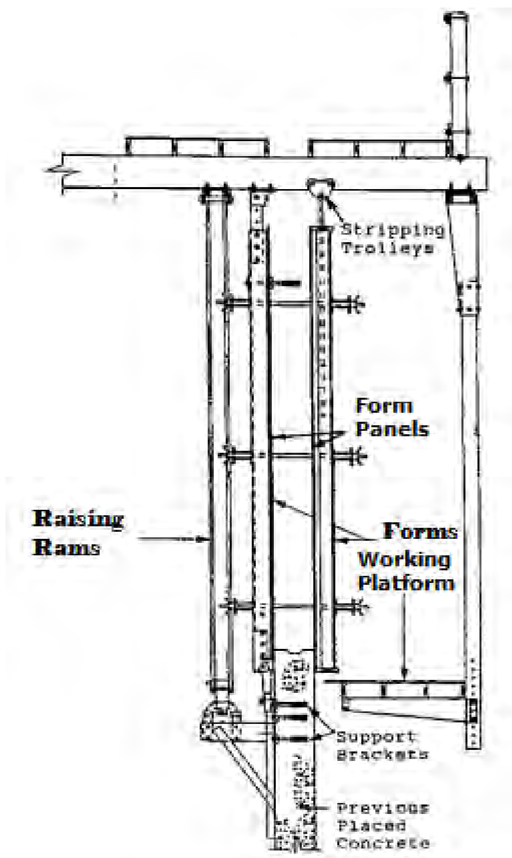

Fig. 2.11 Self- raising formwork Component (Awad S. Hanna, 1999)

2.3 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 and

2.3.1 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:

1. Factors related to building architectural and structural design, which include slab type and building shape and size

2. Factors related to project (job) specification, and schedule, which includes the speed of construction

3. Factors related to local conditions, which include area practices, weather conditions, and site characteristics

4. 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, as shown in figure 2.12. 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.

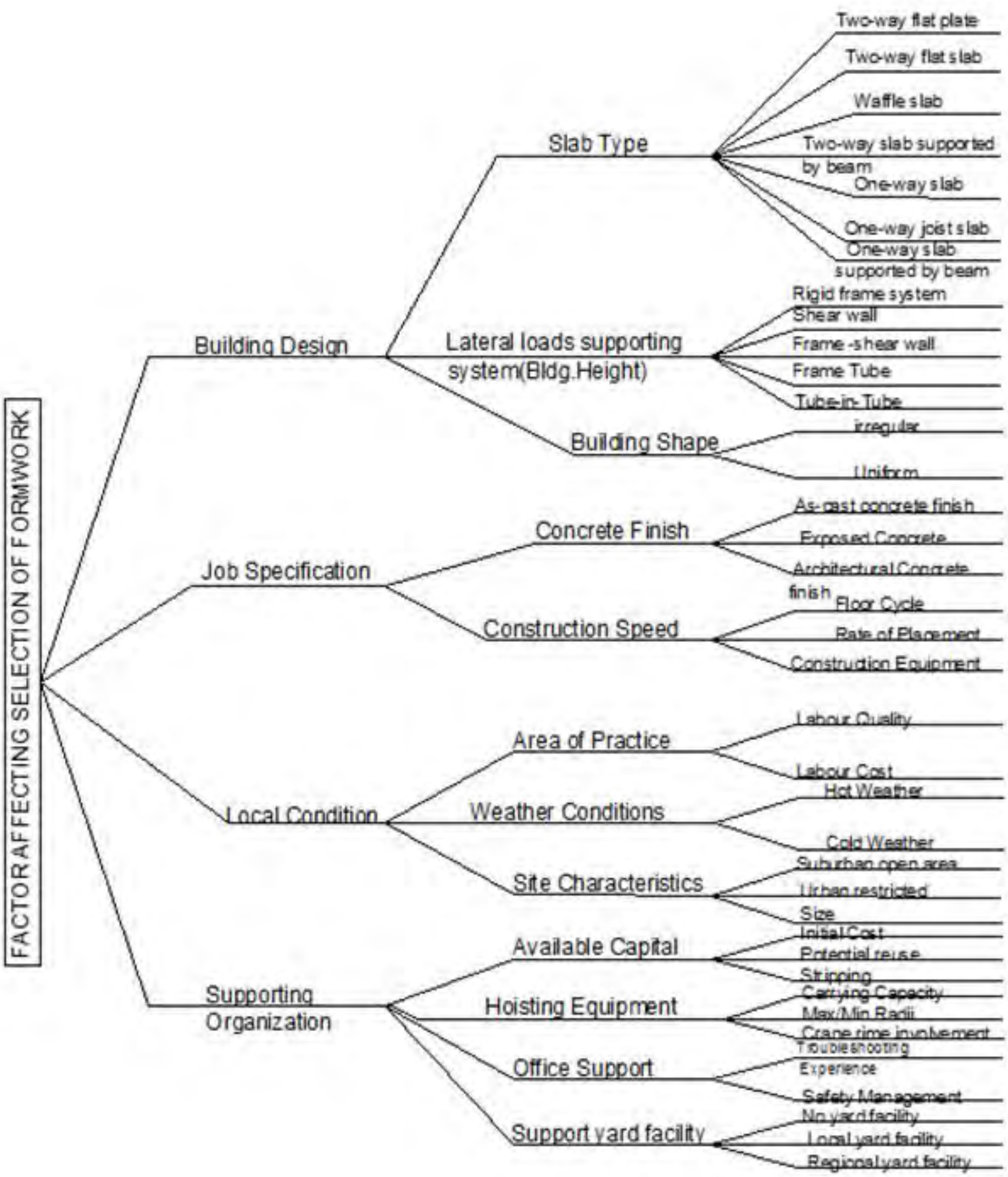

Fig. 2.12 Factor affecting selection of formwork System(Awad S.Hanna,1999)

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 blockouts 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 high-rise 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.

iii) Stripping cost, which also includes the cost of cleaning and repair. This item tends to remain constant for each reuse up to a certain point, at which the total cost of re- pairing and cleaning start rising rapidly.

b) Hoisting Equipment (Cranes)

Some formwork systems require special handling techniques, which can include a good crane service. The flying truss system is a good example of crane influence on the selected system. The size of the flying modules may be limited by the crane carrying capacity and its maximum and minimum lift radii.

c) Supporting Yard Facility

The feasibility of using prefabricated forms such as flying formwork is largely influenced by the availability of a local or central (regional) yard facility. When a local or central yard facility is available, the standard formwork elements can be manufactured and assembled under efficient working conditions. However, the cost of transporting form sections to the site may influence the economy of the selected system (Awad S. Hanna, 1999)

2.3.2. 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 Table 2.1 is presented below. This table was extracted from a Concrete Formwork System by Awad. S. Hanna (1999). 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.

Table2.1 Factor Affecting Selection of Vertical Formwork System (Awad S. Hanna, 1999)

<table>
<tr><th colspan="3">Formwork System / Influence factor</th><th>Conventional column wall form</th><th>Ganged forms</th><th>Jumps form</th><th>Slip form</th><th>Self-raising form</th></tr>
<tr><td rowspan="4">Building Design</td><td rowspan="2">Lateral support</td><td>Lateral support system</td><td>Most suited for frames & retaining walls</td><td>Shear walls
Bearing walls
Retaining walls</td><td>Shear walls
Frames & framed shear wall</td><td>Shear walls</td><td>Shear walls
Tube systems
Tube in tube</td></tr>
<tr><td>Building height</td><td>up to 36m</td><td>Up to 105m</td><td>Up to 105m</td><td>Average 120m
Min recorded=18m
Max “ ‘ “ = 180m</td><td>At least 90mm
No Max.</td></tr>
<tr><td rowspan="2">Building Shape</td><td>Column/wall size & location</td><td colspan="2">System can handle variation of column/ wall size and location</td><td>Systems can handle moderate variation of columns size and location</td><td>Walls should be of the same location
Walls size variation can be accommodated</td><td>System can handle reasonably modular design</td></tr>
<tr><td>Openings/ Inserts</td><td>Systems can handle opening/ inserts of different size and location</td><td>Variation in opening’s size and location can be accommodated at additional cost</td><td>Opening should be regularly placed from floor to floor</td><td>Should be minimum
Too many openings make this system impractical</td><td>System can handle moderate variation in openings size and location</td></tr>
<tr><td rowspan="3">Job specification</td><td rowspan="3">Speed of construction</td><td>Concrete finish</td><td>‘As-cast’ concrete finish</td><td colspan="2">Produces a smooth exposed concrete finish. Tie pattern and number should be designed. Form liners can be used to produce architectural concrete</td><td>System produces rough concrete finish</td><td>Smooth concrete finish
Form liners can be used</td></tr>
<tr><td>Construction sequence</td><td>Slabs and walls are placed concurrently</td><td>Slabs and walls are placed concurrently walls can be placed ahead of the floor slab</td><td>System is used when no floor slab is available</td><td>Typically, walls are placed several stories ahead of the floor</td><td>Walls are ahead of the</td></tr>
<tr><td>Cycle Time</td><td>1 floor per week</td><td>1floor every 3-4 days</td><td>1floor every 2-3days</td><td>1floor every day.
Rate of placing 20-50cm/hr</td><td>1floor every 2-3days</td></tr>
<tr><td rowspan="2">Local conditions</td><td colspan="2">Area Practices</td><td>More efficient in area of high quality. Low cost labor force</td><td>Work best in high-cost, low –quality labor force</td><td>System is easy to learn & adapt
Learning curve is quite short</td><td>System can be learned in 2-3 weeks</td><td>System requires high quality supervision</td></tr>
<tr><td colspan="2">Weather</td><td>Generally not a major factor</td><td colspan="2">A major factor, walls should have sufficient strength before stripping which</td><td>Hot or cold weather affects the concrete</td><td>In cold weather, forms should be</td></tr>
</table>

				is largely influenced by weather condition high winds limits the crane movement		rate of selling which slow the rate of rise	protected and concrete should be healed
	Site Characteristics	Access to site	Generally not a factor for loose forms	Can be a major factor if the system is preassembled in a local yard facility	Site must be accessible, forms can be up to 5m high and 15m wide	System must have a limited access for material delivery	Min. site access is required for concrete placing and rebar delivery
		Site size	Not factor	Can be a major factor if the forms have to be built in site	Not a major factor, forms are preassembled and unload directly	Not a major factors, system can be used in restricted small sites	
Supporting Organization	Cost	stripping	Hand strip High stripping cost	Crane is used to strip the system High stripping cost	Forms are equipped with mechanism for stripping Min stripping cost	Forms are stripped at the end of the project Min. stripping cost	Forms are equipped with mechanism for stripping Min. stripping cost
		Reuse	Less than 10	Between 40 & 50 Reuse could be horizontally or vertically	Between 15 & 30	Between 50 & 100	At least 30 reuse should be available vertically
	Hoisting Equipment	Location of adjacent building & obstruction	Generally not a factor	A major factor, system must have a free space to be moved from floor to floor		Minimum free space should be available for concrete placing	Not a major factor, system can be used in downtown restricted areas
		Crane time	Not a factor, system can be hand –set	Crane-dependant system, sufficient crane time is a must	System substantially reduce crane time Average crane time pick=20min	Crane is used is only to materials delivery & concrete placing	Crane-independent system
		Operating system	Hand-set system, crane increase system efficiency &reduces cost	Crane-set system crane serves two functions; lifting & supporting units by crane	Crane is used only to lift the forms Crane is not used for forms dismantling	Locomotion is provided by electric, pneumatic or hydraulic jacks climbing on smooth steel rods	System is lifted by hydraulic, electric or pneumatic lifters
	Safety Manget.	Safety	No special safety feature is required	Special care for handling the large ganged units by carne	Safety feature Safe guarded platform No one needs to be on the form during crane handling	For hydraulic system special safety precautions must be taken to prevent fire several hundred meter above the ground	

	Yard facility	Supporting yard, facility, supplier or make-up area	Not a major factor, but system is more efficient if a local yard facility is available	A major factor, system must have an adequate make-up area or close by supplier	System is rented or purchased	Continuous materials delivery is a must uninterrupted concrete placement must be assured	System is preassembled make-up area is not a factor. Local suppliers must be available

In the previous two subsections, factors that influence the selection of horizontal and vertical formwork system is discussed in detail. These factors help all the parties that are involved in the building construction project to select the type of formwork system to be used in the project. Figure 2.13 give the parties that can influence the selection of formwork system in the given project.

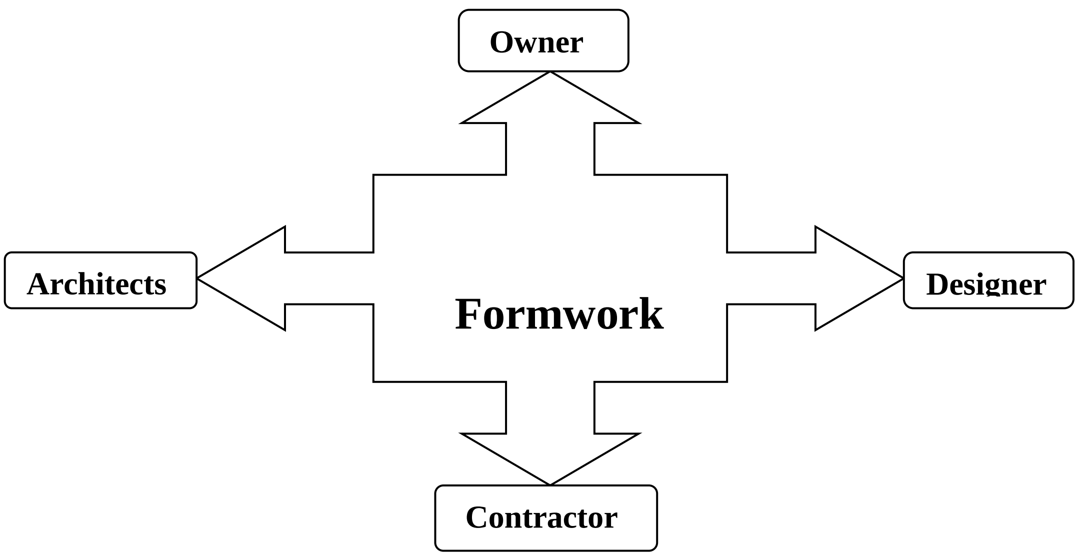

Fig. 2.13 Different parties involved in formwork selection

The summery of the factors that can be taken as the criteria for selection formwork system for building construction projects are given below. These fifteen criteria are accessed from the website, www.masterbuilder.co.in/factors-affecting-the-selection-economics, which deals on the construction process.

The proper selection of the formwork systems to be used in concrete structure is concern to all involved parties. The following selection criteria have to be considered: (www.masterbuilder.co.in/factors-affecting-the-selection-economics, Accessed on December 6, 2013).

1) Geometry of building/structure

a) Internal layout

Some buildings may have very simple layouts with few in-situ walls and floor plates framed with regularly spaced columns, as seen in many commercial and office buildings. However, some developments feature very complicated load bearing internal walls that can make the casting process difficult.

b) Structural forms

Like internal layout, the structural form of buildings also affects the formwork options. For example, buildings with a structural core in the form of a vertical shaft limit the use of other formwork systems other than those of a self-climbing nature. Buildings in flat slab design make table forms or flying forms the most obvious choice. For buildings with regularly arranged shear wall designs, the best selection is large-panel type steel forms or other types of gang forms.

c) Consistency in building dimensions

Some buildings may have non standardized dimensions due to the architectural design and layout or to fulfill other structural requirements. These include the reduction of sizes for beams, columns and walls in high-rise buildings as the structure ascends. Formwork systems like the climb-form or steel form, may be quite difficult to use in such situations, due to the frequent adjustments of the form to meet the changes in dimensions may eventually incur extra cost and time.

d) Headroom

Higher headroom increases the amount (height) of staging required and can also create accessibility and safety problems. It can also make the erection of formwork, ensuring formwork stability and the placing of concrete more difficult.

e) Building span

Large building spans also create problems similar to those with high headroom situations. In addition, long-span structures generally have larger beam sections, heavier reinforcement provisions, or accompany post-tension works. This will further complicate the formwork's design and erection process.

f) Repetitive nature

High-rise block-shaped structures usually require highly repetitive cycles and this is favorable to the use of formwork. However, the degree of repetition in building with very large construction area like a podium or underground structures such as basements is limited and the use of formwork, as an expensive resource, becomes very critical.

2) Project Planning/speed of work

The over-all construction sequence must be planned to use formwork in efficient manner and to permit the optimum investment in formwork to meet schedule requirements. Contractor should plan formwork and job sequence at the time of making a bid. Project planning such as the phasing or sectioning arrangement, integration of the structure, site layout and set-up arrangements or hoisting provisions and concrete placing facilities are influencing factors when considering formwork selection and application.

When working with buildings with large construction areas and horizontal spread, projects can be expedited by the introduction of additional sets of formwork, to create more independent work fronts. This will, of course, increase the cost of construction. For high-rise buildings, increasing the number of formwork used cannot always expedite the project, for the critical path still depends on the floor cycle. However, a properly selected, designed and arranged formwork system will increase work efficacy for each typical cycle. In some cases, adding half or a full set of formwork, especially for the floor forms, may help to speed up the cycle as the additional set can provide more flexibility when the form is struck at an earlier time.

3) Construction process, methods

For selecting formwork one must know the sequence of construction activities and methods to be followed. Construction method will always give idea about inter dependency of the activities, specifications and additional requirements in pour. This will enable us to workout appropriate system which fulfils the construction needs.

4) Site logistics

Exceptionally small or very large sites sloped or very crowded sites, proximity to sensitive structures, sites where other major activities are underway, or sites with many physical or contractual restrictions will increase the difficulty of working with formwork. There is no specific solution to improve the situation in general and problems are tackled according to individual circumstances.

Accessibility to work during the course of construction, accessibility problems may be created through segregation, temporary discontinuation, or blocking of the layout by the partially completed building or, in cases constructing a shaft-type core wall is constructed in an advanced phase, the shaft may stand independently for a long period of time before it is connected to the horizontal elements. Proper access to all components should be considered while planning a site layout.

5) Climate condition

Formwork systems are sensitive to weather conditions. Typically, in vertical forming systems, the newly placed concrete is supported by the wall already cast below it. The lower wall section must get the sufficient strength to support the fresh concrete above. The rate of strength gain of lower wall is influenced by the ambient temperature, moisture content, and the freezing and thawing cycles.

Another factor that affects the economy of the selected system is the effect of stopping formwork activity and concreting because of extreme weather conditions. In the case of a slip-form, the work is usually continuous, 24hrs around the clock. If the slip-form stops because of weather conditions, it may impact structure as well as cost.

6) Labour efficiency

Considering the availability and qualification of the work force, improving labour cost efficiency is a major factor, especially in markets experiencing a building boom. Here, the qualification of workers tends to be low in relation to ever higher demands posed by construction methods.

7) 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.

Avoiding damage reduces costs incurred. Proper storage of formwork materials gives easy reconciliation, faster retrieval of material, better space management and avoids unnecessary expenditures, improve safety at work place.

8) Availability of lifting devices (Crane time)

Many factors should be considered before employment of a construction plan and the selection of the right formwork system. These include considerations of whether there will be lifting appliances provided for the erection of formwork; whether these appliances will be able to access the work spot to assist in the operation as the structural works proceed; whether any special equipment will be required for striking the forms; and how the removed formwork panels can be transported to other spot to continue work.

Characteristic to high rise building sites is the confined and congested space availability for working. Crane time and space is regularly limited. In general, reinforcing (rebar) activities are most critical, since lifting the reinforcement to building level is the most crane- time consuming job of all. Thus, the capability of formwork to rely less on or be used independently of crane time is critical in high rise construction.

9) Simple logic of the system

Formwork system ought to be self-explanatory to use, this automatically eases the usage for the engineers/supervisor and also the labour who are end users of the system.

10) Working safety

Formwork should be self-securing with safe access and working platforms. Thus, it is not left to the end user whether they takes safety measures or not. Creating a safe work environment for the entire work force involved in the construction process, has become the pivotal issue in emerging construction markets.

11) Special requirements on Concrete surface/finish

Fair-faced concrete demands very high quality formwork in terms of surface treatment of the panels, tightness of the formwork joints and in dimensional accuracy. Requirements are slightly relaxed where the concrete surface is to be finished at a later stage.

12) Area or volume of cast per pour

The optimum volume of cast per pour depends on the types of formwork used, the particular elements of structure to be placed, the actual scale of work, and different levels of provisions of plant facilities. It also depends on whether the concrete to be placed is for the vertical elements only or also includes the beams and slabs, as a means of saving an additional phase in the overall work cycle.

13) Involvement of other construction techniques

Tensioning and prefabrication activities are often involved in construction. This may create certain impacts on the use of formwork, especially where precast elements are to be incorporated during the casting process. Provision should be made for temporary supports or slot spaces and box out positions in the formwork for the precast elements, or extra working space for placing stressing tendons and onward jacking.

14) Provision of construction joints in structures

Many a times a large number of construction joints are inevitable in a large structure because of the subdivision of works into effectively workable sizes.

The provision of construction joints can challenge the output and affect the quality of the concrete. Careful selection should be made to ensure a particular formwork system can satisfactorily allow such arrangements.

15) Inventory- The fewer, the better

The most frequent time and cost consuming activity of formwork assembly is the loose and small components/accessories. The lesser inventories will help to reduce risk of losing parts and provide ease in construction.

2.4 Construction consideration of formwork system

Consideration of formwork normally begins when the contractor stars estimating a job for bidding but it is better to start in the design stage. For the most part the contractor can select and use the type of formwork he wishes since he is best equipped to know and analyze the advantages and disadvantages of each method.

The construction of formwork normally involves the following operations: propping and centering, shuttering, provision of camber and cleaning, and surface treatment (Abebe, 2007)

i) *Propping and Centering:* The props used for centering may be of steel or timber posts. In case wooden posts are used as props, they should rest squarely on wooden sole plates laid either on the ground or on brick masonry pillars. The wooden plate should have an area of at least 0.1m2 and 40mm thickness. Double wedges are essentially provided between the sole plates and the timber props with a view to permit accurate adjustment of the shuttering prior to concreting operation and to allow easy removal of shuttering afterwards. In case brick masonry pillars are used at props, the wooden sole plates are provided at the top of the pillars, and the double wedges are inserted between the sole plate and the bottom of the shuttering.

ii) Shuttering: As described earlier the shuttering can be made up of timber planks, it may be in the form of panel units made either by fixing plywood to timber frames or by welding steel plates to angels framing. The shuttering joints should be tight against leakage of cement grout.

iii) *Provision of camber and cleaning:* since it is understood that certain amount of deflection in structure is unavoidable, it is desirable to give an upward camber in the horizontal members of the concrete structures, especially in members having long spans, to counteract the effect of deflection. The provision of desired camber should be made in the formwork itself during its erection. Design codes recommend required camber for different building elements. In the absence of these codes, it is suggested to use a camber of 4mm per meter of span for slabs and beams. In case of cantilevers, the camber at free end should normally be taken as $1/50^{th}$ of the projected length of the cantilever

iv) *Surface treatment:* Before lying concrete the formwork should be cleaned of all rubbish particles. All surfaces of timber shuttering that are to come in contact with concrete should be well wetted with water. Similarly steel forms that have been exposed to hot weather should be cooled by watering before lying concrete. In addition, all surfaces of shuttering which are to come in contact with concrete should be given good coating of linseed oil or soft soap solution or any other suitable material so as to prevent the concrete getting struck to the formwork and thus facilitate easy removal.

Beside construction operation consideration of formwork system that listed above economical, quality, productivity and safety consideration are among the things that should be considered in construction of formwork. Detail descriptions of this are given below.

2.4.1 Economical consideration of formwork

According to the concrete Reinforcing Steel Institute (CRSI), "Formwork and its associated labor is largest single cost segment of the concrete structural frame –generally more than 50%" and the institute has issued a number of suggestions for economy in formwork. The following points are suggestions given by the institute for economic construction of formwork

- Select one framing scheme and stay with it throughout the project. Two framing schemes are justifiable only on large projects, and then only for special reasons such as different occupancies in two parts of building. Each framing scheme costs something for mobilization and formwork material as well as learning curve for workers.
- Arrange framing member sizes and spacing so that the capacity of minimum sized members is used fully. Slabs of minimum thickness controlled by fire ratings should span as least as the minimum reinforcement may carry column loads, act as grade beams or transfer girders, resist lateral loads, and serve as partitions or exterior walls-all at the same time.
- Make beams wider than columns on each side by at least 50mm. This helps reinforcing bars in the corners of beams and columns to pass without obstruction. Remember it is easier and cheaper to cut a hole in the bottom of a beam form for a column penetration than it is to cut holes in the side of a column form for beam penetration.
- Space column uniformly. This helps result in uniform sizes for columns, joists , and beams , thus saving money by simplifying forming
- Make all columns the same size, vertically in one stack as well as horizontally in one story. Adjust the amount of reinforcement or concrete strength as necessary for the loading this will maximize interchangeability and reuse of forms.
- Keep floor-to-floor height constant. If changes are necessary, reduce the height in the height in the upper stories. It is easier and cheaper to cut off a column form than it is to extend it.
- Allow reasonable tolerance. Specify tight tolerance only where they ate needed, or required by code, such for locations of bars in beams and columns. Tight tolerances require more field labor, and hence increase cost.
- Specify when forms may be stripped. Use a time limit for walls and columns, and a strength requirement for beams and slabs, but consider requiring reshoring until strength has been reached to prevent excessive deflection.

ACI also give the guidelines show how the engineer/architect can plan the structure so that formwork economy may best be achieved:

- ✓ To simplify and permit maximum reuse of formwork, the dimensions of footings, columns, and beams should be of standard material multiples, and the number of sizes should be minimized;
- ✓ When interior columns are the same width as or smaller than the girders they support, the column form becomes a simple rectangular or square box without boxouts, and the slab form does not have to be cut out at each corner of the column ;
- ✓ When all beams are made one depth (beams framing into beams as well as beams framing into columns), the supporting structures for the beam form can be carried on level platform supported on shores;
- ✓ Considering available sizes of dressed lumber, plywood, and other ready-made formwork components and keeping beam and joist sizes constant will reduce labor time;
- ✓ The design of the structure should be based on the use of one standard depth wherever possible when commercially available forming systems, such as one or two-way joist systems, are used;
- ✓ The structural design should be prepared simultaneously with the architectural design so that dimensions can be better coordinated. Room sizes can vary a few inches to accommodate the structural design ;
- ✓ The engineer/architect should consider architectural features, depressions, and openings for mechanical or electrical work when detailing the structural system, with the aim of achieving economy. Variations in the structural system caused by such items should be shown on the structural plans. Wherever possible, depressions in the tops of slabs should be made without a corresponding break in elevations of soffits of slabs, beams or joists;
- ✓ Embedment for attachment to or penetration through the concrete structure should be design to minimize random penetration of formed surface; and
- ✓ Avoid locating columns or walls, even for few floors, where they would interfere with the use of large formwork shoring units in otherwise clear bays

2.4.2 Quality consideration of formwork construction

Concrete by itself has no shape or form. It is shaped and molded by being placed in formwork. The formwork face in contact with the wet concrete determines the texture, shape, smoothness or roughness of the concrete surface. The prime purpose of formwork is to shape and mould concrete by containing its flow in its liquid state. But very often the formwork materials that perform this function cannot be relied upon to give a satisfactory surface finish. The selection of the formwork face is therefore critical in the visual appearance of concrete and it is the most important element in achieving concrete finishes. If the concrete mix is consistent throughout a project but the formwork is poorly constructed and panel joints are badly fitted, the support system is not rigid enough to adequately resist the pressure from the liquid concrete; then the surface appearance of the concrete will be poor. Formwork is also the most expensive element involved in concrete finishes and cost versus finish quality often arise (http://www.ecocem. Accessed on December 28,2013)

According to Doka (2008), the following criteria have been established in determining the finish quality of a formed concrete surface:

- Evenness and smoothness
- Surface structure which is flat, plumb and straight with sharp corners and edges
- The presence and extent of panel joint lines
- Presence of tie holes
- Concrete color with regard to staining and discoloration
- Drip marks from grout loss onto previously poured surfaces
- Surface porosity and surface density
- The presence of steps in the concrete surface at the panel joints
- Leakage of fines at joints and tie holes (Watertight seals at joints prevent grout loss and excessive joint markings.)

To use the words of Nemati (2007):

"In designing and building formwork, the contractor should aim for maximum economy without sacrificing quality or safety. Size, shape and alignment of slabs, beams and other concrete structural elements depend on accurate construction of the forms."

The forms must be:

•Sufficiently rigid under the construction loads to maintain the designed shape of the concrete

•Stable and strong enough to maintain large members in alignment, and

•Substantially constructed to withstand handling and reuse without losing their dimensional integrity.

The formwork must remain in place until the concrete is strong enough to carry its own weight or the finished structure may be damaged.

In the discussion of quality consideration of formwork construction it is very curial to understand the finish classes applicable to formed concrete surfaces. This text from the United States Bureau of Reclamation (2009), defines the classes.

The classes of finish for formed concrete surfaces are designated by the symbols (F1, F2, F3 and F4). The classes of finish shall apply as follows :(www.usbr.gov Accessed on December 28, 2013)

- F1:- Finish F1 generally applies to formed surfaces upon or against which fill material, grout, or concrete is to be placed.
- F2:- Finish F2 generally applies to all formed surfaces not permanently concealed by fill material, grout, or concrete, or do not require a finish
- F3:- Finish F3 generally applies to formed surfaces, the appearance of which is considered by the Government to be special importance, such as surfaces of structures prominently exposed to public view. This is after all required patching and correction of imperfections have been completed
- F4:-Finish F4 generally applies to formed surfaces for which accurate alignment and evenness of surface are of paramount importance from the standpoint of eliminating destructive effects of water such as for suction of draft tubes.

The major quality consideration of formwork on the finished concrete discussed below in detail

1) Effects of formwork on concrete discoloration

i) Staining, rust and discoloration of concrete elements formed with steel sheathing.

The appearance of rust on steel formed concrete elements is an inherent possibility due to the properties of steel. Rust can appear on concrete for three reasons:

1. Rust already on the form surface that is not removed before the form is assembled.

2. The formation of rust on forms that are not protected from rain or other water before concrete is poured.

3. The formation of rust on the concrete surface when steel forms are left in place after the concrete is already set.

The first two are obvious and need little explanation. If a layer of rust is present anywhere on the formwork, and the concrete is poured into the form, the discoloration will be imparted onto the surface of the concrete. This is also true for any form of discoloration found on steel formwork, and is the reason that steel form faces are not painted to prevent corrosion, because by solving the one problem, another is created when the paint is imprinted onto the concrete surface (Niekerk, 2009)

Rusted or discolored forms are best prevented rather than treated:

According to Concrete Producer Magazine (2007);

“Removing rust mechanically, such as by sanding, can lead to "activated" steel surfaces, which are especially prone to rust.

The proper storage and sheltering of shutter material, as well as the proper application of release agent is important in this regard, but nobody can be blamed for unexpected rain causing rust on forms.”

The last formwork caused source of rust on formed concrete is when corrosion forms between the concrete and the form in the presence of air and water.

In the words of Concrete Producer Magazine (2007):

“There are several reasons for metal corrosion, and thus different forms: contact corrosion, crack corrosion, inter-crystalline corrosion, pitting corrosion, etc. The corrosion of iron and/or steel is an electrochemical process in the presence of water and oxygen. Metal corrosion occurs at the spot with the higher electro-negative potential.

Here, the metal ions dissolve from the surface into the solution and when they collide with hydroxide ions they precipitate as iron hydroxide.

The resulting iron minerals are formed, depending on temperature and air humidity. Due to constant recrystallization, no permanent protective rust layer is formed on the surface that would prevent further corrosion."

Basically, the steel form, together in the presence of air and water in the concrete initiates the corrosion process and rust appears on the formed concrete after curing.

ii) Discoloration of concrete elements formed by timber sheathing.

The major cause of unsightly discoloration on concrete elements formed by timber sheathing is a result of the absorbency of the timber face as a function of the moisture content of the timber.

The moisture content relies on the age, storage, protection and maintenance of the forms.

Along with a raft of other parameters, the absorbency of the surface of the formwork skin has a major effect on the surface of the concrete.

Absorbency has a number of positive effects such as fewer pores and less blushing, but it also has its downsides.

One effect that often gives raise to complaints becomes apparent if the formwork elements used on a structure have panels that vary in absorbency. The more absorbent the skin of the formwork sheeting, the darker the face of the concrete will generally be (Doka, 2008)

The individual panels in a single assembled form could vary in moisture content or the panels used to assemble another form for the same wall could vary in moisture content from those used for the previous pour. This will result in patches of lighter or darker concrete known as grey shade and ruins the possibility of a uniform surface appearance as shown in Fig. 2.14.

Fig. 2.14 The variation in the grey shade of concrete due to the absorbency of the timber formwork sheathing. (Source: Doka 2008)

Proper planning and management of timber forms to prevent the timber from drying out in full sun or from becoming waterlogged, which also negatively impacts the useable lifespan, should enable the contractor to markedly reduce the effects of timber absorbency on concrete surfaces.

According to Doka, (2008) water absorbed either from the concrete or from weather-related precipitation produces changes in the formwork skin itself. The effects of these changes are most noticeable in the first three use cycles, because it is at this stage of its lifespan that the skin of the formwork undergoes the severest changes. The moisture balance of the formwork then settles to some extent, subsequent changes are no longer as severe and their effects are less noticeable.

2) Effects of formwork on the dimensional conformity of concrete elements

The dimensional conformity of formed concrete is often very important, because services, aesthetic finishing and other successive building activities will be affected when concrete elements are skew, out of square, out of plumb, or not within dimensional tolerances.

If workmanship is removed from the equation, the two factors left to account for the dimensional conformity of formwork are the panel design and the assembly components. A common way to control dimensional conformity of concrete elements is specify limits of deflection in a formwork member to require it to be less than some fraction of its span. A frequently used value is 1/360 of the span. A deflection limit may also be a fixed value, such as 2mm (1/16in) for sheathing and 4mm(1/8in) for other form members. If limits for deflections are given by job specifications, the individual members of the form system should be sized to meet these limits as well as the strength requirements. If no deflection limits are specified, form deformations should not be so large that the usefulness of the cast concrete member is compromised (Arch Alexander, 2003).

3) Effects of formwork on surface regularity and smoothness.

A key point to consider in the surface regularity and smoothness of concrete is that formed concrete, when properly placed and vibrated, will take the exact same surface appearance as the form within which it was molded. So once again, proper management and protection of formwork is essential to attain a quality formed concrete surface.

Even where the concrete is structural only, and will receive further finishing, a rough and untidy concrete surface is of little use. Where the concrete is to be plastered, a cautious contractor would still apply a bonding agent or slurry before plastering to ensure proper adhesion of the rendered finish. Where cladding is intended, irregular concrete surfaces can also cause fixing difficulties for masonry screws as well as causing the supporting framework to be skew and misaligned.

i) Effects of steel sheathing on surface regularity and smoothness.

Steel, as used in formwork will always be smoother than any timber surface man has produced, and thus where an absolutely smooth concrete finish is required; new steel will always be the best. The downside of steel is that damage to the sheathing such as dents, holes, and other surface irregularities are very difficult and very costly to repair as a number of intensive operations such as welding and grinding are involved. Another method to repair holes and dents in steel forms involves patching with putty filler. The authors experience has found that these patches easily flake off and the form surface appears un-refurbished.

Ecocem, (2013), sums up steel formwork "Steel formwork is completely impermeable, and as such it can lead to the formation of blowholes in inadequately compacted concrete, as there is no route for the air to escape through the formwork. Steel will give a good quality, shiny finish to concrete, as long as the internal surface of the steel is smooth and free of markings." (http://www.ecocem.ie Accessed on December 31, 2013)

ii) Effects of timber sheathing on surface regularity and smoothness.

Resin coated timber sheathings as used in formwork system, provides a very smooth forming surface for concrete. It is close but no match for steel, but is still a vast improvement over uncoated timber. One problem with timber facings regarding surface smoothness is function of the moisture content of the timber, and is best explained by Doka (2008): "Surface waviness. Coated birch plywood in particular can form irregular waves along the direction of the fibers when moisture penetration is non-uniform on account of tiny holes in the film coating or damage and nail-holes, and through the edges of the sheets. Although only a few tenths of a millimeter high these waves are clearly perceptible in the surface of the concrete. The waves disappear when the panel has had a chance to balance its moisture content, and when next used the formwork produces a smooth finish."

Timber formwork systems are much easier to refurbish as the sheathing is attached by means of screws or rivets, unlike steel forms where the face and framework are welded together. These fixings are easily removed and the damaged timber surface can be renewed. The timber sheathings are resin coated both sides, so the first renewal will involve reversing the timber insert to reveal the new face, at a minimal cost. When the second face of the timber has been exhausted, the whole timber panel is replaced with a brand new item from the manufacturer (Niekerk, 2009).

2.5 Stripping of formwork

Formwork should be planned and constructed in such a manner that it is possible to remove the different components in the following order of sequence:

a) Shuttering forming vertical faces of walls, beams and columns sides, which beer no load but used only to retain the concrete, should be removed first.

b) Shuttering forming soffit of slabs should be removed next, and

c) Shuttering forming soffit of beams, girders or other heavily loaded shuttering should be removed in the end (Abebe Dinku, 2007)

The designer and contractor can have conflicting goals when to remove forms. The designer wants the maximum strength gain, while the contractor wants to strip and reset(cycle) forms as soon as possible to improve the schedule and maximize form reuse (Argaw Tarekegn, 2010).

Duration of time up to which the formwork should be kept in place depends upon many factors such as types of cement used, shape and position of the member, loads to be carried by the members and the temperature of the air. Different countries have their own recommendation for minimum formwork stripping period for different structural element s of the building. American concrete Institute (ACI), British Standard and Ethiopian standards recommendations for formwork removal is reviewed in this chapter.

2.5.1 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 10 ^{0}C (Table 2.2). The time need not be consecutive, but it is the total time during which the temperature is above 10 ^{0}C. 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. Shorter stripping times listed for live load to dead load ratios greater than 1.0 are the result of more reserve strength being available for dead load in absence of live load at time of stripping.

Table 2.2 ACI General Guidelines for form stripping times(ACI 347R-94)

Member		Time	
Walls		12hrs	
Columns		12hrs	
Sides of beams or Girders		12hrs	
Pan joist forms	760mm wide or less	3days	
	Over 760mm wide	4days	
Arch centers		14days	
Joist, beam or girder soffits		Where design live loads are	
		Less than dead loads	Greater than dead loads

Under 3m clear span between structural supports 3 to 6m clear span between structural supports Over 6m clear span between structural supports	7days 14days 21days	4days 7days 14days
One way floor slabs Under 3m clear span between structural supports 3 to 6m clear span between structural supports Over 6mclear span between structural span	4days 7days 10 days	3days 4days 7days
Two way slab systems	Removal times are contingent on reshores where required, being placed as soon as practicable after stripping operations are completed but not later than the end of working day in which stripping occurs.	
Post-tensioned slab system	As soon as full post-tensioning has been applied	

2.5.2 British Standard Recommendation

The type of material used for the formwork and the gain in strength of the concrete influence the stripping time of the formwork. The strength gain is governed by the mean concrete temperature, the mix design, method of curing etc. when finish and uniform color are important, a consistent timing regime of striking and curing will be critical.

A minimum value of in-situ concrete cube strength of 2 N/mm^2 is generally recommended to reduce the risk of mechanical and frost damage to finishes while striking vertical formwork. A minimum period of 8 hours at 20 ^oc for unsealed plywood or 6 hours at 20 ^oc for impermeable formwork such as overlaid or film coated plywood, steel forms etc. The temperature is concrete temperature. In practice if the temperature of concrete is above 10^oC overnight the vertical formwork can be stuck next morning. Summary of the BS recommendation for concrete made with Portland cement 42.5N/mm^2 and sulfate resisting Portland cement 42.5N/mm^2 are shown in table below.

Table 2.3 Minimum period before striking formwork as per BS (BS8110 1997)

Type of formwork	Minimum period before striking

	Surface temperature of concrete	
	16^0C and above	t^0C(any temperature between 0 and 16^0C)
Vertical formwork to columns, walls and large beams	12hrs	300/(t+10)h
Soffit formwork to slabs	4days	100/(t+10)days
Soffit formwork to beams and props to slabs	10days	250/(t+10)days
Props to beams	14 days	360/(t+10)days

British cement association, the required strength of a concrete slab for striking depends on:

- Characteristics design service loads
- Construction load
- Characteristic concrete design strength
- Actual concrete characteristic strength at the time of striking

The formula for calculating the required early striking strength as per the association's recommendation is determined as follow:

Determination 1: $W/W_{ser} \leq 1.0$

Determination 2: $f_c \geq f_{cu}(W/W_{ser})^{1.67}$

Where: W_{ser} is the total unfactored design service load, kN/m^2: W is the total unfactored construction load on the slab considered, kN/m^2; $f\,c$ is the required characteristic concrete strength to be able to strike the flat slab, N/mm^2: f_{cu} is the characteristic strength of the concrete, N/mm^2.

2.5.3 Ethiopian Standards Recommendations

1) The formwork shall be removed slowly, as the sudden removal of wedges is equivalent to a shock load on the partly hardened concrete

2) The time at which formwork and falsework is removed shall be determined by consideration of the following criteria:

(a) The stresses that will be induced in the concrete when the formwork / falsework has been removed:

(b) The concrete strength at the time of removal;

(c) The ambient conditions and the measures available to protect the concrete once the formwork is removed;

(d) The presence, or otherwise, of re-entrant angle formwork, which should be removed as soon as possible, while complying with other removal criteria

(3) The formwork shall not be removed before the structure has gained enough strength to safely carry all possible loads. The time at which formwork is struck will be influenced by the following factors:

(a) Concrete strength

(b) Stress in the concrete at any stage in the construction period

(c) Curing

(d) Subsequent surface treatment requirements

(e) Presence of re-entrant angles requiring formwork to be removed as soon as possible after concrete has set to avoid shrinkage cracks.

(4) Provided the concrete strength is confined by tests on cubes stored as far as possible under the same conditions, formwork supporting cast-in-situ concrete may be removed when the cube strength is 50% if the nominal strength or twice the stress to which it will then be subjected whichever is greater, provided that such earlier removal will not result in unacceptable deflection such due to shrinkage and creep.

(5) 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 absences of more accurate data, the following minimum periods are recommended

Table 2.3 Minimum period before striking formwork as per ES(EBCS2 1995)

Parts of the building	Period of Removal
1) For non-load bearing parts of formwork (e.g Vertical formwork of beams; formwork for columns and walls)	18hours
2) For soffit formwork to slabs	7days
3) For props to slabs	14days
4) For soffit formwork to beams	14days
5) For props to beams	21days

(5) Where sliding or climbing formwork is used, shorter periods than those recommended above may be permitted.

Engineer's specified criteria based on strength gain of the concrete are the guide in determining formwork removal time according to ACI recommendation. In the absence of such criteria, the guide contains recommendation for the length of time that formwork should remain in place when the air temperature is above 10^0c and when the air temperature remain below 10^0c or retarding admixture are used, these time should be lengthened. On other hand the type of material used for the formwork and the gain in strength of the concrete influence the stripping time of the formwork according to British Standard recommendation. BS sets the determination of stripping time according to the surface temperature of concrete and the type of cement used in the concrete mix. When we come to Ethiopian Standard recommendation postulates the time at which formwork and falsework is removed shall be determined by: stresses that will be induced in the concrete in the concrete, the concrete strength at the time of removal and the ambient condition and the measures available to protects the concrete once the formwork is removed.
Therefore from the above reviews we can make the following general summery; ACI and BS specify similar stripping time, 12 hrs, for formworks of vertical member. While EBCS recommend relatively longer time

2.6 Formwork Construction systems for selected projects in Addis Ababa

Formworks construction technology in Ethiopian is at an infant stage. This situation is attested through reviewing the construction practices of selected sites in Addis Ababa. 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.

A) 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 2.15).Incase of timber boards, the members are nailed together and supported from back in the same manner as that of steel panels. A form release agent, 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.

Fig. 2.15 Footing pad formwork construction system at Addis Ababa, Flintstone Homes, Real estate development projects around Urael

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.

Fig. 2.16 Column formwork construction systems at Sengatera 40/60 projects

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 workmen.

Fig. 2.17 Shear wall formwork construction systems in Addis Ababa around Megegnagnai for office building

B) Slab and Beam Formwork Construction Systems

Steel panels of different sizes such as 0.9m*2m, 1m*1m etc are used as forms for slab construction. Almost all contractors use wooden shores (see Fig. 2.18). 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 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.

Fig. 2.18 Slab formwork construction systems for office building around Megegnsgnai 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. The quality of concrete for beam and slab might be affected unless very experienced man power 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.

2.7 Summery of literature review

Based on the location of formwork system generally two board category of formwork system, horizontal and vertical, was discussed in this chapter. Based method of operation and assembling the horizontal and vertical formwork system was subdivided in to different types and detail description was given for each subdivisions.

Factors related to building architecture, job specification, local condition and supporting organization are main factors that affect the selection of horizontal formwork system for building projects. Many of factors that affect the selection of vertical formwork system for building are similar to those factors affecting the selection of horizontal formwork. However, there are some factors that are particularly important to the selection of vertical formwork system.

Construction consideration of formwork normally begins when the contractor stars estimating a jobs for bidding but it is better to start in the design stage. It normally involves the following operations: propping and centering, shuttering, provision of camber and cleaning, and surface treatment.

Trait for good formwork system in finished concrete surface involves; create even and smooth surface, finished surface structure should be flat, plumb and straight with sharp corners and edge, fewer presences of tie holes, less concrete colored with regards to staining and discoloration, less leakage of fines at joints and tie holes and the formwork must remain in place until the concrete is strong enough to carry its own weight or finished structure may be damaged

Duration of time up to which the formwork should be kept in place depends upon many factors such as types of cement used, shape and position of the member, loads to carry by the members and the temperature of the air. Different countries have their own recommendation for minimum formwork stripping periods for different structural elements of building.

The construction practices of formwork system in the selected projects shows that both steel and timber formwork are used in combination for different parts of the building and manual, labor intensive, method of construction is used to construct formwork in the site. The main forming releasing agent used in the site burnt oil usually applied on the panels and boards before placing the formwork.

Chapter 3 Research Methodology

3.1 Introduction

The purpose of this chapter is to present the assumptions that back up this research, as well as to introduce the research strategy and the empirical techniques applied. The chapter defines the scope and limitations of the research design.

This chapter aims at elaborating the methodological process that used to carry out the research based on the objective of the study. This comprises limitations of the research, the detail section that describes how data were collected, questionnaires survey was made, informal interview were conducted and detail process of how the analysis of the data was made.

3.2 Limitation

This research is intended to compare steel and timber formwork system for a building with respect to cost, quality and speed of construction thus other issues like safety and construction of scaffolding is not included

3.3 The Research Questionnaire Design

The questionnaire design was based on a combination of an extensive review of literatures dealing with influence of formwork type on cost, quality and construction speed of building projects and the researcher's knowledge on the current formwork construction practices of national contractors.

The questionnaire form, which was accompanied by a covering letter, consisted five parts. The questionnaire was a mix of structured (closed) and unstructured (open) type of questions. Basically, the questions were structured or closed type questions. But, in view of obtaining as much information as possible, participants were encouraged to give additional information or comments on the open spaces provided under each question.

3.4 Rationale of the Research Questionnaire

As specified earlier a combination of a closed and open questionnaire types has been used for the survey by which respondents can simply select from closed question and given opinion on open question. Since the questionnaire was determined to be self-administered, it was realized that it should be self-explanatory without sharing any clarifications regarding the questions. To ensure this, a separate page of introduction describing the aim and objectives of the research were attached to the questionnaire.

The questionnaire form consisted five parts, organized in a logical pattern which enclosed the cost, quality and time aspect of formwork utilization. The first part contained general questions regarding how often steel or timber formwork used the professional career of respondent, what type formwork used for different building element in the project where the respondent involved currently, consideration to select the type of formwork used in the project, are there any drawing for the construction of formwork and condition of formwork used in the project. Information on general question part was intended to reveal whether or not the respondent has practical know how and full knowledge with respect to the subject matter. This part also contained questions focused on planning and designing for the type of formwork used in a project before construction begins. As discussed in the literature review section type of formwork used in the project have a direct influence on the successful delivery of the project with respect to cost, quality and completion time.

In the second part, participants were asked to indicate and/or rate which type of formwork is good for different building element with regard to initial and rental cost, average cost of formwork per square meter used in respondent's project, percentage range of formwork cost in the total cost of the project and if there is difference in number of laborers required to execute timber and steel formwork construction. Moreover, participants were asked which type of formwork has to be used to minimize the construction cost of building in Ethiopia with their opinion and reasoning.

The third part contains questions that focus on formwork system and finished concrete quality. The respondents were asked the issue of discoloration of finished concrete, dimensional accuracy, smoothness and regularity of concrete surface. In addition to this the participants were requested to list out the major quality problem that occurs in the time of stripping formwork from concrete in their respective site.

The speed of construction and formwork system was included in the fourth part of the questionnaire for the intention of which type of formwork is faster in the construction process of building projects. In this part the respondents were asked things like does the type of formwork used in their project affect erection and stripping time of the form from the casted concrete. Additionally the concept of productivity of labor were asked to find out whether the type of formwork used affect the output of the project in tern affect the completion time of the project.

Fifth part of questionnaire asks the respondents to give their comments related to formwork construction practices in Ethiopia. This helps to investigate other points that are not included in other part of the questionnaire that can see in the time of analysis.

The format of the questionnaire can be found at the end of this research paper in appendix one.

3.5 The Research Sample Selection

The general population of this research paper is building projects that are under construction in Addis Ababa. The main principle behind selecting sample population is to come up with projects that use both traditional timber formwork and modern steel formwork.

As the specific number of general population is not known, thus method of purposive random sample selection method is used for sample selection. The sample population stratified under office, commercial, multipurpose, apartments (40/60), condominium and hospital buildings that are distributed in Addis Ababa. In subsection 3.7 their total number and returning rate is presented.

3.6 Data Collection methods

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. By the cutoff date, the researcher managed to collect back twenty four useable questionnaires from the respondents. This constitute of a sum of 80 percent response rate.

As the practice of formwork varies from contractors to contractors the distribution of the questionnaires covers all level of contractors that mean high and low grade contractors. This helps the researcher to identify the practices of formwork for large size projects such as 40/60 G+24 apartment buildings and for low size projects like G+4 condominium buildings. The collected questionnaires and their return rate is given in table 3.1 below.

In Table 3.1 the distribution the questionnaires with regard to purpose, location and return rate questioner given:-

Table 3.1 Distribution and Return of the Questionnaires

NO.	Number & Purpose of project	Location	Return rate	% response rate
1	Three Office project	Around Meskel square	All are returned	100%
2.	One Office building in ERA head office	Around Mexico	Returned	100%
3.	Two Commercial buildings	Hayahulet straight	Returned	100%
4	Five apartment (40/60) buildings	Sengatera Mexico	Four are returned	80%
5	Two office buildings	Around Megegnagnai	All are returned	100%
6	Three commercial buildings	Around Arate kilo	All are returned	100%
7	One Hospital building	YekatiteAserahulet	Returned	100%
8	Three Multipurpose buildings	Around merekato area	All are returned	100%
9	Ten Condominium apartments	Kilito site	Five out of ten is returned	50%

3.7 Method of Analysis

This research uses a mixture of descriptive statistics and graphs and some nonparametric inferential statistics to analyze the collected data. 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.

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 detail analysis and interpretation is given in next chapter.

Chapter 4 Data Analysis and Interpretation

4.1 Introduction

This chapter focuses on analyzing and interpreting the result gathered from the respondents through interview and questionnaire. Based on the gathered data from the respondents comparison is made for steel and timber formwork system used in the building projects with respect to cost, concrete quality and speed of construction. The comparison result is interpreted based on information from personal interview with the respondents and site observation data.

4.2 Data analysis

As mentioned in Section 1.3, this research has three objectives; cost comparison of timber panel and steel panel formwork system used for building projects, to compare quality of finished concrete made by timber and steel panel and to compare the speed of construction of building projects.

The research questions which were formulated in view of achieving these objectives were:

1) Which formwork system will provide the best profit money to contractor?

2) Which formwork ensures a better quality of finish concrete element?

3) Which system provides faster speed of construction?

Analysis of the data collected through the research questionnaire has addressed these questions. For the purpose of relating the research questions with the analysis and also for the ease of presentation, the results and discussions are presented in three major themes. Section 4.2.1 presents the first theme which is linked with research question No 1. Accordingly, it presents the research findings with respect to the cost of formwork system. Section 4.2.2 and 4.2.3 are devoted to the second and third themes, which are related to question No. 2 and 3. The issue of quality where analysis in section 4.3.2 and speed of construction analysis in subsection 4.2.3

4.2.1 Cost Analysis

Cost of formwork and its associated labor cost is significant segment of the concrete structural frame. The cost of formwork is influenced by initial cost, reuses cost of formwork system and maintenance and storage cost. These influencing factors has been addressed in the questionnaire and the analysis for each case is presented blow

With respect to the initial cost of formwork system the respondent where asked to select timber, steel or other formwork for different structural element of building such as beam, column, slab , stair and shear wall by considering only initial cost of the formwork. The analysis was made by using bar chart to show the respondent rate preferring steel formwork over timber formwork. The Figure is given blow:-

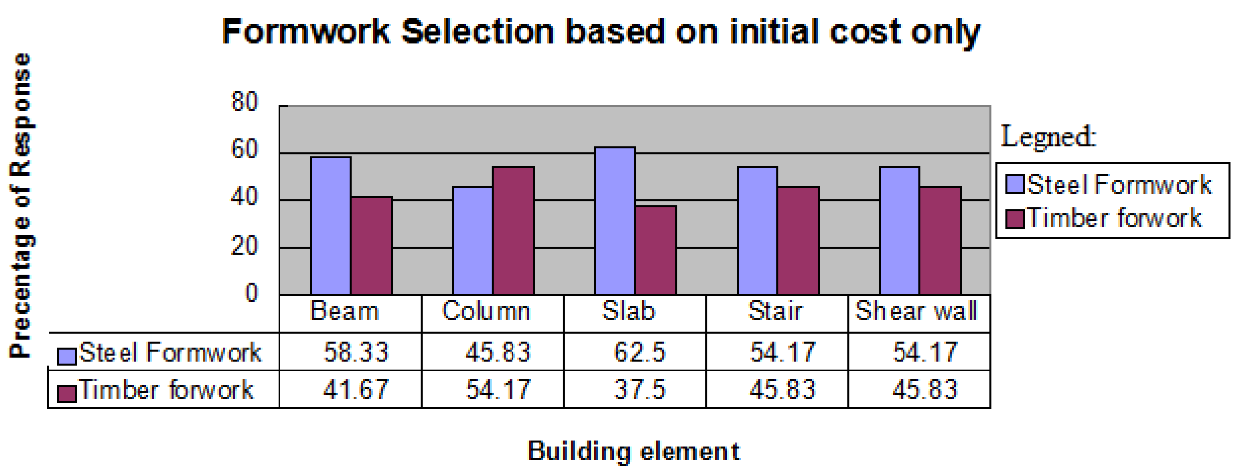

Fig. 4.1: Response rate for selection of formwork based on initial cost only

From the result we can report based on initial cost of the formwork 58.33% of the respondents prefer to buy steel formwork for beams than timber formwork. For the case of column based on initial cost 54.17% of the respondents prefer to buy timber formwork over steel formwork. For slab, staircase and shear wall construction the majority of the respondents prefer steel formwork over timber formwork based on initial cost of the formwork system.

In addition to this two respondents [8.33%] responded to select other type of formwork system such as ply wood and MDF formwork for the construction of different building element.

The interpretation and analysis of Fig 4.1 is given in the following two paragraph

For structural elements such as for beams, slabs, stairs and shear walls most of respondents are preferred to buy steel formwork than timber formwork. But this did not mean steel formwork is cheaper than timber formwork, in fact one can see in Table 4.1 average cost of steel formwork is higher than timber formwork for all structural elements. It means most of respondents when they are planning to buy formwork they will not only consider the advantage of cost difference rather they consider different criteria such as the number of reuse, building architectural and structural design. Hence from the literature part section 2.3, the selection criteria of formwork system, depend on the nature of the project one or more selection criteria can be used to select the type of formwork can recalled here.

In case of columns most of respondents preferred to buy timber formwork than steel formwork. Here respondents are preferring timber formwork over steel formwork considering cost advantage and the numbers of casted columns are less in number. Here we can recall from the literature review, section 2.3.2: although the steel formwork can be reused many times, the high initial cost of providing the form often discourage its selection, especially when there is no need to reuse them too many times, for example in a low-rise development.

From interpretation and analysis one can conclude that a majority of respondents preferred to buy steel formwork than timber formwork for beams, slabs, stairs, and shear walls not based on the advantage of initial cost but rather based on different criteria. For the case of columns majority of the respondents prefer timber formwork than steel formwork considering low initial cost and less number of reuse.

With only rental cost consideration of formwork system the respondents responded to select formwork in such manner. The result is given below in Fig. 4.2:-

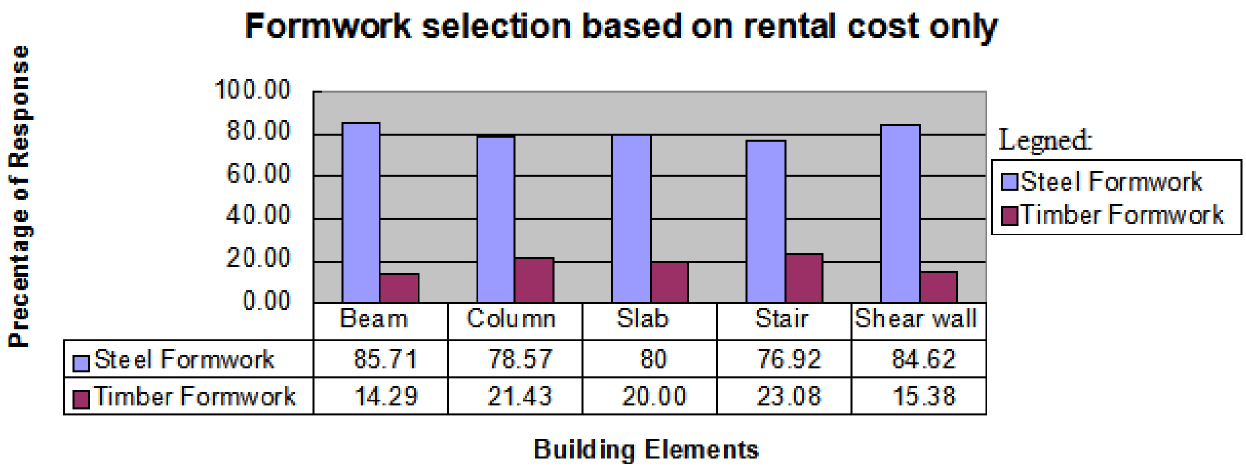

Fig. 4.2: Response rate for selection of formwork based on rental cost only

Interpretation of Fig 4.2 is that based on the result considering only rental cost, steel formwork is by far preferred by the respondents over the timber formwork system. Even if this is the case most of the respondents pointed out that it is impossible to find out rental timber formwork type in Addis Ababa. This makes the difference larger than expected. In addition to this almost 100% of respondents use their own formwork system and did not use the option of rental case.

Average cost of formwork per square meter used in the respondents' project were asked among twenty four collected questionnaires only nine (37.5%), responded on this question the report is given in the Table 4.1 below.

Table 4.1 Average cost of formwork per square meter (Birr/m^2)

Structural elements	Respondents(R)									Steel Average cost	Timber Average cost
	R1	R2	R3	R4	R5	R6	R7	R8	R9		
Beam	35*	65	70*	250*	150	132*	108*	90		119	101.67
Column	35*	65	70*	250*	150	94	108*	90	72	115.75	94.2
Slab	35*	40*	55	250*	150	132*	108*	90	72	113	91.75
Stair	35*	55*	75*	250*	150	132*	108	90	72	109.4	105
Shear wall	35*	90	70*	250*	150	94	108	90	72	118.33	100.67

*For steel

From Table 4.1 interpretations given as follow

One can see that cost per meter square either for steel or timber formwork deviates from project to project. The main reason this variance happen in cost of the formwork is the condition of the formwork used in the building projects. For grade 6 contractors the cost of steel formwork as much as 35 birr per meter square where as for grade 1 contractors, those use sophisticated steel for work; price goes to up to 250 birr per meter square of steel formwork system. To show the difference the cost break down for direct cost of the formwork for grade 1 and grade 6 contractors is shown in table 4.2 below.

Table 4.2 Cost Break down for steel formwork for grade 1 and grade 6 Contractors

MAJOR WORKS BREAK DOWN

A-Material cost					B-Labor Cost						C-Tools & Equipment						
Type of mat.	Unit	Qty	Rate	Cost per unit	Labor by trade	No	UF	Indexed Hr Cost	out put	cost per unit	Type of Equipment	No	UF	Hourly Rental	out put per Hr	Cost per unit	Direct costs A+ B+C
Formwork(Sheat meta	m2	1.00	177.37	177.37	G.leader	1.00	0.10	18.75	0.75	2.50	Tools	3.00	1.00	0.25	0.75	1.00	
Eucalyptus	ml	1.00	7.65	7.65	Carpenter	1.00	1.00	18.75	0.75	25.00							
Nail	kg	0.50	23.90	11.95	D.labour	2.00	1.00	7.50	0.75	20.00							
Black wire, 2.5	kg	0.20	19.16	3.83													
Mold oil	Lt	0.10	7.00	0.70													
				201.50						**47.50**						**1.00**	**250.00**
Formwork (sheet meta	m2	1.00	5.00	5.00	G.leader	0.00	0.10	18.75	0.75	0.00	Tools	3.00	1.00	0.25	0.75	1.00	
Eucalyptus	ml	1.00	4.75	4.75	Carpenter	1.00	0.50	18.75	0.75	12.50							
Nail	kg	0.05	23.90	1.20	D.labour	1.00	1.00	7.50	0.75	10.00							
Black wire, 2.5	kg	0.02	17.75	0.36													
Mold oil	Lt	0.10	2.00	0.20													
				11.50						**22.50**						**1.00**	**35.00**

When it comes to cost of timber formwork price range from 65 birr up to 150 birr per square meter, similar reasoning can mentioned here for the variance of cost from project to project.

From the respondents response the average cost of timber formwork is cheaper than steel formwork for all structural elements. The difference is shown below in table 4.3

Table 4.3 Average cost difference for steel and timber formwork per square meter (Birr/m^2)

Structural elements	Steel formwork average cost per meter square (Birr/m^2)	Timber formwork average cost per meter square (Birr/m^2)	Difference (Birr/m^2)
Beams	119	101.67	17.4
Columns	115.75	94.2	21.55
Slabs	113	91.75	21.25
Stairs	109.4	105	4.4
Shear wall	118.33	100.67	17.66

From table 4.2 we can see that even if the cost of steel formwork is higher than timber formwork the difference is not large but this difference can be selection criteria for the type of formwork used in the project for the case of column formwork.

As general conclusion for the average cost difference for beams, slabs stairs, and shear walls even if timber for work is cheaper than steel most respondents prefer to buy or to rent steel formwork based on initial and rental cost.

In order to come up with the average percentage range of formwork system cost including labor cost the respondents were asked to percentage cost range of their formwork system with respect to the project concrete frame work cost. The category of the range is 0-10%, 10-20%, 20-30%, 30-40%, 40-50%, 50-60% and more than 60%. Most of the respondents responded their formwork system average percentage range of cost is in between 0-10% and next to the dominate range is between 10-20% costs of formwork. The result of the analysis for this range is shown below in graph4.3:-

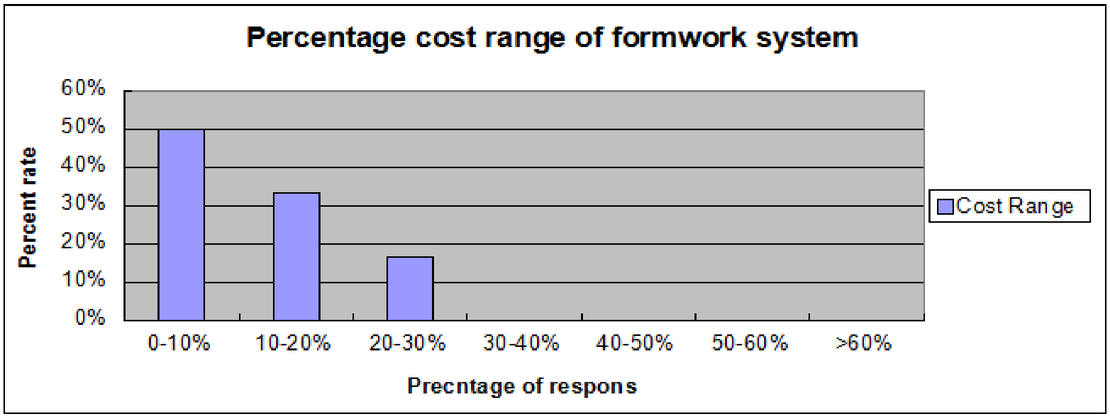

Fig. 4.4 Percentage rage of formwork cost relative to concrete frame of building

The other issue that makes the difference in the cost of formwork system is the amount of labor force involved in the construction. To address this, respondents were asked to select weather there is difference in number of labor used to construct steel and timber formwork system through Yes/No question and also if there is a difference in labor force the respondents required to specify in their labor difference per square meter of the formwork system. The result are reported in Fig. 4.5 below:-

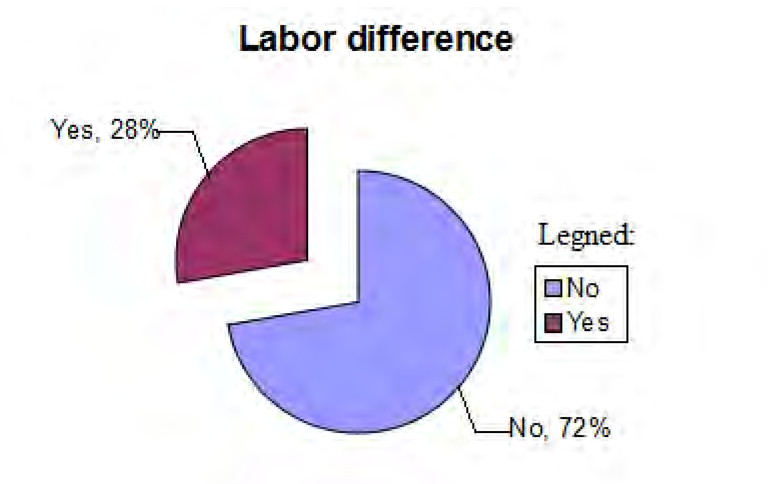

Fig. 4.5 Labor differences in constructing steel and timber formwork

As we see from the report graph the number of respondents that select there is no difference in the labor force dominates, (72%) of the total respondents. The remaining 28 % of the respondents said that yes there is difference in number of labor used in constructing steel and timber formwork system. Among the reasons for this difference stated by the respondents are

1) For timber formwork the labour intensity is less than the steel but the price difference is not much. The reason why there is less intensity of labour for timber formwork is that the scope of the work done by steel and timber formwork, in the most projects steel formwork is used for slab work where as timber mostly implemented for stair and column works.

2) Sometime steel formwork required additional cost straighten of the form after striking

3) If we use MDF/ timber/ one extra person is needed to cut the MDF according to size of the structural element

In regard to the cost of formwork, the last question that the respondents were asked is about their opinion in minimizing the construction cost in Ethiopia and which type of formwork should be recommended for use. Nineteen respondents out of twenty four, (79.17%), responded that steel formwork is the best solution in minimizing the construction cost in Ethiopia whereas only two out twenty four, (8.33%) responded in favor of timber formwork system especially ply wood formwork system and the remaining three respondents indifferent way of this question. The results of the report of the respondents repose is given in Fig. 4.6 below

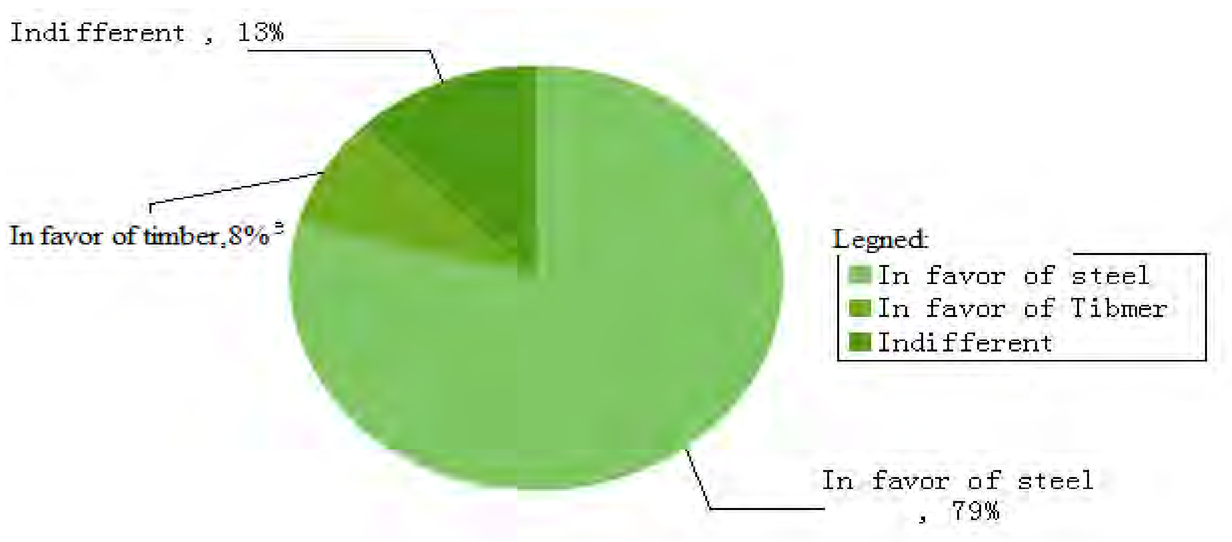

Fig. 4.6 preference of formwork type in minimizing construction cost

From Fig. 4.6 most of respondents responded in favor of steel formwork and their reason of preference is asked in the questionnaire and most of the respondents were given different reasons in the selection. Their reasoning was summarized in Table 4.4 below:-

Table 4.4 Reasoning in preference in the type of formwork to minimize cost

In favor of steel	In favor of Timber
• Its Durability • It require less time than timber to construct • It require less number of props for slab and beam • Minimize deforestation • Strength • Number of reuse • Easy available for rental • It is possible to maintain • Reduce , sometime avoid, the cost of plastering after dismantling of steel formwork	• Give smooth finished surface • It has fair price • Required less manpower

Even if most of my literature reviews showed us the steel formwork system is high in price than timber formwork price, most of the respondents proposed steel formwork system as solution in minimizing the construction cost in Ethiopia.

4.2.2 Concrete quality analysis

Comparing the quality of finished concrete formed by steel and timber formwork system, the issue of discoloration, dimensional accuracy, smoothness and regularity of concrete surface and major quality problem that occurred in the time of stripping were addressed for the respondents with in the category of four distinct questions. The respondent’s response for each question is analyzed as follows

The first question addressed which type of formwork system creates more discoloration of finished concrete. In this context concepts of discoloration taken as staining, rust and the like are described in the questionnaire and the respondents are given choose of selecting steel, timber, both or indifferent type of formwork system. The result of the analysis of response is given below in pie Fig. 4.7

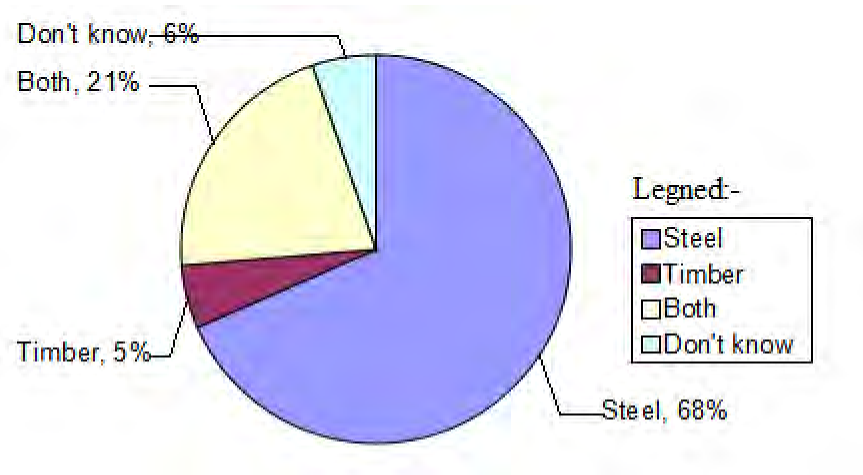

Fig. 4.7 Formwork type and discoloration

From the above response the steel formwork system creates more discoloration than timber formwork system that makes steel formwork inferior with regards to the quality aspect of the finished concrete product. The main reason why this happen is that steel formwork required more buried oil to remove from the concrete and it does not absorb the oil just like timber formwork does.

Maintaining dimensional accuracy in casted concrete is the second question that rose for the respondents with regards to the issue of quality of finished concrete creates by the type of formwork systems. Dimensional accuracy includes size, shape and alignment of structural elements. This verification was given for the respondents and they responded to select which type of formwork system maintains more dimensional accuracy among the given choices. The results of the analysis is presented below in the Fig. 4.8

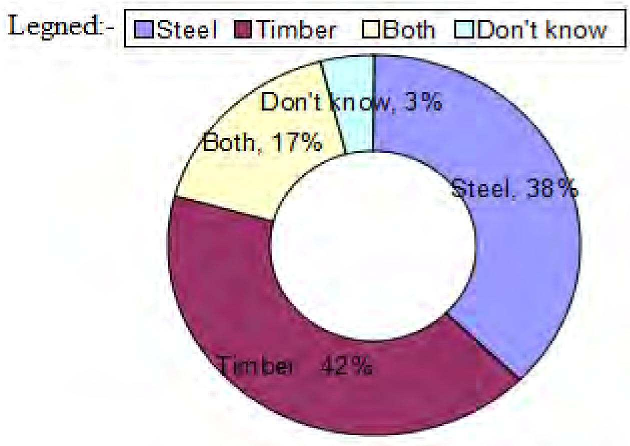

Fig. 4.8: Maintaining dimensional accuracy

Maintaining design size, shape and alignments of structural element is the main trait required from any formwork system used in the construction of building elements with this aspect about 42%, of the respondents prefer timber formwork system especially modern formwork system such as ply wood and MDF type of formwork system. Almost similar number (38%) of respondents select in favor of steel formwork system. Some respondents prefer both steel and timber formwork system in maintaining dimensional accuracy of finished concrete. So we can conclude that regarding to maintaining dimensional accuracy of casted concrete there is no as such difference distinguished attribute between steel and timber formwork system.

Third question in this category address the smoothness and regularity of finished surface as one of the quality measurement of the formwork system. Based on this concept respondents are asked to write the type of formwork system, that they will recommend, for building projects base on only smoothness and regularity of finished concrete. The results of the analysis is given below in Fig. 4.9

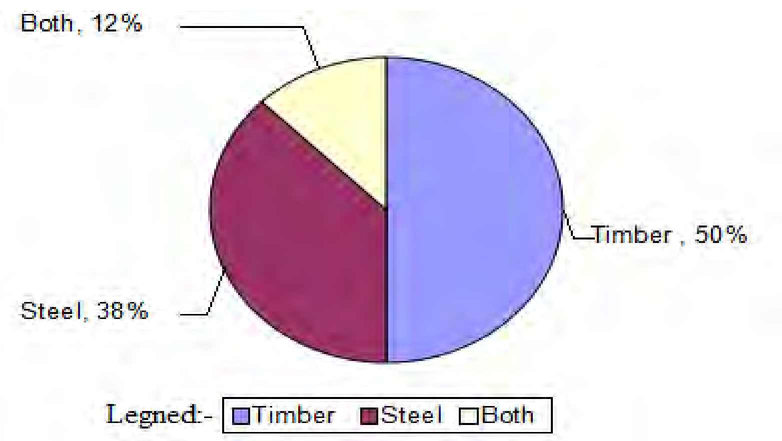

Fig. 4.9 smoothness and regularity of concrete surface

Timber formwork type, especially modern timber formwork, is preferred by 50% of the respondents and the remaining 50% of the respondents select steel formwork system and both type of formwork system with higher response rate for steel formwork. These means half of respondents prefer modern timber formwork system for smooth and regular finished concrete surface.

The last question regards to the quality issue is the respondents were asked to state out the major quality problem happened in their respected projects. The major quality problems stated by respondents are:-

- Inappropriate edge formation
- Honey combing
- Minor change in dimensions of finished concrete
- Smoothness and regularity problems
- Discoloration
- Budge out of the casted concrete
- Unattractive surface
- Difficulty on time of stripping

4.2.3 Speed of construction analysis

One means of minimize the cost of building project to speed up construction works to achieve a very short floor cycle, is to have the structure of a typical floor completed in the shortest time.

The key to achieve this, again from the production point of view, is by the use of a system of efficient and appropriately designed formwork system.

To compare the speed of construction done by steel and timber formwork system the concept of erection time, stripping time and productivity of construction work was asked in the questionnaire in the sense of comparing each type of formwork system. The analyses of respondents' response are made below in the following paragraph:-

With respect to the erection time of formwork respondents responded their observation about the time difference in constructing steel and timber formwork in their respective project, if there is difference they responded which one is faster and which one is slower. Results of the analysis are given below in Fig. 4.10.

Fig. 4.10 Speed of erecting/constructing/ formwork system

From the above Figure we can conclude that 42% observed that steel formwork takes faster time to construct whereas 33% feel that there is no difference in time to construct the two formwork types. Thus generally the type of formwork used in the projects affects erection time of formwork

Regarding to stripping time of formwork, for how long one has to wait to remove the form from concrete, respondents were asked to response whether type of formwork used their respective project affects the stripping time of the formwork. Graphical analysis of their response is given below in Fig. 4.11

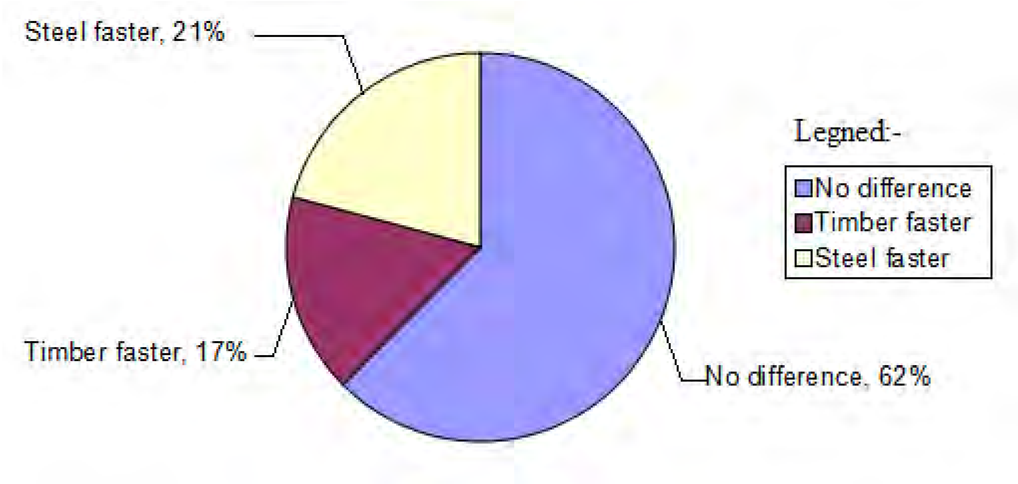

Fig. 4.11 stripping time of formwork system

From the above graph we can see that more than 60% of the respondents feel that type of formwork used in their projects did not affect the stripping time of formwork from the casted concrete, whereas only 21% feel that steel formwork can be stripped faster than timber formwork and 17% of respondents feel that timber formwork can be stripped faster than steel formwork steel. Those respondents that said there is no time difference in stripping the formwork from the concrete feel that length of time that required to remove the formwork actual depend on the type of cement and other environmental factor of the site.

To know the stripping time of respondents' projects a table was provided to be filled by respondents. The response range for almost all respondents is similar to for both type of formwork system. The average range of stripping time filled by the respondents are given below Table 4.5

Table 4.5 Stripping Time for steel and timber formwork

Structural element	Stripping time	
	For steel formwork	For timber formwork
Beam	21 days	21 days

Column	12-24 hours	12-24 hours
Slab	21-28 days	21-28 days
Stair	21 days	21 days
Shear wall	12-24 hours	12-24 hours

From Table 4.4, one can understand that the type of formwork used in building projects does not affect the time it takes to remove the form. But stripping time is a function of how quickly the concrete achieve the desirable strength which in turn depends on the type of cement and admixture used in projects. Thus from this report we can understand that the type and condition of the formwork used in the project can affect the productivity of the crew. Most respondents feel that modern formwork systems such as MDF improves productivity of the crew because it can cover greater area, less in weight and easily handled by the workers

With regard to productivity and type of formwork respondents were asked whether or not the type of formwork used in their projects affect the productivity of the workers by selecting yes or no question. Results of the analysis is given below in Fig. 4.12

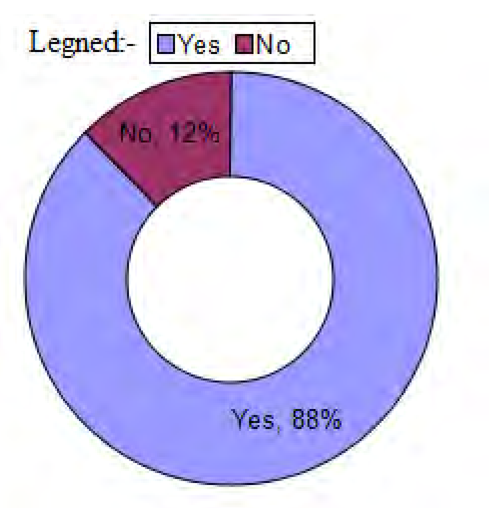

Fig. 4.12 Relation between productivity and formwork system

From this graph we can see that most of respondents, 88%, feel that the type of formwork used their projects affects the productivity of the workers whereas small number of respondents, 12%, feel that the type of formwork did not affects the productivity. From these numbers we can conclude that the type of formwork used in any projects can affects the productivity of works. Modern MDF formwork system improves the productivity of the works by providing larger coverage area for casting concrete.

4.3 Issues related to formwork construction practices in the selected site

The last portion of the questionnaire raised the issue related to formwork construction practices in Ethiopia. Respondents were asked to give their comments other than cost, quality and speed of construction of formwork system that should be raised for further investigation and study. From 24 collected questionnaires only 6 (25%) responded on this part. This further comment helps the researchers and scholars study a detail design and other attribute aspect of formwork construction in Ethiopia. The following are the comments given by the respondents:-

- Most local contractors do not give attention for the important or manufacturing of steel formwork due to financial constraints and awareness problem.
- Our local carpenters had to get training in the usage of steel and timber formwork
- New technology must be implemented as substitution in place of old traditional wooden scaffolding in order to protect our forests and to minimize deforestation
- Higher institutions should try to research and develop new and efficient ways of constructing and erecting formwork.
- Most of the formwork construction practices in Ethiopia carryout without considering loads imposed on it/ in the absence of design/ which cause for construction accident and additional cost for re-erection of formwork.
- Construction and Urban Development Minister should consider formwork, type and amount, as main criteria for grading of the contractors
- Mold oil for formwork shall be thoroughly studied
- Formwork design shall be incorporated in courses at least in bachelor level

4.4 Data analysis summary

The cost analysis of the study shows that even if the cost of steel formwork is higher than timber formwork most respondents prefer to buy or to rent it for their projects. This indicated that the formwork selection is not only based on the cost of the formwork rather it is based on the number of reuse and durability of the formwork.

The quality of finished concrete made by steel and timber formwork is compared by considering different quality issues such as discoloration, dimensional accuracy, smoothness and regularity of finished concrete surfaces. Regarding to discoloration of finished concrete surface steel formwork create more discoloration where as both steel and timber equally maintain dimensional accuracy in casted concrete and timber formwork especially modern for such as plywood and MDF create more smooth and regular finished concrete.

To compare the speed of construction done by steel and timber formwork system the concept of erection time, stripping time and productivity of the construction work was analyzed. And result shows that steel formwork system can be erected with shorter time than timber formwork system. There is no difference in stripping time of steel and timber formwork system from the casted concrete and with regarding to productivity modern timber formwork system improve the productivity of the worker by providing larger coverage area for casting concrete.

Chapter 5 Conclusions and Recommendations

5.1 Conclusions

As it is recalled, the main objective of this research is to compare steel and timber formwork for building projects and to come up which system advantageous in regarding with cost, quality and completion time of the of building projects. Considering these three parameters analysis has been done in chapter four and based the results of the analysis the following conclusion has been made:-

- ✓ Initial cost analysis of the formwork shows that timber formwork is cheaper than steel formwork but most of the respondents prefer to buy steel formwork over timber formwork system.
- ✓ Based on rental cost of the formwork system all respondents prefer steel formwork system than timber formwork system. As remark all respondents pointed out that finding rental timber formwork is difficult and there is no company that involved in renting timber formwork in Addis Ababa.
- ✓ The average per meter square cost of steel formwork is higher than timber formwork system. Cost of steel beam formwork is 17.05% higher than timber beam formwork, column steel formwork costs 22.88% higher than timber column formwork and steel slab formwork costs 23.16% than timber slab formwork. Taking average the difference is steel formwork costs 16.96% higher than timber formwork
- ✓ 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
- ✓ Steel formwork system can be a solution for minimizing the cost of the construction industry in Ethiopia. The main justifications for this statement is steel formwork can be reused for so many time than timber formwork system, it required less number of props for beams and slabs, it easily available for rental and it is possible to maintain
- ✓ For best quality of finished concrete, it is better to use modern timber formwork system such as MDF and ply wood. Modern timber formwork system have smooth surface that helps in the time of removing the formwork from concrete surface
- ✓ The type of formwork used in building projects affects the productivity of labour force
- ✓ Modern timber formwork system such as MDF and ply wood improve productivity of labour force. Factors such as less required time of maintenance, large panel size and

smooth formwork face for modern formwork system with compared to steel formwork system helps in improving productivity of MDF and ply wood formworks.

5.2 Recommendations

Based on my findings the following two recommendations are given on cost and time of construction of the formwork.

1. Cost of formwork system

Unlike our perception the cost of steel formwork system does not have much difference with compared to cost of timber formwork system. Even in same projects the cost of imported modern timber formwork system is greater than conventional steel formwork system. Thus proper life cycle costing should be performed by contractors to accurately determine whether the steel formwork system used in building projects will justify the higher initial cost when looked at over the lifespan of the forms.

2. Completion time of formwork

Steel formwork can have faster rate of erection during construction when we compared with timber formwork system but this is not always true when comes to modern timber formwork system they improve the productivity of the crew. Thus future research should focus on better defining and quantifying the influence of type of formwork on productivity of crew. Factors such as formwork maintenance, panel size and formwork face were touched upon in this thesis, but require further research to determine their precise impact on productivity.

5.3 Future Study

The following three suggestions are put forward for future research to further improve the understanding of formwork construction for building projects:

- The effect of type of formwork on the productivity of the crew
- The impact of formwork maintenance, panel size and formwork face on the productivity
- Life cycle costing of the formwork in the projects

Reference

1. Abebe Dinku. (2007). *A Text book of Building construction.* (1st ed.). Addis Ababa: Addis Ababa University Printing press. P224-238
2. American Concrete Institute (ACI), Committee 347R-94. (1994). *Recommended practice for concrete formwork (ACI 347R 94).* Detroit, Michigan: American Concrete Institute
3. Alamin, B. (1999). *Analysis of construction loads on concrete formwork*. Unpublished master's thesis, Concorde University. USA
4. American Society of Concrete Contractors ASCC (2008), The Contractor's Guide to Quality Concrete Construction, USA
5. Argaw Tarekegn. (2010). *Application of modern formwork system in Ethiopia*. Unpublished master's thesis, Addis Ababa University. Addis Ababa, Ethiopia.
6. British Standards BS8110-1997 part 1, Structural Use Concrete
7. Doka framed formwork. Frami 300 product catalogue. 2005. Doka formwork international.)
8. Edward, G. (2008). *Concrete Construction Engineering Hand Book.* (2nd ed.). New Brunswick, New Jersey
9. Ethiopian Building Codes Standard, EBCS2 (1995). *Structural Use of Concrete.* Addis Ababa.
10. Fetene Nega. (2008). Causes and Effects of Cost overrun on Public building construction projects in Ethiopia. Unpublished master's thesis, Addis Ababa University. Addis Ababa, Ethiopia.
11. Hanna, A.S. (1999). *Concrete formwork system. (*1st ed.). New York: Marcel Dekker, Inc.,
12. Hurd, M.K. (1995). *Formwork for concrete AC1 SP-4*. (6th ed.). Detroit, Michigan: American Concrete Institute.
13. Jensen, D.A. (1986). Choosing a forming system for concrete floors and roofs. *Concrete Construction, 8 1*(1), 5-12
14. Niekerk, A.J. (2009). *Concrete elements: Timber faced formwork versus steel faced formwork systems, and which is truly better for the contractor?.* Unpublished master's thesis, University of Pretoria. Pretoria, South Africa
15. Peurifoy , R.L. and Oberlender, G.D. (2011). *Formwork for concrete structures.* (4th ed.). New York: McGraw-Hill Inc.
16. Ratay, R.T. (1996), *Handbook of temporary structures in construction.* (2nd ed.). New York: McGraw-Hill, Inc.
17. Raymond W M Wong, The construction of the 62-storey Cheung Kong Centre, The Chartered

18. Institute of Building (Hong Kong), Technical Review Paper, Newsletter February 2001 issue
19. Smith, R.C. and Andres, C.K. (1993). *Principles & practices of heavy Construction.* (4th ed.). Englewood Cliffs, New Jersey: Prentice-Hall, Inc.

Internet sources

1. .http://www.concrettecentrte.com/, (Access 5 Dec 2013)
2. www.masterbuilder.co.in/factors-affecting-the-selection-economics, (Access December 6, 2013)
3. www.usbr.gov , (Access December 28 2013)
4. http://www.ecocem.ie, (Access December 31 2013)
5. .http://www.ecocem.ie, (Access December 28 2013)

Appendix

Questionnaires

I. General

1. In your professional career, which type of formwork system did you often use
   a) Timber formwork
   b) Steel formwork
   c) Combination of both
   d) Other (Please specify the name)________________________
   ____
   ____

2. a) Which type of formwork is used in your current project ,in which you are involved, for the following structural element:
   For Beam: ________________________________
   For Column: ______________________________
   For Slab: _________________________________
   For Stair__________________________________
   For shear wall______________________________

b) What are the considerations to select the type formwork used?
(You can select more than one)
a) Cost of formwork
b) Required quality of finished concrete
c) Required completion time of the project
d) Market/ stock availability of formwork
e) Other consideration (please specify)
____
____

3. Does your company plan and design for the type of formwork used in a project before construction begins?

   Yes ☐ NO ☐ don't know ☐

   If yes, please specify the process: _________________________

____
____
____

4. Are there any detail drawings that is used for construction of formwork in the project you are involved with currently?
   Yes / No
5. What is condition of formwork used in your project?
   a) Very good
   b) Good
   c) Normal
   d) Not good
   e) Don't know

II. Cost of Formwork system

1. With regard to initial cost of formwork only to buy from the market what is the preference of your company for the structural element given below.

Element	Steel formwork	Timber formwork	Other / don't know
For beam			
For column			
For slab			
For stair			
For sheer wall			

2. If it is considered the rental cost only, what will be the preference ofyour company

Element	Steel formwork	Timber formwork	Other / don't know
For beam			
For column			
For slab			
For stair			
For sheer wall			

3. What is the average cost of formwork per square meter used in your project for :
   a. Beam _______________
   b. Column______________
   c. Slab ________________
   d. Stair________________
   e. Shear wall_____________

4. What is the percentage range of cost of formwork system used (including formwork labor cost) to total cost of concrete work.
   a. 0-- 10%
   b. 10-20%
   c. 20-30%
   d. 30-40%
   e. 40-50%
   f. 50-60%
   g. >60%

4. Is there a difference in the number of laborers used for to construct steel and timber formwork?
   a) Yes b) no
   If yes, please specify is their labor cost difference per square meter

____
____

5. To minimize the cost of construction which type of formwork system should be used in the construction industry of Ethiopia?
____

Give your opinion and reason?
____
____
____
____
____

III. Formwork system and concrete quality

1. Which type of formwork system creates more discoloration of finished concrete(discoloration include staining, rust, and the like)
   a) Steel formwork
   b) Timber formwork
   c) Both of them
   d) Don't know
2. Which type of formwork system maintain more dimensional accuracy in the time of placing concrete mix (Dimensional accuracy include size, shape and alignment of structural elements)
   a) Steel formwork
   b) Timber formwork
   c) Both of them
   d) Neither of them
   e) Don't know
3. As professional, considering only smoothness and regularity of concrete surface , what type of formwork system do you recommend for building construction
   ____
   ____
4. Please describe major quality problems that occurred in time of stripping formwork from concrete in your site?
   ____
   ____
   ____
   ____
   ____
   ____

IV. Speed of construction and formwork system

1. In the erection or construction of steel and timber formwork system is there any time difference you observe in any project where you are involved? **Yes / No**
   If yes which one is faster and which one is slower.
   ____
   ____
   ____

2. Did the type of formwork used affect the stripping time of form from concrete? **Yes / No**

   ____

   If **yes** please specify which type of formwork is strip faster from steel and timber formwork

   ____
   ____
   ____

   If **No** please fill table below the required stripping time of formwork per each of building element given

Structural element	Stripping day	
	For steel formwork	For timber formwork
Beam		
Column		
Slab		
Stair		
Shear wall		

3. Does the type of formwork used in your project affect productivity of the work? Yes/ No

V. Other comment related to formwork practices in Ethiopia

If you feel is there any other issue related to formwork construction practices in Ethiopia should be raised please do not hesitate to mention?