

JIMMA UNIVERSITY

JIMMA UNIVERSITY INSTITUTE OF TECHNOLOGY

SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT

**Investigation on the Effects of Formwork & Scaffolding Types in Building
Projects in Addis Ababa**

A Thesis Submitted to the School of Graduate Studies of Jimma University in Partial
Fulfillment of the Requirements for the Degree of Masters of Science In Civil Engineering
(Construction Engineering and Management)

BY

MERON TADESSE

OCTOBER, 2016

JIMMA, ETHIOPIA

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OCTOBER, 2016
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DECLARATION

This thesis is my original work and has not been presented for degree in any other university

Name	Signature	Date
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This thesis has been submitted for examination with my approval as university Supervisor

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ABSTRACT

In building construction there are temporary structures such as formwork and scaffoldings have often been just as elements used to construct the permanent structures. However, much greater attention has been paid to the design of permanent structures than to the design of temporary structures. Poor qualities of formwork materials affect the quality of the concrete surface finish, size and dimension of permanent structural members. The objective of this research to investigate the effects of formwork and scaffolding types in building projects in Addis Ababa.

The study design of this research was descriptive and exploratory design. The objective of the research was achieved in accordance with the methodology of Study; Literature review, Survey (i.e. site observation) and Questionnaires. The researches was conducted by using purposive sampling method and select ten building projects from Addis Ababa that are under construction during the study period. The projects contain different category of building such as offices, condominiums, and hospitals. The qualitative and quantitative data that gathered from data collection process was analyzed by using statistically and descriptive analysis method.

Questionnaires and interviews were distributed in the projects to get relevant data which helps to achieve the objectives of this thesis. Thirty copies of questionnaires distributed to the targeted respondents however, 27(90%) useable questionnaires collected from the respondents. The result showed that 70% of the respondents use combination of both steel panels and timber boards as formwork materials, 5% of the respondents use steel, 20% use timber and 5% use yellow timber as formwork material. In addition to this, in Addis Ababa 10% of building contractors use combination of both steel and timber scaffolding and 30% use only steel and 60% use timber scaffolding. The results showed that, Steel and Timber are the most commonly used formwork and scaffolding materials in Addis Ababa. Even though, Steel formwork reuses many times with high rate affect the concrete surface finish. In addition to this, it is easy for erecting and striping with good speed of construction. On other hand, timber formworks was more preferable for the smoothness of surface finish but slow down the speed of construction and cannot reuse many times like steel.

Timber scaffoldings were an ideal solution for irregular shaped building structures but its quality will be affected easily by bad weather condition. It cause failure on the structural elements, injured the workers and difficult to use in high rise buildings. On other hand, steel scaffoldings used for large projects or in high rise buildings. Moreover, Steel scaffolding has longer life than timber scaffolding and much safer for the workers and structures. In terms of quality and safety steel scaffolding was more preferable.

Steel formworks and scaffolding should be maintained after every reuse, cleaning it well, painting and stock in suitable place in order to reuses many times and to keep its quality was recommended.

Keywords: Cost, Formwork, quality, Scaffolding, Steel and Timber.

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ABBREVIATIONS

ACI	American Concrete Institute
BS	British Standard
EBCS	Ethiopian Building Code Standards
ICF	Insulating concrete forms
OSHA	Occupational Safety and Health Administration

CHAPTER ONE

INTRODUCTION

1.1 Background

In building construction, building was said to be ‘good’ only when it is structurally sound, functionally efficient and aesthetically good in appearance. But, in order to attaining all these at the time, economy should be under consideration in different countries. A lot of economy in building project can be achieved by paying attention to factors like proper planning, adequate structural design and use of suitable construction materials (Arora and Bindra, 2010).

Traditionally, much greater attention has been paid to the design of permanent structures than the design of temporary structures. Similarly, during the construction phase of a building, temporary structure such as formwork and scaffolds have often been treated merely as elements used to construct the permanent structure (Aviad, 1999).

Formworks were holds and supports wet concrete until it gets matured and they were a very vital element in concrete construction. In Indian economy and introduction of multinationals and nations pride program for golden quadrilateral of the construction. In order to have speedy construction and timely completion of projects. Now days, low waste modern formwork systems for superstructure construction are commonly adopted. Formwork system effects on the cost, time, and quality of project delivery (Kumathekar, 2007).

Building construction industry in developing country like Ethiopia used basically two types of formwork systems; timber and steel. Due to long existence and preference by most local contractor timber formwork was the most dominant type of formwork used in the building construction industry of the country (Breket, 2015).

In building construction, formwork is used for one purpose which to create the shape of structural elements such as beam, column, shear wall and stair cases. In actual work; by using formwork, we can mold the concrete mix to satisfy the desired shape of the building element (Edward, 2008).

One expression of this renewed interest in formwork design and practice is the emergence of new or revised formwork standards in a considerable number of countries. Among other things, these standards aspire to respond to increasing concerns on construction safety (Edward, 2008).

Scaffolding represents an important trade in the construction of buildings by providing platforms which allow the workers to carry out their works at height. Scaffolding play major role in building construction. They present an important part in construction- especially building operations at height (Hitesh, et al., 2013).

1.2. Statement of the problem

Building projects that are delivered within estimated cost, specified quality and time greatly satisfy client, contractor and consultant. However, almost all building projects in Ethiopia are not lucky to be delivered successfully to the client. Among main factors for the poor performance of the construction sector of Ethiopia was usage and practices of lower quality of formwork system (Bereket, 2015).

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

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

1.3 Research Questions

The research questions that this study was attempt to clarify; are as follows:

1. What are the types of formwork and scaffolding used in building construction?
2. What are the effects of formwork in building construction?
3. What is the quality and cost of formwork and scaffolding?

1.4. Objective

1.4.1. General Objective

The general objective of this study was investigation on the effects of formwork and scaffolding in building projects in Addis Ababa.

1.4.2. Specific Objective

To address the general objective of this study have following specific objective:

1. To determine the types of formwork and scaffolding used in building construction.
2. To determine the effect of formwork in building construction.
3. To compare the quality and cost of formwork and scaffolding.

1.5. Significance of the Study

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

1.6. Scope and limitation of the study

The research focuses on the formwork and scaffolding systems for building projects in Addis Ababa and investigate there effects in building projects. Different types of column, beam and slab are investigated that are casted in the construction site. Formworks for precast concrete elements are out of the scope of this thesis. The study compromise different category of contractors, starting from grade 1 up to grade 5 contractors, involved in the construction of building projects.

CHAPTER TWO

LITERATURE REVIEW

2.1. Background

Temporary supporting structures are those structures which are temporarily required in the building construction for supporting the laying of concrete till it gets matured, such as formwork or forms; or for supporting the material and labor for execution of some construction work, such as scaffolding, shoring and underpinning (Arora and Bindra, 2010).

For concrete formworks, the notion of "*Temporary Structures*" does not quite portray the reality. Forms, its hardware and accessories are used over and over again over their life time. Because of that it is necessary to use materials with high durability and easy to maintain. The disassembly or stripping of forms depends on factors such as the bond between concrete and the form, rigidity and shrinkage of concrete. Since early form removal is desirable for their reuse, a reliable basis for determining the earliest possible stripping time is necessary. Some of the early signs to look for during stripping are no excessive deflection or distortion and no evidence of cracking or other damage to the concrete due to the removal of the forms or the form supports. In any event, forms must not be stripped until the concrete has hardened enough to hold its own weight and any other weight it may be carrying. The surface must be hard enough to remain undamaged and unmarked when reasonable care is used in stripping the forms (Kamran, 2007).

2.2. Temporary Structures

Definition: Any means or methods which provide temporary support, access, enhancement, or otherwise facilitate the construction of permanent structures.

Necessity: Temporary structures form the interface between design and construction. Most Permanent structures simply could not be built without temporary structures (Kamran, 2007).

Impact on Schedule, Cost, and Quality: Losses in time and money will occur if the temporary structures are not planned and coordinated with the same degree of thoroughness as the permanent structures.

Safety: Failure of temporary structures has been responsible for hundreds of deaths on Construction sites. Safety should be the overriding priority of contractors and designers responsible for implementing temporary structures (Kamran, 2007).

2.3. Formwork

“ A mold or box into which wet concrete can be poured and compacted so that it will flow and finally set to the inner profile of the box or mold” (Attaullah, 2011).

Formwork is an ancillary construction, used as a mould for a structure. Into this mould, fresh concrete is placed only to harden subsequently. Shutters or forms are the terms used for made up sections that actually touch the concrete (Chirag, 2011).

As fresh concrete is in a plastic state, when it is placed for construction purpose, it becomes necessary to provide some temporary structure to confine and support the concrete, till it gains sufficient strength for self-supporting. This temporary structure is known as form work (Arora and Bindra, 2010).

Formwork development has paralleled the growth of concrete construction throughout the 20th century. The increasing acceptance of concrete as a major construction material presents the form builder a new range of problems in the development of appropriate sheathing materials and maintenance of rigid tolerances. Formwork is a classic temporary structure in the sense that it is erected quickly, highly loaded for a few hours during the concrete placement, and within a few days disassembled for future reuse. Also classic in their temporary nature are the connections, braces, tie anchorages, and adjustment devices which forms need (Kamran, 2007).

Formwork and its supports (false work) is a structural system and must be designed and built accordingly. The actions (loads) on it may be temporary but they can be extremely large. Frequently they are different in nature to those imposed on the finished concrete structure. Concrete is an extremely plastic and moldable material which will accurately reflect the shape, texture and finish of the surface against which it is cast. Any imperfection or inaccuracy in this surface will be indelibly inscribed on the concrete surface. Form-face materials must therefore be chosen both to achieve the required surface finish and, in conjunction with all the supporting elements, to maintain accuracy and stability under all the loads imposed during erection and concreting, and for some days into the life of the concrete structure (Hiren, et al., 2013).

2.3.1. Functions of formwork

- Forms mold the concrete to desired size and shape and control its position and alignment.
- Formworks also act as a temporary structure that supports: its own weight, the freshly placed concrete and Construction live loads (material, human, logistic).
- Formwork is a classic temporary structure in a sense that: It can be erected quickly ,Highly loaded for a few hours during the concrete placement and within a few days it is disassembled for future use (Attaullah, 2011).

2.3.2. Selecting criteria for formwork system

The selection of the proper formwork system requires adequate information about available horizontal (Slabs), and vertical (Columns/Walls) forming systems. The information collected that describes the formwork systems should include the criteria used by contractors to select the system.

These criteria are:

1. The formwork system should be available and economically feasible for the contractor.
2. All major parties – owner, designer, and contractor – should be familiar with the selected forming systems, since certain systems, such as slip forms, require special economic evaluation, design configurations, and safety precautions (Hiren, et al., 2013).

3. The selected formwork system must be consistent with architectural and structural requirements of the building. For example, if architectural concrete is required for the external columns, then slip form systems do not provide the appropriate forming solution (Hiren, et. al., 2013).

2.3.3. Requirements of formwork

Good forms for concrete structures should satisfy the following requirements;

1. It should be strong enough to resist the pressure or the weight of the fresh concrete and the super imposed loads due to equipment, men etc.
2. It should be rigid enough to retain the shape without undue deformation. Therefore it should be so designed that deflection does not exceed $1/900^{\text{th}}$ of span in normal cases.
3. It must be made or constructed as tight that does not allow the cement paste to leak though the joints.
4. The inside surface of form work should be smooth so as to give good appearance to the resulting concrete surface.
5. The entire form work should be so made that it can be removed easily without causing the least injury to the surface or edge of the concrete.
6. As the form work does not contribute anything to the stability of the finished structure, it should, therefore, be made economically by reducing the cost through Proper design, construction and use of form work (Arora and Bindra, 2010).

To ensure that the formwork is economical and practical to build, the basic technical, economical and functional requirement's that should be kept in mind when designing and constructing formwork. Technical requirements of formwork: it should be of the desired shape, size and fit at the location of the member in structure according to the drawings, it shall be carefully selected for required finish surface and linings to produce the desired concrete surface (civil engineering home, 2015).

Formwork should support the designed loads any other applied loads during the construction period and the formwork must not damage the concrete or themselves during removal from structure. Functional requirements of formwork: Form sections should be of the size that can be lifted and transported easily from one job site to another, it should be dismantled and moved as easily as possible and it should be simple to build. Economic requirements of formwork: Formwork shall be made of low cost materials, energy and labor if possible, it can be repetitively used and it must be able to withstand a good number of reuses without losing their shape (civil engineering home, 2015).

2.4. Classification of Formwork

Formwork can be classified according to a variety of categories, relating to the differences in sizes, the location of use and construction materials.

2.4.1. Classification according to size

Classification according to the size of formwork can be very straight forward. In practice, there are only two sizes for formwork; small-sized and large-sized. Any size which is designed for operation by workers manually is small-sized. Very often, the erection process is preferably handled by a single worker, with site work best done independently to avoid possible waiting times. Due to reasons of size and weight, the materials and construction of small-sized formwork are thus limited. The most common systems are made of timber and aluminum, and are usually in the form of small panels (City University of Hong Kong, 2006).

2.4.2. Classification according to the location of use

Different elements in the structure of building have different design and performance requirements in the use of formwork. A number of formwork systems are particularly designed for constructing internal or external walls, vertical shafts, columns, beams and floor slabs. However, there are not many effective formwork systems for stairs and staircases (City University of Hong Kong, 2006).

2.4.3. Classification according to materials of construction

Timber- in general is still the most popular formwork material for its relative low cost and adaptability.

Steel- in the form of either hot-rolled or cold-formed sections and in combination with other sheeting materials is another popular choice for formwork materials.

Glass Reinforced Plastic- it is very useful for complex shape and special features and easy to disassemble (City University of Hong Kong, 2006).

2.5. Materials for formwork

Formwork can be made out of timber, plywood, steel, precast concrete or fiber glass used or in combination. Steel forms are used in situation where large numbers of re-use of the same forms are anticipated. For small works, timber formwork proves useful. Fiber glass made of precast concrete and aluminum are used in cast-in-situ construction such as slabs or members involving curved surfaces.

2.5.1. Timber Formwork:

Timber for formwork should satisfy the following requirement:

It should be

1. Well-seasoned
2. Light in weight
3. Easily workable with nails without splitting
4. Free from loose knots

Timber used for shuttering for exposed concrete work should have smooth and even surface on all faces which come in contact with concrete. Normal sizes of members for timber formwork. (Chirag, 2011).



Figure 2.1: Wooden formwork (Chirag, 2011).

ADVANTAGES OF TIMBER FORMWORK

- Easy handling because it's light weight
- Easy to disassemble
- Damaged parts can be replaced with new one
- Very flexible
- Reduced construction waste through efficient controlled manufacturing
- Low volume of waste on site requiring removal

DISADVANTAGES OF TIMBER FORMWORK

- Can't be used for long. Have limited re-use. Can only be re-used 5 or 6 times
- If the timber is dry, it will absorb moisture from wet concrete which could weaken the resultant concrete member.
- Timber with high moisture content (more than 20 % moisture content), wet concrete will shrink & cup leading to open joints & leakage of grout. (Attaullah, 2011).

2.5.2. Plywood Formwork

Resin bonded plywood sheets are attached to timber frames to make up panels of required sizes. The cost of plywood formwork compares favorably with that of timber shuttering and it may even prove cheaper in certain cases in view of the following considerations (Chirag, 2011).

1. It is possible to have smooth finish where cost in surface finishing is involved
2. By use of large size panels it is possible to effect saving in the labor cost of fixing and Removal.
3. Number of reuses is more as compared with timber shuttering. For estimation purpose, Number of reuses can be taken as 20 to 25.
4. If you have holes in your ply, plug them up, or else accept ugly lumps and loss of fines on your finished concrete surface.
5. Apart from the nails fixing ply to make up forms, the rest of the nails on a formwork job are never driven home fully. They are left, or bent over so that they can be pulled out easily with a claw hammer or pinch bar when it comes time to strip the forms (Chirag, 2011).

2.5.3. Steel Formwork

This consists of panels fabricated out of thin steel plates stiffened along the edges by small steel angles. The panel units can be held together through the use of suitable clamps or bolts and nuts. The panels can be fabricated in large number in any desired modular shape or size. Steel forms are largely used in large projects or in situation where large number reuses of the shuttering is possible. This type of shuttering is considered most suitable for circular or curved structures. If the form is rusty, you might get rust on the surface of your concrete. Steel forms compared with timber formwork:

1. Steel forms are stronger, durable and have longer life than timber formwork and their reuses are more in number.
2. Steel forms can be installed and dismantled with better ease and speed as compared to Timber formwork.
3. Steel formwork does not absorb moisture from concrete.
4. Steel formwork does not shrink or warp (Chirag, 2011).



Figure 2.2: Steel Formwork (Chirag, 2011).

ADVANTAGES OF STEEL FORMWORK

- Very strong and able to carry heavy load Easy to be fixed
- Uniform size and surface
- Can be used for a very long time

DISADVANTAGES OF STEEL FORMWORK

- Limited size or shape
- Excessive loss of heat
- A very smooth surface will be produced which would give problems for finishing Process
- Limited fixing (Attaullah, 2011).

2.5.4. Plastic Formwork

Re-usable plastic formwork: These interlocking and modular systems are used to build widely variable, but relatively simple, concrete structures. The panels are lightweight and very robust. They are especially suited for low-cost, mass housing schemes. The formwork stays in place after the concrete has cured, and provides advantages in terms of speed, strength, superior thermal and acoustic insulation (Chirag, 2011).

2.6. Modern formwork systems

2.6.1. MIVAN technology

MIVAN is an aluminum formwork technology. MIVAN system is formwork construction, cast – in– situ concrete wall and floor slabs cast monolithic provides the structural system in one continuous pour. Large room sized forms for walls and floors slabs are erected at site. These forms are made strong and sturdy, fabricated with accuracy and easy to handle. Formwork systems for buildings are classified as either horizontal or vertical formwork. Horizontal formwork systems are those used to form the horizontal concrete work (slabs or roofs), while vertical formwork systems are those used to form the vertical supporting elements of the structure, e.g., columns, core walls, and shear walls. The system of Aluminum forms has been used widely in the construction of residential units and mass housing projects. It is fast, simple, adaptable and cost – effective. It produces total quality work which requires minimum maintenance and when durability is the prime consideration. (Kumathekar and Swapnali, 2007).



Figure 2.3:Mivan Formwork (Kumathekar and Swapnali, 2007).

2.6.2. Tunnel form technology

It is a highly efficient Industrialized System of On-Site Construction, which enables putting-up stable structure on a 24-Hour cycle basis Tunnel form is a formwork system that allows the contractor to build monolithic walls and slabs in one operation on a daily cycle. It combines the speed, quality and accuracy of factory/offsite produced ready-mix concrete and formwork with the flexibility and economy of cast in-situ construction (Kumathekar and Swapnali, 2007).

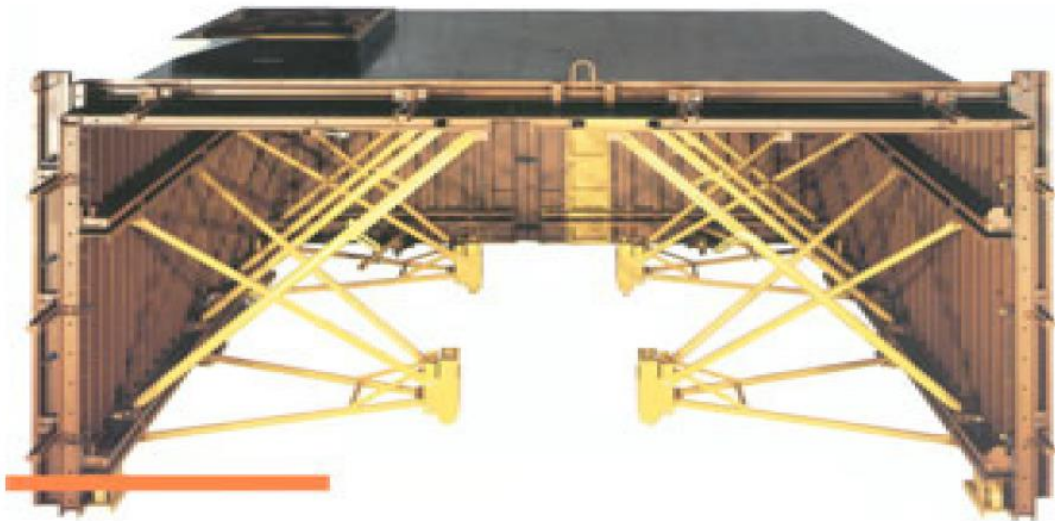


Figure 2.4: Tunnel Formwork (Kumathekar and Swapnali, 2007).

2.6.3. Joist-Slab Forming System

A one-way joist slab is a monolithic combination of regularly spaced joists arranged in one direction and a thin slab cast in place to form an integral unit with the beams and columns. One-way joist slabs have frequently been formed with standard steel pans (Hiren, et. al., 2013).

2.6.4. Self-Raising Forming System

This system consists of upper form(s), and lower lifters (self-raisers). The lifters are attached to the wall already cast below the form. Figure 2.5 shows a schematic representation of the sequential steps involved in self-raising forms (Hiren, et al., 2013).

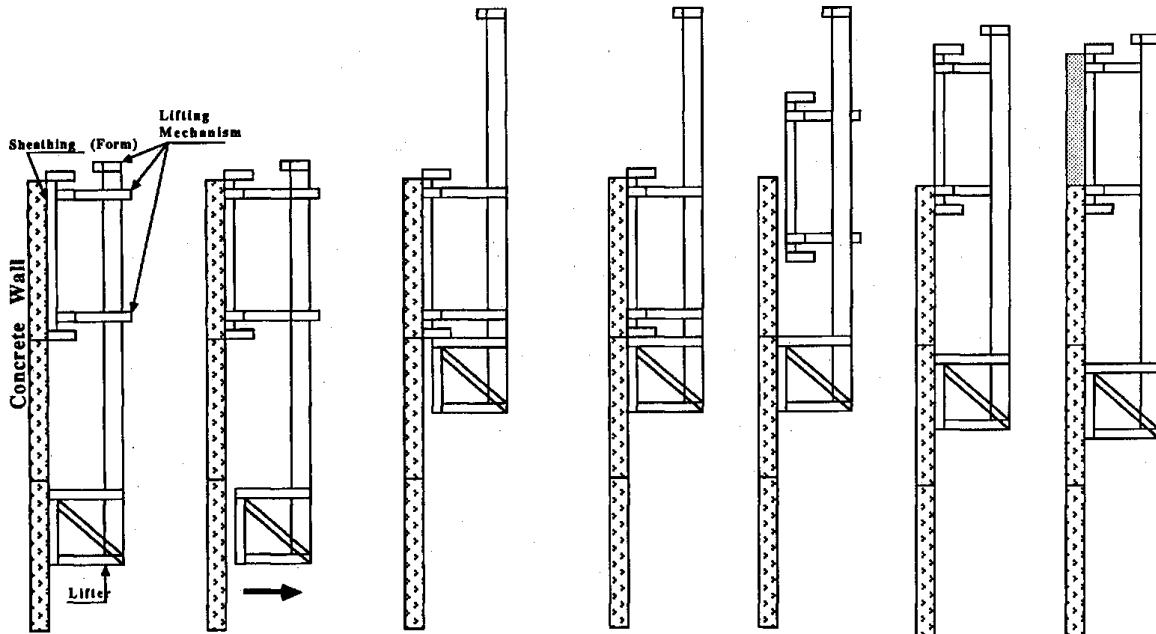


Figure 2.5: self-rising formwork (Hiren, et al., 2013).

2.6.5. Jump Form System

Jump forms are used where no floor is available on which to support the wall formwork, or the wall and column proceed ahead of the floor. Jump-forms consist of a framed panel attached to two or more strong backs. They can be one floor high, supported on inserts set in the lift below. Two sets, each one floor high, that alternately jump past each other can also be used. Typical jump-form cycle consists of three basic operations: strip, fly, and reset. Generally, jump form systems comprise the formwork and working platforms 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 (Hiren, et. al., 2013).

2.7. Forming Systems

The type of forming system has an essential effect in the analysis of concrete structures during construction. Therefore, selecting the forming system, that is, making structural frame, simpler, and less costly to build, must begin in the earliest phase of the design efforts. There are several horizontal and vertical forming systems currently used for different structural elements; these are described below (Alamin, 1999).

2.7.1. Horizontal Forming Systems

There are five horizontal forming systems that can be used to support different slab types. These are conventional, flying truss, column-mounted shoring, tunnel, and joist-slab forming systems. Conventional wood or metal systems may be either hand-set or panelized. Hand-set systems in wood or aluminum generally consist of wood shores supporting wood or aluminum stringers and runners or joists, with the deck surface made of plywood. The same type of deck form can be made up in larger panels tied together and supported on attached scaffold-type shoring. The shoring may be either steel, aluminum, or wood (Alamin, 1999).

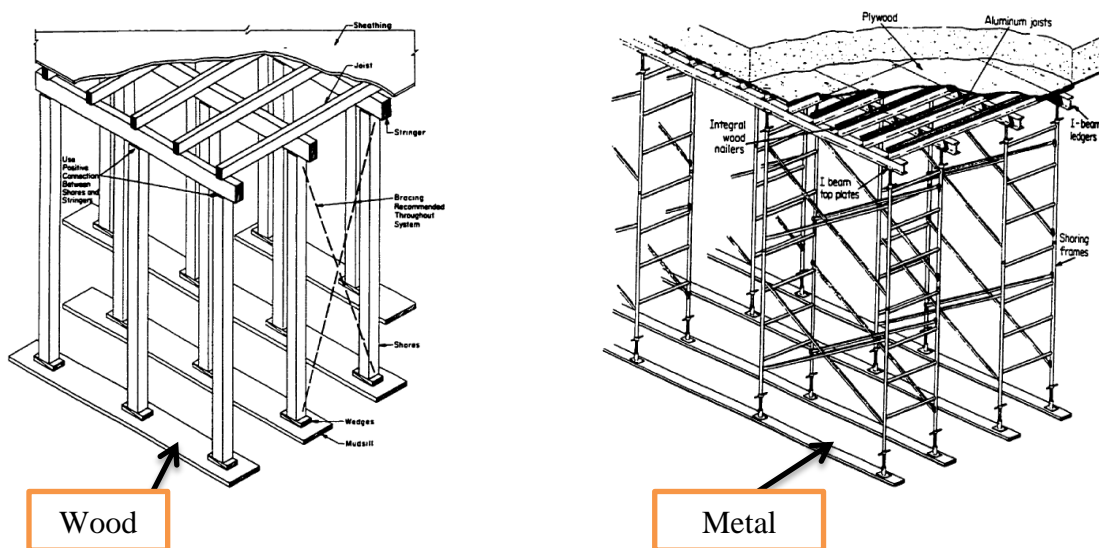


Figure 2.6: conventional wood and metal system (David, 2007).

2.7.2. Vertical Forming Systems

Vertical forming systems are those used to form the vertical supporting elements of the structure (i.e. columns, walls). Five types of vertical forming systems are available. These are conventional, gang, slip, jump, and self-raising forms. Conventional forming system consists of five basic parts. sheathing, made of plywood to shape and retain the concrete until it sets; studs, to form framework and support the sheathing; single or double wales, to keep the form aligned and support the studs; braces, to hold the forms erect under lateral pressure; and ties and spreaders or tie-spreader units, to hold the sides of the forms at the correct spacing (Alamin, 1999).



Figure 2.7: Vertical forming system (David, 2007).

2.8. Formwork for structural elements

2.8.1. Column Forms

Column-form materials tend to vary with the column shape. Wood or steel is often used with square or rectangular columns. Round column forms, more typically pre-manufactured in a range of standard diameters, are available in steel, paperboard, and fiber-reinforced plastic. Square and rectangular forms are composed of short-span bending elements contained by external ties or clamps. Round column forms are more structurally efficient because the internal concrete pressures can be resisted by a hoop membrane tension in the form skin with little or no bending induced. Steel column forms have built-in bracing for short heights so the only external bracing required serves to keep the column plumb and for taller columns. (David, 2007).



Figure 2.8: Modular steel form for rectangular columns and round-column forms with access scaffolding in preparation (David, 2007).

2.8.2. Beam Formwork

Beam formwork consists of open through section and because it is not closed at the top requires more supporting framework to restrain the sides. The supports need to be maintained to the soffit and also provide lateral support to the sides. In timber this is done by the use of a head tree across the top of a vertical member. Metal panels are used with corner pieces, but timber head trees are needed for vertical support (UNITEC, 2009).

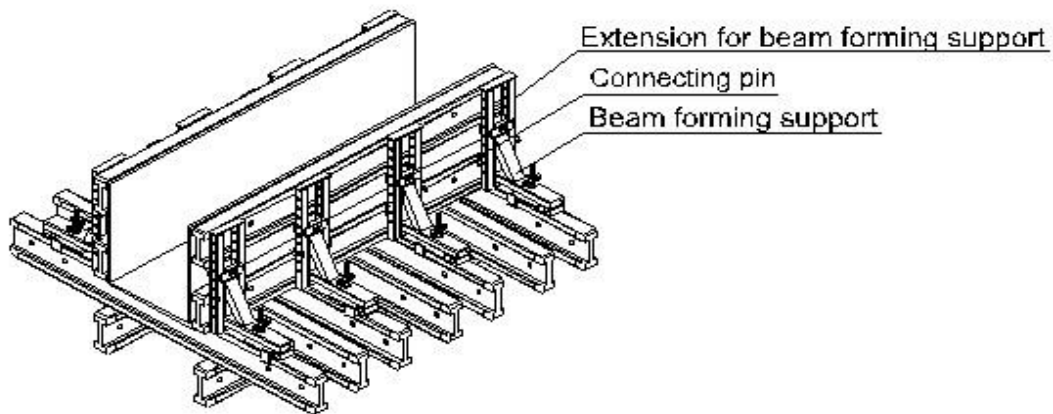


Figure 2.9: Beam formwork (UNITEC, 2009).

2.8.3. Wall Forms

Wall forms principally resist the lateral pressures generated by fresh concrete as a liquid or semi-liquid material. The pressures can be quite large; certainly many times the magnitude of live loads on permanent floors. Thus, wall form design often involves closely spaced and well-supported members, as shown in Figure 2.10. As mentioned, the contact surface of the wall form is referred to as sheathing (David , 2007).

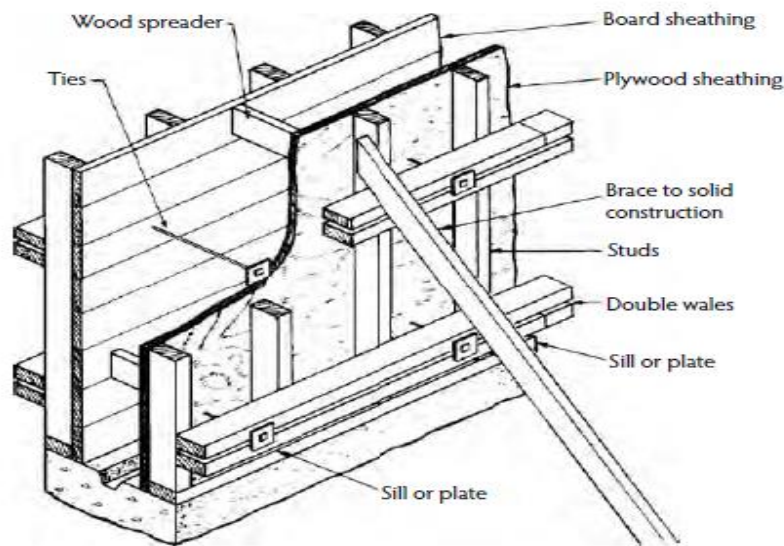


Figure 2.10: Typical wall form components with alternate sheathing materials illustrated (David, 2007).

2.8.4. Slab Formwork

Floors require a large area of formwork to be provided usually form beam to beam. Timber floor formwork consists of timber boards or plywood sheets supported on a frame work and resting on a series of timber joists. Again timber and metal props can be used for vertical supports. Metal panels can be used and bolted or clipped together and held in place by a system of metal beams or a tabular scaffold system. Adjustable props need for leveling purposes (UNITEC, 2009).



Figure 2.9: Slab formwork (UNITEC, 2009).

2.9. Essential consideration selection of formwork

A. STRENGTH:

Formwork must be capable of safely withstanding without distortion or danger the dead weight of the fluid concrete is placed on it, labor weight, equipment weight and any environmental loadings.

B. RESISTANCE TO LEAKAGE:

All joints in form work must be either close fitting or covered with form tape to make them grout tight. If grout leakage occurs the concrete will leak at that point.

Leakages cause honey combing of the surface.

C. ACCURACY:

Formwork must be accurately set out so that the resulting concrete product is in a right place and is of correct shape and dimensions.

D. EASE OF HANDLING:

Form panels and units should be designed so that their maximum size does not exceed that which can be easily handled by hand or mechanical means. In addition all formwork must also be designed and constructed to include facilities for adjustments, leveling, easing and striking without damage to the form work or concrete (Abhiyan, et. al., 2013).

E. FINISH AND REUSE POTENTIAL

The form face material must be selected to be capable of consistently imparting the desired concrete finish (smooth, textured, featured or exposed aggregate etc.). At the same time it should also achieve the required number of reuse.

F. ACCESS FOR CONCERTED:

Any formwork arrangement must be provide access for placing of the concrete. The extent of this provision will be dependent on the ease of carrying out the concrete operations (Abhiyan, et. al., 2013).

2.10. Objectives of Form Building

Forms mold the concrete to desired size and shape and control its position and alignment. But formwork is more than a mold; it is a temporary structure that supports its own weight, plus the freshly placed concrete, plus construction live loads (including materials, equipment, and personnel).

Basic objectives in form building are:

1. Quality – In terms of strength, rigidity, position, and dimensions of the forms
 2. Safety – for both the workers and the concrete structure
 3. Economy – the least cost consistent with quality and safety requirements
- Cooperation and coordination between engineer/architect and the contractor are necessary to achieve these goals (Edward, 2008).

2.10.1. Formwork for concrete quality

Formwork is significantly important activity for concreting. Good quality of formwork can contribute a great too good quality of concrete. It not only holds the concrete during its wet stage but has many other important functions in this activity of concreting. Bad formwork has often yielded failures of minor as well as major magnitude. It is also fairly popular as shuttering. Its functional as well as financial share in the entire concreting activity can't be ignored (Chirag, 2011).

2.10.2. How Formwork Affects Concrete Quality

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 (Kamran, 2007).

The quality of the formwork itself has a direct impact on safety, accidents, and failures. A floor formwork system filled with wet concrete has its weight at the top and is not inherently stable. As a result, one of the most frequent causes of failure is from effects that induce lateral forces or displacement of supporting elements; therefore, inadequate cross-bracing or horizontal bracing is one of the most frequently involved factors in formwork failure. Poor bracing can make a minor failure turn into a major disaster, in what might be thought of as a domino effect or a progressive failure. Vibration is one factor that can trigger failure through inadequate bracing. Two other formwork problems are unstable soil under mudsills and shoring that is not plumb. Formwork is stable if adequately braced and built so all loads are carried to solid ground through vertical and bracing members (David, 2007).

2.10.3. Causes of Formwork Failure

Formwork failures are the cause of many accidents and building failures that occur during concrete construction, usually when fresh concrete is being placed. Generally some unexpected event causes one member to fail, then others become overloaded or misaligned and the entire formwork structure collapses (Frederick and Jonathan, 2000).

The main causes of formwork failure are:

1. Improper stripping and shore removal
2. Inadequate bracing
3. Vibration
4. Unstable soil under mudsills (A plank, frame, or small footing on the ground used as a base for a shore or post in formwork), shoring not plumb
5. Inadequate control of concrete placement
6. Lack of attention to formwork details (Frederick and Jonathan, 2000).



Figure 2.10: Formwork collapse (Attaullah, 2011).

2.10.4. Safety

The general contractor is responsible for the design, construction, and safety of formwork. Subcontractors or material suppliers may subsequently be held responsible to the general contractor. The term “safety” here includes prevention of any type of formwork failure. The damage caused by a failure always includes the expense of the formwork itself, and may also include personal injury or damage to the completed portions of a structure. Safety also includes protection of all personnel on the site from personal injury during construction. Only the supervisor of the work can control the workmanship in assembly and the rate of casting on which formwork safety ultimately depends (Frederick and Jonathan, 2000).

Formwork must be:

- strong to carry the full load and side pressure from freshly placed concrete, together with construction traffic and equipment, and
- sound (made of good quality, durable materials)

To ensure that forms are correctly designed and strong enough for the expected load OSHA (Occupational Safety and Health Administration) regulations, American Concrete Institute (ACI) recommendations, and local code requirements for formwork should be followed (Kamran, 2007).

2.10.5. Economy

Economy is important because the costs of formwork often range from 35 to 60% or more of the total cost of the concrete structure. Considering the impact of formwork on total cost, it is critical that the structural engineer of the facility also design the facility structure for economy of forming, not just for economy of the materials in the finished structure. Ideally, the builder will achieve maximum economy with no cost to either safety or specified quality. In designing formwork, the construction engineer can reduce costs by carefully considering the materials and equipment to be used; the fabrication, erection, and stripping procedures; and the reuse of forms. However, economy measures that result in either formwork failure or poor-quality products that require (often expensive) modification are self-defeating (David, 2007).

Economy is a major concern since formwork costs constitute up to 60 percent of the total cost of concrete work in a project as shown in the figure (Kamran, 2007).

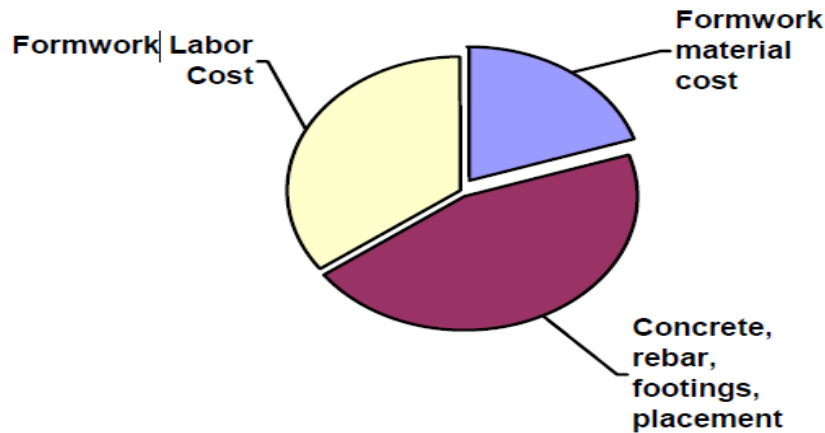


Figure 2.11: Pie chart of cost components in a typical concrete construction (Kamran, 2007).

Every project has unique features, requirements and challenges. As the design of structural concrete projects becomes more and more complex, a simple method for reducing the cost of construction is frequently overlooked. The most common approach to reduce the cost of a structure was solely to search for ways to reduce the amount of permanent material - "lesser the better". However, this approach overlooks the most important component in concrete structure cost which is the concrete formwork. Concrete formwork consists not only of formwork materials, but also the cost of the labor required to use this material (Chirag, 2011).

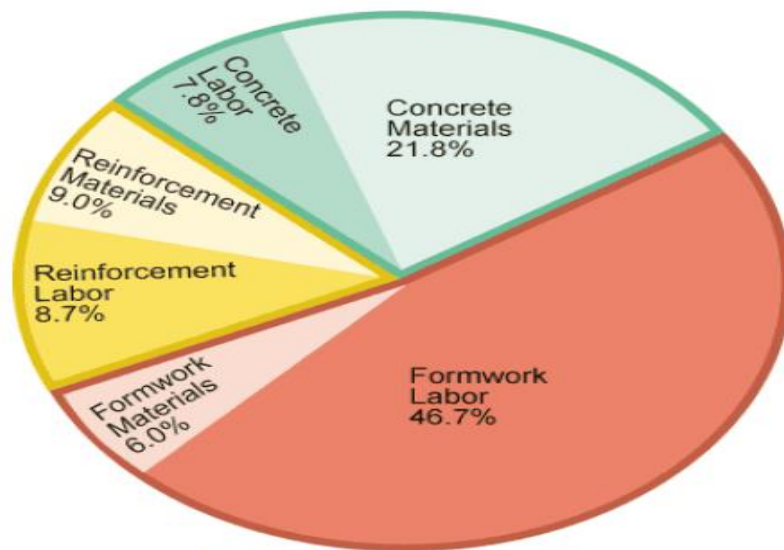


Figure 2.12: cost of concreting activity (Chirag, 2011).

All the formwork is very expensive. On average about 35% of the total cost of any finished concrete unit or element can be attributed to its formwork; of this just over 40% can be taken for material for formwork and 60% for labor. The formwork designer must therefore not only consider the maximum number of times that any form can be reused, but also produce a design that will minimize the time taken for erection and striking (Abhiyan, et. al., 2013).

Concrete formwork cost is significant. The cost of formwork ranges from 40 to 60% of the cost of a concrete structure. The cost of concrete formwork and labor can exceed the combined total cost of concrete and reinforcement materials and labor. Formwork materials are only a small percentage of the total concrete formwork cost. The major cost is the formwork labor - the costs associated with the installation and removal of the formwork (Chirag, 2011).

The quality of finished concrete surface depends to a great extent upon the quality of formwork used in the work. In case the formwork is made out of rough timber and is not constructed properly, the resultant concrete surface will be irregular and full of defects. The expenditure involved in rectification of defects in such works is invariably more than the saving made in the cost of formwork. Thus to effect economy, the formwork should be made with good quality material and should be constructed properly following the steps mentioned as above (Suryakanta, 2015).

2.10.6a. Formwork removal

Much friction between contractors' and owners' representatives is created because of misunderstanding of the requirements for form removal and re-shoring. The contractor is concerned with a fast turnover of form reuse for economy (with safety), whereas the owner wants quality, continued curing for maximum in-place strength, and an adequate strength and modulus of elasticity to minimize initial deflection and cracking. Both want a satisfactory surface (Frederick and Jonathan, 2000).

2.10.6b. 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 0C. The time need not be consecutive, but it is the total time during which the temperature is above 10 0C. When high-early-strength cement is used, these times can be shortened. When air temperatures remain below 10oC or retarding admixtures are used, these times should be lengthened (ACI, 1994).

Table 2.1: ACI Recommendation for formwork stripping (ACI, 1994).

Member		Time
Walls		12hrs
Columns		12hrs
Sides of beams or Girders		12hrs
Pan joist forms	760mm wide or less	3days
	Over 760mm wide	4days

2.10.6c. British Standard Recommendation

A minimum value of in-situ concrete cube strength of 2 N/mm² 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 20oC for unsealed plywood or 6 hours at 20oC 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 10oC overnight the vertical formwork can be stuck next morning. Summary of the BS recommendation for concrete made with Portland cement 42.5N/mm² and sulfate resisting Portland cement 42.5N/mm² (British Standard, 1997).

Table 2.2: British recommendations for formwork removal

Type of formwork	Minimum period before striking	
	Surface temperature of concrete	
Vertical formwork to columns, walls and large beams	160C and above 12hrs	$t0C(\text{any temperature between } 0 \text{ and } 160C)$ $300/(t+10)h$
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	$360/(t+10)days$

2.10.6d. 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 false work is removed shall be determined by consideration of the following criteria:

- ❖ The stresses that will be induced in the concrete when the formwork/false work has been removed;
- ❖ The concrete strength at the time of removal;
- ❖ The ambient climatic conditions and the measures available to protect the concrete once the formwork is removed;
- ❖ 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 the possible loads. The time at which formwork is struck will be influenced by the following factors:

- (a) concrete strength
- (b) stresses 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.

The time between casting and removal of the formwork development of the concrete and on the function of the formwork. In the absence of more accurate: data, the following minimum periods are recommended (Ethiopian Building Code Standard, 1995).

Table 2.3: EBCS recommendations for formwork removal

No.	Structural element	Period of hour
1	For non-load bearing parts of formwork (e.g. vertical formwork of beam; formwork for columns and walls)	18 hours
2	For soffit formworks to slab	7 days
3	For props to slab	14 days
4	For soffit formwork to beams	14 days
5	For props to beams	21 days

5. Where sliding or climbing formwork is used, shorter periods than those recommended above may be permitted (Ethiopian Building Code Standard, 1995).

2.7. Scaffolding

The ‘scaffolding’ is temporary structure, which is used in building operations to support platforms for workmen, structural material and appliances required during construction at raised heights (normally, more than 1.5m). This temporary structure scaffolding is useful in building construction, demolition, maintenance and repair works. The height of the scaffolding can be adjusted with the progress of the work (Arora and Bindra, 2010).

‘Scaffold’ means any temporarily provided structure on or from which persons perform work in connection with operations or works and any temporarily provided structure which enables persons to obtain access to or which enables materials to be taken to any place at which such work is performed, and includes any working platform, gangway, run, ladder or step-ladder (Occupational Safety and Health Branch, 2001).

Scaffolding represents an important trade in the construction of buildings by providing platforms which allow the workers to carry out their works at height. Due to the large amount of developments undertaking throughout the years, scaffoldings are found everywhere. Scaffolding play major role in building construction. They present an important part in construction-especially building operations at height. Safety is a basic human need to achieve zero accidents (Hitesh, et al., 2013).

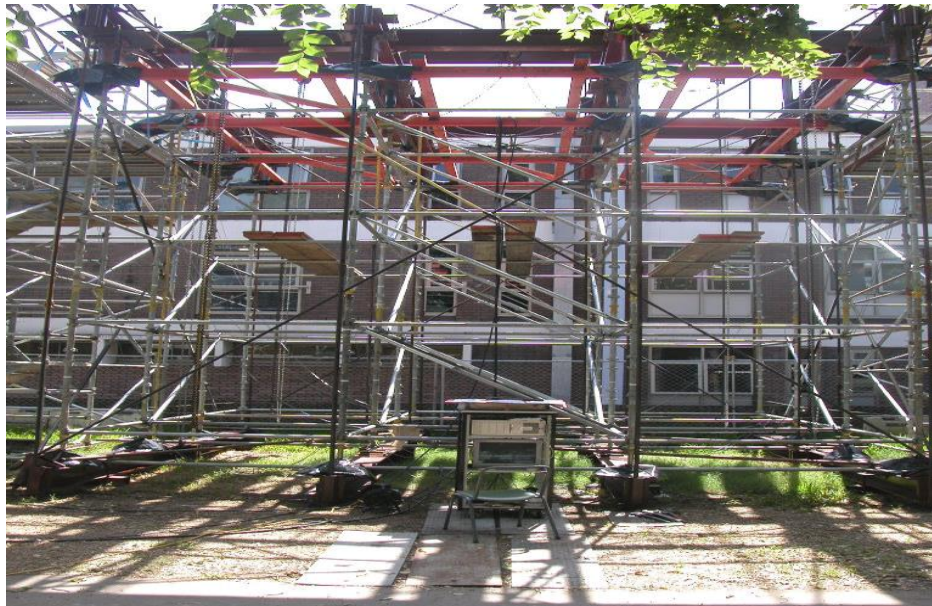


Figure 2.13: Steel Scaffolding (Tayakorn and Rasmussen, 2009).

Scaffolds are temporary structures commonly used in construction to support various types of loads. The vertical loads on scaffold can be from laborers, construction equipment, formworks, and construction materials. Commonly, scaffolds must also be designed to withstand lateral loads, including wind loads, impact loads, and earthquake loads. Depending on their use, scaffolds may be categorized as access scaffolds or support scaffolds. Access scaffolds are used to support light to moderate loads from laborers, small construction material and equipment for safe working space. Support scaffolds, also sometimes called false work, are subjected to heavy loads, for example, concrete weight in the formwork. An example of a support scaffold system is shown in figure 2.14. Support scaffolds normally consist of standards (vertical members), ledgers (horizontal members), and braces. (Tayakorn and Rasmussen, 2009).



Figure 2.14: Typical support scaffold (Tayakorn and Rasmussen, 2009).

Safety is a basic human need. To achieve zero accidents is a common goal that everybody would like to see. However it is not easy to attain it and we still have much to work towards it. In fact, construction safety can be further developed and continually improved by providing adequate and practical training to the relevant workers of the contractors. Nowadays, everything is speed and all projects have to be completed within this time frame. Moreover, for multi-storied buildings, traditional system of wooden poles and bamboos are neither suitable nor meeting any safety parameters. So for staging, centering, Access Scaffolding various metallic system are being used (Hitesh, et al., 2013).

2.7.1. General requirements of metal scaffolding

The general requirements for metal tubes and fittings of steel or aluminum are:

- (a) Metal tubes must be purpose made with outside diameters accurately gauged to fit properly into the metal couplings and to allow complete interchangeability.
- (b) Tubes in use on a scaffold must be in good condition, free from bends and defects that might affect strength, reasonably free from corrosion and cut square at the ends.

Tubes which are 3 m and over in length should be reamed, if cut, to ensure safety when using internal joiners (Chetwin, 1992).

(c) When the loss of metal by corrosion or other causes reduces any cross section of a tube so that its corresponding weight is less than 90 percent of its original weight, the affected length of tube is to be discarded and rendered unfit for further use in scaffolding.

(d) Steel tubes must be hot-dipped galvanized or painted when used in scaffolds which are exposed for prolonged periods to marine or corrosive atmospheres.

(e) Fittings and couplings must be specially made for the tubes in use and must be of a satisfactory quality as to strength and performance.

(f) Fittings must be carefully maintained in good order and condition. They must not be left lying around but stored in bags, boxes or bins, and kept well-oiled and protected from rusting. Special attention must be given to the care and checking of screw threads and nuts; worn or distorted parts must be discarded or replaced (Chetwin, 1992).

2.7.2. Technical requirements for safety in metal scaffolding

(a) Sufficient material should be provided for and used in the construction of scaffolds.

(b) Scaffolding components should be of sound material, good construction, and adequate strength and free from patent defects and should be properly maintained.

(c) Boards and planks used in the construction of working platform should be straight-grained and free from large knots, dry rot, wormholes and other dangerous defects. Where necessary, they should be protected against splitting.

(d) These boards and planks should be unpainted so that any defects are readily visible.

(e) Tube ends should be free from distortion, corrosion, splits, laminations, surface flaws and undue rust.

(f) The safe working loads for individual couplers and Special attention should be paid to the use of joint pins because they cannot bear any tension (Code of practice for metal scaffolding, 2001).

2.7.3. Types of scaffolding

Single scaffolding- This being cheap, is most commonly used in the construction of brick work.

Double scaffolding- This type of scaffolding is stronger than the single scaffolding and is used in the construction of stone work.

Ladder scaffolding- This is a modification over double scaffolding and can be easily assembled.

Cantilever scaffolding- In this, formwork whether of single scaffolding type or double scaffolding type, is supported by a series of cantilevers.

Suspended scaffolding- This type of scaffolding is suitable for light steel frame construction as well as for maintenance works such as painting, pointing, distempering, etc.

Steel scaffolding- The constructional details of steel scaffolding are the same as of timber scaffolding except wooden members are replaced by steel tube and rope lashings are substituted by special couplings.

Trestle scaffolding- In this type, the working platforms supported on the top of mobile devices such as tripods, ladders, etc.

Wooden gantries- It consists of timber staging for carrying traveling crane and is made of squared timbers in similar manner as double scaffolding (Arora and Bindra, 2010).

2.7.4. Uses and Benefits of Wooden Scaffolding

The benefits of using wooden scaffolds include;

1. **Cost Effectiveness;** Kim Sing Scaffolding offers the best rates for timber scaffolds. These scaffolds provide cheaper access solutions and are best suited for light duty jobs (at a working height of 15 m). Using wooden scaffolds on your project will increase your profitability as these scaffolds are lower in cost than metal scaffolds.

2. **Great for irregular foundation/ space where other access equipment's are impossible for use;** Be it narrow voids, shafts, irregular shaped building structures or low weight-bearing flooring that can foster as a challenge for other types of access equipment, timber scaffolding is the ideal solution due to its light weight and versatility.

3. **Durability, Strength and Resilience;** Our timber scaffolds are well credited in Singapore owing to their quality and efficiency (Kim, 2006).

2.7.5 Selection of scaffolding

The safe and efficient use of scaffolding depends first on choosing the right system for the job. If the scaffolds basic characteristics are unsuited to the task, or if all the necessary components are not available, personnel are forced to make do and improvise. These conditions lead to accidents. Proper selection of scaffolding and related components requires basic knowledge about site conditions and the work to be done. Considerations include

- Weight of workers, tools, materials, and equipment to be carried by the scaffold
- Site conditions (e.g., interior, exterior, backfill, concrete floors, type and condition of walls, access for the equipment, variations in elevation, anchorage points)
- Height or heights to which the scaffold may be erected.
- Type of work that will be done from the scaffold (e.g. masonry work, sandblasting, painting, metal siding, mechanical installation, suspended ceiling installation)
- Duration of work
- Experience of the supervisor and crew with the types of scaffolds available
- Requirements for pedestrian traffic through and under the scaffold
- Anticipated weather conditions
- Ladders or other access to the platform
- Special erection or dismantling problems including providing practical fall protection for the erector (Chetwin, 1992).

2.7.6. Special scaffolds

All special scaffolds must be designed in accordance with sound engineering practice, and must be erected, altered or dismantled only under the direct supervision of a certificated scaffolder who has an appropriate certificate. An inspector may require a registered engineer's certificate, certifying the adequacy of the design (Chetwin, 1992).

1. Non-standard standing scaffold

A standing scaffold becomes a special scaffold when it differs from the standard in respect of any of the following:

- (a) Height exceeds 33 metres;
- (b) Maximum bay length exceeds 2.4 metres;
- (c) Width exceeds 1.5 metres; or
- (d) Loading exceeds the heavy-duty load described in this code.

2. Standing scaffolds with attachments

Attachments include:

- (a) Cantilevered loading platforms, which are cantilevered structures erected from the main scaffold to serve as loading bays.
- (b) Protective screens which are fixed to the main scaffold to intercept anything which may fall from the structure

3. Cantilever scaffolds

A cantilever scaffold is an independent tied standing scaffold constructed in accordance with this code but erected on beams cantilevering out from a building. It is used where it is impossible or undesirable to found the scaffold on the ground as shown in figure 2.15 (Chetwin, 1992).

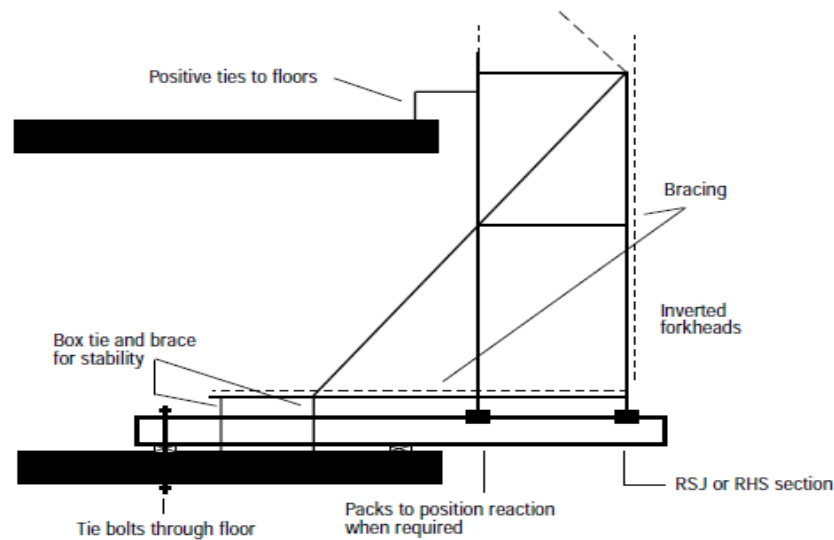


Figure 2.15: Typical cantilever scaffold (Chetwin, 1992).

4. Hanging scaffolds

Hanging scaffolds are platforms suspended by tubes, bolts, fixed-rope slings, or other methods and not intended for raising or lowering while in use. Any suspension point, member or attachment must be specially designed and formed in such a way that it cannot become dislodged or displaced by movement of the hanging scaffold.

5. Tube and Coupler Scaffolds

Tube and coupler scaffolds are assembled from three basic structural elements:

- The uprights, or posts, which rise from ground or other solid support
- The bearer, which supports the work platforms and / or provide transverse horizontal Connections between the posts (Chetwin, 1992).

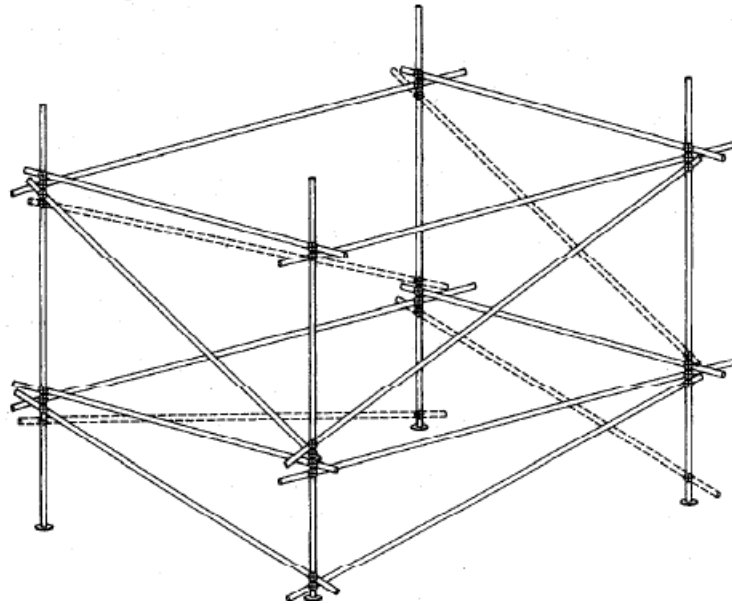


Figure 2.16: The basic assembly of tube and coupler scaffolds (Chetwin, 1992).

2.7.7. Erection, alteration and dismantling

All scaffolding, whether modifiable or not, must be erected, altered and dismantled by competent workers under proper supervision. Scaffolding must not be used unless the employer or employer's representative on the work is satisfied that it is safe for use and complies with the regulations. Scaffolding must not be altered or interfered with except on the instructions of the employer or employer's representative (Chetwin, 1992).

Scaffolds must ensure that members of the public are not endangered while they are erecting, altering or dismantling scaffolds. They should also ensure that the lower working platforms are not used while the upper lifts are being worked on unless a fully decked platform, with screens if necessary, separates the part being erected or dismantled from the lower part in use. All scaffolders should have a basic knowledge of rigging (Chetwin, 1992).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1. Study area

The research was conducted in Addis Ababa for different category of building types. The study compromised different category of contractors, according to their grades, and involvement in the construction of building projects.

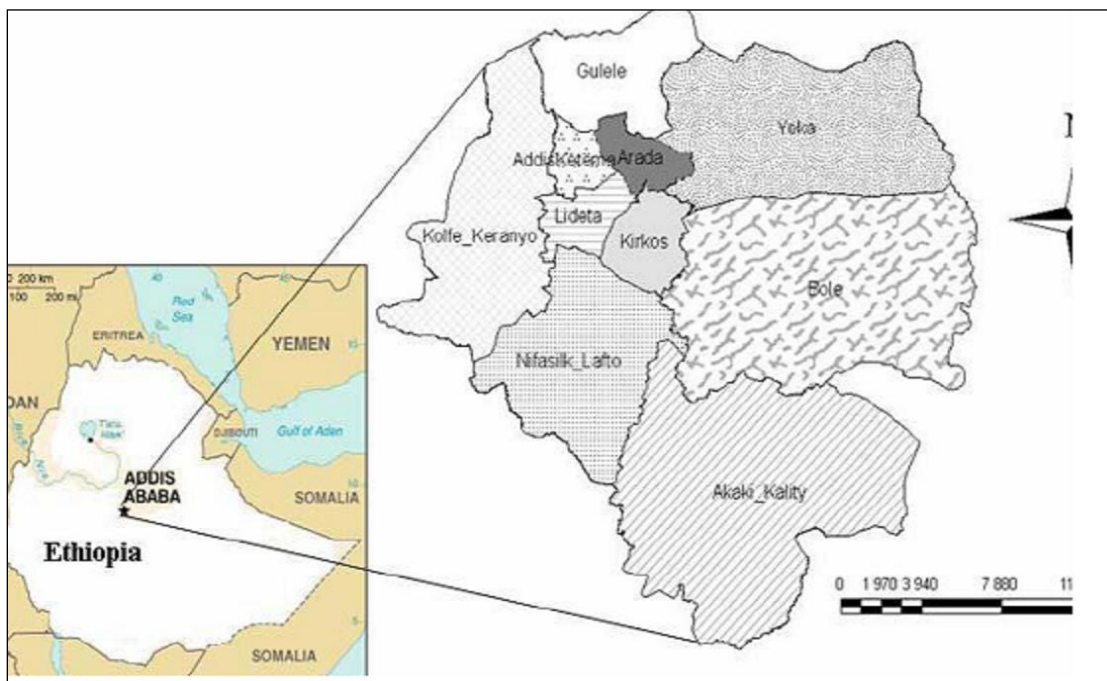


Figure 3.1: Map of Addis Ababa city (Bogale, 2012).

3.2. Study design

A study design/frame is the process that guides researchers how to collect, analyze and interpret and observation data. The study design of this research was descriptive and exploratory design. The collected data from the relevant population to investigate on the effects of formwork and scaffolding types in building projects. The objective of the research was achieved in accordance with the methodology of Study; Survey (site observation), Literature review and Questionnaires.

3.3. Study population

The study population to be considered in order to complete this research was surveying in different types of building in Addis Ababa. The study population was selected building construction in Addis Ababa city which includes from grade one up to grade five contractors.

3.4. Sample size and sampling procedure

Sampling was introduced with a view to making the research findings economical and accurate. The questioner was distributed to the contractor and consultants and filed survey was conducted. The research was conducted by using purposive sampling method. It was selected by some arbitrary method because it is known to be representative of the total population, or it is known that it produce well matched groups. The sampling was chosen purposively with regards to those contractors whose grade one up to grade five contractors. The reason is the contractor's grade one up to grade five and they are participating in large projects and they more experienced.

3.5. Study variables

Independent variable of this research related to the specific objective of the study were economy, quality, time and safety whereas, the dependent variable of this research related to the general objective of the study were formwork and scaffolding.

3.6. Source of Data

To accomplish this research different source of primary and secondary data were used. While questionnaires and interview being the primary source of data although secondary sources were book and journals. The questionnaires were distributed to randomly selected contractors whose grade ranges from level one up to five.

3.7. Filed Survey

To accomplish this research, field observation were done by checking the vertical and horizontal alignment by using hand leveling, plumb bob and meter in addition to this, prepare check lists (Guide line) for the field observation.

The hand leveling is used to check the horizontal alignment of beam and slab while the plumb bob were used to check the vertical alignment of the column formwork.

3.8. The Research Questionnaire Design

The questionnaire design was based on the field observation from the check lists and the specific objectives; dealing with the concrete quality, cost, time and safety of formwork and scaffolding in building construction. The questionnaire form, which was complemented consisted three parts.

In view of obtaining as much information as possible, participants were encouraged to give additional information or comments on the open spaces provided under each question.

The questionnaire form consisted three parts, they arranged based on cost, quality, time and safety of formwork and scaffolding utilization. The first part contained general information which includes name of the company, grade of the company and the respondent's position in the company. In the second part questions regarding which type of formwork system did they use, which formwork has more quality, which formwork is easy for stripping and erecting, which type of formwork materials use for the structural elements and the current cost of the formwork.

The third part contains questions that focus on scaffolding. The respondents were asked which type of scaffolding material is good according to their quality, cost and safety. The participants were requested to list out best formwork and scaffolding systems according to their quality, cost, safety and time.

3.9. Data collection process

The data was used in this research are both quantitative and qualitative data, collected through this research study. The primary data sources were interviews, questionnaires and field survey by visiting the site, checking the horizontal and vertical alignment of the structures and taking pictures. While books, journals and internets were used secondary data sources. The results obtained were also discussed based on literature review and actual observations made from local practice.

3.10. Data processing and analysis

The qualitative and quantitative data that gathered from data collection process was analyzed by statistically and descriptive analysis method. The data has been analyzed to determine investigation on the effects of formwork and scaffolding types in building projects.

The data was processed and analyzed in the form of table and graph. A descriptive method has been used for the analysis of the data which provides a general overview of the results in order to make interpretations and discussions based on the results. Evaluation was made based on the respondents' response for the effects of formwork and scaffolding types in building projects with regards to the cost, concrete quality, safety and speed of construction.

CHAPTER FOUR

RESULT AND DISCUSSION

4.1. Introduction

This chapter focuses on result and discusses the result gathered from the respondents through interview, questionnaire and field observation. Based on the gathered data from the respondents and field observation evaluation was made for formwork and scaffolding system used in the building projects with respect to cost, concrete quality, safety and speed of construction. This research has three objectives; to identify the types of formwork and scaffolding used in building construction, to determine the effects of formwork in building construction and to compare the quality and cost of formwork and scaffolding used.

There were thirty copies of questionnaires distributed to the targeted respondents consisting of different contractors that are involved in construction of building projects in Addis Ababa. The researcher managed to collect back 27 (90%) useable questionnaires from the respondents. The collected questionnaires and their return rate are given in table 4.1.

Table 4.1: Distribution of the questionnaires and response rate

No.	Purpose of project	Number of project	Location	% response rate
1	Office Project	1	Around Megenagna	86%
2	Office Project	1	Around Mexico	100%
3	Condominium	6	Legetafo site	100%
4	Hospital	2	At Paulos Hospital	50%

4.2. Identification of formwork materials used.

According to the survey made in Addis Ababa, 70% of the respondents use combination of both steel panels and timber boards as formwork materials.

These materials were used for casting concrete of almost all structural members such as column, beam, slab and wall.

About 5% of the respondents use steel, 20% use timber and 5% use yellow timber as formwork material. The summary of the results is shown in figure 4.1.

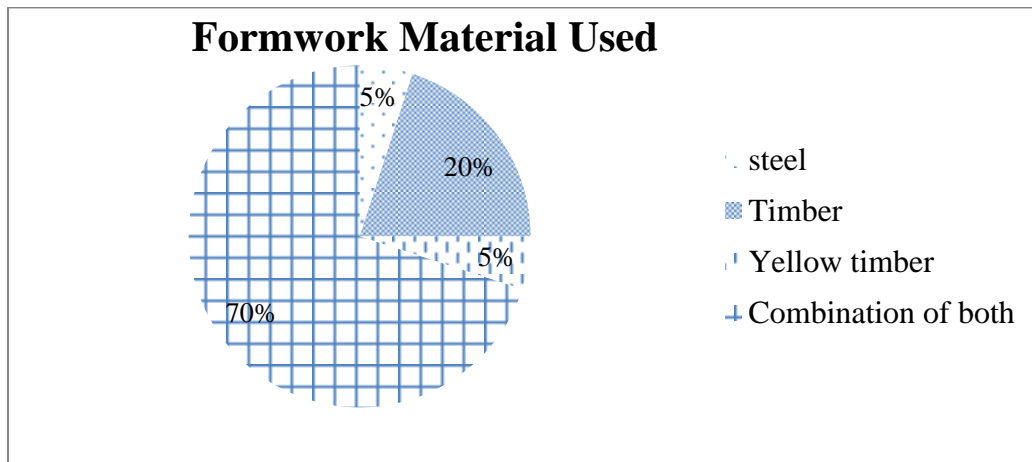


Figure 4.1: Formwork Materials Used by Contractors in Addis Ababa

According to Chirag (2011) formwork can be made out of timber, plywood and steel, precast concrete or fiber glass used separately or in combination. Steel forms are used in situation where large numbers of re-use of the same forms are estimated. For small works, timber formwork proves useful.

From the result Steel and timber were the most prominent formwork material in Addis Ababa. Steel formwork used in large projects with high rate of reuses and timbers used in small projects with low rate of reuses. Alternative formwork materials like aluminum, plastic and modern formwork systems are not adaptable. This is due to low financial capacity of the contractors.

The higher grade contractors use yellow timber formwork. It is different from the conventional timber formwork system good for the quality of surface finish of concrete.



Figure 4.2: Yellow timber formwork at megenagna site

4.3. Sources of formwork material

According to the survey made, 50% of the respondents use owning (local market), 20% use owning (imported), 20% produced by company itself and 10% use rental. The higher grade contractors use their own formwork. This is due to the relatively higher financial capacity and the lower grades use rental formwork system. The result summarized in figure 4.3.

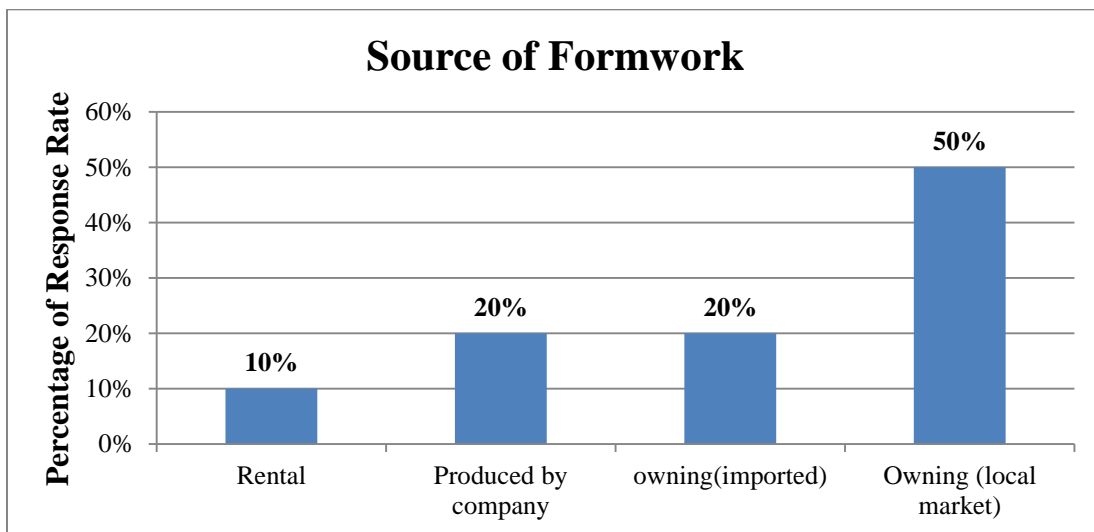


Figure 4.3: Source of formworks

4.4 Selection of formwork for structural elements

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

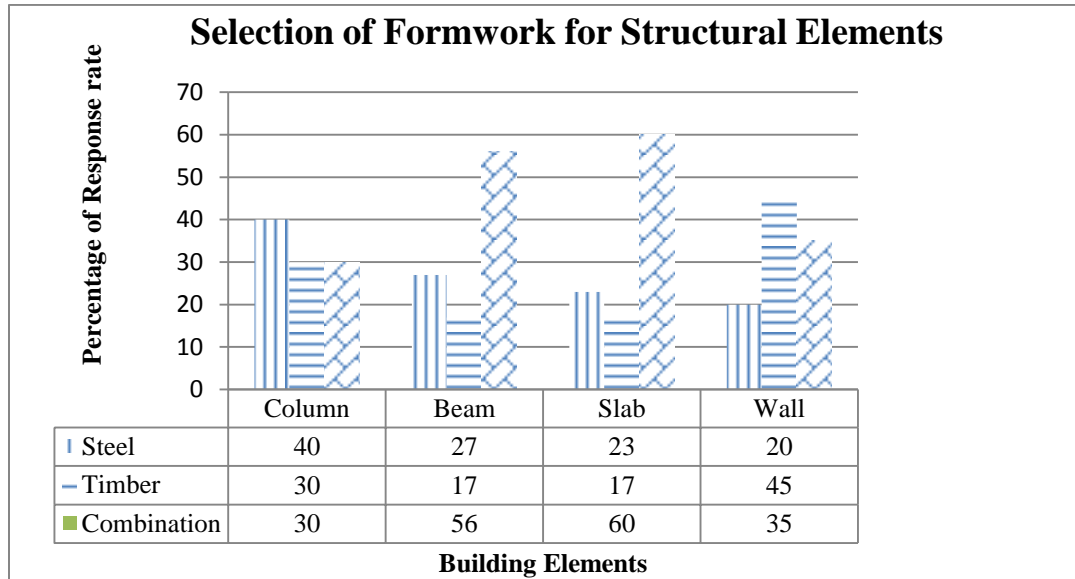


Figure 4.4: Response rate for selection of formwork for structural elements

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

From the result columns formwork materials are vary with their shapes, it casted by using either steel or timber formwork. For rounded shape of columns steel formwork more suitable than timber and for rectangular shaped columns steel or timber formworks are used. Also slab and beam are casted by using combination of both steel and timber formworks. Slabs require more amount of formwork material it covers large area from beam to beam. It supported by timber or steel vertical props. Chirag (2011) stated that Beam formwork has prefabricated formwork sheeting parts (sheeting bottom and side sheeting panels). Wall formwork consists of vertically arranged upright timbers (formwork bearers) to which sheeting boards are nailed at the concrete side.

Similar to beam formworks, the sheeting of column formworks are prefabricated according to the column dimensions from sheeting boards connected by cover straps.

4.5 The effects of formwork in building construction

According to Kamran (2007) the quality of the surface finish of the concrete is directly affected by the formwork materials, not only the surface finish but also the horizontal and vertical alignment and the shape of the structures also affected by the kind of formwork.

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

4.5.1 Column formwork

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



Figure 4.5: Column formwork construction systems using steel at legetafo site



Figure 4.6 : Column formwork construction systems using timber at Paulos site

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

4.5.2 Beam and Slab formwork

In application of formwork very important to select the appropriate formwork kind for different structures. Concerning beam formwork, the construction system is not different from others members. Timber or steel panels are used as sheeting material. To check the horizontal alignment of beam and slab by using hand leveling. After erection of the formwork before placing the concrete alignment should be checked. Put the leveling instrument horizontally at both ends of the side formwork. The bubble of leveling should be at the center if the alignment is correct. As shown in figure 4.7 the bottom formwork is a horizontally placed formwork for the slab and beam. The side formwork is a vertical formwork for the slab at the beam side and prop/shore is the part of formwork which mainly for holding the bottom formwork in position. At the beam side the pope must be erected straight each other; it can check by using meter or string.



Figure 4.7: Slab and beam formwork at legetafo site.



Figure 4.8: Horizontal alignments checking at Mexico site

4.6a Effects of steel formwork on the concrete surface finish

After the vertical and horizontal alignment checking the concrete was placed. The formwork removed or striped by following EBCS standards. In figure 4.9 columns casted by using steel formwork and having size 50cm*30cm after 18hr the formwork removed or striped, check the column dimension using meter 52cm*33cm it has some variation from the actual size. So the formwork material has influence on the size of column.

Also discolorations on the surface finish of concrete due to the burned oils. However, to make stripping easier all the member of formwork oiled burned oils but steel formworks doesn't absorb oil like timber it requires more oil and caused discoloration on the concrete surface finish. There is some roughness on the edge of the column this is due to improper stripping of the formwork. These problems are caused due to lower quality of formwork material. Therefore to correct these problems it requires chiseling the concrete surface.



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

Steel formwork reuses many times and its quality becomes decreases. After many reuses it loses its original shape it might be bending and has irregular shape. This irregularity of the formwork has effect on the concrete surface. Some contractors use such kind of formwork, due to the irregularities of the formwork it causes some roughness on the structures to keep the structures finishing surface smooth chiseling should be needed.

4.7b Effects of timber formwork on the concrete surface finish

Timber formwork removed or striped for column formwork the same as steel. As shown in figure 4.10 column having size 40cm*30cm after 18hr the formwork removed or striped, check the column dimension using meter 41cm*31cm it has some variation from the actual size.

Timber with high moisture content (more than 20 % moisture content), wet concrete will shrink & cup leading to open joints & leakage of grout. Can't be used for long. Have limited re-use the result obtained by Attaullah (2011).

In addition to this timber formwork with high observation capacity affects the concrete strength and also discoloration of the concrete surface finish.



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

Improper stripping of formwork has effect on concrete surface. To make stripping of formworks easier both steel and timber formworks should be oiled. But the release oil has effect on the concrete finishing surface. Timber formwork also requires chiseling but it requires slight chiseling compared to steel.

4.8c Effect of chiseling on concrete surface

From the respondents rate as shown in figure 4.11 chiseling the surface has an effect on the concrete structure yes or no question.

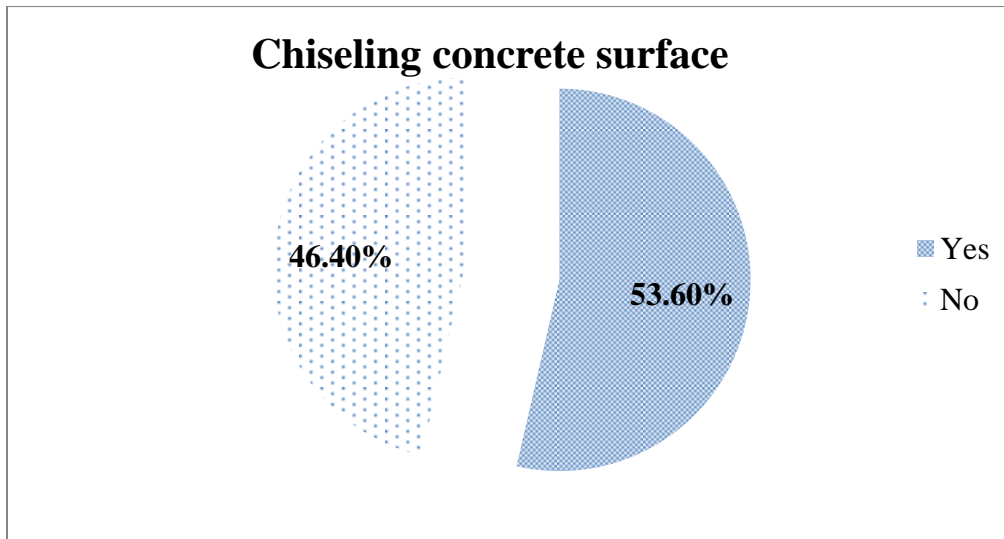


Figure 4.11: Respondents rate on chiseling concrete surface

The result shows as summary 53.60% of the respondent says yes chiseling the concrete surface has effect and 46.40% says chiseling has not effect on the concrete surface.

Chiseling the surface of concrete considered as a habit. And there is lacks of knowledge on; Over Chiseling the surface of concrete structure has effect on the strength and disturbs the bond between the concrete and the reinforcement bars which in turn creates macro cracks and reduce the durability of concrete structure. And also over chiseling and plastering leads to extra cost.

4.9 Comparison of the quality and cost of steel and timber formwork

The formwork material plays a great role on the quality of concrete surface finish, size and dimension. According to the respondents rate timber formwork is more accurate in the time of placing concrete mix, accuracy include size, shape and alignment of structural elements than steel formwork the result of summary shown in figure 4.12.

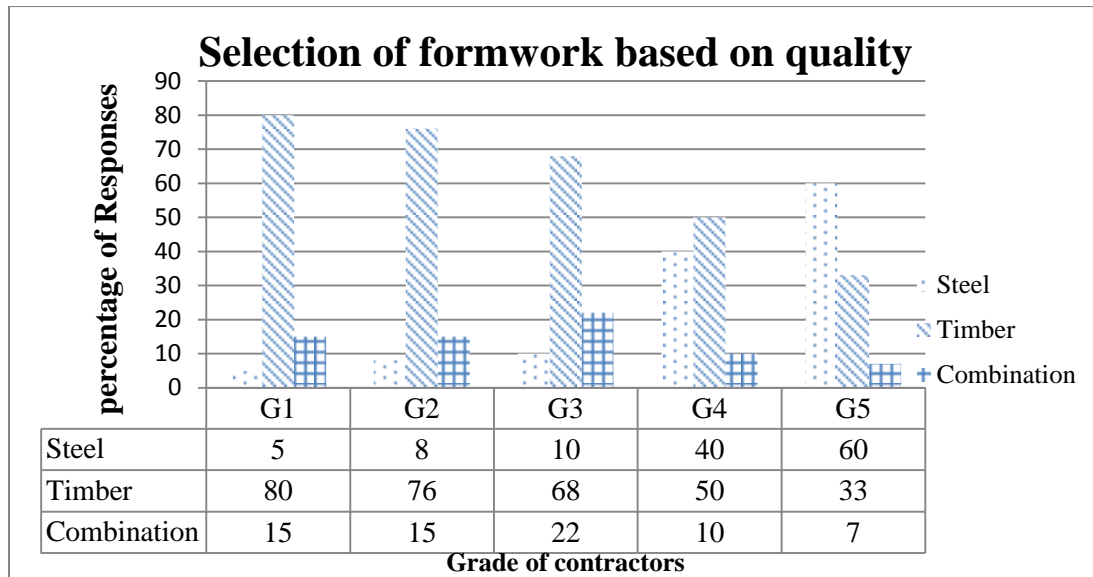


Figure 4.12: Response rate for selection of formwork based on Quality

According to the respondents rate the higher grade contractors prefer timber formwork is more accurate in the time of placing concrete mix, accuracy include size, shape and alignment of structural elements than steel formwork. The lower grade contractors prefer steel formwork were more accurate in the time of placing concrete mix than timber.

In City University of Hong Kong (2006) studied that Steel formwork can be re-used many times, the high initial cost of providing the form often discourages its selection, especially when there is no need to re-use them too many times, for example in a low-rise development. In addition to this Attaullah (2011) studied that timber formwork can't be used for long. Have limited re-use. According to the survey data 100% of contractors say steel formwork reuses many times than timber formwork. From the survey made, steel formworks are used more than ten times without caring for its maintenance and cleaning also timber formwork were used four times. Most of the contractors clean the panels after the concrete was set on them. Cleaning method is done by adding water on set concrete and using sharp metals to release it. Such cleaning procedure affects the quality of panels and subsequently quality of concrete surfaces. Improper storage of steel panels has also resulted in bending and rusting of the elements.

Steel formwork has higher initial cost than timber and can be reused many times for large projects but its quality may become lower and lower with high rate of reuses. Timber formwork can't be reused many times but for the quality of structures it is preferable. It is suitable for small projects.

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

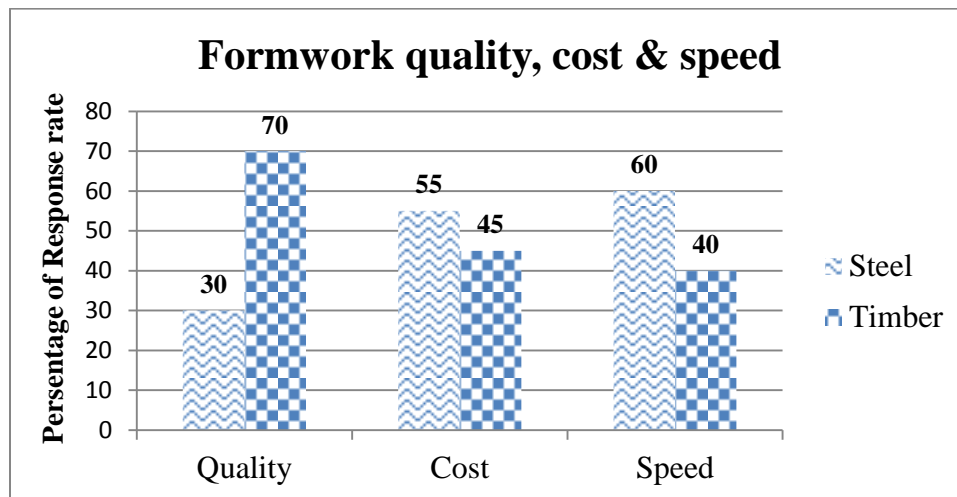


Figure 4.13: Response rate of Formwork quality, cost and speed

According to the respondents rate 70% of the respondents prefer for the quality of concrete timber formwork, 55% of the respondents prefer steel formwork in their cost and 60% of the respondents prefer steel has good speed of construction.

Abhiyan, et. al., (2013) remarked that the timber brought used for formwork must satisfy the following requirements. It should be durable and treatable, have sufficient strength characteristics and light weight, it is economical for small construction jobs. It can easily be made into any shape or size. And it is easy for transporting purpose for in between sites.

The kind of formwork material plays a greater role on the quality of finished concrete. The finished surface of concrete dimension, smoothness and regularity governed by the formwork type. Timber more suitable for small projects in addition to this majority of the contractor prefer for the smoothness of the concrete finished surface timber formwork.

Steel formwork is reused many times for large projects its high rate of use minimize the quality. The reuses are made without maintenance and cleaning of the formwork. Also lack of stock resulted in bending and rusting. Because of this all the above mentioned problems steel formwork has low quality than timber formwork. The speed of construction done by steel and timber formwork system, that means erection time and stripping time is steel formwork is preferable than timber. During erecting and stripping time timber requires more care because it easily be come broke. Therefore steel formwork take shorter time for erecting and stripping than timber formwork system. Abhiyan, et. al., (2013) studied that steel formwork mostly used in large construction projects or in situations where large number of re-uses of the same shuttering is possible. It is suitable for circular or curved shaped structures such as tanks, columns & also used for structures like sewer tunnel and retaining wall. Strong, durable & have longer life. Steel can be installed & dismantled with greater ease & speed resulting in saving in labor cost. No danger of formwork absorbing water from the concrete and minimizing honeycombing

From the literature review and respondents rate according to quality, cost and speed of construction steel and timber formwork has their own merits and demerits. Summarized in the table 4.2.

Table 4.2: Merits and Demerits of steel & timber formwork

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

Suryakanta (2015) obtained that the total cost of concrete construction work includes the cost of formwork also.

Investigation on the effects of formwork & scaffolding types in building projects in Addis Ababa.

Construction of formwork involves considerable expenditure in terms of cost of material, cost of labor for fabrication, erection and removal of formwork and time element. In case of buildings, the cost of formwork may range between 30 to 40% of the cost of concrete work.

From the result initial cost of steel formwork is higher than timber but it has longer use life. In Addis Ababa the formwork material cost coverage in percentage including labour cost according to the respondents responds 10%-20% covers. The cost per meter square either for steel or timber formwork differs 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. To show the difference the cost break down of timber and steel for direct cost and indirect cost of the formwork shown in table 4.3.

Table 4.3: Cost break down for timber and steel formwork.

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	
Wooden form work	M ²	1.05	66.67	70.00	Forman	1.00	0.17	33.65	5.61	Tools	1.00	0.50	0.50	
40 x 50 cm. battens	M	0.80	13.67	10.94	Carpenter	1.00	1.00	26.25	26.25					
Eucalyptus	M	12.50	4.25	53.13	Ass.Carpenter	1.00	1.00	12.25	12.25					
Nails	Kg	0.30	23.63	7.09	DL	1.00	1.00	12.25	12.25					
Mould Oil	Lit.	0.05	17.85	0.80										
Total (1:01)				141.96	Total (1:02)				56.36	Total (1:03)				0.50
A= Materials Unit Cost 141.96 Birr/m ²					B= Manpower Unit Cost 102.47 Birr/m ²					C=Equipment Unit Cost 0.91 Birr/m ²				
					<u>Total of (1:02)</u>					<u>Total of (1:03)</u>				
					Hourly Output: _____					Hourly output: _____				
					Direct Cost of Work Item = A+B+C =				245.34	Birr/m ²				
					Over head cost :				15%	36.80	Birr/m ²			
					Profit Cost:				10%	24.53	Birr/m ²			
					Total Unit Cost :				<u>306.68</u>	Birr/m²				

Investigation on the effects of formwork & scaffolding types in building projects in Addis Ababa.

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)				
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost	
Steel panel	M ²	1.05	35.51	37.29	Forman	1.00	0.17	33.65	5.62	Tools		1.00	0.50	0.50
50 x 70 cm battens	M	1.10	31.91	35.10	Carpenter	1.00	1.00	26.25	26.25					
Strut 0 60 mm	M	36.00	4.00	144.00	Ass.Carpenter	1.00	1.00	12.25	12.25					
wire	Kg	0.30	23.63	7.09	DL	1.00	1.00	12.25	12.25					
Mould Oil	Lit.	0.05	17.85	0.80										
Total (1:01)				224.28	Total (1:02)				56.37	Total (1:03)				0.50
A= Materials Unit Cost		224.28 Birr/m ²	B= Manpower Unit Cost		112.74 Birr/m ²	C=Equipment Unit Cost		1.00 Birr/m ²						
<u>Total of (1:02)</u>					<u>Total of (1:03)</u>									
Hourly Output:									Hourly output: _____					
Direct Cost of Work Item = A+B+C =									338.02 Birr/m ²					
Over head cost :									15% 50.70 Birr/m ²					
Profit Cost:									10% 33.80 Birr/m ²					
Total Unit Cost :									<u>422.53 Birr/m²</u>					

The cost break down of timber formwork the direct and indirect cost was 306.68 Birr/m² and steel cost break down was 422.53 Birr/m².

Table 4.4 : Cost estimation for timber and steel formwork.

Formwork material	Initial cost/m ²	Salvage value/m ²	n = No of uses
Timber	306.68 birr	5% of initial cost=15	4
Steel	422.53 birr	10% of initial cost=42	10

To determine the cost difference between steel and timber formwork by using equation 1 based on engineering economics concept.

$$C = p \left[\frac{(1+i)^n - 1}{i(1+i)^n} \right] - s \left[\frac{(1+i)^n - 1}{i} \right] \dots \dots \dots \text{equation 1 (Leland, 2012).}$$

Where C= cost per use of timber/steel formwork

P= initial cost

S= salvage value

i= interest rate per use = 10%

n= number of use

For Timber cost per use

$$C = 306.68 \left[\frac{(1+0.1)^4 - 1}{0.1(1+0.1)^4} \right] - 15 \left[\frac{(1+0.1)^4 - 1}{0.1} \right] = 902.56 \text{ birr/m}^2$$

The cost per use of timber formwork is 902.56 birr/m²

For steel cost per use

$$C = 422.53 \left[\frac{(1+0.1)^{10} - 1}{0.1(1+0.1)^{10}} \right] - 42 \left[\frac{(1+0.1)^{10} - 1}{0.1} \right] = 1916.5 \text{ birr/m}^2$$

The cost per use of steel formwork is 1916.5 birr/m².

Cost difference= 1916.5 – 902.59= 1013.91 birr/m²

$$\% = \frac{1013.91}{1916.5} = 52\%$$

Therefore steel formwork has better service life than timber formwork and save 52% cost of formwork. Especially for large projects.

4.10 Identification of scaffolding materials used.

Scaffolding as a temporary structure it supports the structures and workers. It is useful in building construction, maintenance and repair works. From the questioners distributed 100% of the respondent prefers steel scaffolding according to safety and quality. In Addis Ababa 10% of building contractors use combination of both steel and timber scaffolding and 30% use only steel and 60% use timber scaffolding as shown in figure 4.14.

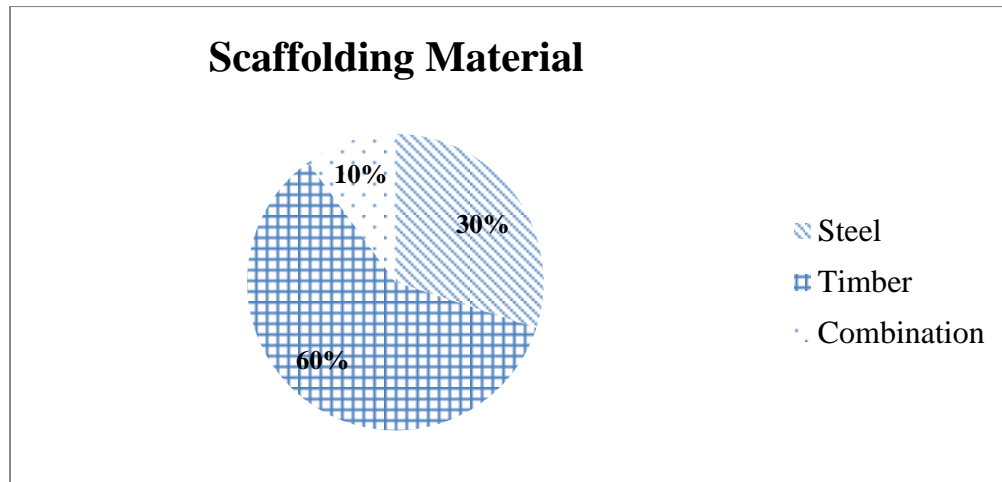


Figure 4.14: Scaffolding Materials Used by Contractors in Addis Ababa

According to Suryakanta (2015) Scaffolding is a temporary rigid structure made of steel, bamboo or timber. The primary aim of constructing a scaffold is to create a platform on which mason can work at different heights. Scaffolds also help to lift materials for the immediate uses at different heights.

The result shows from the pie chart majority of the contractors use timber scaffolding because of cost. Steel scaffolding is better according to quality and safety but it has higher initial cost than timber.

Timber scaffolding was one of conventional scaffolding system in Addis Ababa. It provide cheaper solutions and are best suited for light jobs and for irregular shaped building structures it is an ideal solution but its quality will be affected easily by bad weather condition. It cause failure on the structural elements and injured the workers and difficult to use in high rise buildings.



Figure 4.15: Timber scaffolding at legetafo site.

Steel scaffoldings used for large projects or in high rise buildings. Steel scaffolding has longer life than timber scaffolding and it is much safer for the workers and structures and also it reduce waste of trees. But it rust easily if antirust is not applied.



Figure 4.16: Steel scaffolding at Mexico site

4.11 Source of scaffolding material

According to the survey data 100% of the respondents prefer steel scaffolding for safety, especially for high rise building for the safety of workers and structures steel scaffolding is preferred. But majority of the contractors limited by cost.

The source of the scaffolding from the respondents rate 46% are use owning (from local market), 33.7% are use produced by company itself and 20% are owning (imported). The result summarized in figure 4.17.

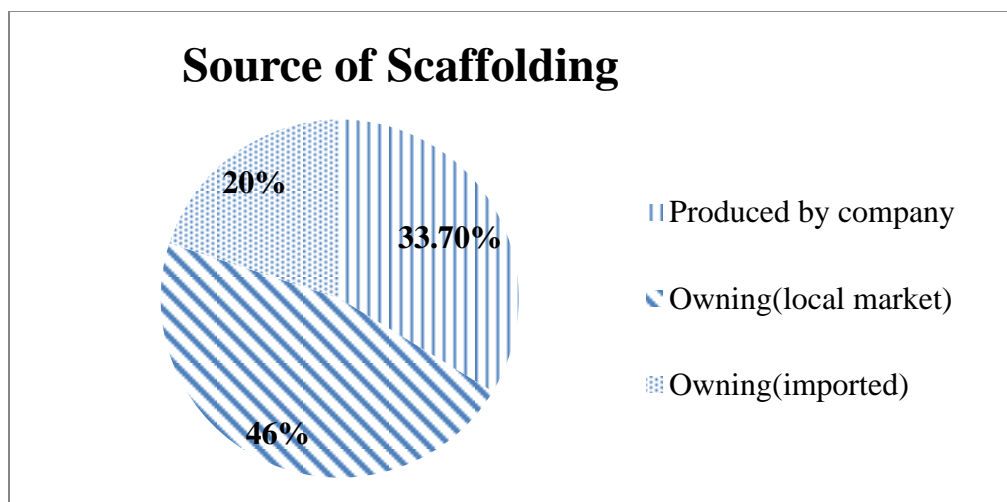


Figure 4.17: Source of scaffolding

4.12 Comparison of the quality and cost of steel and timber scaffolding

In high rise buildings steel scaffolding is recommended than timber scaffolding for the safety of workers and structure. Majority of the contractors choose steel scaffolding according to safety and quality. Steel scaffolding has higher initial cost but it has high rate of reuses. The result shown in figure 4.18.

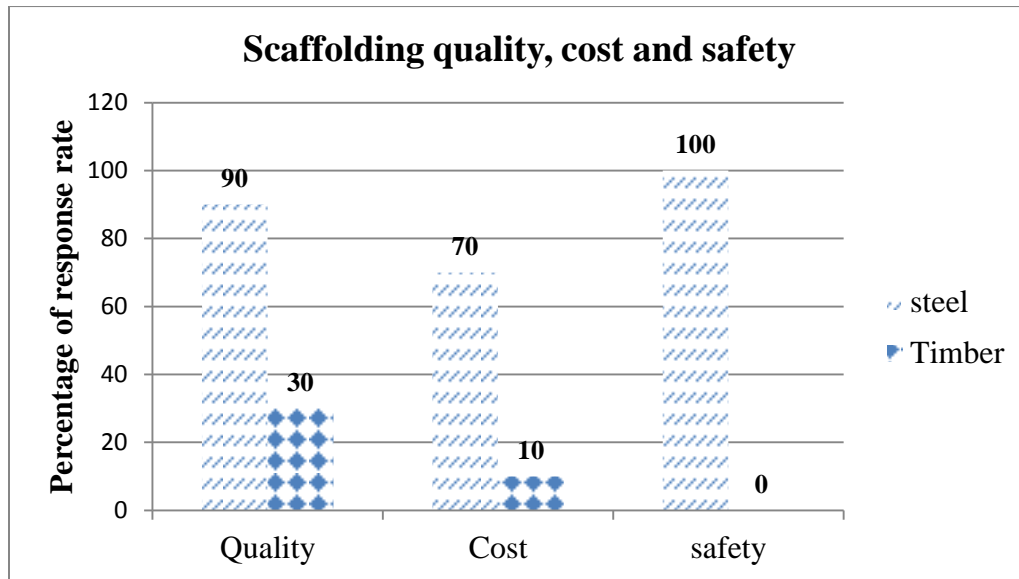


Figure 4.18: Response rate of scaffolding quality, cost and safety.

According to the respondents rate 90% of the respondents prefer steel scaffolding according to quality, also 30% of the respondents prefer steel for cost and 100% of the respondents prefer steel more preferable for the safety of workers and structural elements.

Using timber scaffoldings the contractor increase profitability in small projects as these scaffolds are lower in cost than steel scaffolds. In case of irregular shaped building structures timber scaffolding is the ideal solution than steel scaffolding. Timber scaffolding easily broken when it exposed to rain water and sun light. It becomes weaker, has short period of use and can't carry heavy loads it injured the workers.

Steel scaffolding good solution for large projects with high rate of reuses however it has high initial cost in addition to this it is economical in large projects. It can be erected or dismantled more rapidly in comparison to timber scaffolding which means it has good speed of construction.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

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

Steel and Timber boards are the most commonly used formwork materials in Addis Ababa. The quality of surface finish, horizontal and vertical alignment and shape of structures affected by the kind of formwork. According to the survey made in Addis Ababa, 70% of the respondents use combination of both steel panels and timber boards as formwork materials. About 5% of the respondents use steel, 20% use timber and 5% use yellow timber as formwork material. In Addis Ababa 10% of building contractors use combination of both steel and timber scaffolding and 30% use only steel and 60% use timber scaffolding.

Steel formwork reuses many times with high rate of reuses it affect the concrete surface finish. The irregular shape of formwork causes unpleasant surface finish on the concrete surface. However it is easy for erecting and striping and has good speed of construction. Timber formworks are more preferable for the smoothness of surface finish but it retards the speed of construction and cannot reused many times like steel although it suitable for small projects. The release oil used in the formwork to make striping easier it cause discoloration the concrete surface finish. Over chiseling the surface of concrete structure has effect on the strength and disturbs the bond between the concrete and the reinforcement bar. By the use of lower quality of the formwork chiseling and plastering are mandatory, it is extravagance.

Timber scaffoldings are an ideal solution for irregular shaped building structures but its quality easily affected by bad weather condition. It cause failure on the structural elements and injured the workers and difficult to use in high rise buildings it is for small projects. Steel scaffoldings used for large projects or in high rise buildings. Steel scaffolding has longer life than timber scaffolding and it is much safer for the workers and structures. In addition to this it is economical for large projects. According to quality and safety steel scaffolding is more preferable. Steel formwork has better service life than timber formwork and save 52% cost of formwork.

5.2 Recommendations

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

- Steel formwork and scaffolding can be reused many times. To keep its quality it should be maintained after every reuse, clean it well, painting is applicable and stock in suitable place.
- To prevent or minimize deforestation steel formwork and scaffolding with longer life reuses more preferable.
- Modern formwork technology applied as substitute in place of conventional formwork and scaffolding system.
- To minimize formwork utilization prefabricated (precast) and modular construction was recommended.
- Many construction companies chisel the concrete surface for plastering and because of the quality of formwork. For plastering instead of chiseling rush coat is better. And also through the use of modern formwork the cost of plastering and chiseling will be minimized.
- In construction industry safety has more priority than cost and quality therefor in high rise building construction steel scaffolding is recommended rather than timber scaffolding by considering the workers and structures safety.

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APPENDIX A

QUESTIONNAIRES

This questionnaire consists of;

PART ONE: General information

PART TWO: Formwork

PART THREE: Scaffolding

All information provided in this questionnaire will be treated with strict confidentiality and allowed to serve only for the purpose of the academic research under consideration. Interested participants of this study will be given feedback on the overall research results after the completion of the research work.

Sincerely yours,

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PART ONE: General Information

- a. Name of your Company _____
- b. Grade of the company _____
- c. Your position in the company _____

PART TWO: Formwork

1. In your construction company, which type of formwork system did you use?

Mark on the boxes.

- Steel formwork
- Timber formwork
- Other formwork system please specify _____
- Combination of both
- neither of them

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

- Steel formwork
- Timber formwork
- Other formwork system please specify _____
- Combination of both
- neither of them

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

- Steel formwork
- Timber formwork
- Other formwork system please specify _____
- Combination of both
- neither of them

4. Do you think that chiseling the surface has an effect on the concrete structure?

Yes _____ No _____

Investigation on the effects of formwork & scaffolding types in building projects in Addis Ababa.

5. What type of formwork material is easy for erecting and stripping?

Mark on the boxes.

Steel formwork

neither of them

Timber formwork

Other formwork system please specify _____

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

Structural element	Steel formwork	Timber formwork	Combination of both	Other type of material
Column				
Beam				
Slab				
Wall				

7. What is the source of your formwork materials? (Please mark on the boxes you can mark more than one item).

Rental

Owning (purchase from local market)

Produce by company itself

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

Steel formwork

Timber formwork

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

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

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

	Steel formwork	Timber formwork	Combination of both
Quality			
Cost			
Speed			

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

a. Steel_____

b. Timber_____

c. Other please specify

PART THREE: Scaffolding

1. In your construction company, which type of scaffolding system did you use?

Mark on the boxes.

Steel scaffolding

Combination of both

Timber scaffolding

neither of them

Other scaffolding system please specify_____

Investigation on the effects of formwork & scaffolding types in building projects in Addis Ababa.

2. What is the source of your scaffolding materials? Please mark on the boxes you can mark more than one item.

Rental

Owning (purchase from local market)

Produce by company itself

3. Which type of scaffolding material is safer for the workers? Mark on the boxes.

Steel scaffolding

neither of them

Timber scaffolding

Other scaffolding system please specify _____

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

	Steel scaffolding	Timber scaffolding
Quality		
Cost		
Safety		

Interview

1. Are the quality of building construction affected by the kind of formwork and scaffolding?

2. What type of material is cost effective for formwork and scaffolding?

3. What is the current rental cost of the materials?

Steel _____

Timber _____

4. How many times will the form work material reused?

5. What is the best formwork material in your opinion?

APPENDIX B

JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
CIVIL ENGINEERING DEPARTMENT

MSC PROGRAMME IN CONSTRUCTION ENGINEERING AND MANAGEMENT

Title: Investigation on the effects of formwork and scaffolding types in building projects.

Concrete formwork checklist (Guide line) at site.

Project name.....

In building construction there are temporary structures to support the permanent structures. Concrete formwork is a temporary supporting structure for the concrete when it is placed at the construction site to keep the concrete in position and shape till it gets hardened. Checks for formwork before placing the concrete and after removal of formwork. Concrete formwork plays a great role for the quality of surface finish. The quality of building construction affected by the formwork material used.

1. Basic information

Consultant.....

Contractor.....

Types of formwork material used.....

2. Column formwork

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3. Beam and slab formwork

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4. Formwork removal or stripping:

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5. Effects of formwork on the concrete surface finish

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6. Conclusion

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