JIMMA UNIVERSITY
JIMMA INSTITUTE OF TECHNOLOGY
SCHOOL OF GRADUATE STUDIES
FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING
CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

ASSESMENT OF CURRENT APPLICATION OF FORMWORK IN BUILDING CONSTRUCTION PROJECTS IN HOSSANA TOWN

A Thesis submitted to School of Graduate Studies, Jimma University, Jimma Institute of Technology, Faculty of Civil and Environmental Engineering in Partial Fulfillment of the Requirements for the Degree Master of Science in Construction Engineering and Management

By

Bisrat Zergaw Belew

January, 2022

Jimma, Ethiopia

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Advisor: Dr. LUCY FELEKE ----------

Co-Advisor: AHEMED NUREDIN ----------

January, 2022

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DECLARATION

I declare that this thesis document entitled “assessment on current application of formwork in building projects in Hosanna town” is the result of my own work, it contains no materials previously published or written by another person except where due reference is made. This document has not been previously submitted for any degree at other higher education institutions.

Signature: _____

Name Bisrat Zergaw Belew

As thesis Adviser, I hereby certify that I have read and evaluated this thesis paper prepared under my guidance, by Bisrat Zergaw Belew entitled “assessment on current application of formwork in building projects in Hosanna town” and recommend and would be accepted as a fulfilling requirement for the Degree Master of Science in Construction Engineering and Management.

Advisor: Dr. LUCY FELEKE	NAME	_____ SIGNATURE	29/04/2022 DATE
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ABSTRACT

Formwork is the largest cost component for a reinforced concrete structures. Its cost accounts for 40 to 60 percent of the cost of the concrete frame in developed country. A large proportion of the cost of conventional formwork is related to formwork labor costs. Significant cost saving will be achieved by reducing labor costs.

The main objective of this thesis is to assess on current application of formwork. This can be achieved by identifying formwork types and materials used at building construction project sites in Hosanna, by collecting factors influencing selection of formwork system, by investigate the quality implication of current formwork practice and effects of the using current construction practices

Among the different tools used to collect data, self-administered questionnaire in the form of both close and open-ended questions used to collect all the relevant data used to answer the research question. A total of 60 questionnaires were distributed to contractors & consulting firm. For analysis a total of 57 questionnaires where used. The method of analyzing the collected data is based on ranking the percentage of frequencies and by using relative importance index (RII). This research used a mixture of descriptive statistics, graph and pie chart to present the collected data.

From collected data type of formwork used 65% of respondents use conventional formwork system and the remaining 35% use modern conventional formwork system. Most commonly used formwork materials are plywood and steel formwork materials in Hosanna town. Some of the quality problems of using conventional formwork system are not straight vertical surface, uneven surface and poor construction joint are some problems. The effects of using current formwork practice high influential effect was high labor intensive, secondly limited no of reuse and thirdly high wastage were the most three influential effects. Based on this results construction industry of hosanna town formwork system should be improved by utilizing modern formwork system.

Key Words: Formwork system, formwork materials, quality, Current practice, **Effects& quality implication**

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Acronyms

BC= Building contractor

CSR= Corporate social responsibility

GC= General contractor

GRP= Glass reinforced plastic

GFK= Glass faster verstarkte kunstst

GFRP= Glass fiber reinforced plastic

PU= Polyurethane varnish

RII= Relative important index

RCC= Reinforced cement concrete

CHAPTER ONE
INTRODUCTION

1.1Background

Construction is one of the important sectors in the world. Construction involves huge investment and plays an important role in growth of several other sectors in economy. Globally construction of high rise buildings is increasing in order to save time and space. In construction industry formwork plays an important role. Formwork contributes a major part of cost in construction and gives shape to the fresh concrete and also support the fresh concrete to gain its strength to carry on its own weight [14].

In current construction practice, all over the world due to modernization of construction industry, building projects are constructed in fast track. This requires the minimization of construction time and quality of concrete finish to reach required supply and this is only obtainable when modern construction techniques are implemented by construction industry.

In most developed countries formwork system gates much emphasis on construction industry, due to modernization and projects should be completed based on required time, budget and required quality of finish.

Ethiopia is one of the developing countries with fast urbanization. Many high-rise buildings are being constructed in urban areas, due to increased population and businesses. The majority of high-rise buildings are concrete works which are one of the most important elements in such huge infrastructures. Fast and efficient construction of the concrete is therefore, essential to maintain phased (gradually staged) progress on other parts of the building.

Almost all construction projects are undertaken having a predefined cost, and quality. Common assessment of the success of construction projects is that they are delivered on time, to budget, to technical specification and meet client satisfaction.

From the view point of cost, completion time and quality of the projects, the construction industry of Ethiopia is not at required level compared to the rest of the world. Among different factors that contribute to poor practices of construction industry of the country, the usage of inferior quality of formwork systems. To attain that formwork system plays an important role.

Formwork is a temporary construction to support structural members during concrete hardening stage to with stand oncoming loads like dead load of wet concrete, hydrostatic pressure of concrete and live loads due to labor and equipment, sudden impacts load due to vibrators, pouring of concrete and due to equipment operation etc. Though formwork support structural members and loads it should also give smooth and quality finish. As per construction industry point of view very important element in construction is formwork.

Formwork is the largest cost component for a reinforced concrete structures. Its cost accounts for 40 to 60 percent of the cost of the concrete frame in developed country. A large proportion of the cost of conventional formwork is related to formwork labor costs. Significant cost saving could be achieved by reducing labor costs. Formwork costs can also be reduced by carefully considering the materials and equipment to be used; the fabrication, erection, and stripping procedures; and the reuse of forms [6].

Nowadays generally, formworks exist in three major categories, namely, conventional formwork (the most traditional type of formwork used in the construction industry, which uses timber, bamboo), modern conventional formwork (similar to conventional one but more advanced materials such as steel props and various types of jacks (U jacks, T jacks) are used as supports in the formwork instead of timber supports and ply wood sheets are used instead of timber planks on slab decks, beams and columns) and modern formwork which is modern formwork developed for improved features of concrete and has prefabricated components by patented manufacturers[15].

Conventional formwork construction system in Ethiopia takes relatively longer time to strip and erect. The labor time for production and erecting of formworks is relatively longer. This will also add costs to the project as the contractor’s productivity will be reduced.

1.2 Statement of the problem

‘’The other problem in building construction projects in Ethiopia is that formwork takes relatively longer time to erect and strip. The quality of concrete surfaces is mostly not good as proper formworks are not designed and constructed accordingly [17].

. The type of formwork used and the way it is erected construction sites are among the key factors in determining the success of a construction project in terms of cost, quality, construction speed and safety of the projects [21].

The labor time for production and erecting of formworks is relatively longer. This will also add costs to the project as the contractor’s productivity will be reduced. The quality of concrete surfaces is mostly not good as proper formworks are not designed and constructed accordingly. Hence, study on current application formworks is mandatory to have better concrete fulfilling the requirements and client satisfaction.

1.3 Research Questions

1. Which formwork materials and formwork types are used in hosanna town?

2. What are the influential factors for selection of formwork system?

3. What are the effects and quality implications of using conventional formwork system?

1.4Objectives of the Research

1.4.1 General Objective

The main objective of this thesis is assessing of current application of formwork on building projects in Hosanna town.

1.4.2 Specific Objectives

- To asses formwork materials and types used at building construction project sites in Hosanna Town.

- To identify factors influencing selection of formwork system
- To identify the effects and quality implications of conventional formwork system

1.5 Scope of the Study

The research mainly focuses on the formwork systems for building projects. Only cast in situ concrete formworks are investigated because precast structures are not practiced in hosanna town. It is specifically focused on the structural elements of building projects such as column, beam, slab, shear wall and stair that are casted in the construction site. Projects being undertaken by grade-1to grade 4 contractors were studied considering that these top grade contractors have financial capacity and experience in the field which help to select appropriate formwork for a specific building project.

1.6 Significance of the Study

As construction industry requires substantial amount of money for its work accomplishment. In most of the project formwork activity accounts for 30% to 60% of the cost of the concrete skeleton and extends 40% to 60% of the total project duration. So it will be necessary to study and figure out the effects and quality implications of using convectional formwork system. Moreover to give awareness of local contractors about modern form work system it will improve budget and with required quality to satisfy the need of stakeholders in construction.

This research will be necessary for contractors and other construction stakeholders to improve formwork practice to save time, cost and quality of construction projects.

CHAPTER TWO

LITRATURE REVIEW

2.1 Formwork and Formwork Systems

A form is defined as a temporary structure or mold for the support of concrete while it is setting and gaining sufficient strength to be self-supporting. Formwork has a broader definition: it is the total system of support for freshly placed concrete including the mold or sheathing which contacts the concrete, as well as all supporting members, hardware, and necessary bracing. Forms are essential to concrete construction. They mold concrete to the desired size and shape and control its position, alignment, and surface contour. Formwork is more than a mold. It is a temporary structure that supports its own weight, the weight of the freshly placed concrete, construction loads such as materials, equipment, and workers, and other possible live loads during construction [3].

Various creators give meanings of formwork in an unexpected way. For example as indicated by Hanna (1999) structure and formwork have a similar importance. It is characterized as an impermanent design whose object is to offer help and control for new cement until it can uphold itself. Different creators characterize formwork corresponding to bogus work as brief or long-lasting molds into which concrete or comparable materials are poured. What's more, bogus work as the underlying scaffoldings and propping used to help all or part of the formwork or design [6].

"Formwork means the surface of the form and framing used to contain and shape wet concrete until it is self-supporting" [5]" The definition in this code of practice includes the forms on or into which the fresh concrete is poured to a desired shape and the frames and bracing which provide stability. Frames and bracings used as part of the formwork assembly, namely, the joists, bearers, bracing, foundations and footings are technically referred to as false work in this code of practice.

The type of formwork systems and materials used formwork is the major factors which can determine the efficiently and effectively completing the projects in terms of quality, cost and time.

2.2 Requirements of Good 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 1/900th 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. Suitable arrangements should be there to avoid any settlement in the form work either before or during the placing of concrete.

7. Formwork should be of sufficient stiffness to avoid excessive deflection and joints should be tightly butted to avoid leakage of cement slurry.

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

9. 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 [4].

In order to successfully carry out its function, formwork must achieve a balance of technical, functional and economic requirements. The following categorical requirements of formwork were accessed from [19].

2.2.1. Technical Requirements

Formwork has to be technically sound and designed to achieve the desired specified quality of the concrete. The following are technical requirements of good formwork.

Containment: Formwork must be capable of shaping and supporting the fluid concrete until it cures.

Strength: Formwork should support the designed loads and any other applied loads during the construction period. Thus forms and shutters have to be designed to support deadweight, live load and hydrostatic pressure. Formwork for vertical concrete elements namely, columns and walls are subject to pressures (the hydrostatic pressure) on the form face caused by the fluid action of the fresh concrete. The pressure of the fluid concrete on the vertical faces increases proportionately with the depth of concrete and hence the maximum pressure being at the bottom of the form [19]

Resistance to leakage: Concrete is placed in a mold or form while it is in its liquid state, from which cement and fine aggregates are prone to leak through form joints. The formwork therefore, must be designed and fixed to prevent leakage of cement and fine aggregate from the liquid concrete. The gaps between planks or form sheets must be tightly fitted to prevent the leakage of cement paste.

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. It shall also be carefully selected for required finish surface and linings to produce the desired concrete surface.

Rigidity: The mold into which the fresh concrete is poured must be rigid enough to resist bulging, capable of withstanding without distortion or danger the dead weight of the fluid concrete is placed on it, labor weight, equipment weight and any environmental loadings. Brace

formwork and support to ensure that there exists no movement may take place under hydrostatic pressure when the concrete is being placed and vibrated..

2.2.2 Functional Requirements

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 [19].

Speed of erection and dismantling: The formwork design and the methods of assembly must be as simple as possible to reduce time spent in erection and dismantling. The formwork should be simple to remove without causing damage to the concrete surface and formwork itself [7].

Access for concrete: any formwork arrangement must provide access for placing of the concrete. The extent of this provision will be dependent on the ease of carrying out the concrete operations.

2.2.3 Economic Requirements

For formwork construction to be economically feasible, the following procedures should be considered during selection [19];

- Formwork shall be made of low cost materials, energy and labor if possible.
- Formwork should be manufactured such that it can be repetitively used and shall be as adaptable as possible. It must be able to withstand a good number of reuses without losing its shape.
- Formwork must be designed so that the whole formwork can be assembled and dismantled with unskilled or semi-skilled labor.
- Formwork care and maintenance should be done according to specifications.

2.3 Main consideration during selection of formwork

2.3.1 Safety

Safety in formwork is major concern today especially in high-rise construction and large infrastructure projects like metros, flyovers, bridges etc. It is a known fact that safety levels are so lower the International Standards. Safety cannot be treated as a separate entity; rather it should be an integral part of the formwork system.

Formwork being the major contributors to the safety in construction sites as they are used for the rebar and concreting works. The various areas of safety that need to focus and integrate with formwork are:

- Access (both Vertical & Horizontal)
- Working platforms
- Lifelines and Safety Catch Nets
- Erection & Dismantling of Formwork
- Storage & Maintenance of Formwork
- Simple Tools & Tackles
- Design and Engineering

During selection of formwork system above aspects shall be considered.

2.3.2 Standardization:

Standardization of the various formwork systems is also an aspect to introspect because we cannot afford to have too many systems at sites which leads to lot of complications in terms of usage as well as accountability. The formwork systems should be standardized such that a single system is adaptable to various structural elements and also across various projects. Though it has its own limitations, still standardization can be done to an extent which reduces the number of components involved in a system, increase efficiency of the components involved and the flexibility in usage of these (in terms of sizing and detailing)

2.3.3 Green Formwork

Rapid industrialization, growth in population and urbanization have consumed nonrenewable natural resources of the planet but also caused unprecedented rise in global warming. Most leading business houses and industries across the world have adopted Corporate Social Responsibility (CSR) as the roadmap of their current and future business ethics and principles. Currently no importance is being given to this aspect of Green Concept and Sustainability. In future, our approach should be

"Greener Formwork Systems" to do our part for the betterment of environment. Achievement of a sustainable formwork system could lead for more sustainable construction and enhance the construction industry sector to uphold sustainability for future generations.

2.3.4 Costing of formwork

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

2.4 Factors Influencing Selection of Formwork System

2.4.1 Quality

Quality and Surface Finish Quality of underlying completion of the concrete is to be satisfactorily tended to by strength of the formwork just as its protection from twisting. Structural completion of the concrete relies upon sheathing material utilized. The sheathing materials like plywood, steel, aluminum, and elastic ought to be fittingly picked dependent on the necessary completion and attainability. Also the quality of concrete finish is dependent on the formwork system used.

2.4.2 Availability

Material and supplier availability consider for avoiding shortage problems during execution. Most of the time it is not some modern formwork system is not available in construction industry of Ethiopia especially in hosanna town. So the construction firm selects the available formwork system like conventional and modern conventional formwork system with out considering quality and time consumption of the project.

2.4.3 Adaptability & Flexibility (Fixable Sizes)

Formwork should be modular and adaptable for various sizes and shapes of the structural system, so that it can be used for many projects. Formwork should be viable for the particular project based on cost and availability.

2.4.4 Cost

This is a vital factor for deciding formwork system as one must know the capital provision for formwork in the project. On average about 35% of the total cost of any finished concrete unit or element can be attribute to its formwork; of this just over 40% can be taken for material for formwork and 60% for labor.

2.4.5Type of Structure

The structure may be commercial building or a residential building and the system to be chosen is based on adaptability of formwork to suit the requirement.

2.4.6 Maximum Load Capacity

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.

2.4.7 Suitability of Work for Labors

Easy handling of form materials and work with comfortable that include lifting, erection and dismantling.

2.4.8 Weather Condition

Vertical forming systems are sensitive to weather conditions. Typically, in vertical forming systems, the newly placed concrete is supported by the wall already cast below it. The lower wall section must gain sufficient strength to support the fresh concrete above. The rate of strength gain for the lower wall is influenced by ambient temperature, moisture content, and freezing and thawing cycles. Another factor that affects the economy of the selected system is the effect of stopping forming and concreting because of extreme weather conditions [12].

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

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

2.4.9 Duration of the Project

Faster floor cycle is always desirable for contractors and owners. For contractors, faster floor cycle allows the contractor to finish on schedule or earlier which reduces the overhead cost. For the owner, faster floor cycle reduces the short term financial charges and allows early utilization of the constructed facility [12].

2.4.10 Load Carrying Capacity

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.

2.4.11 Accessibility to Work

Proper access to work place is an important requirement and sufficient space for the shifting of panels and storage.

2.4.12 Maintenance & storage cost:

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

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

2.4.13 Site Condition

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

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

2.4.14 Safety

Formwork should be self-securing with safe access and working platforms. Thus, it is not left to the end user whether they takes safety measures or not. Creating a safe work environment for the

entire work force involved in the construction process, has become the pivotal issue in emerging construction markets.

2.4.15 Building Dimension

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

2.4.16 Life Span

Life span of formwork is the duration of formwork system before rupture. This means number of repetition of use of formwork system for construction.

2.4.17 Construction Cycle time

High-rise block-shaped structures usually require highly repetitive cycles and this is favorable to the use of formwork. However, the degree of repetition in building with very large construction

area like a podium or underground structures such as basements is limited and the use of formwork, as an expensive resource, becomes very critical.

2.5 Formwork materials

The selection of materials suitable for formwork should be based on the price, safety during construction, and the quality required in the finished product. Approval of formwork materials by the engineer/architect, if required by the contract documents, should be based on how the quality of materials affects the quality of finished work.

Materials used for the construction of concrete formwork range from traditional materials such as timber, steel, aluminum, and plywood to nontraditional materials such as fiberglass. The systems

used can be a combination of two materials. Wood products are the most widely used material for formwork. Most widely used formwork materials are listed below:

1. Timber
2. Plywood
3. Steel
4. Aluminum
5. Plastics
6. Yellow Panel
7. Magnesium
8. Fabric
9. Hardboard
10. Green Reinforced Plastic
11. Wood Particle board

2.5.1Timber

Timber is widely used for many construction applications including concrete formwork. Timber is harvested from trees and is classified as hardwood and softwood. Hardwood comes from trees that have broad leaves such as oaks, maples, and basswood. Softwood comes from trees that have needle-like leaves such as pines, cedars, and firs. Softwoods are most commonly used in the construction of formwork [10].

Timber is the most commonly used material for formwork. Timber logs, lumber etc. are used as bracing members from ancient times. So, the Timber formwork is also called as traditional formwork. It is most economical material used for formwork. This is used in sites as formwork material for number of years so, the method of constructing timber framework is well known to the workers [18].

Advantages

- Timber can be cut into any required size easily.
- Timber is light in weight and it can be handled easily.
- Timber has good thermal resistance which prevents the damage of concrete in colder regions.
- It is easy to understand the construction method of timber formwork hence, skilled workers are not necessary.
- It is easy to replace the damaged parts of timber forms.

- Timber formwork can be easily dismantled.

Disadvantages

Dry timber may absorb water from wet concrete which result in the reduction of strength in concrete structure.

Wet timber having high moisture content compress the wet concrete and forms cracks in the structure and grout may leaked through joints when shrinking occurs.

Timber forms have limited usage. So, they cannot be useful for more times or Timber formwork should only be modified 5 to 6 times.

Figure 2.1 Timber formwork

2.5.2 Plywood

Plywood which is a manufactured product of timber is also used for formworks. It consists number of veneer sheets or plies in layers. Now a days, the use of plywood formwork increases especially for facing panels. The reason behind it is that the plywood formwork provides smooth finish when compared to normal timber formwork. Hence, finishing cost may reduce by the use of plywood. For formwork, special type of plywood called exterior plywood is used. The veneer sheets of exterior plywood are bonded with strong adhesive to make it watertight.

The plywood boards are available in thicknesses from 7mm to 32mm. In general, plywood of size 1220 x 2440 and 18mm thick boards are sufficient for most of the works. For curved structures, special types of plywood with sufficient thickness are also available [18].

Formwork of Plywood for structural concrete is often waterproof Boiling level plywood, seems to be a preservative-treated material, and has been particularly suited to be used in shuttering and formwork. Plywood formwork is quite economical, and can also be used repeatedly, based on the precautions given all through erection as well as demolishing of formwork [10].

Plywood is readily acceptable as a form material where curved surfaces of the concrete are desired. Shorter radii can be developed by wetting or steaming the ply prior to bending.

Plywood is available in different thickness ranging from ¼ to 1/4 inches. The thinner sheets are used for lining purpose while thicknesses above V2 inches are used for sheathing material. Mill treated plywood should be oiled between successive uses to prevent the grain from rising, to assure that it will not adhere to the concrete.

Plywood has better mechanical properties than the timber from which it has been manufactured. Shuttering ply is more than twice stronger than the timber of same thickness. The table below shows the comparative strength [10].

Advantages

- Plywood can also be cut into the required size easily.
- Plywood Strong, durable, and light in weight.
- Provides a smooth finish on the surface.
- Very Large size plywood sheets are available which makes the construction of formwork quicker and easier.
- Curved formworks can also be prepared using plywood.
- When compared to timber, it gives more number of reuses. Concrete as well as sound waves.

Disadvantages

- When compared to timber it is costly.
- Thin plywood sheets cannot sustain the weight of concrete they may bow out if proper thickness is not provided.

Figure 2.2 Plywood Formwork

2.5.3 Steel Formwork

Steel can also be used as formwork material. It is very costly but it can be used for more number of times than others. They provide excellent finish to the concrete surfaces. For mass strictures like dams, bridges, etc. steel from work is so strong and safe [18].

The initial cost of metal formwork is more than timber formwork but the number of reuses of metal formwork is higher than that of timber. In the long run metal formwork can be economical. In heavy construction works metal formwork may require a lifting mechanism to handle the formwork panels or props. Steel or aluminum or magnesium is the most widely used metals [10].

Steel is available in various grades of strength but with formwork the usual criteria for design is stiffness of the material. Since stiffness of almost all grades of steel are same so it is not advantageous to spend on higher grade of steel. It is easier to do any wielding job with a low grade of steel. As it is a hard unyielding material so joints between adjacent pieces of steel are difficult to make in a water tight fashion. It should be noted that butt joints, rather than laps of metal, are

used between adjacent sheets to eliminate or reduce the joint effects. Use of steel forms is economical if there is enough number of reuses. Steel forms can be easily erected, disassembled, moved and re-erected rapidly. It can be used for as many as 6 to 7 years if care is taken in its handling. Unless special precaution taken they offer little or no insulation protection to concrete placed [13].

Advantages

- Steel forms are durable and stronger.
- Provides uniform and smooth surface finish to the structure.
- Great reusability.
- Easy to fix the formwork and also easy to dismantle.

Disadvantages

- Cost is very much higher.
- It is heavy in weight and requires lifting equipment for large structure formworks.
- Corrosion will occur when there is a frequent contact with water.
- The size and shapes of forms available are limited

Figure 2.3 Steel Formwork

2.5.4. Aluminum

Use of aluminum as sheathing as well as framing material has been popular in foreign countries. Due to its lower density than steel it is lighter weight and it can be easily handled rather than steel components. The main disqualification is its high cost compared to steel. Because the strength of aluminum in handling, tension and compression is less than the strength of steel, it is necessary to use larger sections when forms are irade of aluminum. Due to its light weight it ensures faster use of formwork and low labor cost on using it. So construction can be completed early.

When used as face contact material, pure aluminum reacts with the alkali in the fresh concrete, in the presence of moisture. This can be minimized by pretreatment and the use of selected release agents. Preetching of the face is essential before first use to ensure uniform concrete color [13].

Aluminum formwork is used often for pre-fabricated formworks. It is getting more popular because of its light weight and good strength. It requires fewer supports and ties.

Advantages

- Easy to fix and easy to dismantle.
- It can be handled easily because of its light weight.
- It can be re-used for many times.
- The walls and slabs of structures can be casted simultaneously.
- Monolithic crack free structures can be built using aluminum formwork.

Disadvantages

- When the load reaches its maximum limit, the lighter sections may deflect.
- Architectural modifications are not possible when aluminum formwork is used.

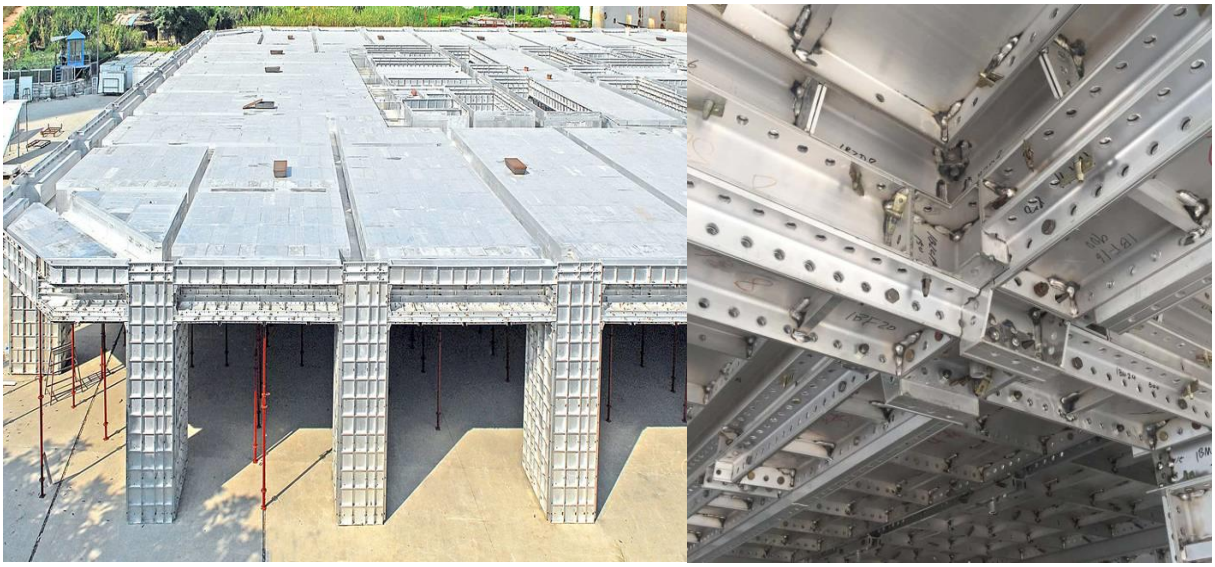

Figure 2.4 Aluminum Formwork

2.5.5 Plastic Formwork

Plastic is another type of formwork material which is used for small concrete structures or for complex portions of the structure. It is light in weight and durable for long periods. For complicated concrete structures, Glass reinforced plastics (GRP) and vacuum formed plastics are used.

A material which softens on heating and then stiffens again on becoming cool is called 'Thermoplastics'. It can also be used for similar purposes Making connections to pieces of plastic like this is difficult, and so it is used for creating patterned finishes where separate pieces are appropriate. Plain thin plastic sheeting as a liner is not satisfactory, because it is extremely difficult to fix ends successfully and the plastic cannot be made to lie completely flat. Plastics are used successfully as surfacing iriaterial bonded to plywood sheets [13].

Advantages

- ✓ Plastic is light in weight and can be easily handled
- ✓ Formwork for complex-shaped structures can be prepared easily.
- ✓ Good resistant against water.
- ✓ The damaged plastic sheets can be recycled and useful to make new sheets.
- ✓ Good quality plastic has great re-usability.

Disadvantages

- ✓ Plastic is weak against heat.
- ✓ It is a costly material.
- ✓ It does not take much load when compared with others.

Figure 2.5 Plastic Formwork

2.5.6 Yellow Panel

Yellow panel formwork is important building product, used to construct shear walls and slabs. At present, they consist of three layers of 9mm (total of 27mm) of carefully dried wood and available in standard width of 50cm and length from 1 to 3 meters. These products are made with certified high quality wood glued at controlled temperature and pressure, to guaranty the best result. On there surface there is melamine resin coating in order to facilitate cleaning operations.

The edges are protected, then, with polyurethane varnish (PU) which reduces the absorption of humidity and increase durability of the yellow panel. The following are the advantages of yellow panel.

Advantages

- ✓ Better stability during use
- ✓ Bending resistance up to 40N/mm^2
- ✓ Easy to use
- ✓ Size stability
- ✓ Elastically module

2.5.7 Magnesium

Magnesium is another metal element which is used for formwork. Magnesium is not directly used for formwork and is used with the combination of oxygen atoms which forms magnesium oxide, usually called magnesia or MgO. Magnesium oxide boards or MgO boards are famous in some countries because of their multiple applications. MgO boards are available in required sizes and grades [18].

Advantages

- Mgo boards are light in weight and easy to handle.
- They are fire proof and waterproof.
- Bio friendly boards cause no harm to the environment.
- They are strong to resist heavy loads.

Disadvantages

- When Mgo boards meet wet concrete, the magnesium chloride present in MgO boards may dissolve and cause corrosion to the reinforcement.
- Skilled supervision is required for installation.
- MgO boards cannot sustain in humid conditions. They absorb moisture easily from atmosphere so; they are called as crying boards.

Figure 2.6 Magnesium Formwork

2.5.8. Fabric

Fabric formwork is the modern technology in construction sector. Fabric can be mold into any required shapes which makes it more famous formwork for architectural purposes.

Fabric formwork is a building technology that employs geotextile fabrics as the formwork material for concrete construction. Its first application can be attributed to Gustav Lilienthal, a builder, and inventor, who combined his knowledge in textiles with construction to invent a fabric-formed suspended floor.

The material used for fabric formwork is geotextile. Geotextile fabrics used for formworks are flexible fabrics that possess high strength and do not tear under the action of loads. These materials are also referred to as polymer fabrics.

Geotextile fabrics used for formworks are flexible fabrics that possess high strength and do not tear under the action of loads. These materials are also referred to as polymer fabrics. Geotextile fabrics are made using polyolefin compounds taken from non-aromatic carbon and oxygen molecules. For formworks, woven types of geotextile fabrics are commonly used. They can be:

2.5.8.1 Woven polyethylene fabrics

Woven polyethylene fabric has the following properties:

- High flexibility
- High resistance to strong acids, bases, gentle oxidants, and reducing agents
- Relatively low melting point depending on its density

2.5.8.2 Woven polypropylene fabrics

Woven polypropylene fabrics are commonly used for fabric-formed concrete. These fabrics as formwork possess the following properties:

- High melting point
- Light in weight
- Low resistance to chemical deterioration

- High flexibility
- Relatively strong

Features of Fabric Formwork System

1. Fabric formwork systems can be used for cast-in-place and precast concrete construction applications.
2. Fabric formwork is flexible enough for the shaping of beams, columns, walls, etc.
3. The fabric mold takes the intended shape under the pressure of wet concrete.
4. Geotextile fabrics as a formwork material work in tension, reducing the amount of form material required to support the hydraulic pressure of the wet concrete.
5. Fabric forms provide better durability, surface finish, and architectural aesthetics compared to traditional formwork.
6. Fabric forms help to achieve complex shapes by using less concrete and reinforcement.
7. Geotextile fabrics are permeable enough to allow excess water and air bubbles in the concrete mix to dissipate through the formwork, providing a stronger and impermeable concrete.
8. Fabric forms have widespread applications in the area of architecture where it is being used to explore new, complex, and intricate shapes.

Advantages

- It weighs very less when compared to any other formwork material.
- It is economical.
- Any complex shape can be constructed using fabric formwork.
- It is waterproof.
- Doesn't affect the concrete properties.
- Easy to removal after the hardening of concrete.

Disadvantages

- For installation skilled workers are required to form perfect and required complex shapes

2.5.9. Hardboard

Hardboard consists of timber particles bonded with a matrix of plastic glue, the low stiffness of the glue leads to a board which is less stiff than plywood or solid timber of same thickness. Quality of concrete produced from using the hardboard may not be smooth enough and the detonation of such surfaces can be fairly rapid. Tempered hardboard is sometimes used to line the inside surfaces of forms as it helps in minimizing the absorption.

Hardboard is frequently used to form lines for architectural concrete where smooth surfaces entirely free from grain markings are desired. The edges of adjacent sheets should be nailed to the same backing boards to prevent slight offsets that may accentuate the joints. Joints between adjacent sheets may be filled with cold water putty. A light sanding with sand paper no: will make the joint smooth and practically invisible. Holes for form ties should be drilled with a worm-center bit to avoid tearing of the board. Surface of the hardboard should be oiled before it is used.

With very good quality hardboard maximum 3 to 4 numbers of reuses are possible. Low cost of hardboard ensures that it can be easily replaced when any wearing occurs.

Hardboards are the densest fiber boards, with a minimum density of 900 kg/m^3.Fibreboards are manufactured from wood or other plant fibers by the application of heat and/or pressure. Hardboards are bonded by the inherent adhesive properties and felting of the fibers.

2.5.10. Green Reinforced Plastic

Glass-reinforced plastic (GRP), also known as glass fiber-reinforced plastic (GFRP), is a composite material made of a plastic matrix reinforced by fine fibers made of glass. It is also known as GFK (Glass faster verstärkter Kunstst off), or simply by the name of the reinforcing fibers themselves: fiberglass [25].

In recent years, forms fabricated from glass-reinforced plastic have found increasing use because of their strength, light weight, and high number of reuses. Glass-reinforced plastic also produces high-quality concrete finishes. They are very flexible and can form complex or nonstandard shapes with little capital investment. To fabricate glass-reinforced plastic forms, models of plaster, wood, or steel are prepared to the exact desired dimensions. The model is then

waxed, polished, and sprayed with a parting agent to prevent sticking of the resin to the master pattern. Glass mat is then fitted over the model and thoroughly saturated with a brush coat of polyester resin. When the resin has set and the heat dissipated, another layer of glass mat and polyester resin is added, and this process is repeated until the desired thickness of the fiberglass sheet is achieved. The major problems associated with glass-reinforced plastic forms are attack by alkalis in the concrete and form expansion because of exposure to hot sun or heat from hydration of cement [6].

2.5.11 Wood Particle board

Wood particle board (chipboard) is manufactured from wood waste or forest thinning's, which are converted into wood chips, dried and graded according to size. The chips are coated with adhesive to approximately 8% by weight and then formed into boards. The woods chips are either formed randomly into boards giving a uniform cross-section or distributed with the coarse material in the center and the finer chips at the surface to produce a smoother product. The boards are then compressed and cured between the plates of a platen press at 200°C [13].Particle board is available with a plain sanded surface or covered with wood veneer, vinyl or melamine plastic. Building industry use particle board for concrete formwork, wall paneling, shelving and waterproof varieties are available for sheet flooring.

2.6 Types of Formwork System

Formwork is a mold or die used to shape and support the concrete until it attains sufficient strength to carry its own weight. Formwork is the largest cost component for a typical multistory reinforced concrete building. Formwork is the largest cost component for a typical multistory reinforced concrete building. Important aspects in the construction of tall structures include type of formwork system, method of concreting, geometric control, material handling etc.

2.6.1 Conventional Formwork System

This is the oldest type of formwork used in the construction industry. This type uses timber, bamboo, masonry and carpentry in the construction. This type is very much suitable for small houses with two to three stories and still they are in use for such constructions [12].

But this is not suitable for the big projects or high-rise buildings. Low initial cost, low experience factor, low weight are some of the advantages of this type. But poor finish, (low quality) high labor requirement and Requirement and consume lot of time are some of the disadvantages.

Also this sort of formworks enjoys benefits for low starting expense; low work experience necessities and low weight, high floor cycle wastage, low reusability, poor finish, and high work necessity are then again, the disservices. This is the sort of formwork where the greater part of the woodworkers began as day by day workers and takes longer time to gather and erect

Figure 2.7 Conventional formwork system

2.6.2 Modern Conventional Formwork system

Modern conventional type of formwork is similar to the traditional slab formwork method but more advanced materials such as steel props and various types of jacks (U jacks, T jacks) are used as supports in the formwork instead of timber supports and ply wood sheets are used instead of timber planks on slab decks, beams and columns. These advanced materials can reuse for several times.

The advantages of this type are low initial cost, low skilled labor requirement and can use in places where there are a lot of deviations in the structure.

Figure 2.8 Modern conventional formwork system

2.6.3 Modern Formwork Systems

The modern formwork systems are designed for speedy and efficient construction. They are designed to provide increased accuracy and minimize waste in construction and most have enhanced health and safety features built-in.

Main type of Modern Formwork Systems in world – wide use are:

1) Table or Flying Formwork

2) Column Formwork

3) Horizontal panel Formwork

4) Vertical Panel Formwork

5) Jump Formwork

6) Slip formwork

7) Tunnel Formwork

2.6.3.1 Table or Flying Formwork Systems

These systems consist of slab formwork "tables" that are reused on multiple stories of a building without being fully dismantled. The assembled sections are either lifted per elevation or using cranes from one story to another. 'Fillers' are used to fill gaps between the tables and walls. The mobility factor, along with the relatively easy installation means that these systems are widely used in construction projects where repetitive structures, where flat slab and slab layouts are involved.

Some of the application areas include residential apartment units and commercial buildings. Since the assembled units can be moved easily, it ensures speedy construction, apart from the high quality surface finish.

Moreover, the wastage generated is negligible as compared to the traditional formwork systems that were earlier used. Another key factor that should be noted is that with the table formwork system time is also saved, which in turn leads to cost savings, particularly in the case with structures with flat slabs. Moreover, the engineered nature of the formwork and the repetitive process ensures that there is almost negligible wastage.

Figure 2.9 Table or flying formwork system [14]

2.6.3.2 Column Formwork System

Column formwork has gained in popularity due to the shortage of labor in recent times. Modular in nature and allowing for quick installation on site, column formwork systems are now available in a variety of materials depending on the concrete finish requirement.

Different formwork systems for different column sizes can be easily assembled on site. Their entire working process is also simple. Once the concrete is poured and hardened, the formwork is then stripped and moved to the next position. In certain cases the formwork systems may be left for a longer period of time for added curing.

One of the major advantages with column formwork systems is the highly engineered nature of the formwork. They ensure greater control over the construction operations. This automatically means reduction in wastage, time and labor costs.

Figure 2.10 Column formwork system [14]

2.6.3.3 Horizontal Panel Systems

Smaller, lightweight modular systems have now days become the requirement. These systems are being made from a variety of materials such as fiber glass, aluminum and steel, apart from other customized options. These easy-to handle systems enable quicker erection, saving precious time and money. Suppliers have also been concentrating on reducing the number of different components in formwork systems, which in turn allows for a quicker installation process. Horizontal panel systems usually consist of a series of interconnected false work bays and preformed decking panels and are typically used for slab construction.

The lightweight nature of the components is perhaps the biggest advantage with horizontal panel systems. They can be moved around the site with relative ease, as compared to traditional formwork. Adding to it is the engineered nature of the formwork which ensures reduced wastage. Another major advantage with lightweight formwork systems is safety, since working from height is not necessary, as erection work can be carried out from below.

Figure 2.11 Horizontal panel system [14]

2.6.3.4 Vertical Panel Systems

Vertical panel systems are used in the construction of standard columns, concrete walls or perimeter basement walls due to their flexible nature. It can either be smaller modular components or larger crane-lifted systems. This can be used for forming vertical elements and are usually modular in nature. Consisting of a steel frame, they are easier to assemble, in turn leads to reduced labor costs, making them a more cost effective option than traditional formwork systems.

Vertical panel systems are popular due to their adaptability to varying wall heights, structural geometries and a less labor intensive. The easier erection process expedites the construction process, apart from the fact that the engineered nature allows for precision and superior control of operations for the on-site team. This can be used repeatedly, after an easy cleaning process.

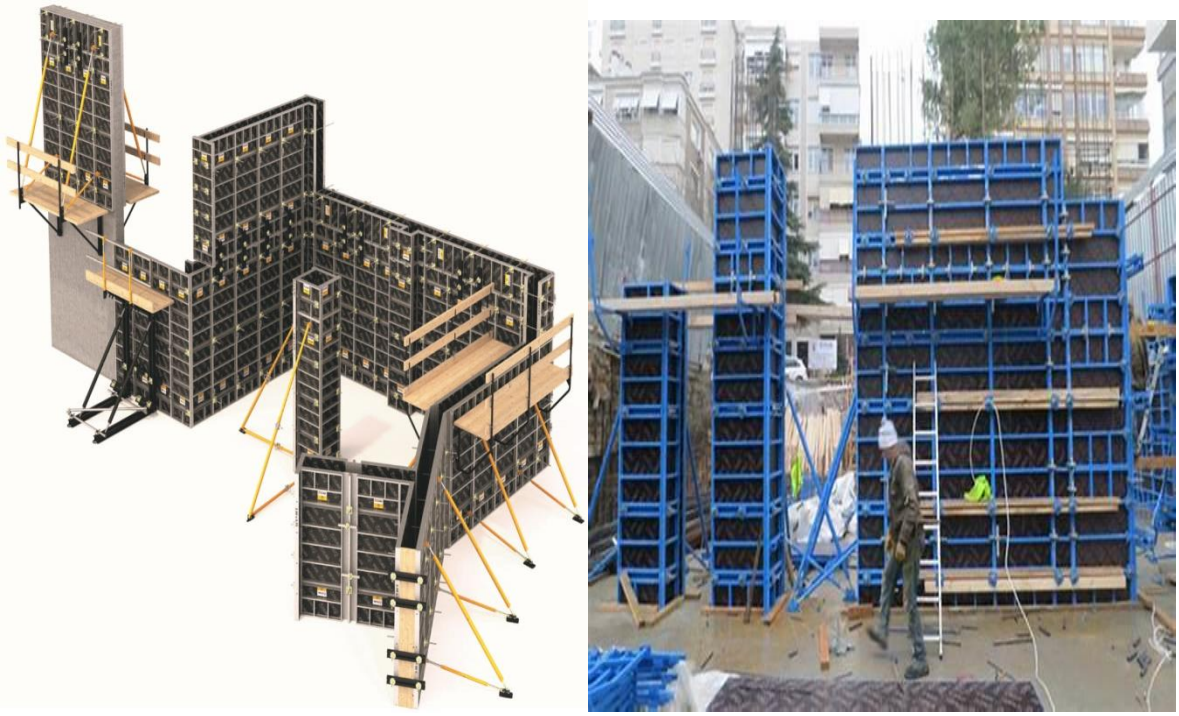

Figure 2.12 Vertical panel system [14]

2.6.3.5 Jump /Climbing Formwork Systems

Jump form systems are becoming popular globally. Jump form, also referred to as climbing form, comprises of formwork systems complete with working platforms that supports itself on the concrete that has been cast earlier. It therefore does not rely on support from the building. They are typically used in construction of multi-storied vertical concrete elements.

Some of the concrete elements that are constructed using jump form systems include, core walls, shear walls, bridge pylons and lift shafts. The use of jump form systems helps in cutting down on labor costs, while increasing construction efficiency.

Climbing formwork is usually used in the construction of buildings over five stories. Self-climbing, automated systems are generally used in the construction of buildings with more than 20-25 floors. Based on the site conditions, there are also instances when a combination of self-climbing and crane-handled jump form systems is used. The engineered nature of the formwork means that jump form systems allows for better control of the construction process. Repetitive use

is possible adding to the cost-effectiveness of the construction process. Apart from offering enhanced safety, the use of jump form systems also ensures minimal concrete wastage and helps to stick to tight project deadlines.

Figure 2.13 Jump or climbing formwork [14]

2.6.3.6 Slip Formwork System

Similar to jump formwork systems, this type of formwork rises continuously, supporting itself on the core. Slip form systems are typically used for the construction of core walls in skyscraper projects. Since very little crane time is required, they are used for the construction of stair shafts and lift shafts in high-rise structures. Slip form systems rely on the quick setting properties of concrete and require balance between quick setting capacity and workability of the concrete.

While the concrete needs to be workable enough to be placed into the form and packed, it should also be quick setting so that it emerges from the form with strength. Moreover, the freshly set concrete should, apart from its strength, also allow the form to 'slip' to the next level above, apart from supporting the freshly poured concrete above it. Typically slip form systems rise at a rate of about 300 mm per hour and with prudent planning, high rates of production are possible.

This also leads to reduced concrete wastage. The integration of work platforms in the formwork systems is another advantage that apart from ensuring safety also makes optimum utilization of

work space available in a construction site. This slip form systems is being preferred in core wall construction.

Figure 2.14 Slip Formwork System [14]

2.6.3.7 Tunnel Formwork System

A tunnel formwork system is the latest innovations in the formwork industry. The use of repetitive cellular structures to construct both horizontal and vertical elements together is something that has got the potential to revolutionize the construction industry in countries like India. They enable construction of walls and floors together which make the process ideally suited for both high and low raise housing.

Easy to clean and reuse, the use of tunnel form systems also enables high quality surface finishes. Engineers are also assured of high dimensional accuracy of structures. The repetitive nature of the construction work is another plus point with this type of formwork system, adding to its other advantage of requirement of a very small team on site.

Tunnel form can accommodate room widths from 2.4 to 6.6m. When rooms are wider (up to 11m), a mid-span table is incorporated between the tunnels. The main component of the system is the half tunnel. Manufactured entirely from steel, including the face of the form, the half tunnel

provides the rigidity and smooth face necessary to produce a consistently high quality finish to the concrete.

Figure 2.15 Tunnel formwork system [14]

2.8 Formwork Construction in Ethiopia

Building construction industry is one of the sectors, where mass construction is taking place in Ethiopia, especially in urban areas, and where many labors are employed. Many high rise buildings are constructed in urban areas of the country, especially in the capital Addis Ababa, by local and international contractors. Clients choose contractors based on the performance of the contractors and their own financing capacities. Most of the banks building constructions in Addis Ababa are awarded to foreign contractors and proceeding with visible success in terms of quality, faster construction time and safer site conditions while it is not a case by local contractors. The quality of work reduces the requirement of additional treatments of concrete surface, speed of construction allows the owner early utilizations of the building structure and safe practices also play great role in reduction of injuries and form failures [2].

Concrete work is the major of the building constructions and formwork is by which the success of construction is determined in terms of quality, construction time, cost and safety. Despite the development and continuity of high rise building constructions in Addis Ababa especially, by local contractors; quality, time, cost and safety still requires improvement. Most of concrete elements are in need of additional treatments to make the concrete surface straight and smooth by

chiseling and plastering with cement mortar of lesser strength than the removed concrete which is also time consuming and costly.

Considering contractors use ready mixed concrete, the type of formwork used and the way it is erected determines success of concrete construction in terms of quality, construction time, cost and safety[2].

2.9 Need for Modern Formwork in Hosanna

Although the conventional formwork systems which are made of wooden scantlings and timber runners have often permitted easy forming and erecting at site, they tend to be labor intensive, take substantial time of construction, and mostly concrete surface needs additional treatments after removal of the formwork which needs additional time and finance. The other most common problem of such formwork systems is, they tend to lose their structural and dimensional properties over a period of time and lead to safety problems after repeated usage which in turn leads to maximized wastage of forms. Many of the accidents take place in Reinforced Cement Concrete (RCC) constructions are because of inferior formwork and scaffolding, [9].

Developing the formwork situation parallel to the booming occurrence of mass building constructions is significant in today`s construction, generally in the Ethiopian building construction sector and specifically in the high rise building constructions in Addis Ababa. Some of the high-rise building constructions, mostly bank buildings, in Addis Ababa by the international contractors have often being preceded with a fast tracking, safe and quality manner. Usually the formwork scenario in Ethiopian building construction industry especially in local construction companies can be stated as:

- High wastage of formwork materials; the timber material reusability is limited because of unplanned and repeated nailing even where nailing is not required, for example nailing pieces of corrugated iron sheet on plywood to stop leakage of concrete paste through the joints.

- Conventional and modern conventional forms are most commonly practiced which is labor intensive, time taking, unsafe and with surface finishing in need of additional treatment.
- Higher wastage of concrete due to leakage through sheeting materials and one of the additional treatments is removing the cement grout through the sheeting joints by chiseling which then followed by plastering to level the surfaces and which is also false economy, unsafe and poor quality.
- Higher wastage of form materials and limited reusability due to unplanned nailing and poor storage.
- Unskilled labor due to lack of willingness in construction companies to give training, fearing laborer would leave at the end of training, and hence have chosen to continue with low productivity labor.
- Low labor productivity and limited circulation spaces through props and braces due to closely fixed bracings and propping, especially when timber products used

In building construction projects some costs of resources like material cost are considered unique based on the type and design of the building. But the cost for most of the resources such as labor, equipment and machinery, safety, waste materials handling, finishing quality and the duration of the project are directly affected by the technologies and the construction methods practiced in the project. The speed of the project is directly affected by the formwork type used in the project. This is the most critical in high-rise building construction. When using latest technologies, the labor requirement and the time duration can be minimized in the project, mainly for the super structure [11].

Now focus has to be shifted to other key factor Formwork, to face the challenges for the completion of fast track projects. By going in for system formwork, substantial savings are possible by faster return on investments [9].

According to Chavan (2016) these systems are pre-engineered to provide increased accuracy and minimize waste in construction and most have, built-in health and safety features. Better

quality buildings at faster speed of construction rate, cost effective and environment friendly manner can be achieved by using advance formwork systems.

Therefore, having known the impact of formwork on the process of the whole building construction in terms of cost, quality, time and safety, lots of improvements have been done on the formwork construction across the globe which Ethiopian building construction is in need of.

The following table shows the comparison of modern formwork and conventional formwork

Table 2.1 Comparison of modern and conventional formwork system

Characteristics	**Modern Formwork**	**Conventional Formwork**
Quality of concrete surface	Excellent, no plastering	Bad, Chiselling & plastering needed
Wastage of formwork materials	Very less	In great amount
Accuracy in construction	Accurate construction	Have errors
Need of any timber or plywood	Not required	Are main components
Speed of construction	1-4 days cycle per floor	21 days min. cycle time
Initial investment in the system	High	Low
Economy in construction	Economical for mass housing	Economical on small scale construction
Re-usage value of formwork	250 - 350	Maximum 50
Suitability for high rise construction	Very much suitable	Not suitable

CHAPTER THREE

METHODOLOGY

3.1 Research Area

The study area is located in Hosanna Town, in the southern region of Ethiopia, the administrative center of Hadiya Zone. Hosanna has a latitude and longitude of 7º33'N 37º51'E with an elevation of 2177 meter above sea level and also about 280 km south of Addis Ababa.

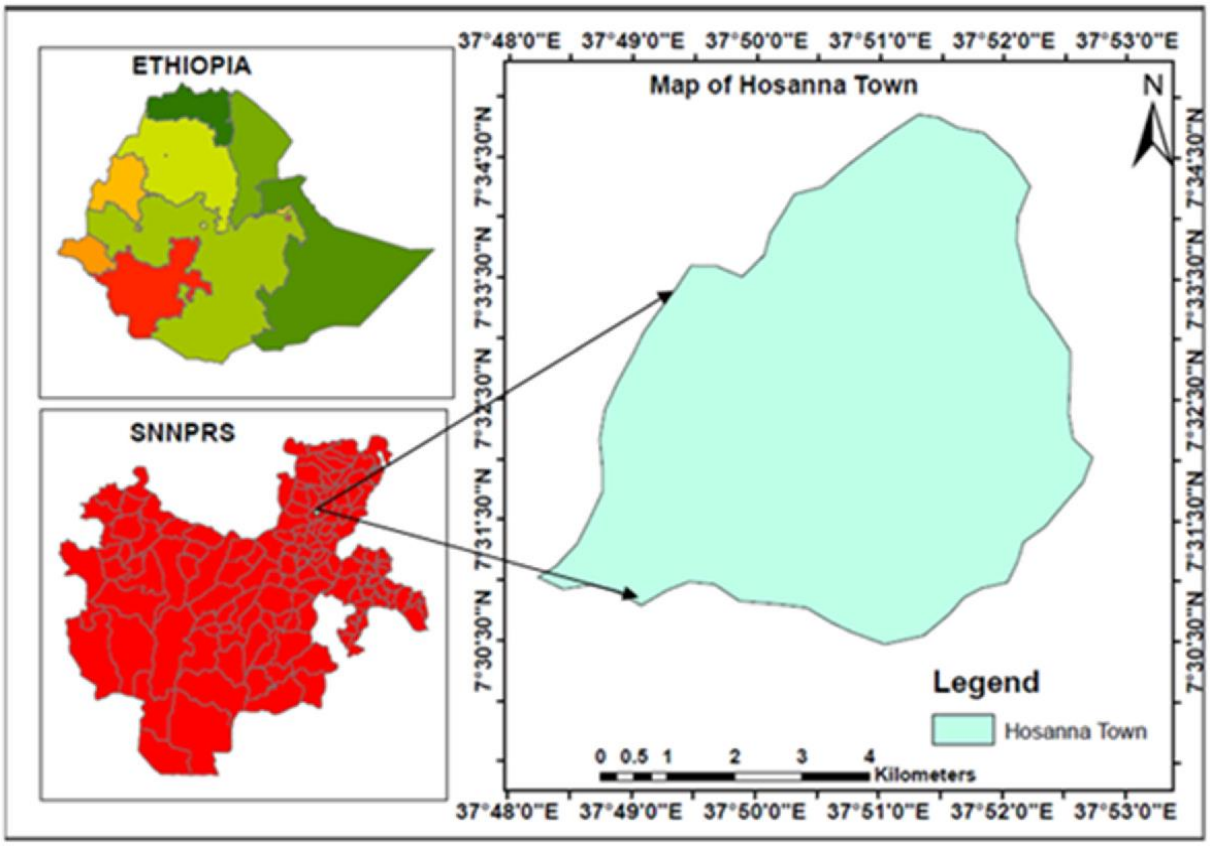

Figure 3.1 Location map of study area

3.2 Research Design

The question design was based on a combination of an extensive review of literatures dealing with current application of formwork on building projects. The procedural stages is applied in this research is described in below figure 3.2, primary data will be collected from namely grade 1 to

grade 4 contractors, BC 1, grade1-4 consulting firm and the secondary data examination from literatures on type of formwork system, through observations at building construction project sites in Hosanna and questionnaire method, then evaluation of the two data from the two sources. The following step listed shows the process of this research paper.

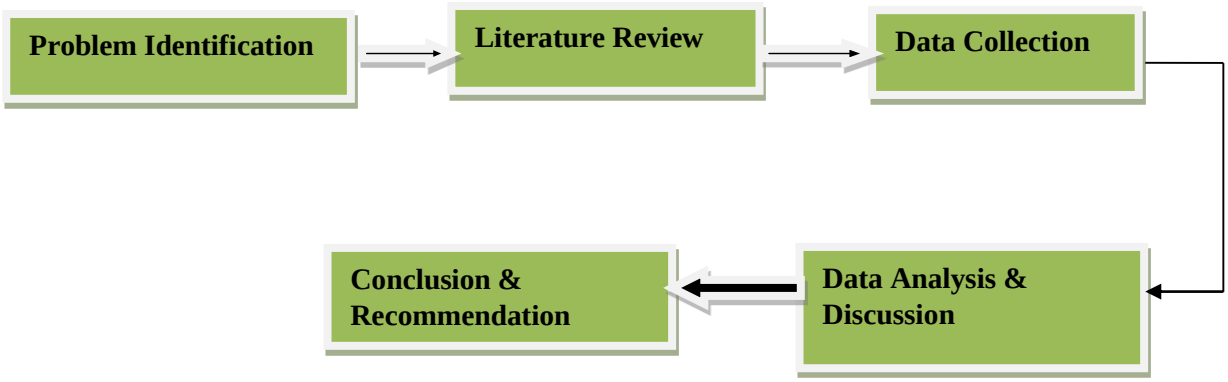

Figure 3.2 Process of research paper

3.3 Population and sampling method

The populations for this research paper is set to be contractors of grades 1, 2, 3 and 4 (GC &BC) and grade 1, 2, 3 and 4 consultants considering the experience and financial capacities they have, which affects the process of formwork selection, and time and economy for the research.

During the study period 18 ongoing projects were selected purposively depend on the progress of the work, financial capacity and experience of contractors. 60 questionnaires are distributed and relevant 57 questionnaires are returned. For which forty four (44) questionnaires for contractor and sixteen (16) questionnaires were distributed to consultant. The numbers of returned questionnaires from contractors were 41 and from consultant were 16.

Many researchers reflect in research activities that it is believed investigation would be better, if all elements or member of the population could be investigated. But due to different constraints in the real areas such as time and economy, representative units (samples) of a population are commonly measured. The advantage of using a sample (proportion of population) is that it is more practical and less cost than collecting data from every members of the whole population although some errors might be expected.

"In addition to the purpose of the study and population size, three criteria usually will need to be specified to determine the appropriate sample size: the level of precision, the level of confidence or risk, and the degree of variability in the attributes being measured".

A stratified random sampling followed by purposive sampling technique was used to select a representative sample from the population for questionnaire

3.4 Study variables

Dependent variable: The dependent variable is current application of formwork.

Independent variable: The independent variables are labor productivity, effects of current application, and stakeholder satisfaction.

3.5 Source of data

Primary data's is collected through questionnaire , while secondary data's were collected through archival documents/literatures (journals, reports, researches, text books and case studies).

3.6 Data collection procedure

Among the different tools used to collect data, self-administered questionnaire in the form of both close and open-ended questions were used to collect all the relevant data used to answer the research question. Questionnaire is the simplest and time saving method to collect data effectively from a huge number of respondents. Formulating questions from the identified variables, the questionnaire will be designed to gather data from professionals that were involved in public building projects in Hosanna. Closed-ended questions were formulated by allowing them to add other variables from their experience at the end of each section.

3.7 Data presentation and analysis

This research used a mixture of descriptive statistics and graphs. A descriptive method will be 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.

As described above this research is considering to questionnaire and interviews to collect data. The method of analyzing the collected data is based on ranking the percentage of frequencies of responses to the factors (requirements) which have influences or significance of formwork design and selection. And the ranking is based on relative importance index (RII) or Likert scale, which is expressed as follows.

$$RII = \frac{5n_5+4n_4+3n_3+2n_2+1n_1}{5\times N} = \frac{\Sigma W_A}{H\times N} \qquad (0 \leq RII \leq 1)$$

Where

N—total number of respondents

ni - the variable expressing the frequency of the i^{th} response

W—weighting given to each statement by the respondents and ranges from 1-5;

A—Higher response integer

Analysis will be made based on the respondents' response for current application of formwork. The comparison was made by using bar graph and pie chart graphs and interpretation were given for each result.

CHAPTER FOUR

RESULT & DISCUSSION

4.1 General

This chapter mainly focuses on analyzing and interpreting the result gathered from the respondents through questionnaire and site observation .Based on the gathered data from the respondents and according to the objective of this research at introduction part. And the objectives were;

- To asses formwork materials and types used at building construction project sites in Hosanna.
- To identify factors influencing selection of formwork system
- To identify the effects and quality implications of using conventional formwork system construction practice.

In successfully achieving main objective of the study, one of the most important phases is collection of accurate data. Data collection is a procedure of collecting crucial data records for a certain sample or population of observations. The thesis is carried out by analyzing the data and information gathered through questionnaires and observations on building construction sites of in Hosanna town.

Table 4.1 Distributed. Returned, unreturned, rejected & analyzed result

Respondent	**Distributed questionnaire**		**Returned questionnaire**		**Unreturned questionnaire**		**Rejected questionnaire**		**Analysed questionnaire**	
9	Frequency	Percent %	Frequency	Percent %	Frequency	Percent %	Frequency	Percent %	Frequency	Percent %
Contractor	44	73.33%	42	72.41%	2	100%	1	100%	41	71.93 %
Consultant	16	26.67%	16	27.59%	0	0%	0	0%	16	28.%

Total	60	100%	58	100%	2	100%	1	100%	57	100%

Sixty questionnaires are distributed and relevant fifty seven questionnaires are returned. The detail of the questionaries' are attached as appendix to this thesis. For which forty four (44) questionnaires for contractor and sixteen (16) questionnaires were distributed to consultant. The numbers of returned questionnaires from contractors were 41 and from consultant were 16. The table above shows the frequency and percentage of distributed, returned, unreturned and rejected questionnaires'.

4.2 Profiles of Respondents and Selected Building Projects

4.2.1 Respondents job position in the company

Table 4.2 Respondents job position in the company

Job Position	**Contractor**		**Consultant**	
	Freq	**Rate**	**Freq**	**Rate**
Project Manager	6	14.63%	2	12.5%
Office Engineer	10	24.4%	4	25%
Site Engineer	11	26.84%	3	18.75%
Construction Engineer	4	9.75%	0	0
Architect	6	14.63%	5	31.25%
Other	4	9.75%	2	12.5%
Total	41	1000%	16	100%

The above table 4.2 shows that the respondents organization for two parties. Site engineer is the highest percentage for contractor with 26.84%.Architect from consulting side with highest percentage of 31.25%. For contractor office engineer is second (24.4%), project manager and Architect are the third (14.63%), Construction Engineer and others (quantity servitor, project engineer & surveyor) are the fourth (9.75%). From consulting side site engineer is the second

(18.75%), project manager and other (site supervisor & quantity servitor) are the third (12.5%) and the construction engineer is the last. The following figure shows the summary of the above table.

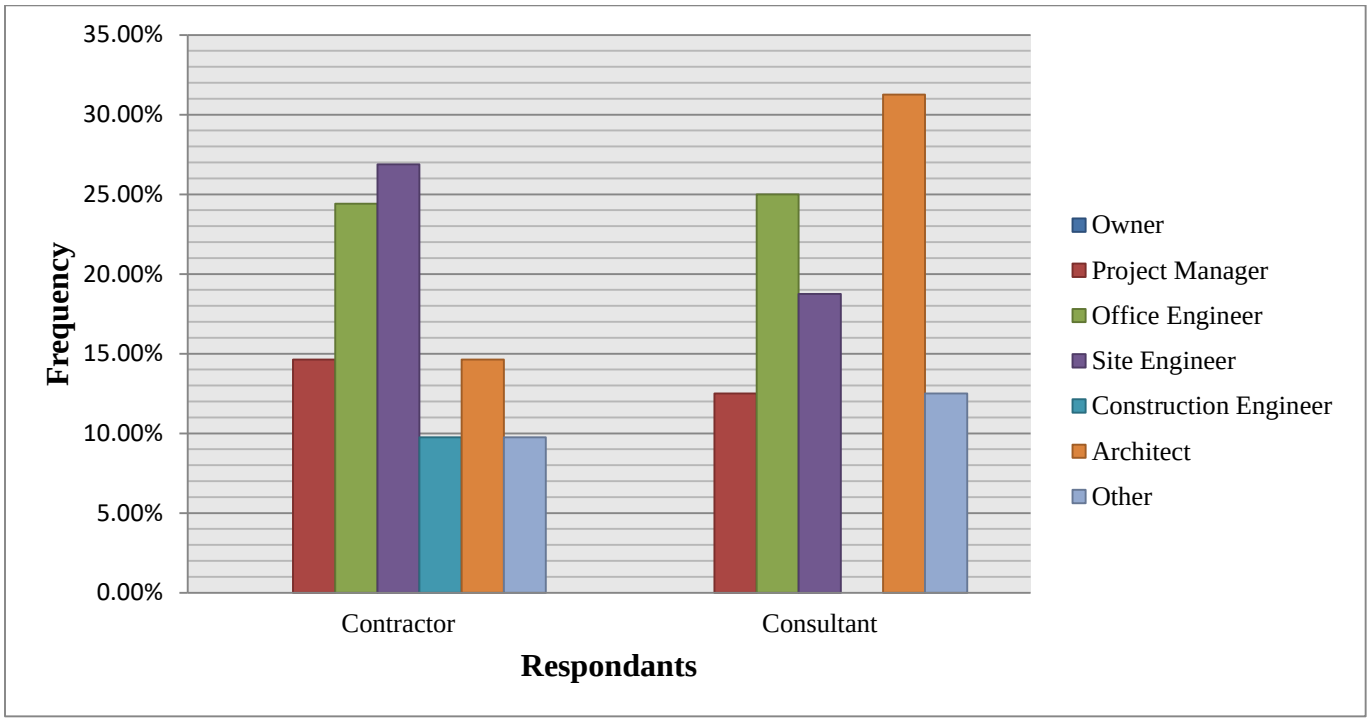

Figure 4.1 Respondents organization position

4.2.2 Respondents experience

Table 4.3 indicates experience of the respondent in building construction site found in hosanna town. The maximum percent of experience by contractor side is 6-10 years (43.9%) and by consultant side also 0-5 years (50%). The experience of the respondents from 0-5 years by contractor side is 31.7%. On behalf of consultant side 6-10 years of experience are 31.25% by percent. Besides, the contractor side year of experience to 10& above (24.4%) and the consultant sides 10& above years of experience are (18.75%). which indicates that the respondents have an appropriate year of experience to understand the research questions and give right answer by using their work experience.

Table 4.3 Respondent's year of experience

Year of experience	Contractor		Consultant	
	Frequency	percentage	frequency	percentage
0-5 years	13	31.7%	8	50%
6-10 years	18	43.9%	5	31.25%
10 & above years	10	24.4%	3	18.75%
Total	41	100%	16	100%

From above table 4.3 experiences of contractors in the construction industry most of contactors is 6-10 years and from consulting side 50% of consultants has 0-5 year of experience. This shows that there is proportional limitation of both parties. The experience of construction parties is very necessary for valuable data and versatile construction practice of formwork.

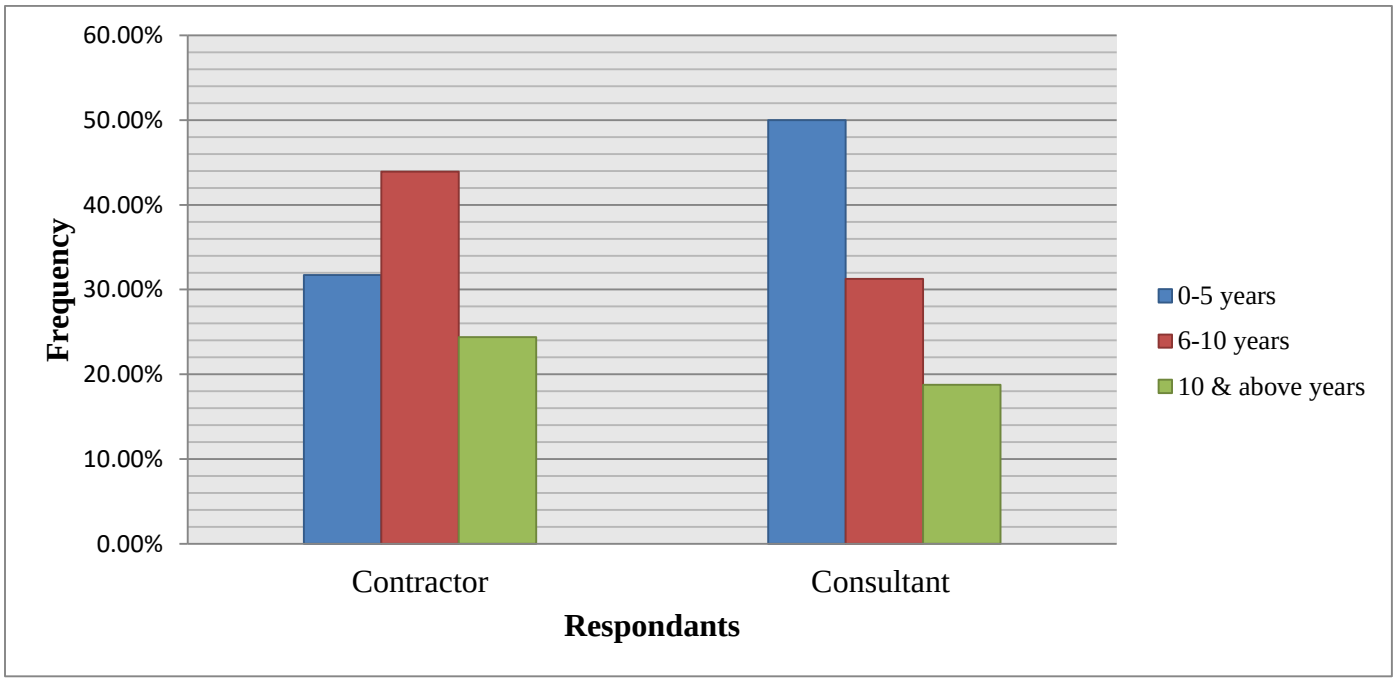

Figure 4.2 Respondents Experience

4.2.3 Grade of contractor

The following table 4.4 shows the grade of contractors. From which maximum no. of grade of contractors are BC1 of 29.3% and the minimum no. of grade of contractors is 12.2% which is GC1.Which shows the capacity of the contractors in hosanna town is very limited in terms of using modern form work system. From consulting office year of experience GC4 is the highest percentage (31.25%), the second grade of consulting office is GC1 (head office is located in Addis Ababa) with percentage of 18.75%. the Third consulting office are GC2&GC3 with percentage of 6.25%.

Table 4.4 Grade of contractors

Grade of contractor	**Contractor**		**Consultant**	
	Frequency	**Rate**	Frequency	Rate
GC1	5	12.2%	3	18.75%
GC2	8	19.5%	1	6.25%
GC3	6	14.6%	1	6.25%
GC4	10	24.4%	5	31.25%
BC1	12	29.3%	0	0
Total	41	100%	16	100%

By researcher perception, Grade of contractors and consultants has high influence in current application of formwork. The main reason for selection of grade 1 to grade 4 contractors is that they have financial capacity and update the way of construction as compared to lower level contractors. And also for consulting side from grade 1 to grade 4 is due to most of consultants for higher grade will consult vast construction project, which uses to asses different formwork system and formwork materials.

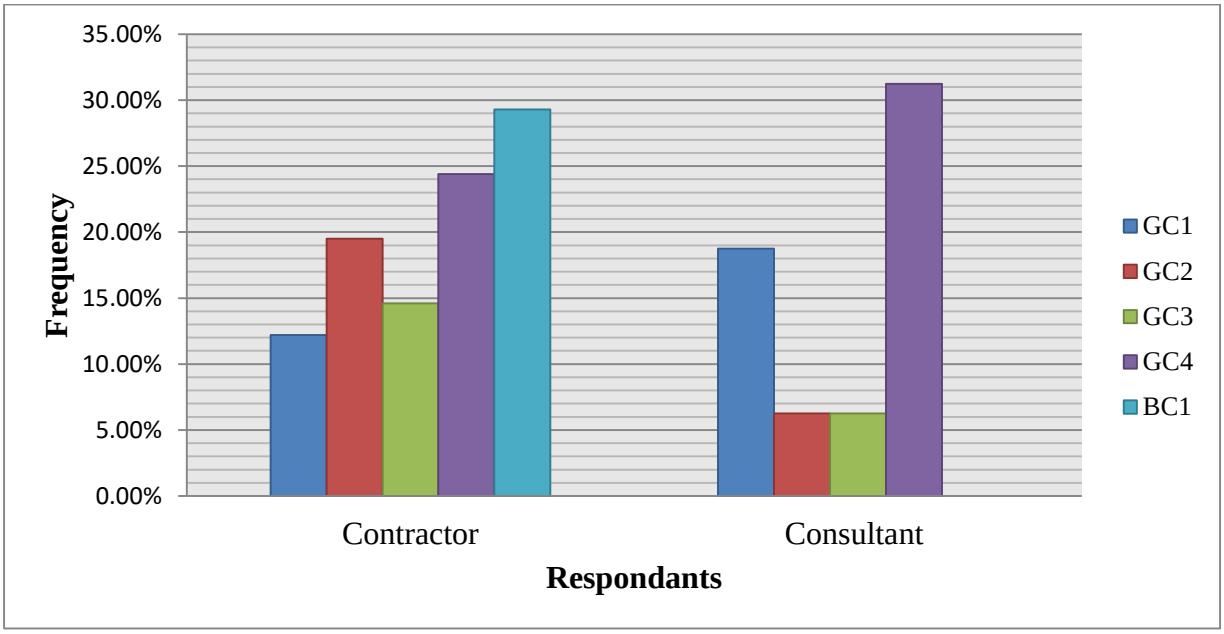

Figure 4.3 Grade of contractors & consultants

4.3 Formwork types and Materials

From literature review described above in section 2.6 there are three major types of form work system and this classification is based on material used, quality, availability re usability, accessibility, safety, easy of handling and other factors. And this types namely, Conventional formwork system this is the oldest type of formwork used in the construction industry. This type uses timber, plywood in the construction. This type is very much suitable for small houses with two to three stories and still they are in use for such constructions. modern conventional, which is differ from conventional but uses steel for supporting members(Christy) and sheeting, plywood and different jacks; and The modern formwork systems are designed for speedy and efficient construction. They are designed to provide increased accuracy and minimize waste in construction and most have enhanced health and safety features built-in. The name modern formwork itself clears that the approach is systematic. Speed in construction activities will lead to faster completion of project .This will save the time and ultimately money involved in it.

From the collected data types of form work used in hosanna 65% of the respondents use conventional formwork system, 35% of the use modern conventional formwork system.

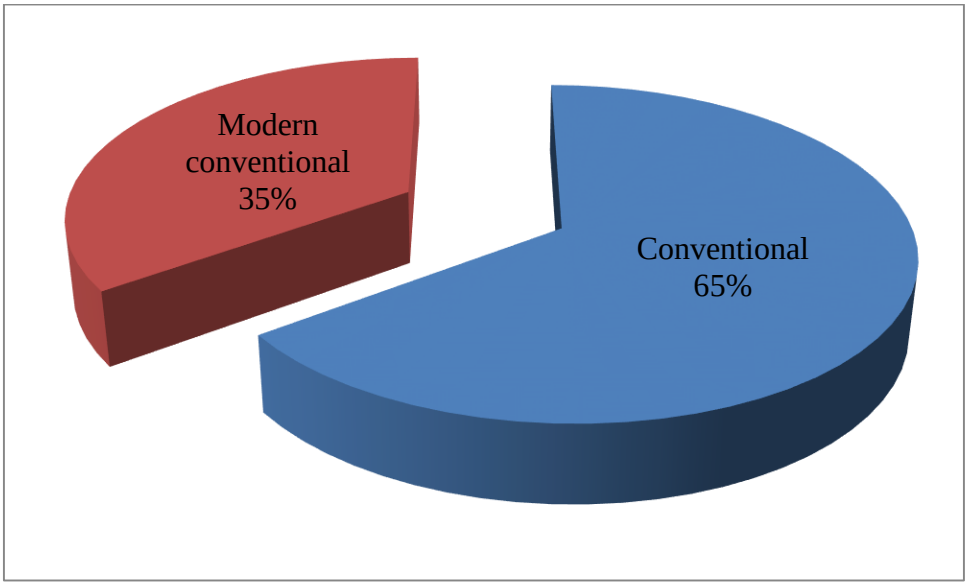

Figure 4.4 formwork systems used in hosanna

As shown above results modern form work system is not practiced accordingly due to the high initial cost, lack of awareness about modern formwork system , contractor selection criteria is mostly depend on least bidder which limits the contractors to use modern formwork system.

From an open ended question asked which formwork types create discoloration of the finish. 100% of the respondents say that conventional formwork system creates discoloration finish described above the type of formwork system for successful completion of the project in best quality, within budgeted cost and specified time modern formwork system very necessary to practice.

From an open ended question asked "Which type of formwork system maintains more dimensional accuracy in the time of placing concrete mix". From the respondents 73% of the respondents say that modern formwork system creates more dimensional accuracy, the remaining 27% say modern conventional creates more dimensional accuracy.

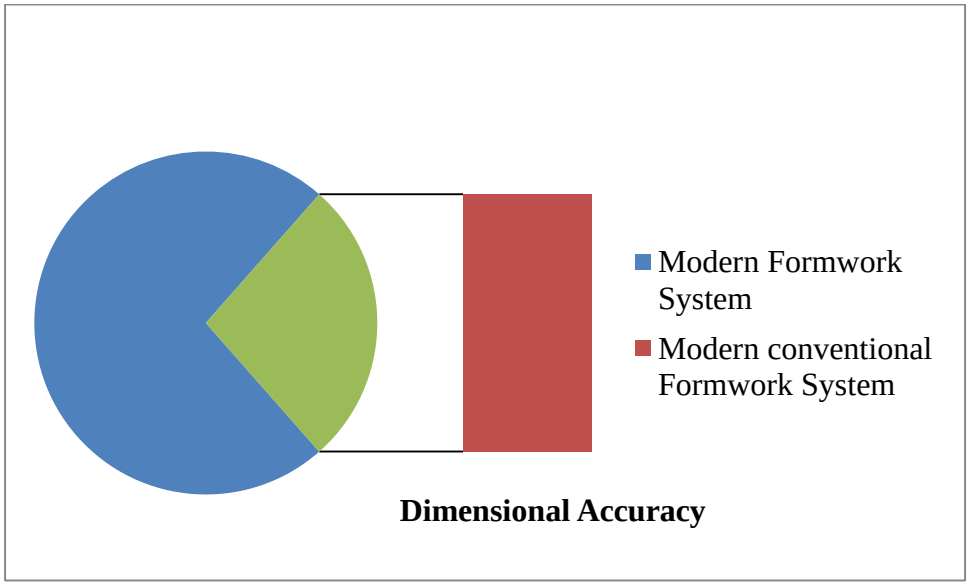

Figure 4.5 dimensional accuracy

4.3.1 Form Work Materials

The selection of materials suitable for formwork should be based on the price, safety during construction, and the quality required in the finished product, labor requirement, erection and striping method labor productivity and other factors. Approval of formwork Materials by the engineer/architect, if required by the contract documents, should be based on how the quality of materials affects the quality of finished work. Where the concrete surface appearance is critical, the engineer/architect should gives special notice and makes provision for preconstruction.

As indicated by figure below the overview made in Hosanna which type of formwork material they use in construction projects .55% of the respondents use ply wood as formwork materials. About 21% of the respondents use steel panel, 14% utilize timber, 10% use Laminated plywood as formwork material. The synopsis of the outcomes is displayed in the accompanying outline.

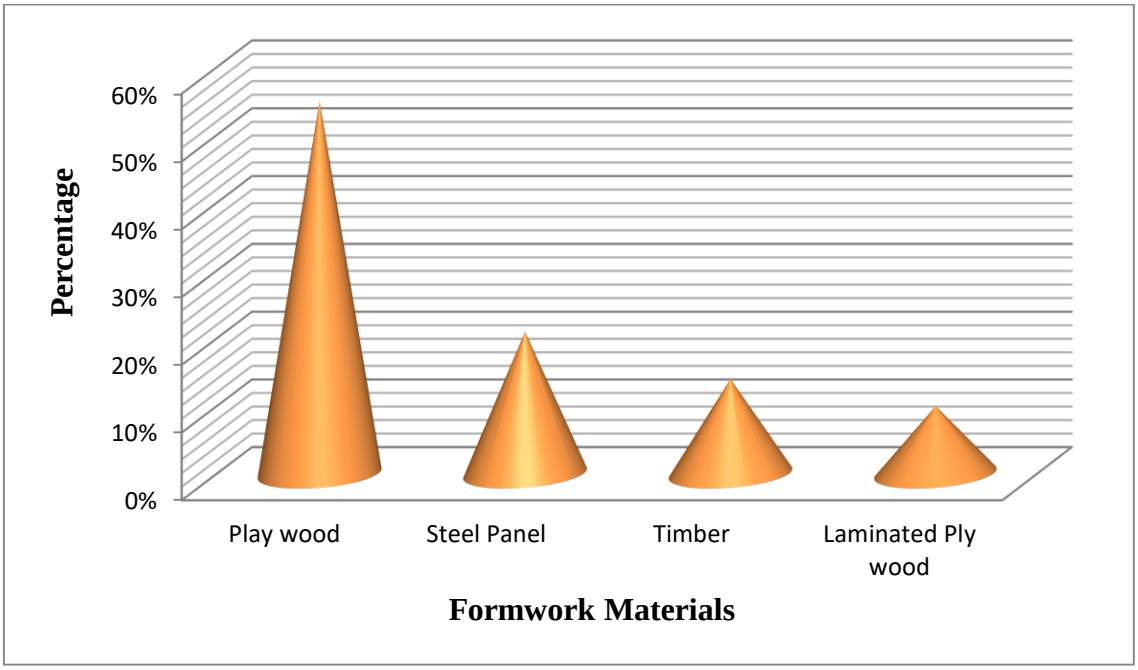

Figure 4.6 Formwork Materials

Other formwork materials like fabric, aluminum, and plastic, yellow panel and green reinforced plastic glass built up plastic also; texture is not practiced in the construction industry of Hosanna. Even though all contactors utilize both ply wood and steel panel due to easy availability in the market.

In spite of its high pace of utilization, the nature of the steel boards utilized by nearby project workers isn't acceptable. The panels are not kept up with well and the substantial surfaces projected utilizing such formworks are not good. From the overview made, steel boards are utilized various occasions without really focusing on its upkeep and cleaning. No substantial delivery specialists are utilized during cleaning of steel boards. The greater part of the workers for hire cleans the boards after the substantial was set on them. Cleaning strategy is finished by including water set cement and utilizing sharp metals to discharge it. Such cleaning method influences the nature of boards and consequently nature of substantial surfaces. Ill-advised capacity of steel boards has additionally brought about twisting and rusting of the components.

4.3.2 Formwork Material for Structural Element

.use of formwork material depends on the location of structural elements. The main structural elements of building are footing pad, foundation column, ground & suspended beam, column, slab & stair case and shear wall. Formwork materials for structural element are very necessary to study in order to select suitable formwork material, which can reduce cost of the project and improved quality.

4.3.2.1 Formwork for Footing Pad

The initial step for any concrete construction starts with the construction of foundation. Foundation can be for columns or walls. So, based on type of structural member, the shape and size of footing are designed. Thus formwork size and shape depends on the type and dimension of the footing.

Formwork for continuous or isolated footing is usually made of wood boards (planks) or plywood supported by vertical stakes driven into the ground. The top of the vertical stake is supported by a diagonal brace driven into the ground. Bracing may be re-placed by the piling up of dirt to support the sides of the form.

Form collected data of formwork materials used for structural elements 62% of respondents use plywood material for footing pad and the remaining 38% of respondents use timber material for footing pad. The above data shows that it is very difficult and unproductive to use other materials for footing pad such as steel because of rigidity and hard to reshape. The following figure shows the materials used for footing pad.

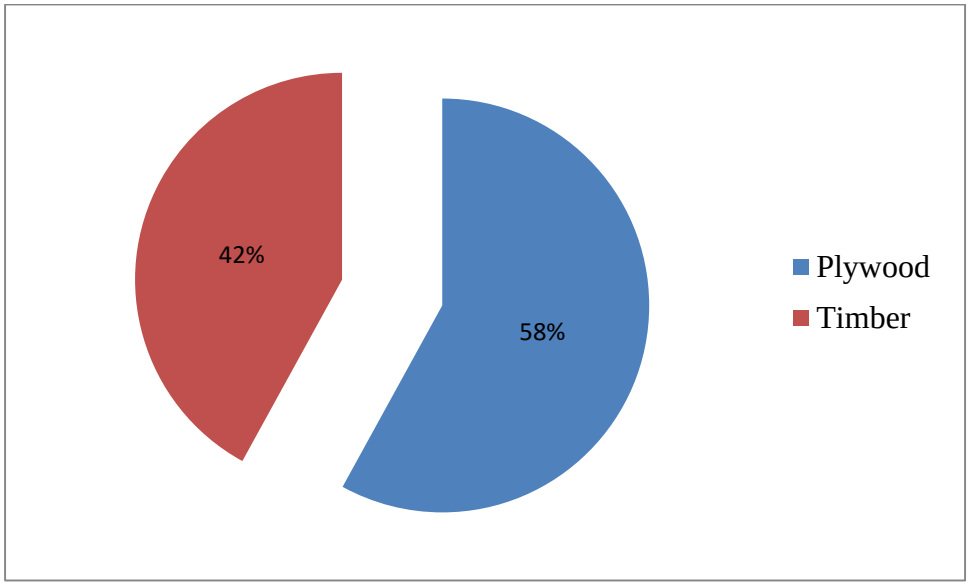

Figure 4.7 Materials for footing pad

4.3.2.2 Formwork for Ground & Suspended Beam

This is basically a three sided box supported and propped in the correct position and to the desired level. The beam formwork sides have to retain the wet concrete in the required shape and be able to withstand the initial hydrostatic pressure of the wet concrete, whereas the formwork soffit apart from retaining the concrete has Whereas the formwork soffit apart from retaining the concrete has to support the initial load of the wet concrete and finally the set concrete until it has gained sufficient strength to be self supporting.

It is essential that all joints in the formwork are constructed to prevent the escape of grout which could result in honeycombing and/or feather edging in the cast beam.

The design of the shuttering should allow the slab and beam side forms to be removed while the beam soffit remains supported

Formwork for beams consists of a bottom and two sides (open through section) in addition to their supporting elements. The bottom is typically made of ply wood or timber sheathing. The bottom is supported by and fastened to horizontal joists. Beam sides are also made of plywood or timber sheathing. Timber items are the most broadly utilized materials for concrete construction

applications as shaping material for the beam structural elements. As indicated by respondents and perceptions made for this examination, plywood is the most broadly utilized shaping material for beam by building contractors. Supporting and propping materials are combination of steel furthermore, eucalyptuses just as upward individuals in the majority of the structure construction projects.

However some contractors use steel for side sheeting material for beam formwork, because of number of reusability of steel formwork has more life span than plywood and timber materials.

As shown from figure 25 below. From the data collected 59% of respondents use plywood as a formwork material for beam structural element. Because of fine surface finish and minimum surface defects of structure.17% of respondents use laminated plywood board(wood particle board), 14% use timber material because of low initial cost from other formwork materials. The remaining 10% use steel for both side way of the beam structure. Due to no of repetition of steel is more than that of other formwork materials.

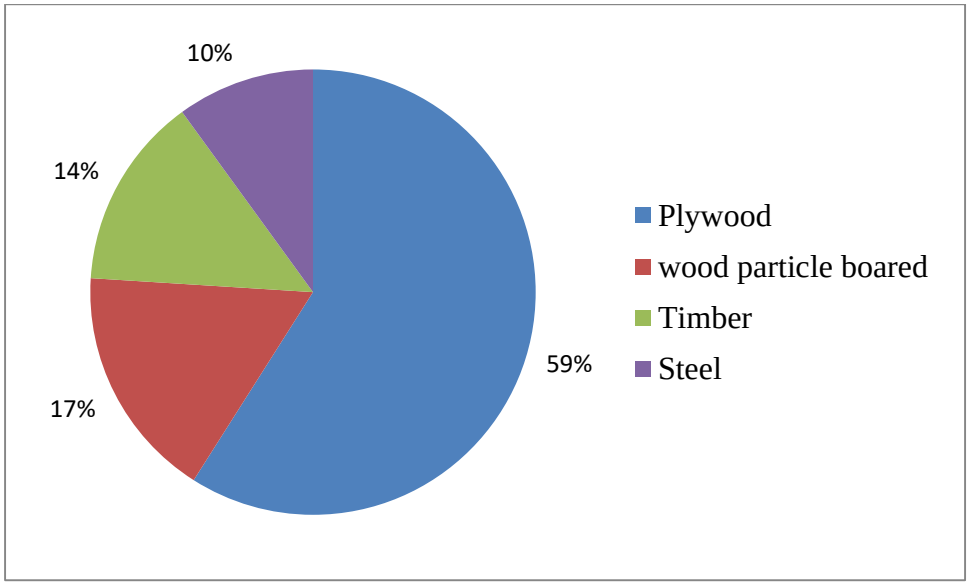

Figure 4.8 Formwork materials for beam

4.3.2.3 Formwork for column

Most commonly in Ethiopia specifically in hosanna town, plywood is used for column formwork as it is readily available for a reasonable cost. However, depending on the type of construction,

other materials are also being used as concrete column formwork. For example, steel is commonly used as system formwork because it can be used repetitively. Although in the construction of high rise buildings, the use of prefabricated formwork will save the time and cost of the construction by different means.

Further, the selection of the materials for formwork will depend on the dimensions of the columns. Due to the increase of the column dimensions, it eventually increases the heat of hydration. In addition, dimensions of the columns are larger when the axial load is higher. In such cases, a higher grade of concrete will also be used. As a measure to reduce the heat gradient and to reduce the heat loss, formwork materials having less thermal conductivity are used.

Due to the dimensional versatility of different site for circular columns steel formwork are used to cast concrete for column. But as information I gained from one of grade 1 contractor want modern Column formwork system has gained in popularity due to the shortage of labor in recent times. Different formwork systems for different column sizes can be easily assembled on site. Their entire working process is also simple. Once the concrete is poured and hardened, the formwork is then stripped and moved to the next position.

As shown from figure 4.6 below. From the data collected 55% of respondents use plywood as a formwork material for column structural element.21% of respondents use steel panel for column formwork construction, 14% use timber material because of low initial cost from other formwork materials. The remaining 10% use laminated plywood board (wood particle board).

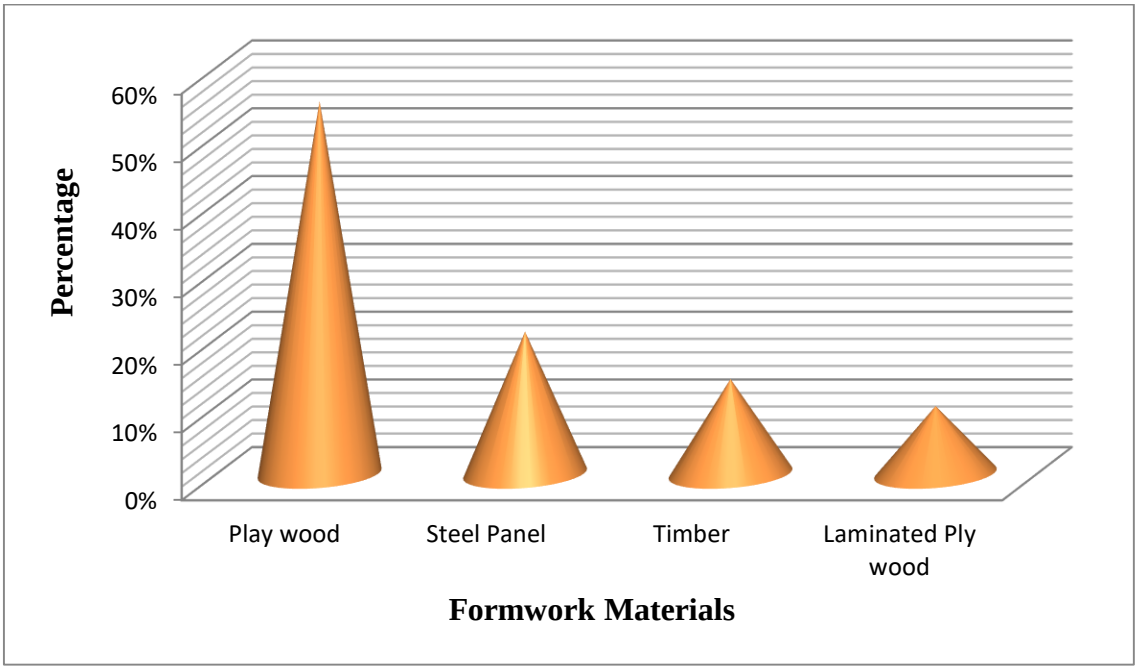

Figure 4.9 Formwork materials for column

4.3.2.4 Formwork material for shear wall

This type of form work consists of timber sheeting supported by vertical studs or posts and horizontal struts or walls.

Vertical formwork systems are those used to form the vertical supporting elements of the structure (i.e. columns, shear walls).Typical vertical formwork systems utilized in construction include modern conventional formwork system.

From collected data gathered 100% of respondents use plywood as a formwork material. The main reason behind that is plywood gives smooth surface, the dimension of plywood from the production is 1220×2440 which can cover large area in short time and for other formwork materials it is not easily accessible, takes time for construction.

4.3.2.5 Formwork for Slab & Stair

There are various types of formwork used depending on the formwork material and the type of structural element being built. For example, slab formwork is used to build concrete slabs.

When suspended concrete slabs are constructed that are not directly supported by the ground, slab formwork is required. Slab formwork includes formwork panels, stringers, joists, shores, and other supporting materials that enable the concrete to be poured and set above the ground. There are a variety of materials used in slab formwork, including plywood, timber, metal, aluminum, and sometimes even plastic components that are used to shape and give strength to the concrete.

Slab formwork essentially supports the weight of the concrete during the curing process and when the concrete slab is positioned on permanent supports. Bases (also known as sills) are required that are made from wood or metal and these bases support the vertical stringers which in turn support the horizontal joists. The horizontal joists create a flat surface where timber, plywood, steel sheets, aluminum or fiberglass can be used as a base onto which the concrete is poured.

In most cases, formwork can be re-used and the method of removing the formwork once the concrete has been set is known as stripping. After the formwork has been stripped, it must be cleaned to ensure the faces of the panels remain straight and there is no built-up of concrete. Reusable forms are known as ‘panel forms’ while non-usable forms are known as ‘stationary forms’.

Formwork to suspended slabs is similar to that for beams, except that the soffit shuttering is far wider.

From collected data 65% used plywood material for slab (conventional formwork system) the remaining 35% use plywood but modern conventional formwork system. Most commonly due to lack of technology most of the contractors use local material for slab and stair case. But this practice will appreciate deforestation of plantation. In order to decrease deforestation modern conventional formwork system should be practiced

4.4 Factors influencing Selection of Different Formwork system

Selection of a formwork for a high rise building mainly depends on individual’s experience or by the senior members of an organization and the availability of the formwork system. The owner of an organization aims to reduce the overall cost of the project with specified quality and safety. Since, formwork is a costly item in construction industry must be involved in formwork selection

system process. Consulting firm should design the building in such a way that it should have more number of similar size structures so that formwork can be used repeatedly which will reduce the quality problems and increase the productivity.

Selection of formwork material to be used should be based on maximum economy to the contractor consistent with safety and quality required in the finished work. Proper selection of formwork has greater influence:

- On reducing materials and labor cost,
- Improving the quality of the produced concrete and Improving the quality of the produced concrete and
- Saving time leading to smooth running of the projects.

Table 4.5 Factors influencing selection of formwork system

SN.	**Factors influencing selection of formwork system**	**Contractor**		**Consultant**	
		RII	**Rank**	**RII**	**Rank**
	1. General Aspect				
1	Quality	**0.99**	**1**	**0.93**	**3**
2	Availability	**0.92**	**2**	**0.86**	**4**
3	Adaptability	**0.89**	**3**	**0.84**	**5**
4	Safety	**0.86**	**4**	**0.95**	**2**
5	Duration of the project	**0.84**	**5**	**0.96**	**1**
	2. Formwork Aspect				
1	Life Span	**0.98**	**1**	**0.97**	1
2	Load Caring Capacity	**0.92**	**2**	**0.93**	**2**
3	Type of Formwork	**0.84**	**3**	**0.87**	**3**
4	Weight of formwork	**0.76**	**4**	**0.79**	**4**

5	Construction Cycle time	**0.74**	**5**	**0.68**	**5**
	3. Structural Aspect				
1	Accessible to work	**0.98**	**1**	**0.93**	**2**
2	Type of structure	**0.93**	**2**	**0.99**	**1**
3	Building dimension	**0.85**	**3**	**0.84**	**3**
	4. Cost Aspect				
1	Capital Cost	**0.97**	**1**	**0.94**	**1**
2	Maintenance cost	**0.95**	**2**	**0.77**	**2**
3	Labour cost	**0.62**	**3**	**0.66**	**3**
4	Transportation cost	**0.54**	**4**	**0.53**	**4**
	5. Environmental Aspect				
1	Exposer to Environment	**0.85**	**1**	**0.88**	**1**
2	Climate Condition	**0.75**	**2**	**0.66**	**2**
3	Site condition	**0.67**	**3**	**0.61**	**3**
4	Storage of formwork	**0.55**	**4**	**0.51**	**4**

There are many factors which influence selection of different formwork system but it will be more specific to classify this based on their aspect.so there are five aspects and A total of 21 factors identified from literature studies were distributed to companies to prioritize the influence level. Evaluation of the given factors using or relevant importance index (RII), as per respondents indicated that ranked top indicated in Table 4.5. Considerations are given to each of the factors not in the same way during formwork selection in different companies.

4.4.1 Selection Based on General Aspects

Table 4.5 shows the attributes which relates to the factors based on relative importance index. From the general aspect under five most important attributes the first attribute that afforded to the formwork selection is quality of formwork system (RII=0.99) is found to achieve superior surface finish of any concrete. The second attribute that comes in formwork selections is Availability (with the factor loading =0.92) has to be checked and purchased or rented in prior. The third factor for selection is Adaptability (RII = 0.89) has to be checked while purchasing the formwork. Safety (RII=0.86) which provide proper access and working platform arrangements to ensure workmen safety and duration of project (RII= 0.84) has to be kept in mind and formwork has to be maintained and stored in care are the remaining three attributes which has the ability to learn from experience, provides an effective solution in construction and completion of project on time.

From Consulting Side respond from the general aspect under five most important attributes the first attribute that afforded to the formwork selection is Duration of the project of formwork system (RII=0.96). The second attribute that comes in formwork selections is safety (with the factor loading =0.95). The third factor for selection is quality of surface finish (RII = 0.93) the fourth and the fifth factors are adaptability and availability

But from this result of contractor side safety issue of the workmanship hasn't gain much emphasis in building construction projects on hosanna town, due to lack of supervision of city administration construction office, lack of awareness and lack of experience sharing with international contractors.

The following figure shows the RII of factors influencing selection of formwork system according to general aspect from contractor side.

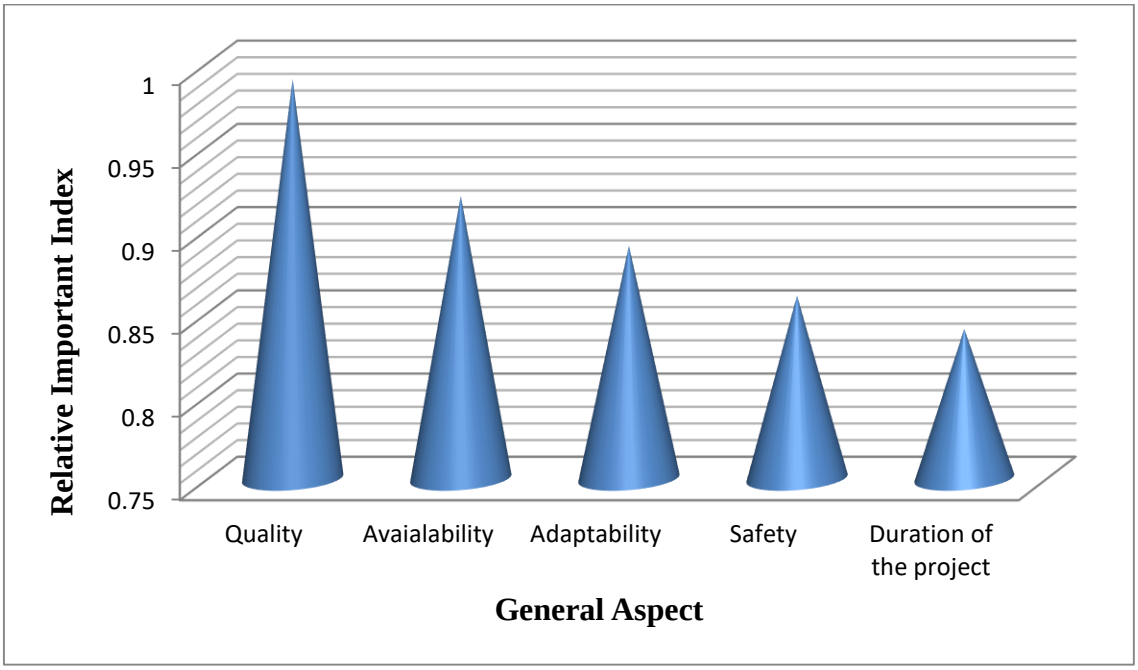

Figure 4.10 Selection based on general aspect

4.4.2 Selection based on Formwork Aspect

From table 4.5 in formwork aspect contractor responded Lifespan of formwork (RII=0.98) which is treated as an important factor results in the reuse of the formwork effectively, which reduces the cost of the project. The load carrying capacity (RII =0.92) which help labor to work in the heights and to lift the materials required for construction from the ground level to the higher levels. Followed to that the third attribute, is type of formwork (=0.84) which is categorized as vertical formwork and horizontal formwork results in the construction of wall, column, beam and slab. The fourth attribute that leads to formwork selection is weight of formwork (RII =0.76), which influences the shuttering and de-shuttering process. The last factor for influencing selection of formwork system is Construction cycle time (RII =0.74), represents the formwork that can be reused number of times effectively with proper maintenance.

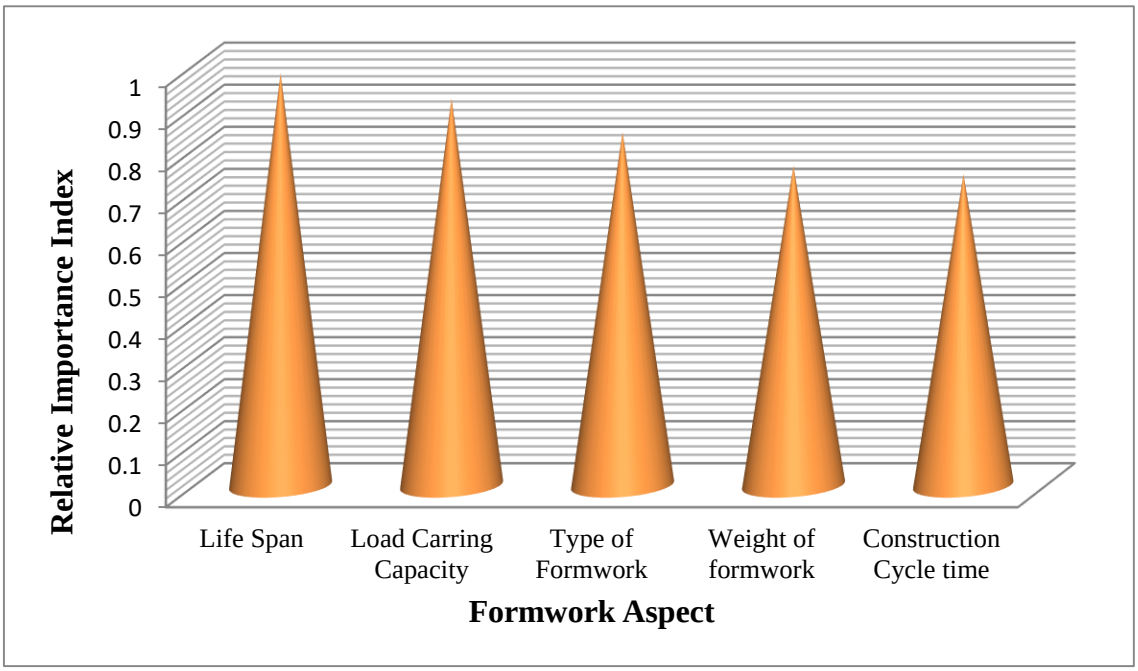

Figure 4.11 Selection based on formwork aspect

Also Consulting firm responded formwork aspect Lifespan of formwork (RII=0.97) which is treated as an important factor results in the reuse of the formwork effectively, which reduces the cost of the project. The load carrying capacity (RII =0.93) which help labor to work in the heights and to lift the materials required for construction from the ground level to the higher levels. Followed to that the third attribute, is type of formwork (=0.87) which is categorized as vertical formwork and horizontal formwork results in the construction of wall, column, beam and slab. The fourth attribute that leads to formwork selection is weight of formwork (RII =0.79), which influences the shuttering and de-shuttering process. The last factor for influencing selection of formwork system is Construction cycle time (RII =0.68), represents the formwork that can be reused number of times effectively with proper maintenance.

4.4.3 Selection Based on Structural Aspect

The most three important aspects are identified. From which accessibility to work (RII=0.98) explained the expediency for the working environment. The second attribute that is the type of structure (RII=0.93) which relates with member constructed separately or the members put together or in the other word structural members are assembled together. Next to that the third attribute that influencing factor to formwork selection is building dimension (RII =0.85) states that varying in size and shape results in the requirement of different type of formwork system.

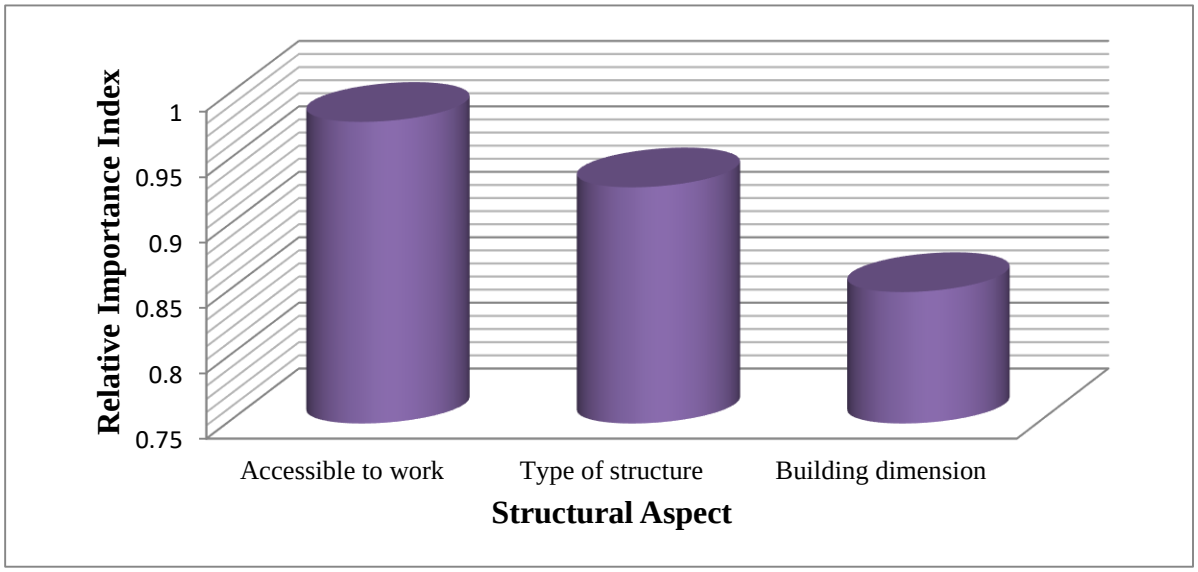

Figure 4.12 Selection Based on Structural aspect

The consulting firm responded The most three important aspects are identified. From which The first attribute that is the type of structure (RII=0.99) which relates with member constructed separately or the members put together or in the other word structural members are assembled together. The second is accessibility to work (RII=0.93) explained the expediency for the working environment. Next to that the third attribute that influencing factor to formwork selection is building dimension (RII =0.84) states that varying in size and shape results in the requirement of different type of formwork system

4.4.4 Selection Based on Cost Aspect

The major factor as contractors responded is cost aspect is very necessary because most of the construction projects relay on cost of formwork system due to the financial capacity of the project is very necessary and is controls the contractor and the construction industry. From cost aspect category the first influence that affects the formwork selection is capital cost (RII =0.97) which is the total cost or the one-time expenses of the project, any issues may lead to the significant changes in the project cost. Followed to that second attribute of formwork is maintenance cost (with the factor loading =0.95) includes types of repair and storage of formwork influence the maintenance cost which results in the increase in cost of the project. Labor cost (RII =0.62) is the attributes in which work like erecting, removing and cleaning results in the efficient completion of project within the proposed budget. Finally, the last influential factor that affords to formwork selection is transportation cost (RII=0.54), Where the formwork is to be transported from the manufacturing unit to the work site and return back to the storage yard once the project is completed.

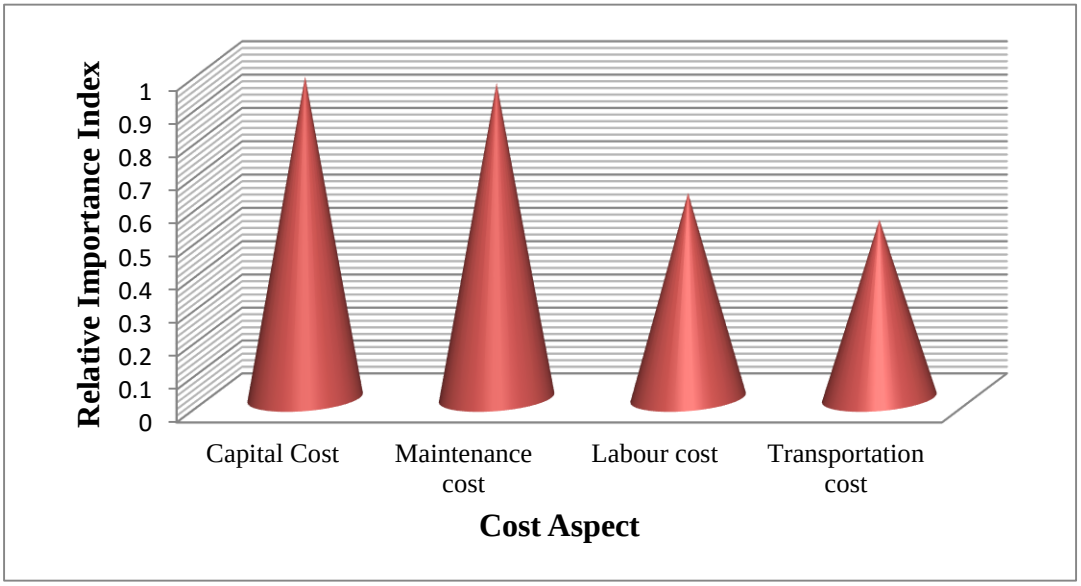

Figure 4.13 Selection Based on Cost aspect

The major factor from consulting side cost aspect is very necessary because most of the construction projects relay on cost of formwork system due to the financial capacity of the project is very necessary and is controls the contractor and the construction industry. From cost aspect

category the first influence that affects the formwork selection is capital cost (RII =0.94) which is the total cost or the one-time expenses of the project, any issues may lead to the significant changes in the project cost. Followed to that second attribute of formwork is maintenance cost (with the factor loading =0.77) includes types of repair and storage of formwork influence the maintenance cost which results in the increase in cost of the project. Labor cost (RII =0.66) is the attributes in which work like erecting, removing and cleaning results in the efficient completion of project within the proposed budget. Finally, the last influential factor that affords to formwork selection is transportation cost (RII=0.53).

4.4.5 Selection Based on Environmental Aspect

From contractor side different formwork system has different property to external environment. Some they are to retain its position, to resist wear and tear, absorption capacity of moisture. Exposure to environment (RII=0.85), indicates if the formwork is subjected to repeated exposure results in the variation of size and leads to replacement of formwork. The second influence is site condition (RII=0.75), it relates with the accessibility to construction site. Climatic condition is the third influence (RII=0.67), which formwork is highly sensitive to weather conditions that leads to the increase in the cost and time duration of project. The last attribute that affects the formwork selection is storage of formwork, about handling and storing properly (RII =0.55), improper storage of formwork to the damage in the formwork materials and requires replacement of the formwork and further leads to cost overrun.

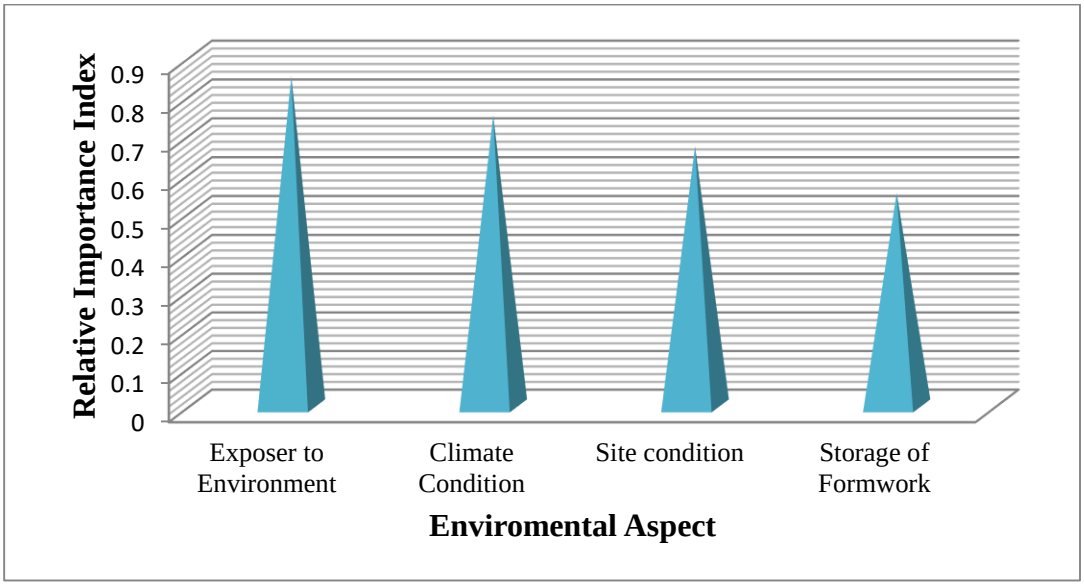

Figure 4.14 Selection based on environmental aspect

From Consulting side different formwork system has different property to external environment. Some they are to retain its position, to resist wear and tear, absorption capacity of moisture. Exposure to environment (RII=0.88), indicates if the formwork is subjected to repeated exposure results in the variation of size and leads to replacement of formwork. The second influence is site condition (RII=0.66), it relates with the accessibility to construction site. Climatic condition is the third influence (RII=0.61), which formwork is highly sensitive to weather conditions that leads to the increase in the cost and time duration of project. The last attribute that affects the formwork selection is storage of formwork, about handling and storing properly (RII =0.51), improper storage of formwork to the damage in the formwork materials and requires replacement of the formwork and further leads to cost overrun.

To summarize from contractor side as indicated in the above table 4.5 the most influential factors from different aspects quality is the first influential factor, secondly both life span and accessibility are influential factors, the third influential factor is capital cost of the project and the last influential factor is exposure to environment. The following figure shows the most 10 attribute factors for selection of formwork system as described above.

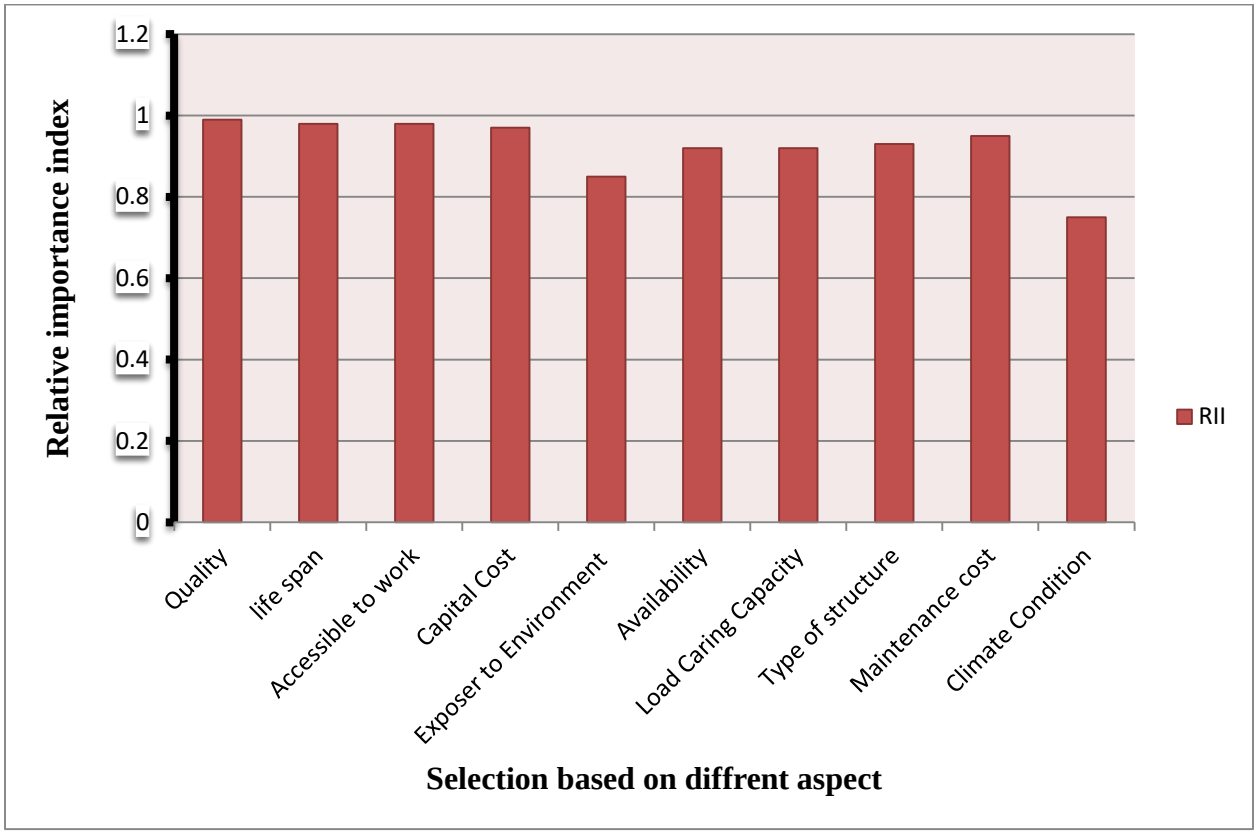

Figure 4.15 Selection based on different aspect

To summarize from consulting side as indicated in the above table 4.5 the most influential factors from different aspects type of structure is the first influential factor, secondly both life span is influential factors, the third influential factor is duration of the project, the fourth factor is capital cost the last influential factor is exposure to environment. The following figure shows the most 5 attribute factors for selection of formwork system as described above.

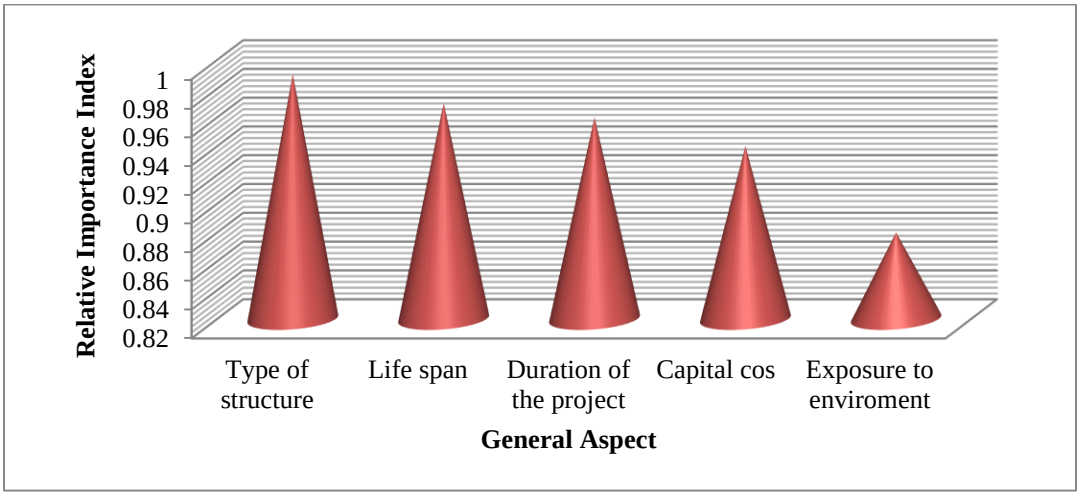

Figure 4.16 General aspect form consulting response

4.5 Effects of Using Conventional Formwork System

From literature review and observation of sites, there are some effects of using conventional form work system by using level of effect RII is calculated. The following table shows the Rll of the Ranges of effects of using conventional formwork system.

Table 4.6 The effects of using current formwork practice (conventional formwork system)

No.	Effects of using conventional formwork system	**Contractor**		**Consultant**	
		RII	**Rank**	**RII**	**Rank**
1	High Labour Intensive System	0.96	1	0.97	1
2	Limited No. of Reuse	0.94	2	0.93	2
3	High Waste	0.91	3	0.87	5
4	Safety & Reliability problems	0.89	4	0.92	3
5	Time Consuming	0.81	5	0.88	4
6	Height Adjustment Problems	0.78	6	0.76	7
7	Limited spans	0.77	7	0.73	8
8	Tendency to swell & shrink	0.65	8	0.66	9
9	adequate supervision	0.61	9	0.79	6

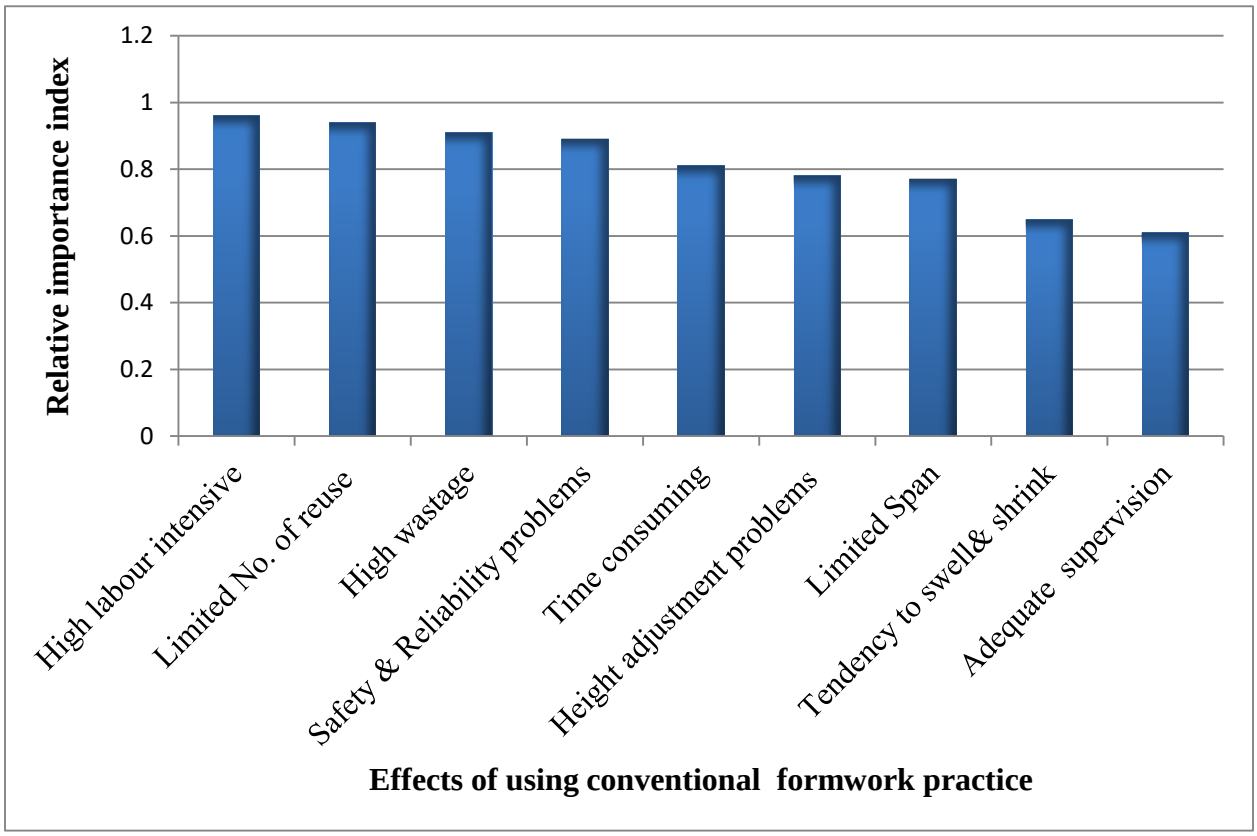

Figure 4.17 Effects of using conventional formwork practice

As shown above figure 4.17 the there are many effects of using current formwork practice. From contractors respond the most influential effects with highest RII is high labor intensive (0.97), secondly effects current formwork practice had a very limited No. of reuse (0.94), thirdly like timber & ply wood had wastage (0.91), fourthly there are safety issue related to current formwork practice (0.89) and also as compared to modern formwork system conventional formwork system is very time consuming, the least four effects of current formwork practice are shown in figure.

As shown below figure 4.18 the there are many effects of using current formwork practice. From consulting firms respond the most influential effects with highest RII is high labor intensive (0.96), secondly effects current formwork practice had a very limited No. of reuse (0.93), thirdly there are safety issue related to current formwork practice (0.92) , fourthly and also as compared to modern

formwork system conventional formwork system is very time consuming, the least five effects of current formwork practice are shown in figure.

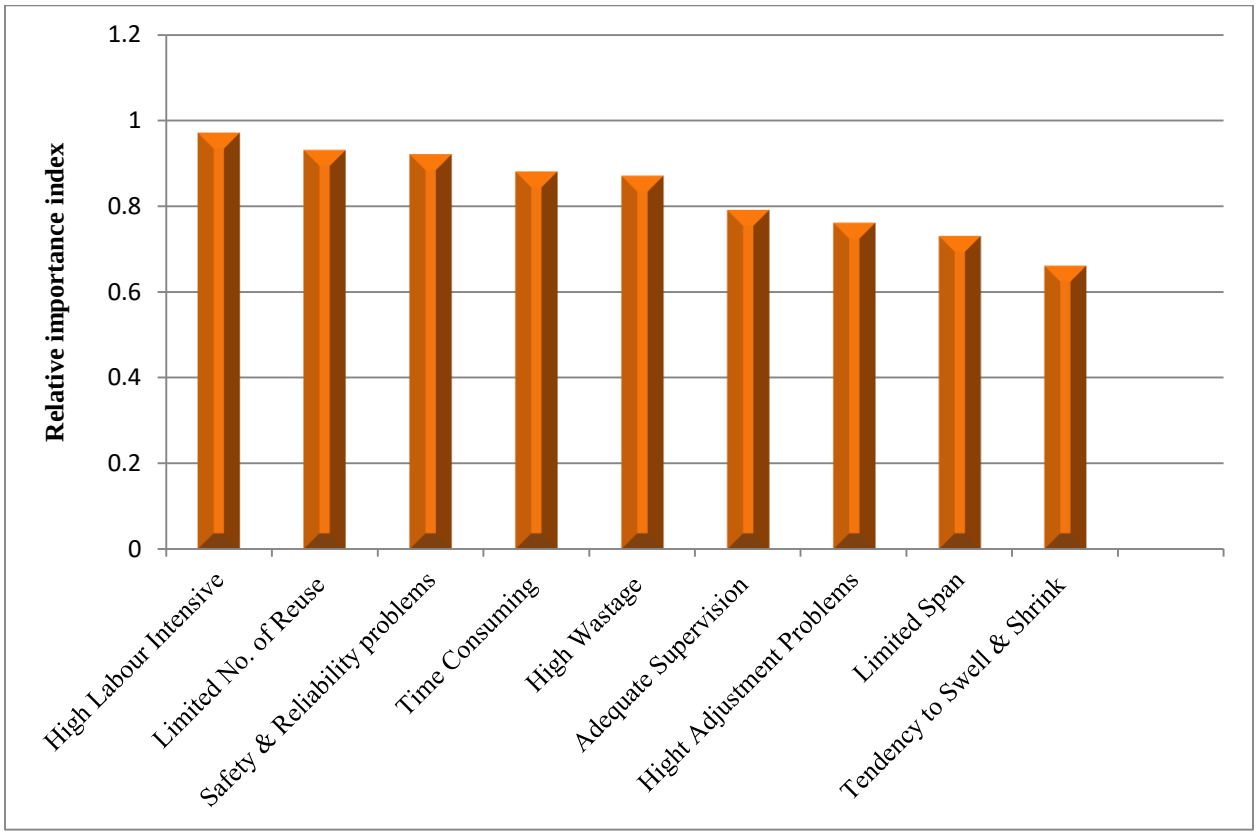

Figure 4.18 Effects of using conventional formwork practice consulting side

4.5.1 Quality Implication of Using Conventional Formwork System

The quality and surface appearance of the concrete structures is normally dedicated by the quality of formwork materials and systems. Using formwork materials with inferior quality usually leads to unsatisfactory result and defects. Failures to achieve the required results in concrete construction may cause additional treatments and elongated time frame to rectify the defects on the surface of concrete after removal of the formwork, which could lead to uneconomical activity. Not straight Vertical surfaces unmaintained formworks and uneven surface, improper terminations of Formwork, Formworks and accessories carelessly dropped upon dismantling. Honey combing, poor construction joints are some of the most common quality implication in concrete construction caused by poor form quality of conventional formwork system.

Table 4.7 Quality implication of Conventional formwork system

Quality Implication	**Consultant**		**Contractor**	
	RII	**Rank**	**RII**	**` Rank**
Not straight Vertical surfaces	**0.76**	**2**	**0.79**	**1**
Unmaintained formworks and uneven surface	**0.69**	**4**	**0.77**	**2**
Poor Construction joint	**0.78**	**1**	**0.73**	**3**
Formwork Stuck on concrete surface	**0.67**	**5**	**0.66**	**4**
Honey Combing	**0.75**	**3**	**0.61**	**5**
Improper terminations of Formwork	**0.55**	**7**	**0.53**	**6**
Formworks and accessories carelessly dropped upon dismantling	**0.58**	**6**	**0.51**	**7**

A total of 7 implications identified from literature studies were distributed to companies to prioritize the influence level. Evaluation of the given factors is made by Lickert scale, or relevant importance index (RII).

From consulting side as shown in the table 4.7 the first quality implication based on RII poor construction joint (0.78), secondly not straight vertical surface (0.76) of shear wall and column, which will increase additional cost for correcting the defect by plastering the surface, thirdly honey combing of the concrete surface, due to lack of tight joint between formwork the cement paste will be loosed which will create honey combing(0.75) , the fourth implication is un maintained formwork and un even surface (0.69) of the slab, caused by using of timber formwork for slab element, the next is formwork stuck on concrete surface (0.67) the main cause for this is improper

use of releasing agent, the last two quality implication are Improper terminations of Formwork and Formworks and accessories carelessly dropped upon dismantling.

From contractor side the first quality implication of using conventional formwork system is not straight vertical surface and secondly unmaintained formwork and un even surface of concrete surface, thirdly poor construction joint and the least implication is Formworks and accessories carelessly dropped upon dismantling. The above table 4.7 shows the RII of these implications.
The following diagram shows quality implications and their relative important index of ranked value data collected from contractors.

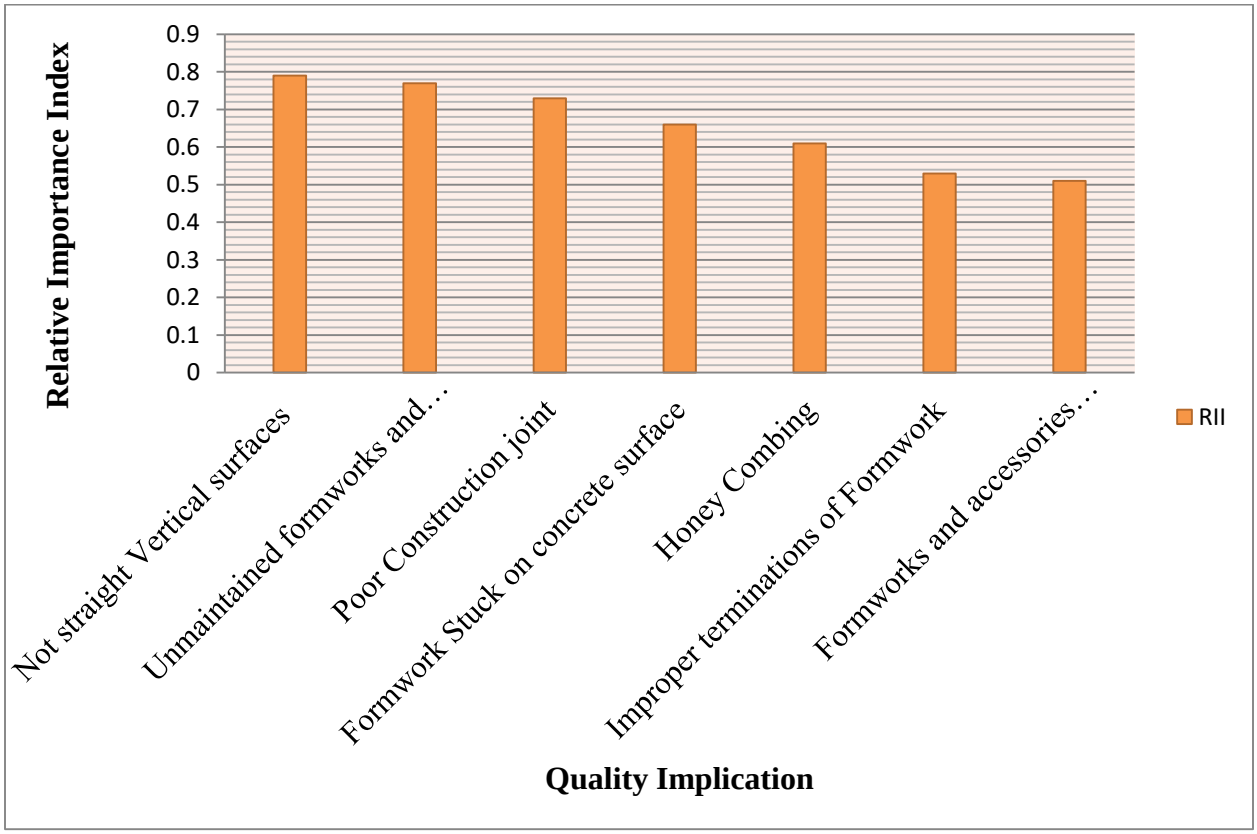

Figure 4.19 Quality Implication of Conventional Formwork System

From consulting side the first quality implication of using conventional formwork system is not straight vertical surface and secondly unmaintained formwork and un even surface of concrete surface, thirdly poor construction joint and the least implication is Formworks and accessories carelessly dropped upon dismantling. The above table 4.7 shows the RII of these implications.

The following diagram shows quality implications and their relative important index of ranked value data collected from consultants.

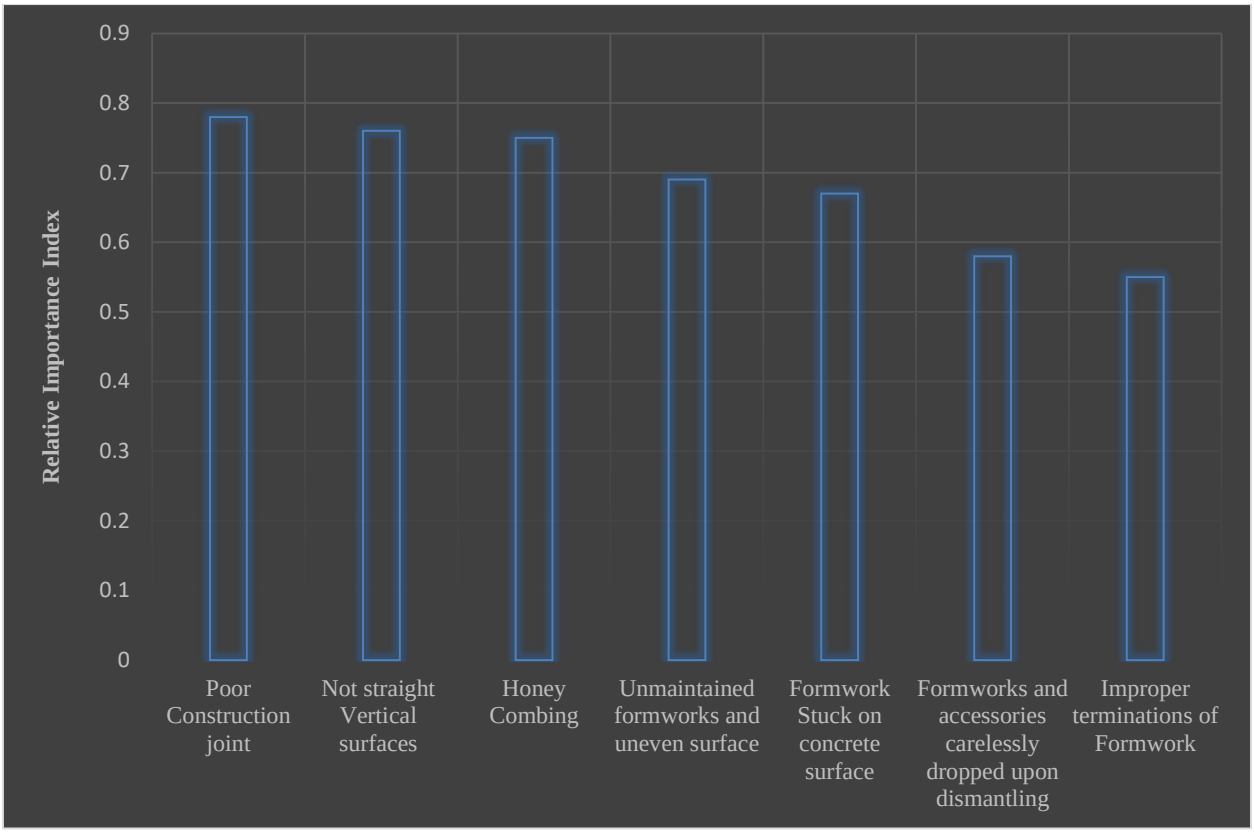

Figure 4.20 Quality Implication of Conventional Formwork System Consulting Response

The following pictures show some quality implication of conventional formwork system.

a) Honey combing

b) improper termination of formwork

c) Poor construction joint

d) formwork stuck on concrete surface

Figure 4.21 Quality problems of Conventional Formwork in Hosanna building projects

4.5.2 Formwork releasing agent and treatments

Releasing agent Facilitate the striking or removal of the formwork. Prevent the concrete adhering to the form face. Most oils will fulfill the function of a release agent, but different oils can produce blow holes or variations in the color of concrete, affect efflorescence, or retard the hardening of the surface

Formwork materials are very important factor for concrete surface quality. Form work releasing agent has a greater impact on quality of concrete finish, color and life cycle of the formwork material. Suitable releasing agent will extend the life span of formwork and its reusability, which interns contribute the advantage of good surface quality and economic advantage off the contractor.

The main purposes of releasing agent in construction are the following:

- Easy of formwork removal at the time of striping (de sheeting) of formwork members
- Extending the useful life of formwork, in order to use formwork materials repeatedly, which otherwise would get swell easily and become unfit for good quality of concrete surface specially plywood
- To help to improve the smoothness and texture of concrete surface after removal of forms
- Minimize the occurrence of blowholes minimize the loss of water from concrete caused by absorption in timber forms

The following table shows from collect data from which types of releasing agents used by your company.

Table 4.8Type of formwork releasing agent

No.	**Releasing Agent**	**Frequency**	**Percentage**
1	Burned oil	17	41.46%
2	Plastic sheet	10	24.39%
3	No releasing agent	6	14.63%
4	Diesel oil	5	12.19%
5	Mould Cream Emulsions	3	7.33%
	Total	**41**	**100%**

From the above table 4.8 shown most of the construction projects use burned oil as releasing agent (41.46%), secondly plastic sheet used as a releasing agent (24.39%).These plastic sheets. Thirdly they didn't use releasing agent which had effect led to formwork stuck in concrete surface.so in order to remove the formwork they chisel the concrete, chiseling the surface of concrete structure affect the strength and disturbs the bond between the concrete constituents and between the concrete and the reinforcement bars which in turn creates macro cracks and reduce the durability of concrete structure, which cost them additional cost for labor and plastering. The fourth releasing agent they use in construction site is diesel oil (12.19%) and the last releasing agent is mould oil (7.33%).

From observation in sites discoloration of concrete constructions observed because contractors use burned oil (burned oil is easily available in garages) and can decrease the reusability of formwork materials. The following figure shows the types of releasing agent used by construction sites

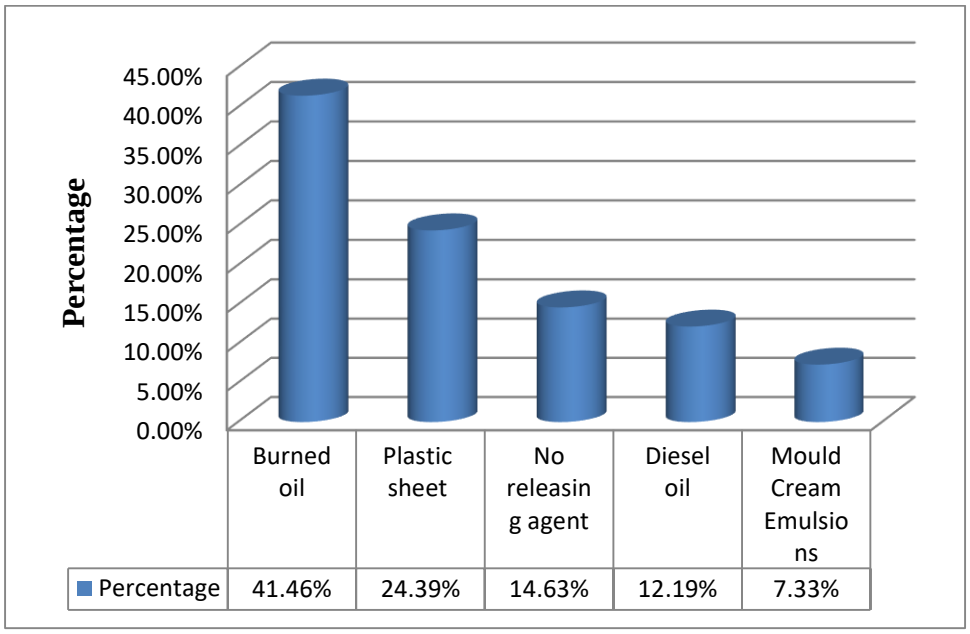

Figure4.22Type of releasing agent

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1CONCLUSION

The main objective of this research is to assess current application of formwork system utilized by selected contractors, consultants and stakeholders in the building construction projects in Hosanna town. From the analysis made the following conclusion were made:

- From the types of form work used in hosanna town building projects 65% of the respondents use conventional formwork system, 35% of the use modern conventional formwork system
- From type of formwork material, they used in construction projects in hosanna town most of the projects use plywood and the second mostly utilized formwork material is steel.
- Depending on the structural element almost most of construction site use plywood material for casting formwork
- One of the influential factors for selection of formwork system is quality of concrete finish. Secondly which contractors depend on are the life span and accessibility to work because of financial instability of contractors
- There are common effects of using current formwork practice and measured their RII. The first effect is higher lab our intensive, secondly limited No. of reuse, thirdly high wastage, the least four are safety& reliability problems, time consuming, height adjustment problems, limited span and adequate supervision.
- There are many quality problems using conventional formwork system and the top ranked are, Not straight vertical surface, most of conventional especially steel and timber formwork are uneven surface. Poor construction joint between structural elements are other implications.

5.2 RECOMMENDATION

From analyzed date in the above chapter the following recommendations are forwarded to insight what the current application of formwork construction in hosanna town needs in the future.

1. For Contractors and consultants

- Contractors should select formwork based on not only initial cost but also quality ,life span of the formwork & safety of labor
- During selection of formwork material and system both contractors and consultants should participate to enhance quality of concrete finish and time consuming.
- Consulting firm& contractors should train their workers to create awareness and understanding about new formwork system to achieve effective and efficient project.
- Wood materials for supporting and bracing of formwork should be replaced by steel props and steel support

2. Regulatory body

- Selection of current formwork practice of Hosanna town appreciates deforestation. According to global warming problems in the world, regulatory body should set laws for practicing modern conventional & modern formwork systems in order to reduce deforestation.
- Financial limit of contractors for hire has made them select formworks of low quality which influences the safety of both concrete and the works. Hence, administration of Ethiopia ought to likewise either uphold financially through long term loans, or restrict them from upgrading their levels except if they have great exhibitions on the area.
- Construction Legislature of Ethiopia ought to plan concrete completing principles and checklist. This will assist with choosing appropriate formwork materials and workmanship.

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APPENDIX

APPENDIX - A

Questionnaire Survey

For the title Assessment on current Application of formwork in building projects in Hossana Town

Questionnaire Survey

Dear respondents:

The purpose of this questionnaire and formats is to obtain information and data for the specified research conducted as partial fulfillment of the requirements for a master's degree in civil engineering (Construction Engineering and Management) Jimma University at Jimma Institute of Technology.

Title:

Study on Assessment on current Application of Formwork in Building Construction Projects In Hosanna Town

Objective

The aim of this questionnaire is to study on Assessment on current Application of Formwork in Building Construction Projects In Hosanna Town

Confidentiality

The data collected and the information to be answered in this questionnaire will be used for academic research purpose only. All specific companies and interviewee information will be kept confidential at all times. Only a generalized analysis of the information contained within this completed questionnaire will be utilized in the research process.

Instruction

Please answer, rate, and thick (✓) the questionnaire by choosing the appropriate choices. The questionnaire and data collection contains four sections. Section one and two contains the company

and respondent's general information, section three deals with formwork materials & system and section four deals with effects of current practice and quality implications. I realize that there are numerous demands on your time. However, your involvement is a vital requisite for this study. I appreciate your anticipated cooperation in answering this questionnaire, which may take less than 30 minutes of your valuable time.

Thank you for your earnest cooperation in advance.

Best Regards,

Sincerely yours

Bisrat

Postgraduate student in Construction Engineering & Management

Jimma University, JIT, Civil Engineering & Envi. Department

Tel: 0932474839

E-mail: Zergawbisrat4@gmail.com

Section 1: Respondent`s (personal) Information

1. Job position in the company:

Owner ☐ Site engineer ☐

Project manager ☐ Construction engineer ☐

Office engineer ☐ Architect ☐

Other Specify _____

2. Experience in construction industry

1-5 years ☐ 6-10 years ☐ 10 & above years ☐

3. Highest number of stories (tallest building) you have practiced:

Less than G+2 ☐ G+3-G+9 ☐ G+10 & Above ☐

Section 2: Specific project information

1. Grade of the contractor in this project

BC1 ☐ GC 1 ☐ GC2 ☐ GC3 ☐ GC4 ☐

2. Grade of the consultant in this project:

Grade 1 ☐ Grade 2 ☐ Grade 3 ☐ Grade 4 ☐

3. Owner of this project

Private ☐ Public ☐

4. Building area: _____

5. Height of building: _____

6. Number of typical floor slabs (slabs with same area): _____

7. Estimated Total Cost of this project: _____

Section 3: Formwork Types & Materials

1. Which formwork type is most practically used in your company (A&B)?

A) Conventional formwork system ☐

B) Modern conventional formwork system ☐

C) Modern formwork ☐

2. Which type of formwork system creates more discoloration of finished concrete?

a) Conventional formwork ☐

b) Modern conventional formwork ☐

c) Modern Formwork ☐

3. Which type of formwork system maintain more dimensional accuracy in the time of placing concrete mix (Dimensional accuracy include size, shape and alignment of structural elements)

a) Conventional formwork ☐

b) Modern conventional formwork ☐

c) Modern Formwork ☐

4. As professional, considering only smoothness and regularity of concrete surface, what type of formwork system do you recommend for building construction

_____

_____.

5. Please describe major quality problems that occurred in time of stripping formwork from Concrete in your site?

_____

_____

_____

_____

6**.** Which formwork materials does your company use? (Please tick the box under column 1 for mostly used, 2 for less used etc.)

Material	**Mostly used**	**Less Used**

Timber		
Plywood		
Fabric		
Steel		
Wood Particle board		
Aluminium		
Precast concrete		
Plastic		
Hardboard		
Green Reinforced Plastic		
Yellow Panel		

Other materials, please specify _____

_____

7. Much formwork material with the structural elements in table below. (Tick the box under the member)

Material	**Structural Element**				
	Footing pad	**Beam**	**Column**	**Shear Wall**	**Slab& Stair Case**
Timber					
Plywood					
Fabric					
Steel					
Wood Particle board					
Aluminium					
Precast concrete					

Plastic					
Hardboard					
Green Reinforced Plastic					
Yellow Panel					

8. Please mark Factors influencing selection of formwork system. The influence levels supposed here in this table is;

1= No influence, 2= Low influence, 3 = Moderate influence, 4 = high influence and 5= Very high influence.

Factors influencing selection of formwork system	**1**	**2**	**3**	**4**	**5**
1. General Aspect					
Quality					
Safety					
Availability					
Adaptability					
Duration of the project					
2. Formwork Aspect					
Load Caring Capacity					
Type of Formwork					
Life Span					
Weight of formwork					
Construction Cycle time					
3. Structural Aspect					
Accessible to work					
Type of structure					
Building dimension					
4. Environmental Aspect					
Exposer to Environment					

Climate Condition					
Site condition					
Storage of formwork					
5. Cost Aspect					
Labor cost					
Transportation cost					
Capital Cost					
Maintenance cost					

Section 4. Effects of different formwork system.

1. The following Table shows the effect of using conventional formwork system in building construction projects in hosanna. The influence effect supposed here in this table is;

1= No influential effect, 2= Low influential effect, 3 = Moderate influential effect, 4 = high influential effect and 5= Very high influential effect.

No.	Effects of using conventional formwork system	**1**	**2**	**3**	**4**	**5**
1	High Labour Intensive System					
2	Limited No. of Reuse					
3	High Waste					
4	High-quality labour force and adequate supervision					
5	Tendency to swell & shrink					
6	Safety & Reliability problems					
7	Limited spans					
8	Time Consuming					
9	Height Adjustment Problems					

2. Please identify the quality implication of using conventional formwork system (**Please tick in the box the degree of occurrence as per the scale.). (5= very high, 4= high, 3= moderate, 2= low & 1= Not at all).**

No.	Quality Implication	1	2	3	4	5
1	Not straight Vertical surfaces				`	
2	Unmaintained formworks and uneven surface					
3	Improper terminations of Formwork					
4	Formworks and accessories carelessly dropped upon dismantling					
5	Honey Combing					
6	Poor Construction joint					
7	Formwork Stuck on concrete surface					

Other implication, please specify _____

_____

3. Which formwork releasing agent practically used by your company? (Only for contractors)

A) Plastic sheet ☐ E) Neat oils with Surfactant ☐

B) No releasing agent ☐ F) Mould Cream Emulsions ☐

C) Burnt oil ☐ G) Chemical Release Agents ☐

D) Diesel oil ☐ H) Water-soluble Emulsions ☐