Evaluation of Kumkang Aluminum Formwork Performance in Federal Housing Corporation Projects

Heaven Yeshineh Yimer

A Thesis Submitted to
The Department of Civil Engineering
School of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement for the Degree of Master's in Civil Engineering (Specialization in Construction Engineering and Management)

Office of Graduate Studies
Adama Science and Technology University

July, 2021
Adama, Ethiopia

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Co-advisor: Yodit Fekadu

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Declaration

I hereby declare that this Master Thesis entitled “Evaluation of kumkang aluminum formwork performance in federal housing corporation projects” is my original work. That is, it has not been published and submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

Heaven Yeshineh ____________ 16-07-2021

Name of the Student Signature Date

Recommendation

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled "Evaluation of kumkang aluminum formwork performance in federal housing corporation projects" prepared under our guidance by Heaven Yeshineh submitted in partial fulfillment of the requirements for the degree of Mater's of Science in Civil Engineering, the Graduate Program of the Department of Construction Engineering and Management, Therefore, we recommend the submission of the revised version of the thesis to the department following the applicable procedures.

Bahiru Bewket (PhD)		16-07-2021
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Approval sheet

We, the advisors of the thesis entitled "Evaluation of kumkang aluminum formwork performance in federal housing corporation projects" and developed by Heaven Yeshineh, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Heaven Yeshineh have read and evaluated her thesis entitled "Evaluation of kumkang aluminum formwork performance in federal housing corporation projects" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Construction Engineering and Management

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ABSTRACT

Due to the rapid population growth and urbanization in Ethiopia over the past decades, there is a shortage of affordable standard housing projects in all towns. To meet the requirements of more housing projects in a short period, the construction firm is in charge of selecting proper formwork material, but one of the major constraints for the timely completion of the housing projects are the formwork used by the company. Conventional formwork construction system in Ethiopia takes relatively longer time to construct, add cost to the project, reduce productivity and quality of concrete surface mostly not good. Thus, the objective of this study is to evaluate the kumkang aluminum formwork performance in federal housing corporation projects. In order to achieve the research objectives, this study targets the total ongoing projects which are owned by federal housing corporation in Addis Ababa city. Due to less number of ongoing projects and the form work system which is applied by one of federal housing projects, the census sampling method was used. The data were collected through a combination of interviews, questionnaires, and case studies. There were 75 questionnaires distributed in all ongoing federal housing projects and 61(81.3%.) were returned and for purpose of the interview, 20 different professional respondents were taken. The data collected by quantitative method were analyzed using statistical package for social science and Microsoft Excel 2007 and Origin pro used for supporting the data analysis and present through Frequency tables, percentages, bar charts, and other descriptive measurements. Qualitative data which is interview also analyses differently and present in a combination of quantitative data. The case studies comparison was present by using tables and graphs. The study result indicates that the kumkang formwork system can construct through manually by unskilled labour and the formwork costs less than wooden formworks, it saves almost 173.29 Birr/m^2 or 40% of formwork cost in construction is reduced by using Kumkang Aluminium formwork. In terms of time, 7 days utilized to construct one-floor formwork by kumkang including formwork strip, while the conventional formwork takes 21 to 31 days for erection only. This implies a 3- 4 floor formwork construction time in kumkang aluminum formwork and the Kumkang Aluminum formwork have improvements on conventional formworks with greater than 60% in all quality of finished concrete measurements. The kumkang aluminum formwork have less risk and better safety during construction in the aspect of health and safety factors. The Kumkang Aluminium formwork is also beneficial for enhancing sustainable construction. Nearly all of the sustainable formwork system elements are fulfilled by this formwork. The productivity of labour in Kumkang Aluminum formwork have an improvement with 0.91, 3.61, 4.59 m^2/hr. for stair, wall and floor slab respectively in formwork erection than in wooden formwork and during formwork stripping the productivity of labour in kumkang formwork enhance the wooden formwork by 0.85, 5.18, 5.95 m^2/hr. in a stair, wall, and floor slab respectively and the monthly progress of labour productivity was increase from month to month in kumkang aluminum formwork but, the reverse in the case of wooden formwork. From the findings of this study, it can be generalized that the kumkang aluminum formwork have a great advantage and better performance with regard to minimize the cost of construction, speed the construction time, good quality of finished concrete, safer construction environment, enhancing sustainable construction, and increasing labour productivity. As an initial study on the performance of kumkang aluminum formwork, further and more detailed studies should be conducted on such formwork system application, construction methodology, design, and formwork management.

Keywords: Formwork, Kumkang Aluminum formwork, Performance, Cost, Time, Quality of finished concrete, Safety, Sustainability, Labour productivity.

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LIST OF ACRONYMS

ACI	American Concrete Institute
BaTCoDA	Building and Transport Construction Design Authority
BC	Building Contractor
BIM	Building Information Modeling
BS	British Standard
EBCS	Ethiopian Building Code of Standard
FHC	Federal Housing Corporation
GC	General Contractor
GFRP	Glass Fiber Reinforced Plastic
GRP	Glass Reinforced Plastic
HCB	Hallow Concrete Block
IBS	Industrialized Building System
IC	Internal Corner
LCC	Life Cycle Cost
MB	Middle Beam
MH	Man Hour
MoUDC	Ministry of Urban Development and Construction
OECD	Organization for Co-Operation and Development
PH	Prop Head
PVC	Poly Vinyl Chloride
RC	Reinforced Concrete
RCC	Reinforced Cement Concrete
SC	Slab Corner
SPSS	Statistical Package for Social Science

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Ethiopia is a developing country with a rising intensity of urban expansion and a population that is growing at an alarming rate. Ethiopia's rising population and quick rate of urbanization are putting significant strain on housing, particularly among the lower-income people. Lower-income households have two obstacles in acquiring a home: a shortage of cheap, high-quality housing supply and the difficulty in getting housing financing. As a result, Ethiopia's urbanization process has been connected with enormous social difficulties such as high unemployment, a high prevalence of poverty, inadequate sanitation, and homelessness (Gorems, 2016).

Due to tremendous urbanization and population expansion growth in Ethiopia over the past decades. The scarcity of affordable standard housing in all places in Ethiopia, particularly Addis Ababa, necessitates quick action to address the issue. To satisfy the needs of more people, new housing developments must be built in a short period of time. The formwork employed by the firm is a key component in the project's prompt completion. The selection of a formwork method in affordable housing is critical for building a house in less time (Sida, 2015).

A lot of research is being done in the construction sector these days to develop cost and time-saving techniques to strengthen the nation's infrastructure. Developing infrastructure is also an important element of a country's economic growth. New methods and materials are being employed as the times change. The most essential factors determining construction success are time, speed, quality, cost, and work safety. Formwork systems are critical elements in determining construction time, speed, quality, and safety. The formwork system transitioned primarily from wood to steel, and now from steel to aluminum (Pujari et al., 2018).

One of the methods recognized as being highly appropriate for mass building, where quality and speed can be accomplished at a high level, is the aluminium formwork system. Aluminum Formwork is effectively utilized in the construction of apartments and buildings, both low and high rise, in Japan, Singapore, Malaysia, and the Middle East. This system's building speed exceeds that of most other construction methods and technologies. This approach is used efficiently by the labor to speed up the building while also ensuring quality control and durability. The use of this technology lowers the overall cost of the construction (Magdum, 2017).

This research work aims to evaluate the performance of kumkang aluminum formwork in federal housing corporation projects. Hence, one of the federal housing corporation projects which is the gerji modern village project adopts this kind of technology. By using literature review, survey questionnaires, and interviews, analyzing the responses about the performance of the formwork system through different parameters, and taking case studies on ongoing projects, the performance of kumkang Aluminium formwork was evaluated.

1.2 Statement of the Problem

Formwork technology is increasingly being used in the construction sector since it allows for faster execution and better outcomes. Formwork accounts for a significant portion of the entire building cost. As a result, effective design of the formwork system to be employed can decrease construction costs (Pujari et al., 2018).

Almost all construction projects have a predetermined cost, completion time, and quality. A typical measure of a construction project's success is that it be completed on schedule, within budget, according to the technical specifications, and to the satisfaction of the customer. In terms of cost, completion time, and project quality, Ethiopia's construction sector falls short of expectations when compared to the rest of the globe. One of the many reasons that contribute to the country's construction industry's poor practices is the use of inferior quality of formwork systems. 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 also add costs to the project as the contractor's productivity reduced. The quality of concrete surfaces is mostly not good as proper formworks are not designed and constructed accordingly. To improve the look of the concrete surfaces, they are either chiseled or extra plastering is placed (Sida, 2015).

Alternative formwork materials such as plastic, glass-reinforced plastic, fabric is not well known and used by local construction companies. Steel panels and timber boards are the most commonly used formwork materials in Ethiopia (Tarekegn, 2010). In addition to this aluminum formworks also not well known and practicable. New technologies or methodologies in the construction that are environmentally friendly are completely absent. In the conventional approach, the subject of construction as an environmentally unfriendly activity has become arguably redundant.

The rapid advancements in the field of formwork, along with the innovations in concrete as a material have led to a revolutionary change where safer, quicker, sustainable, and more efficient construction is possible these days. Modern formwork systems are designed for speedy and efficient construction. These systems are pre-engineered to provide increased accuracy and minimize waste in construction and most have health and safety features built-in (Government of India Minstry of Railways Works Directorate, 2017). Better quality buildings at a faster speed of construction rate, cost-effective and environmentally friendly manner can be achieved by using advanced formwork systems.

This paper was deal with one of modern formwork system called kumkang aluminum form work. Hence, the use of modern formworks which solves the above problems in Ethiopia is very mandatory to have better construction and to accomplish mass housing projects by fulfilling the requirements like less cost, shorter construction time, good quality, safer construction, high labor productivity and sustainable construction.

1.3 Objective of the Study

1.3.1 General objective

The main objective of this study is to evaluate kumkang aluminum formwork performance in federal housing corporation projects.

1.3.2 Specific objectives

- To assess the kumkang aluminum formwork practice system.
- To evaluate the performance of kumkang aluminum formwork in terms of cost, time, quality of finished concrete, and safety by comparing it with conventional formwork construction.
- To assess benefits and barriers of kumkang aluminum formwork with respect to sustainability.
- To assess the labour productivity of the kumkang aluminum formwork system.

1.4. Research Questions

Within the view of accomplishing the above objectives, the research has posed the following questions, which are to be investigated by the selected research instruments:

1. What is the kumkang aluminum formwork practice system?
2. Did kumkang aluminum formwork surpass conventional formwork in the aspect of cost, time, quality, and safety?
3. What are the benefits and barriers of kumkang aluminum formwork concerning sustainability?
4. What is kumkang aluminum formwork advancement on labour productivity?

1.5 Significance of the Study

The outcome of this study will have a multi-dimensional significance to different parties;

For contractors: It helps to create understanding on which formwork construction is better in order to construct a building in an efficient and effective work environment by reducing cost and time expenditures with maintaining the quality and consistency of formwork construction. Also, to increase labor productivity and less wastage of construction material.

For public housing agencies and government policy makers: The study could also create awareness among housing supply agents especially for local governments and public housing agencies about Kumkang Aluminum formwork system impact on meeting the requirements of more housing projects in a short duration of time and its impact on sustainable construction.

For real estate developers: The research is believed to initiate the real estate developers in using this kind of formwork system after knowing the difference between the conventional one. Specially in order to overcome the time issue that is raised by customers all the time.

For consultants: this study be significant to consultants by decreasing the claim raised between the parties in the aspect of cost, time, quality, health and safety, and environmental issues that are related to the formwork system.

For client/owners: The interest of all clients that are involved in the building construction industry is to get a successful completed project at the end within budgeted cost, allocated time, at the proper quality, and safe construction. This research is believed significant for the client by creating understanding on this formwork system on the above aspects.

Future researchers: As an initial study on the performance of kumkang aluminum formwork in the federal housing project, this research is believed to open the door for further and more detailed studies on another advanced formwork system application and performance that enhance our construction industry.

1.6 Scope of the Study

The scope of the study is bounded by three main aspects: geographical, subjective, and performance measurement parameters.

Geographical: Geographically the research scope is limited to federal housing corporation projects in Addis Ababa city. Because of: -

- The kumkang kind aluminum form work adopts only on gerji modern village federal housing corporation project in the country by the mean time.
- The Federal housing corporation projects with the same features of building were better than other building projects for the purpose of comparison of kumkang aluminum formwork with conventional ones.

Subjective: even though there is a different kind of aluminum formwork system adopts by other countries, this study was only focus on the performance of kumkang kind aluminum formwork. The reason for this was, there is no other kind of aluminum formwork apply in the country in now adays to evaluate performance.

Performance measurement Parameter: Many parameters can be used to measure the performance of formwork construction based on the nature, complexity, and objectives of the project to determine which indicator is much more suitable to assess the performance of a particular formwork. In this case time, cost, quality, safety, labour productivity and sustainability which is the predominant performance evaluation dimensions were taken as the performance measurement parameter.

1.7 Limitations of the Study

This research, however, was subjected to several limitations. The major limitation of this research was the research conducted on federal housing projects in Addis Ababa city only because of the form work system which is applied only by one of a federal housing project by the mean time and there is resource constraint on the sample, a smaller number of ongoing projects under federal housing corporation to study. Another limitation was there is a lack of willingness to return the questionnaire survey also to interview within the time since the survey questionnaire and interview needs professionals to attain reliable and valid data on the subject matter. In addition to this, there was a lack of recorded data in the projects for purpose of the case studies. Also, there was a lack of prior research related to the topic and there is no local research conducted before on such kind of formwork performance and applications. Accordingly, this is one step for further and more detailed studies on such formwork systems is recommend.

1.8 Organization of the Study

This research report had five chapters that contain: -

Chapter one: Was composed the background of the study, statement of the problem, research objectives, and questions, scope of the study, the significance of the study, and limitation of the study were included in chapter one.

Chapter two: Was composed of the review of the relevant literature. Company documents, various books, and journal articles was reviewed to base the study on existing literature and discuss relevant issues to build an understanding of the subject matter.

Chapter three: Contains the details of the research methodology and the steps used to gather and analyze data from findings were drawn.

Chapter four: Contains the analysis of the data gathered through data collection methods and instruments indicated in the methodology part.

Chapter five: Discusses the conclusion and recommendation. The references used in the study are listed at the end. Tables, interview guides, and questionnaires used were included in the appendix part.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

When concrete is placed, it is in a plastic state. It requires to be supported by temporary supports and casings of the desired shape till it becomes sufficiently strong to support its own weight. This temporary casing is known as the formwork or forms or shuttering (Patel et al., 2015). “Formwork is the term given to either temporary or permanent molds into which concrete or similar materials are poured” safety (Shaik & Rahul, 2019).

According to Tarekegn (2010), 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 weight, the weight of the freshly placed concrete, construction loads such as materials, equipment, and workers, and other possible live loads during construction.

The construction industry involves various resources such as manpower, machinery, money, materials. The materials itself contribute 70% of the overall cost of the project(Shaik & Rahul, 2019). The construction of formwork takes time and involves expenditure up to 20 to 25% of the cost of the structure or even more (Patel et al., 2015). Also, according to Rajeshkumar et al. (2020), formwork costs 40 to 60% of structural work in construction.

In the present construction, the cost of formwork may differ 20% to 65%, in case of fears competition contractor is always trying to complete the project in time with better and acceptable quality without line and level. To make a tool to effectively shuttering the line, level or quality of concrete is increased the costs for touchup will in times high, again that may become the problem for sustainability and durability of structure (Magdum, 2017). Formwork is one of the important materials in the construction site which affects quality and safety (Shaik & Rahul, 2019).

2.2 Formwork Construction

Construction is one of the important sectors in the world. Construction involves huge investment and plays an important role in the growth of several other sectors in the economy. Globally construction of high-rise buildings is increasing to save time and space. In construction, industry formwork plays an important role. Formwork contributes a major part of the cost in construction and gives shape to the fresh concrete and also supports the fresh concrete to gain its strength to carry on its weight. It shares a considerable cost in building construction. Formwork costs 40 to 60% of structural work in construction (Rajeshkumar et al., 2020).

Formwork is the use of structural support to create structures out of concrete that is poured into the molds. There are many different types of formworks used in construction, usually differing according to what the building requirements and challenges are in construction. Formwork is used by creating molds out of wood, steel, aluminum, or prefabricated forms into which the concrete is poured. This is then allowed to harden and set after which it is stripped, or in the case of stay-in-place formwork, it is left as part of the structure. Formwork allows contractors to cast and construct the main parts of a building which are required to be a strong structure such as floors and walls, as well as smaller parts of a building such as stairs relatively quickly (Dinesh & Soundararajan, 2017).

2.2.1 Background of Formwork

In ancient times the formwork is used, some of the earliest examples of concrete slabs were built by Roman engineers. Because concrete is quite strong in resisting compressive loads but has relatively poor tensile or torsional strength, these early structures consisted of arches, vaults, and domes. The most notable concrete structure from this period is the Pantheon in Rome. To molds, this structure, temporary scaffolding, and formwork or false work were built in the future shape of the structure. Even though, formwork techniques have developed keeping pace with the growth in concrete construction. The material for formwork which was at one time, primarily timber now includes a wide range such as plywood, metals, plastics, and aluminum along with specialized accessories and hardware. Age-old methods of erecting formwork in place, for each user and destroying it thereafter have now been changed to reusable items. This includes pre-fabricated standard or modular panels and accessories including assembly and erection by manual or mechanical means and reusing the forms several times. Large-scale developments in formwork technology took place mainly during the last 50 years. The construction of formwork takes time and involves expenditure up to 20 to 25% of the cost of the structure or even more (Patel et al., 2015).

Formwork development has paralleled the growth of concrete construction throughout the 20th century. The increasing acceptance of concrete as a major construction material presents the form builder with a new range of problems in the development of appropriate sheathing materials and maintenance of rigid tolerances. Lumber was once the predominant form material, but developments in the use of plywood, metal, plastics, and other materials, together with the increasing use of specialized accessories, have changed the picture. In 1908 the use of wood versus steel formwork was debated at the American Concrete Institute (ACI) convention, the advantages of a modular panel formed with its connecting hardware and good for extensive reuse were also realized. By 1910 steel forms for paving were being produced commercially and used in the field Today modular panel forming is the norm (Nemati, 2005).

2.2.2 Formwork Construction in Ethiopia

Building construction is one of the industries in Ethiopia where mass construction is taking place, particularly in metropolitan areas, and where many people are engaged. Local and foreign contractors create several high-rise structures in the country's metropolitan regions, particularly in the capital Addis Ababa. Clients select contractors depending on the contractors' performance and financial capabilities. Foreign contractors are allowed access to the bulk of high-rise building construction projects in Addis Ababa, which are progressing with evident success in terms of quality, quicker construction periods, and safer site conditions, while local contractors are not. The quality of the work reduce the need for extra concrete surface treatments, the speed of construction allows the owner to take advantage of the building structure sooner, and safe methods also help to reduce injuries and form failures (Sida, 2015).

In Ethiopia even though different types of formworks are available there is a lack of due consideration of cost, quality, time, and safety criteria on the selection of Formwork materials. And care is not given on the off-form finish. Formwork materials that do not fulfill good quality criteria are commonly used with many repetitions. There is a misunderstanding on the costs difference while using good and poor quality formwork (Gebrehiwot & Getachew, 2020). As Tarekegn (2010) health, safety, and environmental regulations are not implemented in the construction industry of Ethiopia.

Usually, the formwork scenario in the Ethiopian building construction industry especially in local construction companies can be stated as Conventional and modern conventional forms are most commonly practiced which are labor-intensive, time taking, unsafe, and with surface finishing in need of additional treatment. Also, 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 the corrugated iron sheet on plywood to stop leakage of concrete paste through the joints (Tessema, 2019).

The Low labor productivity and limited circulation space through props and braces due to closely fixed bracings and propping, especially when timber products used. Unskilled labor due to lack of willingness in construction companies to give training, fearing laborers would leave at the end of the training, and hence have chosen to continue with low productivity labor.

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.

The positive environmental impact consists of reduced consumption of wood as no wooden formworks are used. But according to Tarekegn (2010) formwork construction activity in Addis Ababa is seriously threatening the environment. More than three hundred trees are cleared to cast about 100m^2 of the slab. More trees were cleared other activities which need timber were considered.

2.2.3 Formwork Systems

A formwork system is the complete system of support for freshly placed concrete, including supporting elements, hardware, and any necessary bracing. The formwork system is critical in mechanizing processes to improve speed, increase productivity, and use economies of scale to reduce unit cost, particularly in high-rise projects (Dinesh & Soundararajan, 2017).

Formwork system has an important role in the construction, by selecting the appropriate formwork system could lead to sustainable construction. Formwork is specified to support the concrete as temporary structures until it supports itself. This molds the concrete to various types of formworks used in construction, usually varying depending on the building needs. The formwork used for casting structural elements like columns, beams, slabs, and shear walls also used for smaller building pieces like stairs (Gaddam & Achuthan, 2020).

Formwork systems can be generally classified as Vertical Systems (wall and column), Horizontal Systems (slab and beam), and Special Formwork Systems. Formwork horizontal systems are used to temporarily support horizontal concrete work such as concrete beams and slabs. Formwork systems for horizontal concrete work can be also classified into two main categories: hand-set systems and crane-set systems. Conventional wood systems and conventional metal systems are classified as hand-set systems. In hand-set systems, different formwork elements can be handled by one or two laborers. And formwork for slabs, beams, and foundations is included in the traditional wood method. Flying formwork systems, column-mounted shoring systems, and tunnel formwork are classified under crane-set systems. In crane-set systems, adequate crane services must be available to handle formwork components (Krohn, 2011).

Formwork for concrete slabs is one of the horizontal formwork methods (soffit formwork). Plywood, lumber, steel, and aluminum sheathing are used in traditional wood or metal systems for horizontal concrete work. The sheathing is held up by horizontal components known as joists or runners. Stringers are a group of horizontal elements perpendicular to the joists that support them. The stringers are held up by vertical elements known as coasts. Steel, aluminum, or wood shoring can be used (Sida, 2015).

Formwork for concrete beams is another formwork horizontal system. According to Krohn (2011), 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 plywood or lumber sheathing. The bottom is supported by and fastened to horizontal joists. Beam sides are also made of plywood or lumber sheathing. The supports need to be maintained to the soffit and also provide lateral support to the sides. In timber, this is done by the use of a head tree across the top of a vertical member. Metal panels are used with corner pieces, but timber head trees are needed for vertical support. Once the bottom of the beam form is constructed and leveled, one side of the beam is erected first with holes drilled into it for installing the tie rods. Tie rods are steel rods that hold the two sides of the beam together. After the first side of the beam, form is erected, the reinforcement is placed inside the beam and then the other side of the beam is erected. Tie rods are then inserted into all holes and Wales on both sides of the beam. The tie rods' function is to resist the horizontal pressure resulting from the freshly placed concrete and thus keep the sides of the beams in their proper location. Tie rods are fastened to the sides of the beam and also to vertical Wales and clamps.

Formwork Vertical Systems: Vertical formwork systems are those used to form the vertical supporting elements of the structure such as columns and walls (Sida, 2015). Formwork for column systems is one of the formwork vertical systems. Column-form materials tend to vary with the column shape. Wood or steel is often used with square or rectangular columns. Round column forms, more typically pre-manufactured in a range of standard diameters, are available in steel, paperboard, and fiber-reinforced plastic. Square and rectangular forms are composed of short-span bending elements contained by external ties or clamps. Another vertical support element is formwork for the wall system. Wall forms principally resist the lateral pressures generated by fresh concrete as a liquid or semi-liquid material. The pressures can be quite large; certainly, many times the magnitude of live loads on permanent floors. Thus, wall form design often involves closely spaced and well-supported members. As mentioned, the contact surface of the wall form is referred to as sheathing. Studs are vertical supporting members to which sheathing is attached. Wales are long horizontal members (usually double) used to support the studs. The studs and Wales are often wood, steel, or aluminum beam-like elements. Commercial form suppliers are innovative in devising elements as well as hardware for connections. The wall form members are sometimes oriented with the stud members placed horizontally rather than vertical, and Wales are run vertically. Wales are in turn supported on washer plates or other bearing devices attached to form ties. A concrete form tie is a tensile unit connecting opposite sides of the form and providing a link for equilibrium. Form ties are usually steel, although some fiber-reinforced plastic ties are also available (Krohn, 2011).

2.3 Formwork Classification

Form work is classified according to different features one of these features is according to Size. In practice, there are only two sizes for formwork; small-sized and large-sized. Small is any size that is designed to be operated manually by employees. Small- scale systems are typically composed of wood and aluminum and come in the form of small panels. There aren't many options for medium-sized for. When using large-scale formwork, the size of the form can be customized as large as practicable to reduce the quantity of jointing and to minimize the amount of lift (Asadi & Praneeth, 2017).

Another classification is according to the location of use, Different elements in the structure of a building have different design and performance requirements in the use of formwork. Accordingly, classification can be made as wall formwork, column formwork, beam formwork, and slab formwork (Tarekegn, 2010).

According to Asadi & Praneeth (2017), classification according to nature of operation formwork can be operated manually or by other power-lifted methods. Some systems are equipped with a certain degree of mobility to ease the erection and striking processes or to allow horizontal movement using rollers, rails, or tracks. Timber and aluminum forms are among the manually operable types of formworks. They are designed and constructed in ways that they can be completely handled independently without the aid of any lifting appliances. However, it is labor-intensive and is more appropriate to be used in simpler jobs. Power-lifted formwork can be of the self-climbing and crane-lifted types. Crane-lifted systems are usually in the form of large panels.

There is also classification according to the brand name of the product. Several patented or branded formwork systems have successfully entered the local construction market in the past decade. Some firms can even provide a very wide range of services including design support or tender estimating advice. As the use of innovative building methods gains more attention from various sectors in the community, advanced formwork systems will become more widely adopted (Tarekegn, 2010).

Formwork is also classified according to the materials of construction. As per (Asadi & Praneeth, 2017), Formwork is classified based upon material, type of structural member. Like Conventional formwork(timber), Steel formwork, Aluminum formwork, System formwork, and Tunnel formwork.

2.4 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, 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 give special notice and make provision for preconstruction mockups. 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. The objective of this section is to introduce Timber as an important material for formwork (Krohn, 2011).

The most important factor in terms of cost, quality, and speed in a high-rise building construction project is the type of formwork used in the project. The first formwork type to be used is the conventional type formwork where the timber planks were supported on timber columns. With the advancement of technology, it developed gradually and people used plywood sheets instead of timber planks, and steel pipes with jacks were used to support the plywood. Then finally the whole system of formwork is made and initially, the material used to it was steel and it was very heavy. Then the aim was to reduce the weight of the system and the materials for formwork have extended to aluminum, plastic, fiber glass (Dinesh & Soundararajan, 2017).

2.4.1 Conventional Wooden (Timber, Plywood) Formwork

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 needlelike leaves such as pines, cedars, and firs. Softwoods are most commonly used in the construction of formwork. Timber is suitable for constructing concrete forms is available in a variety of sizes, grades, and species groups. The form designer should determine what is economically available before specifying a particular grade or species group of timber for constructing the forms. Timber is a commonly available material and has excellent strength, weight, and cost factors. A special type of timber is known as plywood. It is used extensively for formwork for concrete, especially for sheathing (the material serving as the contact face of), decking, and form linings. The relatively large sheets of plywood have reduced the cost of building and at the same time have provided a smooth surface. That reduces the cost of finishing concrete surfaces, availability in a variety of thicknesses and lengths, and ease of handling during construction. Plywood is a manufactured wood product consist several veneer sheets or plies Type of plywood can be grouped as exterior and interior. For formwork, exterior plywood is used. The adhesive used to bond the piles in the manufacturing of exterior plywood is watertight and gives a maximum number of reuses. The plywood industry manufactures special plywood called Ply form specifically for use in forming concrete structures (Krohn, 2011).

2.4.2 Steel Formwork

Steel is very strong and can be used repetitively without much damage done to the form. Steel forms are also in use in combination with timber. Steel sections are used in the fabrication of different formwork components, namely: steel panel forms, horizontal and vertical shores, steel pan and dome components used for joist and waffle slabs, and steel pipes for formwork bracing (Tarekegn, 2010). Mostly used in large construction projects or in situations where a large number of re-uses of the same shuttering is possible. It is Suitable for circular or curved-shaped structures such as tanks, columns, chimneys and used for structures like sewer tunnels and retaining walls. Strong, durable and have a longer life. Reuses can be assumed to vary from 100 to 120. Steel can be installed and dismantle with greater ease and speed resulting in saving labor costs. No danger of formwork by absorbing water from the concrete and minimize honeycombing (Loganathan & Viswanathan, 2016).

2.4.3 Aluminum Formwork

Aluminum stems from having a lighted weight which reduces handling costs and offsets its higher initial material cost. When compared to steel panels, aluminum panels used for ganged forms weigh approximately 50% less. The major problem with aluminum forms is corrosion: Pure aluminum is attacked chemically by wet concrete. Aluminum alloys have proven to be very successful in resisting corrosion. Forms made from aluminum are in many respects similar to those made of steel. However, because of their lower density, aluminum forms are lighter than steel forms, and this is their primary advantage when compared with 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 made of aluminum. Because wet concrete can chemically attack aluminum, it is desirable to use aluminum alloys in resisting corrosion from the concrete (Krohn, 2011).

Aluminum formwork panels can be designed for any condition/component of a building such as bay windows, stairs, balconies, and special architectural features. This system is unique as all the components in a building, including slabs, floors, walls, columns, beams, staircases, balconies, and window hood, are concrete and there is no need for block works or brick works. It gives a form finish, eliminates the need for external and internal plaster and the walls can be directly painted with a minimal skim coat, all these ultimately resulting in cost-saving (Patel et al., 2015).

2.4.4 Glass-Reinforced Plastic Formwork

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 (Glasfaserverstärkter Kunststoff), or simply by the name of the reinforcing fibers themselves: fiberglass (Tarekegn, 2010).

In recent years, forms fabricated from glass-reinforced plastic have found increasing use because of their strength, light weight, and a 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 the 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 alkalies in the concrete and form expansion because of exposure to hot sun or heat from the hydration of cement (Hanna, 1998).

2.5 Modern Formwork Systems

Nowadays, there are several sorts of contemporary formwork systems. Some examples are flying (table) formworks, jumping (climbing) formworks, slip formworks, tunnel formworks, and aluminum formworks. Flying (table) formwork is a relatively recent formwork technology that was created to decrease labor expenses involved with formwork constructing and dismantling. The term "flying formwork" refers to how forms are flown from story to story by a crane. Flying form systems are ideally suited for high-rise multistory structures, such as hotels and residential complexes, when many reuses are required (Tarekegn, 2010).

Jump form systems are becoming increasingly popular across the world. Jump form, also known as climbing form, consists of formwork systems complete with working platforms that support themselves on previously cast concrete. As a result, it does not rely on building support. They are commonly utilized in the fabrication of multi-story vertical concrete components. Jump form methods are used to build concrete features such as core walls, shear walls, bridge pylons, and elevator shafts. The usage of jump form systems reduces labor costs while boosting building efficiency (Government of India Minstry of Railways Works Directorate, 2017).

Slip formwork is a vertical type of extrusion of a part of reinforced concrete that is appropriate for Core wall building in high-rise buildings-lifting Shafts, stair shafts, walls, and so on. This is a self-contained Formwork system that requires very little crane time, Construction. The formwork rises at a constant pace of 300 mm per hour, sustaining itself in the middle. This formwork is divided into three phases. The top level covers the possible region of circulation, while the center stage performs the major stage of work and has the maximum level of solid dimension spilled out. The lower stage gives strong wrap-up control. Fast construction for broad floor areas, Reduced need for long-term on-site workers, Individual formwork components can be modified with precision (Gaddam & Achuthan, 2020).

A tunnel formwork system is the most recent formwork invention. The utilization of repeating cellular structures to combine horizontal and vertical features has the potential to transform the building sector in nations such as India. They allow for the simultaneous building of walls and floors, making the method suitable for both high and low-rise homes. Tunnel form systems are easy to clean and reuse, and they also allow for high-quality surface treatments. Engineers are also guaranteed of the constructions' excellent dimensional correctness. The repetitive nature of the construction work is another plus point with this type of formwork system, adding to its other advantage of the requirement of a very small team on site (Government of India Minstry of Railways Works Directorate, 2017).

The aluminum formwork system is a relatively new technology that reduces building time and costs while increasing construction efficiency. Aluminum formwork is commonly utilized in Japan, Singapore, Malaysia, and the Middle East for the construction of low and high-rise residences and structures. For repeated construction plans and above-the-plumbing work, the aluminum formwork device is highly cost-effective. It is one of the methods that has been regarded as being highly appropriate for Indian mass construction settings, where great levels of quality and speed may be attained. The construction speed of this system can outperform that of most other building methods/technologies. This method is used efficiently by labor to speed up construction while also ensuring quality control and durability. Aluminum Formwork panels can be constructed for any building condition or component, such as bay windows, staircases, balconies, and other architectural elements. This design is unique in that all of the building components are concrete, including the slabs, floors, walls, columns, beams, stairs, balconies, and window hoods, and no block or brick construction is required. It provides a form finish, eliminates the need for exterior and interior plaster, and allows the walls to be painted directly with minimum skim coat, all of which lead to cost savings in the long run (Gaddam & Achuthan, 2020).

2.6 Kumkang Aluminum Formwork Technology

Aluminum formwork is differentiated based on manufacturers or company or brand name. MIVAN is the first manufacturer who introduced aluminum formwork. Mivan is an aluminum formwork system developed by one of the construction companies from Europe. In 1990, the Mivan Company Ltd from Malaysia started the manufacturing of such formwork systems. Nowadays more than 30,000 sq m of formwork used in the world are under their operation. Kumkang kind is another type that started in Korea in 1979. Kumkang is an upcoming technology that has empowered and motivated mass construction projects throughout the world (Magdum, 2017).

Kumkang technique is a revolutionary aluminum formwork technique that is forming its base in the construction field. It was invented in Korea in 1979. This formwork system is suitable for both residential and commercial construction. Kumkang formwork system is in today’s date is most trustful, safe, and up-to-date formwork technology available in the market. This is a unique formwork system in which walls, columns, beams, staircase, balconies along door and window opening are cast in place. This technique is specially invented for earthquake-prone regions (Pujari et al., 2018). The utilization of kumkang formwork technology reduces the burden of chiseling and series of plastering works which in turn is supposed to reduce the time and cost of construction. In contrast to the conventional wooden formworks, the kumkang formwork can be utilized repeatedly nearly 300 times and is labeled as an environmentally friendly building system.

2.6.1 Components of Kumkang Form Work System

The basic element of the formwork is the panel, which is an extruded aluminum rail section, welded to an aluminum sheet and other components are extruded section. This produces a lightweight component with an excellent stiffness-to-weight ratio, yielding minimal deflection under concrete loading. Panels and extrusions are manufactured in size and shape to suit the requirements of specific projects. Following are the components that are regularly used in construction (Thiyagarajan et al., 2017).

Slab panels: The slab panel can be used to support the concrete weight during concrete pouring and casting (Pujari et al., 2018). Shows in Figure 2.1.

FIGURE 2.1 Slab panel (Pujari et al., 2018)

The standard-sized in which the slab panels are available in Table 2.1:

Table 2. 1 Standard sizes of slab panels (Pujari et al., 2018)

Standard sizes of slab panels	
1. (400 x 2300) mm	5. (600 X 1200) mm
2. (400 X 2450) mm	6. (450 X 1200) mm
3. (450 X 2300) mm	7. (400 X 1200) mm
4. (450 X 2450) mm	8. (300 X 1200) mm

Wall panels: Wall panels are available in various sizes and in the Kumkang formwork technique they can be customized as per the need of the architectural design(Kumkang Kind Co., 2016). Some of the standard sizes are in Table 2.2:

Table 2. 2 Standard sizes of wall panels (Kumkang Kind Co., 2016).

Standard sizes of wall panels	
1. (600 x 2450) mm	5. (400 x 2450) mm
2. (600 x 2300) mm	6. (400 x 2300) mm
3. (450 x 2300) mm	7. (300 x 2450) mm
4. (450 x 2400) mm	8. (300 x 2300) mm

The wall panel figure as shown below in Figure 2.2:

FIGURE 2.2 Wall panel (Kumkang Kind Co., 2016)

Pipe prop support: It remains under the prop head. Pipe support along with prop head remains in place until two levels are cast. The pipe support is used to support the weight of the slab during pouring and casting (Pujari et al., 2018). The sizes in which the prop pipe support: 1800-3200, 2000- 3400, 2400-3800, 2600- 4000. The pipe pro support shown in Figure 2.3.

FIGURE 2.3 Pipe prop support (Pujari et al., 2018)

Slab corners: Acts as a connection wall panel and slab panel. Slab corner is of two types slab corners inner and outer. Size: 150H Weight: 6.6 kg/m (Kumkang Kind Co 2019). The slab corners Figures shown in Figure 2.4.

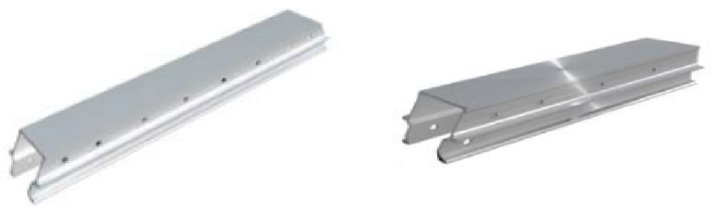
(a) Slab corner(SC) (b) Inner corner(IC) (c) Slab outer corner

FIGURE 2.4 Slab corners (Kumkang Kind Co., 2019)

Prop head [PH]: Used to joint the beams together (Middle beam and/or End beam), the pipe support placed under the prop head. And there is a Special prop head Used to joint the beams together (Middle beam and/or End beam), this special prop head placed where a normal prop head cannot be installed (Pujari et al., 2018). The prop head shown in Figure 2.5.

FIGURE 2.5 Prop head(PH) (Pujari et al., 2018)

Middle beam (MB) and End beam (EB): The middle beam is used to joint the prop heads shown in Figure 2.6 (a), the middle beam supports the slab panels, and the end beam is used to joint the prop head and slab corner shown in Figure 2.6 (b), the end beam supports the slab panels. And there is a joint bar used to join the prop heads with the beams (Middle beam and/or End beam) (Kumkang Kind Co., 2019).



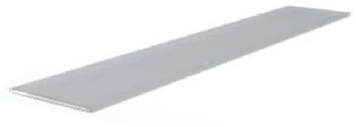
(a) Middle beam (b) End beam

FIGURE 2.6 Middle and end beam (Kumkang Kind Co., 2019)

2.6.1.1 Various Types of Connectors Used in Assembly of Formwork

Long pin along with wedge pin is used to fix joint pin with prop head and beams(Middle beam or End beam) together and Weight (kg) 0.33. Round pin and Wedge pins are used to joint the wall or slab panels together and its weight (kg) 0.085. And a flat tie is used to join the wall panel to the opposite side panel. The use of number, wall panels depend on the wall panel's height. This flat tie is first greased and then used in wall panels along with a round pin. A maximum of 7 to a minimum of 3 flat ties are used in each wall depending on the wall height. Depending on the wall panel's height, the number of flat ties used can vary. The PVC sleeve-Made of PVC material, the PVC sleeve installed between the Wall panel and the opposite side's wall panel. The flat tie inserted inside this item to protect the flat tie to be cast within the concrete (Kumkang Kind Co., 2016). Various types of accessories and connectors used in panels shown in Figure 2.7.

(a) Round pin and wedge (b) Long pin and wedge (c) Flat ties



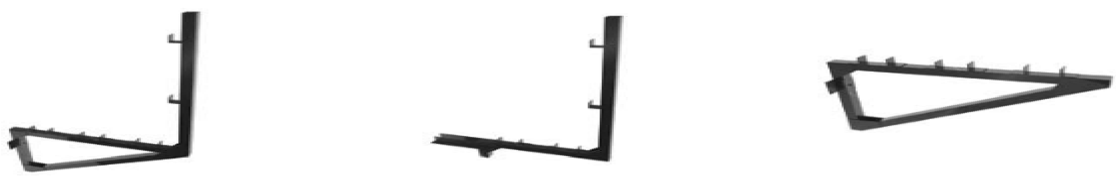
(d) PVC sleeve

FIGURE 2.7 Various types of connectors and accessories (Kumkang Kind Co., 2016)

The Waller-bracket and square pipe are used to allow the horizontal straightness of wall panels and a flat wall surface (especially at the bottom) after concrete casting. And there is a bolt, nut and washer-This set of accessories used as an embedded anchor to fix panels on the concrete surface during its installation. And the Tie rod accessory used as an embedded anchor to fix the Bracket on the concrete surface during its installation. Wall platform, slab platform and elevator platform-as a substitute for a scaffolding system, these wall platforms, slab platform, and elevator platform fixed on the concrete. (wall/slab/elevator) and used as a working platform for workers (Kumkang Kind Co., 2016).

The figure for various types of connectors and accessories for bracket platform shown in Figure 2.8.

(a) Waller-bracket and Square pipe (b) Bolt, nut and washer (c) Tie rod



(d) Wall platform (e) Slab platform (f) Elevator platform

FIGURE 2.8 Various types of connectors and accessories for bracket platform(Kumkang Kind Co., 2016)

2.6.2 Construction Methodology of Kumkang

Due to its easiness of assembly, Kumkang aluminum formwork permits an average of 4-7 days cycle compared to 14-30 days cycle with the conventional method. The setting process of the kumkang aluminum is: The first process is a structural line and level check at that point installation of electrical will be following. After this plumbing components and steel rebar. Installation of I/C and wall panels following to this installation of beam and SC boards continue. At that point installation of staircase boards carried out and installation of slab panels taken after. After installation of slab panels and installation of electrical, plumbing components and steel rebar carried out (Kumkang Kind Co., 2016).

The Cycle of kumkang form-work technique: Kumkang kind aluminum formwork system provides a very fast construction cycle. In which a floor can be erected within 8 day (Pujari et al., 2018). The sequence of the day is as follows: the first day is erecting wall reinforcement and on day two erecting formwork will be done. The third day is slab reinforcement and electrical fittings work done and day four completing electrical works and overall checking then on day five concrete pouring. On day six de-shuttering and vertical formwork stripping next to this day de-shuttering slab and beam panels follow. Finally, Overall checking and finishing works carried out.

The procedure of formwork construction of kumkang is defined as follows: As the panels arrive in the container they are unloaded to the desired location. Then Kumkang Kind supervisor along with the client representative verify and check the material as per the packing list and order list. Next to this as per requirement, the panels are moved to the location where they are to be set up. In the fourth step, the structural line is set up on the shell plan, and based on the structural line the rebar is set up and the panels are set up on both sides of the rebar, before installing the panels they have to be oiled first by formwork oil to avoid concrete to stick on panels. Then the installation of panels is started by installing panels on one side (inner phase or outer phase) along with the flat ties. Once the installation of one side is completed then the other side is done with a PVC sleeve that covers the flat ties after this the panel installation begins with the wall panels. On completion of the installation of wall panels, the next is the opening areas which include window openings, door openings and ventilators. The installation for window opening is as follows: Beam cap slab panel, Beam cap SC, Wall end panel, Beam cap SC, Prop and Prop Head, and Beam panel. Once the wall panel installation is done the kicker plate is installed, it is essential to ensure that the kicker bolts are installed. A kicker panel is installed on top of the wall panel. Next comes the slab installation. In slab installation, the slab corners (SC) are installed then the internal corners (IC). Slab installation starts from any one corner. The Main beam is then installed. The installation of the main beam includes installing; Middle beam, prop head and end beam. Once the panels are installed, they are verified whether they are installed correctly. Then the concrete is poured. After 24 hours of concrete pouring dismantling of panels is started. Dismantling is started with wall panels. Then the panels from the opening areas are removed ensuring the props remain in place up to the next 2 installations. Dismantling would start with walls, leaving rocker plate in place. Then the slab panels are removed very carefully assuring no free fall of the panels takes place. Props and prop heads are kept in place. Slab corners are removed last. Also, the upper floors are assembled in the same manner. For assembly of formwork system on upper floors first, the external working platforms are erected. The tie rods for the platforms are placed at a distance of 1.3 m along with safety rail and safety nets. These platforms are to be kept up to 2 levels. Finally, Once again overall checking is performed (Pujari et al., 2018).

2.6.3 Features of Kumkang Aluminum Formwork Technology

Speed: The kumkang aluminum formwork system allows a single pour of the wall, beam, column, slab, and staircases. Furthermore, our prop-head system allow us to dismantle the slab panels without removing the props. Due to its easiness of assembly, kumkang aluminum formwork allows an average of 4-7 days cycle compared to 14-30 days cycle with the conventional method. As aluminum formwork allows an average of 4-7 days cycle, it considerably reduces the construction period. Reducing the construction period directly reduce the construction cost. Furthermore, the non-structural wall can also be done with our aluminum formwork which will reduce labour time and cost. And on Safety compared with the conventional method, the formwork system allows a large working area for Jobsite workers (fewer props). Furthermore, through the supply of external working platforms, Jobsite workers feel much safer and increase their efficiency. And also eco-friendly, one of the best advantages of aluminum formwork is repetition. While the conventional formwork must be thrown away after 5-10 repetitions and steel formwork after a maximum repetition of 50, the aluminum panels can last for over 300 repetitions. Furthermore, after 300 repetitions, the panels can be recycled. Thus, no harm is created to the environment and produce fewer site wastages (Kumkang Kind Co., 2019).

Durability: Long life being non corrosive in nature, can perform up to 250 repetitions max. with proper maintenance and refurbishment (Pujari et al., 2018).

No need for skilled workers: The Aluminum formwork system is made of lightweight aluminum which allows the largest components to be hand-carried and set up. Even it does not need skilled workers due to the elaborate design provided to make sure that the client's success must be achieved. And cost reduction, a form designed for maximum reuse may have to be stronger and more expensive than one designed for single-use, but it can save a great deal on the total form investment. Extra features that make erection and stripping easier add to original form costs, but labour savings may outweigh the extra cost by using Kumkang Kind Aluminum formwork system. The kumkang Aluminum formwork creates also faster construction. the aluminum formwork system is fast. It is not uncommon for a contractor to double or triple the output of their form crews when they convert from a wood faced form system to a kumkang kind aluminum formwork system. It’s had good quality, due to the smooth surfaces and precisely dimensioned panels produces an unbeatable concrete finishing that does not require any plastering and eliminates grinding task due to joints created by panels. Excellent concrete surface finish, enables elimination of plastering thereby saving project duration and cost. Furthermore, engineers design the staircase formwork so that the concrete poured simultaneously on the wall, slab, column, and beam. It is easy assembly, due to its easiness of assembly, no need for skilled workers nor carpenters. An all-in-one system with kumkang kind’s aluminum formwork system, brackets for wall, slab, elevator, and the external working platform is provided. And also, it has freedom of design and jobsite planning, unlike tunnel or flying formwork, Kumkang Kind’s Aluminum formwork system is a “modular” formwork. It can be used for any architectural and structural layout. 6 floors per month (4 days per floor above 6 days for uncontrollable factors such as, access problems and unavailability of workers) (Kumkang Kind Co., 2016).

2.6.4 Kumkang Versus Conventional

The kumkang aluminum formwork has its advantage and disadvantages to other formwork systems. Advantage and dis advantage of kumkang aluminum formwork technique is described as follows in Table 2.3;

Table 2. 3 Advantages and disadvantages of kumkang form work technique (Pujari et al., 2018)**:-**

Advantages	Disadvantages
Speedy; Floor to floor cycle is achieved within 8 days. And Unsurpassed construction speed can be achieved due to the light weight of forms.	A very high initial investment
Cost; very high no. of repetitions is possible (150-250). Therefore, the unit material cost was achieved after 100 repetitions.	Not cost-effective for small construction projects where the no. of repetitions would be less.
Durability; Long life being non-corrosive, can perform up to 250 repetitions max. with proper maintenance and refurbishment. Also, the durability of a complete concrete structure is more than conventional brickbat masonry.	Compatible only for the projects where the design is repetitive.
High Labor Productivity; Very lightweight, easy manual handling, basically single type of panel joints, no crane dependency and Work being repetitive easily understood by laborers. And Less labour is required for carrying formworks.	The formwork shipping process from Korea is quite time-consuming.
High salvage value: The salvage value of the aluminum alloy formwork system is very high when be scrapped as wastes.	RCC slab to be designed for stripping after 36 hours with props left under.
Quality; Excellent concrete surface finish, enables elimination of plastering thereby saving project duration and cost.	
More seismic resistance; The box-type construction provides more seismic resistance to the structure.	
Lesser number of joints thereby reducing the leakages and enhancing the durability.	
Integral and smooth finishing of wall and slab uniform quality of construction; uniform grade of concrete is used.	
A Strong built-up of concrete needs no maintenance.	
Environmentally friendly; no huge debris, no messy disposals.	

Also, there is conventional formwork which has Advantages over the rest of the formworks and its disadvantages. Conventional formwork systems especially wooden formworks have the following merits and demerits (Tarekegn, 2010). Some of the advantages of such systems are: Flexibility, because the system is built piece by piece, it is virtually capable of forming any concrete shape. A complicated architectural design can be formed by this system. This system is not economical in terms of labor productivity and material waste. However, the system may be economical for small projects with limited potential reuses. The system has the advantage of low makeup cost or initial cost. Also, for restricted site conditions, where storage areas are not available and the use of cranes is difficult, the conventional wood system might be the only feasible alternative. Also, wood is a construction material that is available virtually anywhere. In areas where formwork suppliers are not available, a conventional wood system may be the only feasible alternative.

Even though it's had the above advantages there is a problem raised on it. The major problems associated with conventional formwork systems are: Labor Intensive, the conventional formwork system is a labor-intensive system and considered a demerit for a developed country. High waste: Erecting and dismantling conventional formwork is conducted piece by piece. This causes breaking of edges and deformation of wood. A limited number of reuses, the number of reuses is the key to an economical formwork construction. A limited number of reuses force the contractor to use several sets of formworks; this adds to the expense of formwork construction. Higher quality of labor force and supervision, conventional formwork systems work best with a high-quality labor force and adequate supervision. In areas with an unskilled or semiskilled labor force and minimal supervision, more sophisticated formwork systems are more appropriate. Limited spans, since dimension wood is low strength compared to that of aluminum and steel sections, it has limited use in applications where long spans are desired (Tessema, 2019).

2.7 Requirements of Formwork

Formwork is made from different materials and requires great skill and experience in its manufactures. To produce concrete forms that meet all job requirements, the construction engineer must understand the characteristics, properties, and behaviors of the materials used; be able to estimate the loads applied to the forms; and be familiar with the advantages and shortcomings of various forming systems (Krohn, 2011). In designing and building formwork, economy(cost), quality, speed(time), and the safety those four major objectives must be considered and those objectives describe below:

2.7.1 Economy

The main materials of the reinforced concrete work are concrete, reinforcement, and formwork, so the total cost can be approximately distributed among the three items. The economy should be considered when planning the formwork for a concrete structure. Design of the proposed formwork for a given project usually enable the job planner to determine, in advance of construction, what materials and methods are the most economical. Forms must be built efficiently, minimizing time and cost in the construction process and schedule for the benefit of both the contractor and the owner. Forms must be simple to erect and dismantle and modular dimensions should be used. The economy in formwork design depends partly on the ingenuity and experience of the form designer, whether a contractor or an engineer. Judgment concerning the development of a forming system could both expedite a project and reduce costs. Although firms may be job-built, many proprietary forming systems are available. In addition, a large proportion of the cost of conventional formwork is related to formwork labor costs. Significant cost savings could be achieved by reducing labor costs (Krohn, 2011).

Tarekegn (2010) stated that Formwork is the largest cost component for a typical multistory reinforced concrete building. Formwork cost accounts for 40 to 60 percent of the cost of the concrete frame and approximately 10 percent of the total building cost in a developed country. A large proportion of the cost of conventional formwork is related to formwork labor costs in a developed country. Significant cost savings could be achieved by reducing labor costs. Also, Dinesh & Soundararajan (2017) define that 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 attributed to its formwork; of this just over 40% can be taken for material for formwork and 60% for labour.

Formwork economy involves many factors that need to be considered; including the cost of materials, the cost of labor in making, erecting, and removing the forms, and the cost of equipment required to handle the forms. The economy also includes the number of reuses of the form materials, the possible salvage value of the forms for use elsewhere, and the cost of finishing concrete surfaces after the forms are removed. A high initial cost for materials, such as steel forms, may be good economy because of the greater number of uses that can be obtained with steel so steel formwork has replaced wood formwork to some degree, although the use of wood is still substantial because of its availability and ease of fabrication (Krohn, 2011).

According to Tarekegn (2010), formwork economy is achieved by considering four important factors: cost of form materials, ease of form fabrication, efficient use of forms erecting and stripping, and planning for maximum reuse to lower per-use cost. Formworks that are easy to erect and the strip reduce the overall completion of the project which leads to an early collection of revenues to be generated from the building or other structure. Such economic benefits are obtained when the formworks are modern and efficient. Maximum reuse is obtained when the formworks materials are durable and handled well. The traditional formworks which need many blows of a hammer to strike will not be durable as the material is threatened. Hence innovative formworks which can be easily stripped, more durable, and reusable should be used to ensure formwork economy.

2.7.2 Quality

Formwork should have good quality in terms of strength, durability, and rigidity and it should be safe to workers and concrete structures and should possess good efficiency in operation, easy to handle and dismantle, and should be economical. It should be strong enough to withstand the dead and live load. Therefore, choosing the correct formwork becomes essential in construction. Incorrect selection of formwork lead to an increase in cost and time overrun in the construction project. Different types of formworks are available in construction. Among which choosing an appropriate system of formwork is a crucial factor in the successful completion of a project in terms of time, cost, quantity, and safety (Rajeshkumar et al., 2020).

Many concrete-related problems such as discoloration, stains, and dusting are attributed to concrete formwork. Also, some deformed concrete surfaces are due to deformed formwork systems caused by repetitive reuse and inadequate support of formwork. when the surface of the concrete is good, the cost of finishing to be applied on the surface also be less. On the other hand, when concrete surfaces are of less quality, which results from poor quality of formworks, the cost of grinding and plastering going be higher (Tarekegn, 2010).

The quality of the formwork itself has a direct impact on safety, accidents, and failures. Correctly designed formwork ensure that the concrete maintains the desired size and shape by having the proper dimensions and being rigid enough to hold its shape under the stresses of the concrete. The quality of the resulting concrete is dictated by the quality of formwork materials and workmanship. Many concrete-related problems such as discoloration, stains, and dusting are attributed to concrete formwork. Also, some deformed concrete surfaces are due to deformed formwork systems caused by repetitive reuse and inadequate support of formwork.

Also, insufficiently tight joints leak cement paste. The surface of the concrete thus be disfigured by fins of the cement paste, and honeycombing may result adjacent to the leaking joints. The final shape of the formwork in contact with the concrete should be so arranged and jointed as to produce a concrete surface of good appearance. Wires, nails, screws, and form surface flaws must not be allowed to disfigure the concrete surface. In some cases, a provision of special form lining may be necessary to achieve the desired surface finished (Krohn, 2011).

2.7.1.1 Requirement of Formwork in Quality Consideration

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 dead weight, live load, and hydrostatic pressure (Tessema, 2019). All components should be designed to cater to the most severe loads that are likely to be imposed on the formwork. To achieve this, the design should be done by a person competent in formwork design. The strength of each item of formwork material contributes to the overall safety of the temporary structure (Tarekegn, 2010). The quality of the structural finish of the concrete is to be adequately addressed by the strength of the formwork as well as its resistance to deformation. The architectural finish of the concrete depends on the sheathing material used. The sheathing materials such as plywood, steel, aluminum, and rubber should be appropriately chosen based on the required finish and feasibility (Dinesh & Soundararajan, 2017).

Accuracy: Formwork must be accurately set out so that the resulting concrete product is in a right place and is of correct shape and dimension. All joints in formwork must be either close-fitting or covered with form tape to make them grout tight. While grout leakage occurs, the concrete leak at that point. Leakages cause the honeycombing of the surface (Dinesh & Soundararajan, 2017).

In general, formwork should be built to an accuracy greater than that desired in the finished concrete structure or element. All support structures should ensure that this accuracy is maintained until the concrete has hardened. The accuracy required may affect the selection of the material from which formwork is to be built as some materials may be finished to tighter tolerances than others. All joints should be sealed to stop grout leaking from the formwork (Tarekegn, 2010). Modern formwork system has great advantage on such kind of quality requirement.

Stiffnes**s:** Formwork should not bow, bulge, sag, or otherwise move in such a way that the completed concrete element is outside the tolerances imposed for the work. The formwork designers should detail the units to have adequate stiffness, but site personnel is responsible for ensuring that the correct, good quality materials are used in the proper manner (Tarekegn, 2010).

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 (Sharmila & Christober, 2016).

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 (Arslan et al., 2005).

Finish and reuse potential: The form or molding material must be selected to be capable of creating a uniform, smooth, straight edges and desired concrete. At the same time, it should also achieve the required number of reuses for economical purposes. This may need minimizing nailing as much as possible to required, because nail holes may affect further use of timber formwork. The formwork material must be strong and capable of producing a good surface finish (Tessema, 2019).

Discoloration: may have been caused by differences in form sheathing absorbency. Absorbent forms darken the surface concrete because they absorb water, reducing the water-cement ratio. Variable absorbency of unsealed plywood, for instance, can cause blotchy-looking surfaces. Differences in the type of form release agent, or application rate, may also account for the color variations. So, the type and kind of formwork system depend on the discoloration of concrete.

Dimensional conformity: The dimensional conformity of formed concrete is often very important, because services, aesthetic finishing, and other successive building activities affected when concrete elements are skew, out of square, out of plumb, or not within dimensional tolerances. When the workmanship is removed from the equation, the two factors left to account for the dimensional conformity of formwork are the panel design and the assembly components. A common way to control dimensional conformity of concrete elements is to specify limits of deflection in a formwork member to require it to be less than some fraction of its span (Tessema, 2019).

Surface regularity and smoothness: A key point to consider in the surface regularity and smoothness of concrete is that formed concrete, when properly placed and vibrated, take the same surface appearance as the form within which it was molded. So once again, proper management and protection of formwork are essential to attain a quality formed concrete surface (Tessema, 2019).

2.7.1.2 Factors that Affect Surface Quality of Concrete

According to Tessema (2019), two major factors decide how well the concrete will look in the final result. One is the quality of the formwork and the other is how the concrete is placed and compacted.

The quality of surface finished concrete is affected by the material of the form. The quality of the resulting concrete can be dictated by the quality of formwork materials and workmanship. A correct combination of form material and oil or other parting compounds can contribute materially to eliminating air holes or other surface imperfections in the cast concrete. Many concrete surface problems such as discoloration, stains, and dusting are attributed to concrete formwork. Also, some deformed concrete surfaces are due to deformed formwork systems caused by repetitive reuse and inadequate support of formwork. The formwork and material quality have a major impact on the off-form concrete quality unless it is designed and built accurately so that the desired size, shape position, correct location, quality, and finish of acceptable quality of the cast concrete are attained.

Another factor is concrete placement and compaction the impact of placing fresh concrete can vary depending upon the height of the forms or the height of the drop of concrete. Placing concrete into forms of small height have low impact, but on higher structures, especially walls, the incoming concrete apply additional force to the plastic concrete already in place which transmit this added pressure to the forms. The faster the rate of placement the greater is the impact pressure likely to be on the formwork system. Unless necessary considerations of these additional forces are concerned, they could cause deflection of forms, and hence, bulged concrete surface and alignment problems might be effects. Therefore, forms and ties should have sufficient strength to withstand these impact loads and the rate of placing should not be greater than their safe load capacity. The other related factor which has an impact on the formwork is vibration and consolidation of concrete. Consolidation of concrete by internal vibration causes temporary lateral pressures. Although the information on magnitude is limited, care should be taken not to damage or break any of the ties while vibrating because this would transfer more load to the other ties and load the forms unevenly. External vibration with form vibrators increases loads on formwork systems even higher and causes variation of lateral pressures. The forms materials, in turn, affect the vibration of fresh concrete. For example, wood forms tend to absorb vibration but steel forms tend to reflect the vibrations and bounce them back (Tessema, 2019).

2.7.3 Speed and Time

Speed of construction is defined as the rate at which concrete building is raised and can be expressed in terms of the number of floors erected per week or month. Speed of construction can be also measured in terms of inches or millimeters of concrete poured per hour. Formwork operations can control the pace of construction projects. Formwork is typically supported by several levels of shores and reshores that carry the loads until the concrete gains enough strength to support its weight and all other externally applied loads. Shores are vertical members made of wood that support recently built concrete that has not developed full design strength. On the other hand, reshoring occurs when the original shoring is removed and replaced in such a manner as to avoid deflection of the cured concrete. As a result, several floors may be blocked, preventing the progress of any other construction activities. A faster formwork cycle from erection to stripping would allow for faster removal of shoring and reshoring and faster overall project progress. Reuse of a form is only fully efficient in case the form can be stripped and rebuilt without too much labor time or damage to the form (Krohn, 2011).

A faster floor cycle is always desirable for contractors and owners. For contractors, a faster floor cycle allows the contractor to finish on schedule or earlier which reduces the overhead cost. For the owner, a faster floor cycle reduces the short-term financial charges and allows early utilization of the constructed facility feasibility (Dinesh & Soundararajan, 2017).

The physical activities in the formwork life cycle are represented by these steps: fabricate formwork, erect formwork, and remove the formwork.

The first appropriate formwork material is chosen and fabricated to get the desired shape and size. After that the elements erected, concrete cast and forms going to be stripped. By providing additional shores (reshore) it is possible to remove forms as early as possible. Finally, reshores removed after concrete supports its weight and additional live loads (Tarekegn, 2010). In addition to this the transportation time, concrete plastering time, and concrete chiseling time should be considered. But the above consideration depends on the formwork system.

2.7.4 Safety

Building construction activities are generally associated with high risks and hazards. Building construction workers are also generally exposed to an excessive risk of being injured at work. carpentry (including formwork and roofing) take the first rank from different building trades in recording high-risk level (Okoye, 2018).

Formwork operations are risky, and workers are typically exposed to unsafe working conditions. Partial or total failure of concrete formwork is a major contributor to deaths, injuries, and property damages within the construction industry. Forms must be built with sufficient strength and factors of safety so they are capable of supporting all dead and live loads without collapse or danger to workers and the concrete structure. A formwork failure is a floor formwork system filled with wet concrete that has its weight at the top and is not inherently stable. As a result, one of the most frequent causes of failure is from effects that induce lateral forces or displacement of supporting elements; therefore, inadequate cross-bracing or horizontal bracing is one of the most frequently involved factors in formwork failure. Also, vibration is one factor that can trigger failure through inadequate bracing (Krohn, 2011).

In addition, formwork failures result from faulty formwork structural design, inadequate shoring and reshoring, improper construction practices during construction, unstable support or mudsills, and insufficient concrete strength to sustain the applied load after construction. The failure at one point in the formwork can become an extensive collapse through a chain reaction. Structural collapses and failures involving concrete structures account for 25%of all construction failures. More than 50% of concrete structure failure during construction is attributed to formwork failure. Though there is no proper documentation of the construction failure in Ethiopia, the percentage of collapses that are caused by defects in formwork construction is not less than 50% and 79% of the respondents have a recent record of injury and death which emanates from formwork construction in Ethiopia. (Tarekegn, 2010).

2.7.4.1 Safety Requirement in Formwork

To ensure the safety of the structure and the protection of the workers, formwork must be designed strong to carry the full load and side pressures from freshly placed concrete, together with construction traffic and any necessary equipment and avoid deflection, deflection is the most important consideration for the design of formwork, the limit for deflection varies according to the class of the work. (Krohn, 2011).

Workers are aware of the general health risks associated with working with concrete and concrete additives, and their effects such as dermatitis and silicosis. People may, however, overlook some other chemical hazards, especially when preparing forms (Construction Safety Association of Ontario, 2008). The possible health hazards related to formwork assembly, preparation, and stripping are described in subsequent sections;

Sawdust: respiratory hazards when plywood and other form materials are cut, wood dust and epoxies are released. Cutting plywood with laminates of hardwoods and softwoods produces particles that can induce asthma and bronchitis if inhaled. Adhesives containing formaldehyde can become airborne and breathed, causing irritation.

Form oil: Health risks include respiratory and other ailments. Before the concrete is poured, employees will be subjected to form release oil sprayed on the plywood. Oils in various forms can be employed, and the chemical content varies greatly. Fuel oil, vegetable oil, water-based or oil-based solvents, or naphtha are examples of chemicals (Construction Safety Association of Ontario, 2008).

Physical and another related hazard:

Falls – They are a major hazard because they are potentially fatal. Cramped work areas, inadequate access, failure to install guardrails, failure to use fall arrest systems, tools or material left underfoot, and surfaces slippery from form oil can all lead to falls. Ladders are also frequently involved in falls (Construction Safety Association of Ontario, 2008).

Materials handling – The activity most frequently connected with the injury. Improper or excessive materials handling can result in sprains, strains, and overexertion in shoulders, arms, and back, as well as bruises, abrasions, and crushed fingers.

Struck against – Common because formwork operations are constantly changing and involve the movement of heavy, awkward, and pointed components. Wales, beams, panels, snap-ties, nails, bolts, and rebar can cause punctures, cuts, contusions, and abrasions.

Struck by – is a common cause of injury. Rebar, formwork panels, concrete buckets, and other material hoisted overhead can strike workers. Struck-by injuries can also be caused by hammers, stakes, wedges, and material such as joists and panels during stripping. Another common hazard occurs during stripping of formwork in which loose formwork elements fall on workers under the concrete slab being stripped (Tarekegn, 2010).

Electrical contact – Power tools, extension cords, and temporary supply and wiring systems, used under less-than-ideal conditions – mud, groundwater, wet excavations, fresh concrete – can lead to ground faults, short circuits, and shock hazards. Ground fault circuit interrupters are legally required for portable tools used outdoors or in wet locations (Construction Safety Association of Ontario, 2008).

Collapses – Even with advanced methods of design and installation, there is always the risk that formwork, slab forms, wall forms, and other large components can come loose, slip out of place, or fall over, striking, or crushing workers underneath (Tarekegn, 2010).

Health hazards – The spraying of form oils and curing compounds can irritate the lungs. Contact with these chemicals can irritate the skin, leading to redness, inflammation, or dermatitis. The same conditions can result from the abrasive/corrosive effect of skin contact with concrete or cement, especially when inadvertently left inside boots all day.

Environmental conditions –Wind can be a major hazard. Handling sheets of plywood becomes more difficult, panels may require more bracing, and hoisting gets harder, especially with large panels or tables (Tarekegn, 2010).

Dust and concrete – Blowing dust and flying concrete particles during the chipping or cleaning of formwork can injure unprotected eyes.

Access equipment – Access equipment such as ladders and scaffolds are involved not only in falls but in slips, trips, and other accidents. Hazards include ladders not tied off, workers carrying materials while climbing, ladders obstructed at top or bottom, scaffolds not completely decked in, and scaffolds erected or dismantled without fall protection.

Lighting – Inadequate lighting can create or aggravate hazards when workers install or strip forms in dark areas or place concrete at night (Construction Safety Association of Ontario, 2008).

2.8 Formwork Stripping

Forms can usually be removed when the concrete is strong enough to carry its weight and any construction loads have to support without deflection beyond specified limits. Determination of the time of form removal should be based on the effect on the concrete. When forms are stripped there should be no excessive deflection or distortion and no evidence of damage to the concrete due to either removal of support or to the stripping operation When forms are removed before the specified curing is completed, measures should be taken to continue the curing and provide adequate thermal protection for the concrete. Supporting forms and shores should not be removed from beams, floors, and walls until these structural units are strong enough to carry their weight and any approved superimposed load. In no case should supporting forms and shores be removed from horizontal members before the concrete has achieved the strength specified by the engineer/architect (ACI Committee 347, 2004).

2.8.1 Ethiopian Building Code of Standard Recommendation

According to EBCS-2 (1995), The formwork shall be removed slowly, as the sudden removal of wedges is equivalent to a shock load on the partly hardened concrete. The time at which formwork and falsework is removed shall be determined by consideration of the following criteria: the stresses that will be induced in the concrete when the formwork/falsework has been removed, the concrete strength at the time of removal, the ambient conditions, and the measures available to protect the concrete once the formwork is removed and the presence, or otherwise, of re-entrant angle formwork, which should be removed as soon as possible, while complying with other removal criteria

The formwork shall not be removed before the structure has gained enough strength to safely carry all possible loads. The time at which formwork is struck will be influenced by the following factors: concrete strength, the stress in the concrete at any stage in the construction period, curing, subsequent surface treatment requirements, and presence of re-entrant angles requiring formwork to be removed as soon as possible after concrete has set to avoid shrinkage cracks. Provided the concrete strength is confined by tests on cubes stored as far as possible under the same conditions, formwork supporting cast-in-situ concrete may be removed when the cube strength is 50% of the nominal strength or twice the stress to which it will then be subjected whichever is greater, provided that such earlier removal will not result in unacceptable deflection such due to shrinkage and creep. And the time between casting and removal of the formwork depends mainly on the strength development of the concrete and the function of the formwork. In the absence of more accurate data, the following minimum periods are recommended in Table 2.4.

Table 2. 4 EBCS standard stripping time

Structural member	Time
For non-load bearing parts of formwork (e.g., vertical formwork of beams; formwork for columns and walls)	18 hours
For soffit formwork to slabs	7 days
For props to slabs	14 days
For soffit formwork to beams	14 days
For props to beams	21 days

Where sliding or climbing formwork is used, shorter periods than those recommended may be permitted (EBCS-2, 1995).

2.8.2 American Concrete Institute Recommendation

American Concrete Institute recommends that engineer specified criteria based on strength gain is used to determine form removal time. Shorter stripping times listed for a live load to dead load ratios greater than 1.0 are the result of more reserve strength being available for dead load in the absence of live load at the time of stripping. The form stripping time as shown in Table 2.5.

Table 2. 5 ACI General Guidelines for Form Stripping Times (ACI Committee 347, 2004)

Member	**Time**	
Walls	12hrs	
Columns	12hrs	
Sides of beams or Girders	12hrs	
Pan joist forms† 30 in. (760 mm) wide or less Over 30 in. (760 mm) wide	3 days 4 days	
Joist, beam, or girder bottoms	Structural live load	
	< dead load	>Dead load
Under 10ft(3m) clear span between structural supports	7days	4days
10 to 20ft clear span between structural supports	14days	7days
Over 20 ft (6 m) clear span between structural supports	21days	14days
One way floor slabs		
Under 10ft clear span	4 days	3 days
10 to 20ft clear span	7 days	4 days
Over 20ft clear span	10 days	7 days
Arch centers	14 days	7 days
Two-way floor slabs	Contingent on reshores being placed immediately after stripping.	

2.8.3 Building and Transport Construction Design Authority Recommendation

No undue deflection or damage whatsoever shall be caused to a structure by the removal of formwork. In no circumstances, shall formwork be struck until the concrete attains a cube strength of at least twice the stress to which it may be subjected at the time of striking No formwork shall be removed until the concrete has hardened sufficiently.

Concrete which is damaged by premature removal or collapse of the formwork shall be made good. Formwork shall be removed without such shock or vibration as would damage the concrete. Before the soffit formwork and struts are removed, the concrete surface shall be exposed where necessary, in order to ascertain that the concrete has hardened sufficiently (BaTCoDA, 1991).

Table 2. 6 BaTCoDA recommendation for stripping formwork

Members	Period of removal:
Vertical formwork to columns, walls and beams	16 hours
Soffit formwork to slab	21 days
Props to slabs	14 days
Soffit formwork to beams	21 days
Props to beams	14 days

2.8.4 British Standard Recommendation

The type of material used for the formwork and the gain in strength of the concrete influence the stripping time of the formwork. The strength gain is governed by the mean concrete temperature, the mix design and method of curing. when finish and uniform color are important, a consistent timing regime of striking and curing will be critical. A minimum value of in-situ concrete cube strength of 2 N/mm^2 is generally recommended to reduce the risk of mechanical and frost damage to finishes while striking vertical formwork. A minimum period of 8 hours at 20^0 o c for unsealed plywood or 6 hours at 20^0 c for impermeable formwork such as overlaid or film-coated plywood and steel forms. In practice, if the temperature of concrete is above 10^0 C overnight the vertical formwork can be stuck the next morning. Summary of the BS recommendation for concrete made with Portland cement 42.5N/mm^2 and sulfate resisting Portland cement 42.5N/mm^2 are shown in Table 2.7 (BS 8110, 1997).

Table 2. 7 Minimum period before striking formwork as per BS (BS 8110, 1997).

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

2.9 Sustainable Formwork System

2.9.1 Sustainable Construction

The term “sustainable construction” was originally proposed to describe the responsibility of the construction industry in attaining sustainability. And sustainable construction means ‘creating a healthy built environment using resource-efficient, ecologically-based principles’ (Taher Ahmed et al., 2014).

The global concern of sustainability concept has interacting wider recognition. The rising populations and economic developments are threatening a progressive degradation of the earth's resources (Ahmed et al., 2009). Sustainable development is an issue of worldwide concern, such as pollution or global warming. It has been defined as: to meet the needs of the present without compromising the ability of future generations to meet their own needs. Within the construction industry, advanced design and sophisticated technologies are providing the breakthrough for the growth of real estate and construction development (Gambatese et al., 2014).

The field of sustainable development is conceptually broken into three constituent parts: environmental sustainability, economic sustainability, and socio-political sustainability. Sustainable Construction aims to apply the sustainable development principle to the construction industry by providing ways of buildings that use less virgin material and less energy, cause less pollution and less waste but still provide the benefits that construction projects have brought us throughout history. Such construction processes would bring environmental responsibility, social awareness, and economic profitability objectives to the fore inbuilt environment-related projects. A sustainable building can be defined as those buildings that have minimum adverse impacts on the built and natural environment, in terms of the buildings themselves, their immediate surroundings, and the broader regional and global setting. Sustainable buildings are considering the entire life cycle of buildings, taking environmental quality, functional quality, and future values are taken into account (Ahmed et al., 2009).

The Organisation for Economic Co-operation and Development (OECD) project has identified five objectives for sustainable buildings: Resource efficiency, energy efficiency (including Greenhouse Gas Emissions Reduction), pollution prevention (including Indoor Air Quality and Noise Abatement), harmonization with the environment (including Environmental Assessment) and integrated and systemic approaches (including Environmental Management System).

2.9.2 Sustainable Formwork Construction

According to Al-Ashwal et al. (2017) Concerning the sustainability in formwork concrete construction, it is encouraged to follow most, if not all, sustainable construction criteria. They must be managed and assessed using multi-criteria means to facilitate the decision on the sustainability performance measurement. Sustainable development is “the Development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Sustainability includes social, economic, and environmental pillars as shown in Figure 2.9.

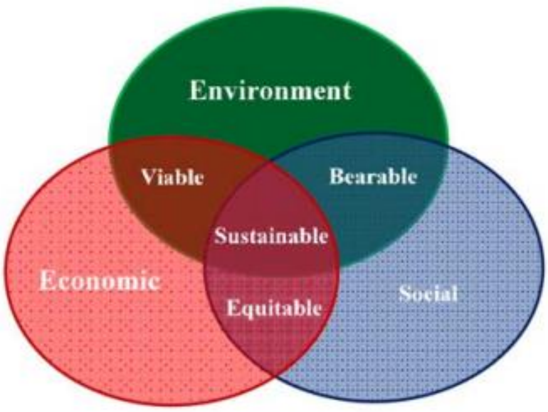


FIGURE 2. 9 Sustainability three main pillars (Al-Ashwal et al., 2017).

The construction should have a holistic design to meet the green building specifications to include materials used, energy consumption, air quality, and adequate space. However, in the current practice, the interest in the temporary work system is more due to its cost-effectiveness ignoring other sustainability factors. This ignorance may happen due to several factors such as the focus on direct cost-effectiveness and the level of awareness of the influence of the formwork type on the overall sustainability performance of the construction project (Al-Ashwal et al., 2017).

2.9.3 Sustainable Formwork System Benchmarks

According to Ahmed et al. (2009), sustainability benchmarks which are related to formwork systems are divided into three main categories refer to sustainable principles main aspects which are economical, social, and environmental. The sustainable principles main aspects and measurement of each sustainable benchmarks are as follows:

2.9.3.1 Environmental Benchmarks

This aspect concern about the construction process affects on the local and global environment, which includes;

Waste generation: The construction industry has long been regarded as one of the major contributors of negative impact to the environment, due to the high amount of waste generated from the construction, demolition, renovation, and activities associated with construction. The major components of construction wastes generated are wood(formwork and falsework), concrete, bricks, metals, and others such as waste generated from finishing works, such as packaging of materials, ceramic tiles, and insulation (Lau et al., 2008).

Energy and resource consumption: Energy and resources saving is minimizing energy and resources consumption with the least negative structure impact on the environment. In construction, taking into account the principles of sustainable development, we should address all stages of the structure life cycle, from research and design to construction work, operation and disposal. Of course, at these stages, much attention should be given to the design. According to statistics, the share of the construction is about 45% of the global energy consumption and 40% of the materials consumption (Kiyanets, 2016). So, the formwork system that is going to be used for construction should have less energy and resource consumption.

Noise pollution: Noise is the most common form of pollution that impairs the living environment; construction noise may be generated by various types of construction machinery, construction process due to multiple devices simultaneously exacerbated the effects of noise;

scaffolding and formwork handling, installation and noise removal can also be formed (Zhang, 2015).

Using renewable material: Choosing materials that use renewable energy sources in their production significantly reduces the environmental impact of pollution and waste (Almusaed et al., 2020).

Formwork reusable: One approach to cut building expenses is to reuse formwork for concrete. After five reuses, the initial cost of formwork materials reduced by 40%. The simplicity with which formwork may be removed from concrete adds to its cost-effectiveness. With this in mind, formwork designers must stay current with formwork production technology so that quality may be maintained while also considering the cost-effectiveness of recycling concrete formwork.

Waste efficiency: It should be pointed out that waste management is a crucial part of the construction industry. In contrary to waste control, waste management involves the investment and development in new technology, products, processes, and training that can reduce waste (Cheng, 2014).

Material efficiency: formwork material efficiency means in other words its utilization of formwork. it can be easily stated, that have profound knowledge of monolithic concrete works' technology and formwork systems' features results in choosing an appropriate system to perform concrete works. This gives rise to a reduction of labor costs, improving the quality and safety of produced concrete, achieving faster work cycles. Formwork selection is, thus, the first problem, that should be considered to improve formwork utilization on the construction site (Krawczyńska-Piechna, 2017).

Impact on the local environment: Environmental aspect is one of the important criteria that define and determine sustainability performance for concrete formwork systems (Taher Ahmed et al., 2014). Modern formwork systems are extremely efficient, and the impact of formwork on the environment is small compared with that of concrete.

2.9.3.2 Economic Benchmarks

The economic aspect of sustainable construction focuses on the importance of stable economic growth. The capacities of the natural environment are considered by adopting measures from fair and rewarding employment through to competitiveness and trade. The economic indicators for a sustainable formwork system include; Labour cost: concrete formwork labour costs constitute over 1/3 of the total cost of concrete construction (Naik et al., 2015).

Material and equipment cost: The main materials of the reinforced concrete work are concrete, reinforcement, and formwork, so the total cost can be approximately distributed among the three items. The economy should be considered when planning the formwork for a concrete structure (Krohn, 2011).

Installation cost: Building concrete forms usually represents a significant portion of the total cost of concrete work, as this is one of the most labor-intensive aspects of the job that need to identify the type of formwork that used, how it installed, and its cost. The majority of the cost is contributed by the formwork labor which is the cost associated with the installation and removal of the formwork (Zakiah et al., 2014). And maintenance cost: Formwork should produce a total quality of work that requires minimum maintenance and durability is a major consideration (Tessema, 2019).

Life-cycle cost: Life cycle costs (LCC) in general consist of an initial investment (usually construction costs) and the follow-on costs (ordinary payments, i.e. energy, utilities, cleaning and maintenance, irregular costs for renewal or replacement), while some life cycle costing methods also include the costs of demolition (Schneiderova-heralova, 2018). And construction time: when the construction timeless the cost of construction could be minimized because of the time value of money.

Cost of energy use: construction activities operated on-site, construction workers consume different amounts of energy while processing different construction tasks (Liu & Gambatese, 2018). And resale value: salvage value is defined as an estimated or expected resale value of an asset at the end of its useful life. It is a parameter that is associated with the depreciation of the assets used in the business. another economical benchmarks are competitive cost: competitive pricing is the process of selecting strategic price points to best take advantage of a product or service-based market relative to the competition.

2.9.3.3 Social Benchmarks

Social sustainability concentrates on responding to the needs of people which providing high customer satisfaction and working closely with clients, suppliers, employees, and local communities (Ahmed et al., 2009). Here are some of social measures:

Safety operating to workers and third parties: When selecting a formwork system for a specific operation, consider the safety of the people that are installing, utilizing, and disassembling the formwork. Consider stability, strength, and the risk of falls, falling items, and manual labour in particular. The best proprietary systems include built-in safety features that reduce the chance of falls and dangerous manual operations. Customer satisfaction, on the other hand, is described as a metric that measures how satisfied consumers are with a company's goods, services, and formwork skills.

Better standard for the local community: Helping local communities and society to better meet basic human needs; improve standards of health and living, and develop financial discipline help the nation achieve sustainable progress. And also, direct employment, the selection of formwork that is related to employment generation. The amount of labour used in the formwork. Another benchmark to measure formwork that is socially sustainable is safety and fire resistance: Fire safety is measured in terms of fire resistance. Fire resistance is defined as a duration during fire exposure the structure not fail or the structure not become hotter than a specified temperature (Zakiah et al., 2014).

2.10 Formwork Labour Productivity

2.10.1 Productivity

Productivity is an effective tool in determining the efficiency of the construction site. It enables the companies to monitor their performance against site performance. The selection of the right formwork for the project increases productivity saves time and also helps in achieving profit for the firm (Prathul et al., 2015).

As Senarth Jayasinghe & Fernando (2017), Productivity is an index that measures output relative to the input, used to produce them. Productivity fosters satisfied clients, attracts investment, and contributes to economic growth and well-being. In the construction industry, it enables the efficient use of resources such as material, labour, and capital, and labour productivity stands as a measuring tool since most activities are labour.

2.10.2 Formwork Construction Labour Productivity and its Measurement

Labour productivity is crucial for the effective and efficient utilization of construction-related resources with minimum waste. Labour is strongly influenced by formwork since it involves a significant portion of the cost of a concrete structure. Aluminum system formwork has been identified as the ideal cost-effective tool to enhance productivity for high-rise housing projects and it is a popular formwork system in urban regeneration projects or low-cost housing projects (Senarath Jayasinghe & Fernando, 2017).

Labour productivity is the measure of the efficiency of labour in turning input, being expressed as man-hours, to output (Tewodros, 2006). And the quantity of work done in a month is determined using quantity estimation. The number of labours worked in a month and average working hours are taken from the labour report. Labour reports are updated on a daily basis from which monthly labour report is prepared. Constraints that affect the overall productivity are also noted. Unit of productivity is square meters per man-day’s (Prathul et al., 2015).

2.11 Summary of Literature Review

The construction industry involves various resources such as manpower, machinery, money, materials. The materials itself contribute 70% of the overall cost of the project. Formwork is one of the important materials in the construction site which affects quality and safety (Shaik & Rahul, 2019).

A formwork system is defined as the total system of support for freshly placed concrete as well as supporting members, hardware, and necessary bracing (Dinesh & Soundararajan, 2017). Formwork systems can be generally classified as Vertical Systems (wall and column), Horizontal Systems (slab and beam), and Special Formwork Systems (Gaddam & Achuthan, 2020).

Formwork is made from different materials such as conventional (timber, plywood), steel formwork, aluminum formwork, and glass-reinforced plastic. In designing and building formwork, economy(cost), quality, speed(time), and the safety those four major objectives must be considered (Krohn, 2011).

Kumkang kind aluminum formwork system is in today’s date is most trustful, safe, and up-to-date formwork technology available in the market. This is a unique formwork system in which walls, columns, beams, staircase, balconies along door and window opening are cast in place (Pujari et al., 2018).

From the literature, the kumkang kind aluminum formwork is better technology with great features and advantages in the aspect of -Speed, Quality, Safety, Easy assembly, Mobility, Freedom of design and Jobsite planning, Durability, No need for skilled workers, Cost reduction, Faster construction, High Labor Productivity and Environmentally friendly.

Formwork system has an important role in construction, by selecting the appropriate formwork system could lead to sustainable construction (Gaddam & Achuthan, 2020). According to Ahmed et al. (2009), sustainability benchmarks which are related to formwork systems are divided into three main categories refer to the sustainable principle's main aspects i.e., economical, social, and environmental.

According to Senarth Jayasighe & Fernando (2017), labour productivity is crucial for the effective and efficient utilization of construction-related resources with minimum waste. Labour is strongly influenced by formwork since it involves a significant portion of the cost of a concrete structure.

According to Tessema (2019) Usually, the formwork scenario in the Ethiopian building construction industry especially in local construction companies can be stated as Conventional and modern conventional forms are most commonly practiced which are labor-intensive, time taking, unsafe, and with surface finishing in need of additional treatment. Also, 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 a corrugated iron sheet on plywood to stop leakage of concrete paste through the joints.

2.12 Research Gaps

From the review of literature under related works, the most important aspects that decide the success rate in construction are Time, Speed, Quality, Cost, and Safety of works but usually the construction firms in Ethiopia are lack of capacity and capability too, in delivering the project on time, with a budget and expected quality. Formwork systems are key factors that decide the time, speed, quality, and safety of construction. The formwork scenario in the Ethiopian building construction industry especially in local construction companies, Conventional and modern conventional forms are most commonly practiced which are labor-intensive, time taking, unsafe, and with surface finishing in need of additional treatment. Moreover, high wastage of formwork materials, Low labor productivity, Higher wastage of concrete, and Unskilled labor due to a lack of willingness in construction companies to give training, fearing laborers would leave at the end of the training, and hence have chosen to continue with low productivity labor.

Alternative formwork materials such as plastic, glass-reinforced plastic, fabric is not well known and used by local construction companies. Steel panels and timber boards are the most commonly used formwork materials in Ethiopia. In addition to this aluminum formworks also not well known and practicable.

As a result, aluminum formworks must consider as a replacement for conventional formworks in order to improve construction features and overcome the limitations of conventional formworks. One of these aluminum formwork kinds is Kumkang, which is being used for the first time in one of the federal housing projects. Furthermore, there has never been any research done in Ethiopia on the performance and applications of this type of formwork.

For the reasons stated above, a study of the performance of kumkang aluminum formwork is required.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the methodology adopted for this study. As stated earlier in chapter one, this research aims to evaluate kumkang aluminum formwork performance in federal housing corporation projects. To achieve the aim of this study, one of the important areas to consider is the kind of method that is adopted.

In this chapter the research area, design, and methods as well as the collection, analysis, and presentation techniques with its validity and reliability measurement is documented to address the key issues raised by the specific objectives. It also explains the data analysis method used in analyzing the data, and how the sampling of the population was determined.

3.2 Description of Study Area

This research was conducted in Addis Ababa federal housing corporation project. Federal Housing Corporation is reestablished in March 2009 hereinafter called corporation is recognized as a public enterprise that was the name Rental house Administration agency since Tikimit 28/1968. The Federal Housing Corporation (FHC) with the vision to share and increase the responsibility of providing housing was given the role to undertake new housing developments. As part of the new role, the corporation plans to construct 16,173 housing units in three years between 2010 and 2012. These new developments are going to take place on the lands under the ownership of the corporation and new land to be granted from the city administrations of Addis Ababa and Dire Dawa.

Meanwhile, the kumkang aluminum formwork system has only been used in Addis Ababa federal housing gerji modern village project. Also, there are no current projects in Dire Dawa city, the research area was limited to federal housing corporation projects in Addis Ababa. Figure 3.1 shows the map of Addis Ababa city.

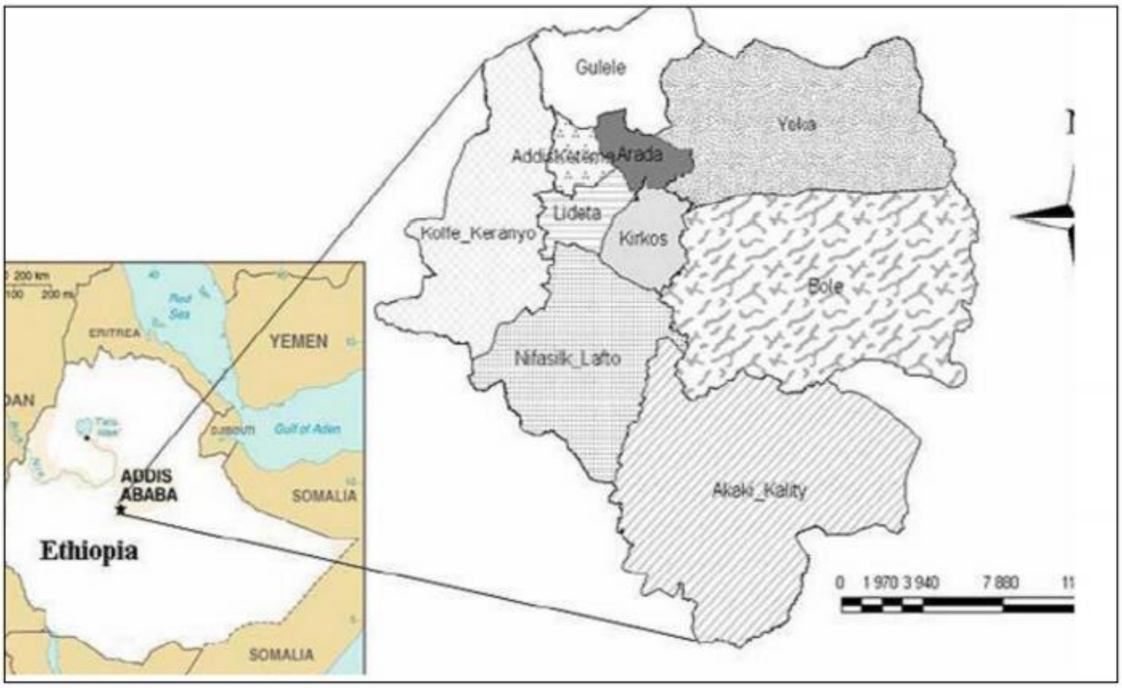


FIGURE 3.1 Map of Addis Ababa (Meron, 2016)

3.3 The Study Design

The research design for this study was both descriptive and exploratory nature. The research methodology is designed in a way that enables the collection of adequate information on the subject matter so that the research can properly answer and clarify the objectives. Therefore, the most known and familiar ways of data collection mechanisms are employed. The case studies were made to examining the federal housing ongoing project that was constructed by conventional system recently and the gerji village project for the purpose of comparison in terms of cost, time, quality of finished concrete, and labour productivity. And the literature review was compiled from reference books, articles, and related kinds of literature. It was used as a base to draw the primary data collection instruments. The primary source of data is obtained in the form of a survey questionnaire and interviews in order to attain the all the research objectives.

The main activities of the research design are summarized in the Figure 3.2: -

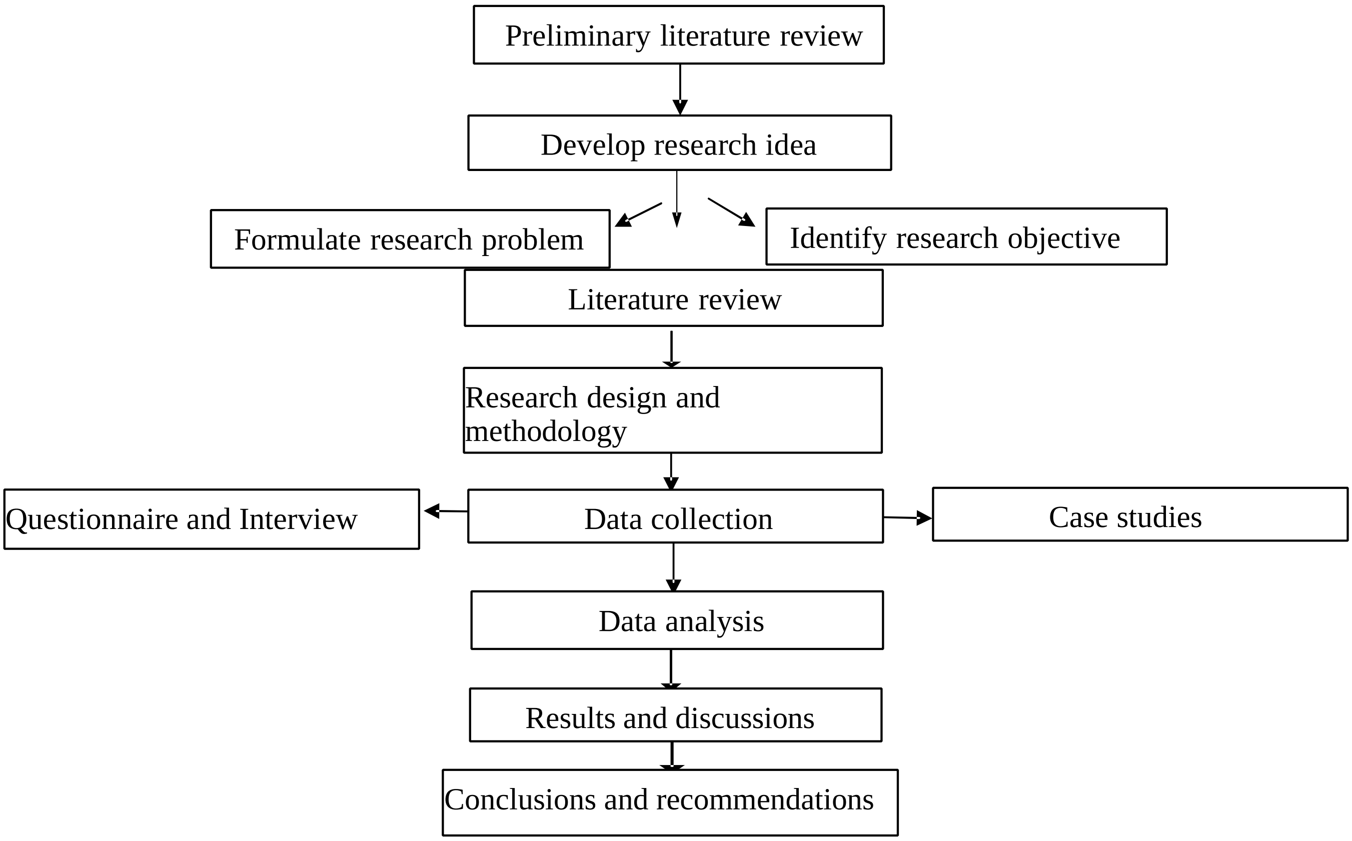


FIGURE 3. 2 Research design flowchart

3.4 Population and Sampling Technique

3.4.1 Target Population

The study population was based on the data acquired from the federal housing corporation office. Due to the formwork system which is applied by one of the federal housing projects, this study targets the projects which are owned by federal housing corporations that are ongoing constructed and their progress on structural part for purpose of comparison and to study the subject matter.

3.4.2 Sampling Technique

For this study, the census method of sampling technique was used. The Census method is the method of statistical enumeration where all members of the population are studied. Five ongoing construction project which construction progress was on the structural part owned by federal housing corporation recently. Because of the kumkang aluminum formwork adopt by one of federal housing project which is gerji modern village housing project by the meantime, in order to collect the required data, knowledge, and expertise on the subject matter and also to make a comparison between those projects, total ongoing federal housing corporation projects which is 5 projects was taken as a sample.

The project that was used for this study was a mixed-used apartment that had more than 9 stories around Kebena, Kokebe tsbeha, Tezenha hospital, and Misrak atekalay. And the gerji modern village project that had 10 blocks of B+G+10 apartment and 6 blocks of B+G+10 sky villas.

3.5 Sources of Data

In order to get sufficient and relevant information, Primary and secondary data are the two categories of data for research. For this specific research, both primary data and secondary data were collected.

Primary sources were used to collect enough information in the study area and primary data are collected from the above-mentioned samples through questionnaires and interviews. The study was also collected relevant information from the secondary data which were described or pre-printed in different books, reports, and company documents to draw the primary data collection instruments and case studies.

3.6 Data Collection Techniques

To collect the intended amount of data to attain the research objectives, a case study, questionnaire, and interview were conducted for this study.

3.6.1 Case Study

Case studies emphasize detailed contextual analysis of a limited number of events or conditions and their relationships. For this study, the case study was made on examining the federal housing ongoing project that was constructed by conventional system recently and the gerji modern village project to evaluate the performance of kumkang aluminum formwork in terms of cost, time, quality of finished concrete by comparing with conventional formwork construction and to assess the labour productivity of the kumkang aluminum formwork system the case study was taken on projects that are constructed through conventional formwork and kumkang aluminum formwork through monthly progress of labour productivity and based on productivity measures on each structural member was computed.

3.6.2 Questionnaires

Questionnaires were used as the main source of data collection. The questionnaires are self-administered whereby hand delivers to the respondents to complete the questionnaires themselves. The questionnaire was contained both closed and open-ended questions to give the chance for respondents to explain issues in detail. The main purpose of these tools was to collect information about the current practices and their perspective on the technology and to assess the safety, quality of finished concrete and sustainable perspective of the formworks see Appendix-B. The questionnaire ware conducted on 5 federal housing projects and 15 questionnaire papers were distributed on each project that means a total of 75 questionaries was distributed for 5 project managers, 5 counterpart engineers, 5 resident engineers,5 safety engineers,5 site managers,15 site supervisors, 10 office engineers, and 10 site engineers on the project site and also 5 project engineers and 10 senior office engineers from head office. The structure of the questionnaire is as follows:

Section one: it’s about the general information of the respondent. Section two: were asked what type of formwork materials are used in the company and their reason to use such kind of formwork material. Section three: it’s about the kumkang Aluminium formwork system and its practice on the site this helps to answer the first research questions (objective one). Section four: were asked about the formwork systems on the quality of finished concrete through common measurement of quality of finished concrete and the formworks perspective through those measurements to attain the second objective of the research. Section five: under this section the formwork safety practice and health and safety risk factors were computed to attain the second objective of the research. This helps to know which kind of formwork has better advancement concerning safety. Section six: under this section formwork sustainability criteria and their elements were computed under a different type of formwork. this helps to know which type of formwork have better benefit and barriers through construction sustainability which means the third objectives.

3.6.3 Interviews

Interviews were also used as one of the sources of collecting primary data. One to one interview was held with 4 project managers, 4 site supervisors, 7 office engineers, 3 federal housing corporation workers, and 2 Ministry of urban development and construction top managers, and 3 construction management directors. All the respondents have experience of 5 years and above.

This assists in explaining and clarifying the information required for attaining the research objectives. The interview asked for different parties seems as follows: -

The interview which held in gerji village project helps to understand the trend of modern formwork system in Ethiopia and to attain all research objectives. For other federal housing projects, the interview was asked to answer the economic viability of the modern formwork system from their perspective. The interview with MoUDC helps to know their role and contribution concerning such kind of formwork and is there any support for the contractors for using such kind of formwork and whether or not to have a follow-up on them. This interview helps to know understanding and implication of MoUDC as of government side. Since federal housing is the client, the interview also holds with the federal housing corporation to get information from the client-side. This interview helps to know their level of satisfaction on formwork system since one of the sustainable elements is customer satisfaction and also to recommend the formwork system for which construction better could be in our country context and housing problem see Appendix-D.

3.7 Data Analysis Techniques

In this study, Analysis of data collected by questionnaire survey were undertaken using Statistical Package for Social Science (SPSS) version 20 to display findings and helps to make it easier. In addition to this Microsoft Excel 2007 and Origin Pro was used for supporting the data analysis.

For safety factor survey questions the Likert Scales had been used to rank the responsive element. Five scales which are 5=Almost certain (Continual or repeating experience), 4=frequent (Common occurrence), 3=occasional (Possible or known to occur), 2=remote (Not likely to occur under normal circumstances), and 1=rarely (Not expected to occur but still possible). The description analysis then applied whereby the mean of results thereafter being differentiated using Average Index Analysis. The rating scales used for the result of the questionnaire in this research are as shown in Table 3.1.

Table 3.1 Respondents' demographics

Rating	Rating scale	Classification
1	Almost certain	4.50 ≤ Average Index, I < 5.00
2	Frequent	3.50 ≤ Average Index, I < 4.50
3	Occasional	2.50 ≤ Average Index, I < 3.50
4	Remote	1.50 ≤ Average Index, I < 2.50
5	rarely	1.00 ≤ Average Index, I < 1.50

According to Rosil et al. (2012), the rating scales used for the result of the questionnaire in this research and the average index is calculated based on the Equation 3.1 as follows;

Average Index,

$$I = \frac{\sum ai\ xi}{\sum xi}$$ -- Equation 3.1

where ai = Constant which represents the weight of I;

xi = Variable that represents the respondent frequency for I;

i = 1, 2, 3, 4, 5…probability of occurrence rating scale (integer values between 1and 5)

Under case studies, the labour productivity for productivity on each structural member was computed according to Tewodros (2006), through Equations 3.2:

$$\text{Labour productivity} = \frac{\text{Output (in units)}}{\text{Input (MH)}}$$ -- Equation 3.2

Labour productivity based on monthly status was computed according to Prathul et al., (2015), through Equations 3.3:

$$\text{Productivity} = \frac{\text{Quantity of work done}}{\text{Number of man}-\text{days}}$$ --Equation 3.3

The data presentation for quantitative data which is questionary that ware collected from sample respondent’s analysis by SPSS was present through Frequency tables, percentages, bar charts and other descriptive for measurement mean (average index) were used to analyze the results.

The Case study comparison was made based on projects document, site inspections, and the respondent's response for conventional formwork and kumkang formwork systems with regards to the cost of the formwork, concrete quality, time of construction, and labour productivity. The comparison was presented by using tables and graphs in combination with other data. And the interview that is collected from different parties were also analyzed separately and present in combination with quantitative data.

3.8 Data Validity and Reliability

3.8.1 Validity

According to Kothari (2004), validity refers to the extent to which the instrument measures what the researcher(s) wishes to measure. A validity test indicates the degree to which an instrument measures what it is supposed to measure. There are different ways of testing the validity of the research. In the case of this research, a content validity test is utilized. Content validity is the extent to which a measuring instrument provides adequate coverage of the topic under study. The validity of this research was measured through a pilot study on the project which means a questionnaire was distributed to five project managers and two project research and development heads to evaluate the quality of the questionnaire before data collection. By modifications based on the opinions of those experts before collecting the data and also based on opinions of academicians the quality of the questionnaire was measured.

3.8.2 Reliability

Reliability is concerned with whether the procedures of data collection and analysis generate the same results on all occasions and whether others can also make similar observations and arrive at the same conclusions from the same given raw data. In other words, it is an attribute in which data collection procedures can be repeated with the same results (Kothari, 2004).

In this research internal consistency was used which involves correlating the responses to each question in the questionnaire with those to other questions in the questionnaire. It, therefore, measures the consistency of responses across either all the questions or a subgroup of the questions from the questionnaire. There are a variety of methods for calculating internal consistency, of which Cronbach's alpha was used for this study to measure the consistency of respondents that were computed with SPSS software.

The minimum advisable level is 0.7 although it may be reduced to 0.6 in exploratory research and anything less than 0.6 is usually eliminated (Kothari, 2004). The formula used for the Cronbach's alpha measurement present on Equation 3.4:

$$\alpha = \frac{N\bar{c}}{\bar{v}+(N-1)\bar{c}}$$ --Equation 3.4

Here N is equal to the number of items, c¯ is the average inter-item covariance among the items and v¯ equals the average variance.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

4.1 Introduction

This research aims to evaluate kumkang aluminum formwork performance in federal housing project in Addis Ababa city. To achieve the aim of this study, the data gathered from data collection techniques which are the interview, case studies, and questionnaires were analyzed and discussed in this chapter.

In this chapter, the questionnaire collected from the respondent was analyzed with the help of SPSS version 20 and MS excel sheet and presented through frequency, percentage means, and other descriptive analysis. And the researcher used graphs and charts to display the findings to support analysis of the results with easy understanding. Also interviews and case studies analysis and presented descriptively and quantitatively under this chapter. The questionnaire was prepared with six sections under these sections the researcher tries to address all the research objectives see Appendix - B. 75 questionnaires were distributed in five projects and among the distributed questionnaire, 61 questionnaires were collected and this makes the response rate 81.3%.

To ensure uniformity in replies, questionnaires were categorized in this research and the result of Cronbach's alphas analysis for the questionnaires is as follows in Table 4.1:

Table 4. 1 Cronbach's Alpha coefficient (Reliability Statistics)

Formwork Parameters	Cronbach's Alpha	Cronbach's Alpha Based on standardized Items	N of Items
The competence of formwork system on quality of finished concrete	0.924	0.926	16
The impact of formwork systems on health and safety risk factors	0.848	0.85	15
The aspect of formwork systems on sustainability elements	0.94	0.95	26

4.2 General Information of the Respondent

The following table describes the respondent class and category of their company in Table 4.2.

Table 4. 2 Respondent category and class of company

Category and class of company	Frequency	Percent (%)
Client	6	9.8
Consultant, grade 1	6	9.8
Contractor, BC-1	23	37.7
Contractor, GC-1	26	42.6
Total	61	100

From the Table 4.2, most of the respondent was on contractor GC-1 (42.6%) and 37.7% of the respondent was Contractor BC-1. The remaining respondent was from the client and consultant, grade1 side.

The following Table 4.3 describes how long has the organization been operating and the number of projects executed in the last five years through Crosstabulation. This helps to know the respondent's company background.

Table 4. 3 Organization operating time and number of projects executed

		Number of projects executed in the last five years			Total
		Less than 10	11 to 20	More than 20	
How long has the organization been operating	Less than 5 years	1	0	0	1
	5 to 10 years	2	21	0	23
	10 years and above	6	22	9	37
Total		9	43	9	61

From Table 4.3, most of the respondent organizations are operating for more than 10 years and most of the respondent organizations executed 11 to 20 projects in the last five years. As shown above, the organization of respondents stayed long years in the construction industry and execute a lot of projects during the past five years.

Most of the respondents were site engineers, office engineers, Project managers, resident engineers, and counterpart engineers see Appendix-C. All the respondents were professionals this helps to get a valid response on the subject matter and for the questionnaire prepared because almost all the questions could be answered by professionals and their experience shows in Table 4.4. Table 4.4, shows the experience of the respondent this helps to increase the validity of the response since more experience on the subject matter helps to get reliable data. Most of the respondents had 5 to 10 years' experience and near to most had 10 years and above experience and the rest, 23% had less than five-year experience in the construction industry. From the result, we can see that almost all respondent has passable experience for prepared questionnaire.

Table 4. 4 Experience of respondent

Years of experience	Frequency	Percent (%)
Less than 5 years	14	23
5 to 10 years	25	41
10 years and above	22	36.1
Total	61	100

And there were 3 projects taken for case studies in order to understand the nature and type of buildings. The project information of those projects described in Table 4.5.

Table 4. 5 Project's information

Project:	Project 1 (Kebena mixed-use apartment)	Project 2 (Misrak atekalay mixed-use apartment)	Project 3 (Gerji modern village)
Type of formwork used:	Wooden	Wooden	Kumkang Formwork
Formwork application (footing, walling,slab)	For all structure	For all structure	Wall, Slab, and Stair
Building area:	1290m^2	1,700m2	Apartment=586m^2 Sky Villa=530m^2
Type of building:	Mixed-use apartment	Mixed-use Apartment	Apartment
Estimated Total Cost of this project	251,225,692birr	359,464,744.33birr	3,066,405,712birr
Estimated formwork cost (%) to total construction cost	18%	19.5%	16%
Estimated total project Duration	18 months	24 months	14 months
Current performance (% completed)	40%	26%	43.75%
Probability of finishing within specified time and budget	less	Moderate	Higher

From Table 4.5, under this research, the project taken for case studies was on the structural stage for purpose of subject matter. All projects have the same building types this helps to make a comparison between projects since it’s has the same features. On the estimated formwork cost of the projects, there is a variation between wooden and kumkang formwork the kumkang formwork is less than the wooden one. The probability of finishing the project within a specified time of gerji modern village is better than other projects.

4.2.1 Formwork Materials Used by Companies

This section of the questionnaire addresses what type of formwork material is used by the company. This helps to understand which type of formwork material is more used and the respondent's perspective on kumkang aluminum formwork system utilization. The following figure describes the formwork material used by the company. From Figure 4.1, most of the respondents used both wooden and steel for supporting members formwork (57.4%) for their construction, and some respondents use a combination of wooden, steel, and kumkang formwork (24.6%). The rest 18% of the respondents use only wooden formwork for both vertical and horizontal systems.

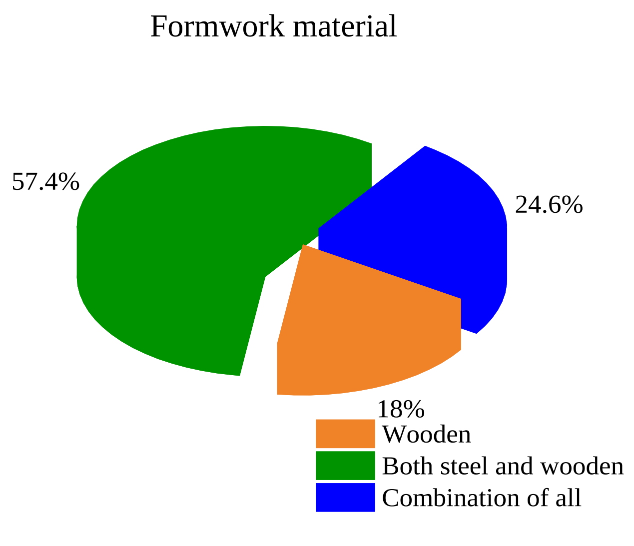


FIGURE 4. 1 Formwork material used by the company

Figure 4.1, shows that about 24.6% of respondents only apply for kumkang formwork with the combination of other formwork material. The gerji modern village project apply the kumkang formwork starting from the ground floor. The basement and footing pad were constructed by using steel supporting members and wood formworks. Initial cost and availability of the material in the local market are most of the respondents raised as a reason for not using kumkang formwork. In addition to this, not flexible for all and any structures especially for foundation work it is not appropriate, since it's new we are not familiar, there is no skilled manpower to construct and lack of information were stated as a reason for not using kumkang aluminum formwork. As KumKang Kind (2016), the aluminum formwork system is made of lightweight aluminum which allows the largest components to be hand-carried and set up. It does not need skilled workers due to the elaborate design. This shows as there is a lack of information and research developments on the formwork material to clear the misunderstanding between the reality and the myth-like it needs a skilled worker.

From an interview conducted even modern formwork systems are efficient and have a better quality its initial cost of formwork is high, availability on market is rare, knowledge share performance with the technology, a fear to adopt new technologies and less study, research related to such kind of technology, economic capacity which means startup capital, Cost of import, trend and culture and the tender procurement system of the country relays on least bidder system let competent and having such modern formwork makes the contractor give a higher price. This means the directivities defects leads to not use modern formwork systems were stated as a reason for less adaptation of modern formworks in Ethiopia. From the response show that, less adaptation on modern formwork systems is there because of fear, lack of research and knowledge also absence of government support.

The analysis from the interview shows that there is no government support on modern construction technologies to adopt in the country the contractors only try by themselves. Also, there is no promotion and platforms to encourage the contractors that try new technologies in the construction. It only takes a plan for the next five years whether to adopt the manufactures or to give promotion for the contractors that adopt construction technologies. Albeit there is no critical support from the government but there is an introduction forum between construction companies. As stated, before the contractors need the government support in adjustment of procurement directivities and prepare a mechanism to get such kinds of technologies on the local market by build manufacturing industries or imported raw materials and machinery to produce aluminum formworks of a similar kind locally and tax reduction. The reason that the government was less adaptation on the support of contractors was due to lack of foreign currency, they cannot enforce them to use such formwork materials and to import them. They don’t make it mandatory to use such formworks also there is a lack of implementation of rules for instance there is a law that state for the construction which is above G+4 forbidden to use wooden formworks but the reality is different.

Also, no registration requirement considers formwork material used by the company to this day the only thing the authorized party do is create understanding and propose of the different formwork systems by studying the viability of the project from time, cost, quality. But most of the respondents from the contractor side agreed on modern formwork system to be a registration requirement especially for grade one contractors because; even though the initial cost is high the easiness, quality of work, and reusability of material is very good to get better quality of work. It’s also helpful to compute with the rest of the world in the construction sector. Also, to modernize the Ethiopian construction industry as well as to get the attribute of modern formwork systems that are speed of erection, efficiency, safety, cost and flexibility. On another hand, some of the respondents didn’t agree with it because it is very expensive for both employees and individuals. And before making the registration requirement the government should amend the procurement directivities and standard bid documents should create skilled lessons to work by modern formwork, should make sure it’s available on the local market and should include on the specification of the country.

The following table describes the respondent criteria to select formwork material. This helps to know the respondent priority by the time of selection formwork for construction. The following Table 4.6 shows the respondent rate for each criterion to select formwork materials.

Table 4. 6 Criteria to select formwork material

Criteria’s	Responses		Percent of Cases (%)
	N	Percent (%)	
Cost of formwork	55	22.80%	90.20%
Speed of construction	40	16.60%	65.60%
Quality of finished concrete	54	22.40%	88.50%
Health and safety factors	22	9.10%	36.10%
Sustainability issue	25	10.40%	41.00%
Labour productivity	43	17.80%	70.50%
Others (please specify)	2	0.80%	3.30%
Total	241	100.00%	395.10%

The Table 4.6 analysis method was carried out by multiple question analysis and one respondent can select more than one option and the result of respondent was based on the criteria rate by the respondent. From Table 4.6, most of the respondents 90.2% agreed on the cost of formwork and quality of finished concrete 88.5% were their criteria to select formwork material mainly. The next prioritized criteria by the respondent were labour productivity (70.5%). this shows the most prioritized factor by the time of formwork selection given to the cost of formwork, less cost is the chosen one rather than other criteria. Speed of construction (65.6%), sustainability issue (41%), and health and safety factors (36.1%) get less rate to consider as criteria on formwork selection. There are other criteria stated by the respondent as criteria available on the local market and easy construction. From the above result, we can understand that they have less adaptation to consider major construction aspects nowadays and stick with less cost things.

4.3 Kumkang Formwork Practice System

The researcher tried to assess the kumkang formwork practice system under this section. As stated earlier, to assess the kumkang formwork practice system is one of the research objectives and this section tries to attain the objective from a different perspective.

The most important aspect of successful structural construction is the formwork system because of always offers the most: trust full, safety provider, cost reducer, quality improvement and its reusability/recycle formwork. Modern formwork systems are any key factors that decide the time, speed, quality, and safety in construction. A modern formwork system has plenty of advantages for quality as well as timely accomplishment of projects, it’s also environmentally friendly and reduces the risk hazards on site.

Analysis from the interview shows that the kumkang formwork system is a durable product that is easy for installation and that can produce high-quality concrete surfaces and edges. The formwork can be used repeatedly for several cycles up to 300 repetitions with properly handled this minimizes the cost of the formwork that deals with conventional one. It's work methodology which means it’s had a fast construction cycle of 7 days to complete one floor while the conventional it takes about 3 weeks and above by the same area. There is no partition construction and HCB work since it is RC wall also plastering and chiseling works is reduced, this reduces time and cost for the work provided. The third thing is getting a better alignment with perfection and perfect sharp age, gives a better output of finish concrete surface that can directly apply paint and finishing. the electrical conduit and fixture install with the rebar before erecting the formwork. Also, the main difference between them is dimensional accuracy because the formwork is designed and manufactured with accuracy the outcome on the structure is accurate which is difficult to achieve by conventional. This increases the quality of finished concrete which is one of the formwork requirements. Can do work with less manpower. There is the limitation of the kumkang formwork raised by the respondent, it is difficult to maintain and design change because it is not flexible and different missed elements and miss much of the design due to communication problems could occur. So, a careful check should give at least the three drawings properly to take a fast remedial measurement, structural drawings, architectural drawings, and kumkang drawings (sheal drawings). From those responses, the kumkang formwork has a better advantage on construction cost, time, and quality which is basic formwork requirements.

From the client-side also the reason to use such formwork is to get better quality, effective time, cost minimization work, and also environmentally sustainable construction. By using such kind of formwork systems, can produce more housing projects within a short period. So, this formwork system helps to attain their objective as an organization. Since Ethiopian construction industries needs to be on time, cost within quality and sustainable way by this reason the modern formwork system like kumkang aluminum help as on those aspects and developing the construction industries. This shows that the kumkang formwork helps to develop the construction industry in one or another way.

The acquiring method of this Kumkang Aluminum formwork system was discussed and the following Table 4.7 describes the acquiring method of the kumkang Aluminium formwork.

Table 4. 7 Formwork acquiring method

Acquiring methods	Responses		Percent of Cases
	N	Percent (%)	
Owning (Import from abroad)	25	100.00%	166.70%
Total	25	100.00%	166.70%

The Table 4.7 analysis method was carried out by multiple question analysis and one respondent can select more than one option and the result of respondent was based on the response rate by the respondent. From Table 4.7, all response of respondent was the formwork acquired by import from aboard. For structures above the basement used the kumkang formwork this formwork is manufactured and imported from Korea based on the design of the building. The reason to use such source was it is not available in our country and since aluminum formwork is not yet being produced in Ethiopia there is no domestic production also the work demand needs this kind of formwork to achieve high quality of work, time efficiency, and good productivity. From an interview with the government side, it’s have a plan to create the market in the country and build the manufacturing industries like IBS, technologies, methodology, digitalization, IBS, and BMI for the next 5 years plans. As the organization plans go better, we can get the modern formwork and other industrialized building systems in the local market. This will be spalling the question raised on the availability of market and cost issue for not using modern formwork systems.

The method used to construct Kumkang Aluminum formwork system is described under the following Figure 4.2, to know the method of construction of this formwork system. Some of the respondent rates show this formwork system construct with manually (40%) since its lightweight, easy to handle, and construct, and most of the respondents responded that this formwork constructs by manually and crane (60%) by considering other related work like a bar setting out. for rebar work like transportation of bars, the crane is used but for the formwork, it can be easily constructed manually.

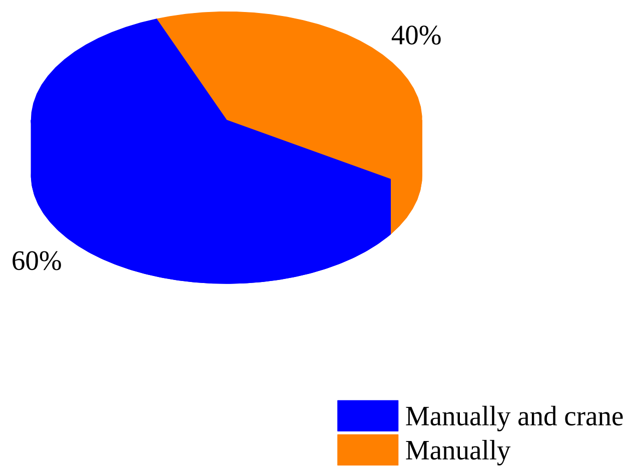


FIGURE 4. 2 Methods of Kumkang Aluminum formwork construction

This shows that, unlike other formwork systems that use a crane, the kumkang formwork system can construct through manually.
This helps to reduce site crowdedness and also costs related to crane and other overhead costs.

Construction labours broadly defined in three categories these are skilled, unskilled and semi-skilled labour. Positions requiring technical skills or specific training, such as electricians and plumbers, are generally referred to as skilled labor. Unskilled labor professions, such as construction laborers, usually do not need employees to have any specific training or abilities. Semi-skilled labor refers to professions that are less difficult but still demand a high level of skill and expertise, such as plasterer, carpenter, and technicians. The respondent rate on the kind of labours used for Kumkang Aluminum formwork system describes in the following Table 4.8.

Table 4. 8 Kind of labour used for Kumkang Aluminum formwork construction

Kind of labour	Responses		Percent of Cases
	N	Percent	
Un skilled labour	13	67.50%	156.20%
Semi-skilled labour	12	32.40%	75.00%
Total	37	100.00%	231.20%

From Table 4.8, most of the response rates were unskilled labor with (156.2%) and 75% of responses were semi-skilled labour. The kumkang aluminum formwork doesn't need skilled labour that are direct to formwork assembly and dismantling see Appendix-B. According to KumKang kind (2016), kumkang formwork does not need skilled workers due to the elaborate design provided to make sure that the client's success must be achieved. But most of the time modern formwork system consider as difficult and it seems only constructed by skilled labours. This is due a fear of new technologies and lack of information on that but it can be constructed through unskilled labour it only needs short-term training on the construction of formwork. The average amount of labours for this formwork system is 50 semiskilled and unskilled labour per floor including bar benders and electricians.

The type of release agent (form oil) used for this kumkang formwork was oil 140 mixed with naphtha with a ratio of 1:3 because this release agent gives good quality of finished concrete and its specification enforced to use such mold oils.

Erection (mantle) and stripping (dismantle) of the kumkang formwork system are different from the conventional system with work methodologies and with time taking to construct the formwork. The first structure that erects is vertical structures, first wall then staircase next to the wall, after wall panels and staircase installed the installation of an opening area like window and door precedes after this the horizontal structural member installed start with beam cap and slab corner and prop supporting follows then finally slap panel and prop support for slab panel installed.

The method used to pour concrete were concrete pump and during casting concrete first vertical (shear wall) and then horizontal members were cast. The concrete pump is prepared to ready after structural member erection work complete the casting work takes one day which means it needs one day to complete one-floor concrete work.

The stripping formwork was, all structural member doesn’t strip within one day. It has the following steps with average hours: first vertical structure, shear wall, and stair within 16 hours after casting of concrete. Then horizontal members slab then beams and slab corners precede after 72 hours but the prop left under up to two levels of floor construction which means after 14 to 7 days. As EBCS-2 (1995), recommended stripping time for vertical formworks is 18 hours and for soffit formwork to slab and beam also for prop supporting is 7-14 days. But where sliding or climbing formwork is used, shorter periods than those recommended may be permitted. As ACI recommendation the wall and column cold strip within 12 hours and beam 3 to 4 days and for slab 4-21 days based on the span length and load distribution. Also, BaTCoDA (1991), vertical formwork column, wall, and beams could strip 16 hours, soffit slab 21 days props for both slabs and beam 14 days soffit beams 21 days. British standard put for a vertical column, walls and large beams 12 hours, soffit slab 4 days, soffit beam and prop slab support 10 days and prop beams 14 days are recommended. So, kumkang formwork full fill their recommendation and somewhat it’s had a short period of stripping time but since it’s one of the modern formwork systems the recommended days could be shorter as stated above.

The respondent's response for the joint system of the formwork was they are fine with the jointing system of the formwork and there is no other suggestion of formwork system for the recent construction industry. To keep up the 250 - 300 repetition (reusability) of the formwork they used scheduled maintenance.

In the utilization of formwork, there is no framework for utilizing kumkang formwork and other formwork systems by an authorized party. The only thing they do is provide the platform for construction companies to introduce and creates recognition by themselves rather than giving certified recognition to this day. The authorized party which is MoUDC believe the contractor should not expect all thing from government support. As a government, they have a plan to create awareness and allocate the benefits and they have a plan to promote and intensify the contractors that use such formwork materials to the next five years with a plan to address the IBS (industrial building system) and BIM to the construction industry. Nearly 50% of construction should build by these systems after the plan is implemented.

4.4 Performance of Kumkang Aluminum Formwork

4.4.1 Performance of Kumkang Aluminum Formwork on Cost

One of the selection criteria of formwork is less cost of formwork material and construction. Formwork cost consumes around one-fourth of total material cost as shown from various literature and this cost can be minimized through good design and proper selection of formwork. The cost of the formwork is computed through labour cost, material cost, equipment cost, number of reusability's, and cost for the surface finish after the formwork strip.

The initial investment cost of kumkang is higher than the wooden formwork but its number of reusability gives low life cycle cost rather wooden formwork had low initial investment cost but its life cycle cost is greater. As we saw from the above most respondent's response that they don't use modern formwork systems was its high initial investment cost but the life cycle cost of formwork costs more than initial investments of these modern formwork systems. The kumkang aluminum formwork is reused 250-300 times, whereas the wooden formwork is reused 3-4 times. Increasing the reusability of the wooden formwork reduces the quality of the formwork and the final concrete surface quality.

Under this section, the formwork cost was computed under labour cost, material cost, equipment cost, number of reusability's, and cost for the surface finish after the formwork strip. The reusability of kumkang aluminum formwork minimum 250 taken and for conventional wooden 3 times were taken for purpose of case studies. The case studies were taken on formwork unit cost which includes material, labour, and equipment cost in both conventional wooden used projects and kumkang aluminum formwork used projects. The following tables describe the unit cost of formwork material comparisons between kumkang and wooden formwork. Here is the unit cost of formwork in all three projects in Table 4.9, 4.10 and 4.11:

Table 4. 9 Formwork unit cost in project 1 conventional (wooden) formwork

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: FORM WORKS — LABOUR HOURLY OUTPUT: 0.6 m^2/hr.

WORK ITEM: _ (5.1) For Super structure column ,Floor beam & slab — EQUIPEMENT:

TOTAL QANTITY OF WORK ITEM: 1 m^2 — RESULT: 429.27 Birr/m^2

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Wooden form work	M^2	1.05	122.00	128.10	Forman	1.00	0.25	56.25	14.06	Tools	1.00	0.50	0.50
40 x 50 cm. battens	M	0.80	35.00	28.00	Carpenter	1.00	1.00	37.50	37.50				
Eucalyptus	M	1.00	27.00	27.00	Ass.Carpenter	1.00	1.00	18.75	18.75				
Nails	Kg	0.30	55.00	16.50	DL	1.00	1.00	15.00	15.00				
Mould Oil	Lit.	0.05	17.69	0.80									
Total (1:-01)				200.40	**Total (1:02)**				85.31	**Total (1:03)**			0.50

A= Materials Unit Cost 200.40 Birr/m^2

B= Manpower Unit Cost 142.18 Birr/m^2 — Total of (1:02) / Hourly Output: ____________

C=Equipment Unit Cost 0.83 Birr/m^2 — Total of (1:03) / Hourly output: ____________

Direct Cost of Work Item = A+B+C = 343.42 Birr/m^2 143.02

Over Over head cost : 15% 51.51 Birr/m^2

Profit Cost: 10% 34.34 Birr/m^2

Total U Total Unit Cost : 429.27 **Birr/m^2**

Remark ____________

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

From Table 4.9, project one which is the Kebena site have a unit cost of formwork 429.27 Birr/m^2.

Table 4. 10 Formwork unit cost in project 2 conventional (wooden) formwork

ANALYSIS SHEET FOR DIRECT & INDIRECT COSTS													
PROJECT:	FORM WORKS							LABOR DAILY OUTPUT:			0.75	m^2 / hr.	
WORK ITEM: (1.03 e &f)	Form work(for all except slab)							EQUIPMENT DAILY OUT PUT:			0.75	m^2 / hr.	
TOTAL QUANTITY OF WORK ITEM:			1	m^2				RESULT:		434.95	Birr/m^2		
Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labor by Trade	No.	UF	** Indexed hourly wage	Hourly wage	Type of Equipment	No.	Hourly Rental	Hourly Rental
wooden formwork	M2	1.05	122.00	128.10	Foreman	1	0.17	65	11.05	tools	2	0.50	1
50 x 70 cm. battens	M	0.8	40.00	32.00	Carpenter	1	1	41.25	41.25				0
Eucalyptus	M	1	26.00	26.00	Ass.Carpen	1	1	28.75	28.75				0
Nails	Kg	0.3	60.00	18.00	D/L	1	1	25	25.00				0
Mould Oil	Lit.	0.045	25.00	1.13					0.00				0
				0.00					0.00				0
				0.00					0.00				0
Total (1:01)				205.23	Total (1:02)				106.05	Total (1:03)			1
A= Materials Unit Cost	205.23	Birr/m^2		B= Manpower Unit Cost			141.40	Birr/m^2	C=Equipment Unit Cost			1.33	Birr/m^2
				Total of (1:02)						Total of (1:03)			
				Daily output:						Daily output:			
				Direct Cost of Work Item = A+B+C =						347.96	Birr/m^2		
						Over head cost :			10%	34.80	Birr/m^2		
						Profit Cost:			15%	52.19	Birr/m^2		
						Total:				434.95	Birr/m^2		
Remark ______________________________											Birr/m2		
UF: UTILIZATION FACTOR						Total unit cost:				434.95	Birr/m2		
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.													
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.													

From Table 4.10, project two which is Misrak ateklay site have a unit cost of formwork 434.95 Birr/m^2.

The following Table 4.11 is the unit cost of kumkang aluminum formwork:

Table 4. 11 Formwork unit cost in project 3 (kumkang aluminum formwork)

ANALYSIS SHEET FOR KUMKANG ALUMINUM FORMWORK INSTALLATION COSTS

PROJECT: **KUMKANG FORMWORK INSTALLATION** LABOR HOURLY OUTPUT: 3.67 m^2/ hr

WORK ITEM: Kumkang Aluminum Formwork Installation

TOTAL QUANTITY OF WORK ITEM 1.00 m2 RESULT: **256.11** Birr/m^2

Material (1:1)					**Labor (1:02)**					**Equipment Cost (1:03)**			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labor by Trade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Panels with accessories	M^2	1.00	170.54	170.54	Forman(technicians)	1	0.25	31.25	7.81	Tools	1	1	1
Mold Oil	lit.	0.05	120.00	5.40	Carpenter	1	1	31.25	31.25				
					Daily Laborer	1	1	16.25	16.25				
					Kumkang Coo	1	1	50	50.00				
									-				
Total (1:-01)				175.94	**Total (1:02)**				105.31	**Total (1:03)**			1.00
A=Materials Unit Cost	175.94	Birr/m^2			**B=Manpower Unit Cost**			28.68	Birr/m^2	**C=Equipment Unit Cost**		0.27	Birr/m^2
					Total of (1:02)					Total of (1:03)			
					Hourly Output					Hourly Output			
				Direct Cost of work item = A+B+C =						**204.89**	Birr/m^2		
						Overhead Cost:			10%	20.49	Birr/m^2		
						Profit			15%	30.73	Birr/m^2		
						Total unit cost:				**256.11**			
Remark ____________________													

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, etc.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT

From Table 4.11, project three which is gerji village site have a unit cost of formwork 256.11 Birr/m^2.

The unit cost of the formwork was taken on the superstructure since the kumkang formwork applies to the superstructure part currently in order to compare the cost formwork between each project the superstructure formwork cost were taken. Therefore, the unit cost of the formwork for each project was summarized below and a comparison was made with the reference of Addis Ababa construction bureau standards see Appendix-A. Figure 4.3 describe the unit cost of each formwork.

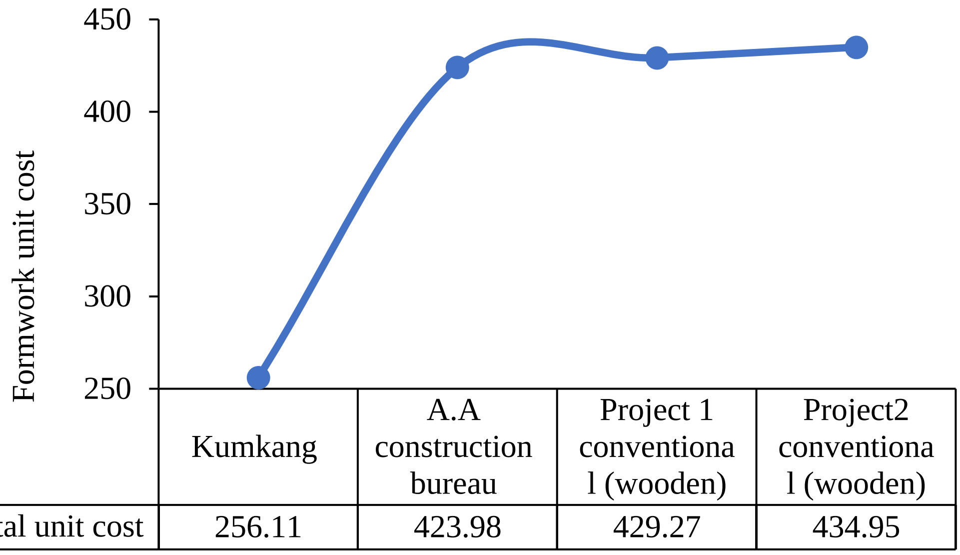


FIGURE 4. 3 Formwork unit cost summary

From Figure 4.3, the kumkang aluminum formwork costs less than other wooden formworks and saves the cost of almost 173.29 Birr in 1 m^2 and 40% of formwork cost in construction is reduced by using this formwork compared through both projects and with Addis Ababa construction bureau. Also, when we show the cost independently like material, labour, and equipment the kumkang formwork had better advancement on that. The number of reusability of the formwork helps the kumkang formwork to be less material cost than others. The kumkang aluminum formwork material provides with accessories, prop head, and bracket (working platform and scaffolding) the cost for additional material to support and construct the formwork panels was reduced. In labour cost, the output of labour was good and more productive than others. That’s why the kumkang aluminum formwork had less labour cost compare to others. Better output value help for equipment cost also the one that had more output have less cost. This is what happened in kumkang formwork.

In order to see the cost-saving by using kumkang aluminum formwork, consider formwork construction unit cost for G+10 apartment which have 10000m^2 formwork construction. The average formwork unit cost for conventional wooden formwork was 429.4Birr/m^2 and the total cost need to complete this apartment formwork construction is 4,294,000 Birr. In the case of kumkang aluminum formwork, 2,561,100 Birr is needed to complete this apartment.

As shown from the above 1,732,900 Birr cost of formwork can be saved by using kumkang aluminum formwork. it's about 40% cost can be minimized by using this formwork. This cost only on unit cost without including salvage value and other costs. Adding such costs lead greater than this.

There is a cost for the surface finish after stripping formwork. This additional treatment cost differs between conventional wooden and kumkang aluminum formwork. The case studies were taken in three projects including the gerji village that uses the kumkang aluminum formwork. There is plastering work before applying the final painting to smooth the surface and accept the final finishing material in the case of gerji. In our case, the Kebena project applied 3 coats of plastering and the Misrak one has used 2 coats of plastering see Appendix-A. The following Table 4.12 shows the summary cost for plastering in conventional wooden formwork used projects.

Table 4. 12 Plastering unit cost

Projects	Plastering unit cost (2 and 3 coats)			
	External wall	Internal wall	Soffit celling	Exposed beams and columns
Kebena mixed use apartment	180.79 Birr/m^2	129.23 Birr/m^2	175.88 Birr/m^2	174.13 Birr/m^2
Misrak atekalay mixed use apartment	140.63 Birr/m^2	137.33 Birr/m^2	170.28 Birr/m^2	148.33 Birr/m^2

From Table 4.12, shows the plastering unit cost is not a little cost it's almost half and above percent of formwork unit cost. For instance, let us take the Soffit ceiling plastering work cost in both projects for 100 m^2 Soffit ceiling to be plastered for preparation of gypsum as a final finishing material. In the case of Kebena project, it costs 175.88 Birr for 1m2, in case 100 m^2 Soffit celling going to be plastered it costs 17,588 Birr. And in the case of Misrak atekalay project, it's 170.28 Birr/m^2. Results for 100 m^2, 17,028-birr cost.

In the case of kumkang aluminum formwork, the cost for plastering work is reduced but there is additional treatment before applying gypsum. Because the output of this formwork surface was very smooth it needs some treatment to make the surface receive the gypsum paint. The following Table 4.13 shows the cost for additional treatment in gerji project.

Table 4. 13 Unit cost of additional treatment

Additional treatment		Unit cost/m^2
Material	Magic bond	10 Birr/m^2
	White cement	8 Birr/m^2
Total cost		18 Birr/m^2

Taking the same assumption for this also, 100 m^2 Soffit celling to be prepared for gypsum as final finishing material. From Table 4.13, shows it costs 18 Birr/m^2. so, for 100m^2 Soffit celling it costs 1800 Birr. When compared this one from the above results of conventional wooden cost there is 90% and 89% additional cost for Kebena and Misrak atekalay projects. Therefore, the kumkang aluminum formwork saves about 155.08 Birr/m^2 which is 89% and above additional costs related to surface finish.

The respondent response from the interview related to kumkang formwork cost and its viability in our country economic capacity were the kumkang formwork is important for Ethiopia because it reduces the extra cost that the construction industry is wasting as a result of project delay (time value of money). The apparent high initial investment cost can absorb by cyclic use of the formwork by minimizing life cycle cost and the economic benefit exaggerated during the later years for construction companies. Its rate of return is very fast since it's had high repetitive use. Another cost reduced by Kumkang Aluminum formwork related to plastering and chiseling works. For the above reason, it is economical. This shows the number of repetitions gives better economical value for the future especially for housing projects but it should have for mass construction and repeated work and also for high rise buildings. It's not economical for small projects.

In order to be one formwork is good in cost performance the formwork should have less cost related to formwork. Therefore, the kumkang aluminum formwork had better cost performance by reducing the cost related to formwork construction.

4.4.2 Performance of Kumkang Aluminum Formwork on Construction Time

Shorter construction time in completing the floor cycle is the criteria that the formworks should have to fulfill in order to be good formwork. One of our construction headaches is completing the project within a specified time. The faster construction time in the floor cycle is helpful to maximize the probability of finishing the project in time or before. By speed up the construction works that are related to formwork, the cost can be minimized which occurs through project delay. Also, when the construction time shorter here is a cost advantage through the time value of money.

The faster floor cycle depends on the formwork system that used in construction. Under this section, the time taken to erect and strip formwork on each member with the time taken to complete one-floor cycle and time need for surface finish were compared by taking case studies on three projects. Two conventional wooden and kumkang aluminum formwork were taken.

Under time taken to erect formwork, based on labour productivity the time need to erect each formwork member in one crew (one carpenter with two daily labour) and which one had quick erection time computed with the same area 100 m^2 formwork construction for all the projects taken in order to compute equally and the result as follows in Table 4.14.

Table 4. 14 Erection time of formwork

Time taken to:	Projects		
	Project 1 (conventional wooden)	Project 2 (conventional wooden)	Project 3 (kumkang aluminum)
Time for erecting a column	0.7 m^2/hr. 100m^2 =143hrs 18days	0.6 m^2/hr. 100 m^2=167 hrs. 21 days	-
Time for erecting beam	0.51 m^2/hr. 100 m^2 =196 hrs. 24 days	0.6 m^2/hr. 100 m^2=167 hrs. 21 days	-
Time for erecting shear wall	0.83m^2/hr. 100 m^2 =120 hrs. 15 days	0.75 m^2/hr. 100 m^2=133 hrs. 17 days	4.4 m^2/hr. 100 m^2 =23 hrs. 3 days
Time for erecting stair	0.52 m^2/hr. 100m^2=192 hrs. 24 days	0.46 m^2/hr. 100 m^2=217 hrs. 27 days	1.4 m^2/hr. 100m^2=71 hrs. 9 days
Time for erecting floor slab	0.58 m^2/hr. 100 m^2=172 hrs. 21 days	0.67 m^2/hr. 100 m^2=149 hrs. 19 days	5.21 m^2/hr. 100 m^2=19 hrs. 2 days

Table 4.14 shows that the kumkang aluminum formwork only applies on the wall, slab, and stair members because the kumkang aluminum formwork technologies are the wall slab and stair system not a frame system. The end beam and middle panels submerged with wall and slab members they don't act like a structural member. Since the hole wall member in gerji village is a shear wall the load transfer from slab direct to the wall. So, the time comparison was made on the wall, slab, and stair structural members. Let us see one by one, the time saving by using kumkang formwork in the erection of wall was 12-14 days in reference to both wooden projects, for the erection of stair 15 -17 days and for erecting floor slab 17- 19 days. The time taken to erect the kumkang formwork was less by triple times and more than in wooden formwork. Therefore, the kumkang formwork had a faster erection time than wooden formwork. This helps to fasten the construction floor cycle and the whole project also.

For formwork stripping time also used the same assumption for better comparison between the formwork systems since it's had a different dimension of structure member between projects the same dimension for all projects needs to take. The stripping time for structural members as follows in Table 4.15.

Table 4. 15 Stripping time of formwork

Time taken to:	Projects		
	Project 1 (conventional wooden)	Project 2 (conventional wooden)	Project 3 (kumkang aluminum)
Time for stripping column	2.5 m^2/hr. 100m^2=40 hrs. 5 days	1.5 m^2/hr. 100m^2=67 hrs. 8 days	-
Time for stripping beam	2.02 m^2/hr. 100 m^2 =49 hrs. 6 days	2.7 m^2/hr. 100 m^2 =37 hrs. 5 days	-
Time for stripping shear wall	2.86 m^2/hr. 100 m^2 =35 hrs. 4 days	2.66 m^2/hr. 100 m^2 =38 hrs. 5 days	7.94 m^2/hr. 100 m^2 =13 hrs. 1 and half days
Time for stripping stair	1.87 m^2/hr. 100m^2=53 hrs. 7 days	1.84 m^2/hr. 100m^2=11 hrs. 7 days	2.7 m^2/hr. 100m^2=8 hrs. 5 days
Time for stripping slab	3.45 m^2/hr. 100 m^2=29 hrs. 4 days	3.5 m^2/hr. 100 m^2=29 4 days	9.42 m^2/hr. 100 m^2=11 hrs. 1 day

From Table 4.15, we can see that kumkang aluminum formwork had a faster stripping time again than wooden formworks. The difference between those formworks was 2 and a half to 3 and half days in slab, 2 days in stair, and 3 days in wall. These differences were the time saves by using kumkang aluminum formwork. Same as the above the kumkang aluminum formwork fastens the construction floor cycle by reducing double times when using conventional wooden formwork.

The planned and actual duration to complete one-floor formwork construction in projects that used conventional wooden and kumkang aluminum as shown in Table 4.16.

Table 4. 16 Time to complete one-floor formwork construction

Time taken to:	Projects		
	Project 1 (conventional wooden)	Project 2 (conventional wooden)	Project 3 (kumkang aluminum)
Planned duration to complete one-floor formwork construction	21 days	31 days	7 days (including formwork dismantle)
Actual duration to complete one-floor formwork construction:	21 days	31 days	7 days (including formwork dismantle)

The time taken to complete one-floor formwork construction ,7 days utilized to construct one-floor formwork by kumkang including formwork strip, while the conventional formwork takes 21 to 31 days for erection only. This implies a 3- 4 floor formwork construction time in kumkang aluminum formwork.

To compute the time to be minimized in using the kumkang aluminum formwork system, the detail difference between the conventional wooden formwork and kumkang aluminum formwork in construction time were compared by taking floor slab formwork construction under productivity rate in Table 4.17. By considering the slab area 100m^2 for both conventional and kumkang formwork.

Table 4. 17 Time comparison on slab formwork construction

Time taken to:	Formwork systems	
	Kumkang aluminum formwork (100m^2)	Conventional wooden formwork (100m^2)
Erecting time	5.21 m^2/hr. 100 m^2= 19 hrs. (3days)	0.58 m^2/hr. 100 m^2= 172 hrs. (21 days)
Stripping time	9.42 m^2/hr. 100 m^2=11 hrs. (1 day)	3.45 m^2/hr. 100 m^2=29 hrs. (4 days)
Waiting time after concrete casting to stripping formwork	3 days	21 days
Total time needed to complete one-floor slab formwork construction	6 days	46 days

From Table 4.17, the time difference between the two formwork is 40 days. 40 additional days had used to construct a one-floor slab when using the wooden formwork system. This means it's about 87 % of construction time minimized by using kumkang aluminum formwork in-floor slab construction. This is means the kumkang formwork avoiding delays by completing the project on or before the completion period. This helps to maximize profit on construction and minimize inflation under the time values of money.

There were additional times need for surface treatments like time for plastering works. In the case of kumkang aluminum formwork, there is no plastering and chiseling work as we have seen from this study. The kumkang aluminum formwork keeps a smooth surface finish and maintains the design shape of members. By this and other surface measurement qualities, we can directly apply finishing material with a combination of material like white cement with gypsum as stated before but this doesn't take additional time for plastering and chiseling work in order to get a smooth and linear surface because the work carried out parallel with gypsum finish. When we see the conventional wooden formwork took additional time for plastering and chiseling work average of 5 days in Kebena project and 4 days in Misrak atekalay project for each floor cycle.

- Each project is a 2B+G+10 mixed-use apartment and lets us take the superstructure construction to compute the average time that consumed by plastering and chiseling work
- Total duration for Kebena project 5 days per floor mean 55 days consumed by plastering and chiseling works.

- Total duration for Misrak atekalay project 4 days per floor 44 days consumed by plastering and chiseling works.
- 100% time can be saved by using kumkang aluminum formwork for plastering and chiseling work. The above time in kumkang aluminum formwork means it's the construction time of 7 and 6 floors minimum.

As shown from the above results and discussion, in all aspects of the time measurement and requirement the kumkang aluminum formwork had better performance and advancement on the conventional wooden formwork within huge gaps. here for the time performance of this formwork was better in the Ethiopian construction industry than recently available formwork systems.

4.4.3 Performance of Kumkang Aluminium formwork on Quality of Finished Concrete

The quality of finished concrete is one of the good formwork requirements in the construction industry as shown from various literature in chapter two. Two major factors decide how well the concrete look in the final result. One is the quality of the formwork material and the other is factors related to concrete which has an impact on the formwork. There are different common measurements of the quality of finished concrete which measure the formwork systems in the aspect of final output in concrete surface and its quality. Under this section, respondents were asked to select the best formwork system in terms of the quality of finished concrete measurement. The following Figure 4.4 contains the response of respondents in formwork systems on common measurement of quality of finished concrete.

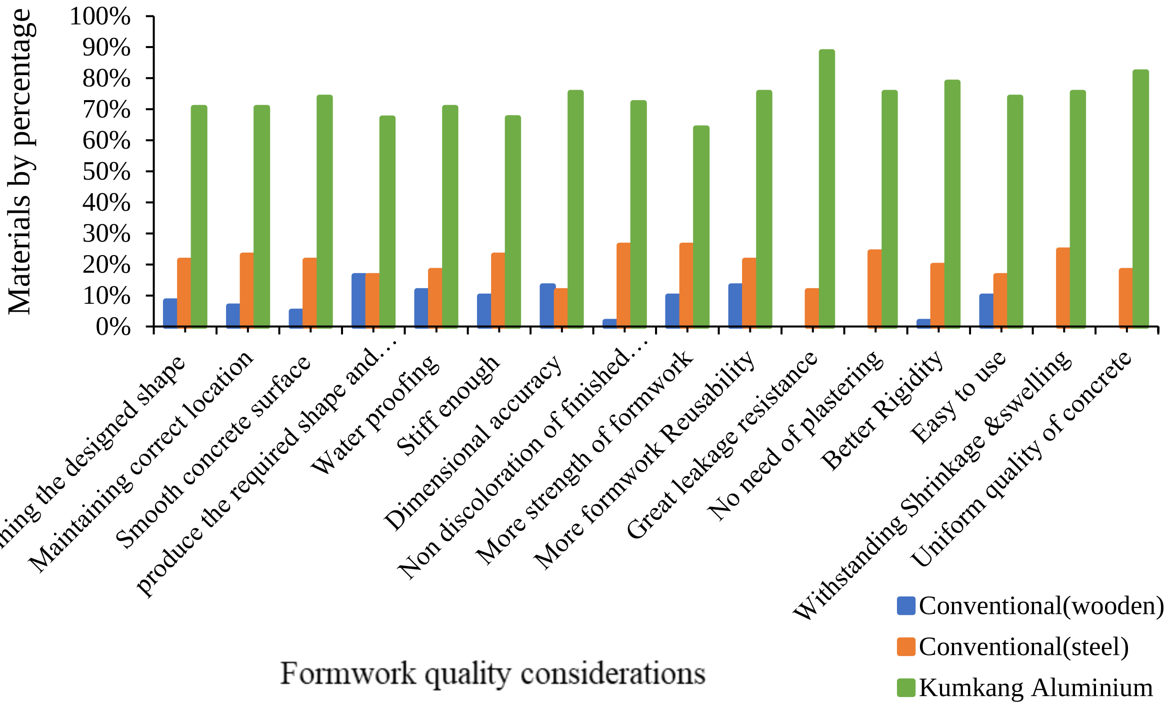


FIGURE 4. 4 Formwork quality consideration and formwork systems

The result from the survey Figure 4.4, shows that kumkang aluminum formwork had better in Maintaining the designed shape of the concrete (70.5%) and steel (21.3%) next to kumkang finally wooden formworks (8.2%). This is due to the kumkang formwork made with its building design and shape there are no cut and drill panels in order to erect the formwork. In Maintaining correct location fewer respondents agreed on conventional(wooden) formwork were better (6.6%) and some of the respondent (23.0%) steel was good. But most of the respondent ware agreed on kumkang aluminum formwork were better with 70.5%. In terms of a smooth concrete surface, able to produce the required shape and surface, waterproofing (not absorb water from concrete), stiff enough against its deflection, buckling under load, dimensional accuracy includes size, shape, and alignment of structural elements, more strength of formwork and more formwork reusability the kumkang aluminum formwork had better advancement than other. Steel formwork achieves better quality in the above aspect next to kumkang formwork. When we reuse wooden formwork to many the quality of surface finish will be reduced and this result additional cost for plastering and chiseling. By this and above aspects wooden formwork had poor quality of finished concrete compare to kumkang and steel.

The other quality measurement that should consider were great leakage resistance, no need for plastering, better rigidity, ease to use, withstanding shrinkage and swelling, and uniform quality of concrete, most of the respondent responses (88.5%, 75.4%, 78.7%, 73.8%, 75.4%, and 82.0% respectively) kumkang aluminum formwork have better quality on the above aspect and steel also a good quality of finished concrete on the above aspects by (11.5%, 24.6%, 19.7%, 16.4%, 24.6%, and 18.0% respectively). While the wooden formwork, the respondent did not agree that wooden formwork fulfills the quality of finished concrete in some measurements like great leakage resistance, no need for plastering, withstanding Shrinkage and swelling, and uniform quality of concrete but few numbers of the respondent (1.6%, 9.8% respectively) agreed wooden formwork had good on better rigidity and easy to use respectively see Appendix-C. Generally based on the result in all quality of finished concrete measurements the kumkang Aluminium formwork had advancement on steel and wooden formworks. Therefore, the kumkang formwork had better performance on the quality of finished concrete in the aspect of the above quality measurement parameters.

Another factor was the factors that have an impact on the formwork system. This affects the quality of finished concrete in final output in addition to formwork material. Concrete placement and compaction, vibration, and form release agent were factors that have an impact on formwork based on various literature. By taking case studies the researcher tries to assess the factor that affects formwork and its quality of concrete on both kumkang aluminum formwork and wooden formwork sites in order to know their practice on such factors and its impact on the concrete surface. The factors which have an impact on formwork and their practice on such factors on those sites are stated in Table 4.18.

Table 4. 18 Factors related to concrete

Factors	Projects		
	Project 1 (conventional wooden)	Project 2 (conventional wooden)	Project 3 (Kumkang Aluminium)
Type of release agent	Form oil	Formwork concrete oil	Form oil 140
Concrete pour / placement rate	3.2m/hr. within smooth operation	2.5m/hr. within smooth operation	3.3m/hr. within smooth operation
Height of concrete pour	2.61m	2m	1m
Vibration	Internal (immersion vibrator)	Internal (immersion vibrator)	Internal (immersion vibrator)

According to Megid & Khayat (2007), The formwork material and release agent have significant impacts on the quality of the formed concrete surface. Also, a good release agent should provide a clean and easy strike without damage to either the concrete face or form, contribute to the production of a blemish-free concrete surface, have no adverse effect on either the form or concrete, assist in obtaining maximum reuse of forms, not inhibit adhesion or penetration of any subsequent finish applied to the formed concrete surface, be inoffensive to the operative concerning odor, skin staining and be suitable for use in the anticipated weather conditions (Tarekegn, 2010). Most construction use burnt oil as mold oil this had a great impact on the quality of finished concrete by causing discoloration and cost for additional treatment. In this study, all projects used the form oil which is recommended to get a good surface finish and to keep the surface of formwork material during removal. And they were applied from oil properly for formwork panels in addition to using form oil, proper application of formwork is an essential thing to get the good surface of the concrete.

Another factor is the concrete placement rate of fresh concrete the faster the rate of placement the greater impact pressure likely to be on the formwork system and cause formwork failure this may result in possible loss of life, property damage, financial burdens, and added time in construction. According to ACI 347 (2014), for walls defined as vertical elements with at least one plan dimension exceeding 2 m the placement rate could be 2.1 to 4.5 m/h. As shown from Table 4.17, those three projects were under ACI recommendation and they had good placement practice in order to avoid formwork failure that causes by excess lateral pressure.

The placing of concrete is the act of depositing into the forms as close as practical to the final position without causing segregation. A good guide is to minimize free fall to less than 1.5m between the discharge portion and pouring portion (Best Practices Guidelines for Concrete Construction, 2005). Placing concrete into forms of small height have a low impact on formwork. from the table the project which used kumkang formwork had good practice compared to others according to recommended height its 1m. this helps to reduce free fall of concrete which cause segregation. But also, according to EBCS2 (1995), To avoid segregation, the free fall of concrete mass shall be restricted to a maximum of three meters unless the system of placing concrete is approved by the designer so, the other projects also under recommendation.

As we seen from literature vibration of concrete by internal vibration causes temporary lateral pressures on formwork. Care should be taken not to damage or break any of the ties while vibrating because this would transfer more load to the other ties and load the forms unevenly. External vibration with form vibrators increases loads on formwork systems even higher and causes variation of lateral pressures. The forms materials, in turn, affect the vibration of fresh concrete. In this case, all projects used an internal vibrator this is somewhat good than external vibration on the impact of formwork.

(a) Wooden formwork concrete surface

(b) Kumkang aluminum concrete surface

FIGURE 4. 5 Effect of formwork material on concrete surface

From the case studies the projects related to such factors, based on their practice the factors had less impact on the quality of finished concrete. So, no factor had an impact on the surface of concrete rather than the material itself under their practice. Therefore, in this study, the formwork system quality measurement factors were differentiated which system had a good quality of finished concrete and kumkang aluminum formwork had a better formwork material according to this. And on factors that are related to site practice which had an impact on formwork by creating lateral pressure the gerji modern village had a good practice and also the formwork itself can withstand the lateral pressure load better than wooden formwork. based on both surface quality measurements and factors that affect surface finish rather than formwork material the kumkang aluminum formwork had better quality performance than steel and wooden formworks.

4.4.4 Performance of Kumkang Aluminum Formwork on Safety

Creating a safer construction environment is one of the considerations in formwork material as stated in literature in chapter two. Safer formwork construction increases the performance of formwork in the aspect of safety since it is one of the criteria of good formwork. Different common measurements show the formwork construction system is safer. Under this section, respondents were asked to select and give a rate to the formwork system and its effects on the health and safety factors of formwork construction.

OSHA reports that nearly two out of three construction workers frequently perform at least part of their work on scaffolding. Although they may not think of scaffolds as dangerous places, roughly 4,500 workers are injured each year in scaffold-related incidents, and as many as 50 deaths. So, good scaffolding increases the safety of construction. The following figure shows the type of external scaffolding that had on the site on formwork construction. From Figure 4.6, 68.9% of respondents responded that they have separate scaffolding types and only 31.1% of respondents had attached scaffolding with the wall. The respondent gives attached with wall is from gerji village project. The kumkang formwork has its own external bracket attached with wall and design with formwork with consideration of man height and working space. And each bracket installed on the wall per floor does not begin from the ground. This helps to minimize the risk raised in separate scaffolding like stability problems when the structure goes up and falling from height. most of the time in conventional formworks the bracket and working platform construct with scaffolding installed from the ground and also it is separate from the wall. This is too difficult when the height of the building goes up.

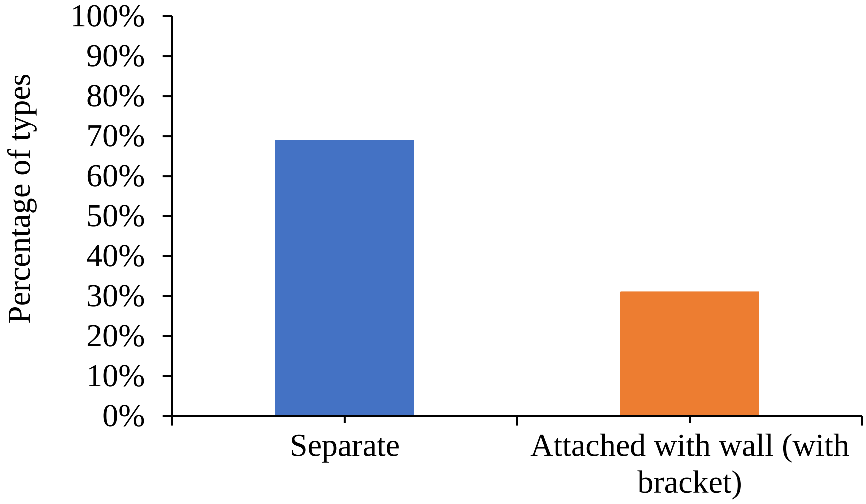


FIGURE 4. 6 Kind of external scaffolding

The result from the interview shows that the kumkang aluminum formwork is strong enough to carry the full load and side pressures from freshly placed concrete, together with live loads (construction traffic and any necessary equipment). And it's had resistance to avoid deflection than wood and steel formwork since it has a great joint system and the flatties hold the formwork through both faces of formwork internally. The kumkang formwork also minimizes collapse during formwork construction because of its prop supporting design with formwork panels and the panels also connect with wadge and pin that are designed within the specified hole on panels. This quality gives good stability against collapse that comes from poor bracing. To ensure the safety of the structure and the protection of the workers during formwork construction the above-specified criteria are essential and the kumkang formwork had better features on each criterion.

Another measurement that describes a safer formwork system during construction was health and safety risk factors. The following Table 4.19 describes the health and safety risk factors related to formwork construction and their frequency of occurrence on different formwork systems were rated. This helps to show which formwork systems have less risk and better safety during construction.

Table 4. 19 Formwork systems to health and safety

Health and safety factors related to formwork	Kumkang formwork		Conventional (wooden) formwork	
	Average index (Mean)	Frequency of Occurrence Rating	Average index (Mean)	Frequency of Occurrence Rating
Falls from height	2.0667	Remote	2.5217	Occasionally
Manual handling activities	2.4667	Remote	3.4783	Occasionally
Exposure to noise	3.1333	Occasionally	3.4783	Occasionally
Risk of pain or injury from performing repetitive tasks	2.4	Remote	2.0435	Remote
Cuts and abrasions	2.9333	Occasionally	3.2826	Occasionally
Risk of eye injury from flying particles and dust	2.2667	Remote	3.1522	Occasionally
Injuring whilst lifting or carrying	2.2667	Remote	3.1087	Occasionally
Slips trips and falls due to untidy work area	2.4667	Remote	2.8261	Occasionally
Risk from exposure to asbestos and hazardous substances	1.6667	Remote	1.8043	Remote
Struck by falling objects or materials	2.6	Occasionally	2.5217	Occasionally
Proximity to flammable or combustible materials	1.9333	Remote	2.3478	Remote
Vibration with finger	2	Remote	2.5	Occasionally
Record of death	1	Rarely	1.1522	Rarely
Hand and foot injury	2.8667	Occasionally	4.8696	Frequent
Panels falling over during installation	2.6	Occasionally	3.1304	Occasionally

Almost certain 4.50 ≤ Average Index, I < 5.00, Frequent 3.50 ≤ Average Index, I < 4.50 Occasional 2.50 ≤ Average Index, I < 3.50, Remote 1.50 ≤ Average Index, I < 2.50 and Rarely 1.00 ≤ Average Index, I < 1.50.

From Table 4.19, there is no difference between two formwork systems on the risk of pain or injury from performing repetitive tasks, the risk from exposure to asbestos and hazardous substances, and Proximity to flammable or combustible materials which rating is remotely occurrence it is not likely to occur under normal circumstances and on the risk, struck by falling objects or materials, exposure to noise, cuts and abrasions and panels falling over during installation by occasionally occurrence this means it is possible or known to occur. There is no record of death rate in both conventional wooden formwork and kumkang formwork which occurs rarely means it is not expected to occur but still possible. On the risk factor falls from height, manual handling activities, risk of eye injury from flying particles and dust, injuring whilst lifting or carrying, slips trips and falls due to untidy work area and vibration with finger the kumkang formwork rate that there is remotely occurrence and the wooden formwork rate occasionally occur. Hand and foot injury risk occur occasionally in kumkang formwork and frequently in wooden formwork which means commonly occurs during the construction of formwork. The above table showed some health and safety risk factors had less occurrence on the kumkang formwork than wooden formwork so, the kumkang Aluminium formwork had less risk and better safety during construction in the aspect of health and safety factors.

The respondent's response from the interview was Kumkang formwork is easy for dismantling at less risk and safe for work as long as proper care is taken during transportation or relocation of site. The climbing method uses its pre-engineered safety scaffolds(brackets) and avoids eucalyptus. Also, it creates a good working environment because it’s had an external attached bracket designed with formwork by the company with height and length of manpower and belt also provided with formwork. This system crate better working environment since it’s had less number of props it helps site organization by reducing site crowdedness’ that creates a hazard on the employer and reduce falling object, nail hazard, cuts, and abrasion. the above reasons show the kumkang formwork has a very good role in minimizing the risk associated with a conventional system and enhance construction safety and create a better work environment for workers.

4.5 Benefit and Barriers of Kumkang Aluminium Formwork on Sustainability

In manner to support sustainable construction, sustainability elements have to be in selecting the type of formwork system. The benefit and the barriers of the formwork systems under sustainable construction are computed by this section through the sustainability benchmarks and their elements. There are three benchmarks under formwork sustainability which are environmental, social, and economical, these benchmarks analyze and rate differently for a different type of formwork. Therefore, the level of response of each element for a different type of formwork was described in this section.

The first benchmark is sustainability with respect to the environment. The environmental sustainability of formwork can measure through 13 elements that were drawn from the different intensive literature studies. The following Figure 4.7 describes the formwork systems rates with respect to each environmental element.

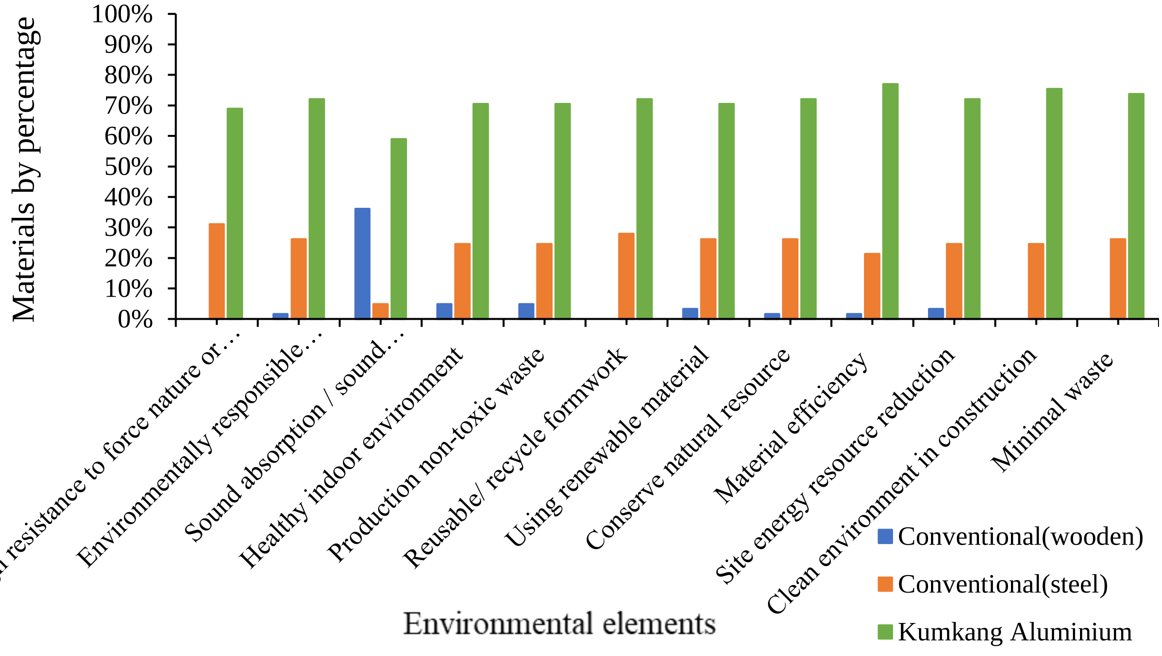
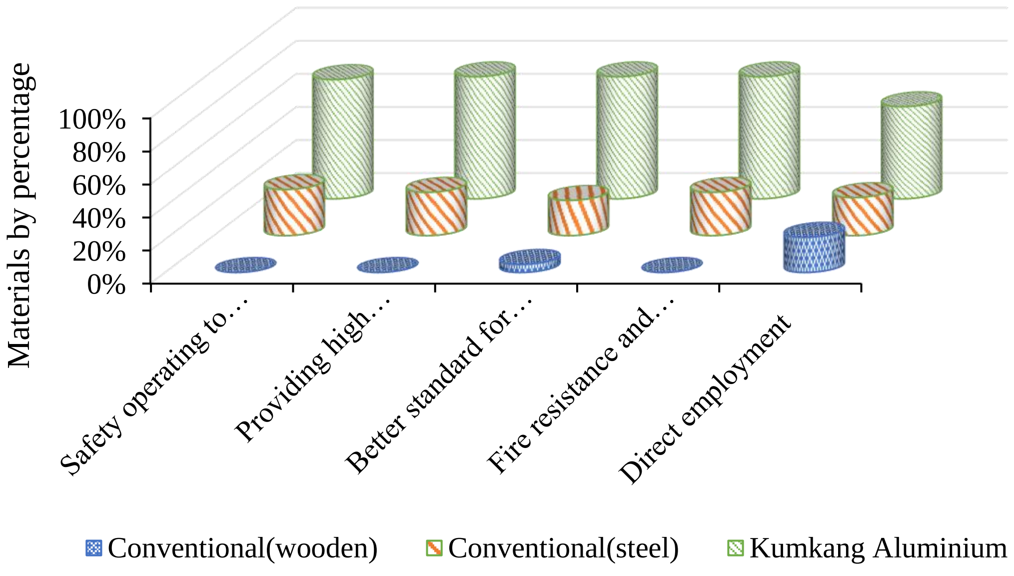


FIGURE 4. 7 Environmental sustainability of formwork systems

From Figure 4.7, kumkang Aluminium formwork is better in high resistance to force nature or climate change with 68.9% and steel formwork rate 31.1% but all of the respondents didn’t agree that the conventional wooden formwork has high resistance to force nature. The next environmental element is the environmental responsible working formwork system the kumkang formwork rate 72.1% and steel 26.2% and wooden formwork was near to null. In sound absorption, the kumkang and wooden formwork have better advancement than steel. the kumkang formwork has a great advantage over other on the rest elements, healthy indoor environment, production of non-toxic waste, reusable/ recycle formwork, using renewable material, conserve the natural resource, material efficiency, site energy resource reduction, clean environment in construction, minimal waste. From the result, we can see that the kumkang aluminum formwork performs better in the aspect of environmental elements. This shows the kumkang formwork has a great benefit on environmentally sustainable construction. On the other hand, the wooden formwork system had less performance in environmental sustainable criteria especially on the reusable/ recycle formwork, material efficiency, clean environment in construction, and minimal waste. Next to kumkang formwork steel formwork have good in keeping environmental sustainable construction see Appendix-C.

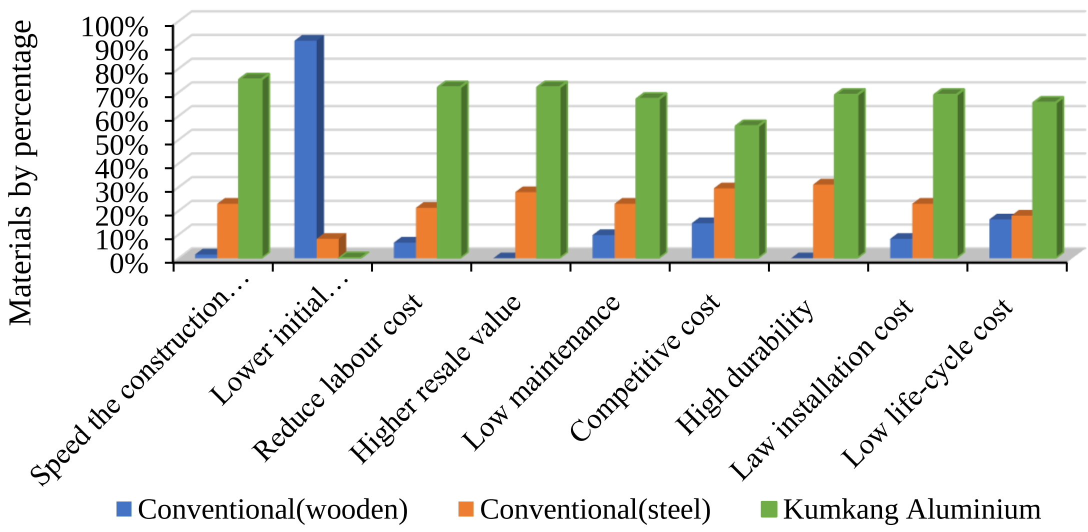
The next benchmark that measures a sustainable formwork system was social elements. The social elements were computed between kumkang, steel, and wooden formwork and the result of the responses described below. From figure 4.8, the kumkang formwork was more advantageous in creating a safe operation to works and the third party with response rate (72.1%), providing high customer satisfaction, better standard for the local community, fire resistance, and flame retard (73.8%) of each and direct employment (55.7%). This shows in all aspect of social sustainability the kumkang formwork had better advancement than other. In somewhat the steel formwork also had a great benefit in fulfilling social sustainable construction. The wooden formwork in this case also had a lower benefit on social elements and doesn’t enhance social sustainable construction see Appendix-C.



Social elements

FIGURE 4. 8 Social sustainability of formwork systems

According to Al-Ashwal et al. (2017), the current practice, the interest in the temporary work system is more due to its cost-effectiveness ignoring other sustainability factors. The economical elements are the major criteria that measure the sustainable formwork system and the most practiced one in every construction. These economical elements were the last benchmark that measures sustainable formwork. The following Figure 4.9 shows the rates of different formwork system benefit and advancement on economical sustainability.



Economical elements

FIGURE 4. 9 Economical sustainability of formwork systems

From Figure 4.9, the kumkang formwork had a great advantage on speed the construction time (75.4%). This is due to the kumkang formwork had a faster construction cycle to complete one floor within seven days per floor. For lower initial investment cost the wooden formwork had great benefit with 91.8% of the response. While the kumkang formwork had a barrier due to its high initial investment cost however its reusability minimizes the life cycle cost of formwork and the wooden formwork cost much amount for formwork throughout the project life cycle. On reducing labour cost the kumkang formwork had a rate of 72.1% this is because the kumkang formwork doesn't need skilled labour to construct, the cost of labour for skilled one will be minimized since the cost of skilled labour is greater than non-skilled one. Also, the kumkang formwork had high resale(salvage) value (72.1%) than the other. This is due to the aluminum material itself has high cost than steel and wooden on local market and also the aluminum could use after recycling again in the form of formwork, unlike wood formwork form in another physical feature. With low maintenance cost (67.2), law installation cost (68.9%) and low life cycle cost (65.6%) response rate the kumkang formwork had a great advantage. Since the kumkang formwork had a greater number of repetitions and use unskilled labour the life cycle cost of formwork and installation cost was lower than steel and wooden formwork. on great competitive cost (55.7%) and high durability (68.9%) elements also the kumkang formwork had a better advantage on the other see Appendix-C. From the above results, the kumkang aluminum formwork had almost a better advantage concerning economical sustainability and there is a barrier also on initial investment cost but this one come over through its number of reusability.

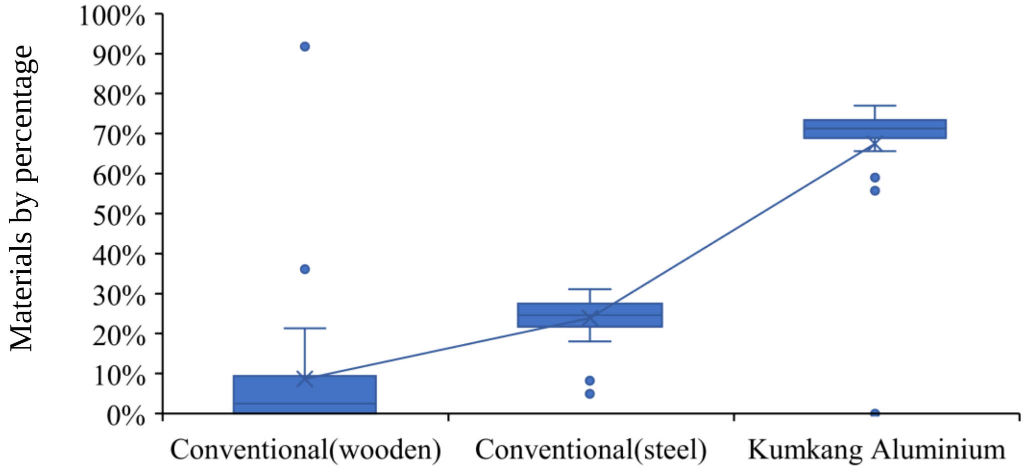


FIGURE 4. 10 Sustainability comparison between formwork systems

At long last, the kumkang aluminum formwork was beneficial for enhancing sustainable construction. Almost all of the sustainable formwork system measurements are fulfilled by this formwork system. Also, the analysis from the interview shows that the kumkang formwork can sustain construction work by less cost, reduce time, great reusability it's the number of repetitions even the design change we can recycle some forms only others like wall formwork used as it is. A quality issue like dimension and smooth surface, it can be recycled and reduces wastage were another reason where kumkang formwork enhance sustainable construction when we compared to conventional (wooden) formwork and steel formwork.

4.6 Labour Productivity of Kumkang Aluminum Formwork

Labour is strongly influenced by formwork since it involves a significant portion of the cost of a concrete structure. By taking case studies on gerji village (kumkang formwork) and the project that used wooden formwork, the labour productivity of kumkang aluminum formwork was evaluated. by making a comparison on the output of labours in one crew per hour for each structural member the comparison was made. The following Table 4.20 shows the productivity of labours in m^2/hr. on each structural member in both formwork systems.

Table 4. 20 Average productivity of labor in erecting and stripping of formworks

Structural Members		Projects		
		Project 1 (conventional wooden) (m^2/hr.)	Project 2 (conventional wooden) (m^2/hr.)	Project 3 (Kumkang Aluminium) m^2/hr.
Column	Erecting	0.7	0.6	-
	Stripping	2.5	1.5	-
Beam	Erecting	0.51	0.6	-
	Stripping	2.02	2.7	-
Stair	Erecting	0.52	0.46	1.4
	Stripping	1.87	1.84	2.7
Wall	Erecting	0.83	0.75	4.4
	Stripping	2.86	2.66	7.94
Floor slab	Erecting	0.58	0.67	5.21
	Stripping	3.45	3.5	9.42

As stated before, the kumkang aluminum formwork applies to the wall slab and stair system. Since the wall member is a shear wall the load transfer from slab direct to the wall. The beam and column members are omitted in gerji modern village project because the wall can do the task of such members. But the kumkang formwork can apply for the structures which have column and beam. So, we can compare the productivity of the formworks on slab, shear wall, and stair structures only. First, let us see the stair member of both formwork productivity. The conventional wooden formwork in project 1 was erected 0.52 m^2/hr. and striped 1.87 m^2/hr. and the kumkang aluminum formwork erected 1.4 m^2/hr. and was striped 2.7 m^2/hr. For wall members, the conventional were erect 0.83 m^2/hr. and striped 2.86 m^2/hr., and in kumkang formwork, the formwork was erected 4.4 m^2/hr. and striped 7.94 m^2/hr. and so on. By taking the average productivity of the two projects which use the wooden formwork to the productivity of the kumkang, kumkang formwork had an advancement with 0.91, 3.61, 4.59 m^2/hr. for stair, wall, and floor slab respectively for formwork erection and during formwork stripping the productivity of the kumkang formwork enhance the wooden one by 0.85, 5.18, 5.95 in stair, wall and floor slab respectively.

And by taking average monthly productivity, productivity was evaluated to know their training curve (performance) progress from first and now. Since the kumkang aluminum formwork was new technology for the country it takes time to adapt and be productive in one time also to identify the productivity on the wooden formwork from month to a month studying monthly progress is needed. The following Table 4.21 shows the average monthly productivity of both kumkang aluminum and conventional formwork.

Table 4. 21 Monthly productivity of labour

No.	Month	Productivity (m^2/hr.)	
		Kumkang Aluminium formwork	Conventional (wooden) formwork
1.	Month 1 (March)	3.05 m^2/hr.	0.82 m^2/hr.
2.	Month 2 (April)	4.06 m^2/hr.	0.68 m^2/hr.
3.	Month 3 (May)	4.35 m^2/hr.	0.62 m^2/hr.

From Table 4.21, the productivity of the kumkang aluminum formwork was an increase from month to month. When the adaptation to the technologies increases also the labour performance increase by repetitive work and training from first to now in the case of kumkang formwork. And the conventional one was decreased when the floor of the building goes up because it's difficult to construct the formwork from a higher level since the working platform and formwork transportation is not comfortable, unlike kumkang formwork. the kumkang formwork can easily transport from floor to floor manually to the next level through a slab transfer box.

Based on interview analysis to evaluate and enhance labour productivity of kumkang aluminum formwork they used a lined schedule to complete one-floor formwork and the floor divided with zones. This zone means one crew usually called and they had five zones (crews) including the core zone on one floor. Each zone had provided time and by evaluating work done on each zone they evaluate the labour productivity. Optimization by fixing crew information through recording data like work done in m^2/hr. and by shifting labours with their specialization by trying on different zones then screwing who is better on that and this. After this by assigning the labours on their specialization with special care in order to attain maximum work with minimum labours by increasing their efficiency. In order to enhance their productivity, there are motivational mechanisms The motivational mechanism had: bonus with milestone(zone) when they finished the seven days work with six days the company give 1-day monthly salary as a bonus, they have a cafeteria (food service) on the site and bank also to develop the better facility.

From observation first, they use an excess amount of labour because there is a fear since there is no reference then by trial and giving them training, they enhance the ability and efficiency of labours and they came up with less number of labours. Also, there is a gap between the time for completing one-floor work from company recommendations and various literature which is seven days cycle but they were complete within 21-19 days for the first two floors. after those floors through the above methods, training, and other motivational mechanisms their labour productivity increases gradually and attain its label which is seven days for one floor.

As we have seen from the above the type of formwork material affected labour productivity and the kumkang aluminum formwork had a great advantage on this. The kumkang formwork productivity was almost double time and above conventional wooden formwork one. Here of the kumkang aluminum formwork had good in enhancing the labour productivity and helps in making the construction faster.

4.7 Triangulation of the Results

The study was undertaken to evaluate the kumkang aluminum formwork performance in Addis Ababa federal housing projects. Multiple data collection methods were used for these approaches. The first research method was a case study, conducted on cost, time, quality, and labour productivity in order to identify the performance of the kumkang aluminum formwork. The result of the case studies was supported by interviews and questionnaires except for the cost performance. The cost of the kumkang formwork undertaken was higher from the result of the interview and questionnaire. Whereas the cost performance of the kumkang aluminum formwork was very much less than conventional wooden formwork from the result of case studies. The second research method was a questionnaire, conducted for answering all the research objectives except on labour productivity performance of kumkang aluminum formwork. For the rest research question, the result from the questionnaire was proof and supplementary with the result of the interview and case study except the cost issue stated above. The third and final method of this study was the interview that is conducted for answering all the research questions. The result from the interview also was supplementary and support each other with other data collection methods of this research except on some research objectives, the cost of the kumkang aluminum formwork was understood as higher in respondent perception from questionnaire and interview but the case studies disproof this. And another variation from the result of other data collection methods was, the kumkang aluminum formwork practice limitation state clearly with the result of the interview but on the questionnaire result the respondent perception was good and the limitation was not stated. The final product represented triangulation in near to all analysis of data from data sources was supplemented each other and this was used to further support for the conclusions made.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

As stated above the objective of this study is to evaluate the kumkang aluminum formwork performance with regard to cost, time, quality of finished concrete, safety, sustainability, and labour productivity aspects. Based on the objectives of the study the results and analysis has been done before and from the findings of the study the following conclusion are drawn: -

The kumkang aluminum formwork is manufactured and imported from Korea based on the design of the building. This system can construct through manually and the panel transport through slab transferring box manually. This helps to reduce site crowdedness and also cost related to crane for transporting formworks. And this formwork system used more unskilled labour than skilled one it only needs short term training. The method of construction of this formwork had differed in practice from than conventional one. The electrical conduit, fixture, and water supply pipes were installed with the rebar before erecting the formwork. Erection and stripping of the kumkang formwork system are also different from the conventional system with work methodologies and with time taking to construct the formwork. Rather than this the kumkang aluminum formwork material itself is a durable product that can be used repeatedly for several cycles, easy to install, a fast construction cycle, and can produce high-quality concrete surface and dimensional accuracy with better alignment. But it's has limitations on maintain and design change because it is not flexible.

The kumkang aluminum formwork have better cost performance by reducing the cost related to formwork construction. These are labour cost, material cost, equipment cost, number of reusability's, and cost for the surface finish after the formwork strip. The kumkang aluminum formwork is reused 250-300 times, whereas the wooden formwork is reused 3-4 times. Increasing the reusability of the wooden formwork reduces the quality of the formwork and the final concrete surface quality. On the formwork unit cost (including material, labour, equipment cost) of formwork, kumkang aluminum formwork costs less than wooden formworks by 173.29 Birr in 1 m^2. 40% of formwork cost in construction is reduced by using this formwork. There is an additional treatment cost difference between conventional wooden and kumkang aluminum formwork. 155.08 Birr/m^2 which is 89% of additional treatment for surface finish cost was reduced by using kumkang formwork rather than wooden formwork for surface finishing works.

In all aspects of the time measurement, the kumkang aluminum formwork have better performance and advancement on conventional wooden formwork with faster construction time. The time taken to erect the kumkang formwork was less by triple times and more than in wooden formwork and the time taken to strip the formwork, the kumkang aluminum formwork fastens the construction floor cycle by reducing double times than using conventional wooden formwork. For the time taken to complete one-floor formwork construction, 7 days utilized to construct one-floor formwork by kumkang including formwork strip, while the conventional formwork takes 21 to 31 days for erection only. This implies a 3- 4 floor formwork construction time in kumkang aluminum formwork. It reduced 40 additional days and 87 % of construction time to construct 100 m^2 floor slab when using the kumkang formwork compared to wooden. And for the time need for surface finish works, an average of 5 days and 4 days are needed for each floor cycle in conventional wooden formwork projects. Whereas using kumkang Aluminium formwork saves 100% time for plastering and chiseling work. In the case of the gerji modern village project, 55 to 44 days were saved by using this formwork system.

Two major factors decide how well the concrete will look in the final result. One is the quality of the formwork material and the other is factors related to concrete which has an impact on the formwork. On the quality of formwork material measurements, the kumkang aluminum have advancement on steel and wooden formworks with the result of greater than 60% in all quality of finished concrete measurements. Another factor was factors related to concrete which has an impact on the formwork. that is type of release agent, concrete pour/placement rate, the height of concrete pour, vibration. The project's practice related to such factors that are impact on the formwork was good and the factors had less impact on the quality of finished concrete. So, no factor had an impact on the surface of concrete rather than the material itself under their practice. If so the kumkang have better performance on formwork material quality measurements and this means it is good in attaining a better quality of the concrete surface.

The kumkang formwork has a very good role in minimizing the risk associated with a conventional system and enhance construction safety by creating a better work environment for workers. This formwork minimizes the risk raised in separate scaffolding like stability problems when the structure goes up and falling from height since it’s had its external bracket attached with wall and design with formwork. This creates a good working environment. The kumkang aluminum formwork is strong enough to carry the full load and side pressures from freshly placed concrete, together with live loads (construction traffic and any necessary equipment). And it’s had resistance to avoid deflection than conventional wood and steel formwork. The kumkang formwork also minimizes collapse during formwork construction because of its prop supporting design with formwork panels and the panels also connect with wadge and pin that are designed within the specified hole on panels. To ensure the safety of the structure and the protection of the workers during formwork construction the above-specified criteria are essential and the kumkang formwork had better performance on each criterion. The kumkang aluminum formwork had also less risk and better safety during formwork construction in the aspect of health and safety factors. Health and safety risk factors had less occurrence on the kumkang formwork than wooden formwork.

In manner to support sustainable construction, sustainability elements have to be in selecting the type of formwork system. The kumkang aluminum formwork is beneficiary for enhancing sustainable construction. Almost all of the sustainable formwork system measurements are fulfilled by this formwork system. Kumkang formwork has a great benefit on environmentally sustainable construction. On the other hand, the wooden formwork system had less performance in environmental sustainable criteria. Next to kumkang formwork steel formwork have good in keeping environmental sustainable construction. In all aspect of social sustainability, the kumkang formwork have better advancement than other. In somewhat the steel formwork also had a great benefit in fulfilling social sustainable construction. The wooden formwork in this case also had a lower benefit on social elements and doesn’t enhance social sustainable construction. The kumkang Aluminium formwork have also a better advantage concerning economical sustainability but there is a barrier on initial investment cost but this one come over through its number of reusability and it's not profitable for small projects.

The kumkang formwork labour productivity is almost double time and above than conventional wooden formwork. Kumkang formwork have an advancement than wooden formwork on formwork erection with 0.91, 3.61, 4.59 m^2/hr. output for stair, wall, and floor slab respectively and during formwork stripping the productivity of the kumkang formwork enhance the wooden one by 0.85, 5.18, 5.95 m^2/hr. in stair, wall and floor slab respectively. On the average monthly productivity, the productivity of the kumkang Aluminium formwork increase from month to month. When the adaptation to the technologies developed and the labour performance increase through repetitive work and training from first to now. The conventional one is decrease when the floor of the building goes up because it's difficult to construct the formwork from the higher floor since the working platform and formwork transportation is not comfortable, unlike kumkang formwork. Here of the kumkang Aluminium formwork had good in enhancing the labour productivity and helps in making the construction faster.

In the end, the kumkang aluminum formwork have a great advantage and better performance with regard to minimize the cost of construction, speed the construction time, good quality of finished concrete, safer construction environment, enhancing sustainable construction, and increasing labour productivity. That is all construction project needed for and this kind of formwork gives rest for the country that have housing problems like Ethiopia. In order to build mass housing projects within a short period of time, less costs, good quality, and the above-stated requirements, the kumkang formwork is a better option recently in our country from other formwork materials.

5.2 Recommendations

Based on the results of the study and the conclusion, I would like to forward the following recommendations /suggestions.

- The formwork should handle properly in order to keep its reusability since the usability depends on the method of handling. There is un-wanted/excess force used to erect the formworks. And there were different missed elements and miss much of the design due to communication problems. A careful check should give before concrete casting to prevent formwork collapse.
- There is a lack of research related to such kind of technology and our knowledge share performance with the technology is less and we have a fear to adopt new technologies we only judge from outside. This is what happens in most of the contractors but rather than decide the modern formwork is costly the contractors should involve and making researches on it. Also, the contractors should aware of and follow up technologies in construction.
- The time to bring such formwork system in the country is such a right decision and in fact, we are late. we can use it for different mass housing projects like condominiums, apartments, real estate, and so on for the past years. So, the housing policy agency

should apply and make policies related to such and other modern formwork systems to rectify our housing problem.

- Real estate developers should adopt such and other modern formworks in order to overcome the time issue that is raised by customers all the time and it's profitable for mass housing projects.
- There is no government support for the contractors that brings this kind of technology. The contractors try themselves this makes it difficult to change the construction industry from conventional to modern formwork one side only. So, the government should support the contractors by making promotions and tax reductions in order to modernize our construction industry.
- Directivities defects lead to not use modern formwork systems ware stated as a reason for less adaptation of modern formworks in our country. So, the government should also support the contractors in the adjustment of procurement directivities and prepare a mechanism to get such kinds of technologies on the local market by build manufacturing industries or imported raw materials and machinery to produce aluminum formworks of a similar kind locally.
- In the utilization of formwork, there is no framework and standards for utilizing kumkang formwork and another modern formwork system by an authorized party. The authorized party which is a ministry of urban and development construction should develop the framework and utilization standard for formwork construction.
- There is a lack of implementation of rules by construction companies as stated before. So, the authorized party should enact and follow up the rules after declaration.
- No registration requirement considers formwork material used by the contractors to this day. The MoUDC should put a regulation for licensing the contractors at least for grade one contractors to use formworks rather than wooden, especially for high-rise buildings.
- The ministry of urban and development construction should have to create knowledge-sharing forums and training between construction companies. Also, should have provided upgrade information about the modern formwork system.
- As an initial study on the performance of kumkang aluminum formwork in a federal housing project, this research is believed to open the door for future study and further and more detailed studies should conduct on such formwork system application, construction methodology, design, and formwork management.

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Appendix-A: Costs of formwork

Table A- 1 Formwork unit cost as Addis Ababa construction bureau

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: FORM WORK — LABOUR HOURLY OUTPUT: 0.5 m^2/hr.
WORK ITEM: _ (4.28) For Super structure column ,Floor beam & slab — EQUIPEMENT:
TOTAL QUANTITY OF WORK ITEM : 1.00 m^2 — RESULT: 423.98 Birr/m^2

Material Cost (1:01)					Labour (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
Wooden form work	M^2	1.05	70.10	73.61	Forman	1.00	0.17	64.21	10.72	Tools	1.00	0.50	0.50
50 x 70 cm battens	M	0.30	39.00	11.70	Carpenter	1.00	1.00	46.37	46.37	Cranes	0.01	2300.00	18.40
Strut 0 60 mm	M	1.50	5.91	8.86	Ass.Carpenter	1.00	1.00	37.10	37.10				
Nails	Kg	0.30	59.50	17.85	DL	1.00	1.00	14.84	14.84				
Mould Oil	Lit.	0.05	17.85	0.80									
Total (1:-01)				112.82	**Total (1:02)**				109.03	**Total (1:03)**			18.90

A= Materials Unit Cost 112.82 Birr/m^2 — B= Manpower Unit Cost 218.06 Birr/m^2 — C=Equipment Unit Cost 37.80 Birr/m^2
Total of (1:02) — Total of (1:03)
Hourly Output: — Hourly output: ________________
Direct Cost of Work Item = A+B+C = 368.68 Birr/m^2
Over head cost : 8% 29.49 Birr/m^2
Profit Cost: 7% 25.81 Birr/m^2
Total Unit Cost : 423.98 **Birr/m^2**

Remark ____
UF: UTILIZATION FACTOR
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

Table A- 2 Plastering cost for the internal and external wall in Kebena

7.Plastering and Pointinting

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: **FINISHING WORKS.** — LABOUR HOURLY OUTPUT: 1.88 m^2/hr
WORK ITEM: (11.1) **3 Coats of cement plastering (1:3) (To internal wall)** — EQUIPEMENT:
TOTAL QANTITY OF WORK ITEM: 1.00 m^2 — RESULT : 125.36 Birr/m^2

Type of Material	Unit	Qty *	Rate	Cost per U	Labour by	No.	UF	** Indexed	Hourly Cos	Type of Eq	No.	Hourly Rer	Hourly Cost
cement	qt.	0.10	420.00	43.26	Forman	1.00	0.25	40.00	10.00	Tools	1.00	0.50	0.50
sand	m^3	0.02	681.12	14.98	Plasterer	1.00	1.00	30.00	30.00	scaffolding	0.50	10.00	5.00
water	m^3	0.07	35.00	2.45	Chiseler	1.00	1.00	16.25	16.25				
					DL	1.00	1.00	12.50	12.50				
	Total (1:01)			60.69	Total (1:02)				68.75	Total (1:03)			5.50

A= Materials Unit Cost 60.69 Birr/m^2 — B= Manpower Unit Cost 36.67 Birr/m^2 — C= Equipment Unit C 2.93 Birr/m^2
Total of (1:02) — Total of (1:03)
Hourly Output: ______________________ — Hourly output: ________________
Direct Cost of Work Item = A+B+C = 100.29 Birr/m^2
Over head cost : 15% 15.04 "
Profit Cost: 10% 10.03 "
35.50 106.51 0.48 Total Unit Cost : **125.36** **Birr/m^2**

Remark ____
UF: UTILIZATION FACTOR
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: **FINISHING WORKS.** — LABOUR HOURLY OUTPUT: 1.88 m^2/hr
WORK ITEM: (11.1) **3 Coats of cement plastering (1:3) (To external wall)** — EQUIPEMENT:
TOTAL QANTITY OF WORK ITEM: 1.00 m^2 — RESULT : 176.93 Birr/m^2

Type of Material	Unit	Qty *	Rate	Cost per U	Labour by	No.	UF	** Indexed	Hourly Cos	Type of Eq	No.	Hourly Rer	Hourly Cost
cement	qt.	0.10	420.00	43.26	Forman	1.00	0.25	42.50	10.63	Tools	1.00	0.50	0.50
sand	m^3	0.02	681.12	14.98	Plasterer	1.00	1.00	30.54	30.54	scaffolding	2.00	10.00	20.00
water	m^3	0.07	35.00	2.45	Chiseler	1.00	1.00	16.25	16.25				
					DL	1.00	1.00	12.50	12.50				
	Total (1:01)			60.69	Total (1:02)				69.92	Total (1:03)			20.50

A= Materials Unit Cost 60.69 Birr/m^2 — B= Manpower Unit Cost 69.92 Birr/m^2 — C= Equipment Unit C 10.93 Birr/m^2
Total of (1:02) — Total of (1:03)
Hourly Output: ______________________ — Hourly output: ________________
Direct Cost of Work Item = A+B+C = 141.54 Birr/m^2
Over head cost : 15% 21.23 "
Profit Cost: 10% 14.15 "
Total Unit Cost : **176.93** **Birr/m^2**

Remark ____
UF: UTILIZATION FACTOR
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

Table A- 3 Plastering cost for exposed beam and columns and slab soffit in Kebena

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: **FINISHING WORKS.** LABOUR HOURLY OUTPUT: 1.875 m^2/hr

WORK ITEM: (11.3) 3 Coats of cement plastering to exposed beams and columns. EQUIPEMENT:

TOTAL QANTITY OF WORK ITEM: 1 m^2 RESULT : 170.26 Birr/m^2

Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
cement	qt.	0.10	420.00	43.26	Forman	1.00	0.25	42.50	10.63	Tools	1.00	0.50	0.50
sand	m^3	0.02	681.12	14.98	Plasterer	1.00	1.00	30.54	30.54	scafolding	1.00	10.00	10.00
water	m^3	0.07	35.00	2.45	Chiseler	1.00	1.00	16.25	16.25				
					DL	1.00	1.00	12.50	12.50				
				60.69					69.92				10.50

A= Materials Unit Cost 60.69 Birr/m^2

B= Manpower Unit Cost 69.92 Birr/m^2
Total of (1:02)
Hourly Output: ______________________

C= Equipment Unit C 5.60 Birr/m^2
Total of (1:03)
Hourly output: ________________

Direct Cost of Work Item = A+B+C = 136.21 Birr/m^2
Over head cost : 15% 20.43 "
Profit Cost: 10% 13.62 "
Total Unit Cost : **170.26 Birr/m^2**

Remark ____

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

ANALYSIS SHEET FOR DIRECT & INDIRECT UNIT COSTS

PROJECT: **FINISHING WORKS.** LABOUR HOURLY OUTPUT: 1.5 m^2/hr

WORK ITEM: (11.3) 3 Coats of cement plastering to Slab soffit beams soffit EQUIPEMENT:

TOTAL QANTITY OF WORK ITEM: 1 m^2 RESULT : 172.01 Birr/m^2

Material Cost (1:01)					Labour Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labour by Grade	No.	UF	** Indexed Hourly Cost	Hourly Cost	Type of Equipment	No.	Hourly Rental	Hourly Cost
cement	qt.	0.10	420.00	43.26	Forman	1.00	0.25	42.50	10.63	Tools	1.00	0.50	0.50
sand	m^3	0.02	681.12	14.98	Plasterer	1.00	1.00	30.54	30.54	scafolding	1.00	10.00	10.00
water	m^3	0.07	35.00	2.45	Chiseler	1.00	1.00	16.25	16.25				
					DL	1.00	1.00	12.50	12.50				
				60.69					69.92				10.50

A= Materials Unit Cost 60.69 Birr/m^2

B= Manpower Unit Cost 69.92 Birr/m^2
Total of (1:02)
Hourly Output: ______________________

C= Equipment Unit C 7.00 Birr/m^2
Total of (1:03)
Hourly output: ________________

Direct Cost of Work Item = A+B+C = 137.61 Birr/m^2
Over head cost : 15% 20.64 "
Profit Cost: 10% 13.76 "
Total Unit Cost : **172.01 Birr/m^2**

Remark ____

UF: UTILIZATION FACTOR

*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.

**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.

Table A- 4 Plastering cost for the internal and external wall in Misrak atekalay

ANALYSIS SHEET FOR DIRECT & INDIRECT COSTS

PROJECT:	FINISHING WORKS							LABOUR DAILY OUTPUT:			1.3	m^2/hr	
WORK ITEM : (6.1d)		2 Coats of cement plastering (1:3) (To internal wall)						EQUIPMENT DAILY OUT PUT:			1.3	m^2/hr	
TOTAL QUANTITY OF WORK ITEM:		1	m^2					RESULT :		137.33	Birr/m^2		
Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labor by Trade	No.	UF	** Indexed hourly wage	Hourly wage	Type of Equipment	No.	Hourly Rental	Hourly Rental
Cement	qt.	0.076	450.0	34.20	Foreman	1	0.1	40	4.00	Hand tools	2.00	0.50	1
Sand	m^3	0.019	600.0	11.16	Plasterer	1	1	35.5	35.50	Scffolding	1	3	3
Water	m^3	0.070	100.00	7.00	D/L	1	1	12.5	12.50				0
					Chisler	1	1	18.75	18.75				0
													0
													0
													0
													0
													0
Total (1:-01)				52.36	Total (1:02)				70.75	Total (1:03)			4
A=Material unit cost	52.36	Birr/m^2			B=Manpower Unit Cost			54.42	Birr/m^2	C=Equipment Unit Cost		3.08	Birr/m^2
					Total of (1:02)					Total of (1:03)			
					Daily Output					Daily output:			
				Direct Cost of work item = A + B + C =					109.86	Birr/m^2			
					Overhead Cost :			10%	10.99	Birr/m^2			
					Profit Cost:			15%	16.48	Birr/m^2			
					Total:				137.33	Birr/m^2			
Remark : ____________________										Birr/m^2			
UF: UTILIZATION FACTOR					Total Unit Cost :				137.33	Birr/m^2			
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.													
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.													

ANALYSIS SHEET FOR DIRECT & INDIRECT COSTS

PROJECT:	FINISHING WORKS							LABOUR DAILY OUTPUT:			1.3	m^2/hr	
WORK ITEM : (6.1b & c)		2 Coats of cement plastering (1:3) (To external wall)						EQUIPMENT DAILY OUT PUT:			1.3	m^2/hr	
TOTAL QUANTITY OF WORK ITEM:		1	m^2					RESULT :		140.63	Birr/m^2		
Material Cost (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labor by Trade	No.	UF	** Indexed hourly wage	Hourly wage	Type of Equipment	No.	Hourly Rental	Hourly Rental
Cement	qt.	0.080	450.0	36.0	Foreman	1	0.1	40	4.00	Hand tools	2.00	0.50	1
Sand	m^3	0.020	600.0	12.00	Plasterer	1	1	35.5	35.50	Scffolding	1	3	3
Water	m^3	0.070	100.00	7.00	D/L	1	1	12.5	12.50				0
					Chisler	1	1	18.75	18.75				0
													0
													0
													0
													0
													0
Total (1:-01)				55.00	Total (1:02)				70.75	Total (1:03)			4
A= Material unit cost	55.00	Birr/m^2			B=Manpower Unit Cost			54.42	Birr/m^2	C=Equipment Unit Cost		3.08	Birr/m^2
					Total of (1:02)					Total of (1:03)			
					Daily Output					Daily output:			
				Direct Cost of work item = A + B + C =					112.50	Birr/m^2			
					Overhead Cost :			10%	11.25	Birr/m^2			
					Profit Cost:			15%	16.88	Birr/m^2			
					Total:				140.63	Birr/m^2			
Remark : ____________________										Birr/m^2			
UF: UTILIZATION FACTOR					Total Unit Cost :				140.63	Birr/m^2			
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.													
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.													

Table A- 5 Plastering cost for exposed beam, columns and soffit slab in Misrak atekaly

ANALYSIS SHEET FOR DIRECT & INDIRECT COSTS

PROJECT:	**FINISHING WORKS**							LABOUR DAILY OUTPUT:			1.3	m^2/hr	
WORK ITEM : (6.1a)	2 Coats of cement plastering to exposed beams and columns.							EQUIPMENT DAILY OUT PUT:			1.3	m^2/hr	
TOTAL QUANTITY OF WORK ITEM:		1	m^2					RESULT :		**148.33**	Birr/m^2		
Material Cost (1:01)					**Labor Cost (1:02)**					**Equipment Cost (1:03)**			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labor by Trade	No.	UF	** Indexed hourly wage	Hourly wage	Type of Equipment	No.	Hourly Rental	Hourly Rental
Cement	qt.	0.097	450.0	43.65	Foreman	1.00	0.17	40	6.68	Hand tools	2.00	0.50	1
Sand	m^3	0.025	600.0	15.00	Plasterer	1.00	1.00	35.5	35.50	Scffolding	1	3	3
Water	m^3	0.005	100.0	0.45	Chilser	1.00	1.00	18.75	18.75				0
					D/L	1.00	1.00	12.5	12.50				0
													0
													0
													0
													0
													0
Total (1:-01)				**59.10**	**Total (1:02)**				**73.43**	**Total (1:03)**			**4**
A=Material unit cost	59.10	Birr/m^2			**B=Manpower Unit Cost**			56.48	Birr/m^2	**C=Equipment Unit Cost**	3.08	Birr/m^2	
					Total of (1:02)					Total of (1:03)			
					Daily Output					Daily output:			
				Direct Cost of work item = A + B + C =					**118.66**	Birr/m^2			
					Overhead Cost :			10%	11.87	Birr/m^2			
					Profit Cost:			15%	17.80	Birr/m^2			
					Total:				**148.33**	Birr/m^2			
Remark : ______________________________										Birr/m^2			
UF: UTILIZATION FACTOR					**Total Unit Cost :**				**148.33**	Birr/m^2			
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.													
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.													

ANALYSIS SHEET FOR DIRECT & INDIRECT COSTS

PROJECT:	**FINISHING WORKS**							LABOUR DAILY OUTPUT:			1.3	m^2/hr	
WORK ITEM : (6.1e)	2 Coats of cement plastering to soffit celling.							EQUIPMENT DAILY OUT PUT:			1.3	m^2/hr	
TOTAL QUANTITY OF WORK ITEM:		1	m^2					RESULT :		**170.28**	Birr/m^2		
Material Cost (1:01)					**Labor Cost (1:02)**					**Equipment Cost (1:03)**			
Type of Material	Unit	Qty *	Rate	Cost per Unit	Labor by Trade	No.	UF	** Indexed hourly wage	Hourly wage	Type of Equipment	No.	Hourly Rental	Hourly Rental
Cement	qt.	0.130	450.0	58.5	Foreman	1	0.17	40	6.68	Hand tools	2.00	0.50	1
Sand	m^3	0.019	600.0	11.16	Plasterer	1	1.00	35.5	35.50	Scffolding	1	3	3
Water	m^3	0.070	100.0	7.00	Chilser	1	1.00	18.75	18.75				0
					D/L	1	1.00	12.5	12.50				0
													0
													0
													0
													0
													0
Total (1:-01)				**76.66**	**Total (1:02)**				**73.43**	**Total (1:03)**			**4**
A= Material unit cost	76.66	Birr/m^3			**B=Manpower Unit Cost**			56.48	Birr/m^3	**C=Equipment Unit Cost**	3.08	Birr/m^3	
					Total of (1:02)					Total of (1:03)			
					Daily Output					Daily output:			
			Direct Cost of work item = A + B + C =						**136.22**	Birr/m^2			
					Overhead Cost :			10%	13.62	Birr/m^2			
					Profit Cost:			15%	20.43	Birr/m^2			
					Total:				**170.28**	Birr/m^2			
Remark : ______________________________													
UF: UTILIZATION FACTOR					**Total Unit Cost :**				**170.28**	Birr/m^2			
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.													
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.													

Appendix-B: Questionnaire

Questionnaire

Dear Respondent;

I am Heaven Yeshineh student at Adama science and technology university and currently working a research on "Evaluation of kumkang aluminum formwork performance in federal housing projects." This research survey is intended to fulfill an academic requirement for a Master of Civil Engineering in program of Construction Engineering and Management.

OBJECTIVES

The objective of this survey is:

- To assess the kumkang aluminum formwork practice system.
- To evaluate the performance of kumkang aluminum formwork in terms of cost, time, quality of finished concrete, and safety by comparing it with conventional formwork construction.
- To assess benefits and barriers of kumkang aluminum formwork with respect to sustainability.
- To assess the labour productivity of the kumkang kind formwork system.

Therefore, it is believed that your participation in this research will contribute to achieving the objectives of the research. Thus, the quality of your response towards the question items determines the quality of the research results. Therefore, please answer the questions as thoroughly, objectively, and honestly as possible according to the instructions contained in the body of the questionnaire.

CONFIDENTIALITY

All information provided in this survey will be treated as strictly confidential, no companies or individuals will be identified in any subsequent research report, and all information collected will be used purely for the purposes of academic research.

CONTACT DETAILS

❖ If you have any questions and clarification regarding this survey, please do not hesitate to contact:

Heaven Yeshineh **Phone No.** 0938346202 **Email:** -heavenyeshineh@gmail.com

Thank you in advance for your co-operation!

Part I. General Information

Please kindly respond to the following questions by ticking (√) the appropriate box or writing your answer in the space provided.

1. Name of company (Optional) ____

2. Category and class of company ____

3. How long has the organization been operating?

☐ Less than 5 years ☐ 5 to 10 years ☐ 10 years and above

4. Number of projects executed in the last five years

☐ Less than 10 ☐ 11 to 20 ☐ more than 20

5. Your position in the firm____________________________________

6. Your experience in construction industry

☐ Less than 5 years ☐ 5 to 10 years ☐ 10 years and above

Formwork materials

Please kindly respond to the following questions by ticking (√) the appropriate box or writing your answer in the space provided.

1. Which formwork materials does your company use?

No.	**Material**	**Fill the answer by ticking (√)**
1.	Wooden	
2.	Steel	
3.	Aluminum(kumkang)	
4.	Both steel and wooden	
5	Both kumkang Aluminium and wooden	
6.	Both kumkang Aluminium and steel	
7.	Combination of all	

Others (please specify): ____________________________

2. For question number 1if your answer is rather than aluminum formwork what is your reason for not using this formwork system?

____

3. What are your criteria to select formwork materials? (You can choose more than one)

☐ Cost of formwork

☐ Speed of construction

☐ Quality of finished concrete

☐ Health and safety factors

☐ Sustainability issue

☐ Labour productivity

Others (please specify): ___________________________

Part II Formwork system (for gerjii village project only)

Please kindly respond to the following questions by ticking (√) the appropriate box or writing your answer in the space provided.

1. What is acquiring method of Kumkang Aluminum formwork materials? (You can choose more than one)

☐ Rental

☐ Owning (from local market)

☐ Owning (Import from abroad)

☐ Produce by the company itself

Others (please specify): ___________________________

2. For question number 1 what is your reason to use such sources?

____

3. What type of form releasing agent have you used in your projects?

____

4. What are your criteria to select this release agent?

☐ Cost

☐ Quality ☐ Labour productivity

Others (please specify): ___________________________

5. Which method you use to construct formwork?

☐ Manually ☐ Manually and Crane ☐ Self-climbing

Others (please specify): ___________________________

6. Which kind of labour you use for formwork construction? (You can choose more than one)

☐ Skilled labour

☐ Semi-skilled labour

☐ Un skilled labour

7. How many numbers of labour do you use to erect and strip formwork per floor?

____

8. Do all structural members erect at the same time?

☐ Yes ☐ No

If your answer is no, please define the sequence of erecting the structural members:

____

9. Which method do you use to pour concrete?

☐ Manually ☐ Crane ☐ Pump

10. During casting concrete which structural member pour in one time?

____

11. Does all structural member strip at the same time?

☐ Yes ☐ No

If your answer is no, please define the sequence of stripping the structural members:

____

12. For props supporting how many days left under after stripping slab members?

____

13. Are you comfortable with the jointing system of the individual formworks? ☐ Yes

☐ No

If no, what do you suggest? ____

14. What methodologies do you deploy to increase the lifetime of the formworks?

____

Part III. Formwork System on Quality of Finished Concrete

The following table contains some common measurement of formwork quality of finished concrete obtained from different works of literature to identify which type of formwork system have a better quality of finished concrete.

Please kindly respond to the following questions by ticking (√) the appropriate box

Quality considerations of formwork	Materials		
	Conventional (wooden)	Conventional (Steel)	Kumkang kind Aluminum
Maintaining the designed shape of the concrete			
Maintaining correct location			
Smooth concrete surface			
Able to produce the required shape and surface			
Waterproofing (not absorb water from concrete)			
Stiff enough against its deflection, buckling under load.			
Dimensional accuracy includes size, shape, and alignment of structural elements			
Non-discoloration of finished concrete			
More strength of formwork			
More formwork Reusability			
Great leakage resistance			
No need of plastering			
Better Rigidity			
Easy to use			
Withstanding Shrinkage and swelling			
Uniform quality of concrete			

Part IV. Formwork safety

A. Safety practice

1. What kind of external surface scaffolding have you?

☐ Separate

☐ Attached with wall (with bracket)

B. Health and safety risk factors

Here are the health and safety risk factors please identify (carefully) the degree of risk factors probability of occurrence on your formwork construction project by ticking (√) the appropriate box.

Almost certain = **5** frequent = **4** occasional=**3** remote = **2** rarely = **1**

No.	Health and safety risk factors	Degree of occurrence				
		1	2	3	4	5
1.	Falls from height					
2.	Manual handling activities					
3.	Exposure to noise					
4.	Risk of pain or injury from performing repetitive tasks					
5.	Cuts and abrasions					
6.	Risk of eye injury from flying particles and dust					
7.	Injuring whilst lifting or carrying					
8.	Slips trips and falls due to untidy work area					
9.	Risk from exposure to asbestos and hazardous substances					
10.	Struck by falling objects or materials					
11.	Proximity to flammable or combustible materials					
12.	Vibration with finger					
13.	Record of death					
14.	Hand and foot injury					
15.	Panels falling over during installation					

Part V. Formwork sustainability

The following table contains some common measurements of sustainability and a list of their elements obtained from different works of literature to identify which type of formwork system have better in the aspect of sustainability.

Please kindly respond to the following questions by ticking (√) the appropriate box

Sustainability elements		Formwork materials		
		Conventional (wooden)	Conventional (steel)	Aluminum (kumkang)
Environmental elements	High resistance to force nature or climate change			
	Environmentally responsible working system			
	Sound absorption/sound attenuation			
	Healthy indoor environment			
	Production non-toxic waste			
	Reusable/ recycle formwork			
	Using renewable material			
	Conserve natural resource			
	Material efficiency			
	Site energy resource reduction			
	Clean environment in construction			
	Minimal waste			
Social elements	Safety operating to workers and third party			
	Providing high customer satisfaction			
	Better standard for the local community			
	Fire resistance and flame retard			
	Direct employment			
Economical elements	Speed the construction time			
	Lower initial investment cost			
	Reduce labour cost			
	Higher resale value			
	Low maintenance			
	Competitive cost			
	High durability			
	Law installation cost			
	Low life cycle cost			

Appendix-C: Questionnaire result

Table C- 1 Job position of the respondent

Position of respondent	Frequency	Percent (%)
Assistant project manager	1	1.6
Assistant site manager	1	1.6
Claim expert and research and development team	1	1.6
Construction engineer	1	1.6
Contract admin	1	1.6
Counterpart engineer	4	6.6
Forman	3	4.9
Formwork supervisor	2	3.3
Health safety and environmental division head	1	1.6
Material engineer	2	3.3
monitoring and evaluating supervision head	1	1.6
Office engineer	9	14.8
Office engineer head	1	1.6
Project coordinator	2	3.3
Project manager	5	8.2
Research and Development Director	1	1.6
Resident engineer	5	8.2
Safety engineer	4	6.6
Senior office engineer	3	4.9
Site engineer	10	16.4
Site manager	1	1.6
Supervisor	1	1.6
technician director	1	1.6
Total	61	100.0

Table C- 2 Formwork quality consideration

Quality considerations of formwork		Frequency	Percent
Maintaining the designed shape of the concrete	Conventional(wooden)	5	8.2
	Conventional(steel)	13	21.3
	Kumkang Aluminium	43	70.5
Maintaining correct location	Conventional(wooden)	4	6.6
	Conventional(steel)	14	23.0
	Kumkang Aluminium	43	70.5
Smooth concrete surface	Conventional(wooden)	3	4.9
	Conventional(steel)	13	21.3
	Kumkang Aluminium	45	73.8

Able to produce the required shape and surface	Conventional(wooden)	10	16.4
	Conventional(steel)	10	16.4
	Kumkang Aluminium	41	67.2
Waterproofing (not absorb water from concrete)	Conventional(wooden)	7	11.5
	Conventional(steel)	11	18.0
	Kumkang Aluminium	43	70.5
Stiff enough against its deflection, buckling under load.	Conventional(wooden)	6	9.8
	Conventional(steel)	14	23.0
	Kumkang Aluminium	41	67.2
Dimensional accuracy includes size, shape, and alignment of structural elements	Conventional(wooden)	8	13.1
	Conventional(steel)	7	11.5
	Kumkang Aluminium	46	75.4
Non-discoloration of finished concrete	Conventional(wooden)	1	1.6
	Conventional(steel)	16	26.2
	Kumkang Aluminium	44	72.1
More strength of formwork	Conventional(wooden)	6	9.8
	Conventional(steel)	16	26.2
	Kumkang Aluminium	39	63.9
More formwork Reusability	Conventional(wooden)	8	13.1
	Conventional(steel)	13	21.3
	Kumkang Aluminium	40	65.6
Great leakage resistance	Conventional(wooden)	0	0
	Conventional(steel)	7	11.5
	Kumkang Aluminium	54	88.5
No need of plastering	Conventional(wooden)	0	0
	Conventional(steel)	15	24.6
	Kumkang Aluminium	46	75.4
Better Rigidity	Conventional(wooden)	1	1.6
	Conventional(steel)	12	19.7
	Kumkang Aluminium	48	78.7
Easy to use	Conventional(wooden)	6	9.8
	Conventional(steel)	10	16.4
	Kumkang Aluminium	45	73.8
Withstanding Shrinkage and swelling	Conventional(wooden)	0	0
	Conventional(steel)	15	24.6
	Kumkang Aluminium	46	75.4
Uniform quality of concrete	Conventional(wooden)	0	0
	Conventional(steel)	11	18.0
	Kumkang Aluminium	50	82.0

Table C- 3 Formwork systems on sustainable elements

Environmental elements		Frequency	Percent
High resistance to force nature or climate change	Conventional(wooden)	0	0
	Conventional(steel)	19	31.1
	Kumkang Aluminium	42	68.9
Environmentally responsible working system	Conventional(wooden)	1	1.6
	Conventional(steel)	16	26.2
	Kumkang Aluminium	44	72.1
Sound absorption/sound attenuation	Conventional(wooden)	22	36.1
	Conventional(steel)	3	4.9
	Kumkang Aluminium	36	59.0
Healthy indoor environment	Conventional(wooden)	3	4.9
	Conventional(steel)	15	24.6
	Kumkang Aluminium	43	70.5
Production non-toxic waste	Conventional(wooden)	3	4.9
	Conventional(steel)	15	24.6
	Kumkang Aluminium	43	70.5
Reusable/ recycle formwork	Conventional(wooden)	0	0
	Conventional(steel)	17	27.9
	Kumkang Aluminium	44	72.1
Using renewable material	Conventional(wooden)	2	3.3
	Conventional(steel)	16	26.2
	Kumkang Aluminium	43	70.5
Conserve natural resource	Conventional(wooden)	1	1.6
	Conventional(steel)	16	26.2
	Kumkang Aluminium	44	72.1
Material efficiency	Conventional(wooden)	1	1.6
	Conventional(steel)	13	21.3
	Kumkang Aluminium	47	77.0
Site energy resource reduction	Conventional(wooden)	2	3.3
	Conventional(steel)	15	24.6
	Kumkang Aluminium	44	72.1
Clean environment in construction	Conventional(wooden)	0	0
	Conventional(steel)	15	24.6
	Kumkang Aluminium	46	75.4
Minimal waste	Conventional(wooden)	0	0
	Conventional(steel)	16	26.2
	Kumkang Aluminium	45	73.8

Table B- 4 Formwork systems on social elements

Social elements		Frequency	Percent
Safety operating to workers and third party	Conventional(wooden)	0	0
	Conventional(steel)	17	27.9
	Kumkang Aluminium	44	72.1
Providing high customer satisfaction	Conventional(wooden)	0	0
	Conventional(steel)	16	26.2
	Kumkang Aluminium	45	73.8
Better standard for the local community	Conventional(wooden)	3	4.9
	Conventional(steel)	13	21.3
	Kumkang Aluminium	45	73.8
Fire resistance and flame retard	Conventional(wooden)	0	0
	Conventional(steel)	16	26.2
	Kumkang Aluminium	45	73.8
Direct employment	Conventional(wooden)	13	21.3
	Conventional(steel)	14	23.0
	Kumkang Aluminium	34	55.7

Table B- 5 Formwork systems on economical elements

Economical elements		Frequency	Percent
Speed the construction time	Conventional(wooden)	1	1.6
	Conventional(steel)	14	23.0
	Kumkang Aluminium	46	75.4
Lower initial investment cost	Conventional(wooden)	56	91.8
	Conventional(steel)	5	8.2
	Kumkang Aluminium	0	0
Reduce labour cost	Conventional(wooden)	4	6.6
	Conventional(steel)	13	21.3
	Kumkang Aluminium	44	72.1
Higher resale value	Conventional(wooden)	0	0
	Conventional(steel)	17	27.9
	Kumkang Aluminium	44	72.1
Low maintenance	Conventional(wooden)	6	9.8
	Conventional(steel)	14	23.0
	Kumkang Aluminium	41	67.2
Competitive cost	Conventional(wooden)	9	14.8
	Conventional(steel)	18	29.5
	Kumkang Aluminium	34	55.7

High durability	Conventional(wooden)	0	0
	Conventional(steel)	19	31.1
	Kumkang Aluminium	42	68.9
Law installation cost	Conventional(wooden)	5	8.2
	Conventional(steel)	14	23.0
	Kumkang Aluminium	42	68.9
Low life-cycle cost	Conventional(wooden)	10	16.4
	Conventional(steel)	11	18.0
	Kumkang Aluminium	40	65.6

Appendix-D: Interview

Interview

For gerji village project

1. What basic differences do you observe between kumkang kind aluminum formwork and conventional? Explain the reasons.
2. Why we should use this formwork system rather than conventional according to our economic capacity? Do you think it is economically viable to use such formwork in the Ethiopian context?
3. Do you believe in the sustaining of such an aluminum formwork building system and does it enhance sustainable construction in Ethiopia? If your answer is no, what another alternative do you suggest?
4. Why our construction industry less adaptation to modern formwork systems? And what do you expect to form government support?
5. How do you evaluate the productivity/performance of labor with respect to Kumkang formwork? And Which method do you use to enhance labour productivity?
6. What is its role (kumkang kind aluminum formwork) on construction safety?
7. Is it timely for the country to bring this formwork technology to Ethiopia? If your answer is no which type of formwork system, do you suggest?

For other federal housing projects

1. What is your perception on modern formwork systems? And why don't you use them?
2. Do you recommend a modern formwork system to be a registration requirement for licensing contractors? Why?

For federal housing corporation

1. What initiate you to invite such kind of construction company that adopts this kind of formwork system?
2. Does this kind of formwork help you to meet the requirement of more housing projects efficiently and effectively?
3. What is your recommendation for other construction industries?

For ministry of urban development and construction

1. Why our construction industry less adaptation in modern formwork systems? And what's your contribution as a government to support such kind of formwork?
2. Is there any requirement related to formwork material for contractor registration mainly for GC1, BC1, SC1?

3. Is there any law that enforces the contractors to use sustainable formwork material?
4. Did you have a legal formwork for utilizing such and similar formwork systems in Ethiopia? Are you in a position to give recognition for the adaptation of this formwork system in Ethiopia?
5. What type of support, follow-up, or promotion does your esteemed office offer for contractors that strive to revolutionize the construction industry?
6. What do you aspire to be done in modernizing the building system of the country? Do you think this is one step forward in developing the building system in the country?
7. How do you plan to incorporate such a building system into the housing policy of the country? At least in promoting fast construction system in the country?

Appendix -E: Figures

(a) Conventional (wooden) formwork

(b) Kumkang aluminum formwork

FIGURE E-1 Formwork materials and safety