DEPARTMENT OF CONSTRUCTION TECHNOLOGY ANDMANAGEMENT

RESEARCH'S TITLE: - THE ROLE OF ALUMINUM FORMWORK SYSTEM ON BULIDING CONSTRUCTION PROJECT AT OVID GROUP

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The Role of Aluminum formwork System on building Construction project At Ovid group (construction).

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Declaration

I hereby declare that this Master Thesis entitled "The Role of Aluminum formwork System on building Construction project At Ovid group (construction)" 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.

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I, the advisor of this thesis, hereby certify that we have read the revised version of the thesis entitled “The Role of Aluminum formwork System on building Construction project At Ovid group (construction)” prepared under my guidance by Rehobot Seid submitted in partial fulfillment of the requirements for the degree of Master’sthe Graduate Program of the Department of Construction technology and Management, Therefore, we recommend the submission of the revised version of the thesis to the department following the applicable procedures.

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I, the advisor of the thesis entitled “The Role of Aluminum formwork System on building Construction project At Ovid group (construction)” and developed by Rehobot Seid, 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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The undersigned, members of the Board of Examiners of the thesis by Rehobot Seid have red and evaluated her thesis entitled “The Role of Aluminum formwork System on building Construction project At Ovid group (construction)’’ 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 technology and Management

Advisor Signature Date

External Examiner Signature Date

Internal Examiner Signature Date

Chair person Signature Date

School Dean Signature Date

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ABSTRACT

The rapid urbanization and growing population of Ethiopia are placing a heavy burden on housing, especially for those with lower incomes. The construction industry in Ethiopia faces a variety of challenges. Although the construction company is responsible for choosing the right formwork material, the formwork that the company uses is one of the main obstacles to the housing projects' timely completion. The second Cost limitations are one of the main issues in building construction, and quality limitations are another major issue. An aluminum formwork system is structural work material used in construction to form a building's cast-in-place concrete structure One of the systems found to be highly appropriate for mass construction buildings, where high levels of quality and speed can be achieved, is aluminum formwork. While the wooden formwork is reused three to four times, the Kumkang aluminum formwork is reused 250 to 300 times. Increasing the wooden formwork's reusability lowers both the formwork's and the finished concrete surface quality. A combination of case studies, questionnaires, and interviews were used to gather the data. According to the study's findings, the Kumkang formwork system can be built by hand using unskilled labor and is less expensive than wooden formwork; using Kumkang Aluminum formwork reduces construction costs by nearly 104 Birr/m2, or 52%. In terms of time, Kumkang took 5 days to construct one-floor formwork, including formwork strips, whereas it takes 46 days to complete one floor of conventional formwork. Interview-based qualitative data is also analyzed differently and presented alongside quantitative data.

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

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LIST OF ACRONYMS

BaTCoDABuilding and Transport Construction Design Authority

BIMBuilding Information Modeling

BSBritish Standard

CSRCommunity support responsibility

EBCSEthiopian Building Code of Standard

GFRPGlass Fiber Reinforced Plastic

GRPGlass Reinforced Plastic

HCBHallow Concrete Block

IBSIndustrialized Building System

IC Internal Corner

LCCLife Cycle Cost

MBMiddle Beam

MH Man Hour

MoUDCMinistry of Urban Development and Construction

NIT National Institute Technology

OECDOrganization for Co-Operation and Development

PHProp Head

PVCPoly Vinyl Chloride

RCReinforced Concrete

RCCReinforced Cement Concrete

SCSlab Corner

SPSSStatistical Package for Social Science

CHAPTER ONE

1. Introduction

1.1 back ground of the study

In the late 1970s, Canadian engineer W. J. Malone created the Aluminum Formwork System as a way to build affordable housing units in developing nations. Following steel and wood formwork, this is a new generation of formwork systems. A cutting-edge construction method that expedites the process of creating concrete structures is aluminum formwork. This kind of formwork is renowned for its effectiveness and efficiency in creating a mold for wet concrete, which subsequently solidifies into structural elements like walls and floors. It is mainly made of high-strength aluminum alloys.

Aluminum formwork is unique because of its exceptional ease of assembly and disassembly, providing a reusable solution that reduces waste and expedites construction. Adopting aluminum formwork is an embrace of a faster, cleaner, and more economical building future. With proper care and minimal maintenance, this detachable formwork system can be replaced hundreds of times. The system is quick, easy to use, flexible, and incredibly economical.

The aluminum formwork system is a structural work material used in construction to form a building's cast-in-place concrete structure. (Kumkang Kind Co., 2016 & GRS formwork, scaffolding, and centering). Unskilled personnel can assemble the aluminum formwork system without the use of lifting cranes. Since the largest panel weighs little more than 25 kg, it may be handled by a single worker. Under concrete loads, these materials produce low deflection since they are lightweight and have an excellent stiffness to weight ratio. For cheap construction, choosing a formwork system's materials is essential to constructing a home faster. In every aspect, this technique is effective. This formwork method is appropriate for both low-rise and high-rise residential and commercial construction types. The aluminum template may be freely assembled to accommodate varying structural sizes, is extruded using specialized technology, and is created based on the modulus.

The most adaptable contemporary building technique is most likely the aluminum formwork system for concrete (Side, 2015). The Aluminum Formwork System allows slabs and walls to be poured simultaneously and offers Aluminum Formwork for RCC load-bearing or RCC-framed multi-story buildings. In addition to increasing efficiency, these create a very sturdy structure with a superb concrete surface. Floor after floor has uniform concrete shapes and finishes because of the precise accuracy attained in the machined metal formwork components. This makes it possible to prefabricate electrical and plumbing fixtures with the assurance that they will fit precisely when put together. It is special because it precisely conforms to the architects' design while forming all of the concrete in a building, including the walls, floor slabs, columns, beams, staircases, window hoods, balconies, and other decorative elements. Investors and engineers are working hard to lower building costs and make housing more affordable in order to satisfy the population contractors' and investors' ever-increasing needs (Kumkang type 2019).

Since the purpose of this study is to determine how the aluminum formwork system affects the performance of building construction projects, Ovid Construction Company only uses Kumkang aluminum formwork in its projects.

1.2 Statement of the problem

Time consideration: -The time delivery of building construction projects is one of the main issues. This research focuses on the technological development challenge in formwork material processes, and it examines many prevalent factors that may impact project delivery time. It is difficult for construction companies to complete projects on trucks, even though 90% of large-scale projects are completed. In our nation, it is nearly impossible to deliver mass production on time, and when material costs fluctuate out of budget over time or immediately, it becomes difficult to finish building construction projects on time or finish them on time. One-story construction using traditional formwork is expected to be finished in 21–31 days. It takes four days to strip, twenty-one days to erect, and twenty-one days to wait after concrete is cast before formwork is erected. Complete one-story slab formwork building. Formwork construction and production take a comparatively longer amount of labor. B+G+10 building with only structural work done in 210 days or 7 mouths using traditional formwork.

- **Cost constraints**: - Cost limitations are another issue in building construction. Construction projects frequently exceed their budgets because of unforeseen costs and fluctuating material prices. In the building industry, cost overruns have been a frequent occurrence. In actuality, only 31% of all projects within the last three years came within 10% of the budget, per a 2021 KPMG report. However, given the increased scrutiny of project budgets and ongoing concerns about the competitiveness of the industry as a whole, construction workers cannot afford to accept the new standard. Structural work accounts for 40% of the overall cost of building construction projects. Many clients want to cut construction costs, but doing so may degrade the building quality of the project. The extra plastering cost in m2 (145-200birr) for traditional formwork is 89%. (2021 KPMG).

- **Quality consideration**: -can be brought on by a variety of factors, including weather, labor shortages, material availability, and the structural phase of concrete curing time. It has the biggest impact on the construction industry because formwork accounts for a large portion of the overall cost of construction. Therefore, by properly planning the formwork system, construction costs can be decreased. For certain clients, time is the most important factor. Time delays then have an impact on the project budget, which means that material fluctuations result in overspending, affect the quality of the work and materials, alter the scope of the project, and even cause it to be terminated. In our nation, the construction industry frequently struggles to complete projects on schedule and frequently terminates contracts, particularly when it comes to public building construction projects.

  One of the issues with building construction in our nation is quality, which can be attributed to a variety of factors that frequently justify time and expense. This indicates a lack of materials; fluctuating material costs lead to the selection of low-cost materials that must be of low quality due to time delays. The alternative is to choose or concentrate on time delivery while ignoring quality after structural work, chiseling, and plastering are finished on schedule

  - This paper was deal with one of modern formwork system called Kumkang aluminum formwork. 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 (researcher).

1.3 objectives

1.3.1 General objective

- ✓ The general objective of this research is to identify the Role of aluminum formwork system on building construction project at Ovid Group.

1.3.2 Specific objective

1. To identify, the benefit and challenge of aluminum formwork system for building construction project performance in the case study of Ovid group.
2. To examine the Role of aluminum formwork on building construction project triple constraints in the case study Ovid group
3. To identify the comparable advantages of aluminum formwork as compare to conventional formworks in building construction projects in Ovid group.

1.4Research questions

The main purposes of study based on the problem that has been stated, the following research question are developed.

1. What is aluminum formwork system and what It's benefit and challenges of aluminum formwork on building construction project?
2. Identify the Role of aluminum formwork system performance in cost, quality and time on building construction project?
3. To identify the comparable advantages of aluminum form work and conventional formwork system in building construction projects?

1.5scope of the study

Geographical: Geographically the research scope is limited to Gerji modern village federal Housing Corporation, all CSR projects (community support responsibility: Lideta, Riche and Abware) and Kazanchis real estate delivery project and current status defiance or Army, Tiyte bet and Gelan Guran village Bulbula site (60, 0000, homes), Chaka projects. The aluminum formwork adopts only on first Gerji modern village federal housing corporation project in Ethiopia. Ovid construction company building projects with the same features of building were better than other company 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 applies in the country in now days to impact performance.

Temporary: -Since 2013 E.C Ovid group adapted Kumkang aluminum formwork system technology to Ethiopian construction industry, the proposed thesis address the Kumkang aluminum formwork system to identify the opportunity and challenges, triple constrain impacts and comparable advantages with conventional formwork within those years.

1.6 limitation of the study

This research particularly allocated near in Addis Ababa Ovid Construction Company constructed use in aluminum formwork system only. This research, however, was subjected to several limitations. The major limitation of this research was the research conducted on Ovid construction company housing projects in Addis Ababa city only. Because of the formwork, system, which applied only by first, adapted this company of a housing project by the mean time and there is resource constraint on the sample, a smaller number of ongoing projects under Ovid construction company building project. Another limitation was there is luck of willingness to return the questionnaire survey also to interview within the time since survey. Questioners and interview need professionals to attain reliable and valid data on the subject matter more. In additional to this, there was luck of recorded data in the project for purpose of the case study.

1.7 Significant of the study

The significant of the study Role and performance of aluminum formwork technology (Kumkang technology) system on building construction .TO introduce the advantages of this formwork technology positive impact, increasing mass production building construction sector. Balancing housing demand and supply in Ethiopian. To maximize formwork system, use reputation time since minimize cost, once time or initial cost highly and return maximize cost .to keep building construction project short period of time complete and to spilling or attacking Ethiopian shortage of housing need and supply problem. Private batching cost that means after demolition or striping the aluminum building formwork, the surface quality of the concrete is smooth and smooth so finished without batching, which can save the batching cost. Work opportunity unskilled labor, to compute building construction sector participate company. Supporting country growth, market growth. To use the analysis of data qualitative method and to supporting decision making to use which formwork system more much the best one quality in this industrial revolution know generation. To guide which one is themost simply and easily arrange and dismounted formwork. Which one system is daily good productivity increasing? Income and decreasing outcome. To manage time effectively and efficiently Ovid Company's states how to use this technology and how to use or fix the materials is there any obstacle introduce these material supply import condition time.

1.8. Back ground of the Organization 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

2. Literature review

2.1 Introduction

One of the fundamental requirements for building construction materials is formwork. Formwork systems are either mold used for precast or cast-in-place concrete or similar materials. The shuttering molds are supported by the false work in concrete construction. Formworks are various molds used to create concrete that is built according to the structural shapes of buildings, such as beams, columns, slabs, and shells. (Editor of Britannica, Kathleen Kuiper). The usually temporary structure is used to hold poured concrete and form it into the required size and shape until it can support itself. Formwork systems for concrete frame construction have advanced significantly since the early 1990s G.C. Conventional formwork for concrete construction typically involved custom solutions that required highly skilled artisans; this kind of formwork system frequently had inadequate safety features, resulted in slow construction rates on site, and generated large amounts of waste. (Concrete Center MPA). Different form systems provide a range of concrete construction options that can be chosen to satisfy the needs of a particular development. The most well-known concrete structure from this era is the Pantheon in Rome. Formworks, which were formerly primarily composed of wood, are now made of a range of materials, such as plywood, aluminum, plastics, and specialized hardware and accessories. Using formwork, Roman engineers built some of the earliest concrete slabs in history. Because concrete has a strong ability to withstand compressive loads but a relatively low tensile or tensional strength, this early structure was composed of arches, vaults, and domes. Rome's Pantheon is the most famous concrete building from this era. In order to create the future shape of the structure, temporary scaffolding, formwork, or false work, and this structure were constructed. It is essential to guaranteeing the precision, caliber, and security of the concrete construction procedure. Formwork must be built to withstand the pressure of the concrete during pouring and curing. It can be constructed from a range of materials, such as steel, wood, and prefabricated panels. Throughout the 20th century, formwork development has kept pace with the expansion of concrete construction. Formworks that don't meet high quality standards are frequently utilized and reused. Misunderstandings exist regarding the cost differences when employing subpar formwork.

The productivity of the concrete construction process and other crafts like plumbing, electrical, and mechanical work are greatly impacted by the installation and disassembly of formwork. The right formwork system selection, management, and planning are essential for a cost-effective and efficient construction because of its substantial influence on the entire process. The background of research on formwork systems and BIM technology is covered in this section. The construction sector uses a variety of resources, including labor, equipment, capital, and supplies. Seventy percent of the project's total costs are attributable to the material itself (Shaik and Rahul 2019).Formwork system construction is time-consuming and can cost as much as 20–25% of the structure's total cost, or more (Patel et al., 2015). Additionally, formwork accounts for 40–60% of structural work in construction, according to Rajesh Maret al. (2020). The cost of touchups will occasionally be high in order to create a tool that effectively shutters the line, level, or quality of concrete, which could again pose a challenge to the sustainability and durability of the structure (Magdum, 2017). One of the key components on a building site that influences both quality and safety is the formwork system.A more comprehensive definition of formwork is the entire system of support for freshly laid concrete, which includes all necessary bracing, hardware, and supporting members in addition to the molds or sheathing that come into contact with the concrete. In order to build with concrete, forms are necessary. They control the concrete's position, alignment, and surface contour in addition to molding it into the appropriate size and shape. A mold is only one aspect of formwork. A temporary structure bears its own weight, the weight of the recently laid concrete, the weight of the materials, tools, and laborers used in the construction process, as well as any additional live loads that may arise.

2.2. Theoretical literature review

2.2.1. Back ground Formwork system

Particularly in high-rise building projects, the formwork system is essential for automating processes to boost productivity and speed while lowering unit costs through the use of cost-effective scales (Dinesh and Soundararaja, 2017). Bearers that directly support the face contact material and the face contact materials themselves make up the majority of it. (MPA 2019 Concrete Center). Additionally, as the information above makes clear, system formwork adoption is increasing at a very quick rate. The need for skyscrapers, particularly in cities with limited space like Bangalore and Mumbai, the lack of skilled labor, and the high end's understanding and adoption of system formworks make this even more crucial in a country like India where thelikelihood of delivering the (sumathkashyap2016 G.C).The entire system of support for freshly laid concrete is the formwork system, which includes any bracing, hardware, and supporting elements that may be required. The formwork system is crucial for automating processes to increase productivity, expedite turnaround times, and take advantage of economies of scale to reduce unit costs, particularly in high-rise projects (Dinesh and Soundararajia, 2017). Building structures using advanced formwork techniques has grown in popularity over time (IJRETVolume: 04 Issue: 12). Since the advent of advanced formwork techniques, there has been a great deal of comparison between them and conventional formwork techniques. According to Swapnali Karkeet al. (2010) claim that using the MIVAN system and tunnel from system can save us time and money. Formwork is used to safely support reinforced concrete until it reaches a sufficient strength. Formwork can be a permanent mold or a temporary structure. The cost of formwork in current construction can vary by 20% to 60%; if this is a concern, the competition contractor will always try to finish the project on schedule and with better, acceptable quality without lines and levels. The cost of touch-up will eventually rise in order to create a tool that can effectively shutter the line, level, or quality of concrete, which could again pose issues for the sustainability and durability of the structure (Magdum, 2017). Formwork systems fall into two general categories. Formwork systems can be broadly divided into two categories, such as horizontal and vertical systems. Special formwork systems, as well as vertical (wall and column) and horizontal (slab and beam) systems. Concrete beams and slabs that are horizontal are temporarily supported by formwork horizontal systems.

2.2.2. Formwork role in building construction project

Construction entails significant financial outlays and contributes significantly to the expansion of numerous other economic sectors. In addition to giving the fresh concrete shape and supporting it so that it can regain its strength to support its weight, formwork accounts for a significant portion of construction costs. When it comes to building construction, it shares a significant cost. According to Rajesh Kumar et al. (2020), formwork accounts for 40–60% of the cost of construction structure work. There are numerous varieties of formworks that are employed in construction, typically varying based on the building's requirements and difficulties. Formwork enables contractors to quickly cast and construct the major building components that must have a string structure, like the floor and walls, as well as smaller building components like stairs.

Formwork is the process of making molds out of prefabricated forms, steel, aluminum, or wood before pouring concrete (Dinesh and Soundararajan, 2017). The majority of the contemporary formwork systems mentioned above is modular and made with efficiency and speed in mind. Most of them have improved health and safety features built in, and they are made to provide more accuracy and reduce waste in construction (MPA concrete center). Formwork can be used to pour concrete in a liquid viscosity, which makes transportation easier, and the concrete will cure and solidify into a strong, safe structure. In conclusion, your ideal construction project may not succeed before you've even begun if you lack the necessary tools, such as scaffolding and formwork. Formwork systems are essential to construction; sustainable building can be achieved by selecting the appropriate formwork system. Formwork is necessary to give the concrete temporary support until it can sustain itself. This shapes the concrete to fit various formworks used in construction, depending on the requirements of the building. In the Ovid group formwork evaluation of Kumkang aluminum formwork performance, structural elements such as columns, beams, slabs, and shear walls were cast, as well as smaller building components like stairs (Gaddam and Achuthan, 2020). In general, there are three types of formwork systems: vertical (wall and column), horizontal (slab and beam), and specially designed. Concrete beams and slabs that are horizontal are temporarily supported by formwork horizontal systems. For horizontal concrete work, formwork systems can also be divided into two groups: crane-set systems and hand-set systems. Even though there are many different kinds of formworks available in Ethiopia, care is not taken on the off-from finish, and construction costs, quality, time, and safety are crucial considerations. Formwork materials that don't meet quality standards are frequently used repeatedly. The differences in cost between using high- and low-quality formwork are misunderstood (Ghebrehiwet and Getachew 2020). According to Tarekegn (2010), Ethiopia's construction sector does not adhere to environmental, health, and safety regulations. Numerous high-rise buildings are constructed by domestic and international contractors in the nation's metropolitan areas, especially in Addis Ababa, the capital. Contractors are chosen by clients based on their financial capabilities and performance. In contrast to local contractors, foreign contractors are permitted to work on the majority of high-rise building construction projects in Addis Ababa. These projects are progressive and have demonstrated success in terms of quality, shorter construction times, and safer site conditions. The speed of construction enables the owner to utilize the building structure sooner, the quality of the work lessens the need for additional concrete surface treatments, and safe practices also help to lower injuries and form failures (Sida,2017).

2.2.3 Types of formworks

As big as is practical in order to minimize lift and lower jointing quality (Asadi and Praneeth, 2017). The cost, construction safety, and final product quality should all be taken into consideration when choosing materials for formwork. The engineer or architect's approval of formwork materials, which is mandated by the contract documents, ought to be predicated on how the materials' quality impacts the final product's quality. Formwork is also categorized based on the building materials used. Formwork is categorized according to the kinds of materials used for structural members (Asadi and Praneeth, 2017). Formwork is categorized based on various characteristics. Among these characteristics one of these characteristics is based on size, among other characteristics. In actual use, formwork comes in just two sizes: small and large. Any size intended for employee manual operation is considered small. Usually made of aluminum and wood, small-scale systems are in the shape of tiny panels. The form's size can be altered when utilizing large-scale formwork.

- **Technological integration**

Modern formwork system also benefits from the integration of technology, including the use of computer-aided design (CAD) to plan and customize formwork solution precisely. These integration facilities the construction of complex structures with higher accuracy and efficiency.

- **Environmental impact**

Compared to traditional timber formwork, which produces more waste because of its short lifespan and limited reusability, modern formwork systems' durability and reusability help to lessen their environmental impact.

- **Choose between traditional and modern formwork system**

The decision between a traditional and modern formwork system is influenced by a number of variables, such as project specifications, financial limitations, and environmental factors. Although modern formwork systems offer significant advantages in terms of efficiency, safety, and long-term cost savings for large-scale constructions, traditional formwork may still be preferred for smaller, customs projects due to its flexibility.

2.2.3.1. Traditional formwork system (Conventional Formwork)

Plywood or wood are usually used in traditional formwork. It is distinguished by the materials used: plywood for the facing material and wood, which is easily cut to size and easily accessible, have been the main materials for formwork. One of the earliest forms of formwork utilized in the construction industry is the traditional formwork system. In the construction industry, this formwork makes use of carpentry, masonry, bamboo, and wood. Traditional formwork is still used for small, two- or three-story homes because it works well for these kinds of buildings. This is not appropriate for large projects or hugs in a different standard. Typically, the traditional formwork system is made up of standard plywood panels that are fastened together with a timber frame across their backs and horizontal components known as walling to provide resistance the weight and horizontal force of wet concrete.

A system or approach that is commonly used and adheres to accepted conventions or customs is referred to as conventional. It can be used to describe a number of different kinds of systems, including transportation, financial, and electrical power systems. A conventional system is one that has been in use for a considerable amount of time and is typically regarded as dependable and well-established. Special plywood, known as ply, is produced by the plywood industry specifically for use in forming concrete structures (Krohn 2011). Major issues with conventional treatments include high operating costs, the creation of toxic metabolites, incomplete mineralization of the substances, and the high expense of disposing of chemical waste sludge (Mukherjiee et al., 2013).Flexibility: traditional formwork is highly adaptable to various shapes and size, making it suitable for customized structures.

1. Labor intensity: Traditional formwork requires a large amount of manual labor to construct and disassemble.
2. Cost: while the initial materials costs may be lower, the labor-intensive natural and lower reusability factor can lead to higher overall costs for larger projects.
3. Reusability: timber formwork has limited reusability, as it can suffer from wear and tear after a few uses, affecting its cost- effectiveness over time.

Formwork is necessary in the construction industry to create concrete structures. Formwork systems have changed over time, moving from antiquated techniques to cutting-edge, contemporary solutions. To choose the best and most economical option for a project, it is essential to comprehend the main distinctions between these systems. Let's examine how traditional and contemporary formwork systems differ from one another.

❖ Classification of conventional formwork

A) Steel Formwork

This type of formwork system refers to building techniques that support the pouring and shaping of concrete structures by using steel panels, beams, or plates to create temporary molds or formworks. Steel formwork consists of an operating plate form, accessories, support system, and formwork surface structure. It is a formwork tool used to build cast-in-place walls and other wall structures. It is used for sewer tunnels and retaining walls, and it is compatible with curved or circular structures such as chimneys, columns, and tanks. Sturdy, resilient, and long-lasting. It is safe to assume that between 100 and 120 reuses occur. Steel reduces labor costs because it is quicker and easier to install and disassemble.Formwork is safe because it eliminates water from the concrete and minimizes honeycombing (Loganathanviswanathan, 2016). The operating platform, support system, accessories, and formwork surface structure are the parts of steel formwork. It is a type of loot formwork used to construct cast-in-place walls and other wall structures. Because of its exceptional durability, steel can be used repeatedly without suffering major form damage. Additionally, timber is combined with steel forms. Steel sections are used in the fabrication of various formwork components because of their strength and ability to be used repeatedly without seriously damaging the form. Additionally, timber is combined with steel forms. A variety of formwork components, including vertical and horizontal steel panel forms, are made from steel sections.

B) Glass-Reinforced Plastic Formwork

This kind of formwork composite material composed of fine glass fibers reinforced by a plastic matrix. It can also be referred to as GFK (glas fsterverstar kterkunstoff) or just fiberglass, which is the name of the reinforcing fibers (Tarekegn 2010). High-quality concrete finishes are also produced using glass-reinforced plastic. Because of their extreme flexibility, they can take on complex or unusual shapes with minimal financial outlay. Models of steel, wood, or plaster are prepared to the precise dimensions needed to fabricate glass-reinforced plastic forms. Glass-reinforced plastic forms have become more and more popular in recent years due to their strength, portability, and high reusability. After that, the model is polished, waxed, and sprayed with a parting agent to stop the resin from adhering to the master pattern. Glass After that, the mat is placed over the model and completely covered with a layer of polyester resin. The primary problems with glass-reinforced plastic forms are alkali-attacked concrete and form expansion from exposure to hot sun or heat from cement hydration. Once the polyester resin has solidified and the heat has dissipated, another layer of glass mat and resin is applied. Until the fiberglass sheet reaches the desired thickness, this process is repeated.

2.2.3.2 Modern formwork system

Steel, aluminum, and plastic are among the materials used in modern formwork systems, which also have notable improvements in both design and functionality.

Material: engineered formwork systems are made of sturdy materials like steel and aluminum, which are stronger than wood and can tolerate the pressure of concrete.

1. Efficiency: Modern systems are made to be simple to assemble and disassemble, which drastically cuts down on the time and effort needed to construct formwork.
2. Cost-Effectiveness: Modern formwork systems may require a larger initial investment, but over time, their reusability and durability save money, particularly for projects that call for multiple formwork uses.
3. Reusability; The cost per use is greatly decreased by the fact that engineering formwork can be reused repeatedly while retaining its integrity over a large number of projects.
4. Safety and precision: In order to improve overall quality and worker safety on site, modern formwork systems frequently incorporate safety features and enable more precise construction.

- **Aluminum Formwork (Kumkang) Technology**

In the late 1970s, Canadian engineer W. J. Malone created aluminum formwork systems as a way to build affordable housing units in developing nations. The unit was to have load-bearing walls made of aluminum panel formwork and be constructed of cast-in-place concrete. All walls and partitions are built in-situ, which eliminates the need for follow-on wet trades. The system ensured a quick and cost-effective construction method, and the concrete surface finish made with aluminum forms allows for the achievement of a high-quality wall finish created with aluminum forms.To be erected by the hundreds, of a repetitive design, the system ensured a fast and economical method of construction. (Prasanths grand edifice developers 9840539538/ 9498002004).

The system, which was built using a repetitive design with hundreds of pieces, guaranteed a quick and cost-effective construction process. The developers of Prasanth's grand edifice are 9840539538 and 9498002004. Formwork made of aluminum is distinguished by its manufacturer, company, or brand. The first manufacturer to use aluminum formwork was MIVAN. An aluminum formwork system called Mivan was created by a European construction company. The Malaysian company Mivan Company LTD began producing these formwork systems in 1990. They currently operate more than 30,000 square meters of formwork used worldwide. Another kind that originated in Korea in 1979 is the Kumkang kind. Kumkang is a new technology that has inspired and enabled large-scale construction projects worldwide (Magdum 2017). The aluminum formwork system is appropriate for construction in both residential and commercial settings. Both commercial and residential construction can use this formwork system. The most reliable, secure, and modern formwork technology on the market today is this system. Walls, columns, beams, staircases, balconies, and door and window openings are all cast into place using this special formwork system. This method is specifically used in areas that are prone to earthquakes (Pujari et al., 2018). The Kumkang formwork is referred to as an environmentally friendly building system and can be used almost 300 times, in contrast to the traditional wooden formworks..

❖ Why use Aluminum formwork for building?

Because of its many benefits, including its strength and low weight, ease of processing and assembly, high efficiency and energy savings, durability and dependability, safety and environmental protection, and aesthetic appeal, aluminum formwork is frequently used in the construction of a variety of building structures and concrete pouring. Consequently, the construction industry enjoys numerous economic benefits and conveniences.

- After using aluminum concrete formwork, the concrete's surface is flat and smooth, creating the illusion that plastering is not necessary.
- Formwork aluminum is very precise and strong, and the board surface has fewer seams.
- The aluminum formwork system's easy assembly and convenient construction allow it to be assembled manually or mechanically once the panels are assembled?
- Standardized construction that is used frequently for up to 200 times and has a high turnover rate.

- It is widely used in a variety of applications, such as aluminum wall formwork and aluminum column formwork.
- Lightweight, weighing less than 19,000 grams per square meter.
- The construction time of short aluminum formwork is 40% to 50% faster than that of regular formwork.
- The China aluminum formwork panel has a large bearing capacity, able to support 60Kn per square meter.
- High recycling value and a high cost of recycling aluminum formwork panels made in China.

2.2.4 Benefits and challenges of aluminum formwork

- **Advantage of aluminum formwork**

- ✓ Lightweight and strong: Aluminum alloy, which is used to make shuttering material, has a lower density and a higher strength, making it stiff and lightweight. Shuttering material is lighter and easier to transport and install than steel shuttering and plastic formwork, which lowers worker labor intensity.

- ✓ Simple assembly and processing: Aluminum formwork can be tailored to meet particular needs and processed to fit various building shapes and structures. The aluminum formwork construction process is made more convenient and effective by its modular design and connection system, which increases construction efficiency.
- ✓ Excellent thermal conductivity in aluminum shuttering allows heat to be transferred quickly and evenly, which leads to more concrete solidification and increased efficiency and energy savings. Additionally, the smooth surface of aluminum shuttering makes system formwork more reusable by lowering friction between the concrete during formwork remove.
- ✓ Durable and reliable: aluminum formwork exhibits excellent corrosion resistance and mechanical properties, allowing it to withstand heavy loads. It has a long service life and, with proper maintenance, can be used repeatedly, reducing construction costs.
- ✓ Safety and environmentally friendly: aluminum system formwork uses nontoxic and environmentally friendly materially materials that do not have harmful effects on construction workers or the environment. The surface coating and anti-corrosion

treatment enhance the fire resistance and weather ability of the formwork, providing higher construction safety.

❖ Disadvantage of aluminum formwork

Once the structure is fabricated, it cannot be altered architecturally.For a small project, the initial cost may exceed the budget. A brief training is necessary for workers to become familiar with the entire process due to the accuracy of alignment and safety regulations. Intricate procedures for modification and repair. Restricted ability to adapt to intricate architectural designs, potential lack of availability in comparison to alternative materials, Concrete curing may be impacted by thermal conductivity (GRS scaffolding)

A. Initial Cost

– Higher upfront costs compared to traditional formwork materials.

B. Handling and Repair

– Requires careful handling to avoid damage.

– More complex to repair if damaged.

C. Adaptability Issues

– Less adaptable to complex architectural features.

– Difficulties in modifications and adjustments on site.

D. Thermal Conductivity

– Potential issues with heat transfer affecting concrete curing.

E. Availability

– Possible issues with sourcing and availability compared to more common materials.

Overall benefits

Because aluminum formwork is lightweight and quick to assemble and disassemble, it saves labor, cuts down on construction time, lowers material handling and transportation costs, and shortens tower crane operating times. Surface plastering is not necessary, which can reduce labor costs and do away with the need for internal wall hole-filling and external wall waterproofing. This lowers the cost of aluminum formwork panels and the expenses associated with the removal and processing of construction waste. Aluminum formwork productivity is high, and it only takes about four days to build one floor. The aluminum formwork design is advance, offering high flatness and verticality, and there will be no problems of external walls, doors and windows, bathrooms, etc, and reduce the common building quality problem of wall cracking.Construction safety is ensuring because of the convent assembly and disassembly, which reducethe safety hazard for workers. By reducing on-site hosting, the risk of hoisting drops is lower. Since on site cutting is not required, the safety hazards during the construction process are reduced. (Thiyagarajian et al. 2017).

2.2.5 Aluminum formwork Roll on building construction

1. The construction quality of aluminums formwork

Strong bearing capacity, high precision, smooth and flat surface, and seamless connection are all features of the aluminum alloy formwork. Aluminum's inherent qualities of light weight and resistance to corrosion make it a popular material for construction. Aluminum is utilized in a variety of applications, including stairways, railings, shelves, windows, doors, exterior facades, roofs, and walls. The advantages of employing aluminum formwork as a construction method have been emphasized by the National Institute of Technology (NIT). One of the biggest benefits is that, in comparison to traditional methods, it can cut a building's construction time by up to 50%. Stakeholders complete their projects on schedule when they use Knest aluminum formwork. Every time.

(1) The uniform load and the concrete lateral pressure bearing capacity are strong, which can effectively improve the quality of the project.

(2) High precision and small error, which is conducive to improving the overall strength and service life of the building.

(3) The surface is smooth and flat, and can be seamlessly connected. The poured concrete can meet the requirements of fair-faced concrete, which ensures the appearance and quality of the formed concrete.(knest aluminum formwork 2017-2014)

2. Speed of construction efficiency of aluminum alloy formwork.

The aluminum alloy formwork is easy to assemble and disassemble, and the construction period is short.

(1) Easy to install. The shape and splicing are easy, the density is small, the average weight is light, there is no need to manually locate the reserved holes, and the assembly is simple and convenient.

(2) Quick release. Using the early dismantling formwork support system, the dismantling can be carried out in a short time after the construction is completed.

(3) The construction period is short. At the same time of construction, the doors and windows can be prefabricated according to the design size, and the doors and windows can be installed after the template is removed; the structural surface formed by pouring can achieve the effect of clear water, eliminating the need for plastering and leveling. (knest aluminum formwork 2017-2014)

3. Aluminum alloy formwork has high economic benefits

- ❖ Reduced Labor Cost

The aluminum alloy formwork has a smooth and flat surface, a high degree of precision, a strong bearing capacity, and a seamless connection. Aluminum is a common building material because of its inherent light weight and corrosion resistance. Stairways, railings, shelves, windows, doors, exterior facades, roofs, and walls are just a few of the many places aluminum is used. The National Institute of Technology (NIT) has highlighted the benefits of using aluminum formwork as a construction method. One of the main advantages is that it can reduce the time required to construct a building by up to 50% when compared to traditional methods. When stakeholders use Knest aluminum formwork, their projects are finished on time.

- ❖ Lower Maintenance Costs

Because of the high quality of the structure, maintenance expenses may be reduced by as much as 15%. Increasing the construction project's return on investment. Aluminum formwork reduces the capital cost of other building materials, despite the initial investment appearing high (Knest aluminum formwork 2017-2014).

- ➢ The aluminum alloy formwork has a high turnover rate, easy installation by workers, no secondary batching, strong reusability, and low average cost.

(1) The early dismantling technology is integrated into the roof support system, the formwork turnover rate is high, and the average use cost is low. (knest aluminum formwork 2017-2014).

(2) Save labor costs. The design is intuitive and easy to understand, and the installation efficiency of workers is high. Each skilled installation worker can install 20-30 square meters per day. (knest aluminum formwork 2017-2014).

(3) Reduce or eliminate the cost of plastering. The surface is flat and the size is more accurate, which effectively avoids the second batching operation. (knest aluminum formwork 2017-2014).

(4) It is highly reusable and has low amortized cost. In theory, it can be reused 150-300 times. When the used formwork is reused in a new building, only about 10%-20% of non-standard panels need to be replaced. If it is used 100 times or more, the actual cost of the aluminums formwork will be less than wooden mold. (knest aluminum formwork 2017-2014).

- ❖ Minimal Wastage

Over the coming years, there will likely be a 4-6% increase in the demand for aluminum scrap worldwide. Motivated by growing knowledge of the advantages recycling aluminum has for the environment. Aluminum Formwork can produce up to 300 repetitions, which significantly lower the quantity of materials required and minimizes waste. This results in less money being spent on capital projects. (2017-2014 Knest Aluminum Formwork).

❖ Formwork Construction in Ethiopia

One of the sectors in Ethiopia where a lot of people work is building construction, especially in urban areas where mass construction is occurring. Numerous high-rise buildings are built by domestic and international contractors in the nation's urban areas, especially in Addis Ababa, the capital. Contractors are chosen by clients based on their financial and performance capabilities. In contrast to local contractors, foreign contractors are permitted to work on the majority of high-rise building construction projects in Addis Ababa, which are moving forward with noticeable success in terms of quality, shorter construction times, and safer site conditions. The speed of construction enables the owner to utilize the building structure sooner, the quality of the work lessens the need for additional concrete surface treatments, and safe techniques 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 of plywood to stop leakage of concrete paste through the joints (Tessema, 2019).

The Low worker productivity and restricted space for movement through braces and props because of tightly fastened bracings and propping, particularly when using timber products. Unskilled labor because construction companies are unwilling to provide training because they are afraid that workers will quit after completing it, so they have opted to continue using low-productivity labor. Concrete waste is increased as a result of leaks through sheeting materials, and one of the extra treatments is chiseling the cement grout out of the sheeting joints, followed by plastering to level the surfaces. This is a poor, unsafe, and false economy method. Increased form material waste and reduced reusability as a result of haphazard nailing and inadequate 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 100m2 of the slab. More trees were cleared other activities which need timber were considered.

2.2.6 comparable of aluminum formwork and conventional formwork

Tightly fastened bracings and propping, especially when using timber products, result in low worker productivity and limited movement space through braces and props. Unskilled labor because construction companies have chosen to continue using low-productivity labor because they are unwilling to provide training because they fear that workers will quit after completing it. Leaks through sheeting materials increase the amount of concrete waste, and one additional treatment is to chisel the cement grout out of the sheeting joints before plastering the surfaces to level them. This is a bad, risky, and deceptive economic strategy. Because of careless nailing and poor storage, there is more waste from form materials and less reusability.

Conventional formwork system usually consists of standard plywood panels tied together with timber frame over their backs with horizontal members called walling to resisting the weight and horizontal force of wet concrete. A careful handling of the wall forms is needed as it is considered susceptible to edge and corner damage. There is a need to choose a formwork type as there are different systems because they have their advantages and disadvantages. Cheap conventional formwork is time consuming to use for larger structures. (IRJMETS VOLUME 07/39415&1712036 papers).Aluminum formwork offers durability, efficiency, and high-quality finishes, making it ideal for large-scale projects. Timber formwork, on the other hand, is cost-effective, flexible, and provides natural insulation properties. Maintenance and Storage: Aluminum formwork requires minimal maintenance and can be stored easily due to its lightweight nature. Conventional formwork, however, needs regular maintenance, such as cleaning, treating, and storing in a dry environment to prevent rot and deterioration (Tecon construction technology co.ltd).

Conventional formwork: Formwork made from timber, plywood, or moisture-resistant particleboard is flexible, easy to use, and requires no preplanning. However, it lacks quality assurance, requires time, and is nondurable.

Aluminum formwork: The modern approach to construction uses lightweight aluminum alloy panels, offering advantages such as easy assembly, durability, and a smooth finish, but also requiring high initial costs, limited modification options, and uniform planning.(IJRESM Volume7)

2.2.7. Components of Kumkang Form Work System

2.2.7.1Major components of aluminum formwork

Considering using aluminum formwork for your next construction project, firstly it is important to understand the different components that make up this type of formwork. A quick overview of the most important components of aluminum. However, the components of aluminum formwork are majorly divided in to 3 main components including the panels, post, beams, connectors, and braces.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 project. Following are the components that are regularly used in construction (thiyagarajian et al., 2017). Mr. Jaywalk is the CEO of GRS (INDIA) in the year 2001SCAFFOLDING

2.2.7.2. Panels

The panels are the main structural element of the system. They are the largest most important component of the formwork. They are made up of sheets of aluminum that are held together by braces. The panels are what give the structure is shape and strength. They have interlocking features, so they can be quickly assembled without the need for tools. Apart from these, the aluminums formwork is divided into 3 components – slab components, wall components & beam components

- ❖ **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 1. Slab panel

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

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

standard size of slab panel	
1. (400x2300) mm	5. (600x1200) mm
2.(400x2450) mm	6.(450x1200) mm
3. (450x2300) mm	7 .(400x1200) mm
4. (450x2450) mm	8. (300x1200) 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). The wall panel figure as shown below in Figure 2.2:

Figure 2. Wall panel (Kumkang Kind Co.2016)

Table 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

2.2.7.3. Pipe prop support

It stays beneath the prop head. Until two levels are cast, the prop head and pipe support stay in place. During pouring and casting, the slab's weight is supported by the pipe support (Pujari et al., 2018). The prop pipe can accommodate the following sizes: 1800–3200, 2000–3400, 2400–3800, and 2600–4000. The pipe pro support shown in Figure 2.3.

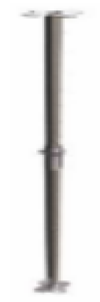


Figure 3 Pipe prop support (Pujari et al., 2018)

- **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 4 (Kumkang Kind Co., 2019)

2.2.7.4. Prop head [PH]

The pipe support is positioned beneath the prop head and is used to connect the middle and/or end beams. Additionally, there is a unique prop head. This unique prop head is used to connect the beams (Middle beam and/or End beam) in situations where a standard prop head cannot be installed (Pujari et al., 2018).

Figure 5 Prop head (PH) (Pujari et al., 2018)

2.2.7.5. Middle beam (MB) and End beam (EB)

The middle beam is used to join the prop heads shown in Figure 2.6 (a), the middle beam supports the slab panels, and the end beam is used to join the prop head and slab corner shown in Figure 2.6 (b), the end beam supports the slab panels. In addition, 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 6. Middle and end beam (Kumkang Kind Co., 2019).

2.2.7.6. Various Types of Connectors Used in Assembly of Formwork

- ✓ The panels are connected together using connectors. They are simple to use and composed of aluminum. No additional tools are required to quickly connect and disconnect them. While the concrete is being poured, the clamps are used to keep the panels together. Bolts are used to secure them to the panels so that they are securely fastened.
- ✓ **The flathead pin: -** is used in lay down applications with standard ties. Can also be used when pouring a concrete wall against an existing structure (see page #34). This pin is the only design used in lay down applications in walls over 36" tall.
- ✓ **FLAT TIES: -**Flat tie is used to join the wall panel to opposite side panel. Use of no, of wall panels depends on wall panel's height. This flat tie is first greased and then used in

wall panels along with a round pin. Maximum of 7 to minimum of 3 flat ties are used in each wall depending on the wall height.

- ✓ **PVC Sleeves**: -PVC Sleeve as name suggests is a sleeve parse PVC material coating. Flat tie is inserted inside this sleeve; its function is to protect the flat tie to be casted within the concrete.
- ✓ **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 join the wall or slab panels together and its weight (kg) 0.085. In addition, 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 seven to a minimum of three 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). Wages, round pains and long pins. Long pin along with wedge pin is used to fix joint pin with prop head and beams. Round pin and Wedge pins are usedvarious types of accessories and connectors used in panels shown in Figure 2.7.

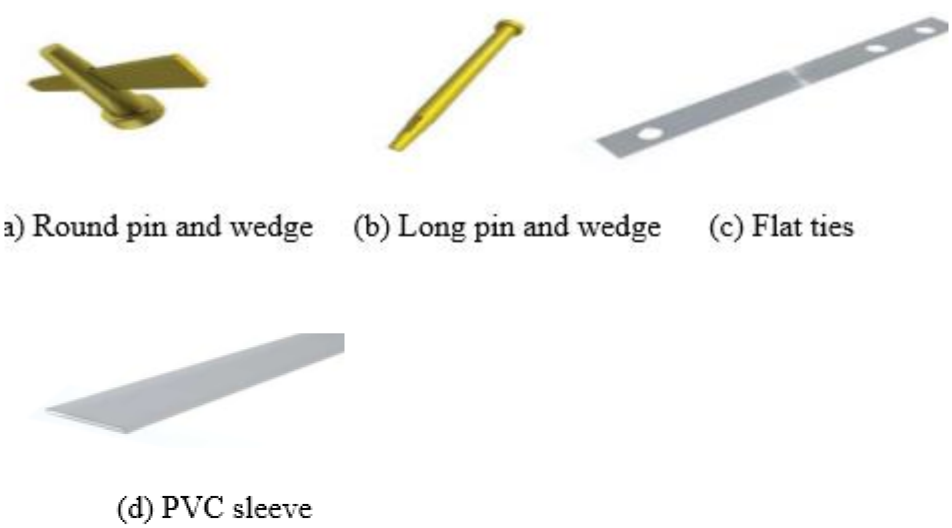
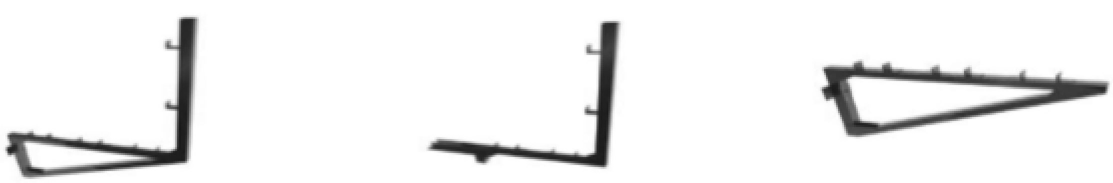


Figure 7. different types of long pin (Kumkang Kind Co., 2019).

- ✓ **The Waller-bracket and square pipe: -**After concrete casting, tare is used to enable the horizontal straightness of wall panels and a flat wall surface, particularly at the bottom. After casting, the wall panel and wall surface can be made horizontally straight thanks to the Waller bracket and square pipes. A bolt, nut, and washer are also included; these accessories serve as an embedded anchor to secure panels to the concrete surface while they are being installed. Additionally, during installation, the bracket is fixed to the concrete surface using the tie rod accessory, which serves as an embedded anchor. Wall platforms, slab platforms, and elevator platforms all of which are fixed to the concrete can be used alternatively to scaffolding systems. (Wall, slab, or elevator) and utilized as a surface for work. (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 8. Various types of connectors and accessories for bracket platform (Kumkang Kind Co., 2016)

2.2.7.7 Bracing

The panels are joined together by the braces. They are welded or bolted to the panels and are composed of aluminum. The primary purpose of aluminum braces is to support building components such as beams, columns, and roofs. The brace's "boxed" design prevents concrete from entering and building up inside. To reinforce the form and guarantee that concrete cannot enter the brace, ends are welded to the sides and tops. Although they are serrated to help with handling and prevent slipping, extruded braces won't collect concrete. In order to prevent weight gain due to concrete accumulation beneath the horizontal brace, bracing construction is crucial. When there is an open hat section, concrete can accumulate. Gaining weight shortens life expectancy and raises the risk of back injuries. By enclosing the hat section, world technological factors ensure no accumulation of concrete, subsequently, no weight gain. Braces are serrated to simplify carrying and using of the concrete forms (wall ties and forms).

There are different bracing types: -

5” CHANNEL BRACE

- Aluminum tube to control deflection, “ridges” on bracing provides additional strength and dent resistance.
- Serrated for ease of use
- 5” fully enclosed brace, eliminates concrete accumulation inside the brace

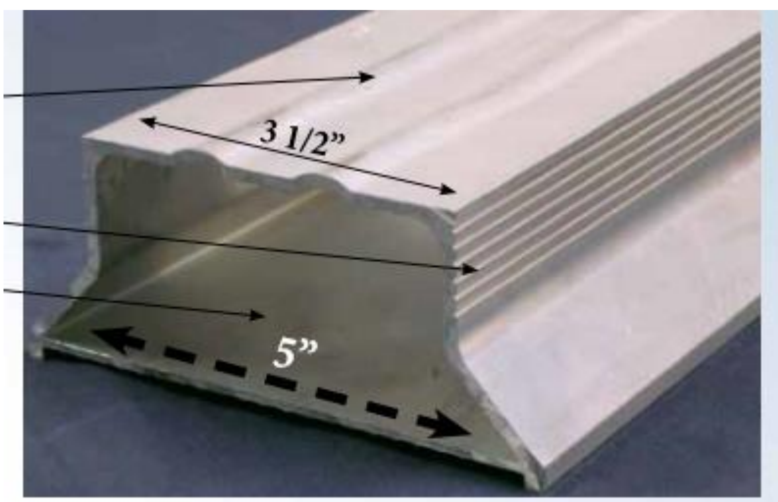
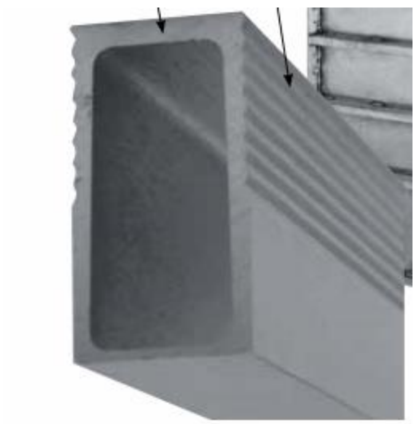


Figure 9. channel bracing

~ 1 x 2 Tube Brace

~ Serrated for ease of use

~ Tube is fully enclosed eliminating concrete build-up



5” channel with shim design makes it impossible for concrete to enter and accumulate inside brace. * Ends are welded on sides and tops to strengthen the form and ensure concrete cannot enter brace. * Extruded Braces are serrated to prevent slipping and aid in handling, yet will not accumulate concrete.

“Boxed” design makes it impossible for concrete to enter and accumulate inside brace. * Ends are welded on sides and tops to strengthen the form and ensure concrete cannot enter brace. * Extruded Braces are serrated to prevent slipping and aid in handling, yet

Will not accumulate concrete. Ends are welded on sides and tops to strengthen the form and ensure concrete cannot enter brace. * Three convened “ridges” on bracing provide additional strength.

2.2.8. The aluminum (Kumkang) formwork construction methodology

Because Kumkang aluminum formwork is so easy to assemble, it can cycle for an average of 4–7 days as opposed to 14–30 days using the traditional method. A structural line and level check are the first steps in the Kumkang aluminum setting process. Electrical installation will come next, followed by plumbing parts and steel rebar. Beam and SC board installation is followed by the installation of I/C and wall panels. After that, the staircase boards were installed, and the slab panels were installed. Slab panel installation was followed by the installation of steel rebar, plumbing, and electrical components (Kumkang Kind Co., 2016). 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. (Pujari et al.2018).

The panel installation procedure is then started by installing panels and flat tires on one side (either the inner or outer phase). Following the installation of one side, the flat tires on the other side are covered with a PVC sleeve. The wall panels are then put in place first. The opening areas, which include ventilators, door openings, and window openings, are installed after the wall panels. The parts that are installed for window opening are the beam panel, prop and prop head, wall end panel, beam cap SC, beam cap slab panel, and beam cap SC. It is imperative that the kicker plate be installed following the completion of the wall panel installation. 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 installationsWalls wouldbe disassembled first, leaving the rocker plate in situ. After that, the slab panels are carefully removed to prevent any panel free fall. Prop heads and props are maintained in position. Finally, slab corners are cut out. Furthermore, the upper floors are put together similarly. External working platforms are set up in order to assemble the formwork system on the upper floors first. The platforms' tie rods, safety rail, and safety nets are all positioned 1.3 meters apart. These platforms must be maintained at two levels. Lastly, an overall check is conducted once more (Pujari et al., 2018).

2.2.9. Method of Aluminum Formwork System

Before pouring the concrete on the upper layer, place the formwork thickness control piece sat the root of the shear wall. The first row of control pieces should not be more than 100mmfrom the main reinforcement of the shear wall, should not be more than 300mm from the internal corner, and the spacing of control pieces should not be more than 2m, so as to ensure the flatness of the root of the shear wall and avoid the concrete ground unevenness during the installation of the wall column formwork.Following the floor's concrete casting, the positioning rebar is welded between 50 and 100 mm above the floor to reinforce the wall. The thickness of the wall determines the length of the positioning rebar, and the appearance of the wall line determines the welding. To guarantee the wall thickness of the lower portion of the shear wall when the formworks are installed, the tolerance between the rebar and the wall control line should be less than 2 mm (aluminum formwork method statement

Precautions for aluminum formwork installation

1. All aluminum formwork panels should be clean and coated with a form formwork release agent.
2. Ensure that the aluminum wall formwork is installed according to the line.
3. Check whether all opening dimensions are correct and without distortion.
4. Whether the slab and beam formwork aluminum are levels.
5. Ensure that the bottom shoring props of the aluminum formwork system are vertical and there is no looseness.
6. Check whether the wall waler and push-pull prop of the aluminum wall formwork and aluminum column formwork are correct.
7. Check that the wall tie for aluminum formwork, pins, and wedges are kept in their originalposition and firmly fixed
8. Cleaning all remaining materials and other objects.
9. That the support brackets for the suspended working platform are fixed to the concrete structure.

2.2.9.1 Aluminum Formwork assembly

Installation Stage: Installing aluminum formwork correctly is essential to guaranteeing the caliber and advancement of construction. Sturdy support structures are provided by accurate installation, guaranteeing the exact placement and verticality of aluminum formwork components like walls and slabs. To ensure the overall stability and safety of the aluminum formwork, tight control over connections and fastenings is also required during the installation process. Work (manufacturing scaffolding and formwork).

1. Technical instruction: -before aluminum formwork installation, the technical personnel should conduct technical instruction. Only after confirmation by the management personnel can large-scale construction is carried out.
2. Draw location line: -after checking and confirming the flatness of the ground, according to the requirements of the building design drawings and section drawings draw the structural lines on. The ground. Then, draw positioning lines according to the structural lines.
3. Rebar binding, sanitary work, electricity installation Rebar binding, and installation of water and electricity should be carried out strictly according to the requirements of the design plan. After completion of the installation, confirmation should be made to Party A or the supervisor, and the next step of work can only be carried out after passing the acceptance inspection. (Aluminum form work production).
4. Aluminum wall formwork installation: - before installing s form aluminum formwork, it is necessary to ensure that the pipefittings have been pre-embedded and the openings have been reserved and that the pipelines have been properly laid out. The reinforcement binding and installation of shear wall end columns, corner columns, and concealed columns should be confirmed as qualified through acceptance inspection. When installing the s form aluminum formwork, it is necessary to start from the position of the door and window openings. (Aluminum form work production center)

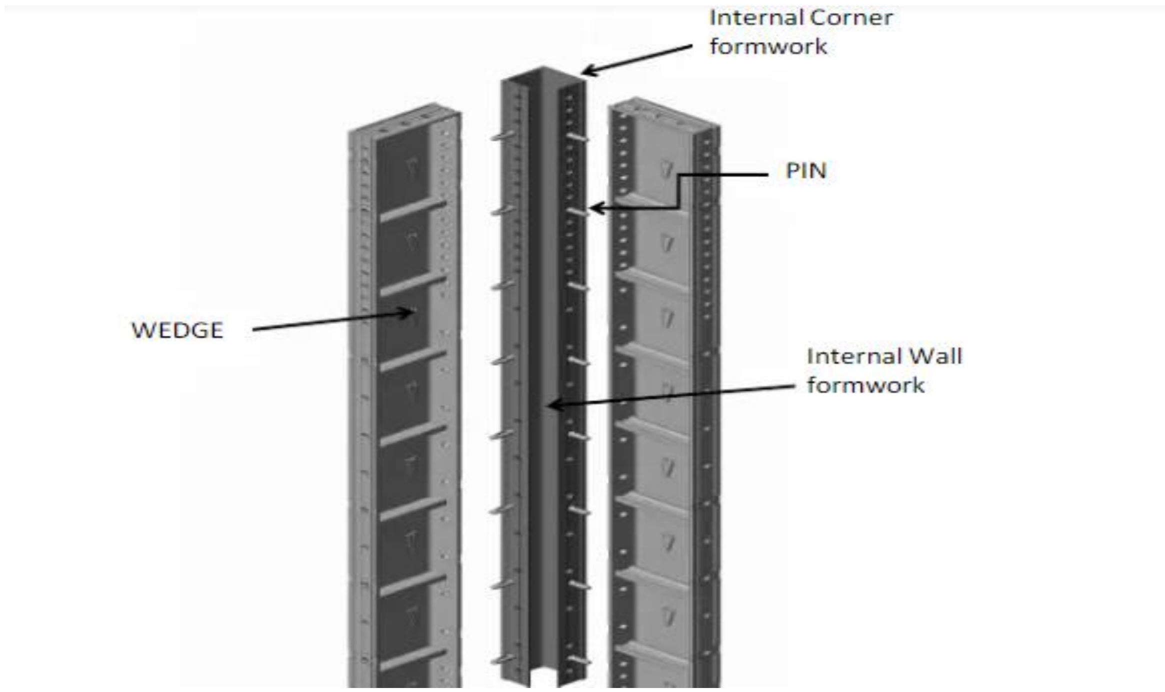


Figure 10. A Aluminum wall formwork parts(Aluminum form work production center)

2.10. Bafter wall panel connecting (Aluminum form work production center)

5. Aluminum formwork beams installation: - Before construction, the bottom beam s form Aluminum formwork should be connected to the side s form aluminum formwork using bolts. Install the beam bottom support to the center of the beam bottom s form aluminum formwork and fix it with pins. Then lift the entire beam support and place it in the corresponding position, connecting it with pins and wedges preliminary adjustments to the horizontal level according to the construction drawings. (Aluminum form work production center)

Figure 11. Abeam and slab assembly Aluminum form work production center)

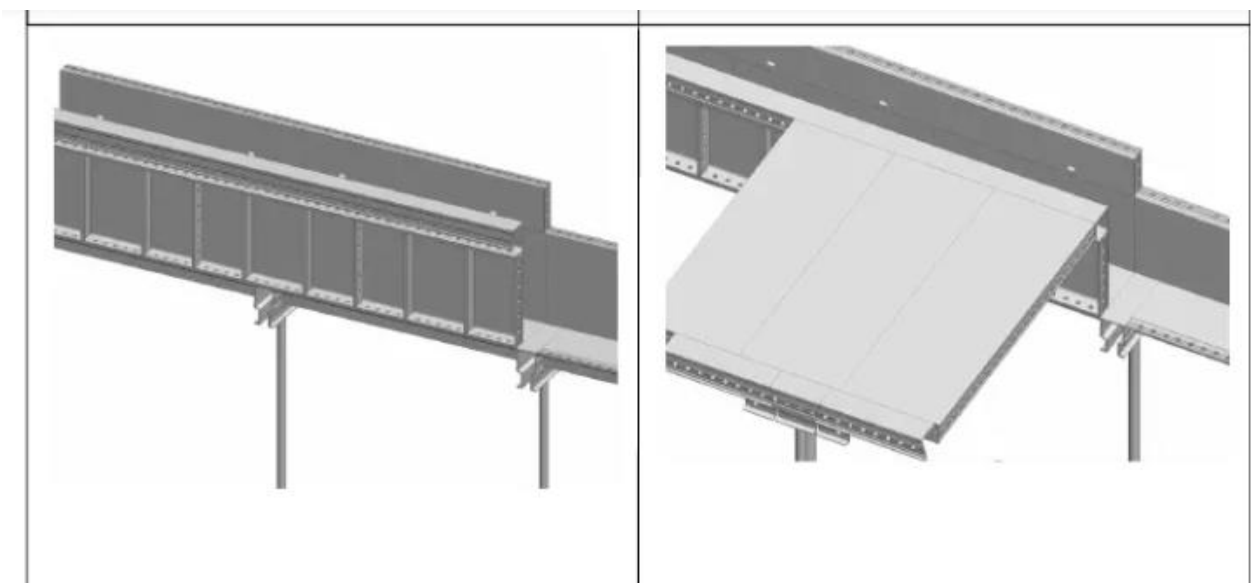


Figure 12. B Abeam and slab assembly Aluminum form work production center)

6. Stair and duct: -Form aluminum formwork for staircases and elevator shafts installation thestair form aluminum formwork must be erected starting from the corner to maintain temporary lateral stability. (Aluminum form work production center)

Figure 13. (a) aluminum formwork for staircases

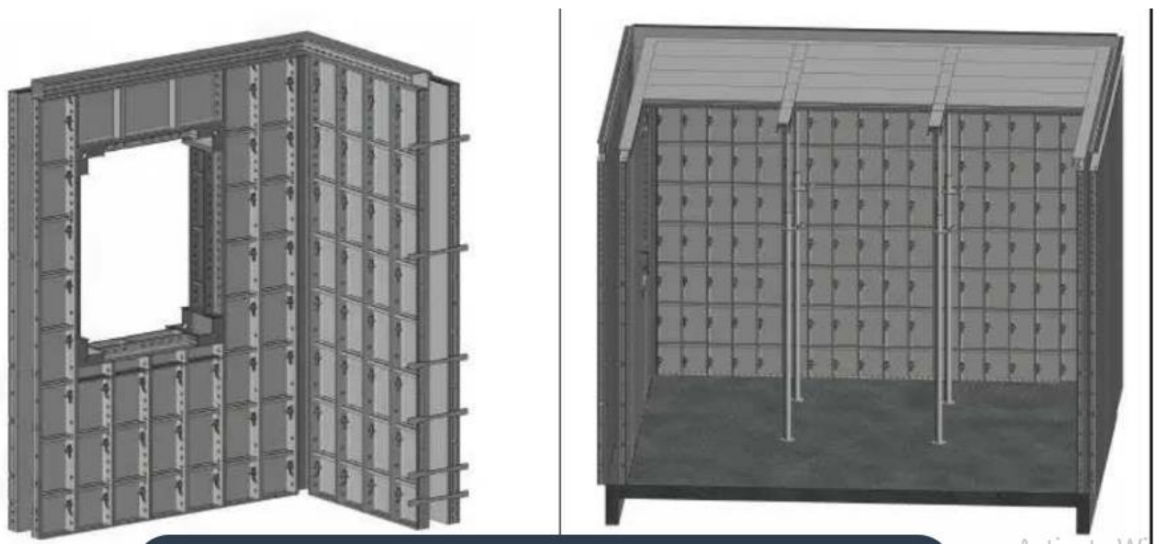


Figure 14. (b) aluminum formwork elevator shafts installation

7. Slap installation: - aluminum formwork floor slab installation Insert a long connecting pin between two adjacent beams, and support them in the middle with steel pillars to firmly assemble the adjacent beams and slab panels together. Assembly of the system is very simple requiring few tools. The adapters are attached to the wall panels using locking details provided by work technology factor. (Aluminum form work production center)

Figure 15. (a) Slap installation (Aluminum form work production center)

Figure 16. (b) aluminum formwork assembly slab, wall, beam, window, and door (Aluminum form work production center)

8. Adjustment: - After the form,aluminum formwork is fixed in place, its verticality and flatness should be checked and necessary adjustments made. Only by ensuring that the s form aluminum formwork meets the requirements can construction quality and safety be ensured.

9. Concrete pouring: - When constructing, shear walls, columns, and beams should be poured first, followed by horizontal floor slabs. The pouring of concrete should be layered to prevent the occurrence of "cold joints".

10. Concrete maintenance after pouring concrete, it should be promptly cured according to regulatory requirements. When the temperature is high, continuous watering should be carried out to reduce the temperature difference inside and outside of the concrete, prevent cracks from forming, and accelerate the improvement of concrete strength.

Over all after formwork assembly

Figure 17. Over all after formwork assembly (Aluminum form work production center)

2.2.9.2 Dismantle aluminum formwork

Dismantling Stage: - It is equally important to remove aluminum formwork properly following safety guidelines and operating procedures is essential during the disassembly process in order to avoid misshapes. Proper dismantling techniques can minimize damage, preserve the integrity of the aluminum formwork, and get ready for further work (manufacturing scaffolding and formwork). To remove the internal wall panels, knock out the wedges and pins after twelve hours. As mentioned, the slab opening must be used to move the wall panels to the upper floor. The panels should be moved carefully and systematically to ensure that the next cycle or level is unaffected. Since each panel has a unique color scheme for identification, the transfer process can be planned and determined based on the building's sections, such as the bathroom, room 1, and so on. The disassembled wall forms are moved to the upper floor after the External Wall Forms are removed, making sure the starter Block (kicker) is not damaged. Get in External wall panels are moved from the ground floor level using scaffolding. For level 1 and above, an external working platform is fixed to the external wall. The kickers shall support the external wall forms from level 1onward. (These steps are to be repeated from one floor to another floor). After removing the Wall Panels, proceed to the Slab Panels after 36 hours by removing the long pins and wedges on the joint bars the end and middle beam section. Upon removing the Aluspan Mid Beams and Aluspan, cantilevers End Beams, the prop shall remain undisturbed during this process to support the concrete slab. (Shengzuo Group).

1. Aluminum wall formwork dismantle: -The demolition sequence involves first removing the steel walker, then the pin and wedges, followed by the flat tie, and finally the aluminum wall formwork. When removing the aluminum wall formwork, which can be removed using a panel puller.
2. Aluminum formwork beams dismantle when dismantling the aluminum formwork beams, all pins and wedges in each section must be removed first. Next, insert a panel puller into the top or bottom of one side of the aluminum formwork beams and proceed with the disassembly.
3. Form aluminum formwork floor slab dismantle after removing all the pins and wedges from the slab panel, a panel puller can be used to tap the junction of adjacent s form aluminum formwork floor slab, which helps loosen them.
4. Clean s form aluminum formwork after disassembling the s form aluminum formwork, it is necessary to clean it promptly with a scraper. If the cleaning is delayed for too long, it

will become increasingly difficult. In addition, all formwork accessories need to be cleaned.

5. Form aluminum formwork transfer the s form aluminum formwork can be transferred through the transfer box. After the transfer is completed, the transfer box can be filled with concrete.
6. cycle construction After the s form aluminum formwork removal, the cleaning work should be carried out as early as possible and then transferred to the lower floor for classification and neat stacking, entering into the cycle of construction.

2.2.9.3 Considerations for Installation and Dismantling of aluminum formwork

Assure Construction Safety and Wear Personal Protective Equipment: Workers should wear the proper PPE, such as dust masks, gloves, safety shoes, and helmets, when installing and disassembling aluminum formwork systems. Maintaining a safe working environment is crucial, and this can be achieved by keeping unwanted workers out of the construction site and averting mishaps. To ensure the continuity and smooth progress of the construction process, the team should improve cooperation, communicate effectively, and make sure that various trades are integrated and coordinated seamlessly. Examine Stability and Quality to Prevent Safety Hazards: It is crucial to thoroughly assess the stability and quality of aluminum formwork before the company installs it. Ensure that the connections of aluminum formwork team are securely fastened without any visible damages or deformations. If any issues are identified, prompt measures should be taken to repair or replace them in order to avoid safety hazards. Aluminum formwork installation and dismantling are indispensable and crucial components in the construction process. The construction team must prioritize construction safety and quality control, adhering strictly to regulations and guidelines during the operations to ensure a smooth installation and dismantling process. By conducting proper installation and dismantling, construction efficiency can be enhanced, costs can be reduced, and successful project delivery can be guaranteed. (Shengzuo Group).

2.3. Empirical literature review

2.3.1 The Role of aluminum formwork system

According to Prasanth investigates the ease of use of aluminum It is feasible to precisely program construction sequences and, consequently, cycle times well in advance thanks to formwork and the repetitive nature of the assembly process. Additionally, when skilled labor is scarce, this lessens the strain on skilled labor by allowing unskilled labor to work with the formwork. All panels are properly labeled when they leave the factory so that they can be quickly identified on location and assembled seamlessly using the formwork modulation drawings. The demand for housing has increased geometrically as a result of rapid urbanization and cannot be met with traditional building materials and techniques For high-rise buildings and mass housing, the traditional or conventional method of construction is comparatively slow and has little quality control, especially when a large project is involved. Therefore, it is necessary to devise a plan or method that uses a methodical approach to automatically control the speed and quality of construction. As a result, the Aluminum Formwork System (AFS) was found to be appropriate for mass housing construction in India, where a respectable level of quality and speed can be maintained (Prasanth s).

Benefits of aluminum form work

- NO Plastering required.
- Savings on overhead expenses due to speedy construction (4 days per floor).
- Monolithic crack free structures.
- Doesn't require timber or plywood for construction activities.
- Casting of walls and slabs possible simultaneously.
- Doesn't require skilled labor.
- Floor slab forms removed without moving props.
- Earthquake resistance of resulting structures increases manifold.
- The Formwork is specifically designed to allow rapid construction on all types of architectural layouts.
- Total system forms the complete concrete structure.
- Custom-designed to suit project requirements.
- Unsurpassed construction speed.

- High quality finish.
- Eliminates plastering, saves almost 50 percent construction time.
- The system becomes cost effective where there is considerable repetition of floor layouts on a project such as in the case of low-cost mass housing.
- Panels can be re used up to 280 times.
- Erected using unskilled labor.
- Requires no cranes or heavy lifting equipment.
- Suitable for low as well as high rise buildings. Aluminum form work system Prasanth s Grand Edifice Developers 9840539538 / 9498002004.
- No need to use any timber or plywood.
- The resulting structures are highly durable and this ensures that the expenditure on maintenance is kept to a minimum.
- After the 25 cycles of reusing of our formwork system we will reach the breakeven point of the conventional formwork cost.
- Aluminum formwork supplied by other companies will consist of two panels. i.e. standard panel up to the door level and special panels above the door level. Since there is a joint in the door level, the panels will easily bulge which affects the plumb of the wall/column. But our panels are designed for the full height of the structure which will eliminate the above problem.
- Sheet panels are generally used in the Aluminum Kumkang formwork system. Since the sheet panels are made by welding the rails on four sides the joints will easily get damaged. To avoid this problem, we use 450mm wide panels which are being made by welding two ‘L’ shaped extrusions. So, the corners will be stronger than the sheet panels.

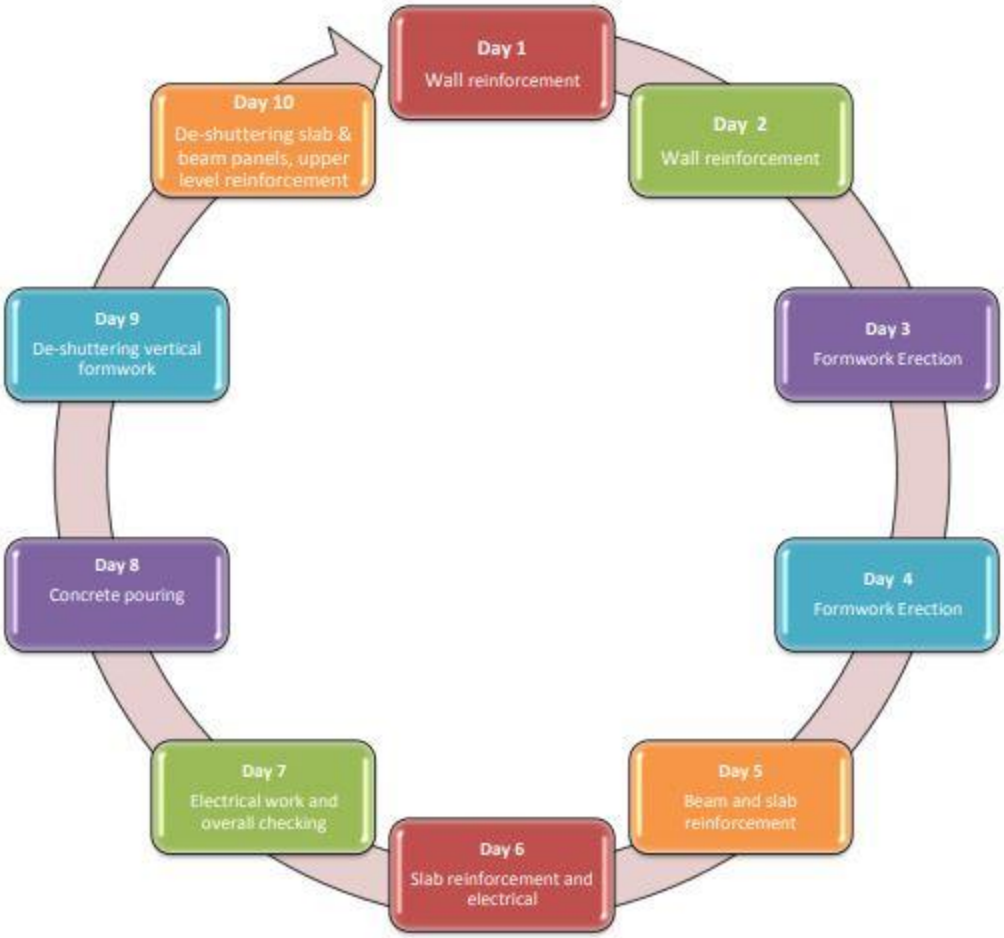
2.3.2. Cost consideration

According to the Prasanth researches Utilizing this formwork in load-bearing design results in an average 15% reduction in building structure costs and an 8% increase in usable floor space compared to RCC design. With minimal maintenance, the detachable Aluminum Formwork System can be utilized hundreds of times. Unlike tunnel framework, aluminum formwork is lightweight, so it doesn't require tower cranes, which lowers machine rental or parches pay. Due to the system's ease of assembly, only unskilled laborers need to be used, and they will receive minimal supervision and compensation for their additional training. By eliminating the need for plastering, the formwork system lowers the cost of both labor and materials. High Reusability: The longer lifespan and high reusability of aluminum formwork systems are its defining characteristics. It can be used repeatedly because it is more resilient and less likely to deform and wear than traditional wooden formwork. Unlike tunnel framework, aluminum formwork is lightweight, so tower cranes are not needed. The economy of formwork involves a number of factors that must be taken into account, such as the cost of materials, labor costs for creating, erecting, and removing the forms, and the cost of the equipment needed to handle the forms. The economy also takes into account how often the form materials are reused, how much the forms may be worth if they are salvaged and used elsewhere, and the, and as well as the price of completing concrete surfaces following the removal of the forms. Although wood is still used extensively due to its availability and ease of fabrication, steel formwork has somewhat replaced wood formwork due to the higher number of uses that steel can provide, even though steel forms have a higher initial cost (Krohn, 2011). Formwork is the most expensive element of a typical multistory reinforced concrete building, according to Tarekegn (2010). In a developed nation, the cost of formwork makes up about 10 percent of the total building cost and 40 to 60 percent of the cost of the concrete frame. A significant amount of the price of traditional formwork is Formwork labor costs in a developed nation are correlated with the cost of conventional formwork. Lowering labor costs could result in significant cost savings. Additionally, according to Dinesh &Sundararajan (2017), knowing the project's formwork capital provision is a crucial consideration when choosing a formwork system. Formwork typically accounts for around 35% of the overall cost of any completed concrete unit or element; slightly more than 40% of this can be allocated to formwork materials, and 60% to labor.

2.3.3. Time consideration

According to Dinesh & Sundararajan, 2017: **-** For 100 per cent work, construction through slab beam wall construction takes X time and through aluminum formwork, technology the time required is 1/6th of the X time. Rapid Construction: aluminum formwork system employs standardized design and assembly methods, making the installation process simple and fast. Compared to traditional construction, it significantly enhances construction efficiency, reduces project duration, and saves time and manpower resources. A faster floor cycle is always desirable for contractors and owners.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. For contractors, a faster floor cycle allows the contractor to finish on schedule or earlier which reduces the overhead cost. A quicker floor cycle lowers the owner's short-term expenses and permits early use of the built facility. Faster shoring removal and restoring as well as faster project progress would be possible with a quicker formwork cycle from erection to stripping. The rate at which concrete buildings are raised is known as the speed of construction, and it can be expressed in terms of the number of floors that are constructed each week or month. Inches or millimeters of concrete poured per hour can also be used to gauge construction speed. Construction projects' pace can be managed through formwork operations. Usually, multiple levels of shores and restores support the formwork, bearing the weight until the concrete becomes strong enough to support it every additional externally applied load. Shores are wood vertical members that hold up freshly constructed concrete that hasn't reached its full design strength. A quicker floor cycle lowers overhead costs for contractors by enabling them to complete projects on time or earlier. A quicker floor cycle saves the owner money in the short term and makes it possible to use the built facility sooner. According to Prasanth Sht, the cycle below

Figure 18. **Aluminum Formwork - Project cycle**



2.3.4. Quality consideration

According to Rajeshkumar et al., 2020: - shows excellent manufacturing accuracy, guaranteeing a smooth surface. It also has outstanding stability and seismic resistance, which ensures construction quality by offering a solid supporting structure throughout the process. In addition to being safe for both workers and concrete structures, formwork should be of high quality in terms of strength, durability, and rigidity. It should also be economical, easy to handle and disassemble, and operate efficiently. It ought to be robust enough to support both the live and dead loads. As a result, selecting the appropriate formwork becomes crucial when building. An improper choice of formwork causes the construction project to go over budget and take longer than expected. In construction, a variety of formworks are available. Choosing the right formwork system is one ofthe most important aspects of

. Among these, selecting the right formwork system is essential to completing a project successfully in terms of quantity, cost, time, and safety. Strength: Throughout the building phase, formwork should sustain both the intended loads and any additional applied loads. As a result, forms and shutters must be made to withstand hydrostatic pressure, dead weight, and live load (Tessema, 2019).
Every component should be made to withstand the most extreme loads that are anticipated to be placed on the formwork, according to Tarekegn (2010). A person skilled in formwork design should create the design in order to accomplish this. The overall safety of the temporary structure is influenced by the strength of each piece of formwork material (Dinesh & Soundararajan, 2017).
Sharmila &Christober,:-2016The 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 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

According to Tarekegn, 2010.In general, formwork should be built to accuracy greater than that desired in the finished concrete structure or element. All support structures should ensure that this accuracy is maintained until the concrete has hardened. The accuracy required 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
According to Tessema (2019) Modern formwork system has great advantage on such kind of quality requirement. 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.

2.3.4.1. Factors that Affect Surface Quality of Concrete

Tessema (2019) asserts that the final appearance of the concrete is determined by two primary factors. The first is the formwork's quality, and the second is the placement and compacting of the concrete. The form's material has an impact on the surface-finished concrete's quality. The caliber of the formwork materials and workmanship can determine the caliber of the final concrete. Air holes and other surface flaws in cast concrete can be significantly reduced with the right mix of form material, oil, or other parting compounds. Concrete formwork is responsible for a number of surface issues with concrete, including dusting, discoloration, and stains.Additionally, distorted formwork systems brought on by frequent reuse and insufficient formwork support are the cause of some deformed concrete surfaces. Unless it is precisely designed and constructed to achieve the required size, shape, position, location, quality, and finish of the acceptable quality of the cast concrete, the formwork and material quality have a significant influence on the quality of the off-form concrete. Concrete placement and compaction are additional factors. Depending on the height of the forms or the concrete drop, the effect of pouring new concrete can change. Concrete placement in small-height forms has little effect, but on taller structures—particularly walls—the incoming concrete exerts more force on the pre-existing plastic concrete, which transmits this additional force. Which transmit this added pressure to the forms. The faster the rate of placement the greater is the pressure that will probably affect the formwork system. If these extra forces are not taken into account, they may cause forms to deflect, which could result in bulged concrete surfaces and alignment issues. As a result, forms and ties should be strong enough to support these impact loads, and the rate at which they are placed shouldn't exceed their safe load capacity. Concrete consolidation and vibration are the other related factors that affect the formwork. Temporary lateral pressures are created when concrete solidifies due to internal vibration.

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. Form vibrators' external vibration raises the loads on formwork systems even further and modifies lateral pressures. In turn, the materials used to form the concrete have an impact on how fresh concrete vibrates. For instance, steel forms tend to reflect and bounce back vibrations, whereas wood forms tend to absorb them (Tessema, 2019).

2.3.4.2. 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 closefitting 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 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.

Stiffness: 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.

2.3.5. Safety consideration

Since no wood is used, the technology is environmentally friendly. The walls support the superstructure in two directions thanks to the formwork's box or cellular design. Compared to the conventional RCC column and beam designs, the structures are therefore more earthquake-resistant. Activities involving the construction of buildings are typically linked to significant risks and hazards. Additionally, building construction workers typically face an elevated risk of workplace injuries. Out of all the building trades, carpentry—which includes formwork and roofing—ranks highest in terms of risk (Okoye, 2018). Forms must be constructed with enough strength and safety considerations to support all loads, both live and dead, without collapsing or endangering the workers.

. A floor formwork system filled with wet concrete that is not naturally stable and has its weight at the top is called a formwork failure. Consequently, one of the most common reasons for failure is caused by effects that cause lateral forces or displacement of supporting elements; as a result, one of the most common factors in formwork failure is insufficient cross-bracing or horizontal bracing. Additionally, failure due to insufficient bracing can be caused by vibration (Krohn, 2011). Formwork must be built robustly to support the entire weight and side pressures of freshly laid concrete, construction traffic, and any required equipment in order to guarantee the structure's safety and the safety of the workers. Deflection is the most crucial factor to take into account. For the design of formwork, the limit for deflection varies according to the class of the work. (Krohn, 2011).

- ✓ 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).

- ✓ 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.
- ✓ 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.
- ✓ 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).
- ✓ 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).

2.3.6. The advantages and disadvantages of aluminum formwork

One of the primary benefits of aluminum formwork, according to Davy D's 2017 research, is how quickly it can be constructed. The formwork can be swiftly assembled and disassembled due to its pre-engineered and prefabricated design, which speeds up construction and reduces costs. The durability of aluminum formwork is an additional benefit. The system is a long-term cost-effective solution because it is made to resist the deterioration that comes with frequent use. Additionally, it offers a high-quality finish, which further saves time and money by lowering the need for additional finishing work. Aluminum formwork is also more environmentally friendly because it uses less heavy machinery and generates less waste than conventional construction techniques, both of which can have a big effect on the environment.

Its high cost, lack of field modification (you must use wood where your existing parts don't fit), and significantly increased risk of theft (for the aluminum's scrap value) are its drawbacks. For workers to become familiar with the entire process, a brief training is necessary due to the accuracy of alignment and safety regulations. However, aluminum formwork technology makes it less difficult.

Table 3. Advantages and Disadvantages of aluminum formwork system

Advantages	Disadvategs
Cost; very high no. of repetitions is possible (150-300). 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.
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
High salvage value: The salvage value of the aluminum alloy formwork system is very high when be scrapped as wastes	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 timeconsuming.
Quality; Excellent concrete surface finish, enables elimination of plastering thereby saving project duration and cost.	RCC slab to be designed for stripping after 36 hours with props left under.
Integral and smooth finishing of wall and slab uniform quality of construction; uniform grade of concrete is used.	Not Available
Lesser number of joints thereby reducing the leakages and enhancing the durability.	Architectural :- not construct any design
Environmentally friendly; no huge debris, no messy disposals.	Not accessabile
A Strong built-up of concrete needs no maintenance.	
Environmentally friendly; no huge debris, no messy disposals.	
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.	

2.3.7 Kumkang Versus Conventional

Table 4.Comparation of Kumkang aluminum and conventional formwork

No	FACTOR	CONVENTIONAL	IN – SITU ALUMINIUM FORM SYSTEM	REMARKS
1	Quality	Normal	Superior. In – Situ casting of whole structure and transverse walls done in a continuous operation, using controlled concrete mixers obtained from central batching, mixing plants and mechanically placed through concrete buckets using crane and compacted in leak proof moulds using high frequency vibrator	Superior quality in "System housing
2	Speed of construction	The pace of construction is slow due to step – by – step completion of different stages of activity the masonry is required to be laid brick by brick. Erection of formwork, concreting and deshuttering forms is a two – week cycle. The plastering and other finishing activities can commence only thereafter.	In this system, the walls and floors are cast together in one continuous operation in matter of few hours and in built accelerated curing overnight enable removal and re-use of forms on daily cycle basis.	System construction is much faster.
3	Aesthetics.	In the case of RCC structural framework of column and beams with partition brick walls is used for construction, the columns and beams show unsightly projections in room interiors.	The Room – Sized wall panels and the ceiling elements cast against steel plates have smooth finishing and the interiors have neat and clean lines without unsightly projections in various corners. The walls and ceilings also have smooth even surfaces, which only need colour/white wash	

4	External finishes.	Cement plastered brickwork, painted with cement – based paint. Finishing needs painting every in three years.	Textured / pattern coloured concrete facia can be provided. This will need no frequent repainting.	Permanent facia finishes feasible with minor extra initial cost	
	Consumption of basic raw materials				
5	Cement.	Normal	Consumption somewhat more than that used in conventional structures	Although greater consumption strength and durability is also more.	
6	Reinforcing Steel	Reinforcing steel required is less as compared to the in situ construction as RCC framework uses brick wall as alternative	It may, however will be slightly more than corresponding load – bearing brick wall construction for which, requirements of IS 456 have to be followed for system housing.	Steel requirement is more, as it is required for the shear wall construction. But shear wall construction increases safety against earthquake	

2.3.8 Ethiopian Building Code of Standard Recommendation

Since the abrupt removal of wedges would result in a shock load on the partially hardened concrete, EBCS-2 (1995) states that the formwork should be removed gradually. The stresses that will be induced in the concrete after the formwork and false work have been removed, the strength of the concrete at the time of removal, the ambient conditions, the available protection measures for the concrete after the formwork is removed, and the presence or absence of re-entrant angle formwork—which should be removed as soon as possible while adhering to other removal criteria—will all be taken into account when determining when to remove the formwork and false work. Before the structure has become strong enough to safely support all potential loads, the formwork cannot be removed.The strength of the concrete, the stress in the concrete at any point during the construction process, curing, the need for surface treatment later on, and the existence of re-entrant angles will all affect how long it takes to strike formwork. In order to prevent shrinkage cracks, formwork must be removed as soon as the concrete has set. As long as the concrete strength is limited by tests on cubes that have been stored thus far, the cubes will be removed when their strength equals 50% of the nominal strength or twice the stress to which they will subsequently be subjected, whichever is higher. This is only possible if the removal of the cubes earlier won't cause an intolerable deflection because of shrinkage and creep. Additionally, the concrete's strength development and the formwork's purpose determine how long it takes to cast and remove the formwork. Table 2.3 suggests the following minimum periods in the absence of more precise data.

Table 5. 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	21days

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

2.3.9 American Concrete Institute Recommendation

According to the American Concrete Institute, form removal time should be determined using engineer-specified criteria based on strength gain. Because there is more reserve strength available for dead load in the event that live load is not present at the time of stripping, shorter stripping times are reported for live load to dead load ratios larger than 1.0. Table 2.6 displays the form stripping time.

Table 6Americanstandard stripping time

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	
	Structural live load	
	< dead loa	>Dead load
Joist, beam, or girder bottoms	7days	4days
Under 10ft(3m) clear span between structural supports	14days	7days
10 to 20ft clear span between structural supports 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	

2.3.10 British Standard Recommendation

The formwork's stripping time depends on the kind of material used and the concrete's strength increase. The mix design, curing technique, and average concrete temperature all affect the strength gain. A regular striking and curing schedule is essential when finish and consistent color are desired. When striking vertical formwork, it is generally advised to have an in-situ concrete cube strength of at least 2 N/mm2 to lower the possibility of mechanical and frost damage to finishes. At least 8 hours at 200 degrees Celsius are required for unsealed plywood, and 6 hours are required for impermeable formwork, such as steel forms and plywood that has been overlaid or film-coated.In actuality, the vertical formwork may become stuck the following morning if the concrete temperature rises above 100C^{0}overnight. According to BS 8110 (1997), Table 2.7 summarizes the BS recommendation for concrete made with Portland cement 42.5N/mm2 and sulfate-resistant Portland cement 42.5N/mm2.

Table 7.BaTCoDA recommendations for stripping formwork

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

Table 8.Minimum periods before striking formwork as per BS (BS 8110, 1997).

Type of formwork	Minimum period before striking	
	The surface temperature of concrete	
	160C and above	t0C (any temperature between 0 and 160C)
Vertical formwork to colum	12hrs	300/(t+10) h
Soffit formwork to slabs	4days	100/(t+10) days
Soffit formwork to beams ar	10days	250/(t+10) days
Props to beams	14 days	360/(t+10) days

2.4 Sustainable Formwork System

2.4.1 Sustainable Construction

The phrase "sustainable construction" was first used to refer to the construction industry's obligation to achieve sustainability. "Creating a healthy built environment using resource-efficient, ecologically-based principles" is another definition of sustainable construction (Taher Ahmed et al., 2014). The idea of sustainability is becoming more widely recognized on a global scale. The earth's resources are in danger of gradually degrading due to economic growth and population growth (Ahmed et al., 2009). Like pollution or global warming, sustainable development is a global concern. According to one definition, it means providing for current needs without sacrificing the capacity of future generations to provide for themselves. Advanced design and cutting-edge technologies are enabling the construction industry to make significant strides in both real estate and construction development (Gambatese et al., 2014).

Environmental, economic, and socio-political sustainability are the three conceptual subfields that make up the field of sustainable development. By offering methods for creating buildings that use less energy and virgin materials, produce less waste and pollution, and still offer the advantages that construction projects have historically provided, sustainable construction seeks to apply the concept of sustainable development to the construction sector. In built environment-related projects, such construction processes would prioritize social awareness, environmental responsibility, and economic profitability goals.

In terms of the building itself, its immediate surroundings, and the larger regional and global context, a sustainable building is one that has the fewest negative effects on the built and natural environment. According to Ahmed et al. (2009), sustainable buildings take into account the building's whole life cycle, including its functional and environmental qualities as well as its potential future values.

Five goals for sustainable buildings have been established by the Organization for Economic Co-operation and Development (OECD) project: resource efficiency, energy efficiency (including reducing greenhouse gas emissions), pollution prevention (including noise reduction and indoor air quality), environmental harmonization (including environmental assessment), and integrated and systemic approaches (including environmental management system).

2.4.2 Sustainable Formwork

Constructing It is advised to adhere to the majority, if not all, of the sustainable construction criteria when it comes to formwork concrete construction, according to Al-Ashwalet al. (2017). To make the decision on the sustainability performance measurement easier, they need to be managed and evaluated using a variety of criteria. "Development that meets the needs of the present without compromising the ability of future generations to meet their own needs" is what is meant by sustainable development. The social, economic, and environmental pillars are all part of sustainability.

In order to satisfy the green building requirements, the construction should be designed holistically, taking into account the materials used, energy consumption, air quality, and available space. However, the current practice ignores other sustainability factors in favor of the temporary work system because it is more cost-effective. This ignorance could result from a number of things, including the emphasis on direct cost-effectiveness and the degree of knowledge regarding the formwork type's impact on the construction project's overall sustainability performance (Al-Ashwal et al., 2017).

2.4.3 Sustainable Formwork System

Comparisons According to Ahmed et al. (2009), formwork systems sustainability benchmarks fall into three primary categories that pertain to the economic, social, and environmental facets of sustainable principles. The following are the primary components of sustainable principles and how each sustainable benchmark is measured:

2.4.3.1 Environmental Benchmarks

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

Waste generation: Because of the large volume of waste produced by building, demolition, renovation, and related activities, the construction industry has long been recognised as one of the main causes of environmental harm. Wood (formwork and falsework), concrete, bricks, metals, and other materials, including waste from finishing tasks like material packaging, ceramic tiles, and insulation, make up the majority of construction waste (Lau et al., 2008).

Energy and resource consumption: Saving energy and resources means consuming as little of them as possible while having the least detrimental structural effect on the environment. From research and design to construction, operation, and disposal, we should consider all phases of the structure life cycle when building, keeping in mind the principles of sustainable development. Naturally, the design should receive a lot of attention at these points. Statistics show that construction accounts for roughly 40% of global material consumption and 45% of global energy consumption (Kiyanets, 2016). Therefore, less energy and resources should be used in the formwork system that will be used for construction.

The most prevalent type of pollution that negatively impacts living conditions is noise pollution. Construction noise can be produced by a variety of construction machinery, and the handling, installation, and noise removal of scaffolding and formwork can all contribute to the noise problem (Zhang, 2015).

Using renewable materials: Selecting materials that are produced using renewable energy sources greatly lessens the impact of waste and pollution on the environment (Almusaed et al., 2020).

Reusable formwork: Reusing formwork for concrete is one way to reduce construction costs. The initial cost of formwork materials decreased by 40% after five reuses. Concrete is more cost-effective because formwork can be easily removed from it. In light of this, formwork designers need to stay up to date on formwork production technology in order to maintain quality while also taking recycling concrete formwork's economics into account.

Waste efficiency: It should be noted that one of the most important aspects of the construction industry is waste management. Waste management, as opposed to waste control, entails the development and investment in new products, processes, technology, and training that can reduce waste (Cheng, 2014).

Efficiency of materials: formwork In other words, material efficiency refers to the use of formwork. It is simple to say that selecting the right system to carry out concrete work requires a thorough understanding of the features of formwork systems and the technology of monolithic concrete works. Because of this, labor costs are decreased, concrete produced is safer and of higher quality, and work cycles are accelerated. Therefore, the first issue that should be taken into account in order to enhance formwork utilization on the construction site is formwork selection (Krawczyńska-Piechna, 2017).

Environmental impact: According to Taher Ahmed et al. (2014), one of the key factors defining and assessing sustainability performance for concrete formwork systems is the environmental aspect. Concrete has a greater environmental impact than formwork, and modern formwork systems are incredibly efficient.

2.4.3.2 Economic Benchmarks

The significance of steady economic growth is the main focus of the economic side of sustainable building. By implementing policies ranging from competitiveness and trade to equitable and rewarding employment, the natural environment's potential is taken into account. The following are some economic indicators of a sustainable formwork system:

Labor cost: According to Naik et al. (2015), labor costs for concrete formwork account for more than one-third of the overall cost of concrete construction.

Materials and equipment Cost: Since formwork, reinforcement, and concrete are the primary components of reinforced concrete work, the overall cost can be roughly split between the three.

When designing the formwork for a concrete structure, the economy should be taken into account (Krohn, 2011).

Installation cost: Building concrete forms is one of the most labor-intensive parts of the job that requires determining the type of formwork used, how it is installed, and how much it costs. As such, it typically accounts for a sizable amount of the overall cost of concrete work. According to Zakiah et al. (2014), the labor costs for installing and removing the formwork account for the majority of the total cost. And the cost of upkeep: Formwork should result in a high-quality product that needs little upkeep, and durability is a key factor (Tessema, 2019).

Life-cycle cost: Some life cycle costing methods also include the costs of demolition. In general, life cycle costs (LCC) consist of an initial investment (typically construction costs) and follow-on costs (ordinary payments, such as energy, utilities, cleaning and maintenance, irregular costs for renewal or replacement) (Schneiderova-heralova, 2018). And construction time: due to the time value of money, construction costs could be reduced when the project was timeless.

Cost of energy use: On-site construction activities are carried out; workers use varying amounts of energy to complete various tasks (Liu & Gambatese, 2018). Additionally, resale value The estimated or anticipated resale value of an asset at the end of its useful life is known as salvage value. The depreciation of the assets utilized in the business is linked to this parameter. Competitive costs are additional cost-effective benchmarks. The process of choosing strategic price points to outperform the competition in a market for goods or services is known as competitive pricing.

2.4.3.3 Benchmarks Social

According to Ahmed et al. (2009), sustainability focuses on meeting people's needs while delivering excellent customer satisfaction and collaborating closely with customers, suppliers, staff, and local communities. The following are a few social measures: Operational safety for employees and outside parties: The safety of the individuals installing, using, and disassembling the formwork should be taken into account when choosing a formwork system for a particular operation. Take into account strength, stability, and the potential for falls, falling objects, and manual labor in particular. The most effective proprietary systems have integrated safety features that lower the risk of falls and hazardous manual tasks.

Contrarily, customer satisfaction is defined as a metric that assesses how pleased customers are with a business's products, services, and formwork abilities.

Improved standards for the local community: Assisting local communities and society in better meeting basic human needs, raising living and health standards, and cultivating financial discipline all contribute to the country's sustainable development. Additionally, direct employment and formwork selection are linked to the creation of jobs. The amount of labor used in the formwork. Safety and fire resistance are additional criteria to gauge socially sustainable formwork: Fire resistance is a metric used to quantify fire safety.

According to Zakiah et al. (2014), fire resistance is the length of time that a structure is exposed to fire without failing or becoming hotter than a predetermined temperature.

2.5 Formwork Labor Productivity

2.5.1 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, labor, and capital, and labor productivity stands as a measuring tool since most activities are labour.

2.5.2 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 labor 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 labor 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).

2.6 Summary of Literature Review

The construction sector uses a variety of resources, including labor, equipment, capital, and supplies. The materials alone account for 70% of the project's total cost. One of the crucial components on a building site that influences both quality and safety is formwork (Shaik & Rahul, 2019).

According to Dinesh and Soundararajan (2017), a formwork system is the entire system of support for freshly laid concrete, including bracing, hardware, and supporting members. According to Gaddam and Achuthan (2020), formwork systems can be broadly categorized as Vertical Systems (wall and column), Horizontal Systems (slab and beam), and Special Formwork Systems.

Formwork is composed of various materials, including glass-reinforced plastic, steel, aluminum, and traditional materials like plywood and timber.

The four main goals of formwork design and construction are economy (cost), quality, speed (time), and safety (Krohn, 2011).

The most reliable, secure, and modern formwork technology on the market today is the Kumkang type aluminum formwork system. Walls, columns, beams, staircases, balconies, and door and window openings are all cast in place using this special formwork system (Pujari et al., 2018).

In terms of speed, quality, safety, ease of assembly, mobility, flexibility in design and jobsite planning, durability, lack of skilled labor, cost reduction, faster construction, high labor productivity, and environmental friendliness, the Kumkang type of aluminum formwork is a superior technology, according to the literature.

Formwork systems play a crucial role in construction; choosing the right formwork system can result in sustainable building (Gaddam & Achuthan, 2020). The formwork scenario in Ethiopia's building construction industry, particularly in local construction companies, can be described as follows: Conventional and modern conventional forms are most commonly used, which are time-consuming, labor-intensive, dangerous, and require additional treatment for surface finishing (Tessema, 2019). High formwork material waste is another issue. Unplanned and frequent nailing, even when it is not necessary, limits the reusability of timber materials. For instance, pieces of corrugated iron sheet are nailed to plywood to prevent concrete paste from leaking through the joints.

2.7 Research Gaps

The most crucial factors influencing construction success rates, according to the literature review under related works, are time, speed, quality, cost, formwork material availability, and safety of work. However, Ethiopian construction companies typically lack the capacity and capability to complete projects on schedule, within budget, and with the desired level of quality. Construction time, speed, quality, and safety are all influenced by formwork systems. The formwork scenario in Ethiopia's building construction industry, particularly in local construction companies, is characterized by the use of both conventional and modern forms, which are time-consuming, labor-intensive, dangerous, and require additional treatment for surface finishing.

Additionally, there is a lot of waste from formwork materials, low labor productivity, more concrete waste, and unskilled labor because construction companies are reluctant to provide training because they are afraid that workers will quit after the training and instead prefer to use low productivity labor.

Alternative formwork materials, like fabric, glass-reinforced plastic, and plastic, are not widely recognized and utilized by nearby construction firms. The most widely used formwork materials in Ethiopia are steel panels and timber boards. Aluminum formworks are also not widely recognized or feasible.

In order to improve construction features and get around the drawbacks of traditional formworks, aluminum formworks must be taken into consideration as a substitute. These aluminum formwork types include Kumkang, which is being utilized for the first time in OVID Group projects. Additionally, Ethiopia has never published any studies on the functionality and uses of this kind of formwork. For the previously mentioned reasons, an evaluation of Kumkang aluminum formwork's performance is necessary.

CHAPTER THREE

3. RESEARCH METHODOLOGY

3.1. Introduction

This chapter discusses the methodology adopted for this study. As stated earlier in chapter one, this research aims to the impacts of aluminum formwork system on building construction project performance in Ovid group (construction). 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 Ovid group address using aluminum formwork system construction project. For the Kumkang aluminum formwork project, only the Ovid group in the construction sector was addressed.

Meanwhile, the Kumkang aluminum formwork system has only been used in Addis Ababa federal housing Gerji modern village project, CSR (riche, lideta and aware) on company donation collaborate with Addis Ababa city administration and prime minister, koye fiche army deface house project own by Ethiopian army or deface and the other projects on going company real estateprojects.

Figure 3.1 shows the map of Addis Ababa city.

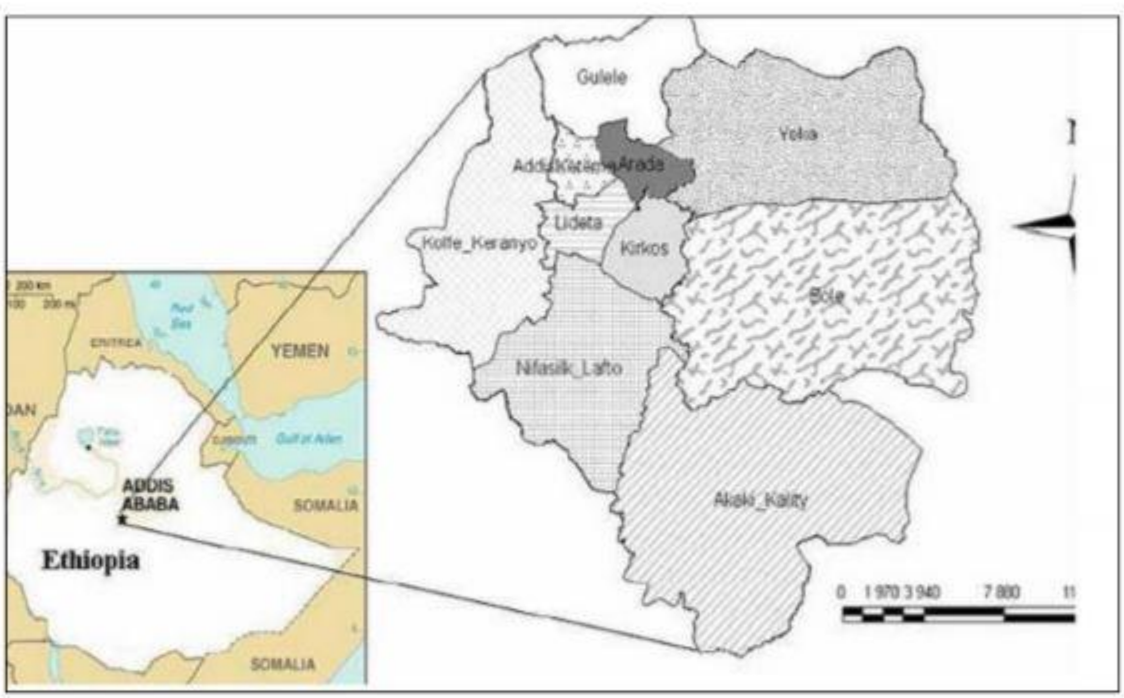


Figure 19. Map of Addis Ababa (Meron, 2016)

3.3. The Study Design

This study's research design was both exploratory and descriptive. The design of the research methodology makes it possible to gather sufficient data on the topic so that the study can appropriately address and elucidate the goals. As a result, the most well-known and recognizable data collection methods are used. The Ovid Group's ongoing delivery project, which was built using an aluminum formwork system, was the subject of case studies in order to analyze the effects on the final concrete's quality, cost, and time. Additionally, reference books, articles, and other relevant types of literature were used to compile the literature review. It served as the foundation upon which the main tools for gathering data were drawn.

To achieve all of the research goals, the first source of data is gathered through interviews and survey questionnaires.

3.4 Population and Sampling Technique

3.4.1 Target Population

The study population was based on the data acquired from Ovid group in building construction project team and maims office work man ships. Due to the formwork system which is applied by in Addis Ababa housing projects, this study targets 11 projects which are owned by federal housing corporations, Army, CSR and company real state that are ongoing constructed and delivery their progress on structural part and finished for purpose the role of this system to study the subject matter.

3.4.2 Sampling Technique

Due to the small target population, the study's focus on a single company, and the study's geographic scope, the census method of sampling was employed for this investigation. The census method is a statistical enumeration technique that examines every member of the population. There are eleven projects in total, but only six have been delivered, and there are five ongoing construction projects whose structural portion is currently owned by the prime minister office and the company. Ovid Group's adoption of Kumkang aluminum formwork led to the first federal housing project, the Gerji Modern Village Housing Project. A sample of 11 projects—five ongoing and six delivery projects—was selected in order to gather the necessary information, knowledge, and experience on the topic and to assess the performance of the aluminum formwork system between those projects.

The mixed-use apartment complex used for this study was a nine-story building surrounded by ten blocks of B+G+10 apartments and six blocks of B+G+9 sky villas in the Gerji modern village project. Ovid building ongoing construction project in which Ovid Group Construction recently made progress on the structural portion. Due to the fact that one of the first federal housing projects, the Gerji Modern Village Housing Project, used Kumkang aluminum formwork, Kumkang formwork was used for a single mass production building.

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 preprinted 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. Selected project in this research case study Gerji modern village, Misrak atekalay & Kebena the risen of selection, those projects all projects own by federal hose and started the same time. The results of this research chapter four results & discussion.

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 Ovid group ongoing and delivery project that was constructed by Kumkang formwork system recently and the Ovid construction project the impact of Kumkang aluminum formwork in terms of cost, time, quality of finished concrete impact formwork construction and to assess the labor productivity of the Kumkang aluminum formwork system the case study was taken on projects that are constructed through Kumkang aluminum formwork through monthly progress of labor productivity and based on productivity measures on each structural member was computed.

3.6.2. Questionnaires

The primary tool for gathering data was a questionnaire. Self-administered questionnaires are given to respondents by hand so they can fill them out on their own. Both closed-ended and open-ended questions were included in the questionnaire to allow respondents to elaborate on topics. These tools were primarily used to gather data regarding current practices and their attitudes toward technology, as well as to evaluate the formworks' sustainability, safety, and finished concrete quality.

Five project managers, ten site engineers, three resident engineers, four site managers, two office engineers, two office engineers head, four structural engineers, five general directors, four project coordinators, two senior office engineers, two research and development directors, six superintendent foramen, one contract administration engineer, four construction engineers, two assistance project managers, and one safety officer were all given questionnaires, which were distributed for a total of eleven Ovid construction projects. Selection criteria adaptable aluminum formwork system, FHC leads the same time conventional & aluminum formwork use.

The structure of the questionnaire is as follows:

The first section contains the respondent's general information. In the second section, we were asked what kind of formwork materials the company uses and why. Section 3: two questionnaire types (closed and open) It addresses the first and second research questions (objective one and two) by examining the effects of the Kumkang Aluminum formwork system on building construction time constraints and its practice on the site opportunity and challenges. In order to achieve the research's primary goal, section four asked about the impact of formwork systems on the quality of completed concrete using standard metrics for evaluating finished concrete quality and the formworks' perspective based on those metrics The investigation. Section five: under this section, the formwork safety practice and health and safety risk factors were computed to attain the impacts of aluminum formwork; this helps to the results of the first research questioners. This makes it easier to determine which formwork type has made the most progress in terms of safety. The third goal and the second goal are cost constraints. Section six: formwork sustainability criteria and their components were calculated under a different type of formwork. This helps determine which type of formwork has better benefits and barriers through construction sustainability.

3.6.3. Interviews

One of the methods used to gather primary data was interviewing. Four project managers, four site supervisors, seven office engineers, three employees of the Federal Housing Corporation, and two subcontractors were interviewed one on one. Every respondent has five years or more of experience, which helps to explain and make clear the data needed to meet the goals of the study.

The following appears to be the interview question for various parties: The interview conducted as part of the Gerji Village project aids in understanding Ethiopia's modern formwork system trend and achieving all research goals. Interview questions for the Ovid group focused on the time constraints of the contemporary Kumkang aluminum formwork system while also addressing economic, time, and cost viability. Interview point More questioner types are addressed due to the other constraint. Knowing their role and contribution in relation to this type of formwork, as well as whether or not there is any support for the contractors using it and whether or not to follow up with them, is made easier by the interview with MoUDC. This interview aids in understanding the contractor's perspective on the MoUDC and its implications. Since the Ovid group is the client and contractor, the interview is also conducted with the Ovid group to gather information from both the contractor and the client.

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.

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 Liker 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 9. Respondents' demographics

no.	Rating Rating	scale Classification
5	Almost certai	4.50 ≤ Average Index, I < 5.00
4	Frequent	3.50 ≤ Average Index, I < 4.50
3	Occasional	2.50 ≤ Average Index, I < 3.50
2	Remote	1.50 ≤ Average Index, I < 2.50

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 = $\sum aixi \sum xi$

-- 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 labor productivity for productivity on each structural member was computed according to Tewodros (2006), through Equations 3.2:

Labor productivity = Output (in units) Input (MH) -- Equation 3.2

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

Productivity= Quantity of work done Number of man−days --Equation 3.3

The data presentation for quantitative data which is questioners that were 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 labor productivity. The comparison was presented by using tables and graphs in combination with other data. And the interview that is collected from different parties was also analyzed separately and present in combination with quantitative data.

3.8. Data Validity and Reliability

3.8.1. Validity

According to Kothari (2004), the degree to which the instrument captures what the researcher or researchers want to capture is known as validity. The extent to which an instrument measures what it is intended to measure is indicated by a validity test. The validity of the research can be tested in a variety of ways. A test of content validity is used in this investigation. The degree to which a measuring tool adequately covers the subject being studied is known as content validity. The project's pilot study, first test 5 person selects & distribute questioner after the result, which involved distributing a questionnaire to three project managers and two project research and development heads to assess the questionnaire's quality prior to data collection, was used to gauge the validity of this study. 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

The two primary concerns of reliability are whether procedures for data collection and analysis yield consistent results and whether other people can view and infer comparable conclusions from the same raw data. In other words, it is a characteristic that makes it possible to repeat data collection techniques with the same results (Kothari, 2004). This study used internal consistency, which involves comparing each questionnaire question's response to those of other questions. As a result, it evaluates how consistently responses to a subset or all of the questionnaire's questions are consistent. There are several methods for calculating internal consistency. Cronbach's alpha, which was computed using SPSS software, was used in this study to assess the consistency of respondents. Although it may be lowered to 0.6 in exploratory research, the minimum recommended level is 0.7; anything below 0.6 is typically disregarded (Kothari, 2004).

The formula used for the Cranach's alpha measurement present on Equation 3.4:

$\alpha =$

Ncv+ $(N-1)$ 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.

Rule of Thumb for Outcomes

When interpreting alpha for Likert scale or dichotomous questions (those with two possible answers), the general rule is:

Table 10 Cronbach's alpha standards

Cronbach's alpha	Internal consistency
α ≥ 0.9	Excellent
0.9 > α ≥ 0.8	Good
0.8 > α ≥ 0.7	Acceptable
0.7 > α ≥ 0.6	Questionable
0.6 > α ≥ 0.5	Poor
0.5 > α	Unacceptable

This research result below table.

Table 11 Cronbach's Alpha test (on 2017)

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	0.95	0.95	16
The impact of formwork systems on health and safety risk factors	0.952	0.956	15
The aspect of formwork systems on sustainability elements	0.787	0.812	25

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. Introduction

The purpose of this study is to examine the effects of Kumkang aluminum formwork performance on the Ovid group in Addis Ababa. The data collected through questionnaires, case studies, and interviews was examined and discussed in this chapter in order to accomplish the study's goal.

The questionnaire that was obtained from the respondent was examined in this chapter using SPSS version 20 and an Excel spreadsheet. The results were displayed using descriptive analysis, frequency, and percentage means. Additionally, the researcher displayed the results using charts and graphs to facilitate easy comprehension of the analysis. Under this chapter, case studies and interviews are also analyzed and presented both quantitatively and descriptively.

The researcher attempted to address all of the research objectives in the six sections that made up the questionnaire (see Appendix A). Fifty-two questionnaires were distributed across eleven projects, and forty-five of those were collected, yielding a response rate of 79%. Questionnaires were categorized in this study to guarantee consistency in responses, and the results of Cranach's alphas analysis for the questionnaires are as follows:

Table 4.1: Table 4. 1 Cranach’s Alpha coefficient (Reliability Statistics)

4.2. General Information of the Respondent

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

Table 12. Respondent category and class of company (on 2017)

Category and class of company	Frequency	Percent (%)
Client		
Consultant, grade 1	5	11%
Contractor, GC-1	40	89%

From the Table 4.2, most of the respondent was on Consultant GC-1 (11%) and 89% 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 the organization has been operating and the number of projects executed in the last five years through Cross tabulation. This helps to know the respondent's company background.

Table 13. Organization operating time and number of projects executed(on 2017)

How long has the organization been operating		Number of projects executed in the last five years		
		Less than 10	11 to 20	More than 20
Less than 5 years	0	0	0	0
5 to 10 years	0	0	0	0
10 years and above	45	40	5	0

According to Table 4.3, all of the respondent organizations have been in business for more than ten years, and the majority of them have completed fewer than ten projects.In the last five years, some of the respondent organizations have completed ten to twenty projects. As demonstrated above, the respondents' organization has been in the construction industry for a long time and has completed numerous projects over the last five years. Site engineers, office engineers, project managers, construction engineers, general directors, resident engineers, and so on made up the majority of the respondents. Refer to Appendix-B.

Since all of the respondents were professionals, the questionnaire was prepared with a valid response in mind. Nearly all of the questions could be answered by professionals, whose experience is listed in Table 4.4.

The respondent's experience is displayed in Table 4.4, which enhances the response's validity because more knowledge of the topic yields more trustworthy data. The majority of respondents (66.67%) had less than five years of experience in the construction industry, while only a small percentage (15.56%) had five to ten years. Nearly all respondents had sufficient experience with the prepared questionnaire, according to the results, and three projects were selected for case studies to better understand the types and characteristics of buildings.

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Table 14. Experience of respondent (on 2017)

Years of experience	Frequency	Percent (%)
Less than 5 years	8	17.78%
5 to 10 years	7	15.56%
10 years and above	30	66.67%
total	45	100%

Project details for the projects listed in Table 4.5.

Table 15. Project's information (on 2017)

Project:	Project A (Gerji modern village)	Project B (misraq mixed use apartm
Type of formwork used:	Kumkang Formwor	Wooden
Formwork application (footing, walling,slab)	Wall, Slab, and Sta	For all structure
Building area:	Apartment=586m2 Sky Villa=530m2	1,700m2
Type of building:	Apartment	Mixed-use apartment
Estimated Total Cost of this project	4,000,000,000birr	251,225,692birr
Estimated formwork cost (%) to total construction cost	16%	19.50%
Estimated total project Duration	14 months	24 months
Current performance (% completed)	43.75%	26%
Probability of finishing within specified time and budget	Higher	Moderate

From Table 4.5, under this research, the project taken for case studies data gathering (document collected) structural and current status (more of finished and half building delivery) was on stage for purpose of subject matter. All projects have the same building types this helps to make a comparison between projects since it's having 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 project A is better than project B.

4.2.1 Formwork Materials Used by Companies

The type of formwork material that the company uses is covered in this section of the questionnaire. This aids in determining the most popular formwork material type and the respondent's viewpoint regarding the use of Kumkang aluminum formwork system. The formwork material that the company uses is depicted in the following figure. According to Figure 4.1, the majority of respondents used a combination of formwork and steel to support members during construction. A smaller percentage of respondents used both steel and wood, while the remaining respondents used aluminum Kumkang and wood.

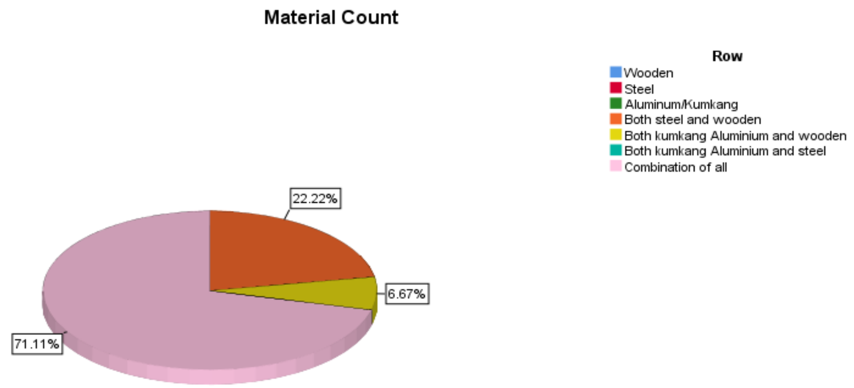
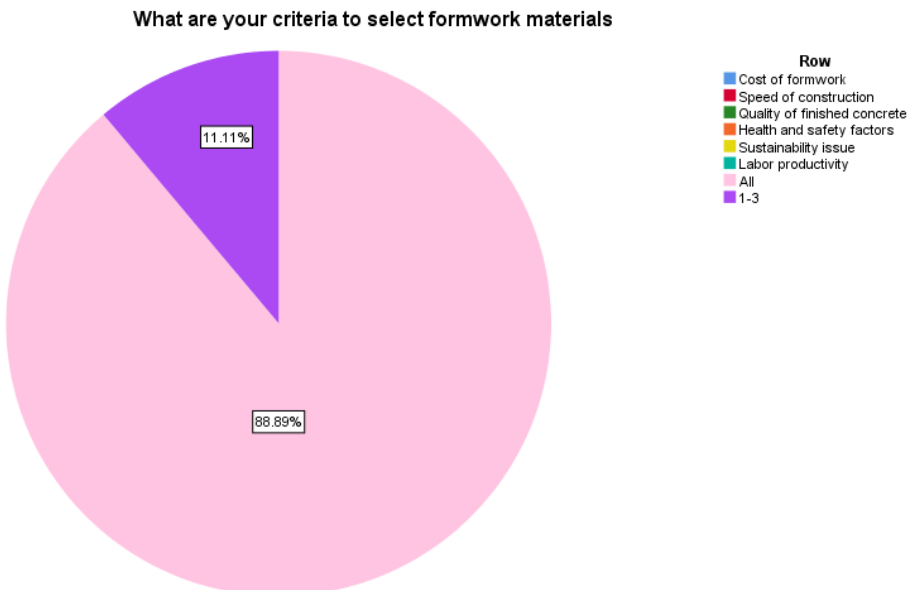


Figure 20. Formwork material used by the company (on 2017)

Figure 4.1, shows that about 71.11 % of the respondents apply combination ofall because of foundation and basement not constructed use aluminum formwork system, 22.22 % both steel and wooden formwork material the others 6.6% Kumkang and aluminum formwork material used.Beginning on the ground floor, the Gerji modern village project uses Kumkang formwork. Wood formworks and steel supporting members were used in the construction of the footing pad and basement. The majority of respondents cited the initial cost and the material's accessibility in the local market as reasons for not utilizing Kumkang formwork. Furthermore, since it is new and unfamiliar, there is no skilled labor to construct it, and lack of knowledge were cited as reasons for not using Kumkang aluminum formwork. It is also not flexible for all and any structures, especially for foundation work. According to Kumkang Kind (2016), aluminum because the formwork system is made of lightweight aluminum, even the largest parts can be set up and carried by hand. Its intricate design eliminates the need for skilled labor. This is evident in the dearth of knowledge and advancements in research regarding formwork material to dispel the myth that it requires a skilled worker. According to an interview, even though modern formwork systems are more effective and of higher quality, their initial cost is high, they are rarely available on the market, knowledge sharing performance with the technology, people are afraid to adopt new technologies and do less research on them, economic capacity, or startup capital, Import prices, trends, and The nation's culture and tender procurement system rely on the least bidder system, so if a contractor is skilled and has such modern formwork, they will offer a higher price. This indicates that the lack of use of modern formwork systems due to directivities defects was cited as the reason Ethiopia adopted modern formworks less frequently. According to the response, there is less adaptation to modern formwork systems due to a lack of government support, a lack of research and knowledge, and fear. According to the analysis of the interview, the government does not support the adoption of modern construction technologies in the nation; instead, contractors attempt them on their own. Additionally, there are no platforms or promotions to support contractors experimenting with new technologies in construction. All it takes is a five-year plan to decide whether to promote contractors who use construction technologies or to adopt manufacturers. Although the government does not provide crucial support, there is a forum for introductions between construction companies. As previously mentioned, the government must assist the contractors in modifying procurement regulations and creating a system to bring these technologies to the local market by establishing manufacturing sectors or importing machinery and raw materials to manufacture local aluminum formworks of a comparable type and tax breaks. Due to a shortage of foreign currency, the government was less willing to support contractors; they were unable to compel them to import and use such formwork materials. In addition to not enforcing the rules, they do not make the use of these forms mandatory. For example, a law prohibiting the use of wooden formworks for constructions over G+4 is not followed in practice. Additionally, there is no registration requirement for formwork materials used by the business; the only action taken by the authorized party is develop knowledge and make recommendations about the various formwork systems by researching the project's feasibility in terms of time, money, and quality. However, the majority of respondents from the contractor side concurred that a modern formwork system should be a prerequisite for registration, particularly for grade one contractors, because, despite the high initial cost, the quality of the work, ease of use, and material reusability are excellent for obtaining higher-quality work. In the construction industry, it's also beneficial to compute with the rest of the world. Additionally, to modernize Ethiopia's construction sector and acquire the benefits of contemporary formwork systems which include cost, flexibility, efficiency, safety, and speed of erection.However, because it is highly costly for both individuals and employees, some respondents disagreed with it. Additionally, before requiring registration, the government should change the standard bid documents and procurement directives, develop skilled lessons to operate modern formwork, ensure that it is available locally, and include it in the national specification. The criteria used by respondents to choose formwork material are shown in the following graph. When choosing formwork for construction, this aids in determining the respondent's priority. The following graphs figure 4.2 shows the respondent rate for each criterion ontoselect formwork materials



.Figure 21.Formwork material selection criteria (on 2017)

Multiple question analysis was used as the analysis method, and each respondent was allowed to choose more than one option. The respondent's score was determined by the criteria rate. According to figure 4.2B, the majority of respondents (88.89%) agreed that the cost of formwork, construction speed, and finished concrete quality were the primary criteria they used to choose formwork material. Above these criteria, respondents prioritized labor productivity, health and safety considerations, and sustainability issues, but 11.11% chose materials based on cost, quality, and construction time or speed.

The respondent also mentioned other criteria, such as ease of construction and availability on the local market. We can infer from the above result that they have less flexibility to take into account important construction factors these days and stick with less expensive items.

4.3. Kumkang aluminum Formwork Practice System opportunity and challenges

1) OPPORTUNITY

In this section, the researcher attempted to examine the Kumkang formwork practice system's potential advantages and disadvantages for building construction. As previously mentioned, one of the goals of the research is to identify potential opportunities and challenges in the formwork system; this section attempts to achieve the goal from a different angle. Because it always provides the most: trust, safety, cost reduction, quality improvement, and the ability to reuse and recycle formwork, the formwork system is the most crucial component of successful structural construction. One of the main determinants of construction time, speed, and quality is the use of contemporary formwork systems. Modern formwork systems are not only environmentally friendly but also offer many benefits for timely and high-quality project completion. The Kumkang formwork system is a long-lasting product that is simple to install and can create excellent concrete edges and surfaces, according to the analysis of the interview. When handled properly, the formwork can be used repeatedly for up to 300 cycles, which reduces the cost of the formwork compared to a conventional one. Because of its work methodology, a single floor can be completed in five days, whereas a conventional construction cycle takes three weeks or more for the same area. Because it is an RC wall, there is no need to construct a partition or do HCB work, and there is less plastering and chiseling, which saves time and money on the work. Getting better alignment is the third step. A better finished concrete surface that can be painted and finished right away is produced by perfect and precise ageing. Before the formwork is erected, the electrical conduit and fixture are installed alongside the rebar. Additionally, the primary distinction between them is dimensional accuracy; since the formwork is precisely designed and manufactured, the result on the structure is accurate, something that is challenging to accomplish with conventional methods. As one of the formwork requirements, this improves the quality of the final concrete. Able to complete tasks with fewer workers.

2) CHALLENGES

The respondent brought up Kumkang limitations, stating that it is hard to maintain and modify the design because it is rigid and may miss many design elements due to communication issues. Therefore, in order to take a quick corrective measure, a thorough check should provide at least three drawings: structural, architectural, and Kumkang (sheal) drawings. Kumkang aluminum formwork material is imported from Korea since it is not manufactured or sold in our nation, resulting in a high cost without the need for an upfront purchase price, which indicates a tax system. All of the accessories for this type of formwork are being kept very carefully because they are not readily available on the market.

Table 16. Formwork acquiring method (on 2017)

Acquiring methods	Responses	
	N	Percent (%)
Owning (Import from abroad)	42	100.00%
Total	42	100.00%

The multiple question analysis method used in Table 4.6 allowed a respondent to choose more than one option, and the respondent's response rate determined the outcome. According to Table 4.6, every response from the respondent involved formwork that was imported from overseas. The Kumkang formwork, which is made and imported from Korea according to the building's design, is utilized for structures above the basement. Since aluminum formwork is not yet produced in Ethiopia, there is no domestic production, which is why we had to use this source. Additionally, the work demand requires this type of formwork in order to achieve high quality of work, time efficiency, and good productivity.From an interview with the government side, it’s intended to establish the nation's market and develop the manufacturing sectors, including IBS, digitalization, technologies, and BIM, over the course of the following five years. Modern formwork and other industrialized building systems are available in the local market as the organization's plans progress. This will address the concerns regarding market availability and the cost of not utilizing contemporary formwork system

- ❖ According to those answers, the Kumkang formwork offers a greater advantage in terms of construction time, cost, and quality—all of which are fundamental formwork requirements. Utilizing such formwork is also motivated by the client's desire for higher-quality, more efficient, cost-effective, and ecologically friendly construction. Such formwork systems allow for the rapid production of more housing projects. Thus, this formwork system aids in achieving their organizational goal. Modern formwork systems like Kumkang aluminum aid in these areas and the development of the construction industry since Ethiopian construction must be completed on schedule, within budget, and in a sustainable manner.

❖ 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 4.6 describes the acquiring method of the kumkang Aluminum formwork

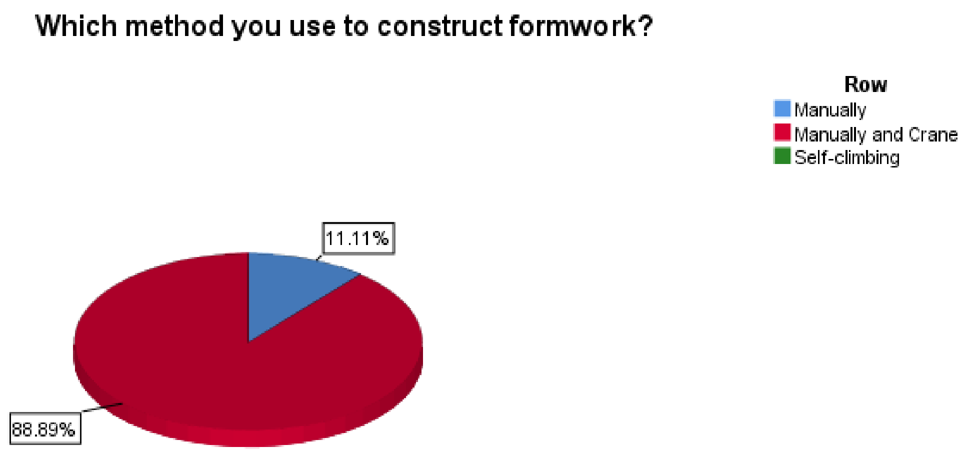


Figure 22. Methods of Kumkang Aluminum formwork construction (on 2017)

This demonstrates that the Kumkang formwork system can be built manually, in contrast to other formwork systems that require a crane. This lessens the congestion on the site as well as crane and other overhead expenses.

Three broad categories can be used to describe construction workers: skilled, unskilled, and semi-skilled. Generally speaking, skilled labor refers to jobs like electricians and plumbers that call for specialized training or technical skills. Construction workers and other unskilled labor occupations typically don't require workers to possess any particular skills or training. The term "semi-skilled labor" describes occupations like plasterer, carpenter, and technician that require a high degree of skill and expertise but are less demanding. The respondent rate on the kind of labors used for Kumkang Aluminum formwork system is described in the following Table4. 7

Table 17 Types of labor employed in the construction of Kumkang Aluminum Formwor (on 2017)

Kind of labour	Responses	
	N	Percent
Un skilled labour	4	8.33%
semi skill labour	3	6.25%
all	38	85.42%
total	45	100.00%

According to Table 4.7, the majority of responses (8.3%) were from unskilled labor, followed by semi-skilled labor (6.25%), and this formwork system built all types of labor use manpower personal status (85.42%). See Appendix-B for information on how to assemble and disassemble Kumkang aluminum formwork without the need for skilled labor. Kumkang Kind (2016) asserts that because of the intricate design offered to ensure the client's success must be attained, Kumkang formwork does not require skilled labor. However, most of the time, modern formwork systems are regarded as challenging and appear to be built exclusively by skilled laborers.

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 labours 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.

Initially, vertical structures are constructed, followed by a wall and a staircase beside it. Following the installation of wall panels and a staircase, an opening area such as a window or door is installed. Next, horizontal structural members are installed, beginning with a beam cap and a slab corner and prop support, followed by a slap panel and prop support for a slab panel. Concrete was poured using a concrete pump, and horizontal members were cast after the vertical (shear wall) members were cast. After the structural member erection work is finished, the concrete pump is ready to use. The casting process takes one day, so one floor of concrete work takes one day to finish. All structural members did not strip within the stripping formwork.

After the concrete is cast, it takes 16 hours on average to complete the first vertical structure, shear wall, and stair. After 72 hours, the horizontal members slab, beams, and slab corners are completed; however, the prop remains under two levels of floor construction, which takes 5–10 days. According to EBCS-2 (1995), stripping vertical formworks should take 18 hours, and soffit formwork to slab and beam, as well as prop supporting, should take 7–14 days. However, shorter durations than suggested might be allowed when using sliding or climbing formwork.

As ACI recommendation the wall and column cold strip within 12 hours and beam 3 to 4 days and for slab 4–21 days, depending on the load distribution and span length. Additionally, according to BaTCoDA (1991), vertical formwork columns, walls, and beams could be stripped in 16 hours, soffit slabs in 21 days, and fixtures for both slabs and beams in 14 days. The British standard recommends 12 hours for vertical columns, walls, and large beams, 4 days for soffit slabs, 10 days for soffit beam and prop slab support, and 14 days for prop beams. Kumkang formwork thus fully satisfies their recommendation, and although it has a brief stripping time, it is a modern formwork. systems, as previously mentioned, the suggested days could be shortened. Regarding the joint system of the formwork, the respondent stated that they were satisfied with the jointing system and that no alternative formwork system was recommended for the current construction sector. They employed scheduled maintenance to maintain the formwork's 250–300 repetitions (reusability). There is no framework in place to allow authorized parties to use Kumkang formwork and other formwork systems. Instead of providing certified recognition to this day, they only give construction companies a platform to introduce themselves and gain recognition. The MoUDC, the authorized party, feels that the contractor shouldn't count on government assistance for everything. With a plan to address the industrial building system (IBS) and building information modeling (BIM) in the construction industry, the government has a plan to raise awareness, distribute the benefits, and encourage and intensify the use of such formwork materials over the next five years. After the plan is put into action, these systems should be used for almost 50% of construction.

4.4 Performance of Kumkang Aluminum Formwork

4.4.1. Performance impacts of Kumkang Aluminum Formwork on Construction Time constrain

The floor cycle's quicker construction time helps to increase the likelihood that the project will be completed on schedule or earlier. The cost of a delayed project can be reduced by expediting the formwork-related construction activities. Additionally, there is a financial benefit due to the time value of money when construction takes less time. For formworks to be considered good, they must meet the requirement of having a shorter construction time for finishing the floor cycle. A challenge we face in construction is finishing the project on schedule. The formwork system used in construction determines the faster floor cycle.

In this section, case studies of three projects were used to compare the time required for surface finish, the time required to complete a one-floor cycle, and the time required to erect and strip formwork on each member. Kumkang aluminum formwork and two traditional wooden formwork were taken. Based on labor productivity, the amount of time required to erect each formwork member in a single crew (one carpenter with two daily laborers) and determine which one had a quick erection time were calculated using the same area (100 m2) for all the projects taken in order to compute equally. The results are shown in Table 4.8.

Table 18 erection time of formwork (on 2017)

Time taken to:	Projects		
	Project A (kumkang aluminum)	Project B (conventional wooden)	Project C (conventional wooden)
Time for erecting a column	-	0.6 m2 /hr. 100 m2=167 hrs. 21 days	0.7 m2 /hr. 100m2 =143hrs 18days
Time for erecting beam	-	0.6 m2 /hr. 100 m2=167 hrs. 21 days	0.51 m2 /hr. 100 m2 =196 hrs. 24 days
Time for erecting shear wall	4.4 m2 /hr. 100 m2 =23 hrs. 3 days	0.75 m2 /hr. 100 m2=133 hrs. 17 days	0.83m2 /hr. 100 m2 =120 hrs. 15 days
Time for erecting stair	1.4 m2 /hr. 100m2=71 hrs. 9 days	0.46 m2 /hr. 100 m2=217 hrs. 27 days	0.52 m2 /hr. 100m2=192 hrs. 24 days
Time for erecting floor slab	5.21 m2 /hr. 100 m2=19 hrs. 2 days	0.67 m2 /hr. 100 m2=149 hrs. 19 days	0.58 m2 /hr. 100 m2=172 hrs. 21 days

Because Kumkang aluminum formwork technologies are wall slab and stair systems rather than frame systems, Table 4.8 demonstrates that the formwork is only applicable to wall, slab, and stair members. The middle panels and the end beam are submerged with the wall and slab members; they do not function as structural elements. The load is transferred directly from the slab to the wall in Gerji Village because the entire wall member is a shear wall. Thus, the structural members of the wall, slab, and stairs were compared in terms of time. Let's examine each in turn. Using Kumkang formwork saved 12–14 days for the construction of the wall for both wooden projects, 15–17 days for the stair construction, and 17–19 days for the floor slab construction. Compared to wooden formwork, the Kumkang formwork was constructed in three times less time. Consequently, compared to wooden formwork, Kumkang formwork required less time to erect. This speeds up the construction floor cycle and the project as a whole. Since each project has a different dimension of the structure member, the same dimension must be taken for all projects. This assumption was also used for formwork stripping time in order to improve comparisons between the formwork systems. Table 4.9 shows the structural members' stripping time.

Table 19. Stripping time of formwork (on 2017)

Time taken to:	Projects		
	Project A (kumkang aluminum)	Project B (conventional wooden)	Project C (conventional wooden)
Time for stripping column	-	1.5 m2 /hr. 100m2=67 hrs. 8 days	2.5 m2 /hr. 100m2=40 hrs. 5 days
Time for stripping beam	-	2.7 m2 /hr. 100 m2 =37 hrs. 5 days	2.02 m2 /hr. 100 m2 =49 hrs. 6 days
Time for stripping shear walL	7.94 m2 /hr. 100 m2 =13 hrs. 1 and half days	2.66 m2 /hr. 100 m2 =38 hrs. 5 days	2.86 m2 /hr. 100 m2 =35 hrs. 4 days
Time for stripping stair	2.7 m2 /hr. 100m2=8 hrs. 5 days	1.84 m2 /hr. 100m2=11 hrs. 7 days	1.87 m2 /hr. 100m2=53 hrs. 7 days
Time for stripping slab	9.42 m2 /hr. 100 m2=11 hrs. 1 day	3.5 m2 /hr. 100 m2=29 4 days	3.45 m2 /hr. 100 m2=29 hrs. 4 days

As can be seen from Table 4.9, Kumkang aluminum formwork again had a quicker stripping time than wooden formworks. Those formworks differed in that the slab took two and a half to three and a half days, the stair took two days, and the wall took three days. The use of Kumkang aluminum formwork resulted in time savings. Similar to the previous example, Kumkang aluminum formwork doubles the construction floor cycle compared to traditional wooden formwork. Table 4.10 displays the anticipated and actual time needed to finish one-story formwork construction in projects utilizing traditional wood and kumkang aluminum.

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Table 20. Time to complete one-floor formwork construction (on 2017)

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

It takes seven days for Kumkang to construct one floor formwork, including formwork strips, whereas it takes twenty-one to thirty-one days for conventional formwork to be erected alone. This suggests that Kumkang aluminum formwork will take three to four floors to construct. Floor slab formwork construction under productivity rate in Table 4.11 was used to compare the detail differences in construction time between Kumkang aluminum formwork and conventional wooden formwork in order to calculate the time to be minimized when using the Kumkang aluminum formwork system. by taking into account the 100 m2 slab area for both Kumkang and conventional formwork.

Table 21. Time comparison on slab formwork construction (on 2017)

Time taken to:	Formwork systems	
	Kumkang aluminum formwork (100m2)	Conventional wooden formwork (100m2)
Erecting time	5.21 m2 /hr. 100 m2= 19 hrs. (3days)	0.58 m2 /hr. 100 m2= 172 hrs. (21 days)
Stripping time	5.21 m2 /hr. 100 m2= 19 hrs. (3days)	3.45 m2 /hr. 100 m2=29 hrs. (4 days)
Waiting time after concrete casting to stripping formwork	3 days	21 days
one-floor slab formwork construction	6 days	46 days

According to Table 4.11, there is a 40-day time difference between the two forms. Using the wooden formwork system, a one-floor slab had taken 40 extra days to construct. This indicates that utilizing Kumkang aluminum formwork in floor slab construction reduces construction time by roughly 87%. By finishing the project on schedule or ahead of schedule, Kumkang formwork is preventing delays. In light of time values of money, this helps to minimize inflation and maximize construction profit. Additional time was required for surface treatments, such as plastering. As this study has shown, plastering and chiseling are not necessary in the case of Kumkang aluminum formwork. The Kumkang aluminum formwork preserves the members' intended shape and a smooth surface finish. As previously mentioned, we can apply finishing material directly using this and other surface measurement qualities. This eliminates the need for extra time for plastering and chiseling to create a smooth and linear surface because the work is done in parallel with the gypsum finish. It is evident that the traditional wooden formwork required more time for plastering and chiseling every floor cycle, averaging five days for the Kebena project and four days for the Misrakatekalay project. 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 Misrakatekalay 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.

The aforementioned findings and discussion demonstrate that the Kumkang aluminum formwork outperformed the traditional wooden formwork in every area of time measurement and requirement, with significant improvements. For the time being, this formwork's performance in the Ethiopian construction industry was superior to that of more recent formwork systems.

4.4.2 Performanceimpact of Kumkang Aluminum formwork on Quality of Finished Concrete

According to several studies in chapter two, one of the good formwork requirements in the construction industry is the quality of the finished concrete. The final appearance of the concrete is determined by two main factors. The first is the formwork material's quality, and the second is concrete-related factors that affect the formwork. The formwork systems in relation to the final output of the concrete surface and its quality are measured using a variety of standard metrics for finished concrete quality. Respondents were asked to choose the best formwork system in this section based on the measurement of the finished concrete quality.

. The following Figure 4.4 contains the response of respondents in formwork systems on common measurement of quality of finished concrete.

Formwork quality consideration

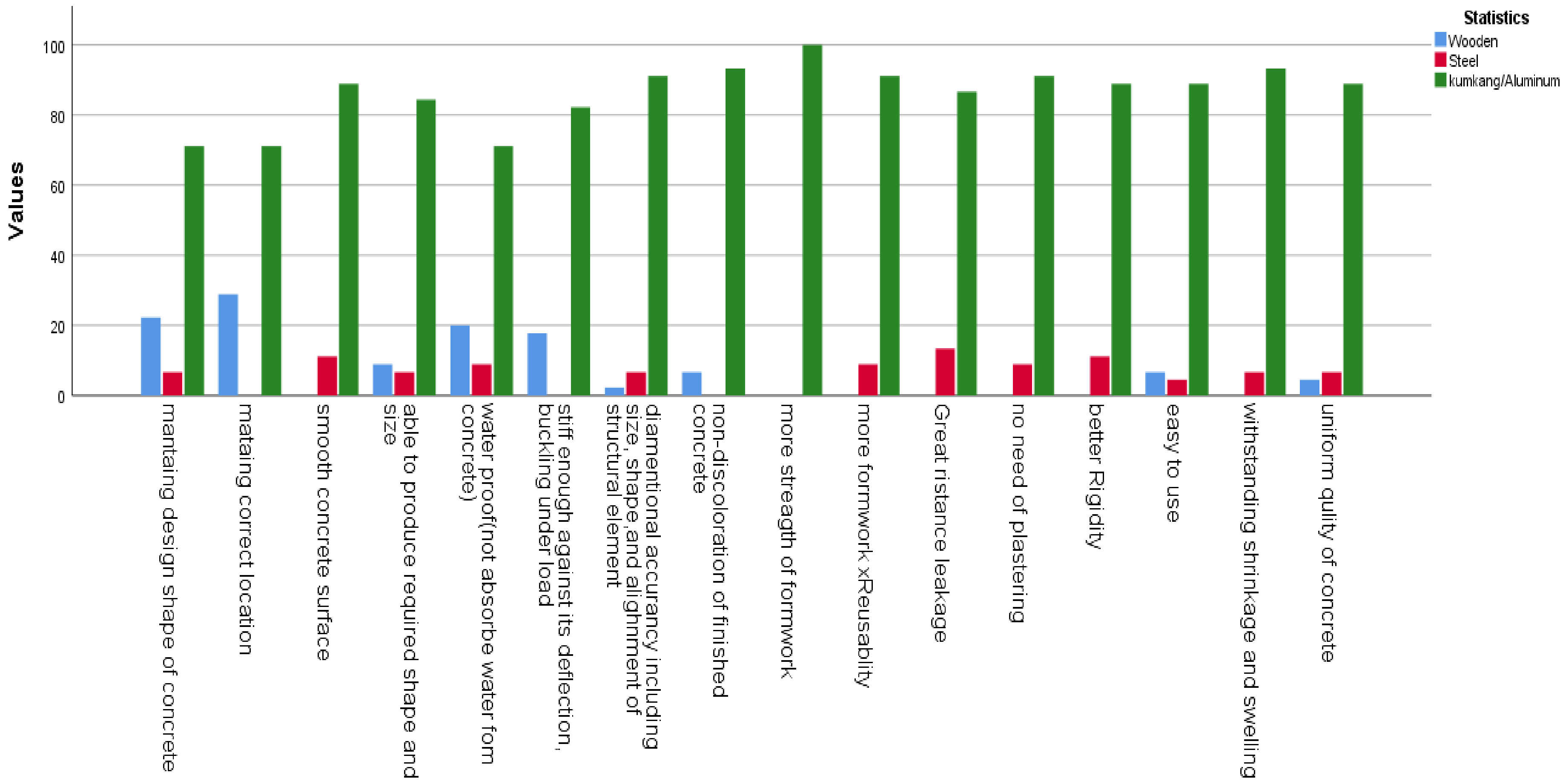


Figure 23. Formwork quality consideration and formwork systems (on 2017)

According to the survey results (Figure 4.4), Kumkang aluminum formwork performed better than steel (6.667%) and concrete (71.8%) in maintaining the concrete's intended shape, followed by Kumkang and then wooden formwork (22.22%). This is because the kumkang formwork was created with the building's shape and design in mind; no panels were cut or drilled in order to erect the formwork. Fewer respondents (28.89%) thought that traditional (wooden) formwork was good for maintaining the proper location. However, the majority of respondents (71.11%) thought Kumkang aluminum formwork was superior. Regarding a smooth concrete surface, the respondent is very satisfied with Kumkang aluminum formwork (88.89%), but the same respondent (11.11%) thought steel formwork was superior to wooden formwork. Steel formwork (6.667%) and wooden (8.889%) respondents are better at producing the necessary shape and surface, and 84.44% of respondents are able to do so. The waterproofing of aluminum formwork, also known as Kumkang formwork (71.11%), is superior to that of steel and wood formwork (20% and 8.889%, respectively), as it does not absorb water from concrete. buckling under load and being sufficiently rigid to prevent deflection (82.22%) respondents The wooden formwork (17.78%) of the respondents protects against water absorption, while Kumkang aluminum formwork is of good quality. According to the respondents' answers to the above graphs, dimensional accuracy includes the size, shape, and alignment of structural elements (91.11%) of the Kumkang aluminum formwork system, as well as the types of wooden formwork (2.222%) and steel formwork (6.667%).The Kumkang aluminum formwork was more advanced than the others, with greater strength (100%) and reusability (91.11%). In the aforementioned aspect, steel formwork (8.889%) outperforms kumkang formwork. In comparison to steel and kumkang, wooden formwork produced concrete that was of lower quality in all of the aforementioned aspects. According to the majority of respondent responses (86.67%, 91.11%, 88.89%, 88.89%, 93.33%, and 88.89% respectively), the other quality metrics that should be taken into account were excellent leakage resistance, no need for plastering, better rigidity, ease of use, and the ability of concrete to withstand shrinkage and swelling. Kumkang aluminum formwork is superior in the aforementioned aspects, and steel and finished concrete are superior in the aforementioned aspects by 13.33%, 8.889%, and 11.11%, respectively. 6.667%, 6.667%, and 4.44%, in that order. Few respondents (6.67% and 4.447%, respectively) agreed that wooden formwork had better rigidity and was easier to use, but they disagreed that it meets the quality of finished concrete in some measurements, such as excellent leakage resistance, no need for plastering, withstanding shrinkage and swelling, and uniform quality of concrete. Compared to steel formwork systems, wooden formwork types are easier to use (see Appendix-C).

The Kumkang Aluminum formwork was generally superior to the steel and wooden formworks based on the results of all quality measurements of the finished concrete. In light of the aforementioned quality measurement criteria, the Kumkang formwork performed better in terms of the final concrete's quality. The elements that affect the formwork system were an additional consideration. This impacts not only the formwork material but also the final concrete quality. According to a variety of literature, formwork is impacted by concrete placement and compaction, vibration, and form release agent. The researcher attempts to evaluate the factors influencing formwork and concrete quality by using case studies. to learn about their practices regarding these factors and how they affect the concrete surface on both Kumkang aluminum formwork and wooden formwork sites.

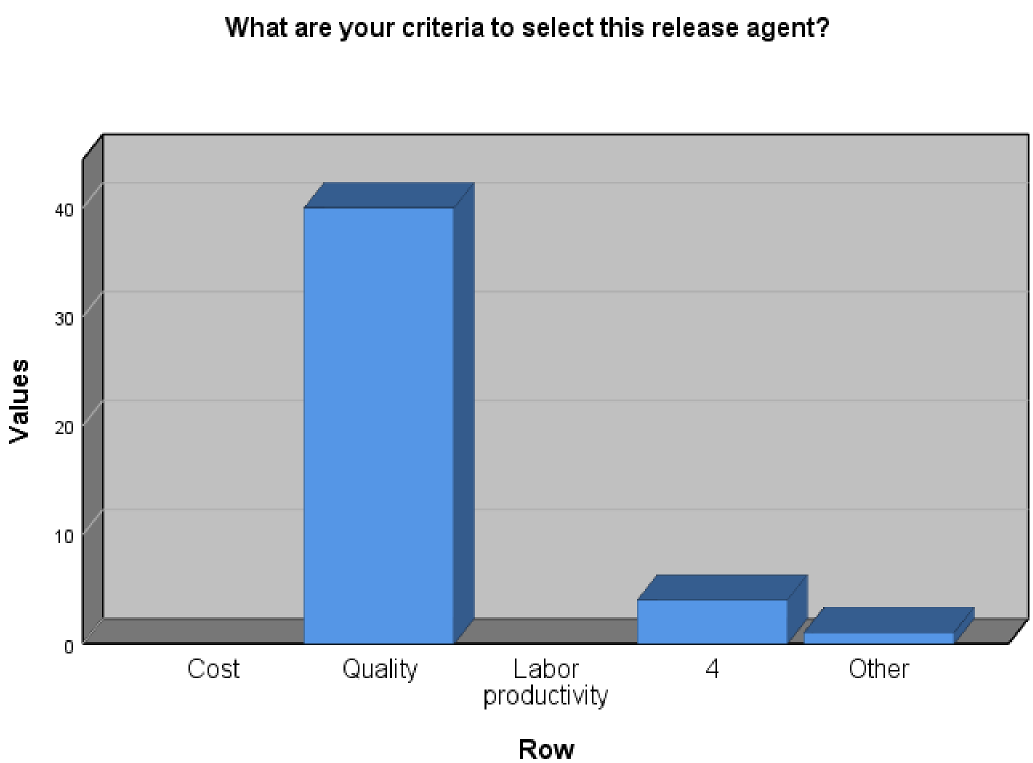


Figure 24. Select released agent criteria (on 2017)

The factors which have an impact on formwork and their practice on such factors on those sites are stated in Table 4.12.

Table 22. Factors related to concrete (on 2017)

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

The quality of the formed concrete surface is greatly influenced by the formwork material and release agent (Megid & Khayat, 2007). According to Tarekegn (2010), a good release agent should also be easy to use, provide a clean strike without damaging the concrete face or form, help create a flawless concrete surface, have no negative effects on the form or concrete, help maximize form reuse, not interfere with the adhesion or penetration of any subsequent finish applied to the formed concrete surface, be inoffensive to the operator in terms of smell or skin staining, and be appropriate for use in the expected weather conditions. All projects used form oil, which is advised to obtain a good surface finish and to preserve the surface of formwork material during removal. Most construction use burnt oil as mold oil, which significantly affected the quality of finished concrete by causing discoloration and increasing the cost of additional treatment in this study. In addition to applying form oil, they were properly applied to formwork panels; a good concrete surface depends on formwork being applied correctly. The rate at which fresh concrete is placed is another factor. More impact pressure is likely to be placed on the formwork system at a faster rate, which could lead to formwork failure and potential fatalities, property damage, financial hardships, and longer construction times. ACI 347 (2014) states that the placement rate for walls—which are defined as vertical elements with at least one plan dimension greater than 2 m—could range from 2.1 to 4.5 m/h. Table 4.12 demonstrates that those three projects were in compliance with ACI's recommendations and used appropriate placement techniques to prevent formwork failure brought on by excessive lateral pressure. Concrete is deposited into the forms as near to the final location as is practical without causing segregation. Reducing free fall between the pouring and discharge portions to less than 1.5 meters is a good rule of thumb (Best Practices Guidelines for Concrete Construction, 2005). Concrete has little effect on formwork when it is placed into small-height forms.

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. Because this would put additional strain on the other ties and load the forms unevenly, care should be taken to avoid breaking or damaging any of the ties while vibrating. Form vibrators that use external vibration raise the loads on formwork systems even further and result in changes in lateral pressures. In turn, the materials used to form the concrete have an impact on how fresh concrete vibrates. All of the projects in this instance used internal vibrators, which are marginally better than external vibrations when it comes to the impact of formwork. According to the case studies and projects involving these factors, the factors had less of an effect on the final concrete's quality. Therefore, under their practice, no factor affected the concrete's surface other than the material itself. Accordingly, the formwork system quality measurement factors were differentiated in this study, indicating which system produced finished concrete of good quality and which Kumkang aluminum formwork had superior formwork material. Additionally, Gerji Modern Village had good site practices that affected the formwork by creating lateral pressure, and the formwork itself is more resilient to the lateral pressure load than wooden formwork. The Kumkang aluminum formwork outperformed steel and wooden formworks in terms of quality performance, as determined by both surface quality measurements and factors that influence surface finish rather than formwork material.

4.3 Performance of Kumkang Aluminum Formwork on Cost

Reduced formwork material and construction costs are one of the selection criteria for formwork. According to numerous studies, the cost of formwork accounts for about one-fourth of the total cost of materials; this expense can be reduced with careful formwork selection and design.

Labor, material, equipment, number of reusability, and surface finish costs after formwork

The cost of the formwork is calculated with stripping taken into consideration. Kumkang is more reusable than wooden formwork, despite requiring a higher initial investment. Rather than having a high life cycle cost, wooden formwork had a low initial investment cost. As we can see from the above, the majority of respondents stated that they do not use modern formwork systems because of their high initial investment costs, even though the life cycle costs of formwork are higher than these systems' initial costs. While the wooden formwork is reused three to four times, the Kumkang aluminum formwork is reused 250 to 300 times. Increasing the wooden formwork's reusability lowers both the formworks and the finished concrete surface quality. This section included the cost of labor, materials, equipment, the number of reusable parts, and the cost of surface finishing after the formwork strip. For case studies, a minimum of 250 Kumkang aluminum formwork reuses and three conventional wooden formwork reuses were used. Formwork unit cost, which includes material, labor, and equipment costs, was the subject of case studies for both traditional wooden used projects and Kumkang aluminum formwork used projects. The unit costs of formwork material comparisons between wooden and Kumkang formwork are shown in the following tables. The formwork unit cost for each of the two projects is shown in Tables 4.8 and 4.9.

Table 23. Formwork unit cost in project A (Kumkang aluminum formwork)

	ANALYSIS SHEET FOR KUMKANG ALUMINUM FORMWORK INSTALLATION COSTS												
									LABOR HOURLY OUTPUT:	3.67 m 2/ hr			
PROJECT: KUMKANG FORMWORK INSTALLATION									RESULT:	256.11 Birr/m2			
WORK ITEM: Kumkang Aluminum Formwork Installation													
TOTAL QUANTITY OF WORK ITEM: 1.00 m2													
materail cos (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of materal	Unit	Qut *	Rate	cost per unit	Labor by Trade	No.	UF	Indexed ** hourly wage	Hourly wage	Type of Equipment	No	Hourly Rental	Hourly Rental
Panels with accessories	M 2	1	171	170.54	Forman(technicians)	1	0.25	31.25	7.81	Tools	1	1	1
Mold Oil	Lit	0.05	120	5.4	Carpenter	1	1	31.25	31.25				
					Daily Laborer	1	1	16.25	16.25				
					Kumkang Coo	1	1	50	50				
Total (1:01)				175.94	Total (1:02)				105.31	Total (1:03)			1.00
A =Materal unit cost	175.94	birr/ M2			B =Labor cost	28.68	Birr/m2			C =Equipment cost	0.27	Birr/m2	
					Total of (1:02)					Total of (1:03)			
					Hourly Output					Hourly Output			
					Direct Cost of Work Item = A+B+C =					204.89	Birr/m2		
					Over head cost :				10%	20.489			
					Profit Cost:				15%	30.7335			
					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 4.8, project A which is Gerji site have a unit cost of formwork 352.81 Birr/m2 .													

Table 24. Formwork unit cost in project B 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 QUANTIT	1 m 2					RESULT:	390.35 Birr/m 2							
materail cos (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)				
Type of materal	Unit	Qut *	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	0.5	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.Carpenter	1	1	28.75	28.75				0	
Nails	Kg	0.3	60.00	18.00	D/L	1	1	25	25				0	
Mould Oil	Lit	0.045	25.00	1.13					0				0	
				0.00					0				0	
				0.00					0				0	
Total (1:01)				205.23	Total (1:02)				106.05	Total (1:03)			1	
A =Materal unit cos	205.23	birr/ m2			B =Labor cost	106.1	birr/ m2		C =Equipment cost		1	birr/ m2		
					Total of (1:02)					Total of (1:03)				
					Direct Cost of Work Item = A+B+C =					312.28				
					Over head cost :				10%	31.228				
					Profit Cost:				15%	46.842				
					Total unit cost:					390.35				

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 B which is Misrak ateklay site have a unit cost of formwork 390.35 Birr/m2 .

Table 25.Formwork unit cost in project C conventional (wooden) formwork

		ANALYSIS SHEET FOR DIRECT & INDIRECT COSTS											
PROJECT	FORM WORKS							LABOR DAILY OUTPUT:	0.6 m 2 / hr.				
WORK ITEM: (5.1	Form work(for all except slab)							EQUIPMENT DAILY OUT PUT:	0.75 m 2 / hr.				
TOTAL QUANTITY OF WORK ITEM:	1 m 2					RESULT:	364.43 Birr/m 2						
	materail cos (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)		
Type of materal	Unit	Qut *	Rate	cost per unit	Labor by Trade	No.	UF	Indexed ** hourly wage	Hourly wage	Type of Equipment	No	Hourly Rental	Ho Re
wooden formwork	M2	1.05	122.00	128.10	Foreman	1	0.25	56.25	14.06	tools	2	0.5	
40 x 50 cm. battens	M	0.8	35.00	32.00	Carpenter	1	1	37.5	37.5				
Eucalyptus	M	1	27.00	26.00	Ass.Carpenter	1	1	18.75	18.75				
Nails	Kg	0.3	55.00	18.00	D/L	1	1	15	15				
Mould Oil	Lit	0.05	17.69	1.13					0				
		Total (1:01)		205.23	Total (1:02)				85.31		Total (1:03)		
A =Materal unit cost	205.23	birr/ m2			B =Labor cost	85.31	birr/ m2		C =Equipment cost		1	birr/ m2	
					Total of (1:02)					Total of (1:03)			
					Direct Cost of Work Item = A+B+C =					291.54			
					Over head cost :				10%	29.154			
					Profit Cost:				15%	43.731			
					Total unit cost:					364.43			

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 4.10, project C which is kebena site have a unit cost of formwork 364.43 Birr/m2 .

Since the Kumkang formwork is currently used for the superstructure portion, the unit cost of the formwork was taken on the superstructure. This allowed the cost of the formwork to be compared between each project. As a result, the formwork unit cost for each project was compiled below, and Appendix-C, the Addis Ababa Construction Bureau standards, was consulted for comparison. Each formwork's unit cost is shown in Figure 4.3.

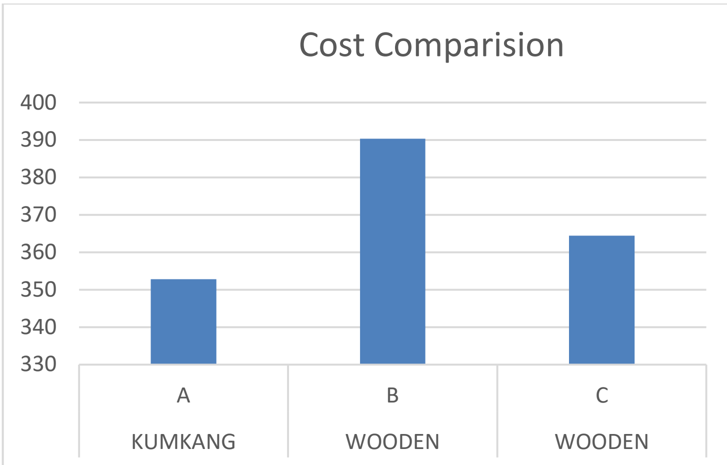


Figure 25. A formwork cost summery graph (on 2017)

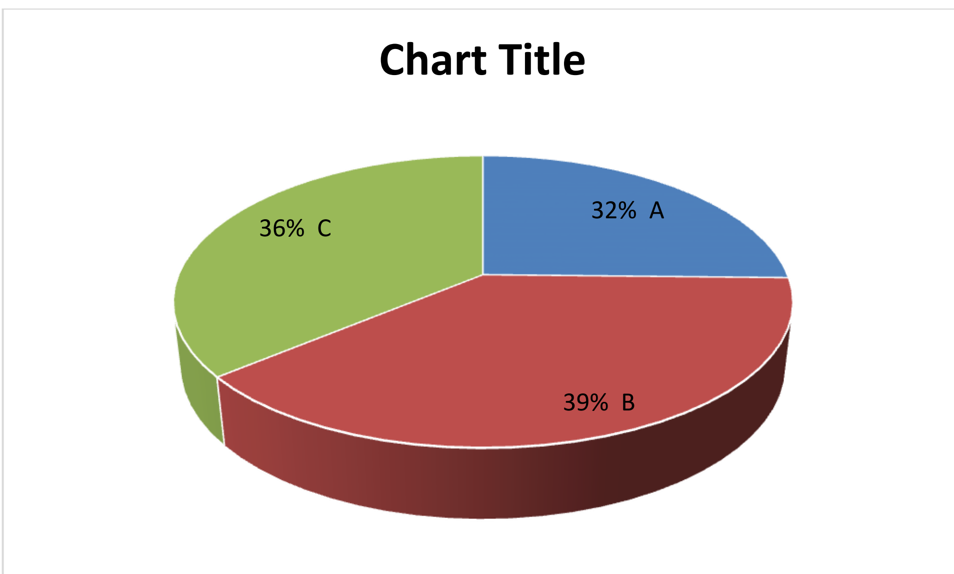


Figure 26. B formwork cost graph (on 2017)

According to Figure 4.4, the Kumkang aluminum formwork project costs 256.11birr/m2, or 32%; the wooden formwork project costs 390.35, or 39%; and the other wooden formwork project costs C364.43, or 36%. When comparing the two projects, Kumkang (project A) uses less formwork

than wooden project B, saving nearly 134 Birr per square meter and lowering the formwork cost in construction by 42.29%. Kumkang (project A) uses less formwork than wooden project C, saving nearly 104 Birr per square meter and 52% of the formwork cost in Using this formwork reduces construction as compared to both projects with the Addis Ababa Construction Bureau. Also, the Kumkang formwork made more progress when we looked at costs separately, such as material, labor, and equipment. The Kumkang formwork has a lower material cost than others because of its degree of reusability. The cost of additional materials to support and construct the formwork panels was decreased by using Kumkang aluminum formwork material, which comes with accessories, prop head, and bracket (working platform and scaffolding). Compared to other labor costs, the labor output was high-quality and more productive. Because of this, the Kumkang aluminum formwork was less expensive than others.
A higher output value lowers the cost of the equipment, and the more output, the lower the cost. What transpired in Kumkang formwork was this. Examine the formwork construction unit cost for G+ 10 apartments, which have a 10000m2 formwork construction, to see how much money can be saved by using Kumkang aluminum formwork. The total cost required to finish the formwork construction of this apartment is 3,640,000.00 Birr, with the average formwork unit cost for traditional wooden formwork being 364.43 Birr/m2. To finish this apartment and the sky villa, 3,528,200.00 Birr is required for Kumkang aluminum formwork. As can be seen from the above, Kumkang aluminum formwork can reduce the formwork cost by 104,000.00 Birr.This formwork can reduce the cost by roughly 52%. Salvage value and other costs are not included in this cost, which is only the unit cost. These expenses add up to more than this. After formwork is stripped, the surface finish has a cost. The cost of this extra treatment varies between Kumkang aluminum formwork and traditional wooden formwork. Three projects were used as case studies, one of which was the Geri village, which makes use of Kumkang aluminum formwork. In order to smooth the surface and accept the final finishing material in the case of gerji, plastering is done before applying the final painting. In our instance, the Misrak project used two coats of plastering (see Appendix C) and the Kebena project applied three coats.

The following Table 4.11 shows the summary cost for plastering in conventional wooden formwork used projects.

Table 26. Plastering unit cost (on 2017)

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/m2	129.23 Birr/m2	175.88 Birr/m2	174.13 Birr/m2
Misrak atekalay mixed use apartment	140.63 Birr/m2	137.33 Birr/m2	170.28 Birr/m2	148.33 Birr/m2

Table 4.11 demonstrates that the cost of a plastering unit is not negligible; rather, it is nearly half of the cost of a formwork unit. Consider, for example, the cost of plastering a 100 m2 soffit ceiling in both projects in order to prepare gypsum for use as a final finishing material. If 100 m2 of soffit celling is to be plastered, the cost of the Kebena project is 175.88 Birr for 1 m2. Table 4.11 demonstrates that the cost of a plastering unit is not negligible; rather, it is nearly half of the cost of a formwork unit. For example, we will consider the cost of plastering a 100 m2 soffit ceiling in both projects in order to prepare the gypsum as But before using gypsum, there is more treatment. This formwork surface required some treatment in order to receive the gypsum paint because the final product was extremely smooth. The cost of additional treatment in the Gerji project is displayed in Table 4.12 below.

Table 27 Unit cost of additional treatment (on 2017)

Additional treatment		Unit cost/m2
Material	Magic bond	10 Birr/m2
	White cement	8 Birr/m2
Total cost		18 Birr/m2

Assuming the same thing, 100 m2 of Soffit ceiling will be ready for gypsum as the last finishing material. Table 4.11 indicates that the cost is 18 Birr/m2. Therefore, the cost of 100m2 Soffit ceiling is 1800 Birr. The Kebena and Misrak atekalay projects have additional costs of 90% and 89%, respectively, when compared to the conventional wooden cost results above. As a result, the

Kumkang aluminum formwork saves approximately 155.08 Birr/m2, or 89%, in addition to additional surface finish costs. The interviewee's response regarding the cost of Kumkang formwork and its feasibility in our nation's economic capacity was the Kumkang Formwork is crucial for Ethiopia because it lowers the additional expenses that the building sector wastes due to project delays (time value of money). By reducing life cycle costs and the inflated economic benefit for construction companies in later years, the seemingly high initial investment cost can be offset by periodic use of the formwork. Because it has been used a lot, its rate of return is very quick. Kumkang Aluminum formwork also lowers the cost of chiseling and plastering. For the reasons mentioned above, it is cost-effective. This demonstrates that the number of repetitions provides greater economic value for the future, particularly for housing projects, but it should also be present for high-rise buildings, mass construction, and repetitive work. For small projects, it is not cost-effective. One formwork must have lower formwork-related costs in order to have good cost performance. As a result, the Kumkang aluminum formwork performed better financially by lowering the formwork construction costs.

4.4.4 Performance of Kumkang Aluminum Formwork on Safety

According to the literature in chapter two, one factor in formwork material is creating a safer construction environment. Since safety is one of the requirements for quality formwork, safer formwork construction improves formwork performance in this area. The formwork construction system is safer, according to various standard measurements. Respondents were asked to rate and choose the formwork system and its impact on the safety and health aspects of formwork construction in this section. According to OSHA, almost two out of every three construction workers regularly use scaffolding for at least some of their work.Even though they might not consider scaffolds to be hazardous, every year about 4,500 workers are hurt in incidents involving scaffolds, and up to 50 people are killed. Thus, sturdy scaffolding improves construction safety. The kind of external scaffolding used on the formwork construction site is depicted in the following figure. According to Figure 4.5, only 68.75% of respondents had scaffolding attached to the wall, while 31.25% of respondents said they had different types of scaffolding. The wall that the respondent provides is from an ongoing project and an Ovid group delivery. Kumkang Formwork is designed with man height and workspace in mind, and it has its own external bracket that is attached to the wall. Furthermore, the brackets that are mounted on the walls of each floor do not start at the ground. This lessens the risk associated with independent scaffolding, such as stability issues that arise when the structure rises and falls from a height. In traditional formworks, the bracket and working platform are typically constructed with scaffolding that is anchored to the ground and is not attached to the wall. When the building's height increases, this becomes too challenging.

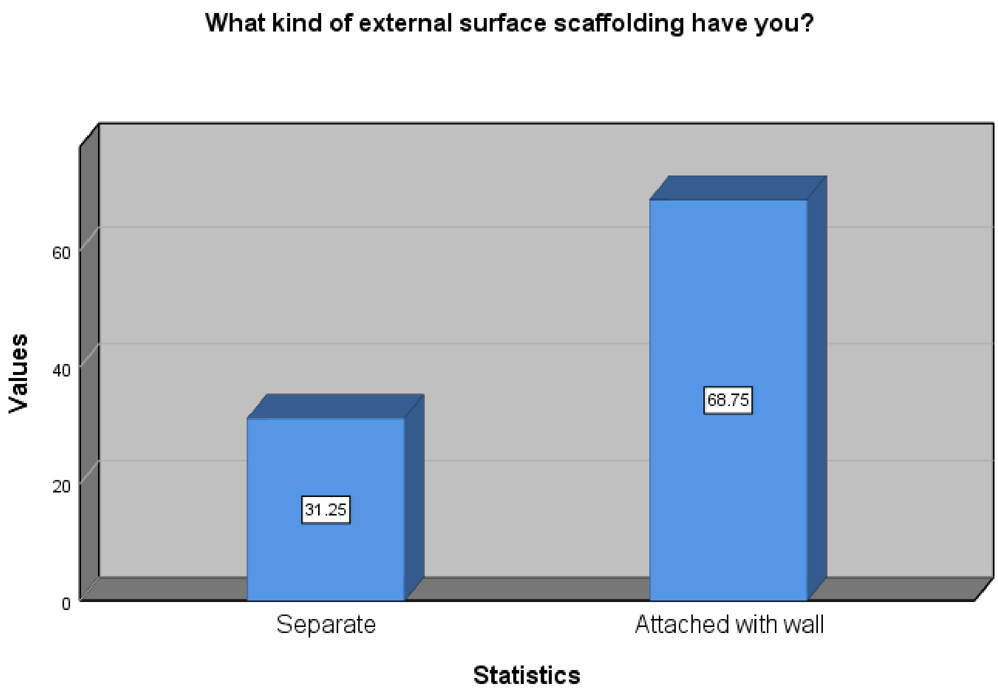


Figure 27. Kind of external scaffolding (on 2017)

The interview's outcome demonstrates that the kumkang aluminum formwork is robust enough to support live loads (construction traffic and any required equipment) in addition to the full load and side pressures from recently laid concrete. Additionally, because of its excellent joint system and the flatties that hold the formwork through both internal faces, it has been more resistant to deflection than steel and wood formwork. By using formwork panels and a prop-supporting design, the Kumkang formwork also reduces collapse during formwork construction. Additionally, panels are connected by wadges and pins that are made to fit into the designated holes on panels. This feature provides good stability against collapse caused by inadequate bracing. The aforementioned requirements are crucial for guaranteeing the structure's safety and the workers' protection while formwork is being constructed, and the Kumkang formwork excelled in each area. Health and safety risk factors are another metric that characterizes a safer formwork system during construction. The health and safety risk factors associated with formwork construction are described in Table 4.14 and Figure 4.6, along with the frequency of occurrence of each on various formwork systems. These aids in demonstrating which formwork systems are safer and less hazardous during construction.

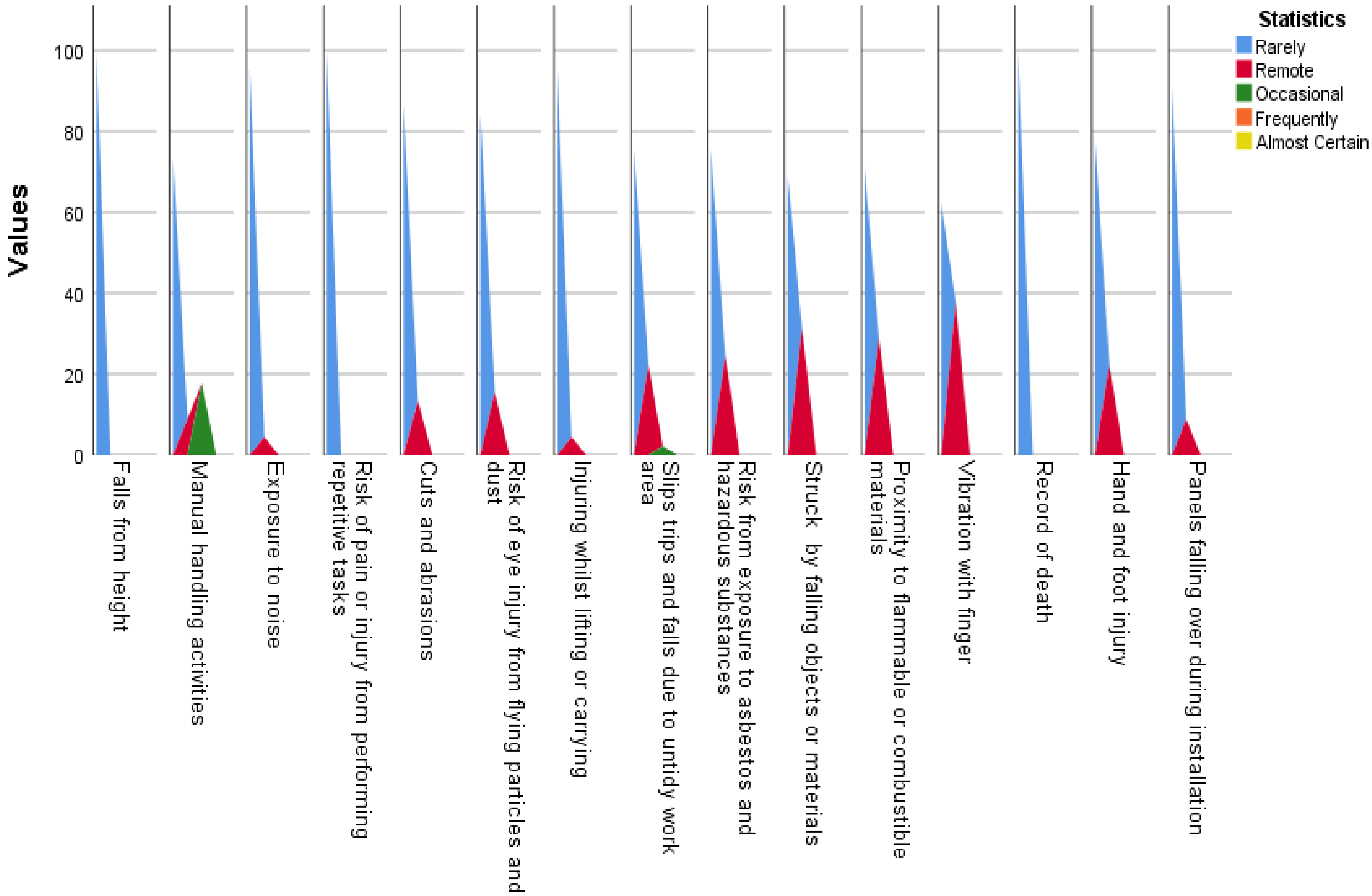


Figure 28. Kumkang aluminum formwork safety factor (on 2017)

Table 28. Formwork systems to health and safety(on 2017)

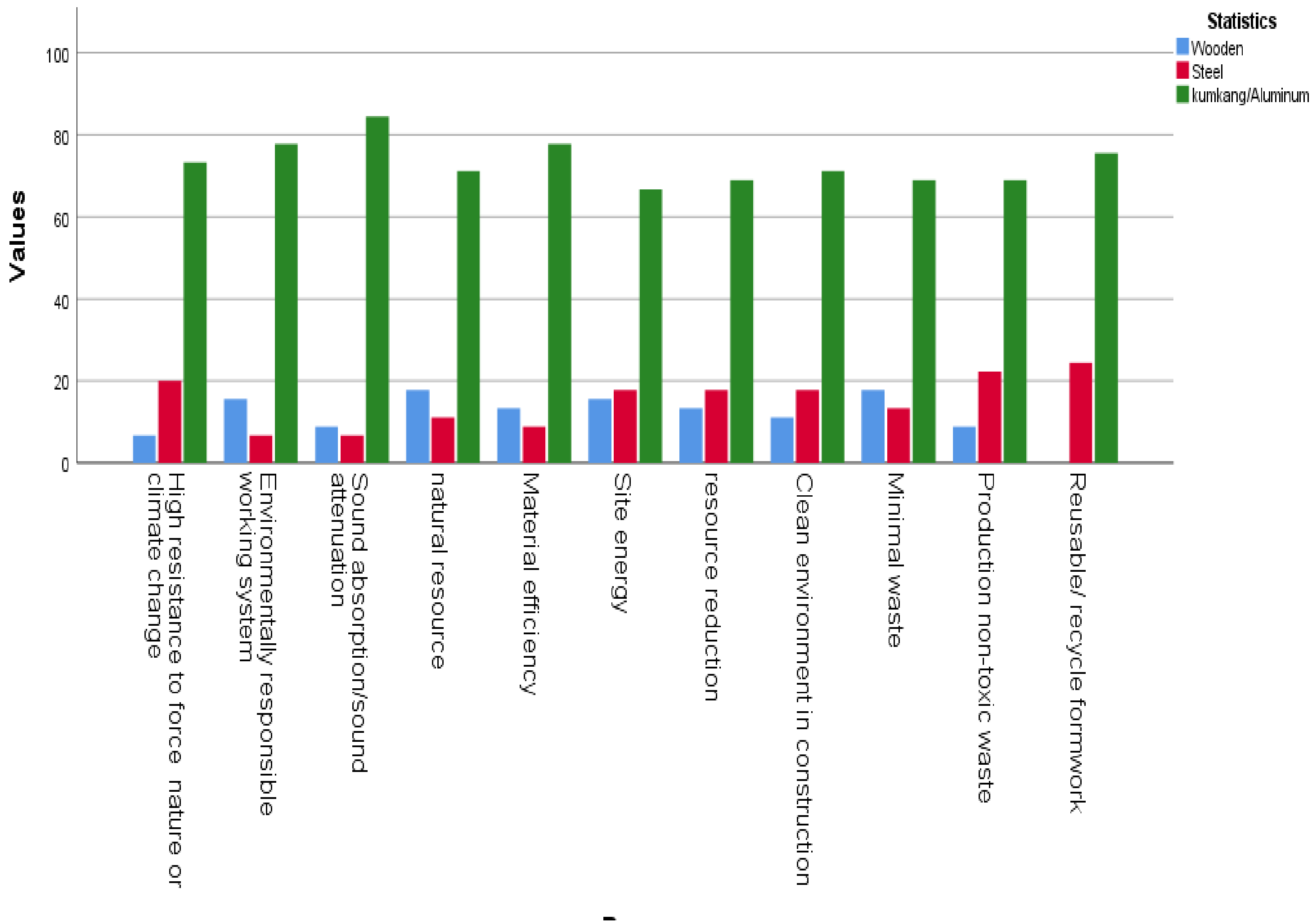
Health and safety factors related to formwork	Kumkang formwork		Conventional (wooden) formwork	
	Average index (Mean)	Frequency of Occurrence Rating	Average index (Mean)	Frequency of Occurrence Rating
Falls from height	1.16	rarely	2.5217	Occasionally
Manual handling activities	1.27	rarely remote occasional	3.4783	Occasionally
Exposure to noise	1.56	rarely remote	3.4783	Occasionally
Risk of pain or injury from performing repetitive tasks	1.56	rarely	2.0435	Occasionally
Cuts and abrasions	1.51	rarely remote	3.2826	Remote
Risk of eye injury from flying particles and dust	1.6	rarely remote	3.1522	Occasionally
Injuring whilst lifting or carrying	1.24	rarely remote	3.1087	Occasionally
Slips trips and falls due to untidy work area	1.51	rarely remote occasional	2.8261	Occasionally
Risk from exposure to asbestos and hazardous substances	1.67	rarely remote	1.8043	Occasionally
Struck by falling objects or materials	1.44	rarely occasional	2.5217	Remote
Proximity to flammable or combustible materials	1.58	rarely remote	2.3478	Occasionally
Vibration with finger	1.51	rarely remote	2.5	Remote
Record of death	1.24	rarely	1.1522	Rarely
Hand and foot injury	1.4	rarely remote	4.8696	Frequen
Panels falling over during installation	1.33	rarely remote	3.1304	Occasionally

Very likely the average index is 4.50 ≤ I < 5.00, and the frequency is 3.50 ≤ I < 4.50. I < 3.50 whenever I am 2.50 ≤ Average Index, I < 2.50 when I am 1.50 ≤ Average Index, and I < 1.50 when I am 1.00 ≤ Average Index. Based on Table 4.14The majority of respondents believe that aluminum formwork systems are safe in terms of safety factors, but they choose to use them infrequently and remotely (noise exposure, cuts and abrasions, risk of eye injury from flying dust and particles, injury during lifting or carrying, risk of asbestos exposure and hazardous substances, proximity to flammable or combustible material, vibration with finger, hand, and foot injury, and panels falling over during installation). The aluminum formwork system from Kumkang can be the positive safety-related activities (height-related falls, repetitive task pain or injury risk, and death records). Activities involving manual handling, trips and falls, and an untidy workspace Respondents selected three options from the above table, and the graphs selected higher percentages or more of them. Choose infrequently but nearly equally remote and sporadic. Respondent is struck by falling objects or materials (rarely, remotely, and occasionally). Convectional form work causes the height drop. Activities involving manual handling, noise exposure, repetitive task pain or injury risk, dust and flying particles causing eye injuries, lifting or carrying injuries, trips and falls because of an untidy work area, and exposure to The following factors make Kumkang aluminum formwork comparisons less safe: asbestos and hazardous materials, closeness to flammable or combustible materials, and panels that occasionally topple over during installation. Danger of being exposed to dangerous materials and asbestos, and The rating of "remote occurrence" indicates that it is unlikely to happen under normal conditions. On the risk list are things like being struck by falling objects or materials, being exposed to noise, getting cuts or abrasions, and occasionally having panels topple over during installation. Both traditional wooden formwork and Kumkang formwork have no recorded death rates, which indicate that while they are unlikely to happen, they are still possible.Kumkang aluminum formwork comparisons are less safe because of the following: asbestos and hazardous materials, proximity to combustible or flammable materials, and panels that occasionally topples over during installation. risk of coming into contact with hazardous substances and asbestos, and The "remote occurrence" rating denotes that it is unlikely to occur in typical circumstances. Among the risks are collisions with falling objects or materials, noise exposure, cuts or abrasions, and the occasional panel toppling over during installation. Death rates have not been documented for either kumkang formwork or traditional wooden formwork, suggesting that although they are unlikely, they are still possible. As long as appropriate care is taken during transportation or site relocation, Kumkang formwork is safe for work and easy to disassemble at low risk, according to the interviewee. The climbing technique stays away from eucalyptus and makes use of its pre-engineered safety scaffolds (brackets). Additionally, the company's externally attached bracket, which was designed with formwork and includes a belt and height and length of manpower, creates a good working environment. Because there are fewer props, this system creates a better working environment. Organization by lowering site crowdedness, which puts the employer at risk and lowering the risk of cuts, abrasions, falling objects, and nail hazards. The aforementioned arguments demonstrate how well Kumkang formwork reduces the risk connected with traditional systems, improves construction safety, and improves worker conditions.

4.5 Benefit and Barriers of Kumkang Aluminum Formwork on Sustainability

This section calculates the sustainability benchmarks and their components in order to support sustainable construction, which requires consideration of sustainability factors when choosing abuilding. Under formwork sustainability, there are three benchmarks: economic, social, and environmental. Each of these benchmarks evaluates and rates formwork differently. Consequently, this section described each element's degree of response for a distinct formwork type.Sustainability in terms of the environment is the first standard. Eleven components that were selected from the various in-depth literature reviews can be used to gauge the environmental sustainability of formwork.

The formwork systems rates in relation to each environmental factor are shown in Figure 4.7 below.



Environmental element

Figure 29.Environmental sustainability of formwork systems (on 2017)

From Figure 4.7, Kumkang Aluminum formwork is better in high resistance to force nature or Although steel formwork has a 20% rate and climate change has a 73.33% rate, all respondents (6.667%) concur that traditional wooden formwork has a high resistance to natural forces. The next environmental component is the environmentally responsible working formwork system. The Kumkang formwork rate was 77.78%, the wooden formwork was 15.56%, and the steel formwork was 6.667%. The Kumkang aluminum formwork (84.44%) outperforms the wooden (8.889%) and steel (6.667%) formwork in terms of sound absorption. The Kumkang formwork has a significant advantage over the other components in terms of site energy, material efficiency (77.78%), and natural resource conservation (71.11%). (66.67%), Resource reduction (66.89%), clean environment in construction (71.11%), minimal waste (68.89%), healthy indoor environment production of non-toxic waste (68.89%), reusable/ 75.56% of formwork is recycled.While respondents' results for wooden formwork were (site energy 15.56%, resource reduction 13.33%, clean environment in construction 11.11%, production of non-toxic waste 8.880% reusable/recyclable was close to null), steel form work is superior for the following results from wood (site energy 17.78%, resource reduction 17.78%, clean environment in construction 17.78%, production of non-toxic waste 22.22% reusable/recyclable 24.44). According to the sustainability environmental elements (natural resource, material efficiency, and minimal waste) shown in figure 4.7, wooden formwork performs better than steel formwork (17.78%, 13.33%, and 17.78%), while steel performs worse (11.11%, 8.889%, and 13.33%). According to the outcome, the Kumkang aluminum formwork performs better when considering environmental factors. This demonstrates the significant advantages of kumkang formwork for ecologically friendly building. However, in terms of environmentally sustainable criteria, the wooden formwork system performed worse, particularly in the areas of non-toxic waste production, site energy, resource reduction, reusable/recyclable formwork, and clean construction environments. In addition to Kumkang formwork, steel formwork is good at maintaining environmentally sustainable construction (see Appendix-BT). The following figure compares the five components of social sustainability in form work.

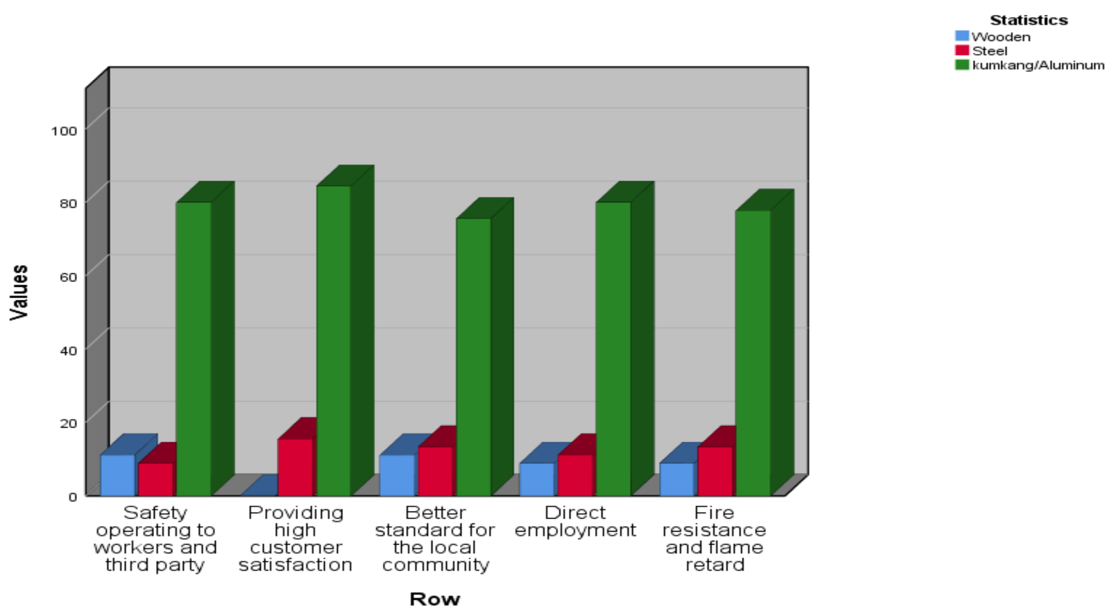


Figure 30. Social sustainability of formwork systems (on 2017)

The results of the responses are detailed below, and the social elements were calculated between Kumkang, steel, and wooden formwork. With an 80% response rate, high customer satisfaction (84.44%), improved standards for the local community (75.56%), direct employment (80%), fire resistance, and flame retard (77.78%) of each, the Kumkang formwork was more beneficial in establishing a safe operation for both the third party and the workers (figure 4.8). The next better steel depends on The results of respondents without safe operation to work and the third party with a response rate of 8.889% and high customer satisfaction (15.56%) are then displayed in figure 4.8. improved fire resistance, flame retardant (13.33%), direct employment (11.11%), and local community standard (13.33%). With a response rate better than steal formwork (11.11%), a higher standard for the local community (11.11%), direct employment (8.889%), fire resistance, and flame retardant (8.889%), the other wooden formwork result is shown in figure 4.8. It also provides high customer satisfaction close to null and safe operation to works and the third party. This demonstrates that the Kumkang formwork advanced more than others in every area of social sustainability. In a way, steel formwork was also very helpful in achieving socially responsible, sustainable building. Additionally, as shown in Appendix C, the wooden formwork in this instance had less of an impact on social elements and did not improve socially sustainable construction.

. The last elements of sustainability figure show economical parts of comparation.Economical elements

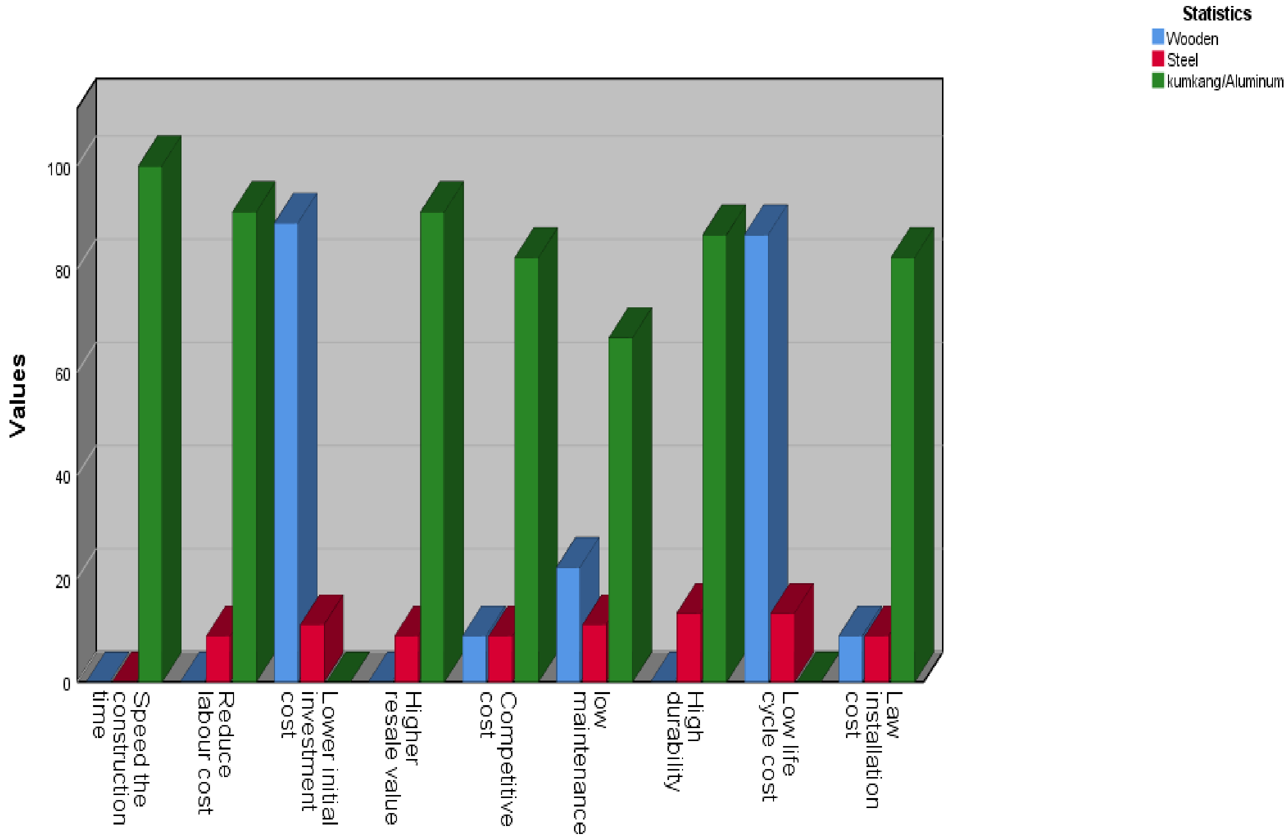


Figure 31. Economical sustainability of formwork systems (on 2017)

Al-Ashwal et al. (2017) claim that the current system of temporary work is more popular because it is cost-effective, disregarding other sustainability considerations. The most common and important criterion for evaluating a sustainable formwork system in any construction project is its cost-effectiveness. The final criterion used to evaluate sustainable formwork was these cost factors. The benefits and advancements of various formwork systems on economic sustainability are displayed in Figure 4.9 below. As can be seen in Figure 4.9, the Kumkang formwork greatly accelerated the construction time (100%). This is because Kumkang formwork had a quicker construction cycle, allowing one floor to be finished in five days. With 91.8% of the response, the wooden formwork was a great benefit for a lower initial investment cost. Although the Kumkang formwork was initially prohibitively expensive, its reusability reduces the formwork's life cycle costs, and the wooden formwork was expensive for formwork over the course of the project. Regarding labor cost reduction. The rate for the Kumkang formwork was 91.11%. This is due to the fact that the Kumkang formwork can be constructed without the need for skilled labor, which lowers labor costs (91.1%) because skilled labor is more expensive than non-skilled labor. In comparison to the other formwork, the Kumkang formwork had a higher resale (salvage) value (91.11%). This is because aluminum is more expensive than steel and wood in the local market, and unlike wood formwork, aluminum can be recycled and used again as formwork, which is a different physical feature.The Kumkang formwork had a significant advantage due to its low maintenance cost (66.67), law installation cost (82.22%), and low life cycle cost close to null response rate. Compared to steel and wooden formwork, Kumkang formwork had a lower life cycle cost and installation cost because it used unskilled labor and had more repetitions. As can be seen in Appendix-C, the Kumkang formwork had a greater advantage over the competition in terms of both high durability (86.67%) and great competitive cost (82.22%). According to the aforementioned findings, the Kumkang aluminum formwork had a slight advantage in terms of cost-effective sustainability. The initial investment cost is another obstacle, but it is overcome by its numerous reusability features. Formwork made of wood low initial investment cost (88.89%), making it cost-effective for Kumkang and steel formwork. accelerate the building process almost to zero This outcome discusses the drawbacks or how the formwork type's impact on construction delivery time affects building construction costs. the same to lower labor costs, height durability, and height reusable value, almost to zero negative effects of this type of work on the cost of building construction, Butter has a lower maintenance cost than steel formwork (22.22%), but the installation cost of both wood and steel formwork is the same (8.889%). In comparison to wooden formwork, steel lessens labor costs, has a higher resale (salvage) value, and is more durable in terms of height (8.889%, 8.889%, 13.33%), but requires less maintenance (11.11).

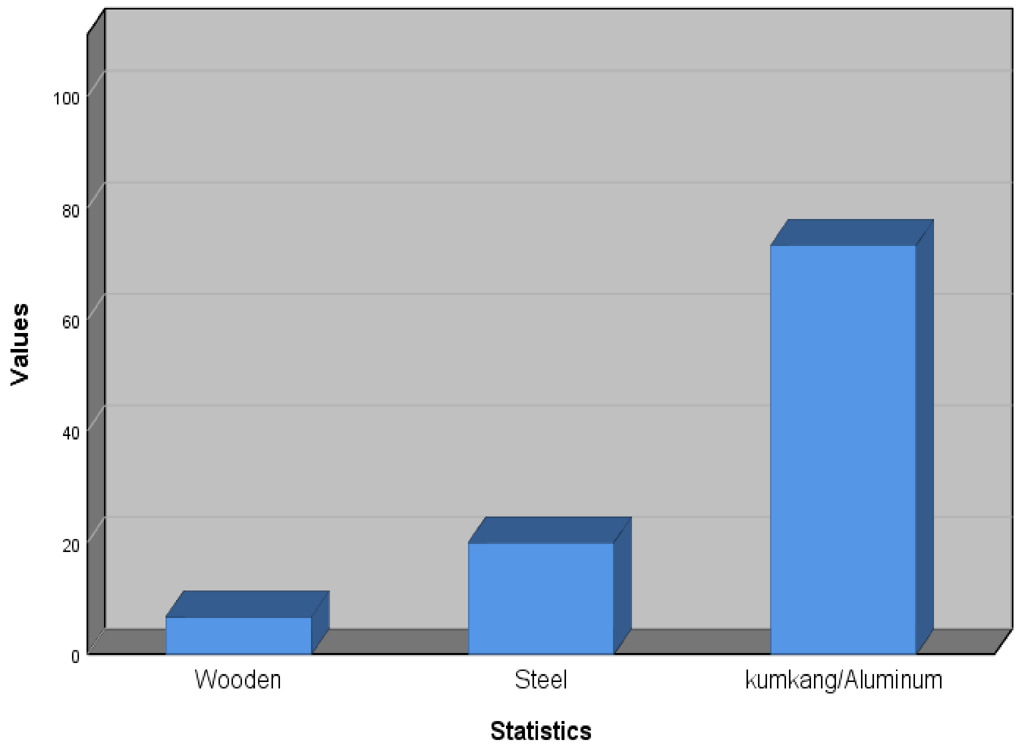


Figure 32. Sustainability comparisons between formwork systems (on 2017)

4.6 Labour Productivity of Kumkang Aluminum

Formwork has a big impact on labor because it accounts for a large amount of a concrete structure's cost. The labor productivity of Kumkang aluminum formwork was assessed by using case studies of the project that used wooden formwork and Gerji village (Kumkang aluminum formwork). The comparison was made by calculating the hourly labor output for each structural member of a single crew. The productivity of workers in m2/hr on each structural member in both formwork systems is displayed in Table 4.15 below.

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Table 29. Average productivity of labor in erecting and stripping of formworks (case study)

Structural Members		Projects		
		Project A (Kumkang Aluminium) m2 /hr	Project B (conventional wooden) (m2 /hr.)	Project 1 (conventional wooden) (m2 /hr.)
Column	Erecting	-	0.6	0.7
	Stripping	-	1.5	2.5
Beam	Erecting	-	0.6	0.51
	Stripping	-	2.7	2.02
Stair	Erecting	1.4	0.46	0.52
	Stripping	2.7	1.84	1.87
Wall	Erecting	4.4	0.75	0.83
	Stripping	7.94	2.66	2.86
Floor slab	Erecting	5.21	0.67	0.58
	Stripping	9.42	3.5	3.45

As previously mentioned, the stair system and wall slab are covered by the Kumkang aluminum formwork. The load is transferred directly from the slab to the wall because the wall member is a shear wall. Since the wall can perform the function of beam and column members, they are not included in the Gerji Modern Village project. However, Kumkang formwork can be used for structures with beams and columns. Therefore, we can only compare the formworks' productivity on slab, shear wall, and stair structures. Let's start by looking at both formwork productivity's stair member. In project C, the traditional wooden formwork was installed 0.52 m2 and striped 1.87 m2 per hour, while the Kumkang aluminum formwork was installed 1.4 m2 per hour and striped 2.7 m2 per hour. In Kumkang formwork, the formwork was erected 4.4 m2 /hr and striped 7.94 m2 /hr, while the conventional method for wall members was to erect 0.83 m2 /hr and strip 2.86 m2 /hr. The Kumkang formwork advanced by 0.91, 3.61, and 4.59 m2 /hr for the stair, wall, and floor slab, respectively, for formwork erection. During formwork stripping, the Kumkang formwork's productivity increased by 0.85, 5.18, and 5.95 in the stair, wall, and floor slab, compared to the average productivity of the two projects that used the wooden formwork.

Slab of the floor, respectively. Additionally, productivity was assessed to determine their training curve (performance) progress from the beginning to the present by calculating the average monthly productivity. Since Kumkang aluminum formwork is a new technology in the nation, it takes time to get used to it and become productive all at once. Additionally, it takes month-to-month research to determine the productivity of the wooden formwork. The average monthly productivity of both traditional formwork and Kumkang aluminum is displayed in Table 4.16 below.

Table 30. Monthly productivity of labour. (Case study)

Month	Productivity (m2 /hr.)	
	Kumkang Aluminium	Conventional (wooden) formwork
Month 1 (March)	3.05 m2 /hr.	0.82 m2 /hr.
Month 2 (April)	4.06 m2 /hr.	0.68 m2 /hr
Month 3 (May)	4.35 m2 /hr.	0.62 m2 /hr.

According to Table 4.16, the Kumkang aluminum formwork's productivity increased month over month. With repeated work and training from the beginning to the present, labor performance improves along with technological adaptation in the case of Kumkang formwork. Additionally, the conventional one was reduced as the building's floor rose because, in contrast to Kumkang formwork, it is challenging to construct formwork from a higher level due to the uncomfortable working platform and formwork transportation. A slab transfer box makes it simple to manually move the Kumkang formwork from one floor to the next. Considering Kumkang aluminum formwork employed a lined schedule to finish one floor of formwork, with the floor divided into zones, in order to assess and improve labor productivity. With four zones (crews) including the core zone on a single floor, this zone indicates that one crew typically calls. Time was allotted to each zone, and labor productivity was assessed by analyzing the work completed in each zone. Optimization involves adjusting crew information by recording data such as work done in m2/hr and redistributing workers according to their areas of expertise by trying out various zones and then screwing who is better at that and that. Afterwards, by carefully allocating the workers to their areas of expertise, they can achieve the most work with the least amount of effort by raising their Effectiveness. There are motivational mechanisms to increase their output. The mechanism of motivation had: bonus with milestone (zone): the company offers a one-day monthly salary as a bonus to employees who complete seven days of work in six days. They also have a cafeteria (food service) on site, and they have a bank to improve their facilities. Since there is no reference, they initially employ an excessive amount of labor due to fear. However, through trial and error and training, they improve the skills and productivity of workers and reduce the number of workers. The first two floors were finished in 21–19 days, but there is a discrepancy between the six-day cycle time for one-floor work as recommended by the company and other literature. Following those floors, their labor productivity progressively rises and reaches its label, which is six days for one floor, thanks to the aforementioned techniques, training, and other motivating mechanisms. The type of formwork material had an impact on labor productivity, as can be seen from the above, and Kumkang aluminum formwork had a significant advantage in this regard. The productivity of Kumkang formwork was nearly double that of traditional wooden formwork. This Kumkang aluminum formwork did a good job of increasing worker productivity and speeding up construction.

4.7 Triangulation of the Results

The company's suggested six-day cycle time for one-floor work and other literature differ, although the first two floors were completed in 21–19 days. The aforementioned methods, training, and other motivating factors enable their labor productivity to gradually increase after those floors and reach its label, which is six days for one floor. As the above illustrates, the type of formwork material had an effect on labor productivity, and Kumkang aluminum formwork had a major advantage in this area. Compared to traditional wooden formwork, Kumkang formwork was almost twice as productive. Construction was sped up and worker productivity was increased thanks to this Kumkang aluminum formwork. was greater than the questionnaire and interview results. However, case studies showed that Kumkang aluminum formwork performed significantly better in terms of cost than traditional wooden formwork. With the exception of the labor productivity performance of Kumkang aluminum formwork, all research objectives were addressed using a questionnaire as the second research method. With the exception of the previously mentioned cost issue, the results of the questionnaire for the remaining research questions were evidence and supplemental to the findings of the interview and case study. The interview was the third and last method used in this study to address all of the research questions. With the exception of certain research objectives, the interview results were supplementary and supported each other with other data collection methods. Respondents' perceptions from thequestionnaire and interview indicated that the Kumkang aluminum formwork was more expensive, but the case studies refuted this. And yet another variant of the Other data collection methods revealed that the Kumkang aluminum formwork practice limitation was clearly stated in the interview results, but the respondent's perception was positive and the limitation was not mentioned in the questionnaire results. Nearly every analysis of data from data sources was supplemented by the final product, which represented triangulation and was used to further support the conclusions drawn.

CHAPTER FIVE

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

As previously mentioned, the goal of this research is to determine how the aluminum formwork system affects the performance of building construction projects. In addition to finished concrete, Kumkang aluminum formwork performance is evaluated in terms of cost, time, quality, safety, sustainability, and labor productivity. The results and analysis have previously been conducted based on the study's objectives and findings.Based on the building's design, the following conclusions are reached: -The Kumkang aluminum formwork is made and imported from Korea. This system can be built by hand, and the panel can be transported manually using a slab transferring box. This lessens site congestion and the expense of using a crane to move formworks. Comparing the Kumkang aluminum formwork type to a traditional formwork system, this analysis shows that the former has better effects on the growth of building construction activity in the following areas: cost, quality, time, safety, labor productivity, and sustainability. This type of formwork is currently unavailable or inaccessible in theEthiopian market, so the The company only built identical designs and structural levels for mass production. Because Kumkang aluminum formwork types eliminate the basic need for mass house production in the country, they can be stripped and erected quickly without requiring all workers to be skilled. This means that unskilled labor uses these formwork types to provide some training before active laborers do. By lowering the cost associated with formwork construction, the Kumkang aluminum formwork offers superior cost performance. These include the cost of labor, materials, equipment, the quantity of reusable items, and the cost of surface finishing following formwork stripping. While the wooden formwork is reused three to four times, the Kumkang aluminum formwork is reused 250 to 300 times. Growing the quality of the formwork and the finished concrete surface are both diminished by the wooden formwork's reusability. In terms of formwork unit cost (which includes labor, material, and equipment costs), Kumkang aluminum formwork is 173.29 Birr less expensive per square meter than wooden formwork. This formwork lowers the cost of formwork in construction by 40%. Kumkang aluminum formwork and traditional wooden formwork have different treatment costs. 155.08 Birr/m2, or 89% of the extra surface finish treatment. This formwork was constructed using a different technique. more practical than the traditional one.

Before the formwork was erected, the rebar was installed along with the water waste point pipes, electrical conduit, and fixture. In terms of work procedures and formwork construction time, the Kumkang formwork system differs from the conventional system in both erection and stripping. Instead, the Kumkang aluminum formwork material is a long-lasting product that can be used for multiple cycles, is simple to install, has a quick construction cycle, and produces concrete with a high-quality surface and dimensional accuracy with improved alignment. However, because it lacks flexibility, it has limitations when it comes to maintenance and design changes. The Kumkang aluminum formwork has superior time measurement capabilities in every way. speedier construction time and improved performance on traditional wooden formwork. The Kumkang aluminum formwork speeds up the construction floor cycle by reducing the time required to strip the formwork by double, and the time required to erect the formwork was three times shorter than that of traditional wooden formwork. The construction of one-floor formwork by Kumkang, including formwork strip, took five-six days, whereas the erection of conventional formwork alone takes 21 to 31 days. This suggests that Kumkang aluminum formwork will take three to four floors to construct. It cut down on construction time by 87–89% and 41–42 extra days. to build a 100 m2 floor slab using Kumkang formwork instead of wood. Additionally, surface finish work takes an average of five days, while traditional wooden formwork projects require four days for each floor cycle. On the other hand, plastering and chiseling tasks take 100% less time when Kumkang Aluminum formwork is used. By using this formwork system, 55 to 44 days were saved in the Gerji Modern Village project. The concrete's quality is determined by two main factors.With a result of more than 60% in all quality measurements of the finished concrete, Kumkang aluminum has improved on steel and wooden formworks in terms of formwork material quality. The final appearance of the concrete is determined by several important factors. The first is the formwork material's quality, and the second is concrete-related factors that affect the formwork. Concrete-related factors that affect the formwork were another factor. These include the kind of release agent, the height at which the concrete is poured, the rate at which it is placed, and vibration. These include the kind of release agent, the height at which the concrete is poured, the rate at which it is placed, and vibration. The undertaking'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.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 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). Additionally, it is more resistant to deflection than traditional steel and wood formwork. By improving the working conditions for employees, the Kumkang formwork improves construction safety and plays a significant role in reducing the risk connected with a traditional system. Since this formwork has an external bracket attached to the wall and is designed using formwork, it reduces the risk associated with separate scaffolding, such as stability issues when the structure rises and falls from height. If so, the Kumkang performs better on measurements of the quality of the formwork material, which indicates that it is effective in achieving a higher level of concrete surface quality. The Kumkang aluminum formwork is robust enough to support the entire weight of freshly laid concrete as well as any side pressures. This fosters a productive workplace. Due to its prop-supporting design with formwork panels and the fact that the panels connect with wedges and pins that are positioned within the designated holes on the panels, the Kumkang formwork also reduces collapse during formwork construction. The aforementioned requirements are necessary to guarantee the structure's safety and the workers' protection during formwork construction, and the Kumkang formwork performed better on each criterion.

- The Kumkang formwork labour productivity is almost double time and above than Conventional wooden formwork. With outputs of 0.91, 3.61, and 4.59 m2 per hour for stair, wall, and floor slab, respectively, Kumkang formwork outperforms wooden formwork in formwork erection. Additionally, during formwork stripping, the productivity of Kumkang formwork surpasses that of wooden formwork by 0.85, 5.18, and 5.95 m2 per hour for stair, wall, and floor slab, respectively. According to the average monthly productivity, Kumkang Aluminum formwork's productivity rises each month. When labor performance improves and technological adaptation increases
- The Kumkang aluminum formwork had also rarely risk and better safety during formwork construction in the aspect of health and safety factors. Health and safety risk factors had fewer occurrences 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

When it came to environmentally sustainable criteria, the wooden formwork system performed worse. Steel formwork is a good alternative to Kumkang formwork for maintaining environmentally friendly construction. In every facet of social sustainability, the Kumkang formwork has excelled over the competition. In a way, steel formwork was also very helpful in achieving socially responsible building. In this instance, the wooden formwork did not improve socially sustainable construction and had less of an impact on social elements. Although the initial investment cost is a barrier, Kumkang Aluminum formwork has a greater advantage in terms of economic sustainability. However, it is not profitable for small businesses. Kumkang formwork has an improvement over wooden formwork on formwork erection with 0.91, 3.61, and 4.59. projects.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 KumkangAluminum formwork had well in enhancing the labour productivity and helps in making the construction faster.In the final recommendation of this thesis, 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 in 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

I would like to forward the following recommendations and suggestions in light of the study's findings and conclusion.

.Contractors

- Real estate Companies adapted modern formwork system overcomes the time issue that is raised by customers all the time and it's profitable for mass housing projects.
- Import different Kumkang aluminum formwork shape and size because of constructed in any design building project.

- Support for local rental company to import and rent different types of formworks that could help sub-contractors that are not able to afford at the beginning of the business.

Government

- 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.
- Governmental support in modern construction provides, the real estatecompany important ofKumkang aluminum system introduce in different ways like tarring, site invitation and communicate use this formwork company integrates with other used conventional system.
- The construction company import this formwork system support governmental should support the contractors by making promotions and tax reductions in order to modernize our construction industry. In different real estate Company Integrate Kumkangformwork company in Korea and how to easily accessible in different size and shape.
- Government should invite different Aluminum formwork companies from all over the market to invest in Ethiopia and also the government has to start to establish formwork manufacturing companies to satisfy the demand.
- Different construction sector in governmental level owners mass house production like condominiums, apartments, real estate, and so on.The housing policy agency should apply and make policies related to such and other modern formwork systems to rectify our housing problem.
- 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.

Suggestion

- In financial study of Kumkang formwork researchers are highly recommended to precede the initial cost analysis deeply to assure that the cost for the formwork is not high as it is pre-assumed.
- The other research person refer different thesis and the advantages of kumkangaluminum formwork mass house production, local investors how to create kumkang aluminum formwork manufacturing company.

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Appendix-A: Questionnaire

Questionnaire

Dear Respondent;

I am Rehobot seid student at Addis collage and currently working research on "impacts of aluminum formwork performance onbuilding project performance in Ovid construction group" This research survey is intended to fulfill an academic requirement for a Master of program of Construction technology and Management.

The objective of this survey is:

4. To identify, the possible opportunities and challenge of aluminum formwork system for building construction project performance in the case study of Ovid group.
5. To examine the impacts of aluminum formwork on building construction project triple constraints in the case study Ovid group
6. To identify the comparable advantages of aluminum formwork as compare to conventional formworks in building construction projects.

   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. 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.

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

Rehobot Seid Phone No. 0942577176 Email: -rehobotseid7@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?

1) Less than 5 years 2)5 t ears 3) 10 years and al

4. Number of projects executed in the last five years

1) Less than 10 2)11 to 20 3) r an 20

5. Your position in the firm______________________________________

6. Your experience in construction industry

1) Less than 5 years 10 years ears 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	

(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)

1) Cost of formwork ☐

2) Speed of construction ☐

3) Quality of finished concrete ☐

4) Health and safety factors ☐

5) Sustainability issue ☐

6) Labor productivity ☐

7) All ☐

8) 1-3 ☐

Others (please specify): ___________________________

Part II Formwork system (for Gerji 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)

1) Rental ☐

2) Owning (from local market) ☐

3) Owning (Import from abroad) ☐

4) 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?

1) Cost ☐

2) Quality ☐

3) Labor productivity ☐

Others (please specify): ___________________________

5. Which method you use to construct formwork?

1) Manually ☐

2) Manually and Crane ☐

3) Self-climbing ☐

Others (please specify): ___________________________

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

1) Skilled labour ☐

2) Semi-skilled labour ☐

3) Unskilled labour. ☐

4) all ☐

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

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

1) Yes ☐ 2) No ☐

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

9. Which method do you use to pour concrete?

1) Manually ☐ 2) Crane ☐ 3) Pump ☐

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

____

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

1) Yes2) ☐ ☐

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?

1) Yes ☐ 2) 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. Code 1) steel 2) wooden 3) Kumkang aluminum

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

Quality consideration of formwork	materails		
	conventional		kumkang aluminum
	wooden	steel	
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?

1) Separate ☐

2) Attached with wall (with bracket) ☐

B. Health and safety risk factors

Here is 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	No. Health and safety risk factors	Degree				
		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		Alumunium formwork
		Wood	Steel	
enviromental elements	High resistance to force nature or climate change			
	Environmentally responsible working system			
	Sound absorption/sound attenuation			
	natural resource			
	Material efficiency			
	Site energy			
	resource reduction			
	Clean environment in construction			
	Minimal waste			
	Production non-toxic waste			
	Reusable/ recycle formwork			
Socail elements	Safety operating to workers and third party			
	Providing high customer satisfaction			
	Better standard for the local community			
	Direct employment			
	Fire resistance and flame retard			
Economical elements	Speed the construction time			
	Reduce labour cost			
	Lower initial investment cost			
	Higher resale value			
	Competitive cost			
	low maintenance			
	High durability			
	Low life cycle cost			
	Law installation cost			

Appendix-B: Questionnaire result

Table B- 1 Job position of the respondent

Position of respondent	Frequency	Percent (%)
structural engineer	4	6.6
site engineer	5	8.2
office engineer	2	3.3
Office engineer head	2	3.3
Project coordinator	4	6.6
Project manager	4	6.6
Resident engineer	3	4.9
Senior office engineer	2	3.3
Site manager	4	6.6
Research and Development Directo	2	3.3
supper intendent Forman	4	3.3
Contract admin	1	1.6
Construction engineer	4	6.6
Assistant project manager	2	3.3
Safety officer	2	3.3
total	45	100

Table B- 2 Formwork quality consideration

Quality considerations of formwork		Frequency	Percent
Maintaining the designed shape of the concrete	Conventional(wooden)	10	22.22
	Conventional(steel)	3	6.667
	Kumkang Aluminum	34	71.11
Maintaining correct location	Conventional(wooden)	13	11.11
	Conventional(steel)	-	0
	Kumkang Aluminum	32	71.11
Smooth concrete surface	Conventional(wooden)	-	0
	Conventional(steel)	5	11.11
	Kumkang Aluminum	40	88.89
Able to produce the required shape and surface	Conventional(wooden)	4	8.889
	Conventional(steel)	3	6.667
	Kumkang Aluminum	38	84.44
Waterproofing (not absorb water from concrete)	Conventional(wooden)	9	20
	Conventional(steel)	4	8.889
	Kumkang Aluminum	32	71.11
Stiff enough against its deflection, buckling under load.	Conventional(wooden)	8	17.78
	Conventional(steel)	-	0
	Kumkang Aluminum	37	82.22
Dimensional accuracy includes size, shape, and alignment of structural elements	Conventional(wooden)	1	2.222
	Conventional(steel)	3	6.667
	Kumkang Aluminum	41	91.11
Non-discoloration of finished concrete	Conventional(wooden)	3	6.667
	Conventional(steel)	0	0
	Kumkang Aluminum	42	93.33
More strength of formwork	Conventional(wooden)	-	0
	Conventional(steel)	-	0
	Kumkang Aluminum	45	100
More formwork Reusability	Conventional(wooden)	-	0
	Conventional(steel)	4	8.889
	Kumkang Aluminum	41	91
Great leakage resistance	Conventional(wooden)	-	0
	Conventional(steel)	6	13.33
	Kumkang Aluminum	39	86.67

No need of plastering	Conventional(wooden)	-	0
	Conventional(steel)	4	11.11
	Kumkang Aluminum	41	91.11
Better Rigidity	Conventional(wooden)	-	0
	Conventional(steel)	5	11.11
	Kumkang Aluminum	40	88.89
Easy to use	Conventional(wooden)	3	6.667
	Conventional(steel)	2	4.44
	Kumkang Aluminum	40	88.89
Withstanding Shrinkage and swelling	Conventional(wooden)	-	0
	Conventional(steel)	3	6.667
	Kumkang Aluminum	42	93.33
Uniform quality of concrete	Conventional(wooden)	2	4.444
	Conventional(steel)	3	6.667
	Kumkang Aluminum	40	88.89

TableB-3Formwork systems on sustainable elements

Environmental elements		Frequency	Percent
High resistance to force nature or climate change	Conventional(wooden)	3	6.667
	Conventional(steel)	9	20
	Kumkang Aluminum	33	73.33
Environmentally responsible working system	Conventional(wooden)	7	15.56
	Conventional(steel)	3	6.667
	Kumkang Aluminum	35	77.78
Sound absorption/sound attenuation	Conventional(wooden)	4	8.889
	Conventional(steel)	3	6.667
	Kumkang Aluminum	38	84.44
natural resource	Conventional(wooden)	8	17.78
	Conventional(steel)	5	6.667
	Kumkang Aluminum	32	71.11
material efficiency	Conventional(wooden)	4	13.33
	Conventional(steel)	6	11.11
	Kumkang Aluminum	35	77.11
site energy	Conventional(wooden)	7	15.56
	Conventional(steel)	8	8.889
	Kumkang Aluminum	30	66.67
resource reduction	Conventional(wooden)	6	13.33
	Conventional(steel)	8	17.78
	Kumkang Aluminum	31	68.89

Clean environment in construction	Conventional(wooden)	5	11.11
	Conventional(steel)	8	17.78
	Kumkang Aluminum	32	71.11
Minimal waste	Conventional(wooden)	8	17.78
	Conventional(steel)	6	13.33
	Kumkang Aluminum	31	68.89
production non-toxic waste	Conventional(wooden)	4	8.889
	Conventional(steel)	10	22.22
	Kumkang Aluminum	31	68.89
reusable/recycle formwork	Conventional(wooden)	-	0
	Conventional(steel)	11	24.44
	Kumkang Aluminum	34	75.56

Table B- 4 Formwork systems on social elements

social elements		Frequency	Percent
Safety operating to workers and third party	Conventional(wooden)	5	11.11
	Conventional(steel)	4	8.859
	Kumkang Aluminum	36	80
Providing high customer satisfaction	Conventional(wooden)	-	0
	Conventional(steel)	7	15.56
	Kumkang Aluminum	38	84.44
Better standard for the local community	Conventional(wooden)	5	11.11
	Conventional(steel)	6	13.33
	Kumkang Aluminum	34	75.56
Fire resistance and flame retard	Conventional(wooden)	4	3
	Conventional(steel)	5	13.33
	Kumkang Aluminum	36	77.78
Direct employment	Conventional(wooden)	3	8.889
	Conventional(steel)	6	11.11
	Kumkang Aluminum	36	80

Table B- 5 Formwork systems on economical elements

Economical elements		Frequency	Percent
Speed the construction time	Conventional(wooden)	-	0
	Conventional(steel)	-	0

	Kumkang Aluminum	45	100
Reduce labour cost	Conventional(wooden)	-	0
	Conventional(steel)	4	8.889
	Kumkang Aluminum	42	91.11
low intial cost	Conventional(wooden)	40	88.89
	Conventional(steel)	5	11.11
	Kumkang Aluminum	-	0
Higher resale value	Conventional(wooden)	-	0
	Conventional(steel)	4	8.889
	Kumkang Aluminum	41	91.11
competitive cost	Conventional(wooden)	4	8.889
	Conventional(steel)	4	8.889
	Kumkang Aluminum	37	82.22
Low maintenance	Conventional(wooden)	10	22.22
	Conventional(steel)	5	11.11
	Kumkang Aluminum	30	66.67
High durability	Conventional(wooden)	-	0
	Conventional(steel)	6	13.33
	Kumkang Aluminum	39	86.67
Low life-cycle cost	Conventional(wooden)	39	86.67
	Conventional(steel)	6	13.33
	Kumkang Aluminum	-	0
low installation cost	Conventional(wooden)	4	8.889
	Conventional(steel)	4	8.889
	Kumkang Aluminum	37	82.22

Appendix-C: Costs of formwork

Table c- 1 Plastering cost for exposed beam and columns and slab soffit in Kebena

Table c- 1 Plastering cost for exposed beam and columns and slab soffit in Kebena

		ANALYSIS SHEET FOR DIRECT & INDIRECT COSTS											
PROJECT: FINISHING WORKS								LABOR DAILY OUTPUT:			1.875 m2/hr		
WORK ITEM:	11.13						EQUIPMENT DAILY OUT PUT:						
TOTAL QUANTITY OF WORK ITEM:	1.00 m 2		3 Coats of cement plastering (1:3) (To internal wall)						RESULT:		169.83Birr/m 2		
materail cos (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of materal	Unit	Qut *	Rate	cost per unit	Labor by Trade	No.	UF	Indexed ** hourly wage	Hourly wage	Type of Equipment	No	Hourly Rental	Hourly Rental
cement	qt	0.1	420.00	43.26	Foreman	1	0.25	40	10.63	tools	1	0.50	0.5
sand	m3	0.7	681.12	14.98	Plasterer	1	1	30	30.54	scafolding	1	10.00	10
water	m3	0.7	35.00	2.45	Chiseler	1	1	16.25	16.25				0
				0.00	Dl	1	1	12.5	12.5				0
Total (1:01)				60.69	Total (1:02)				69.92	Total (1:03)			10.5
A =Materal unit cost	60.69	birr/ m2			B =Labor cost	69.92	birr/ m2			C =Equipment cost	5.25	birr/ m2	
					Total of (1:02)					Total of (1:03)			
					Direct Cost of Work Item = A+B+C =					135.86			
					Over head cost :				15%	13.586			
					Profit Cost:				10%	20.379			
					Total unit cost:					169.83			
Remark ______________________________________													
UF: UTILIZATION FACTOR													
*: INCLUSIVE OF WASTAGE, TRANSPORTING, HANDLING, ETC.													
**: INCLUSIVE OF BENEFITS, TRAVEL SUBSIDES AND COST OF OVERTIME RELATED TO TARGETED OUTPUT.													

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

		ANALYSIS SHEET FOR DIRECT & INDIRECT COSTS											
PROJECT: FINISHING WORKS							LABOR DAILY OUTPUT:				1.875 m2/hr		
WORK ITEM:	11.13		3 Coats of cement plastering (1:3) (To internal wa				EQUIPMENT DAILY OUT PUT:						
TOTAL QUANTITY OF WORK ITEM:		1.00 m 2							RESULT:		172.01Birr/m 2		
materail cos (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of materal	Unit	Qut *	Rate	cost per unit	Labor by Trade	No.	UF	Indexed ** hourly wage	Hourly wage	Type of Equipment	No	Hourly Rental	Hourly Rental
cement	qt	0.1	420.00	43.26	Foreman	1	0.25	40	10.63	tools	1	0.50	0.5
sand	m3	0.7	681.12	14.98	Plasterer	1	1	30	30.54	scafolding	1	13.50	13.5
water	m3	0.7	35.00	2.45	Chiseler	1	1	16.25	16.25				0
				0.00	Dl	1	1	12.5	12.5				0
Total (1:01)				60.69	Total (1:02)				69.92	Total (1:03)			14
A =Materal unit cost	60.69	birr/ m2			B =Labor cost	69.92	birr/ m2			C =Equipment cc	7	birr/ m2	
					Total of (1:02)					Total of (1:03)			
					Direct Cost of Work Item = A+B+C =					137.61			
					Over head cost :				15%	13.761			
					Profit Cost:				10%	20.6415			
					Total unit cost:					172.01			

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 COSTS											
PROJECT: FINISHING WORKS									LABOR DAILY OUTPUT:		1.88 m2/hr		
WORK ITEM:	11.11		3 Coats of cement plastering (1:3) (To internal wall)						EQUIPMENT DAILY OUT PUT:				
TOTAL QUANTITY OF WORK ITEM:	1.00 m 2								RESULT:		176.39 Birr/m 2		
materail cos (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of materal	Unit	Qut *	Rate	cost per unit	Labor by Trade	No.	UF	Indexed ** hourly wage	Hourly wage	Type of Equipment	No	Hourly Rental	Hourly Rental
cement	qt	0.1	420.00	43.26	Foreman	1	0.25	40	10.63	tools	1	0.50	0.5
sand	m3	0.7	681.12	14.98	Plasterer	1	1	30	30.54	scafolding	1	10.00	10
water	m3	0.7	35.00	2.45	Chiseler	1	1	16.25	16.25				0
				0.00	Dl	1	1	12.5	12.5				0
Total (1:01)				60.69	Total (1:02)				69.92	Total (1:03)			10.5
A =Materal unit cost	60.69	birr/ m2			B =Labor cost	69.92	birr/ m2			C =Equipment cost	10.5	birr/ m2	
					Total of (1:02)					Total of (1:03)			
					Direct Cost of Work Item = A+B+C =					141.11			
					Over head cost :				15%	14.111			
					Profit Cost:				10%	21.1665			
					Total unit cost:					176.39			

Remark ____

UF: UTILIZATION FACTOR

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

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

Table C- 3 Plastering cost for the internal and external wall in Misrak atekalay

		ANALYSIS SHEET FOR DIRECT & INDIRECT COSTS											
PROJECT: FINISHING WORKS							LABOR DAILY OUTPUT:				1.875 m2/hr		
WORK ITEM:	6. ld		3 Coats of cement plastering (1:3) (To internal wall				EQUIPMENT DAILY OUT PUT:						
TOTAL QUANTITY OF WORK ITEM:	1.00 m 2								RESULT:		137.23Birr/m 2		
materail cos (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of materal	Unit	Qut *	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	34.2	Foreman	1	0.1	4	4	hand tools	2	0.50	1
sand	m3	0.019	600.00	11.16	Plasterer	1	1	35.5	35.5	scafolding	1	3.00	3
water	m3	0.07	100.00	7.00	Chiseler	1	1	12.5	12.5				0
				0.00	Dl	1	1	18.75	18.75				0
Total (1:01)				52.36	Total (1:02)				70.75	Total (1:03)			4
A =Materal unit cost	52.36	birr/ m2			B =Labor cos	54.42	birr/ m2			C =Equipment	3	birr/ m2	
					Total of (1:02)					Total of (1:03)			
					Direct Cost of Work Item = A+B+C =					109.78			
					Over head cost :				15%	10.978			
					Profit Cost:				10%	16.467			
					Total unit cost:					137.23			

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 COSTS											
PROJECT: FINISHING WORKS							LABOR DAILY OUTPUT:				1.875 m2/hr		
WORK ITEM:	(6.1b & c		3 Coats of cement plastering (1:3) (To internal wall)				EQUIPMENT DAILY OUT PUT:						
TOTAL QUANTITY OF WORK		1.00 m 2							RESULT:		140.53Birr/m 2		
materail cos (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of materal	Unit	Qut *	Rate	cost per unit	Labor by Tra	No.	UF	Indexed ** hourly wage	Hourly wage	Type of Equipment	No	Hourly Renta	Hourly Rental
cement	qt	0.08	450	36	Foreman	1	0.1	4	4	hand tools	2	0.50	
sand	m3	0.02	600.00	12.00	Plasterer	1	1	35.5	35.5	scafolding	1	3.00	
water	m3	0.07	100.00	7.00	Chiseler	1	1	12.5	12.5				
				0.00	Dl	1	1	18.75	18.75				
Total (1:01)				55.00	Total (1:02)				70.75	Total (1:03)			
=Materal unit cost	55.00	birr/ m2			B =Labor cos	54.42	birr/ m2			C =Equipmen	3	birr/ m2	
					Total of (1:02)					Total of (1:03)			
					Direct Cost of Work Item = A+B+C =					112.42			
					Over head cost :				15%	11.242			
					Profit Cost:				10%	16.863			
					Total unit cost:					140.53			

Remark ____

UF: UTILIZATION FACTOR

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

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

Table C- 4 Formwork unit cost as Addis Ababa construction bureau

		ANALYSIS SHEET FOR DIRECT & INDIRECT COSTS											
PROJECT	FORM WORKS			LABOR DAILY OUTPUT:			0.5 m2/hr.						
WORK ITEM: (4.28)	Form work(for all except slab)				EQUIPMENT DAILY OUT PUT:								
TOTAL QUANTITY OF WORK ITEM:		1 m 2			RESULT:		442.96 Birr/m 2						
materail cos (1:01)					Labor Cost (1:02)					Equipment Cost (1:03)			
Type of materal	Unit	Qut *	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	70.10	73.61	Foreman	1	0.17	64.21	10.72	tools	1	0.50	0.5
50 x 70 cm. battens	M	0.3	39.00	11.70	Carpenter	1	1	46.37	46.37	cranes	0.01	2300.00	23
Strut 0 60 mm	M	1.5	5.91	8.86	Ass.Carpenter	1	1	37.1	37.1				0
Nails	Kg	0.3	59.50	17.85	D/L	1	1	14.84	14.84				0
Mould Oil	Lit	0.05	17.85	0.8					0				0
				0.00					0				0
				0.00					0				0
Total (1:01)				112.82	Total (1:02)				109.03	Total (1:03)			23.5
A =Materal unit cost	112.82	birr/ m2			B =Labor cost	218.06	birr/ m2			C =Equipment	23.5	birr/ m2	
					Total of (1:02)					Total of (1:03)			
					Direct Cost of Work Item = A+B+C =					354.38			
					Over head cost :				8%	35.438			
					Profit Cost:				7%	53.157			
					Total unit cost:					442.98			

Remark ____

UF: UTILIZATION FACTOR

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

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

Appendix-D: Interview

Interview for Ovid group

1. What are the basic differences between you observe Kumkang aluminum formwork and conventional? Briefly define?
2. Why our construction industry less adaptation to modern formwork systems? And what do you expect to form government support?
3. How do you evaluate the productivity/performance of labor with respect to Kumkang formwork? And which method do you use to enhance labor productivity?
4. What is it’s the roleof Kumkang aluminum formwork on construction safety?
5. What is it’s the role of Kumkang aluminum formwork on building construction project in triple parameters?
6. What is aluminum formwork system and what is possible opportunity and challenges of aluminum formwork on building construction project?
7. Why your company select in Kumkang aluminum formwork material? Explain in your reason?
8. Do you think it is economically viable to use such formwork in the Ethiopian context?
9. 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?
10. What is your recommendation for other company and governmental support in Kumkang kind market availability, design, and size and shape perspective?
11. What is your suggestion for the other company aluminum formwork material for your assessment /trained?

Interview forFHC (Federal House Corporation)

1. Why you should be select in use the company Kumkang aluminum formwork material with conventional.

2. What is your perception on modern formwork systems? And why don’t you use them?

4. What initiate you to invite such kind of Construction Company that adopts this kind of formwork system?