A Comparative Study on the impact of using conventional and Aluminum form-work on building construction: A case study on Ovid Real Estate project in Addis Ababa

Debebe Kubrael Kurka

A Thesis Submitted to the Department of Civil Engineering

College of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement of Masters of Science in Civil Engineering (Specialization in Construction Engineering and Management)

Office of Graduate Studies

Adama Science and Technology University

May, 2025

Adama, Ethiopia

A Comparative study on the impact of using conventional and Aluminum form-work on building construction: A case study on Ovid Real Estate project in Addis Ababa

Debebe Kubrael Kurka

Advisor: Lemma Beressa (Ph.D.)

Co-advisor: Zerihun Mamo(MSc.)

A Thesis Submitted to the Department Of Civil Engineering
College Of Civil Engineering and Architecture

Presented in Partial Fulfillment of the Requirement of Masters of Science in Civil Engineering (Specialization in Construction Engineering and Management)

Office of Graduate Studies
Adama Science and Technology University

May, 2025
Adama, Ethiopia

Declaration

I declare that this Master Thesis entitled “A Comparative study on the impact of using conventional and Aluminum form-work on building construction: A case study on Ovid Real Estate project in Addis Ababa” is my original work. That is, it has not been submitted for the award of any academic degree, diploma or certificates in any other university.All sources of materials that are used for this thesis have been duly acknowledged through citation.

Debebe Kubrael	________________	________________
Name of student	Signature	Date

Recommendation of Advisors

We, the advisors of this thesis, hereby certify that we have closely advised the student while developing this thesis and read the thesis entitled "A Comparative study on the impact of using conventional and Aluminum form-work on building construction: A case study on Ovid Real Estate project in Addis Ababa" prepared under our guidance by Debebe kubrael. Therefore, we recommend the submitting the thesis to the department for further review and evaluation.

Lemma Beressa (Ph.D.)	________________________	________________
Major Advisor/Supervisor	Signature	Date
Zerihun Mamo (MSc.)	________________________	________________
Co-advisor/Co-supervisor	Signature	Date

Approval Sheet

We, the advisors of the thesis entitled "A Comparative study on the impact of using conventional and Aluminum form-work on building construction: A case study on Ovid Real Estate project in Addis Ababa" and developed by Debebe Kubrael, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

Lemma Beressa (Ph.D) ______________________ _______________

Major Advisor/Supervisor Signature Date

Zerihun Mamo (MSc.) ______________________ _______________

Co-advisor/Co-supervisor Signature Date

We, the undersigned, members of the Board of Examiners of the thesis by Debebe Kubrael have read and evaluated his thesis entitled "A Comparative Study on the impact of using conventional and Aluminum form-work on building construction: A case study on Ovid Real Estate project in Addis Ababa" and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Construction Engineering and Management.

______________________ ______________________ ______________________

Chairperson Signature Date

______________________ ______________________ ______________________

Internal Examiner Signature Date

______________________ ______________________ ______________________

External Examiner Signature Date

Finally, approval and acceptance of the thesis is contingent upon submission of its final copy to the Office of Postgraduate Studies (OPGS) through the Department Graduate Council (DGC) and School Graduate Committee (SGC).

______________________ ______________________ ______________________

Department Head Signature Date

______________________ ______________________ ______________________

College Dean Signature Date

______________________ ______________________ ______________________

Office of Postgraduate Studies Dean Signature Date

Acknowledgement

First and foremost, I would like to be praise to the Almighty God for his blessing to complete this Thesis paper.I extend my sincere appreciation to my advisor,Lemma Beressa(Ph.D.), and my co-advisor, Zerihun Mamo (MSc.), for their invaluable guidance and support. I am also thankful to the Ovid Construction staff, including Eng. Dress Abadi, Mr. Belete Gebre, and Mr. Natinael, for their assistance. A special thank you goes to my family for their unwavering encouragement, and to Mr. Besufikad Habtamu for his exceptional support during this endeavor.

Abstract

*This study examines the comparative impact of conventional and aluminum form-work systems on building construction, focusing on the Ovid real estate project in Addis Ababa. While conventional form-work increases labor costs and delays timelines, aluminum form-work offers speed, re-usability, and cost efficiency. The objective of this research is to analyze and evaluate implementation processes, time and cost performance, challenges in adopting kumkang aluminum form-work, and project quality using both qualitative and quantitative research approach. The research combines the use of descriptive and explanatory approach in which questionnaires, interviews and case studies are used to obtain relevant information about the subject from professional from ovid real estate project. Questionnaires (86.6% response rate from 52 participants), interviews, and case studies data were analyzed using tools such as spss-v27, excel 2010, and ms project. Key findings reveal that Kumkang aluminum form-work reduced costs by 48.54% (saving 8,653,220.83 ETB**)** and cut construction time by 67.6% (190.26 days faster) compared to timber form-work to construct 13 floor blocks. Aluminum form-work also demonstrated superior durability and re-usability (mean = 4.30 vs. 3.60), significantly improving construction outcomes ($\beta = 0.526$, $p < 0.01$). Its assembly was easier, requiring less labor, with a positive impact on performance ($\beta = 0.342$, $p < 0.01$). Additionally, it enhanced material efficiency (mean = 4.09), worker safety (mean = 4.09), and long-term cost-effectiveness despite higher initial investment cost (mean = 4.05). However, challenges such as high upfront costs, lack of skilled labor, and limited technical support hindered adoption (aggregate mean = 4.06).the study concludes that aluminum form-work outperforms conventional systems in cost, time, durability, safety, and sustainability, making it a superior choice for large-scale projects. Addressing adoption barriers could further enhance its implementation in Ethiopia's construction industry.*

Key words: Aluminum Form-work, Conventional Form-work, Cost, Duration and Quality

Table of Content

List of Table

List of Figure

List Of Appendixes

List of Acronyms

ACI	American Concrete Institute
BaTCoDA	Building and Transport Construction Design Authority
BIM	Building Information Modeling
BS	British Standard
EBCS	Ethiopian Building Code of Standard
GC	General Contractor
HCB	Hallow Concrete Block
IBS	Industrialized Building System
IC	Internal Corner
LCC	Life Cycle Cost
MB	Middle Beam
MH	Man Hour
MoUDC	Ministry of Urban Development and Construction
PH	Prop Head
PVC	Poly Vinyl Chloride
RC	Reinforced Concrete
RCC	Reinforced Cement Concrete
SC	Slab Corner
SPSS	Statistical Package for Social Science
IP	Implementation Process
DR	Durability and re-usability
MRR	Material and Resource Requirements
FDA	Flexibility and Design Adaptability
BC	Building Construction

1. INTRODUCTION

1.1 Background of the study

In recent years,the construction industry has undergone essential transformation, driven by advancements in technology, materials, & methodologies. One of the most notable innovations is the development and application of advanced form-work systems, which play an important role in shaping the efficiency, safety, and quality of building projects. In Ethiopia, the construction industry is growing and the need for specialization, technology, and proper management of projects is becoming vital. Especially in a country where shortage of resources is prevalent, significant amount of time and ultimately cost (Zinabu, 2022).

"Ethiopia is one of the developing countries with fast urbanization". Many high-rise buildings are being constructed in urban areas, especially in the capital Addis Ababa, due to increased population and businesses. The majority of high-rise buildings are concrete works which are one of the most important elements in such huge infrastructures. Fast and efficient construction of the concrete is therefore, essential to maintain phased (gradually staged) progress on other parts of the building (Getaw Tessema, 2019).

The advancement of technology, increase of population and the space limitation lead the way to construct high-rise buildings. But the task was not very easy at the beginning but now the man made the task easy by inventing new machinery and new techniques(Sandip.P.Pawar1, 2014).

In the construction of a building, contractors always need form-work to cast concrete. form-work is a temporary mold used to bear the load during which the concrete is poured and molded according to the desired shape. Due to its function as a temporary mold, the form-work will be removed or dismantled when the concrete has dried up and reached sufficient strength. Good form-work material is one that meets several requirements. The form-work material should have good quality in terms of strength, durability, and rigidity, should be safe for workers and concrete structures, should possess good efficiency in operation, easy to handle, and dismantle, and should be economical. It also should be strong enough to withstand the dead and live load(Risma Apdeni1*, James Hellyward 2, 2024).

Form-work systems are among the key factors determining the success of a construction project in terms of speed, quality, cost and safety of the works. Construction industry is seen to be able to play a bigger role into a sustainable society by offering sustainable construction.

form-work system is one of the important construction methods in building construction(Ashish P. Waghmare, 2017).

In Ethiopia, the real estate sector has experienced substantial growth, fueled by urbanization, population growth, and increased demand for housing. This surge in construction activity has necessitated the adoption of modern building techniques to meet the growing needs of the population while ensuring sustainability and cost-effectiveness. As a result, companies like Ovid Real Estate have begun implementing advanced form-work practices to enhance their project delivery and competitiveness. To speed up form-work assembling time, OVID Construction Plc., a GC-1 Contractor of the project, deployed modern form-work technology which is new to the country called Kumkang Aluminum form-work technology. Easy assembling mechanism used in this form-work system enabled the project to speed up the casting of concrete structures(Zinabu, 2022).

Aluminum form-work is gaining traction due to its lightweight properties, ease of handling, and re-usability. It allows for faster construction times and reduced labor costs, making it an attractive option for developers and contractors. In contrast, conventional form-work systems, while widely used and understood, can lead to increased material waste, longer setup times, and higher labor costs due to their heavier nature and the complexity of assembly. The selection of a form-work system and materials for the construction of concrete structure would seriously influence the quality as well as cost and time of project delivery (Getaw Tessema, 2019).

The need for a comparative study arises from the increasing interest in optimizing construction processes in the face of rising costs and project delays. The current study aims to evaluate the impact of using conventional versus aluminum form-work on three critical dimensions: cost, duration, and quality. By focusing on a specific case study involving Ovid Real Estate's selected project, this research provide valuable insights into how different form-work systems affect project outcomes.

Understanding these impacts is essential for stakeholders in the construction industry, including project managers, architects, engineers, and investors.

1.2 Statement of the Problem

The construction industry faces persistent challenges related to cost overruns, project delays, and quality assurance, which significantly impact overall project success and stakeholder satisfaction. Almost all building projects in our country are not lucky to be delivered successfully to the client according to finding of (Bereket Amare Sida, 2015).

Form-work, a crucial component in concrete construction, plays a vital role in determining these outcomes. Traditional conventional form-work systems, while widely used, often lead to increased material waste, longer setup and dismantling times, and higher labor costs. The use of modern form-work systems will increase the local labor productivity to ten times the traditional one(Argaw Tarekegn, 2010).

In contrast, aluminum form-work systems have emerged as a modern alternative that claims to offer advantages in terms of reduced weight, faster assembly, and enhanced re-usability. The system of Aluminum forms has been used widely in the construction of residential units and mass housing projects. It is fast, simple, adaptable and cost - effective. It produces total quality work which requires minimum maintenance and when durability is the prime consideration(Harle, 2018).

Despite the theoretical benefits of aluminum form-work, there is a lack of empirical evidence comparing its performance against conventional form-work systems in Ethiopia construction projects. This gap in knowledge raises critical questions regarding the actual impact of these two form-work systems on key project metrics: cost, duration, and quality. Specifically, stakeholders in the construction industry, including project managers and investors at Ovid Real Estate, require a comprehensive understanding of how the choice of form-work can influence project outcomes.

Therefore, current study seeks to address the impacts of using conventional versus aluminum form-work on the cost, duration, and quality of construction projects. By focusing on a selected project by Ovid Real Estate, the current research aims to provide valuable insights that can inform decision-making processes and contribute to more efficient construction practices. The findings help stakeholders understand the trade-offs involved in selecting form-work systems and ultimately support improved project delivery in the competitive landscape of real estate development.

1.3 Research Questions

1. How is aluminum form-work implemented in Ovid Real estate construction work process?
2. What are the differences in construction costs between conventional and aluminum form-work systems in the Ovid Real Estate project?
3. How do the time-frames for various construction phases differ when using conventional versus aluminum form-work?
4. How does selection of form-work system affect the quality of the structure, re-usability, durability , flexibility and design adaptability?
5. What challenges do the Ethiopian contractor face in adapting Aluminum form-work?

1.4 Objectives of the study

1.4.1 General objective

This study aimed to obtain a Comparative study on the impact of using conventional and Aluminum form-work on building construction: a case study on Ovid Real Estate selected project in Addis Ababa.

1.4.2 Specific objectives

The specific objectives of the current study is to adhere the impact of using aluminum and conventional form-work by analyzing the following critical project factor:-

1. To examine the implementation process of aluminum form-work
2. To compare the construction costs associated with conventional form-work and aluminum form-work
3. To evaluate the time required for the construction work using both conventional and aluminum form-work
4. To assess the impact of form-work selection on the structural quality, durability, while assessing their adaptability to design changes and re-usability for sustainable practices
5. To evaluate the challenges encountered by Ethiopian Contractor to use aluminum form-work .

1.5 Significance of the Study

The significance of this study lies in its potential to provide valuable insights into the construction industry, particularly in the context of form-work systems. The comparative study of conventional and aluminum form-work in relation to cost, duration, and quality. The study also holds significance for multiple stakeholders in the construction field by enhancing understanding of form-work systems, promoting cost and time efficiency, ensuring quality outcomes, and supporting sustainable practices. The insights derived from this research have the potential to influence project success and drive innovation in construction methodologies.

The findings also contribute to a deeper understanding of how modern construction techniques can influence various aspects of building projects, including cost efficiency, time management, quality control, and the adaptability of local contractors to innovative methods.

Implementation of Aluminum Form-work: By examining how aluminum form-work is integrated into the construction processes at Ovid Real Estate, this study will highlight best practices and potential areas for improvement. This knowledge can serve as a reference for other construction firms looking to adopt similar systems, ultimately promoting efficiency and innovation in the industry.

Cost Comparison: Investigating the differences in overall construction costs between conventional and aluminum form-work systems will provide crucial data for stakeholders. Understanding the financial implications of each system can aid in decision-making for future projects, potentially leading to cost savings and more strategic resource allocation. This analysis is particularly significant in a developing economy like Ethiopia, where budget constraints are often a critical concern.

Time-frame Analysis: The study's focus on time management will shed light on how different form-work systems impact the duration of various construction phases. Efficient time management is essential for project success, and insights gained from this research can help optimize scheduling and improve project delivery timelines, which is vital for maintaining competitive advantage in the real estate market.

Quality Assessment: By evaluating how form-work systems affect the quality of finished structures, including surface finish and structural integrity, this study will contribute to the discourse on construction quality standards. High-quality construction is essential for safety, durability, and customer satisfaction. Findings from this research can inform best practices that ensure high-quality outcomes in future projects.

Challenges Faced by Ethiopian Contractors: Understanding the challenges that Ethiopian contractors encounter when adapting aluminum form-work is crucial for fostering innovation and improving local capacity. This aspect is particularly significant for enhancing the competitiveness of local contractors in an evolving market.

1.6 Scope of the Study

This study focuses on a comparative study of the impact of using conventional form-work versus aluminum form-work in building construction, specifically within the context of the Ovid Real Estate project located in Addis Ababa, Edthiopia. Geographical Limitation of research is confined to the Ovid Real Estate project in Addis Ababa project of G+12+Terrace mixed block project found at in-front of Ras Amba hotel and Ovid Gelan Gura City projects due to the only active project currently used Aluminum Form-work in Ovid Company. Findings may not be directly applicable to other regions or projects due to variations in local construction practices, materials, labor availability, and regulatory frameworks. The study exclusively examines the impact of form-work systems on building construction, particularly in residential or commercial structures developed by Ovid Real Estate. It does not extend to infrastructure projects such as bridges or roads. The analysis focus only on two types of form-work, conventional timber form-work and aluminum form-work. Other form-work systems, such as plastic, steel, or modular systems, will not be considered in this study. The study also evaluate specific impact parameters including construction time, cost efficiency, labor productivity, and quality of finished work. Other aspects such as environmental impact or long-term durability of the structures will not be the primary focus of this research.

1.7 Limitations of the Study

The study faced several limitations,One of the significant limitations encountered during this study was the shortage of skilled manpower available to respond to the questionnaires. Many potential respondents, including project managers, engineers, and construction workers, were often engaged in their daily tasks and responsibilities, limiting their availability for participation. Another challenge faced during the research was a lack of interest among some potential respondents to engage with the study survey.The study was also constrained by the limited number of projects available for analysis within Ovid Real Estate that employed aluminum form-work systems. This restriction not only reduced the pool of potential respondents but also limited the diversity of experiences and perspectives that could be captured.

1.8 Organization of the study

The researcher organized the current study into five chapters. The first chapter cover's the background of the study, the statement of the problem, study objectives, research question, significance of the study and scope of the study. The second chapter discussed the related literature review about the subject matter. Chapter three contained the research methodologies such as research design and research approach, source of data, data gathering tools, sample size and sample techniques, and methods of data analysis. The fourth chapter discussed about research finding and analysis. The fifth chapter also incorporated conclusion and recommendations of the research.

2.LITERATURE REVIEW

2.1 Introduction

This chapter aimed at giving insight to the researcher regarding the study. It included literature works from the books, articles, journals and previous studies which are relevant to Conventional and Aluminum form-work based on Cost, Duration and Quality.

2.2 Concrete form-work

Form is a temporary structure or mold for the support of concrete while it is setting and gaining sufficient strength to be self-supporting (Bezaye Girma Tamer, 2017). Form-work is the total system of support for freshly placed concrete including the mold which contacts the concrete, as well as all supporting members, and necessary bracing. Forms are essential to concrete construction. They mold concrete to the desired size and shape and control its position, alignment, and surface contour. It is a temporary structure that supports its own weight, the weight of the freshly placed concrete, construction loads such as materials, equipment, and, and other possible live loads during construction (Argaw Tarekegn, 2010).

According to (Loganathan & Viswanathan, 2016) form-work is defined as temporary structures to support the concrete until it support itself. It moulds the concrete to different types of form-work used in construction, generally differing according to the building requirements. form-works are generally made by wood, steel, aluminum or prefabricated forms into which the concrete is poured. The form-work used to cast the structural elements such as, columns, beams, slabs and shear walls also used for smaller parts of building such as stairs, etc.

As fresh concrete is in a plastic state, when it is placed for construction purpose, it becomes necessary to provide some temporary structure to confine and support the concrete, till it gains sufficient strength for self-supporting. This temporary structure is known as form work(Meron Tadesse, 2016)

Form-work is a crucial component of construction influencing various factors such as cost, time, wastage, and labor requirements. Proper selection of form-work is essential to reduce overall construction project costs, ensuring efficient project completion and reduced wastage.(Chitra Kendre1*, 2024)

form-work, which consists of a die or mold and any supporting structures, is used to shape and support concrete until it reaches a strength that allows it to support itself. Aside from its own weight, it should be able to support any imposed dead and live loads. The surface in contact with the concrete and any required supporting structure are included in the form-work(Sharma et al., 2024)

(Rajeshkumar & Sreevidya, 2019) finds that form-work cost 40 to 60% of structural work in construction. form-work should have good quality in terms of strength, durability and rigidity and it should be safe to workers and concrete structures and should possess good efficiency in operation, easy to handle and should be economical.

2.3 Form-work System

A form-work system is a temporary or permanent structure used to support and shape concrete while it sets and hardens. It provides the necessary mold for the concrete to achieve the desired shape and dimensions. form-work is crucial in construction, particularly for elements such as walls, slabs, beams, and columns. The type of form-work systems used is among the key factors determining the success of a construction project in terms of speed, quality, cost and safety of works. Therefore, selecting the form-work system, that is, making structural frames faster, simpler, and less costly to build, must begin in the earliest phase of the design efforts.(Bereket Amare Sida, 2015)

Construction industry is seen to be able to play a bigger role into a sustainable society by offering sustainable construction. form-work system is one of the important construction methods in building construction.(Ashish P. Waghmare, 2017)

System form-work has prefabricated modular components with casting panels. The system form-work is fabricated as it suits the required shape. The biggest advantage of this type is the speedy and quality construction. But the high initial cost is the main disadvantage and hence it is not economical to use in low – rise buildings. But this is the most economical form of form-work type to be used in high-rise building construction when it is having few typical stores.(Sandip.P.Pawar1, 2014)

2.4 Selecting criteria for form-work system

(Chitra Kendre1*, 2024) states that during a planning and Selection of form-work for a given building shall be considered the listed factor :-Erection time, Cost of Labor and labor skill requirements, Ease of Installation method , Repetitive Nature of Structure and Geometry of Structure.

2.5 Requirements of form-work

Economy, safety, speed and quality are some of the requirements to be fulfilled by form-works. These requirements has been be described in the following sub-sections

2.5.1Economy

The cost of material should not be very high. The assembly and dismantling or stripping time should not be very long, to save time and money during concreting.(Harle, 2018)

According to (Argaw Tarekegn, 2010) form-work is the largest cost component for a typical multistory reinforced concrete building. its cost accounts for 40 to 60 percent of the cost of the concrete frame and for approximately 10 percent of the total building cost in developed country. A large proportion of the cost of conventional form-work is related to form-work labor costs in developed country. Significant cost saving could be achieved by reducing labor costs (Nawy, 2008)

2.5.2 Speed

Speed of construction is defined as the rate in which concrete building is raised and can be expressed in terms of number of floors erected per week or months. Speed of construction can be also measured in terms of inches or millimeters of concrete poured per hour(Argaw Tarekegn, 2010). form-work operations can control the pace of construction projects. Faster form-work cycle from erection to stripping would allow for faster removal of shoring and reshoring and faster overall project progress (Nawy, 2008)

2.5.3 Quality

Many concrete-related problems such as discoloration, stains, and dusting are attributed to concrete form-work. Also, some deformed concrete surfaces are due to deformed form-work systems caused by repetitive reuse and inadequate support of form-work and states that the quality of concrete can be affected by form-work in the following ways(Getaw Tessema, 2019)

a. The accurate shape of the form-work panel
b. Dimensional accuracy of the form-work
c. The verticality, leveling or alignment of the form-work
d. The tightness of joining of the panels
e. Whether the panel surfaces is in good condition

The form-work should give adjust right edges and plane surface with the goal that completing expense subsequent to expelling form-work is limited. The joints in the form-work ought to be unbending with the goal that the swelling, turning, or listing, because of dead and live load is as little as could be expected under the circumstances. Unnecessary distortion may deform the surface of cement(Harle, 2018)

2.5.4 Safety and Health

Form-work operations are risky, and workers are typically exposed to unsafe working conditions. Partial or total failure of concrete form-work is a major contributor to deaths, injuries, and property damages within the construction industry. Structural collapses and failures involving concrete structures account for 25 percent of all construction failures. More than 50 percent of concrete structure failure during construction is attributed to form-work failure (Nawy, 2008). Though there is no proper documentation of the construction failure in Ethiopia, the percentage of collapses which are caused by defects in form-work construction is not less than.(Argaw Tarekegn, 2010)

2.6 Classification of form-work

Form-work can be classified according to a variety of categories; relating to the differences in sizes, the location of use, construction materials, nature of operation, or simply by the brand name of the products (Harle, 2018)

2.6.1 Classification according to size

Classification according to the size of form-work can be very straight forward. In practice, there are only two sizes for form-work; small-sized and large-sized. Any size which is designed for operation by workers manually is small-sized. Very often, the erection process is preferably handled by a single worker, with site work best done independently to avoid possible waiting times. Due to reasons of size and weight, the materials and construction of small-sized form-work are thus limited.(Harle, 2018)

2.6.2 Classification according to the location of use

Different elements in the structure of building have different design and performance requirements in the use of form-work. A number of form-work systems are particularly designed for constructing internal or external walls, vertical shafts, columns, beams and floor slabs.

i. Slab form-work

Slab form-work is the type of form-work mostly found in structures/buildings. The form-work sheeting may consist of sheeting boards or prefabricated sheeting panels. The form-work sheeting lies on squared timber form-work bearers which are arranged on main bearers carrying off the forces to round timber columns. With smaller rooms, the main bearer together with two columns, form a trestle.

ii. Wall form-work

Wall form-work consists of vertically arranged upright timbers (form-work holder) to which sheeting boards are nailed at the concrete side. The upright timbers are diagonally braced by means of boards at both sides. On cleats situated at every third upright timber, there are horizontally arranged wall clamps. The opposite wall clamps are tied at specified distances. Prefabricated sheeting panels may also be used instead of sheeting boards. Cleaning holes are to be provided at the foot of the form-work.

iii. Beam form-work

Beam form-work has prefabricated form-work sheeting parts (sheeting bottom and side sheeting panels). Such individual parts are manufactured based on the beam dimensions specified in the project. For prefabrication of the form-work sheeting parts, a special preparation table must be manufactured on site.

The sheeting bottom and the side panels consist of sheeting boards nailed together by means of cover straps. Depending on the size of beam, the width of sheeting bottom is dimensioned so as to accept, at both sides of the width of the reinforced concrete column, the thickness of the sheeting and cover straps and the width of a thrust-board (approximately 100 mm). The sheeting bottom can be placed on a pedestal support (a support formed by a wall clamps connected with two columns by means of cleats) or on a round timber column also supporting a wall clamps with cleat connection. In the latter case, the round timber column is located under the center of the beam.

By diagonal board bracing the round timber column and the wall clamps above it, a composite triangle is formed. The side sheeting is erected on the sheeting bottom and held by a thrust-board. At the upper edge of the side sheeting a wall clamps is mounted at both sides holding together the form-work by wire or spindle ties. A stull-batten is to be nailed on the form-work immediately above the ties to ensure that the projected beam width is kept when tying the form-work. The wall clamps and the columns are additionally braced by diagonal boards

iv. Column form-work

Similar to beam form-works, the sheeting of column form-works are prefabricated according to the column dimensions from sheeting boards connected by cover straps. The sheeting panels are placed in a foot rim which is anchored in the soil by steel bolts. The foot frame consists of double-nailed boards. The foot frame must be exactly measured-in because it is decisive for the exact location of the column. It has the same functions as the thrust-board for foundation or beam form-work.

When the sheeting panels have been inserted in the foot frame, vertical arch timbers are placed to take up the forces from the cover straps of the form-work sheeting. Around the arch timbers, which have the function of walers, column clamps of flat steel are clamped with wedges or a rim of boards is arranged similar to the foot frame. Additional form-work teeing by tie wires or steel screws is not necessary. The distances of the clamps are specified in the form-work project. Normally they are approximately 700 mm (Harle, 2018)

2.6.3 Classification according to materials of construction

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

i. Timber form-work

Timber for form-work should satisfy the following requirement: It should be Well-seasoned, Light in weight, easily workable with nails without splitting and Free from loose knots. Timber used for shuttering for exposed concrete work should have smooth and even surface on all faces which come in contact with concrete. Normal sizes of members for timber form-work Plywood form-work

Resin bonded plywood sheets are attached to timber frames to make up panels of required sizes. The cost of plywood form-work compares favorably with that of timber shuttering and it may even prove cheaper in certain cases in view of the following considerations (Harle, 2018)

It is possible to have smooth finish where cost in surface finishing is involved, By use of large size panels it is possible to effect saving in the labor cost of fixing and Removal, Number of reuses is more as compared with timber shuttering. For estimation purpose, Number of reuses can be taken as 20 to 25., If you have holes in your ply, plug them up, or else accept ugly lumps and loss of fines on your finished concrete surface, Apart from the nails fixing ply to make up forms, the rest of the nails on a form-work job are never driven home fully. They are left, or bent over so that they can be pulled out easily with a claw hammer or pinch bar when it comes time to strip the forms (Harle, 2018)

ii. Steel form-work

This consists of panels fabricated out of thin steel plates stiffened along the edges by small steel angles. The panel units can be held together through the use of suitable clamps or bolts and nuts. The panels can be fabricated in large number in any desired modular shape or size. Steel forms are largely used in large projects or in situation where large number reuses of the shuttering is possible. This type of shuttering is considered most suitable for circular or curved structures. If the form is rusty, you might get rust on the surface of your concrete(Harle, 2018)

iii. Plastic form-work

Re-usable plastic form-work: These interlocking and modular systems are used to build widely variable, but relatively simple, concrete structures. The panels are lightweight and very robust. They are especially suited for low-cost, mass housing schemes. The form-work stays in place after the concrete has cured, and provides (Harle, 2018)

2.7 Building Construction form-work Practices in Ethiopia

There are not many literature s written on the form-work construction practices in our country, however it is clearly noticed that the technology of form-works in Ethiopia is at an infant stage and conventional timber, plywood and steel form-works widely implemented. This situation is attested through reviewing the construction practices of sites in capital Addis Ababa and other cities in the country.

2.7.1 Types of form-work Used In Ethiopia

By reviewing the existing literature's and present the following findings on sample construction projects in Addis Ababa, Bahirdar and benishangul gumuze region.

According to (Bezaye Girma Tamer, 2017) finding the observation and interview made in Bahir Dar, form-work materials of timber, steel and reworked old metal barrel are commonly used for construction of different parts of the building as shown on figure -1 below.

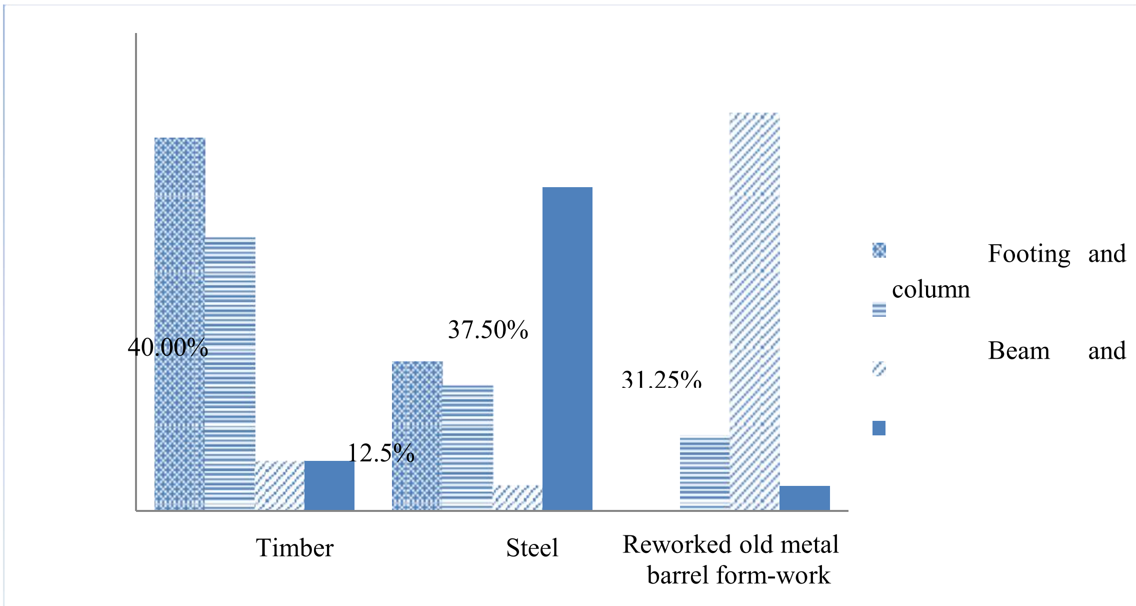


Figure 2: 1Summary of finding of form-work (Bezaye Girma)

According to the survey made in Addis Ababa 70% uses combination of both steel panels and timber boards as form-work materials. About 5% of the respondents use steel, 20% use timber and 5% use yellow timber as form-work material.(Meron Tadesse, 2016)

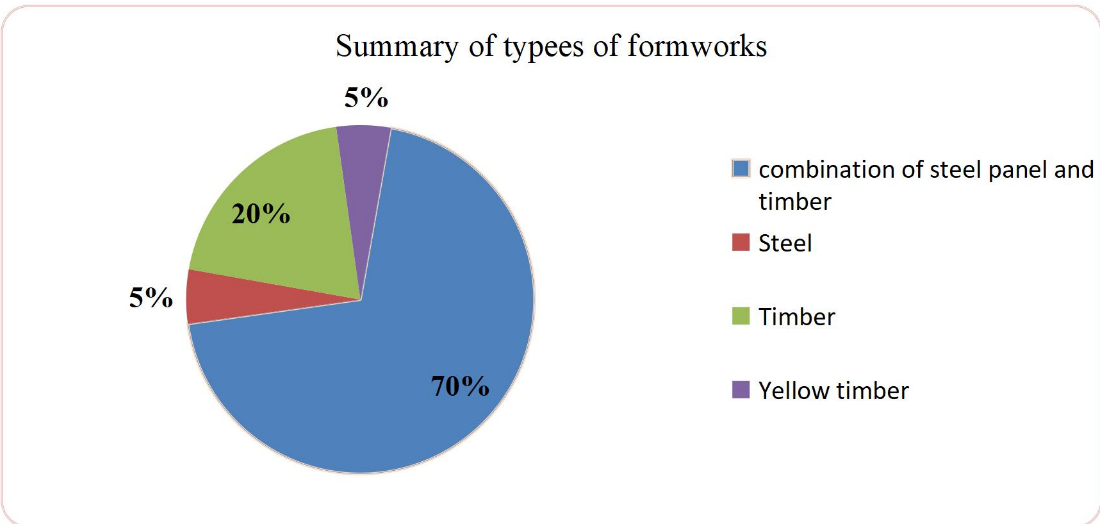


Figure 2: 2 Summary of finding 0n form-work (Meron Tadase 2016)

Another survey made by (Argaw Tarekegn, 2010) on twenty-five contractors of grade one to six in Addis Ababa indicates that, 100% of the respondents use steel panels and timber boards as form-work materials. These materials are used for casting concrete of almost all structural members such as footing pad, column, beam, slab and wall. About 79% of the respondents use plywood, 16% use precast concrete and wood particle boards and 11% use hardboard as form-work material.

(Bereket Amare Sida, 2015) finds from his survey on ongoing building construction projects in Benshangul Gumuz region. 69% of the respondents agreed that the most common form-work material is timber. The second available form-work material is steel or metal form-work since 27% of the respondents said so. The left 4% respondents said Bamboo.

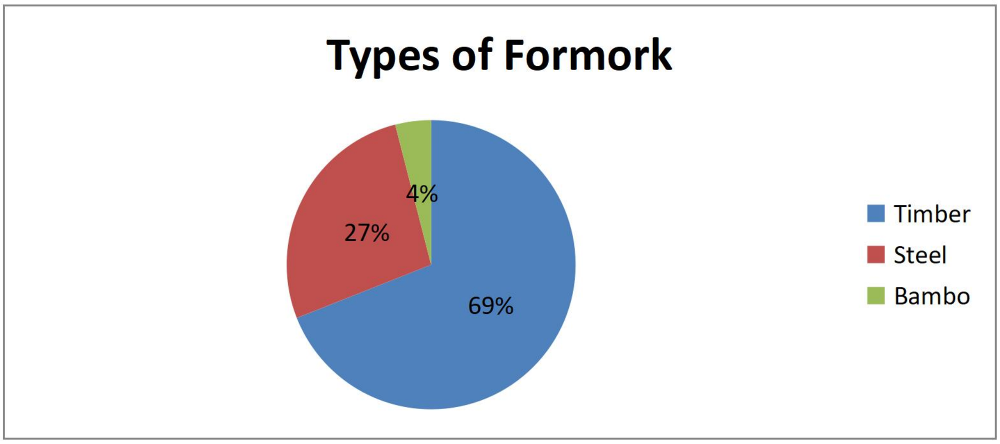


Figure 2: 3 Summary of finding on form-work (Bereket Amare ,2015)

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

From the above observations it can be conclude that Ethiopian building construction industry is dominated by conventional timber and steel form-works.

2.7.2 Conventional form-work Systems

This is the oldest type of form-work used in the construction industry. This type uses timber, bamboo, masonry and carpentry in the construction. This type is very much suitable for small houses with two to three stories and still they are in use for such constructions. However, this is not suitable for the big projects or high-rise buildings states by (Loganathan & Viswanathan, 2016). It is form-work 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 non-durable(Chitra Kendre1*, 2024)

Although this type of form-works has advantages for low initial cost, low labor experience requirements and low weight, high floor cycle wastage, low re-usability, poor finish, and high labor requirement are on the other hand, the disadvantages. This is the type of form-work where most of the carpenters started as daily laborers and takes longer time to assemble and erect(Getaw Tessema, 2019). Conventional form-work systems especially wooden form-works have the following merits and demerits(Getaw Tessema, 2019)

Some of the advantages such systems are:

Flexibility. Because the system is built piece by piece, it is virtually capable of forming any concrete shape. A complicated architectural design can be formed by this system.

Economy. This system is not economical in terms of labor productivity and material waste. However, the system may be economical for small projects with limited potential reuses. The system has the advantage of low makeup cost or initial cost. Also, for restricted site conditions, where storage areas are not available and the use of cranes is difficult, the conventional wood system might be the only feasible alternative.

Availability. Wood is a construction material that is available virtually anywhere. In areas where form-work suppliers are not available, a conventional wood system may be the only feasible alternative.

The major problems associated with conventional form-work systems are:

Labor Intensive. The conventional form-work system is a labor-intensive system and considered as demerit for developed country.

High waste. Erecting and dismantling conventional form-work is conducted piece by piece. This causes breaking of edges and deformation of wood. It is estimated that 5 percent waste is generated from a single use of form-work.

Limited number of reuses. Number of reuses is the key to an economical form-work construction. A limited number of reuses force the contractor to use several sets of form-work; this adds to the expense of form-work construction.

Higher quality of labor force and supervision. Conventional form-work systems work best with a high-quality labor force and adequate supervision.

Limited spans. Since dimension wood is low strength compared to that of aluminum and steel sections, it has limited use in applications where long spans are desired (Www.kumkangkind.com, 2016)

The listed problems listed above leads us to assess the newly emerging form-work system in Ethiopia construction sector involved on aluminum form-work system.

2.7.3 Trends of Implementing Modern form-work systems in Ethiopia

The implementation of modern form-work system is very rare in Ethiopian construction sector. But, Recently Federal Housing Corporation with collaboration of OVID Construction PLC started using South Korean Kumkang form-work technology on two sites in Addis Ababa. At Gerji site for 500 units of housing construction project which is being undertaken by OVID Construction PLC in which the project has a total consumption of 59,966.46 m3 of concrete (Zinabu, 2022)

It is noticed that the stakeholders is surprised by the achieved speed of construction and it was remain the headlines on many media outlets. However, since there are no literature s and accessible data about comparisons of achieved results in these typical projects with similar sites constructed in conventional systems, this research paper have used other literature s to discuss the characteristic findings on application of aluminum form-work in other countries.

Figure 2: 4 Gerji higher official housing projects in Ethiopia

2.7.4 Aluminum form-work System

It is 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.(Chitra Kendre1*, 2024) Aluminum form-work is concurring the world of construction in today's date. To meet the ever increasing demands of the population contractors, investors and engineers are striving hard to reduce cost of construction and making housing economical. Pr-fabricated technology, form-work technology, Precast technology are various technologies which cater speed in construction.(Bhargavi S. & Shelake, 2018)

In Ethiopia the modern technology of form-work is not well adapted, instead mostly used type is timber planks supported on timber columns. Contractors select their own type based on the availability of form-work materials; without considering the influence of form-work on the strength and durability of concrete, cost and safety during construction and surface quality of the finished product(Bezaye Girma Tamer, 2017)

Aluminum form-work system used in cast in-situ concrete wall and floor slabs, and provides cast monolithic structural system in one continuous pour. Large room sized forms for walls and floors slabs are erected at site. These forms are made strong and sturdy, fabricated with accuracy and easy to handle. They afford large number of repetitions (around 250 times).(Getaw Tessema, 2019)

Aluminum form-work has been shown to significantly improve construction speed and efficiency compared to traditional construction methods due to the reusable and easy-to-assemble nature of aluminum form-work, which allows for rapid progression of construction projects and enables the construction of monolithic structures, which results in better structural integrity and reduced risk of leakage or cracking(Sharma et al., 2024)

Aluminum form-work is a modular construction technology that involves the use of pr-engineered and pr-fabricated form-work systems to construct walls, slabs, and columns in a building. It was developed by W. J. Malone, a Canadian Engineer in the late 1970s as a system for constructing low–cost housing unit in developing countries.

Aluminum form-work is highly suited to load bearing wall construction whereas traditional form-work consisting of plywood and timber is not suitable to the high pressures of fresh concrete on the wall(Bhargavi S. & Shelake, 2018)

There are many manufactures and different brands of modular aluminum form-works however; in this Research KUMKANG aluminum form-work system is discussed.

2.7.5 Kumkang Aluminium form-work Technique

Kumkang technique is a revolutionary aluminum form-work technique which is forming its base in construction field. It was invented in Korea in 1979.This form-work system is suitable for both residential &commercial construction.(Bhargavi S. & Shelake, 2018)

This is a unique form-work system in which walls, columns, beams, staircase, balconies along with door and window opening are cast in place.

2.7.5.1 Components used in Kumkang Aluminium form-work technique

Slab Panels- The slab panel will be used to support the concrete weight during concrete pouring and casting.

2Wall Panels - Wall panels are available in various sizes and in Kumkang form-work technique they can be customized as per the need of the architectural design. .

Pipe Prop Support- It remains under the prop head. Pipe support along with prop head remains in place until two levels are casted. The pipe support is used to support the weight of slab during pouring and casting.

Slab Corner- Acts as a connection wall panel and slab panel. Slab corner is of two types slab corners inner and outer.

Prop Head: Used to join mid beam and end beam, pipe support is placed under the prop.

Wedges, Long Pins And Round Pins: Long pin along with wedge pin is used to fix joint pin with prop head and beams. Round pin and Wedge pins are used in securing flat ties.

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.

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.

Waller Bracket And Square Tie: The Waller bracket and square pipes are used to allow the horizontal straightness of the wall panel as well as wall surface after casting.(Bhargavi S. & Shelake, 2018)

2.7.5.2 Advantage of Kumkang Aluminum form-work System

It will offer the most trustful, secure, efficient, and cutting edge of form-work system technology available on the market(Www.kumkangkind.com, n.d.)

Speed - Due to its easiness of assembly, Kumkang Aluminum form-work allows an average of 4~7 days cycle compared to 14~30 days cycle with the conventional method.

Quality - With a smooth surface and accurate dimension of panels, there is no requirement of plastering or remedial work after concrete casting.

Safety - No need to remove props and prop heads when dismantling slab panels.

Easy assembly - No need for skilled workers nor carpenters.

All-in-one system - With Kumkang Aluminum form-work, shoring and external working platforms are also supplied.

Mobility - The form-work panels will be transferred manually to the next level through a slab transfer box; thus, the crane can be used for other tasks.

Freedom of design & jobsite planning - Unlike tunnel for table form-work, Kumkang Kind's Aluminum form-work is a "modular" form-work; there is no constraint on any architectural or structural design.

Durability - Manufactured through a state of art technology with an aluminum alloy extrusion, this form-work can be repeated over 300 times.(kumkangkind.com, n.d.)

Table 2: 1 Advantage of Kumkang aluminum form-work

Characteristics	**Formwork Type Comparison**				
	Hard held Formwork	**Tunnel Formwork**	**Table Formwork**	**Traditional Form-work**	**Kumkang Aluminum Formwork**
No cranes or other heavy equipment required	✓				✓
Allows to pour wall, slab, beam, column, and staircase in 1 single concrete pour		✓			✓
Dismantle slab panels without removing props					✓
Can form concrete columns and beams together	✓			✓	✓
NO Skilled labor required	✓				✓
Suitable for stage (10 or two) (2 storey buildings)		✓	✓	✓	✓
Suitable for high-rise buildings				✓	✓
Form-work equipment adapts to different designs					✓
Able to form all				✓	✓

concrete elements					
Lowest form-work to forming area ratio					✓
Meets all architectural and structural requirements of the client, without modification	✓			✓	✓
Self-correction feature providing unmatched forming accuracy	✓				✓
Environmentally-friendly - no huge debris, no messy disposals					✓

2.7.5.3 Working cycle of Kumkang Aluminum form-work System

According to (Bhargavi S. & Shelake, 2018) the erection process of kumkang aluminum form-work system takes eight major steps to construct within eight day.

DAY 1 Erecting wall reinforcement.

DAY 2- Erecting form-work

DAY 3- Slab reinforcement and electrical fittings

DAY 4- Completing Electrical works and overall checking

DAY 5- Concrete pouring

DAY 6- De-shuttering and vertical form-work

DAY 7- De-shuttering slab and beam panels

DAY 8- Overall checking and finishing works

2.7.6 Components of Aluminum form-work systems

Aluminum form-work is a modular system comprised from different components, the basic element of the form-work is the panel, which is an extruded aluminum rail section, welded to an aluminum sheet. This produces a lightweight panel with an excellent stiffness to weight ratio, yielding minimal deflection under concrete loading. Panels are manufactured in the size and shape to suit the requirements of specific projects. The panels are made from high strength aluminum alloy with a 4 mm thick skin plate and 6mm thick ribbing behind to stiffen the panels(Www.kumkangkind.com, n.d.)

The components are interconnected to each other and also designed in the same perspective. The different components are named or numbered according to the series of their construction erection progress and should be done in the similar way. This makes it easier for the supervisor to understand the errors to be minimized during erection.

The Following are the components that are regularly used in the construction(Www.kumkangkind.com, n.d.)

i. Slab Components:

Slab panel (sp), slab prop head (sph), mid / end beam (mb / eb), slab corner (sc), beam splice bar (bsb) and prop length (pl)

ii. **Wall Components:**

Wall panel (wp), external corner (ec), rocker (rk), internal corner (ic), kicker (k) and pin and wedge

iii. Beam Components:

Beam panel (bp), bulk head horizontal (bhh), beam prop head (bph), soffit corner internal (sci), beam soffit panel (bsp) and soffit corner external (sce)

2.7.7 Floor cycle

The following chart shows the slab cycle for construction in Aluminum form-work, showing the minimum required cast for casting a slab in such form-work proving time efficient factor (kumkangkind.com, n.d.)

2.7.8. Reference projects of KUMKANG aluminum technology on the world

Figure 2: 780 logements LPA, Oued-Rhiou Algeria

Figure 2: 8 50,000 housing project, Tripoli Libya

2.8 Gap Identification

(Argaw Tarekegn, 2010)"Application of Modern form-work Systems in Ethiopia"; found that Steel panels and timber boards are the most commonly used form-work materials in Ethiopia and the cost of form-work is about 26% of the total cost of in-situ concrete in Addis Ababa. form-work material costs more than form work labor costs in Ethiopia, The study only shows conventional form-work system not newly emerged form-work such as aluminum form-work system.

(Bezaye Girma Tamer, 2017) "Cost and quality comparison of different types of form-work systems in concrete structure buildings, The case study in Bahirdar, Ethiopia" concludes From interpretation and analysis the majority of respondents preferred to buy timber form-work for beams and column, reworked old metal barrel form-work for slab and stair case and for shear walls steel form-work is the preferred type. It is based on the advantage of initial cost. There is no contractor using alternative form-work materials such as aluminum, plastic, etc in Bahir Dar.

(Bereket Amare Sida, 2015)"Cost, quality and speed comparison of steel and timber form-work Systems used for building Projects; Addis Ababa" indicates that Based on rental cost of the form-work system all respondents prefer steel form-work system than timber form-work system.

While there is extensive research on traditional form-work systems, there is a scarcity of studies focusing specifically on aluminum form-work systems and their performance in modern construction practices in Ethiopia related to with conventional form-work and its impact with respect to Cost, duration and Quality. In addition most of the study done on Ethiopia related to form-work didn't indicate the advantage of using newly emerging form-work type and the cost and time compression with Aluminum form-work, Implementation process and challenge encountered to implement by Ethiopian Contractor.

Therefore, this study aims to fill this gap in previous research by comparison study on the impact of using conventional and Aluminum form-work of building construction form-work practices, on project cost, time and quality in the Ethiopian construction industry, implementation process and the challenge encountered to use by Ethiopian Contractor with a case study of Ovid Real Estate selected project in Addis Ababa.

Literature Study summary indicated below shows each research method, data analysis , method of data collection and result of the research and limitation of the study.

2.9 Conceptual Framework

This conceptual framework provides a structured approach to understanding the relationships between the types of form-work used in construction and their impacts on various performance metrics within the context of the Ovid Real Estate Project in Addis Ababa.

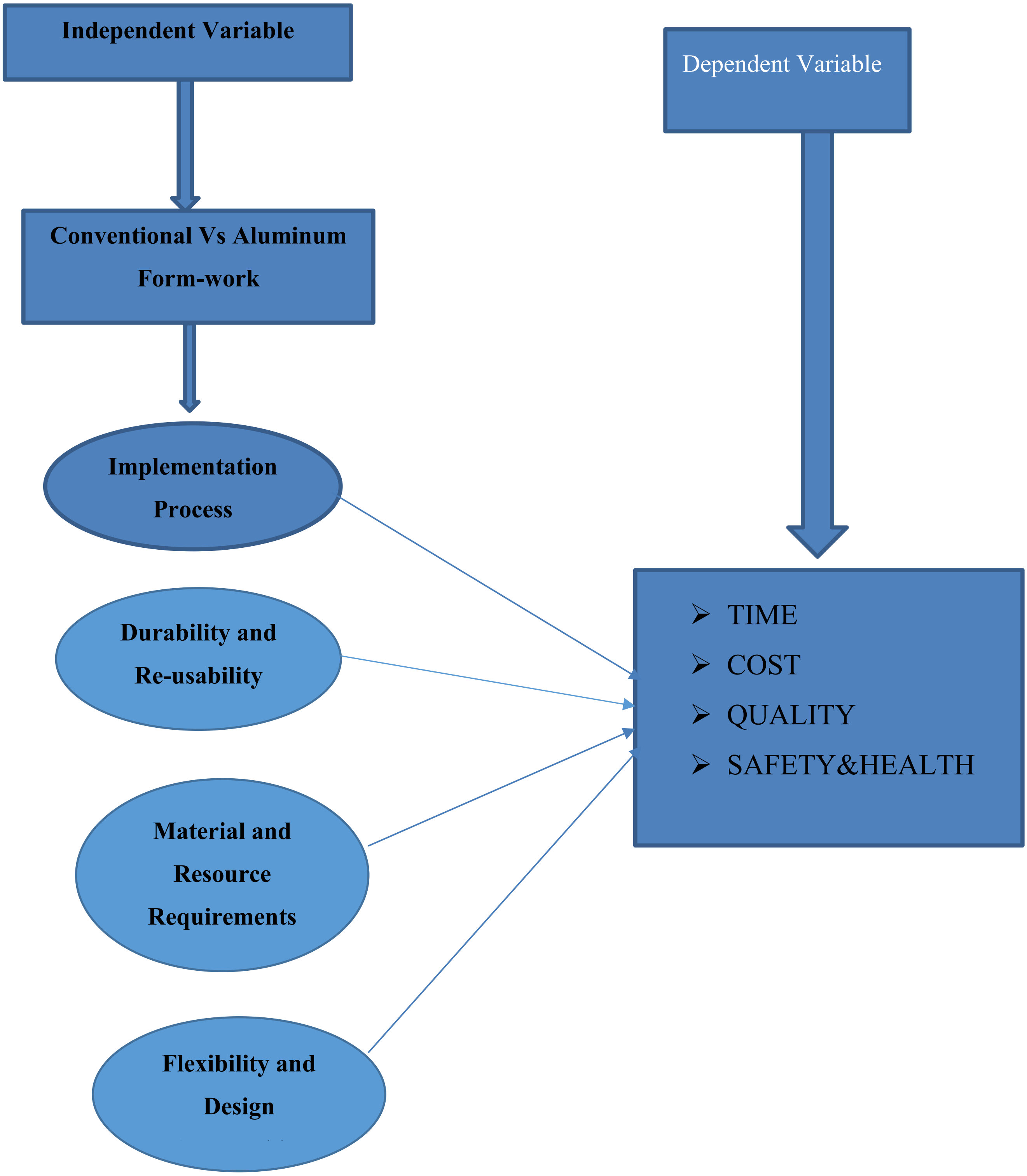


Figure 2: 9 Conceptual Framework Diagram

Table 2: 2 Literature review summary

It No	Researcher Name	Reference Type	Title	Study Location	Year	Objective	Analysis Metod				Result	Limitation	Gaps
							Research design/ strategy	Research approach	Method of data collection	Method of data analysis			
1	BEZAYE GIRMA TAMER	Thesis Paper	COST AND QUALITY COMPARISON OF DIFFERENT TYPES OF FORMWORK SYSTEMS IN CONCRETE STRUCTURE BUILDINGS CASE STUDY IN BAHIR DAR	BAHIR DAR, ETHIOPIA	2017	1. To compare the cost between substandard formwork with theoretical standard formwork. 2. To assess concrete formwork materials and methods of formwork constructions which fulfill quality and safety requirements.	non experimental and descriptive	qualitative as well as quantitative	observation and interview	Excel and Charts	1. using modern formwork and scaffolding can avoid plastering and chiseling works and that also lower the costs of construction.	1. there were no construction sites and supplying institute of modern formwork and scaffolding materials in Bahir Dar especially modern steel formwork and scaffolding used in this research, it was	1. only formwork materials of timber, steel and reworked old metal barrel are used for the study 2.No Empirical data for Quality related issue 3. The problem of Safety not described
2	MERON TADESSE	Thesis Paper	Investigation on the Effects of Formwork & Scaffolding Types in Building Projects in Addis Ababa	Addis Ababa,Ethiopa	2016	1. To determine the types of formwork and scaffolding used in building construction. 2. To determine the effect of formwork in building construction.	descriptive and exploratory	quantitative and qualitative analysis	interviews, questionnaires and field survey	statistically and descriptive analysis method	Steel and Timber boards are the most commonly used formwork materials in Addis Ababa.	Formworks for precast concrete elements are out of the scope of this thesis.	The study did not inculde Aluminum Formwork system,
3	Argaw Tarekegn	Thesis Paper	APPLICATION OF MODERN FORMWORK SYSTEMS IN ETHIOPIA	Addis Ababa,Ethiopa	2010	To introduce modern formwork systems which fulfill the quality, safety, environment and economic requirements to the construction industry of Ethiopia	descriptive and exploratory	qualitative and quantitative.	Surveys and interviews	Statistical analysis and content analysis.	Steel panels and timber boards are the most commonly used formwork materials in Ethiopia. and The cost of formwork is about 26% of the total cost of in-situ concrete in Addis Ababa.	Limited to specific projects	Resarch Methodology gap and Empirical data limitation on Time and Cost of Convensional and Alumninim Formwork
4	BEREKET AMARE SIDA	Thesis Paper	COST, QUALITY AND SPEED COMPARISON OF STEEL AND TIMBER FORMWORK SYSTEM USED FOR BUILDING PROJECTS (A CASE STUDY IN ADDIS ABABA)	Addis Ababa,Ethiopa	2015	2.Cost wise comparison of timber and steel formwork system used for building projects. 2.To compare quality of finished concrete made by timber and steel formwork system	descriptive	qualitative and quantitative.	questionnaires	descriptive statistics and graphs	The average per meter square cost of steel formwork is higher than timber formwork system. Cost of steel beam formwork is 17.05% higher than timber beam formwork, column steel formwork costs 22.88% higher than timber column formwork and steel slab formwork costs 23.16% than timber slab formwork. Taking average the difference is steel formwork costs 16.96% higher than timber formwork	Limited to only Steel and Timber Formwork type	1.No Empirical data for Speed(time) b/n Steel and Timber Formwork

It No	Researcher Name	Reference Type	Title	Study Location	Year	Objective	Analysis Metod				Result	Limitation	Gaps
							Research design/ strategy	Research approac	Method of data collection	Method of data analysis			
5	Getaw Tessema	Thesis Paper	"STUDY ON CURRENT FORMWORK PRACTICES AND TRENDS IN ETHIOPIAN BUILDING CONSTRUCTION INDUSTRIES: CASE OF SELECTED CONTRACTORS IN ADDIS ABABA	Addis Ababa,Ethiopa	2019	1.To identify formwork types and materials used at building construction project sites in Addis Ababa undertaken by local and international contractors 2. To identify formwork selection criteria and factors affecting formwork selection	descriptive	qualitative	questionnaires	Descriptive statistics and Graph	1.Finding of 58% of the respondents are using modern conventional, 36% conventional and 6% system formworks. 2. 81% of revealed that formwork has great impact on cost and duration of total project. The minimum costs of formwork according to this research, are 23% and 32% of the concrete structures, for local and international contractors respectively.	Limitied only Convenstional Formwork type	Imact of Formwork on project duration not clearly Described Empirically
6	Shumet Getahun Reda and Biruk Yenehun Lemlem	Article	Assessment of Concrete Formwork Practices in Bahir Dar City, Ethiopia	BAHIR DAR, ETHIOPIA	2024	To assess the erection practices, challenges, types, quality and cost of formwork on active building construction projects in Bahir Dar	Case study approach	qualitative and quantitative.	Questionnaires, site observations and oral interviews	Descriptive statistics and Graph	timber formwork is the most dominant type of formwork used for the construction of slabs, beams, columns and stairs due to its availability and low cost.	Limited on small contractor	The study focues only Conventional Formwork type
7	SHRIKANT M HARLE*	Article	COMPARISION OF CONVENTIONAL WITH ALUMINIUM FORMWORK SYSTEM	India	2018	1. to compare different Formwork systems on the basis of Time & Cost.	Qualitative	qualitative and quantitative.	Questionnaires, site observations and oral interviews	Descriptive statistics and Graph	1. aluminum formwork is cost effective on comparison with conventional formwork and 2. Aluminum formwork system also helps to saves the time. It also saves the time and cost of finishing.		1.Empirical data Limitation
8	Reena Sharma1, Dr. Bipasha Kumar2, Dr. Deepashree Choudhury3	Journal	Integration of Aluminium Formwork in Sustainable and Affordable Housings	India	2022	to determine how aluminum formwork might assist satisfy the nation's expanding housing demand while reducing its negative environmental effects.	case studies of existing projects, interviews with stakeholders and comparative analysis	Quantitative and qualitative analysis	integration process right from drawings to construction	quantitative and qualitative analysis	Highlighting the advantages and challenges of using aluminum formwork in affordable and sustainable housing		2.Empirical data Limitation on enviromntal impact and waste Material

3. RESEARCH METHODOLOGY

3.1 Introduction

This study addresses critical gaps in the existing literature on aluminum form-work systems in Ethiopia, focusing on their implementation, cost and time efficiency, quality impact, and adoption challenges. Limited comparative analysis exists between aluminum and traditional form-work systems regarding cost, duration, and quality in Ethiopia's construction sector. Additionally, the benefits of aluminum form-work such as time and cost savings remain under-explored, hindering its wider adoption. Practical challenges, including high initial investment, training, material availability, and technical expertise, have not been sufficiently investigated. Furthermore, the broader impact of aluminum form-work on construction efficiency, labor productivity, safety, and sustainability requires deeper examination. There is also a scarcity of studies on the implementation procedures of aluminum form-work in Ethiopia

Research methodology provided a techniques used on comparison of conventional versus aluminum form-work on the "cost", duration, and quality of construction projects to fulfill the research objective entailed a deep understanding by analyzing. The selected Ovid real estate projects were been taken by sample selection technique for this study. Based on the basic information obtained from research respondent, the results of the two form-work system has been compared using research tools.

This section also outlines the research scope, design, and methodologies, along with the methods employed for data collection, analysis, and presentation, while also addressing the validity and reliability measures to tackle the key concern identified by the specific objectives. Additionally, it details the data analysis approach utilized and the criteria for determining the sampling of the population.

3.2 Study Area

The researcher conducted the current study in Addis Ababa. It covers total area of 527km^2 at elevation 2,355km from sea level. The estimated population up around 5,005,524 (Addis Ababa City Administration office Page. The targeted study area selected Ovid real estate projects in Addis Ababa City. Figure 3.1 showed the current study location.

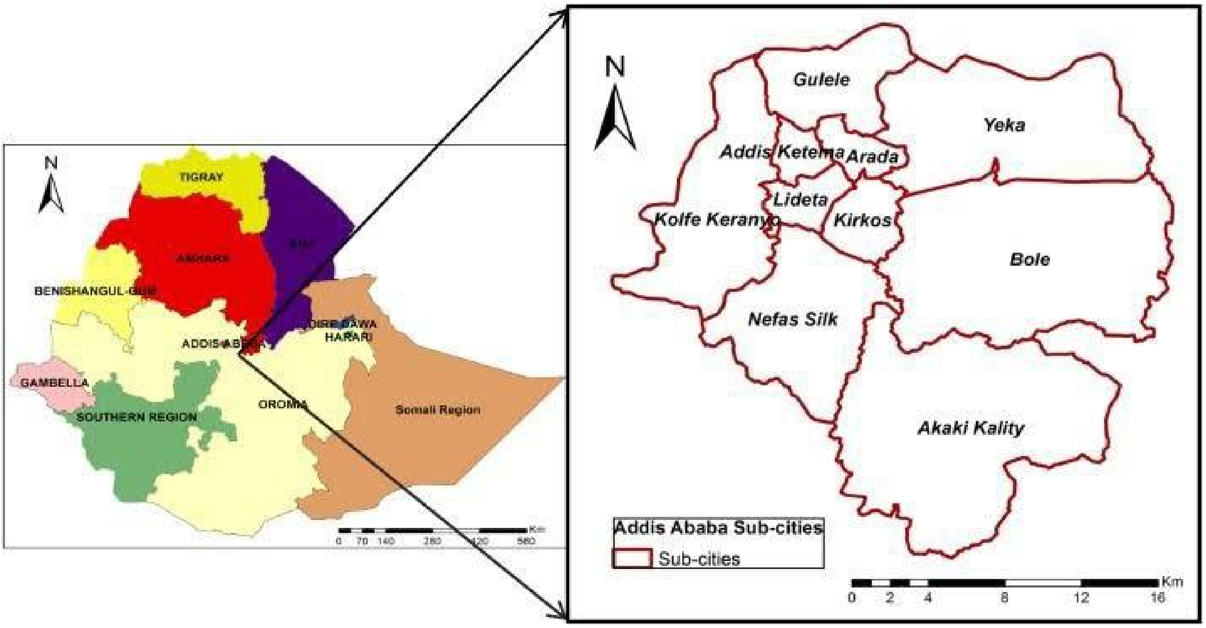


Figure 3: 1 Study area location Addis Ababa (Source: Addis et.al.2024)

3.3 Research Design

Designing a study helps the researcher to plan and implement the study in a way that helped the researcher to obtain intended results, thus increasing the chances of obtaining information that could be associated with the real situation (Creswell, 2003). The current study utilized descriptive and exploratory research design. The methodology was structured to gather sufficient information on the topic, enabling a thorough response to the research objectives. Consequently, well-established and widely recognized data collection methods were employed. Case studies were conducted to analyze the ongoing Ovid Real-estate projects built using aluminum form-work and conventional form-work methods at G+12+Terrace mixed block project found at in-front of Ras Amba hotel and Ovid Gelan Gura City projects, allowing for a comparative analysis of cost, time, quality of finished concrete, and labor productivity. A literature review was compiled from various reference books, articles, and related sources, serving as a foundation for developing the primary data collection instruments. Primary data was gathered through surveys and interviews to achieve all research objectives. Figure 3.2 below shows the research design methodology flow chart for the study.

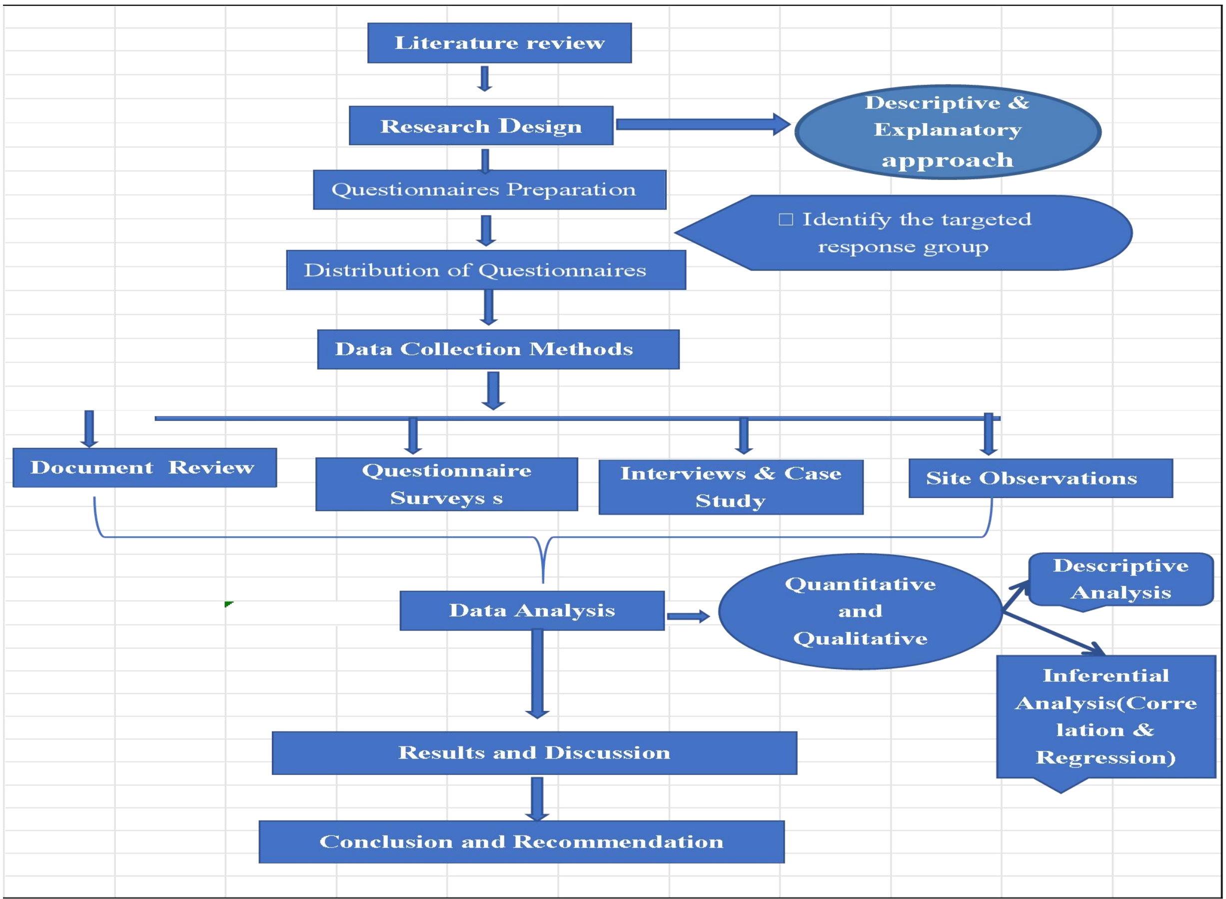


Figure 3: 2 Methodology Flow Charts

3.4 Research Approach

The research approach, which is the combination of both the qualitative and quantitative methodologies, is adopted in this research. This research has the advantage of gaining a stronger research design and achieving more valid and reliable findings. As such, semi-structured interview, case study and questionnaire survey be the methodologies conduct to carry out the objectives of the research. Accordingly, it believes that a deeper and more detail quality of information is expected to obtain with interview as the methodology instrument whereas questionnaire survey covers a broad range of the study in fulfilling both objectives(Swanson & III, 2005).

3.5 Population and Sampling Technique

3.5.1 Target Population

The target population for this study consists different professionals of two specific ovid real-estate projects currently under construction that utilize aluminum form-work G+12+Terrace mixed block project found at in-front of Ras Amba hotel and Ovid Gelan Gura City projects , selected to ensure a comprehensive study of the implementation process, construction costs, time efficiency, quality of finished structures, and challenges faced by Ethiopian contractors in using aluminum form-work compared to conventional form-work. which are owned by Addis Ababa housing corporation and Ovid construction PLC. for the study 60 structured questioners are distributed for the professionals on the project like project manger, site engineer, office engineer, Consultant and client.

3.5.2 Sampling Technique

For the study the research census method of sampling technique is used and census sampling technique is applied in this study by including all key stakeholders such as contractors, engineers, project managers, and workers directly involved in the two selected construction projects of G+12+Terrace mixed block project found at in-front of Ras Amba hotel and Ovid Gelan Gura City using both conventional and aluminum form-work systems. Since the population is small and well-defined, every relevant participant is engaged through surveys, interviews, and site observations, ensuring complete data representation without the need for random sampling. This approach eliminates sampling bias and provides a comprehensive data set for analyzing implementation processes, cost comparisons, time efficiency, construction quality, and challenges faced by Ethiopian contractors when using aluminum form-work.

The census method is chosen because the limited scope of only two projects makes a full population study feasible and more accurate than sampling. By examining all stakeholders, the study captures precise insights into the differences between conventional and aluminum form-work systems, avoiding the risk of missing critical perspectives that could arise from a smaller sample. This ensures high reliability in findings, which is essential for making informed conclusions about the feasibility and effectiveness of aluminum form-work in Ethiopia’s construction industry.

3.6 Data Collection Methods

The data collection methods for this research include a comprehensive document review to analyze existing records and reports related to the construction projects, a questionnaire survey to gather quantitative data from stakeholders involved in the projects, structured interviews to obtain qualitative insights from key participants, site observations to assess real-time construction practices and challenges, and case studies to provide an in-depth understanding of specific instances of aluminum form-work implementation in the selected housing projects.On this study we use five method of data collection system which are:-

3.6.1 Document Review

Conduct a thorough review of existing literature on advanced form-work systems, with a focus on aluminum form-work. This includes academic journals, industry reports, and case studies to establish a theoretical framework and context for the study.

3.6.2 Questionnaire Surveys

Structured 60 questionnaires was developed and distributed for on the two projects who are professionals and key stakeholders on G+12+Terrace mixed block project found at in-front of Ras Amba hotel and Ovid Gelan Gura City projects that utilize aluminum form-work. The questionnaires have been developed into three section and this include section 1: form-work direct cost-related questions, section 2: safety and health-related questions, section 3: challenges in adopting aluminum form-work.

3.6.3 Interviews

Conducted semi-structured interviews with selected stakeholders, including project managers, engineers, site supervisors, and workers. These interviews provided qualitative insights into.

3.6.4 Site Observations

Perform direct observations at construction sites where aluminum form-work is being utilized. This allow for the assessment of the application process, safety measures, and overall workflow efficiency.

3.6.5 Case Study

This study involves a case study analysis of two housing projects: a recently under construction. The aim is to compare the relation to cost, time, and the quality of the finished concrete by comparing it with conventional form-work techniques and also the implementation process and challenge faced by Ethiopian contractor who are under development project of real-estate projects to use it. Additionally, the research assesses labor productivity associated with the Kumkang aluminum form-work system. To achieve this, the study examines projects constructed with both conventional form-work and Kumkang aluminum form-work.

3.7 Method of data analysis

The purpose of any research undertaken is to provide information in order to help answer the research question(Swanson & III, 2005). A data analysis plan is a road map for how you are going to organize and analyze your survey data. This study analysis both quantitative and qualitative analysis.

3.7.1 Quantitative Analysis

Analyze survey data using statistical software (SPSS Version27) to identify trends, correlations, and patterns related to project performance metrics such as cost and time efficiency outcome. And also Microsoft Excel 2010 and MS-project for analyzing of cost and duration is used .

3.7.2 Qualitative Analysis

Transcribe and code interviews to identify common themes and insights regarding the use of aluminum form-work. Thematic analysis has been employed to categorize responses and highlight key challenges and benefits of quality related result.

By employing this methodology, the assessment aims to provide a thorough evaluation of aluminum form-work practices at Ovid Real Estate, contributing valuable insights to the field of advanced building construction techniques in Ethiopia.

3.8 Validity

The study adopts two approaches of validity to ensure validity of measurements. They included as follows;

Criterion validity- is established when the results are obtained from one measure are similar to results obtained with more direct or already validated measure of the same phenomenon (criterion) (Engel and Schutt, 2014). The study measure which were validated from previous studies to measure the same phenomenon hence increased confidence the measures have measured what they were intended in the first place.

Construct validity - is demonstrated by showing that a measure is related to a variety of other measures of other concepts as specified in the theory (Engel and Schutt, 2014). The study variables will be derived from accepted theories that were tested in previous studies and shown positive results.

Reliability

The reliability of this study will ensure by using the Cronbach’s alpha coefficient of internal consistency because it provides a unique quantitative estimate of the internal consistency of the scale (Zikmund, 2009). According to (Cooper & Schindler, 2007), for the instrument to be reliable, the coefficient has to be above 0.7.

3.9 Ethical Consideration

This study has fully considered the ethical matters of the organization. The study observe the non-negotiable value of honesty and fairness. Respect for persons be maintained properly. Employees has be informed about the research and their response is confidential and the research is for academic purpose.

4. RESULTS AND DISCUSSIONS

4.1 Introduction

This study aimed to obtain a Comparative study on the impact of using conventional and Aluminum form-work on building construction: a case study on Ovid Real Estate selected project in Addis Ababa kumkang aluminum form-work. This study is to adhere the impact of using aluminum and conventional form-work by analyzing the implementation process of aluminum form-work, compare the overall construction costs associated with conventional form-work and aluminum form-work , evaluate the time taken for various phases of construction using both conventional and aluminum form-work, assess the quality of the finished structures achieved with conventional versus aluminum form-work and evaluate the challenges encounter to use aluminum form-work by Ethiopian Contractor. To achieve the aim of this study, the data gathered from data collection techniques which are the interview, case studies, and questionnaires were analyzed and discussed in this chapter.

4.2 Response Rate

The response rate for this study was 86.6% (52/60), indicating a commendable level of participation from the sampled respondents. This high response rate is significant, as it reflects strong engagement from stakeholders involved in building construction activities within the Ovid Real Estate project in Addis Ababa.

Several factors contributed to this favorable response rate. First, the researcher applied effective sampling techniques to ensure that participants were accurately drawn from diverse stakeholder categories such as project managers, consultants, contractors, and government representatives. This approach, following guidelines from Saunders, Lewis, and Thornhill (2007), helped in reaching a representative sample and encouraging wider participation.

Additionally, the researcher communicated the purpose and potential academic and practical benefits of the study clearly to the participants (Saunders et al., 2007). By emphasizing how the findings could improve future decisions in form-work selection and construction efficiency, interest and buy-in from respondents were effectively secured.

The design of the questionnaire was user-friendly, concise, and easy to understand, following best practices suggested by Bryman and Bell (2015). This simplicity reduced the burden on respondents, encouraging full completion and minimizing non-response.

The robust response rate enhances the credibility and generalization of the findings. With 86.6% of the target population contributing data, the study is well-positioned to offer comprehensive and reliable insights into the comparative impacts of conventional and aluminum form-work systems in the Addis Ababa construction context.

4.3 Respondents' Profile

Analyzing the profile of the respondents provides essential insights into the demographic and professional backgrounds of stakeholders participating in the construction projects. Understanding these characteristics supports better interpretation of the data and the diversity represented.

4.3.1 Education Level

Education levels give an indication of professional expertise among respondents.

Table 4. 1: Education Level of the Respondents

Qualification	Frequency	Percent
College diploma/level	17	32.7%
First Degree	24	46.2%
Master’s	11	21.1%
Ph.D. or above	0	0.0%
Total	52	100%

Source: Researcher’s Survey, 2025

The majority of respondents (46.2%) hold a first degree, indicating a solid academic foundation among participants. 32.7% have a college diploma or equivalent, while 21.1% have attained a Master’s degree, demonstrating a good representation of postgraduate-level professionals in the construction sector. No respondents hold a Ph.D. or higher, which is common in more practice-oriented industries like construction. Overall, the education profile suggests a well-qualified workforce, capable of informed decision-making in technical and managerial roles.

4.3.2 Work Experience

Experience levels reflect the practical knowledge respondents bring to their roles.

Table 4. 2: Work Experience of the Respondents

Experience Range	Frequency	Percent
1 – 5 years	22	42.3%
5 – 10 years	14	26.9%
10 – 15 years	10	19.2%
Above 15 years	6	11.6%
Total	52	100%

Source: Researcher’s Survey, 2025

The data show that 42.3% of respondents have 1–5 years of experience, indicating a relatively young or early-career workforce. Another 26.9% fall within the 5–10 years category, suggesting a solid group of mid-level professionals. 19.2% have 10–15 years of experience, and 11.6% have over 15 years, representing more seasoned individuals. This blend of early-career and experienced professionals can be advantageous for balancing innovation with practical know-how, and it highlights the need for ongoing mentor ship and training opportunities in the construction sector.

4.3.3 Stakeholder Role

Understanding stakeholder roles ensures diverse functional perspectives are captured.

Table 4. 3 : Current Role of the Respondents

Role	Frequency	Percent
Project Manager	5	9.6%
Consultant	10	19.2%
Quantity Surveyor	5	9.6%
Construction Engineer	13	25.0%
Accountant	2	3.8%
Foreman	8	15.4%
client	9	17.3%
Total	**52**	**100%**

Source: Researcher's Survey, 2025

With 5 project managers (9.6%), the table now reflects a smaller project management presence. To balance this, roles like consultants (19.2%), construction engineer(25.0%), foremen (15.4%), and client representatives (17.3%) are relatively higher, indicating stronger representation in technical, operational, and regulatory roles. This distribution provides a diverse set of perspectives across the project life-cycle, from oversight to execution and compliance.

Table 4. 4: Summary of Direct Material cost from the respondent

SN	Type of material	unit	Unit Rate(birr)
1	Timber	pcs	2500
2	Eucalyptus dia 12mm	ml	90
3	Eucalyptus dia 10mm	ml	80
4	Eucalyptus dia 6mm	ml	60
5	Nail 12-15mm	kg	170

6	Nail 10-12mm	kg	170
7	Black wire 2.5	kg	180
8	Mold oil	lit	150
9	Morale 50*70	ml	72.4

Table 4. 5 :Respondent Summary on Material re-uses and initial investment cost Kumnkank Aluminum Form-work

SN	form-work Type	No. Of Repetition of Use(Re-use)	Remark
1	Kumkang Aluminum form-work	250 to 300	No. of Re-use
2	Conventional (Timber) Form-work	3 to 5	No. of Re-use
3	Kumkang Aluminum form-work	68,000	Initial investment Cost in Birr/m2

Table 4. 6 : Respondent Summary on Labor Rate for Timber and Kumnkank Aluminum Form-work

SN	Labor By Trade	Kumkang Aluminum form-work(Labor cost per day in Birr)	Conventional (Timber) Form-work(Labor cost per Day in Birr)
1	Chief Carpenter	500	500
2	Daily Labor	280	280
3	Kumkang Specialized		700
4	Forman	800	800

Table 4. 7: Respondent Summary on crew productivity for both Timber and Kumnkank Aluminum Form-work

SN	form-work Type	Work Type	Crew Productivity per day in m2
1	Kumkang Aluminum form-work	Wall Panel Work	20
		Slab Panel Work	20
		Staircase Panel Work	10
2	Conventional (Timber) Form-work	Footing Pad	6
		Foundation Column	6
		Grade Beam	6
		Elevation Column	4.8
		Floor Beam	4.8
		Floor slab	6

4.4 Implementation process of Kumkang aluminum form-work

Implementing Kumkang aluminum form-work in Ethiopia involves a series of systematic construction steps. This form-work system is widely used for fast and quality construction of reinforced concrete structures and Ovid Real-estate construction company currently are using this technology at different project and I selected Design and build of G+12+Terrace Mixed use building project of at Ginfile in front of Ras Amba Hotel phase-one, Ten (10) typical Block project and Ovid Gelan Gura City projects.

The implementation process of kumkang aluminum form-work used by Ovid real-estate is the same across all site due to similarity of the real-estate and propose of the building and its design are the same except foundation work and the location.

On this section we will discuss the implementation process of kumkang aluminium form-work using G+12+Terrace mixed block project found at in-front of Ras Amba hotel and Ovid Gelan Gura City projects as case study for this thesis project.

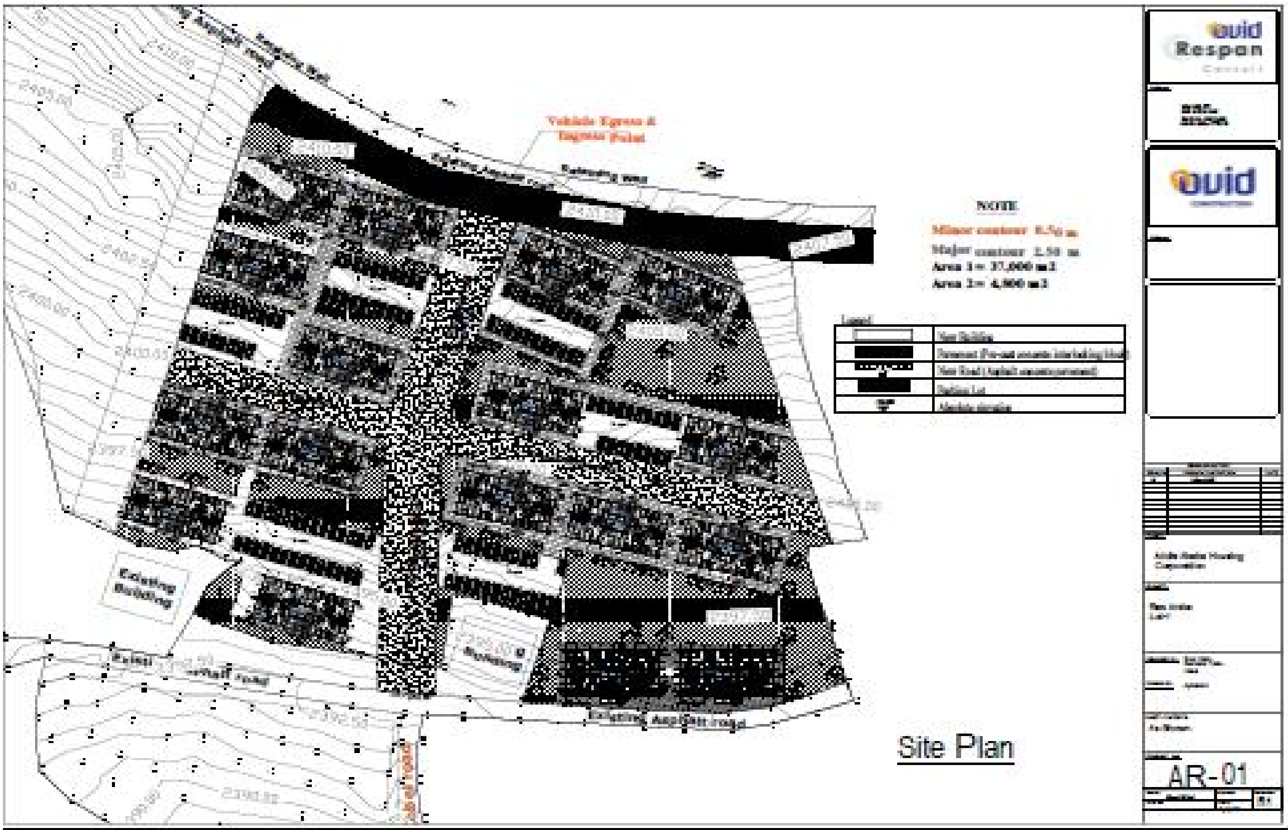


Figure 4.1: Design and build of G+12+Terrace Mixed use building project of at Ginfile Project

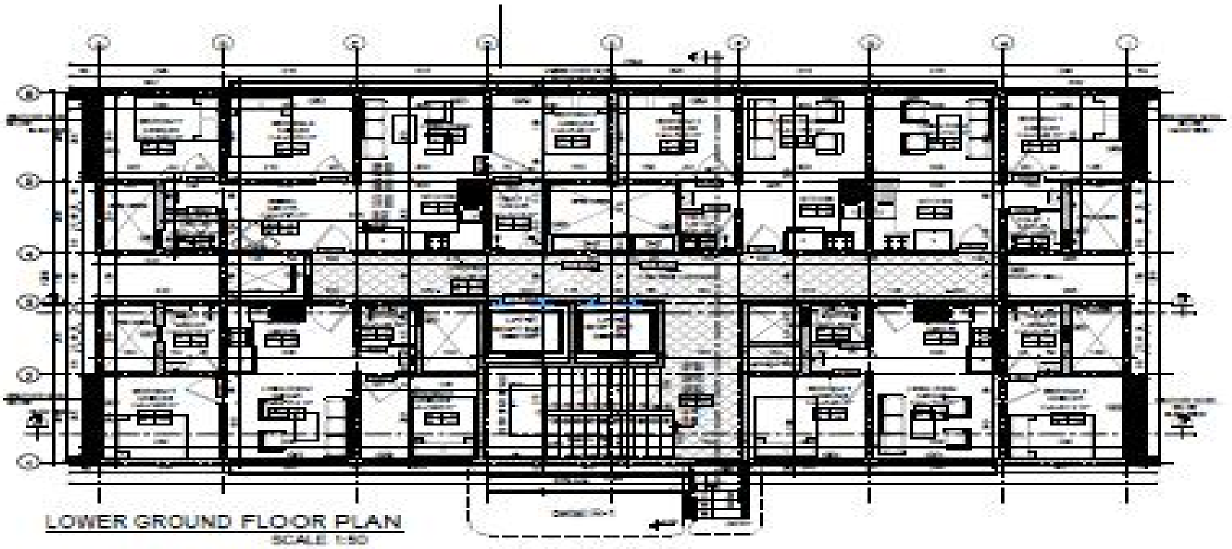


Figure 4. 2: Ground Floor plan of Project

4.4.1 Kumkang Aluminum Form-work Erection Producers

4.4.1.1 Design Review and material logistics

Review architectural and structural drawings to ensure compatibility with aluminum form-work and Ensure wall thickness, slab thickness, and beam dimensions align with form-work specifications and Ensure proper storage to prevent damage.

Figure 4 3: Kumkang Aluminum form-work Component material Stock on site Ginfile project

4.4.1.2 Form-work Installation Process

Step 1 – Foundation & Ground Floor Setup

Step 2 – Erecting wall reinforcement.

Step 3- Erecting Wall and slab form-work

Step 4- Slab reinforcement and electrical conduit fittings

Step 5- Completing Electrical and sanitary works and overall checking

Step 6- Concrete pouring

Step 7- De-shuttering vertical and Slab form-work

Step 8- Overall checking and finishing works

1. Foundation & Ground Floor Setup

In Ovid Real-estate construction they use traditional form-work (Timber) for foundations up to grade beam, Excavation and pouring of foundation pad done according to structural drawings and Kumkang aluminum form-work starts from the first suspended floor. In this step of form-work construction timber form-work are used and after casting the grade beam concrete the project will be ready to use Kumkang aluminum form-work.

Figure 4. 4: Lean concrete preparation and footing pad concrete work of Ginfile project

Figure 4. 5: Foundation Column form-work and Concrete work of Ginfile project

Figure 4. 6: Grade Beam form-work and Concrete work of Ginfile project

2. Erecting wall reinforcement

In this stage after casting Grade beam concrete work Fixing of Vertical and horizontal reinforcement for Wall and shear wall will be done as per the drawing. In this stage the following work will be done parallel way.

- Structural line and level checked
- Height of reinforcement bar overlap and spacing checked
- Installation of Spacer for concrete cover will be checked
- Vertical and horizontal wall reinforcement installation will be done
- Opening of Windows and Door location on wall will be checked
- Electrical installation inside all wall will be done according to the drawing

Figure 4. 7: Erection of Vertical and Horizontal Reinforcement bar

Figure 4. 8: Electrical installation inside wall Switch and socket points

3. Erecting Wall and Slab Panel and Staircase Form-work

The procedure of erecting wall panel will be done after finalizing vertical and horizontal reinforcement bar, electrical work inside wall and other works. And this stage includes the following works:-

- Installation of PVC Sleeve, Flat tie is inserted inside this sleeve; its function is to protect the flat tie to be casted within the concrete.
- Different type of wall panel will be installed after checking all electrical and Flat tie work is done.
- Erecting slab panel will done after finishing wall panel
- Staircase landing, riser and trade panel will be done after slab panel

Figure 4. 9: PVC Sleeve and Flat tie installation

Figure 4. 10: Wall Panel installation and Middle beam erection

Figure 4. 11: Wall panel pin and pin key

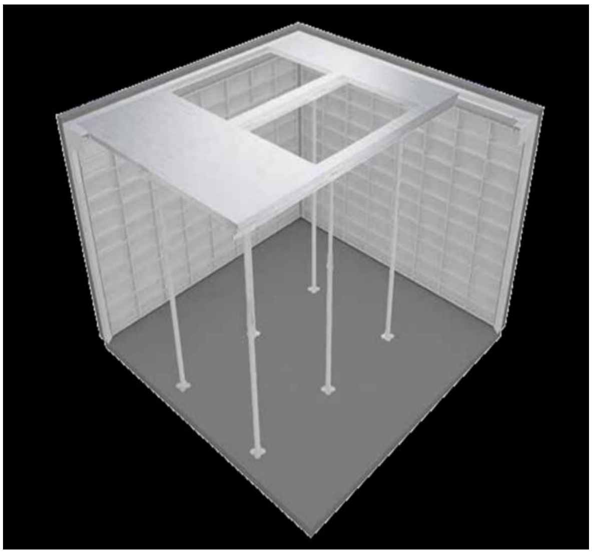
 

Figure 4. 12: Slab Panel installation mock-up and Slab Panel installation

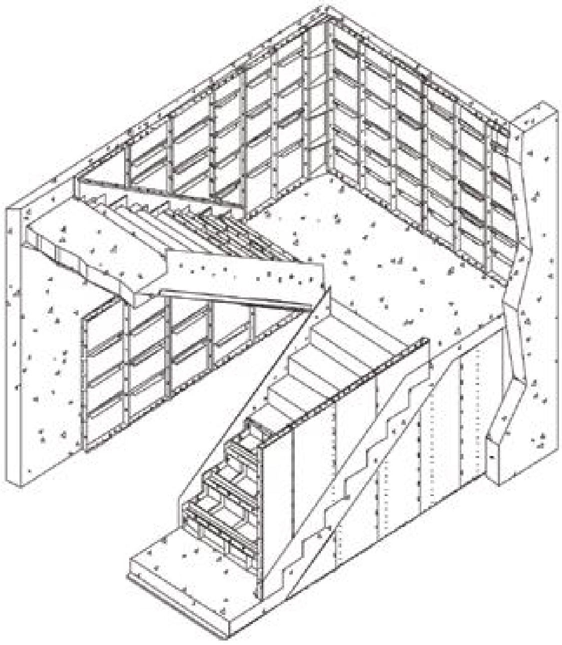
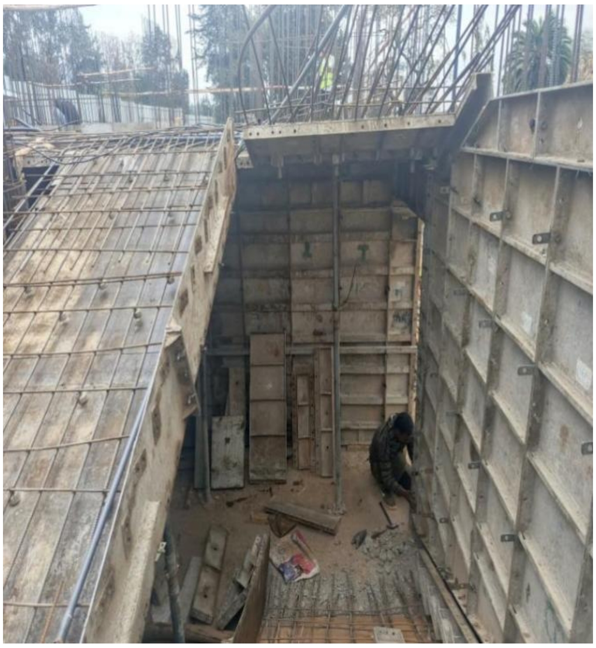
 

Figure 4. 13: Staircase Panel installation mock-up and Panel installation

4. Slab reinforcement and electrical fittings

The installation of re-bar in concrete slabs and electrical conduits is critical for ensuring structural integrity and facilitating electrical systems within a building. In this stage both top and bottom reinforcement bar, Spacer for concrete cover and electrical conduit instillation will be done accordingly.

Figure 4. 14: Slab reinforcement bar and Electrical Conduit installation

5. Completing Electrical and sanitary works and overall checking

On this stage overall installation of Wall Panel, Slab Panel, Staircase, electrical installation and sanitary installation will be checked before casting concrete work.

* leveling of Floor finish will be checked using leveling instrument
* Electrical and sanitary installed point will be checked
* concrete spacer will be checked
* overlap height and starter re-bar will be checked
* Thickness and dimensions of each structure item will be checked

Figure 4. 15: Floor Leveling Check before concrete casting

6. Concrete pouring

Once all the re-bar, electrical conduits and sanitary installation have been installed and inspected then concrete work of Monolithic slab, beam and wall casting process done.

Figure 4. 16: Monolithic slab, beam and wall concrete casting process

7. De-shuttering and vertical form-work

After 12–24 hours Wall panels will be started De-shuttering and also After 36–72 hours slab panels starts removing and de-shuttering work and the removed panels will be used for the next floor shifting it carefully. Removal Process:

* Carefully remove pins and wedges.

* Remove panels without damaging concrete.

* Clean and oil panels for reuse

* Internal wall and slab panels will be transferred to next floor by the hole prepared for this propose at slab of compression zone

* External wall panels will be transferred using crane when the height of the building increases and also using manpower

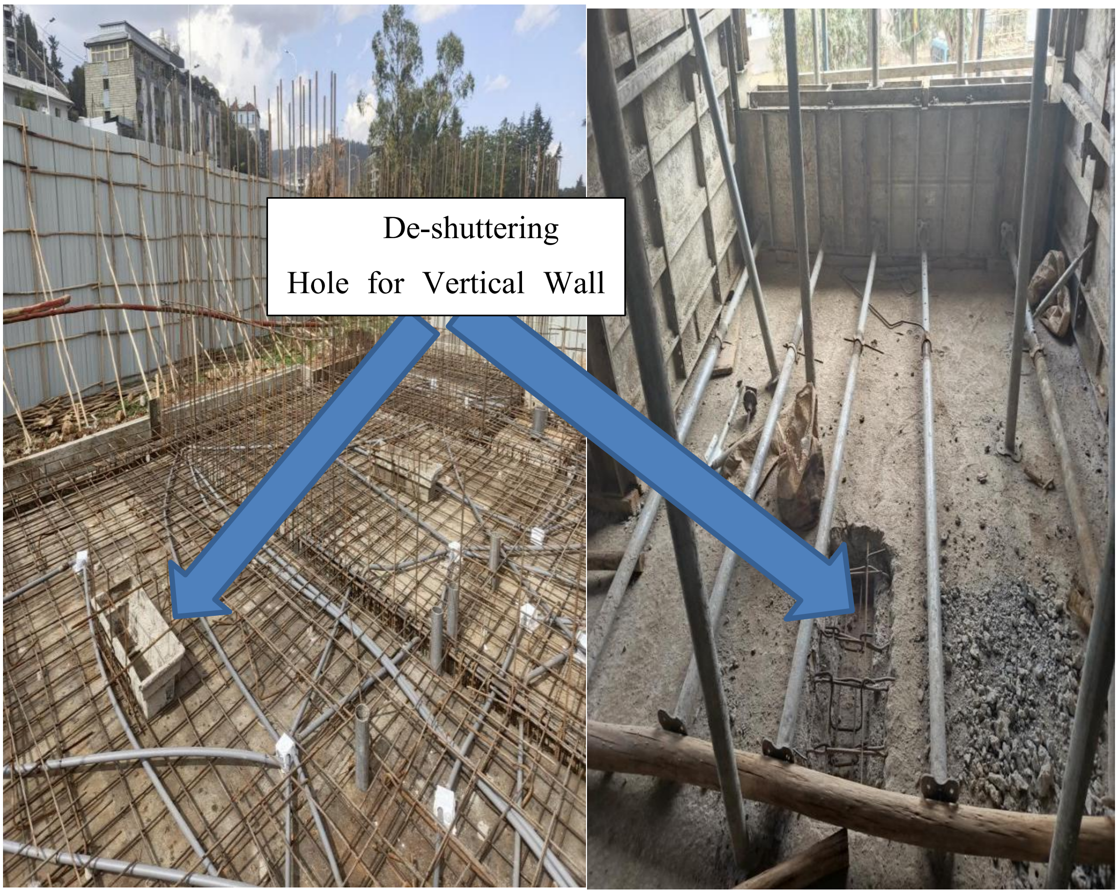


Figure 4. 17: Tool transfer box for D-shuttering of Internal vertical and slab Panel

8. Overall checking and finishing works

After finalizing removal of internal and external panel, the the whole step will be repeated by adding some safety working tools for erection work and also until concrete attain its strength.

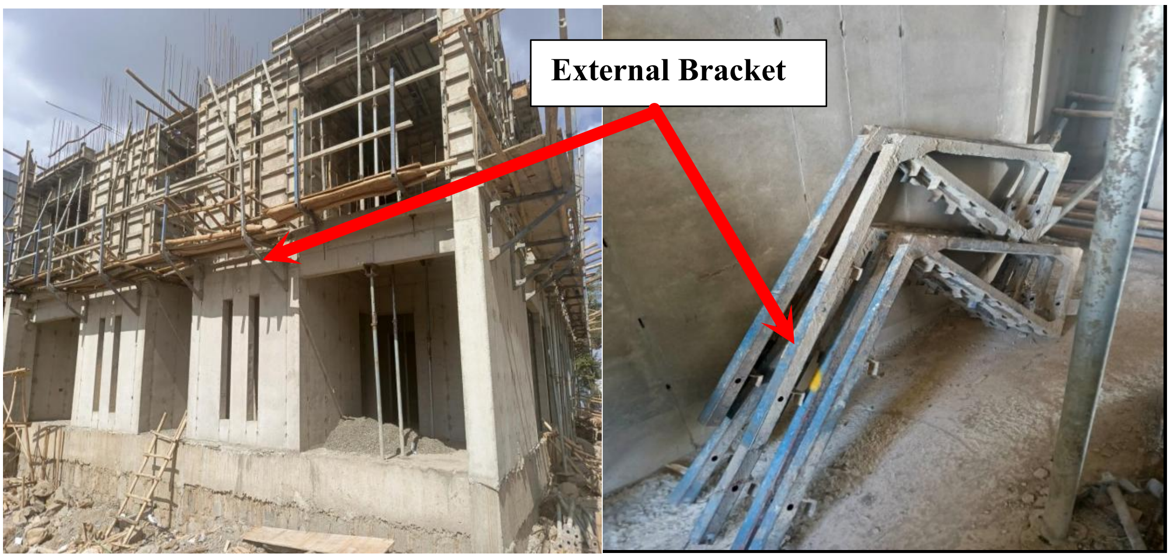


Figure 4. 18: External Bracket for supported suspended wall panel

Figure 4. 19: Props head support after de-shuttering

4.5 Analysis of construction costs associated with conventional form-work and aluminum form-work

Case study for this was done based on overall form-work type used on G+12+Terrace mixed block project found at in-front of Ras Amba hotel project. The selected project for this case study is a project on development of a housing and the study has been carried out on site were Kumkang technique is being executed.

- Name of Project: Design and Build of G+12+Terrace mixed block project found at in-front of Ras Amba hotel project
- Name Of Project Manager:Eng. Diress Abadi
- No. of Floors: G + 12+Terrace
- Construction method adopted: Kumkang aluminium Form-work
- Client: Addis Ababa Housing Cooperation
- Consultant : Resapan
- Contractor : Ovid Construction P.L.C
- Built-up area of the building =25.84*12.66=327.1344m2

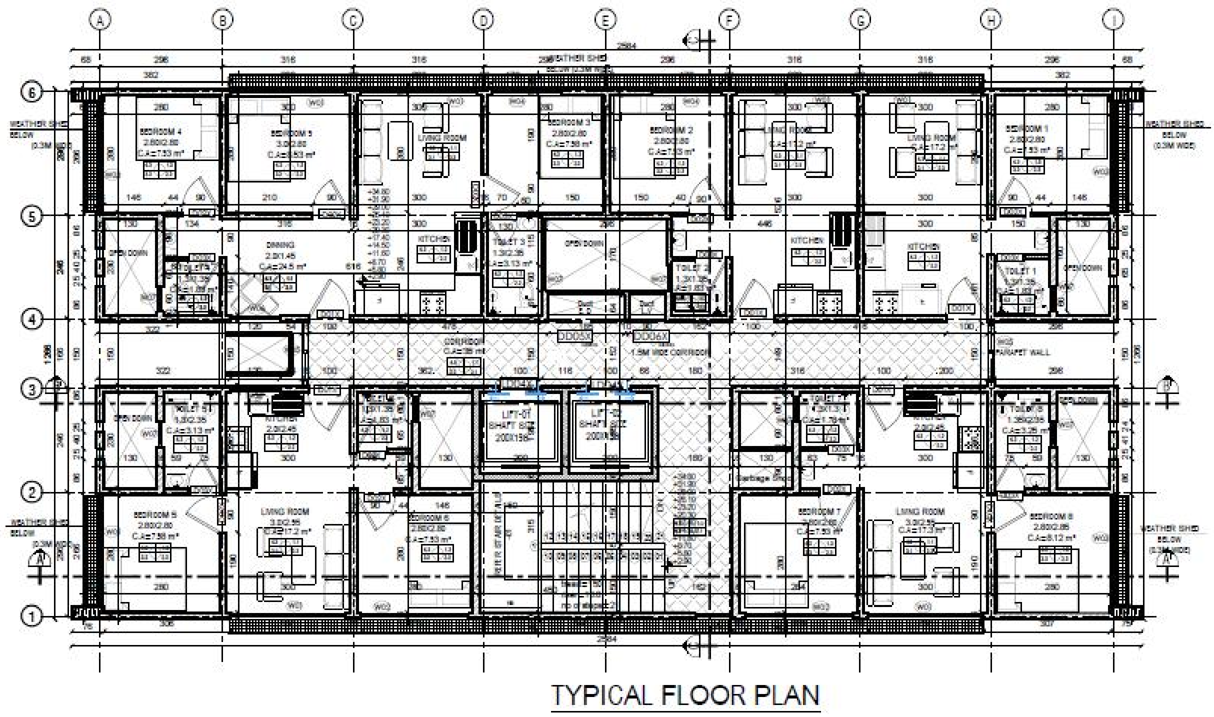


Figure 4. 20: Typical Floor Plan of the project

4.5 .1 Analysis of construction costs of Kumkang Aluminum form-work

Calculating the cost of using Kumkang aluminum form-work necessitates a comprehensive analysis that considers initial investment, maintenance, labor productivity, and the long-term financial benefits associated with its high reuse potential. By evaluating these factors, the study gain insights into how the upfront costs of aluminum form-work can be offset by reduced expenses in labor and materials over time. This study aims to provide a detailed assessment of the cost implications of utilizing Kumkang aluminum form-work, with a specific focus on its reuse capabilities.

Through this analysis, the study explores the economic advantages of adopting aluminum form-work in construction projects compared to conventional methods. By quantifying costs associated with multiple uses ranging from 250 to 300 applications this research illuminates the potential for significant savings and enhanced project efficiency.

To determine the cost implications of using Kumkang aluminum form-work for this project, a detailed analysis was conducted, taking into account various factors including material costs, labor productivity, and the expected number of reuses.

Initial Investment: the cost per square meter for the aluminum form-work was obtained from questionnaires and its about 68,000Birr/m2 and taken based on its reuse potential as minimum of 250times for the study.

Effective Cost per Use = Initial Cost / Number of Reuse=68,000/250=272birr/use

Labor Productivity : the use of Kumkang aluminum form-work also contributed to enhanced labor productivity. It allowed for quicker assembly and disassembly compared to traditional form-work systems. Labor costs were analyzed by estimating the time saved during construction due to the efficiencies gained from using aluminum form-work. Based on this the rate required to execute one (1) m2 of kumkang aluminum form-work is calculated on the table below. Table 4.8 and Table 4.9

Table 4. 8: Unit rate calculation for Kumkank aluminum formwork

Kumkang Alumnium Form-work Direct Cost Calculation

PROJECT	G+12+Terrace Mixed use building project of at Ginfile in front of Ras Amba Hotel	CREW DAILY OUTPUT	20
WORK ITEM	**Kumkang Aluminum Form-work**	EQUIPMENT	1
QUANTITY OF WORK ITEM	**1m2**	**RESULTANT**	2.50 m2/hr

MATERIAL COST					**LABOR COST**					**EQUIPMENT COST**				
Type of material	unit	qty	rate	cost/un	Labor by trade	No	UF	indexed Daly cost	Daly cost	Type of equipment	No.	UF	Daly rental rate	hourly cost
Kumkang Panel	m2	1	272	272.00	Kumkang Technical	1.00	0.50	700.00	350.00	Tools	1.00	1.00	0.50	0.50
Mould oil	lit	0.06	190.00	11.40	Carpenter	1.00	1.00	500.00	500.00					-
Maintance cost	m2	1	40	40.00	DL	2.00	1.00	280.00	560.00					
				-					-					
				-					-					
				-					-					-
				-					-					-
				-					-					
TOTAL				323.40	TOTAL				1410.00	TOTAL				0.50
material unit cost				323.40	manpower unit cost				70.50	equipment unit cost				0.50

DIRECT COST OF WORK ITEM	394.40	
overhead 10%	39.44	
Profit 15%	59.16	
Total	**493.00**	Birr/m2

REMARK & ASSUMPTIONS: From The data collected the invstiment cost for Kumkang Aluminum for one m2 is about =68,000 ET Birr/m2 and and considering No. of Repitation of reuse =250times, the cost of 1m2 panel is about =272ET birr/m2

Table 4. 9: Total Cost of Kumkang Aluminum Form-work for 13 floors

Ovid CONSTRUCION

PROJECT:	Genfile
CLIENT:	Addis Ababa Housing
CONSULTANT:	Resapan
CONTRACTOR:	Ovid Construction
Formwork Type	Kumkang Aluminum
Title	Total Cost of Formwork to Construct 327.1344m2 Built-up area

Story	Description	Unit	Formwork qty	Rate	Total Amount
Supper Stracture					
1ST STORY	**GF Shear wall**	m2	600.06	493.00	295,827.61
	GF up Standing wall	m2	61.47	493.00	30,305.40
	GF Non Stractural Wall	m2	309.74	493.00	152,701.82
	GF Stair Case	m2	20.19	493.00	9,953.30
	1ST Slab	m2	261.24	493.00	128,791.91
	1ST Beam	m2	163.52	493.00	80,615.29
Total		**m2**	**1,416.22**		**698,195.33**
2nd STORY	**1ST Shear wall**	m2	600.06	493.00	295,827.61
	1ST USW	m2	61.47	493.00	30,305.40
	1ST NSW	m2	309.74	493.00	152,701.82
	1ST Stair Case	m2	20.19	493.00	9,953.30
	2ND Slab	m2	261.24	493.00	128,791.91
	2ND Beam	m2	163.52	493.00	80,615.29
Total		**m2**	**1,416.22**		**698,195.33**
3RD STORY	**2ND Shear wall**	m2	600.06	493.00	295,827.61
	2ND USW	m2	61.47	493.00	30,305.40
	2ND NSW	m2	309.74	493.00	152,701.82
	2ND Stair Case	m2	20.19	493.00	9,953.30
	3RD Slab	m2	261.24	493.00	128,791.91
	3RD Beam	m2	163.52	493.00	80,615.29
Total		**m2**	**1,416.22**		**698,195.33**
4th STORY	**3RD Shear wall**	m2	600.06	493.00	295,827.61
	3RD USW	m2	61.47	493.00	30,305.40
	3RD NSW	m2	309.74	493.00	152,701.82
	3RD Stair Case	m2	20.19	493.00	9,953.30
	4TH Slab	m2	261.24	493.00	128,791.91
	4TH Beam	m2	163.52	493.00	80,615.29
Total		**m2**	**1,416.22**		**698,195.33**

PROJECT:	Genfile
CLIENT:	Addis Ababa Housing
CONSULTANT:	Resapan
CONTRACTOR:	Ovid Construction
Formwork Type	Kumkang Aluminum
Title	Total Cost of Formwork to Construct 327.1344m2 Built-up area

Story	Description	Unit	Formwork qty	Rate	Total Amount
Supper Stracture					
5th STORY	4TH Shear wall	m2	600.06	493.00	295,827.61
	4TH USW	m2	61.47	493.00	30,305.40
	4TH NSW	m2	309.74	493.00	152,701.82
	4TH Stair Case	m2	20.19	493.00	9,953.30
	5TH Slab	m2	261.24	493.00	128,791.91
	5TH Beam	m2	163.52	493.00	80,615.29
Total		m2	1,416.22		698,195.33
6th STORY	5TH Shear wall	m2	600.06	493.00	295,827.61
	5TH USW	m2	61.47	493.00	30,305.40
	5TH NSW	m2	309.74	493.00	152,701.82
	5TH Stair Case	m2	20.19	493.00	9,953.30
	6TH Slab	m2	261.24	493.00	128,791.91
	6TH Beam	m2	163.52	493.00	80,615.29
Total		m2	1,416.22		698,195.33
7th STORY	6TH Shear wall	m2	600.06	493.00	295,827.61
	6TH USW	m2	61.47	493.00	30,305.40
	6TH NSW	m2	309.74	493.00	152,701.82
	6TH Stair Case	m2	20.19	493.00	9,953.30
	7TH Slab	m2	261.24	493.00	128,791.91
	7TH Beam	m2	163.52	493.00	80,615.29
Total		m2	1,416.22		698,195.33
8th STORY	7TH Shear wall	m2	600.06	493.00	295,827.61
	7TH USW	m2	61.47	493.00	30,305.40
	7TH NSW	m2	309.74	493.00	152,701.82
	7TH Stair Case	m2	20.19	493.00	9,953.30
	8TH Slab	m2	261.24	493.00	128,791.91
	8TH Beam	m2	163.52	493.00	80,615.29
Total		m2	1,416.22		698,195.33

PROJECT:	Genfile
CLIENT:	Addis Ababa Housing
CONSULTANT:	Resapan
CONTRACTOR:	Ovid Construction
Formwork Type	Kumkang Aluminum
Title	Total Cost of Formwork to Construct 327.1344m2 Built-up area

Story	Description	Unit	Formwork qty	Rate	Total Amount
Supper Stracture					
9th STORY	8TH Shear wall	m2	600.06	493.00	295,827.61
	8TH USW	m2	61.47	493.00	30,305.40
	8TH NSW	m2	309.74	493.00	152,701.82
	8TH Stair Case	m2	20.19	493.00	9,953.30
	9TH Slab	m2	261.24	493.00	128,791.91
	9TH Beam	m2	163.52	493.00	80,615.29
Total		**m2**	**1,416.22**		**698,195.33**
10th STORY	9TH Shear wall	m2	600.06	493.00	295,827.61
	9TH USW	m2	61.47	493.00	30,305.40
	9TH NSW	m2	309.74	493.00	152,701.82
	9TH Stair Case	m2	20.19	493.00	9,953.30
	10TH Slab	m2	261.24	493.00	128,791.91
	10TH Beam	m2	163.52	493.00	80,615.29
Total		**m2**	**1,416.22**		**698,195.33**
11th STORY	10TH Shear wall	m2	600.06	493.00	295,827.61
	10TH USW	m2	61.47	493.00	30,305.40
	10TH NSW	m2	309.74	493.00	152,701.82
	10TH Stair Case	m2	20.19	493.00	9,953.30
	11TH Slab	m2	261.24	493.00	128,791.91
	11TH Beam	m2	163.52	493.00	80,615.29
Total		**m2**	**1,416.22**		**698,195.33**
12th STORY	11TH Shear wall	m2	600.06	493.00	295,827.61
	11TH USW	m2	61.47	493.00	30,305.40
	11TH NSW	m2	309.74	493.00	152,701.82
	11TH Stair Case	m2	20.19	493.00	9,953.30
	12TH Slab	m2	261.24	493.00	128,791.91
	12TH Beam	m2	163.52	493.00	80,615.29
Total		**m2**	**1,416.22**		**698,195.33**
13th STORY	12TH Shear wall	m2	600.06	493.00	295,827.61
	12TH USW	m2	130.62	493.00	64,397.34
	12TH NSW	m2	309.74	493.00	152,701.82
	12TH Stair Case	m2	20.19	493.00	9,953.30
	Roof Slab	m2	261.24	493.00	128,791.91
	Roof Beam	m2	163.52	493.00	80,615.29
	Roof Up standing	m2	138.30	493.00	68,183.87
Total		**m2**	**1,623.67**		**800,471.13**
Grand Total		**m2**	**19,415.34**		**9,178,815.05**

Estimation of cost incurred in completion of all the major structural activities performed on site by using Kumkang form-work technique to built-up area of 327.1344m2 building from 1st floor up-to 13rd floor is of 9,178,815.05 ET Birr.

4.5 .2 Analysis of construction costs of Conventional Timber form-work

The cost analysis for conventional timber form-work utilized in the Design and Build of the G+12+Terrace mixed block project, situated in front of the Ras Amba hotel, involved several key components.

During the assessment, it was determined that material costs constituted a significant portion of the overall budget due to the price of timber and associated materials. Labor costs also represented a considerable factor, as the installation of timber form-work required skilled labor to ensure proper assembly and safety. On the analysis to get unit cost of timber form-work the study considers the purchasing cost and its reuse time on the project.

Estimated Lifespan of Timber Form-work: determine how many times the timber can be reused effectively before it needs replacement and from the questionnaires the study found that it is 3 up-to 5 time. And cost of purchasing of 1pcs of timber form-work is 2500Et.Birr and the area of 1pcs of timber =1.22*2.44=2.98m2. by considering 3 times of number of reuse,

Cost Per Use = Total Initial Cost / Number of Reuse=2500/2.98/3=279.64birr/use

Based on this the rate required to execute one(1) m2 of conventional timber form-work is calculated on the table below. Table 4.10 and Table 4.11

Table 4. 10: Unit Rate Calculation for Conventional Timber Form-work

Formwork Direct Cost Calculation Convensional Timber

PROJECT	G+12+Terrace Mixed use building project of at Ginfile in front of Ras Amba Hotel	CREW DAILY OUTPUT	6
WORK ITEM	**Conventional Timber Form-work**	EQUIPMENT	1
QUANTITY OF WORK ITEM	1m2	**RESULTANT**	0.75 m2/hr

MATERIAL COST					LABOR COST					EQUIPMENT COST				
Type of material	unit	qty	rate	cost/un	Labor by trade	No	UF	indexed Daly cost	Daly cost	Type of equipment	No.	UF	Daly rental rate	hourly cost
Timber	m2	1.05	279.64	293.62	Forman	1.00	0.10	700.00	70.00	Tools	1.00	1.00	2.50	2.50
Eucalyptus dia 12mm	ml	1	90.00	90.00	Carpenter	1.00	1.00	500.00	500.00					-
Eucalyptus dia 10mm	ml	0.53	80.00	42.40	DL	2.00	1.00	280.00	560.00					
Eucalyptus dia 6mm	ml	0.5	60.00	30.00					-					
Nail 12-15mm	kg	0.2	170.00	34.00										
Nail 10-12mm	kg	0.10	170.00	17.00					-					-
Black wire 2.5	kg	0.01	180.00	1.44					-					-
Mould oil	lit	0.06	150.00	9.00					-					
Morale 50*70	ml	0.8	72.4	57.92										
TOTAL				575.38	TOTAL				1130.00	TOTAL				2.50
material unit cost				575.38	manpower unit cost				188.33	equipment unit cost				2.50

DIRECT COST OF WORK ITEM	766.22
overhead 10%	76.62
Profit 15%	114.93
Total	**957.77** Birr/m2

REMARK & ASSUMPTIONS

Assuming No. of Repitation of reuse for Timber formwork 3 times and purchasing cost of Timber =2500ET birr/pcs, the rat will be=2500/2.98/3=279.64birr/use

Table 4. 11: Total Cost Calculation for conventional Timber form-work for 13 floors

PROJECT:	Genfile
CLIENT:	Addis Ababa Housing
CONSULTANT:	Resapan
CONTRACTOR:	Ovid Construction PLC.
Formwork Type	Conventional Timber Formwork
Title	Total Cost of Formwork to Construct 327.1344m2 Built-up area

Story	Description	Unit	Formwork qty	Rate	Total Amount
Supper Stracture					
1ST STORY	GF Shear wall	m2	600.06	957.77	574,715.64
	GF up Standing wall	m2	61.47	957.77	58,875.46
	GF Non Stractural Wall	m2	309.74	957.77	296,659.68
	GF Stair Case	m2	20.19	957.77	19,336.66
	1ST Slab	m2	261.24	957.77	250,208.98
	1ST Beam	m2	163.52	957.77	156,614.41
Total		**m2**	**1,416.22**		**1,356,410.83**
2nd STORY	1ST Shear wall	m2	600.06	957.77	574,715.64
	1ST USW	m2	61.47	957.77	58,875.46
	1ST NSW	m2	309.74	957.77	296,659.68
	1ST Stair Case	m2	20.19	957.77	19,336.66
	2ND Slab	m2	261.24	957.77	250,208.98
	2ND Beam	m2	163.52	957.77	156,614.41
Total		**m2**	**1,416.22**		**1,356,410.83**
3RD STORY	2ND Shear wall	m2	600.06	957.77	574,715.64
	2ND USW	m2	61.47	957.77	58,875.46
	2ND NSW	m2	309.74	957.77	296,659.68
	2ND Stair Case	m2	20.19	957.77	19,336.66
	3RD Slab	m2	261.24	957.77	250,208.98
	3RD Beam	m2	163.52	957.77	156,614.41
Total		**m2**	**1,416.22**		**1,356,410.83**
4th STORY	3RD Shear wall	m2	600.06	957.77	574,715.64
	3RD USW	m2	61.47	957.77	58,875.46
	3RD NSW	m2	309.74	957.77	296,659.68
	3RD Stair Case	m2	20.19	957.77	19,336.66
	4TH Slab	m2	261.24	957.77	250,208.98
	4TH Beam	m2	163.52	957.77	156,614.41
Total		**m2**	**1,416.22**		**1,356,410.83**

PROJECT:	Genfile
CLIENT:	Addis Ababa Housing
CONSULTANT:	Resapan
CONTRACTOR:	Ovid Construction PLC.
Formwork Type	Conventional Timber Formwork
Title	Total Cost of Formwork to Construct 327.1344m2 Built-up area

Story	Description	Unit	Formwork qty	Rate	Total Amount
	Supper Stracture				
5th STORY	4TH Shear wall	m2	600.06	957.77	574,715.64
	4TH USW	m2	61.47	957.77	58,875.46
	4TH NSW	m2	309.74	957.77	296,659.68
	4TH Stair Case	m2	20.19	957.77	19,336.66
	5TH Slab	m2	261.24	957.77	250,208.98
	5TH Beam	m2	163.52	957.77	156,614.41
Total		m2	1,416.22		1,356,410.83
6th STORY	5TH Shear wall	m2	600.06	957.77	574,715.64
	5TH USW	m2	61.47	957.77	58,875.46
	5TH NSW	m2	309.74	957.77	296,659.68
	5TH Stair Case	m2	20.19	957.77	19,336.66
	6TH Slab	m2	261.24	957.77	250,208.98
	6TH Beam	m2	163.52	957.77	156,614.41
Total		m2	1,416.22		1,356,410.83
7th STORY	6TH Shear wall	m2	600.06	957.77	574,715.64
	6TH USW	m2	61.47	957.77	58,875.46
	6TH NSW	m2	309.74	957.77	296,659.68
	6TH Stair Case	m2	20.19	957.77	19,336.66
	7TH Slab	m2	261.24	957.77	250,208.98
	7TH Beam	m2	163.52	957.77	156,614.41
Total		m2	1,416.22		1,356,410.83
8th STORY	7TH Shear wall	m2	600.06	957.77	574,715.64
	7TH USW	m2	61.47	957.77	58,875.46
	7TH NSW	m2	309.74	957.77	296,659.68
	7TH Stair Case	m2	20.19	957.77	19,336.66
	8TH Slab	m2	261.24	957.77	250,208.98
	8TH Beam	m2	163.52	957.77	156,614.41
Total		m2	1,416.22		1,356,410.83
9th STORY	8TH Shear wall	m2	600.06	957.77	574,715.64
	8TH USW	m2	61.47	957.77	58,875.46
	8TH NSW	m2	309.74	957.77	296,659.68
	8TH Stair Case	m2	20.19	957.77	19,336.66
	9TH Slab	m2	261.24	957.77	250,208.98
	9TH Beam	m2	163.52	957.77	156,614.41
Total		m2	1,416.22		1,356,410.83

PROJECT:	Genfile				
CLIENT:	Addis Ababa Housing				
CONSULTANT:	Resapan				
CONTRACTOR:	Ovid Construction PLC.				
Formwork Type	Conventional Timber Formwork				
Title	Total Cost of Formwork to Construct 327.1344m2 Built-up area				
Story	**Description**	**Unit**	**Formwork qty**	**Rate**	**Total Amount**
Supper Stracture					
10th STORY	**9TH Shear wall**	m2	600.06	957.77	574,715.64
	9TH USW	m2	61.47	957.77	58,875.46
	9TH NSW	m2	309.74	957.77	296,659.68
	9TH Stair Case	m2	20.19	957.77	19,336.66
	10TH Slab	m2	261.24	957.77	250,208.98
	10TH Beam	m2	163.52	957.77	156,614.41
Total		**m2**	**1,416.22**		**1,356,410.83**
11th STORY	**10TH Shear wall**	m2	600.06	957.77	574,715.64
	10TH USW	m2	61.47	957.77	58,875.46
	10TH NSW	m2	309.74	957.77	296,659.68
	10TH Stair Case	m2	20.19	957.77	19,336.66
	11TH Slab	m2	261.24	957.77	250,208.98
	11TH Beam	m2	163.52	957.77	156,614.41
Total		**m2**	**1,416.22**		**1,356,410.83**
12th STORY	**11TH Shear wall**	m2	600.06	957.77	574,715.64
	11TH USW	m2	61.47	957.77	58,875.46
	11TH NSW	m2	309.74	957.77	296,659.68
	11TH Stair Case	m2	20.19	957.77	19,336.66
	12TH Slab	m2	261.24	957.77	250,208.98
	12TH Beam	m2	163.52	957.77	156,614.41
Total		**m2**	**1,416.22**		**1,356,410.83**
13th STORY	**12TH Shear wall**	m2	600.06	957.77	574,715.64
	12TH USW	m2	130.62	957.77	125,107.17
	12TH NSW	m2	309.74	957.77	296,659.68
	12TH Stair Case	m2	20.19	957.77	19,336.66
	Roof Slab	m2	261.24	957.77	250,208.98
	Roof Beam	m2	163.52	957.77	156,614.41
	Roof Up standing	m2	138.30	957.77	132,463.42
Total		**m2**	**1,623.67**		**1,555,105.96**
Grand Total		**m2**	**19,415.34**		**17,832,035.88**

Estimation of cost incurred in completion of all the major structural activities performed site by using conventional timber form-work technique to built-up area of 327.1344m2 building from 1st floor up-to 13rd floor is of 17,832,035.88 Et. Birr.

In a comprehensive cost analysis of form-work options for a construction project of built-up area of 327.1344 m² and encompassing 13 floors, a striking contrast emerged between conventional timber form-work and Kumkang aluminium form-work. The total expenditure for conventional timber form-work is 17,832,035.88 ETB, while the innovative Kumkang aluminium form-work proved to be significantly more economical, costing only 9,178,815.05 ETB. As shown Figure 4.21 below.

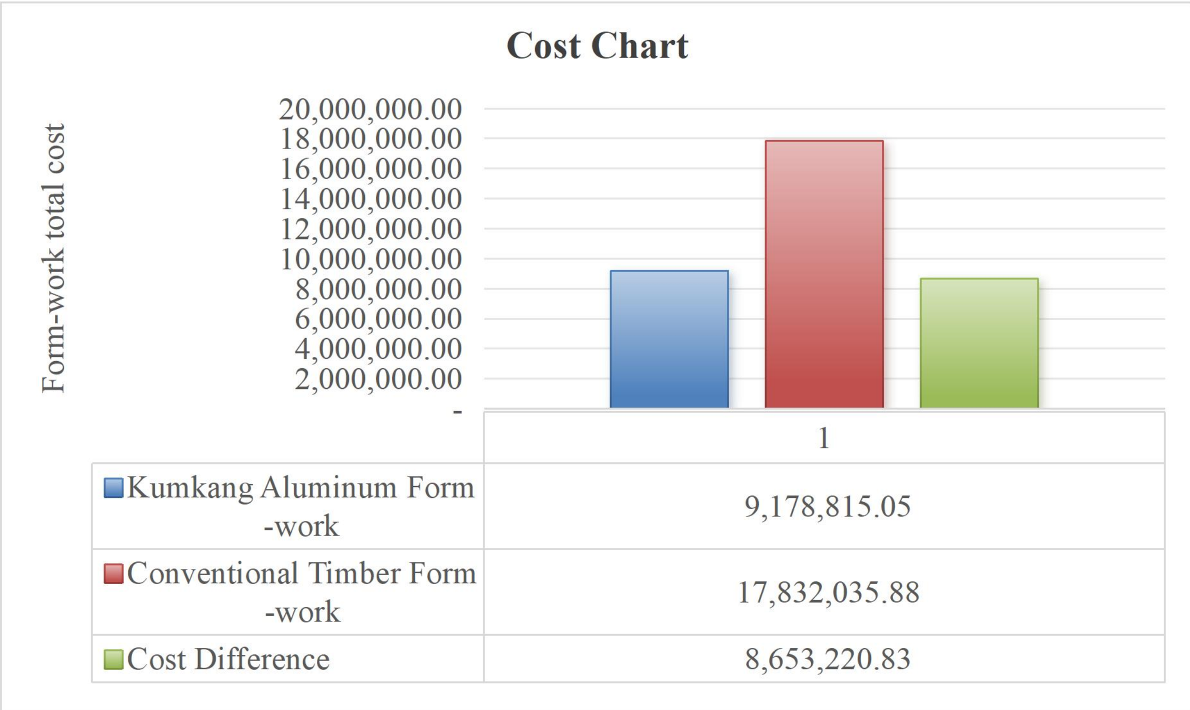


Figure 4. 21: Total cost summary of form-work

The cost savings by utilizing Kumkang form-work over conventional timber form-work amounted to 8,653,220.83 ETB, which represents a 48.54% reduction in costs. This analysis indicates that switching from conventional timber form-work to Kumkang form-work can lead to substantial cost savings while completing major structural activities in building construction.

4.6.Analysis of time taken for the construction using both conventional timber and Kumkang aluminum form-work

The speed of construction work using form-work not only accelerates project timelines but also enhances efficiency, quality, and safety, ultimately leading to more successful construction outcomes. The expedited construction timeline for the floor cycle significantly increases the likelihood of completing the project on schedule or even ahead of time. By accelerating the construction activities associated with form-work, costs can be reduced, particularly those resulting from project delays. Additionally, shorter construction duration provides a financial advantage due to the time value of money.

This analysis evaluate the time taken for construction using both conventional timber and Kumkang aluminum form-work in the Design and Build of the G+12+Terrace mixed block project, located in front of the Ras Amba Hotel, by utilizing MS Project and Excel sheets by assessing labor productivity, crew output, and the specified quantities from the project.

4.6.1 Analysis of time taken for the construction using Kumkang aluminum form-work

To analyze the duration of construction using Kumkang aluminum form-work, this study considers the main key factors, including the quantity of work, crew productivity, and the number of crew members involved to execute the form-work.

Quantity of Work (Q): total area that has been formed using the aluminum form-work.
Crew Productivity (P): the output of the crew per unit time.
Number of Crew Members (N): the total number of workers in the crew

* Total Daily Output = P × N
* Duration (D) = Q / Total Daily Output

Using this crew productivity format the study calculates the time taken to finalize G+12+Terrace mixed block project, by using Excel and Ms-project. The relationship and total required time to finish the project using kumkang aluminum form-work as shown table below Table.4.12 and Table 4.13

Table 4.1 2: Duration Calculation for Kumkang Aluminum form-work

Duration & Resource Calculation For Kumkang Alumninum Formwork

I.No	Work Description	Unit	Qty 1	Productivity/ Crew/Day 2	Duration /Crew 3=1/2	Estimat Days 4=3/5	No.Crews 5	Man Power: Description	UF 6	No. /Crew 7	No/day 8=5*6*7	Machinary: Description	UF 9	No/day 10=5*9	Material: Description	Unit	Qty per Unit 11	Total Quantity 12=1*11
1	GF Shear wall	m2	600.06	20.00	30.00	2.00	15	Forman	0.20	1.0	3.00				Wall Panel	m2	1	600.1
								Kumkang Technical	1.00	1.0	15.00				PVC Sleeve	pcs	5	3000.3
								DL	2.00	1.0	30.00				Tie Raod	pcs	1	600.1
2	GF up Standing wall	m2	61.47	20.00	3.07	1.02	3	Forman	0.20	1.0	0.60			0	Wall Panel	m2	1	61.5
								Technical	1.00	1.0	3.00				PVC Sleeve	pcs	5	307.4
								DL	2.00	1.0	6.00				Tie Raod	pcs	1	61.5
3	GF Non Stractural Wall	m2	309.74	20.00	15.49	1.03	15	Forman	0.20	1.0	3.00			0	Wall Panel	m2	1	309.7
								Kumkang Technical	1.00	1.0	15.00				PVC Sleeve	pcs	5	1548.7
								DL	2.00	1.0	30.00				Tie Raod	pcs	1	309.7

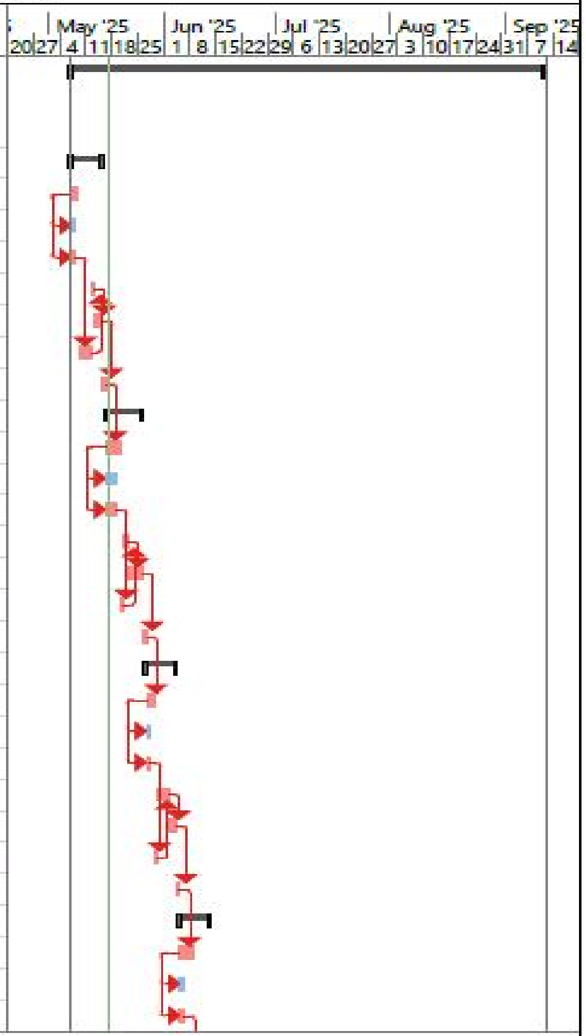
Duration & Resource Calculation For Kumkang Alumninum Formwork

I.No	Work Description	Unit	Qty 1	Productivity/ Crew/Day 2	Duration /Crew 3=1/2	Estimat Days 4=3/5	No.Crews 5	Man Power				Machinary			Material			
								Description	UF 6	No. /Crew 7	No/day 8=5*6*7	Description	UF 9	No/day 10=5*9	Description	Unit	Qty per Unit 11	Total Quantity 12=1*11
4	GF Stair Case	m2	20.19	10.00	2.02	1.01	2	Forman	0.20	1.0	0.40			0	Wall Panel	m2	1	20.2
								Kumkang Technical	1.00	1.0	2.00				PVC Sleeve	pcs	5	100.9
								DL	2.00	1.0	4.00				Tie Raod	pcs	1	20.2
5	1ST Slab	m2	261.24	15.00	17.42	1.94	9	Forman	0.20	1.0	1.80			0	Wall Panel	m2	1	261.2
								Kumkang Technical	1.00	1.0	9.00				PVC Sleeve	pcs	5	1306.2
								DL	2.00	1.0	18.00				Tie Raod	pcs	1	261.2
6	1ST Beam	m2	163.52	20.00	8.18	1.02	8	Forman	0.20	1.0	1.60			0	Wall Panel	m2	1	163.5
								Kumkang Technical	1.00	1.0	8.00				PVC Sleeve	pcs	5	817.6
								DL	2.00	1.0	16.00				Tie Raod	pcs	1	163.5

Table 4. 13: Total Time taken by Kumkang aluminum form-work to finalize 13 floor blocks

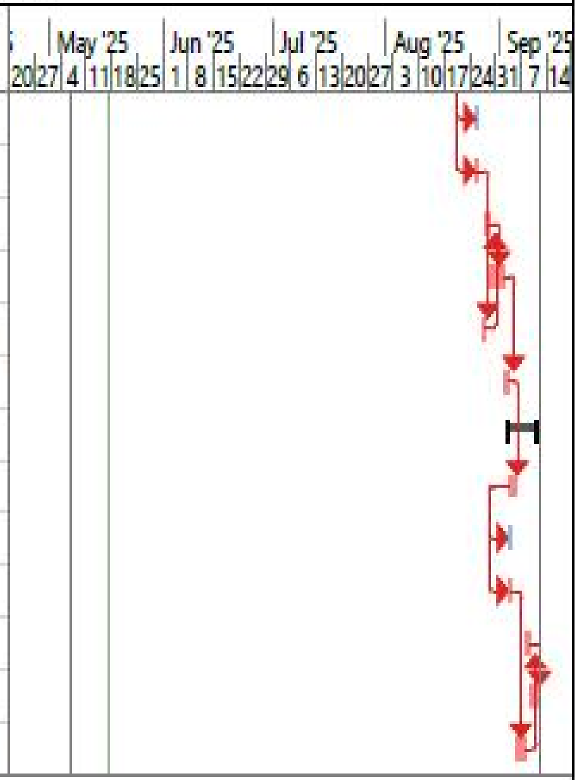
Genfile Ras Amba Project Kumkang Alumnium Formwork work Duration

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors
1			**Genfile Ras Amba Project Kumkang Alumnium Formwork work**	**91.39 days**	**Wed 5/7/25**	**Thu 9/11/25**	
2			**1ST STORY**	**6.03 days**	**Wed 5/7/25**	**Thu 5/15/25**	
3			GF Shear wall	2 days	Wed 5/7/25	Thu 5/8/25	
4			GF up Standing wall	1 day	Wed 5/7/25	Wed 5/7/25	3SS
5			GF Non Stractural Wall	1.03 days	Wed 5/7/25	Thu 5/8/25	3SS
6			GF Stair Case	1 day	Mon 5/12/25	Tue 5/13/25	8
7			1ST Slab	2 days	Tue 5/13/25	Thu 5/15/25	6
8			1ST Beam	1 day	Fri 5/9/25	Mon 5/12/25	5FS+1 day
9			Dismantling of Formwork	1 day	Thu 5/15/25	Fri 5/16/25	7
10			**2ND STORY**	**6.03 days**	**Fri 5/16/25**	**Mon 5/26/25**	
11			GF Shear wall	2 days	Fri 5/16/25	Tue 5/20/25	9
12			GF up Standing wall	1 day	Fri 5/16/25	Mon 5/19/25	11SS
13			GF Non Stractural Wall	1.03 days	Fri 5/16/25	Mon 5/19/25	11SS
14			GF Stair Case	1 day	Wed 5/21/25	Thu 5/22/25	16
15			1ST Slab	2 days	Thu 5/22/25	Mon 5/26/25	14
16			1ST Beam	1 day	Tue 5/20/25	Wed 5/21/25	13FS+1 day
17			Dismantling of Formwork	1 day	Mon 5/26/25	Tue 5/27/25	15
18			**3RD STORY**	**6.03 days**	**Tue 5/27/25**	**Wed 6/4/25**	
19			GF Shear wall	2 days	Tue 5/27/25	Thu 5/29/25	17
20			GF up Standing wall	1 day	Tue 5/27/25	Wed 5/28/25	19SS
21			GF Non Stractural Wall	1.03 days	Tue 5/27/25	Wed 5/28/25	19SS
22			GF Stair Case	1 day	Fri 5/30/25	Mon 6/2/25	24
23			1ST Slab	2 days	Mon 6/2/25	Wed 6/4/25	22
24			1ST Beam	1 day	Thu 5/29/25	Fri 5/30/25	21FS+1 day
25			Dismantling of Formwork	1 day	Wed 6/4/25	Thu 6/5/25	23
26			**4TH STORY**	**6.03 days**	**Thu 6/5/25**	**Fri 6/13/25**	
27			GF Shear wall	2 days	Thu 6/5/25	Mon 6/9/25	25
28			GF up Standing wall	1 day	Thu 6/5/25	Fri 6/6/25	27SS
29			GF Non Stractural Wall	1.03 days	Thu 6/5/25	Fri 6/6/25	27SS



Genfile Ras Amba Project Kumkang Alumnium Formwork work Duration

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors
92			GF up Standing wall	1 day	Mon 8/25/25	Tue 8/26/25	91SS
93			GF Non Stractural Wall	1.03 days	Mon 8/25/25	Tue 8/26/25	91SS
94			GF Stair Case	1 day	Thu 8/28/25	Fri 8/29/25	96
95			1ST Slab	2 days	Fri 8/29/25	Tue 9/2/25	94
96			1ST Beam	1 day	Wed 8/27/25	Thu 8/28/25	93FS+1 day
97			Dismantling of Formwork	1 day	Tue 9/2/25	Wed 9/3/25	95
98			13TH STORY	6.03 days	Wed 9/3/25	Thu 9/11/25	
99			GF Shear wall	2 days	Wed 9/3/25	Fri 9/5/25	97
100			GF up Standing wall	1 day	Wed 9/3/25	Thu 9/4/25	99SS
101			GF Non Stractural Wall	1.03 days	Wed 9/3/25	Thu 9/4/25	99SS
102			GF Stair Case	1 day	Mon 9/8/25	Tue 9/9/25	104
103			1ST Slab	2 days	Tue 9/9/25	Thu 9/11/25	102
104			1ST Beam	1 day	Fri 9/5/25	Mon 9/8/25	101FS+1 day



From table above 4.15 and 16 the study investigates the construction duration associated with the erection and disassembly of Kumkang aluminum form-work in the context of a 13-floor residential block. The result indicate that the total time required for the erection of one floor is approximately 7.03 days using Ms-project planning, with an additional day allocated for disassembly (dish-uttering). The cumulative duration to complete the entire 13-floor structure is 91 days.

4.6.2 Analysis of time taken for the construction using conventional timber form-work

This study establish a systematic approach for calculating the duration of conventional timber form-work using various factors such as crew productivity, quantity of work, and other influencing variables. By leveraging tools like Microsoft Excel for item duration calculations and Microsoft Project for overall project duration assessments.

Quantity of Work (Q): total area that has been formed using the aluminum form-work.
Crew Productivity (P): the output of the crew per unit time.
Number of Crew Members (N): the total number of workers in the crew

* Total Daily Output = P × N
* Duration (D) = Q / Total Daily Output

Using this crew productivity format the study calculates the time taken to finalize G+12+Terrace mixed block project, by using Excel and Ms-project. the relationship and total required time to finish the project using conventional timber form-work as shown table below Table.4.14 and Table 4.15

Table 4. 14: Duration calculation for Timber Formwork

Duration & Resource Calculation For Conventional Timber Formwork																		
						Estimate		Man Power				Machinary			Material			
I.No	Work Description	Unit	Qty 1	Productivity/ Crew/Day 2	Duration /Crew 3=1/2	Days 4=3/5	No.Crews 5	Description	UF 6	No. /Crew 7	No/day 8=5*6*7	Description	UF 9	No/day 10=5*9	Description	Unit	Qty per Unit 11	Total Quantity 12=1*11
1	GF Shear wall	m2	600.06	6.00	100.01	5.00	20	Forman	0.17	1.0	3.34			0	Plywood(Timber), 18 mm	m2	1.1	660.1
								Carpenter	1.00	1.0	20.00				Eucalypts, Dia 12 cm	ml	1	600.1
								DL	2.00	1.0	40.00				Eucalypts, Dia 10 cm	ml	0.53	318.0
															Eucalypts, Dia 6 cm	ml	0.5	300.0
															Nail 12 cm	kg	0.2	120.0
															Nail 10 cm	kg	0.1	60.0
															Carpenter wire, Dia 2.5mm	kg	0.008	4.8
															Clear Mould Oil	lit	0.06	36.0
2	GF up Standing wall	m2	61.47	6.00	10.25	2.05	5	Forman	0.17	1.0	0.84			0	Plywood(Timber), 18 mm	m2	1.1	67.6
								Carpenter	1.00	1.0	5.00				Eucalypts, Dia 12 cm	ml	1	61.5
								DL	2.00	1.0	10.00				Eucalypts, Dia 10 cm	ml	0.53	32.6
															Eucalypts, Dia 6 cm	ml	0.5	30.7
															Nail 12 cm	kg	0.2	12.3
															Nail 10 cm	kg	0.1	6.1
															Carpenter wire, Dia 2.5mm	kg	0.008	0.5
															Clear Mould Oil	lit	0.06	3.7

Duration & Resource Calculation For Conventional Timber Formwork

I.No	Work Description	Unit	Qty 1	Productivity/ Crew/Day 2	Duration /Crew 3=1/2	Estimate Days 4=3/5	No.Crews 5	Man Power Description	UF 6	No. /Crew 7	No/day 8=5*6*7	Machinary Description	UF 9	No/day 10=5*9	Material Description	Unit	Qty per Unit 11	Total Quantity 12=1*11
3	GF Non Stractural Wall	m2	309.74	6.00	51.623333	3.441556	15	Forman	0.17	1.0	2.51			0	Plywood(Timber), 18 mm	m2	1.1	340.7
								Carpenter	1.00	1.0	15.00				Eucalypts, Dia 12 cm	ml	1	309.7
								DL	2.0	1.0	30.00				Eucalypts, Dia 10 cm	ml	0.53	164.2
															Eucalypts, Dia 6 cm	ml	0.5	154.9
															Nail 12 cm	kg	0.2	61.9
															Nail 10 cm	kg	0.1	31.0
															Carpenter wire, Dia 2.5mm	kg	0.008	2.5
															Clear Mould Oil	lit	0.06	18.6
4	GF Stair Case	m2	20.19	6.00	3.364875	1.682438	2	Forman	0.17	1.0	0.33			0	Plywood(Timber), 18 mm	m2	1.1	22.2
								Carpenter	1.0	1.0	2.00				Eucalypts, Dia 12 cm	ml	1	20.2
								DL	2.0	1.0	4.00				Eucalypts, Dia 10 cm	ml	0.53	10.7
															Eucalypts, Dia 6 cm	ml	0.5	10.1
															Nail 12 cm	kg	0.2	4.0
															Nail 10 cm	kg	0.1	2.0
															Carpenter wire, Dia 2.5mm	kg	0.008	0.2
															Clear Mould Oil	lit	0.06	1.2

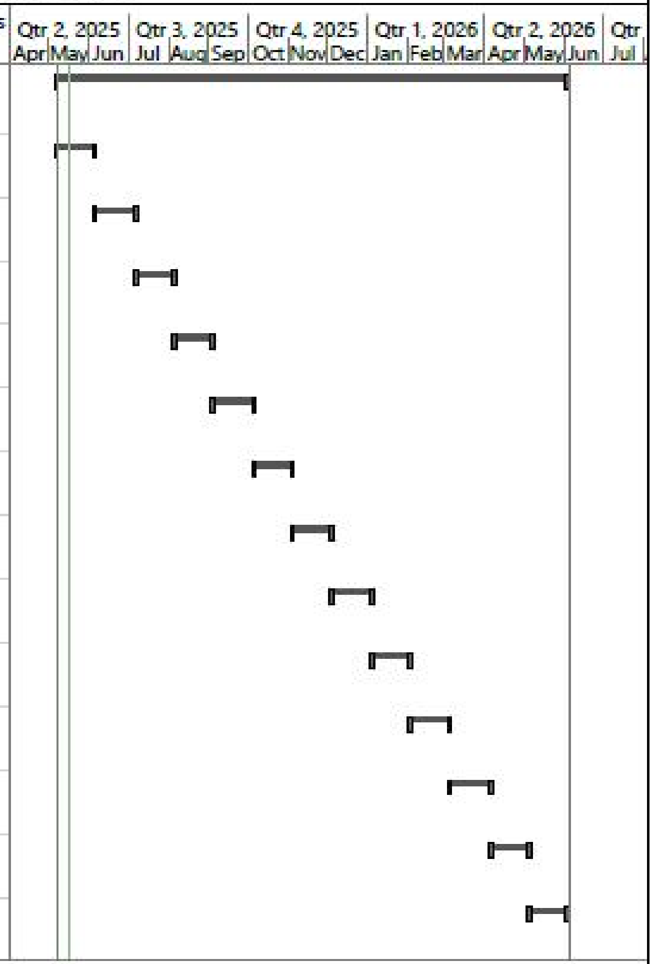
Duration & Resource Calculation For Conventional Timber Formwork

I.No	Work Description	Unit	Qty 1	Productivity/ Crew/Day 2	Duration /Crew 3=1/2	Estimate Days 4=3/5	No.Crews 5	Man Power				Machinary			Material			
								Description	UF 6	No. /Crew 7	No/day 8=5*6*7	Description	UF 9	No/day 10=5*9	Description	Unit	Qty per Unit 11	Total Quantity 12=1*11
5	1ST Slab	m2	261.24	6.00	43.54	4.8	9	Forman	0.2	1.0	1.50			0	Plywood(Timber), 18 mm	m2	1.1	287.4
								Carpenter	1.0	1.0	9.00				Eucalypts, Dia 12 cm	ml	1	261.2
								DL	2.0	1.0	18.00				Eucalypts, Dia 10 cm	ml	0.53	138.5
															Eucalypts, Dia 6 cm	ml	0.5	130.6
															Nail 12 cm	kg	0.2	52.2
															Nail 10 cm	kg	0.1	26.1
															Carpenter wire, Dia 2.5mm	kg	0.008	2.1
															Clear Mould Oil	lit	0.06	15.7
6	1ST Beam	m2	163.52	6.00	27.253308	2.725331	10	Forman	0.2	1.0	1.67			0	Plywood(Timber), 18 mm	m2	1.1	179.9
								Carpenter	1.0	1.0	10.00				Eucalypts, Dia 12 cm	ml	1	163.5
								DL	2.0	1.0	20.00				Eucalypts, Dia 10 cm	ml	0.53	86.7
															Eucalypts, Dia 6 cm	ml	0.5	81.8
															Nail 12 cm	kg	0.2	32.7
															Nail 10 cm	kg	0.1	16.4
															Carpenter wire, Dia 2.5mm	kg	0.008	1.3
															Clear Mould Oil	lit	0.06	9.8

Table 4. 15: Overall Duration calculation for Timber form-work to finalize 13 floor block

Genfile Ras Amba Project Conventional Timber Form-work work Duration

ID		Task Mode	Task Name	Duration	Start	Finish	Predecessors
1			Genfile Ras Amba Project Timber Formwork work	281.45 days	Wed 5/7/25	Thu 6/4/26	
2			1ST STORY	21.65 days	Wed 5/7/25	Thu 6/5/25	
12			2ND STORY	21.65 days	Thu 6/5/25	Mon 7/7/25	
22			3RD STORY	21.65 days	Mon 7/7/25	Tue 8/5/25	
32			4TH STORY	21.65 days	Tue 8/5/25	Thu 9/4/25	
42			5TH STORY	21.65 days	Thu 9/4/25	Mon 10/6/25	
52			6TH STORY	21.65 days	Mon 10/6/25	Tue 11/4/25	
62			7TH STORY	21.65 days	Tue 11/4/25	Thu 12/4/25	
72			8TH STORY	21.65 days	Thu 12/4/25	Mon 1/5/26	
82			9TH STORY	21.65 days	Mon 1/5/26	Tue 2/3/26	
92			10TH STORY	21.65 days	Tue 2/3/26	Thu 3/5/26	
102			11TH STORY	21.65 days	Thu 3/5/26	Mon 4/6/26	
112			12TH STORY	21.65 days	Mon 4/6/26	Tue 5/5/26	
122			13TH STORY	21.65 days	Tue 5/5/26	Thu 6/4/26	



From table above 4.18 and 4.19 the study investigates the construction duration associated with the erection and disassembly of conventional timber form-work in the context of a 13-floor residential block. The result indicates that the total time required for the erection of one floor is approximately 21.65 days using Ms-project planning. The cumulative duration to complete the entire 13-floor structure is 281.45 days. As shown in figure below

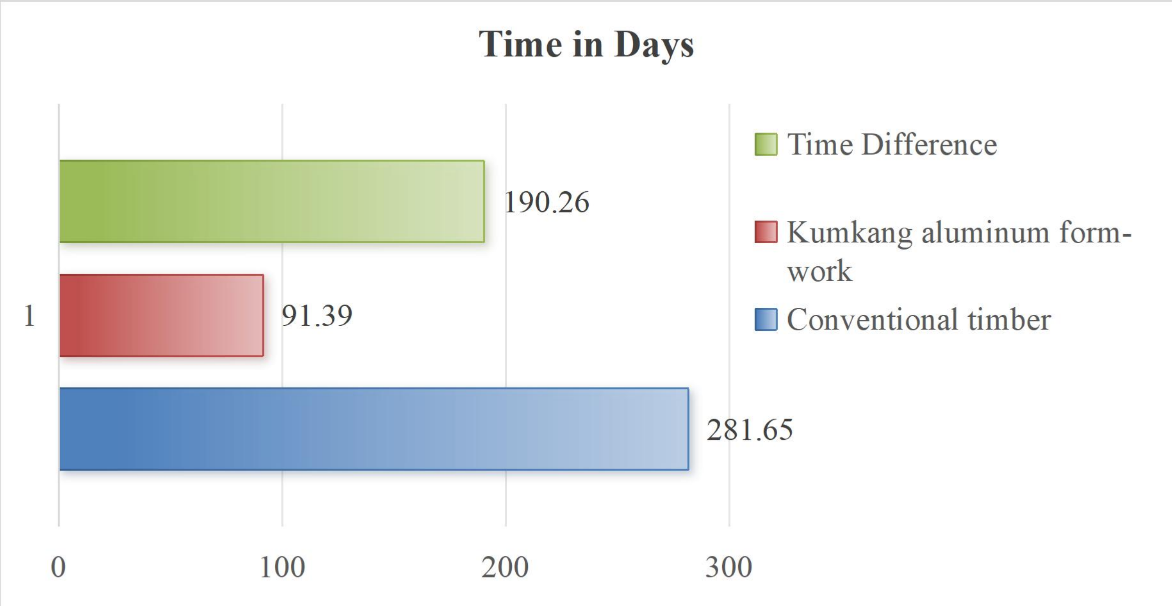


Figure 4. 22: Time summary for Timber and Kumkang aluminum form-work

The analysis of construction times for major structural activities using conventional timber form-work compared to Kumkang form-work highlights significant differences in efficiency. For the 1st floor, the timber form-work required 21.65 days, while the Kumkang form-work completed the same task in just 7.01 days. When considering the time taken to complete floors 1 to 13, timber form-work took an extensive 281.65 days, whereas Kumkang form-work accomplished this in only 91.39 days.

This results in a remarkable time difference of 190.26 days between the two methods for completing the same number of floors. In terms of efficiency, the use of Kumkang form-work led to a reduction in construction time by approximately 67.6% compared to conventional timber form-work. This substantial time savings underscores the effectiveness of the Kumkang system in expediting construction processes, making it a more efficient choice for large-scale projects.

4.6. Descriptive Analysis of Safety and Health-Related Practices

The descriptive analysis of safety and health-related questions provides valuable insights into how respondents perceive the safety benefits and health implications of using aluminum form-work compared to conventional form-work within the ovid construction projects. This section presents the mean scores and standard deviations for each statement related to safety and health, enabling a comprehensive understanding of both the perceived strengths and areas that may require attention.

Table 4. 16: Descriptive Statistics for Safety and Health-Related Practices

No	Statement	N	Mean	Std. Deviation
1	The lightweight nature of aluminum form-work improves worker safety.	52	4.10	0.60
2	Conventional form-work poses greater risks of workplace injuries.	52	3.95	0.55
3	The ergonomic design of aluminum form-work reduces worker fatigue.	52	4.05	0.58
4	Adherence to safety protocols is critical when using aluminum form-work.	52	4.20	0.50
5	The type of form-work significantly influences overall construction site safety.	52	4.15	0.45
Aggregate Mean			**4.09**	**0.54**

Source: (Researcher's Survey, 2025)

The analysis reveals an aggregate mean score of 4.09 and a standard deviation of 0.54, based on responses from 52 participants. This result indicates that respondents generally hold a strong and positive perception of aluminum form-work's role in enhancing worker safety and improving health conditions on construction sites. The high mean values across individual statements suggest widespread recognition of the safety advantages offered by aluminum form-work over conventional systems.

Specifically, the highest mean score (4.20) is attributed to the statement emphasizing the critical role of adherence to safety protocols when using aluminum form-work. This reflects strong agreement among respondents that procedural compliance is essential, regardless of the form-work type. Similarly, the lightweight nature of aluminum form-work, with a mean score of 4.10, is seen as an important factor in reducing physical strain and minimizing injury risks among workers.

The relatively low standard deviation, ranging from 0.45 to 0.60, indicates consistent responses among participants, suggesting a shared understanding and agreement about the positive impact of aluminum form-work on site safety. This consistency enhances the reliability and validity of the research data.

Overall, while perceptions are highly favorable, the findings also highlight the continuing need for rigorous safety protocols and training to further optimize outcomes. These insights can guide project managers and construction firms in reinforcing health and safety practices while adopting modern form-work solutions, thus contributing to safer and more efficient construction environments.

4.7.Descriptive Analysis of Implementation Process

The descriptive analysis of the implementation process offers detailed insights into respondents' experiences and perceptions regarding the ease of assembling and disassembling aluminum form-work, the skills required, and the complexity involved. This section summarizes the mean scores and standard deviations for statements related to the implementation process, helping to identify both strengths and potential challenges in adopting aluminum form-work within construction projects.

Table 4. 17 : Descriptive Statistics for Implementation Process

No	Statement	N	Mean	Std. Deviation
1	The assembly process of aluminum form-work is easier compared to conventional form-work.	52	4.05	0.55
2	The disassembly process differs significantly between aluminum and conventional form-work.	52	3.90	0.50
3	Availability of skilled labor is critical for implementing conventional form-work.	52	3.85	0.58
4	Technical training is important for effective use of aluminum form-work.	52	4.20	0.45
5	The complexity of design affects the ease of implementing aluminum form-work.	52	3.95	0.52
Aggregate Mean			**3.99**	**0.52**

Source: (Researcher's Survey, 2025)

The results, with an aggregate mean of 3.99 and a standard deviation of 0.52, suggest that respondents generally perceive the implementation process of aluminum form-work positively, though with recognition of certain challenges that require attention. The relatively high aggregate mean points to an overall favorable view, especially regarding the ease of assembly and the importance of training to maximize effectiveness.

The highest mean score (4.20) corresponds to the statement emphasizing the necessity of technical training for effectively using aluminum form-work. This finding highlights that while aluminum form-work systems offer operational advantages, proper training remains a critical factor in their successful implementation. The ease of assembly, with a mean of 4.05, is also well-regarded, reinforcing the perception that aluminum systems simplify on-site processes compared to conventional alternatives.

Meanwhile, slightly lower but still favorable mean scores (ranging from 3.85 to 3.95) indicate that respondents acknowledge the differing requirements and complexities in both form-work types, particularly regarding disassembly and design considerations.

The standard deviations, which range from 0.45 to 0.58, show moderate variability in responses, suggesting a fairly consistent understanding among respondents while allowing for some diversity of experience.

Overall, the findings demonstrate that while the implementation of aluminum form-work is generally seen as advantageous in terms of ease and efficiency, the role of skilled labor, technical training, and consideration of design complexities must not be overlooked. These insights can guide construction managers and trainers in developing targeted interventions to further streamline the form-work implementation process and improve project outcomes.

4.8. Descriptive Analysis of Durability and re-usability

The descriptive analysis of durability and re-usability provides valuable insights into respondents' evaluations of how aluminum and conventional form-work systems perform over time, particularly in terms of their robustness and capacity for repeated use. This section presents the mean scores and standard deviations for statements that examine these critical attributes, shedding light on factors that influence form-work selection and long-term project efficiency.

Table 4. 18: Descriptive Statistics for Durability and re-usability

No	Statement	N	Mean	Std. Deviation
1	Aluminum form-work is more durable compared to conventional form-work.	52	4.30	0.48
2	The re-usability of aluminum form-work influences its selection over conventional form-work.	52	4.15	0.50
3	The re-usability of conventional form-work often meets large-scale project needs.	52	3.60	0.55
4	Durability of aluminum form-work ensures consistent project outcomes.	52	4.25	0.47

5	Wear and tear reduce the effectiveness of conventional form-work over time.	52	4.10	0.51
Aggregate Mean			**4.08**	**0.50**

Source: (Researcher's Survey, 2025)

The findings, reflected by an aggregate mean score of 4.08 and a standard deviation of 0.50, indicate that respondents view aluminum form-work as highly durable and reusable, with clear advantages over conventional systems. The relatively high mean values show strong positive perceptions, suggesting that durability and re-usability are among the primary drivers behind the preference for aluminum form-work in construction projects.

The highest mean score (4.30) is associated with the durability of aluminum form-work compared to conventional options. This underscores the strong belief among respondents that aluminum systems provide superior long-term performance and structural integrity, making them a reliable choice for multiple project cycles. Closely following is the mean of 4.25, which points to aluminum form-work's contribution to consistent project outcomes, further reinforcing its reputation as a durable solution.

The statements concerning the re-usability of aluminum form-work (mean 4.15) and the negative effects of wear and tear on conventional systems (mean 4.10) also received favorable ratings, highlighting a clear consensus that aluminum outperforms traditional materials in sustaining quality over time.

Conversely, the relatively lower score (3.60) for the re-usability of conventional form-work suggests that respondents recognize some limitations in its application, particularly for large-scale projects where durability and repeated use are critical.

The standard deviations, ranging from 0.47 to 0.55, suggest low to moderate variability in responses, indicating a fairly uniform view among respondents with minimal disagreement. Overall, the analysis confirms that durability and re-usability are key strengths of aluminum form-work, contributing to its growing adoption in the construction sector. However, it also highlights that while conventional form-work remains usable, it is increasingly seen as less effective for projects demanding long-term performance and minimal material degradation.

4.9. Descriptive Analysis of Material and Resource Requirements

The descriptive analysis of material and resource requirements offers key insights into respondents' perceptions of how aluminum and conventional form-work systems differ in terms of material efficiency, transportation ease, resource availability, and environmental impact. This section presents the mean scores and standard deviations for each statement, providing a clearer picture of the strengths and challenges associated with each system in the context of material and resource use.

Table 4. 19: Descriptive Statistics for Material and Resource Requirements

No	Statement	N	Mean	Std. Deviation
1	Aluminum form-work is significantly more material-efficient than conventional form-work.	52	4.20	0.45
2	The lightweight nature of aluminum form-work makes it easier to transport and handle.	52	4.35	0.48
3	Availability of materials for conventional form-work influences its usability.	52	3.70	0.50
4	Material wastage occurs more frequently in projects using conventional form-work.	52	4.05	0.52
5	Reliance on timber in conventional form-work affects sustainability efforts.	52	4.15	0.49
Aggregate Mean			**4.09**	**0.49**

Source: (Researcher's Survey, 2025)

The analysis, with an aggregate mean of 4.09 and a standard deviation of 0.49, reveals that respondents largely recognize the material and resource advantages offered by aluminum form-work over conventional methods. The high mean values demonstrate strong agreement on the efficiency, sustainability, and practical benefits of aluminum systems in modern construction.

The highest mean score (4.35) pertains to the ease of transportation and handling due to the lightweight nature of aluminum form-work. This suggests that respondents perceive this attribute as a significant logistical advantage, reducing labor strain and facilitating smoother operations on construction sites.

Closely following are statements about material efficiency (mean 4.20) and the negative impact of timber reliance in conventional form-work (mean 4.15), both of which indicate a broad consensus that aluminum systems contribute positively to sustainability and resource optimization. The statement regarding frequent material wastage in conventional form-work projects (mean 4.05) further reinforces concerns over inefficiency and environmental impact associated with traditional methods.

The comparatively lower mean score (3.70) for the availability of materials for conventional form-work, while still moderately positive, suggests that respondents see material sourcing as a relevant but less critical factor in form-work selection. It may also point to localized variations in supply chains.

The standard deviations, ranging between 0.45 and 0.52, indicate low to moderate variability among responses, reflecting general agreement with minimal divergence in views.

In summary, this analysis highlights that aluminum form-work is widely viewed as superior in terms of material efficiency, ease of handling, and alignment with sustainability goals. These perceptions support the growing trend towards adopting aluminum systems in projects where resource management and environmental considerations are increasingly prioritized.

4.10. Descriptive Analysis of Flexibility and Design Adaptability

The descriptive analysis of flexibility and design adaptability explores respondents' perceptions regarding how aluminum and conventional form-work systems meet the diverse and evolving design needs of modern construction projects. By examining the mean scores and standard deviations for each statement, this section offers insights into the adaptability and practical usability of each form-work type in various construction contexts.

Table 4. 20: Descriptive Statistics for Flexibility and Design Adaptability

No	Statement	N	Mean	Std. Deviation
1	Aluminum form-work is flexible in adapting to complex architectural designs.	52	4.00	0.50
2	The modularity of aluminum form-work simplifies construction processes.	52	4.15	0.47
3	Design changes during construction affect the usability of conventional form-work.	52	3.90	0.52
4	The adaptability of aluminum form-work suits different project sizes and types.	52	4.10	0.46
5	Conventional form-work meets the design flexibility needs of modern projects.	52	3.60	0.54
Aggregate Mean			**3.95**	**0.50**

Source: (Researcher's Survey, 2025)

The analysis, with an aggregate mean of 3.95 and a standard deviation of 0.50, indicates that respondents generally perceive aluminum form-work as offering a higher level of flexibility and adaptability than conventional systems. While the overall assessment is favorable, it is slightly lower than other attributes previously discussed, suggesting moderate room for improvement.

The highest mean score (4.15) is attributed to the modularity of aluminum form-work, reflecting respondents' strong agreement that its modular design streamlines construction processes and enhances operational efficiency. This modularity is evidently seen as a significant advantage in meeting diverse project requirements.

The adaptability of aluminum form-work to various project sizes and types also received a high mean score (4.10), reinforcing the perception that aluminum systems are well-suited for the evolving demands of the construction industry.

Conversely, the statement on conventional form-work's ability to meet modern design flexibility needs garnered the lowest mean (3.60), indicating a comparatively weaker endorsement. This suggests that while conventional form-work is still used, it may struggle to keep pace with the dynamic requirements of contemporary projects.

The statement regarding the impact of design changes on conventional form-work usability (mean 3.90) points to a recognized limitation, where modifications during construction could disrupt efficiency and increase costs.

The standard deviations range from 0.46 to 0.54, indicating moderate variability among respondents but still reflecting an overall consensus in favor of aluminum form-work's superior flexibility and adaptability.

In summary, this analysis highlights that while both form-work types are used, aluminum systems are generally viewed as more adaptable to complex designs, varying project scales, and construction process simplification. These attributes position aluminum form-work as a forward-looking solution for projects that require design versatility and efficient implementation.

4.11. Descriptive Analysis of Cost of Initial Investment and Maintenance

The descriptive analysis of the cost of initial investment and maintenance examines respondents' perspectives on the financial implications of using aluminum versus conventional form-work. This includes insights into upfront costs, maintenance expenses, and the long-term economic viability of each system. By analyzing the mean scores and standard deviations, this section sheds light on the balance between cost and value in form-work selection decisions.

Table 4. 21: Descriptive Statistics for Cost of Initial Investment and Maintenance

No	Statement	N	Mean	Std. Deviation
1	The high initial cost of aluminum form-work is significant compared to conventional form-work.	52	4.20	0.48

2	The low maintenance requirement of aluminum form-work justifies its cost.	52	4.05	0.50
3	Maintenance costs for conventional form-work often exceed the expected budget.	52	3.85	0.53
4	The ability to reuse aluminum form-work is critical in recovering the initial investment.	52	4.25	0.46
5	The cost of repairs and replacements reduces the effectiveness of conventional form-work.	52	3.90	0.52
Aggregate Mean			**4.05**	**0.50**

Source: (Researcher's Survey, 2025)

The analysis, with an aggregate mean of 4.05 and a standard deviation of 0.50, reveals that respondents recognize both the high initial cost and the long-term financial benefits associated with aluminum form-work. The overall assessment suggests that while the upfront investment is considerable, it is generally justified by lower maintenance demands and re-usability, leading to long-term cost recovery.

The highest mean score (4.25) was recorded for the statement that highlights the critical role of re-usability in offsetting aluminum form-work's initial cost. This strong endorsement underscores a key economic advantage that makes aluminum form-work attractive for projects with multiple reuse cycles.

Similarly, the perception that the high initial cost of aluminum form-work is significant (mean 4.20) confirms that financial entry barriers remain a primary concern, particularly for smaller firms or projects with limited budgets.

The low maintenance requirement of aluminum form-work received a favorable mean score (4.05), indicating that respondents see reduced ongoing expenses as a major benefit that justifies the higher initial outlay.

Statements concerning conventional form-work reflect more moderate scores. The costliness of maintaining conventional systems (mean 3.85) and the impact of repairs and replacements on their effectiveness (mean 3.90) suggest that while conventional form-work is less expensive initially, its long-term maintenance can erode these cost advantages.

The standard deviations, ranging from 0.46 to 0.53, demonstrate a reasonable consistency in respondents' views, with most sharing similar opinions about the cost dynamics between aluminum and conventional form-work systems.

In conclusion, the findings affirm that while aluminum form-work requires a higher initial investment, its durability, low maintenance, and re-usability contribute significantly to cost recovery over time. This makes aluminum systems particularly appealing for large-scale or long-term projects where these benefits can be fully realized.

4.12. Descriptive Analysis of Challenges in Adopting Aluminum form-work

The descriptive analysis of challenges in adopting aluminum form-work explores respondents' experiences and perceptions regarding the obstacles faced when implementing this modern form-work system. By examining the mean scores and standard deviations, this section highlights the major barriers that may hinder wider adoption, such as skill shortages, costs, technical support, and regulatory issues.

Table 4. 22: Descriptive Statistics for Challenges in Adopting Aluminum form-work

No	Statement	N	Mean	Std. Deviation
1	Finding skilled workers proficient in aluminum form-work installation and handling is difficult.	52	4.30	0.45
2	The high upfront cost of aluminum form-work is a major barrier for our company.	52	4.35	0.47
3	Our team lacks sufficient training to efficiently use aluminum form-work systems.	52	4.10	0.50
4	Transporting and storing aluminum form-work is challenging due to its weight and bulkiness.	52	3.90	0.52
5	Maintaining aluminum form-work in good condition over multiple projects is difficult.	52	3.85	0.51
6	There is limited local supplier support for spare parts and technical assistance.	52	3.95	0.50
7	Aluminum form-work is not suitable for most of the projects we undertake.	52	3.60	0.55
8	Local construction standards and regulations do not fully support the use of aluminum form-work.	52	3.70	0.53
9	Aluminum form-work is not flexible enough to accommodate frequent design changes in projects.	52	3.80	0.51
Aggregate Mean			**4.06**	**0.50**

Source: (Researcher's Survey, 2025)

The analysis reveals an aggregate mean score of 4.06 with a standard deviation of 0.50, indicating that respondents generally perceive significant challenges in adopting aluminum form-work. The relatively low standard deviation reflects a consistent pattern in respondents' experiences, suggesting a shared recognition of these obstacles across the industry.

The highest mean score (4.35) pertains to the high upfront cost, highlighting it as the most critical barrier preventing broader adoption. This confirms that financial constraints remain a pressing concern, especially for companies operating with tight budgets or smaller-scale projects.

Similarly, the difficulty in finding skilled workers (mean 4.30) and the lack of sufficient training among existing teams (mean 4.10) underscore the skills gap as another major obstacle. This suggests that without targeted training and workforce development, the benefits of aluminum form-work may remain underutilized.

Challenges related to transportation and storage (mean 3.90) and maintenance (mean 3.85) also appear noteworthy, reflecting practical difficulties that can impact operational efficiency.

Limited local supplier support (mean 3.95) highlights supply chain issues that can affect project timelines and maintenance, while concerns about suitability for projects (mean 3.60) and regulatory support (mean 3.70) indicate contextual factors that may influence adoption rates.

Flexibility concerns (mean 3.80) suggest that while aluminum form-work offers many advantages, it may not yet fully meet the demands of projects requiring frequent design adjustments.

Overall, the findings emphasize that while aluminum form-work presents clear technical and economic benefits, addressing these key challenges — particularly cost, skills, and supply chain limitations — will be essential to facilitate wider adoption in the construction sector.

4.13. Inferential Analysis

Inferential analysis is an essential statistical technique used to draw conclusions and make generalizations about a population based on sample data. In this study, inferential analysis aims to explore the relationships between the independent variables (Conventional form-work vs. Aluminum form-work) and the dependent variables (Time, Cost, Quality, and Safety & Health) within the context of the Ovid Real Estate Project in Addis Ababa. The goal is to assess how the type of form-work used in construction impacts project success across these key performance indicators.

This section will provide insights into the strength and direction of these relationships, helping to identify which type of form-work significantly influences time, cost, quality, and safety outcomes in building construction projects. Through inferential techniques such as correlation and regression analysis, the study will evaluate how the two form-work systems (conventional and aluminum) are associated with the performance outcomes observed on the project.

4.13.1 Correlation Analysis

Correlation analysis measures the strength and direction of a linear relationship between two variables. In this study, correlation analysis will help determine the degree of association between the independent variable (form-work type) and the dependent variables (Time, Cost, Quality, and Safety & Health).

Rule of Interpretation for Correlation Analysis:

The interpretation of the correlation coefficient (r) focuses on the strength and direction of the relationship between two variables. The coefficient ranges from -1 to +1:

- **Positive correlation (r > 0)** indicates that as one variable increases, the other also increases.
- **Negative correlation (r < 0)** suggests that as one variable increases, the other decreases.
- **A value closer to ±1** implies a stronger relationship between the variables, while a value closer to 0 indicates a weaker relationship.

Table 4. 23: shows the correlation analysis results between the use of Conventional form-work vs. Aluminum form-work and the project outcomes of Time, Cost, Quality, and Safety & Health**.**

Correlations						
		IP	DR	MRR	FDA	BC
Implementation Process (IP)	Pearson Correlation	1				
Durability and re-usability (DR)	Pearson Correlation	.037	1			
Material and Resource Requirements	Pearson Correlation	.080	.204	1		
Flexibility and Design Adaptability	Pearson Correlation	.138	.185	.766**	1	

Building Construction time, cost, quality, and Safety and Health	Correlation	.369**	.552**	.297*	.207	1
**. Correlation is significant at the 0.01 level (2-tailed).						

Source: (SPSS Result, V27)

The correlation matrix presents the relationships among five key variables: Implementation Process (IP), Durability and re-usability (DR), Material and Resource Requirements (MRR), Flexibility and Design Adaptability (FDA), and Building Construction outcomes in terms of time, cost, quality, and safety and health (BC). The results indicate a moderate positive and statistically significant correlation between Implementation Process and Building Construction outcomes ($r = 0.369$, $p < 0.01$), suggesting that an effective implementation process contributes to better construction performance.

Durability and re-usability also show a strong positive and significant correlation with Building Construction outcomes ($r = 0.552$, $p < 0.01$), implying that emphasizing durable and reusable materials enhances construction efficiency and quality.

A particularly strong and significant relationship is observed between Material and Resource Requirements and Flexibility and Design Adaptability ($r = 0.766$, $p < 0.01$), indicating that flexible and adaptable designs often demand more material and resource planning. Additionally, Material and Resource Requirements show a weak to moderate but statistically significant positive correlation with Building Construction outcomes ($r = 0.297$, $p < 0.05$), suggesting a modest influence of resource intensity on construction success. On the other hand, the correlation between Flexibility and Design Adaptability and Building Construction is weak and not statistically significant ($r = 0.207$), indicating a limited direct impact.

Furthermore, the Implementation Process has weak and statistically insignificant correlations with Durability and re-usability ($r = 0.037$), Material and Resource Requirements ($r = 0.080$), and Flexibility and Design Adaptability ($r = 0.138$), implying that implementation strategies may function independently of material and design considerations in this context. Similarly, Durability and re-usability show low and non-significant correlations with both Material and Resource Requirements and Flexibility and

Design Adaptability. Overall, the findings highlight that while some variables, such as MRR and FDA or DR and BC, are closely associated; others appear to have minimal direct relationships, indicating the potential presence of additional mediating or moderating factors within the construction process.

4.13.2 Regression Analysis

This section presents the results of the regression analysis conducted to explore the predictive relationship between selected independent variables and construction project outcomes. The aim was to determine how factors such as Implementation Process (IP), Durability and re-usability (DR), Material and Resource Requirements (MRR), and Flexibility and Design Adaptability (FDA) influence Building Construction (BC) outcomes, which include time efficiency, cost control, construction quality, and occupational safety and health. Building on the findings from the correlation analysis, the regression model was employed to assess not only the strength but also the statistical significance and relative contribution of each variable to the overall performance of construction projects. The following discussion interprets the findings and evaluates their implications for theory, practice, and future research in the field of construction project management.

Histogram of Regression

As part of the regression diagnostic process, a histogram of the residuals was generated to assess the assumption of normality. The distribution of residuals is a critical indicator of whether the linear regression model is appropriate and unbiased. In this study, the histogram of the residuals appeared approximately symmetric and bell-shaped, suggesting that the residuals are normally distributed. This supports the validity of one of the key assumptions underlying the use of multiple linear regression.

The near-normal distribution of the residuals indicates that the model errors are randomly and independently distributed, which enhances the reliability of the estimated coefficients and significance tests. No substantial skewness or outliers were observed, further confirming that the regression model fits the data reasonably well. As such, the model's predictions regarding the impact of Implementation Process, Durability and re-usability, Material and Resource Requirements, and Flexibility and Design Adaptability on Building Construction outcomes can be considered statistically sound and robust.

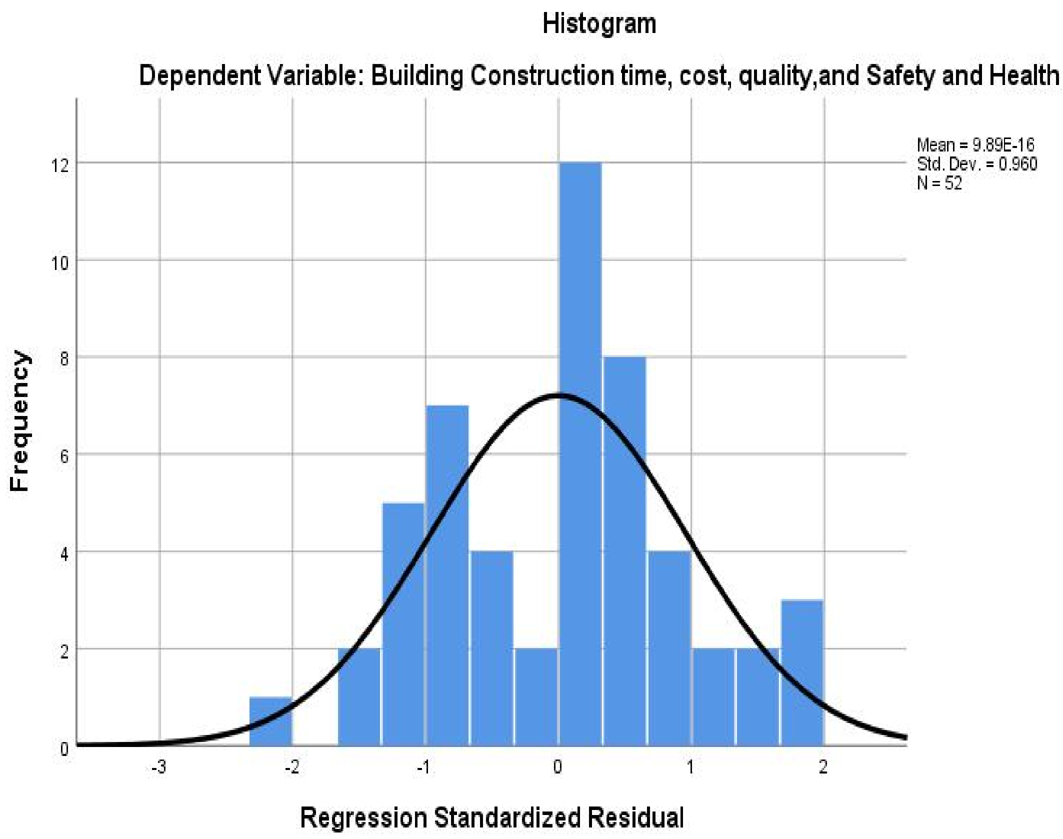


Figure 4. 23: Histogram (*Source: (SPSS Result, V27))*

Normality Test

As part of the regression diagnostics, a normality test was conducted to examine whether the residuals from the regression model followed a normal distribution. This is a critical assumption in multiple linear regression, as normally distributed residuals indicate that the model's estimates are unbiased and that hypothesis tests, such as t-tests for coefficients, are valid.

In this study, the histogram of residuals demonstrated a distribution that was approximately bell-shaped and symmetric, with no evident skewness or heavy tails. This suggests that the model errors are randomly distributed around the mean, which is consistent with the assumption of normality. The histogram supported the view that the differences between the observed and predicted values of Building Construction outcomes were normally distributed.

Additionally, a normal probability plot (P-P plot) was examined, and the residuals were observed to align closely with the reference diagonal line. This further reinforced the assumption that the residuals were normally distributed.

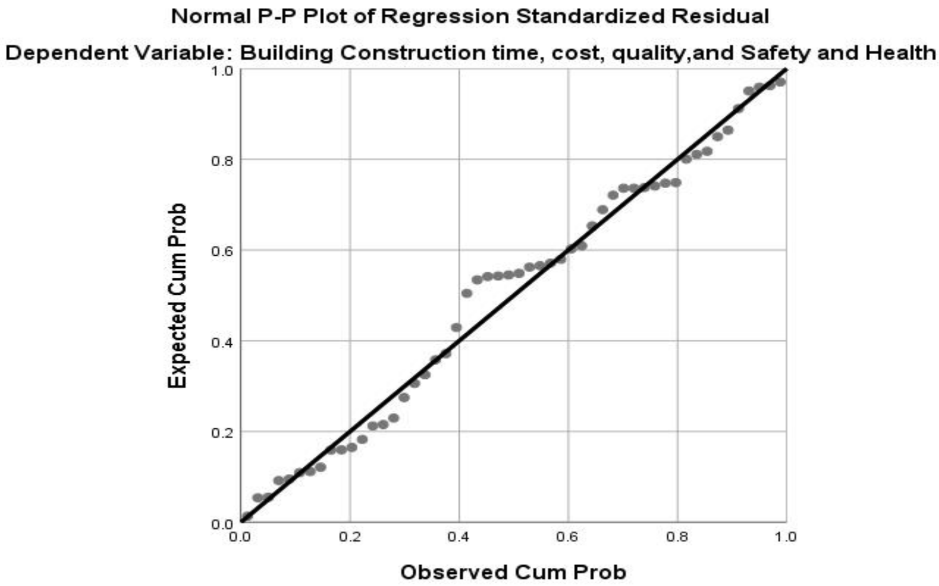


Figure 4. 24: P-P Plot (Source: (SPSS Result, V27))

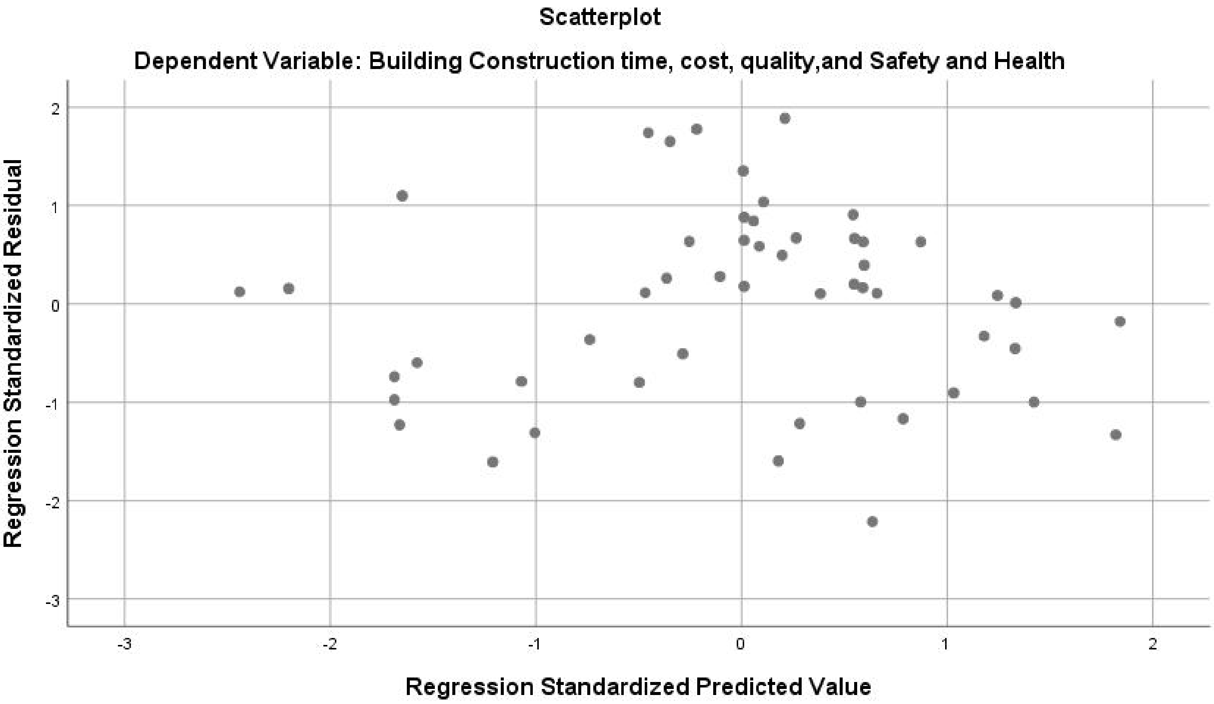


Figure 4. 25: Regression standardizes predicated value (Source: (SPSS Result, V27))

Col-linearity Statistics

Before interpreting the results of the regression model, it is essential to examine whether multi-collinearity exists among the independent variables. Multicollinearity occurs when two or more predictor variables are highly correlated, which can distort the estimation of regression coefficients, inflate standard errors, and reduce the overall reliability of the model. To assess this, **Variance Inflation Factor (VIF)** and **Tolerance** values were used. A general rule of thumb is that Tolerance values below 0.1 or VIF values above 10 indicate serious multicollinearity, while VIF values between 1 and 5 are considered acceptable and manageable.

Table 4. 24: shows the Collinearity Statistics

	Collinearity Statistics	
	Tolerance	VIF
Implementation Process (IP)	.979	1.021
Durability and re-usability (DR)	.956	1.046
Material and Resource Requirements	.409	2.447
Flexibility and Design Adaptability	.407	2.459

Source: (SPSS Result, V27)

The collinearity statistics in this study revealed that the **Implementation Process (IP)** had a Tolerance value of 0.979 and a VIF of 1.021, and **Durability and re-usability (DR)** showed a Tolerance of 0.956 and a VIF of 1.046. Both of these variables have VIF values very close to 1, indicating **no multicollinearity issues** and suggesting that they are statistically independent from the other predictors in the model.

On the other hand, **Material and Resource Requirements (MRR)** and **Flexibility and Design Adaptability (FDA)** presented lower Tolerance values of 0.409 and 0.407, respectively, with corresponding VIF values of 2.447 and 2.459. While these VIF values are still below the common threshold of 5, they indicate a **moderate level of multicollinearity** between MRR and FDA. This is consistent with the earlier correlation analysis, which showed a very strong correlation between these two variables ($r = 0.766$, $p < 0.01$). Although the multicollinearity is not at a critical level, it suggests that MRR and FDA share a substantial amount of variance, which could affect the interpretation of their individual regression coefficients.

Model Summary

To assess the overall fit of the regression model, a model summary was generated, which provides key statistics including the multiple correlation coefficient (R), coefficient of determination (R Square), adjusted R Square, and the standard error of the estimate. These indicators help evaluate how well the independent variables—**Implementation Process**

(IP), **Durability and re-usability (DR)**, and **Flexibility and Design Adaptability (FDA)**—collectively explain the variation in the dependent variable, which is **Building Construction outcomes** in terms of time, cost, quality, and safety and health (BC).

Table 4. 25: Model Summary

Model Summary[b]				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.656a	.431	.382	.42734
a. Predictors: (Constant), Flexibility and Design Adaptability, Implementation Process, Durability and re-usability				
b. Dependent Variable: Building Construction time, cost, quality,and Safety and Health				

Source: (SPSS Result, V27)

ANOVA[a]						
Model		Sum of Squares	df	Mean Square	F	Sig.
	Regression	6.497	4	1.624	8.895	.000[b]
	Residual	8.583	47	.183		
	Total	15.081	51			
a. Dependent Variable: Building Construction time, cost, quality, and Safety and Health						
b. Predictors: (Constant), Flexibility and Design Adaptability, Implementation Process, Durability and re-usability , Material and Resource Requirements						

Source: (SPSS Result, V27)

From the ANOVA table, the regression sum of squares is 6.497 with 4 degrees of freedom, while the residual sum of squares is 8.583 with 47 degrees of freedom, making the total sum of squares 15.081. The F-statistic is 8.895, and the associated significance value (Sig.) is .000, which is less than 0.01. This indicates that the overall regression model is statistically significant at the 1% level.

In other words, there is a very low probability (less than 0.1%) that the observed relationship between the independent variables and the dependent variable occurred by chance. Therefore, the model as a whole reliably predicts the outcome variable. This means that the combined effect of Implementation Process, Durability and re-usability , Material and Resource Requirements, and Flexibility and Design Adaptability has a significant impact on building construction outcomes related to time, cost, quality, and safety and health.

This statistically significant result supports the inclusion of these variables in the model and confirms their collective importance in explaining construction project performance.

Table 4. 26 Coefficients a

Coefficients [a]						
		UnstandardizedCoefficients		Standardized Coefficients		
Model		B	Std. Error	Beta	t	Sig.
	(Constant)	-.221	.574		-.384	.702
	Implementation Process	.474	.154	.342	3.073	.004
	Durability and re-usability	.697	.149	.526	4.672	.000
	Material and Resource Requirements	.42	.210	.034	2.000	.042
	Flexibility and Design Adaptability	.039	.184	.037	.212	.833

Source: (SPSS Result, V27)

The coefficients table presents the individual contribution of each predictor variable to the dependent variable, which is **Building Construction outcomes** (covering time, cost, quality, and safety and health). Both unstandardized and standardized coefficients are provided, along with t-values and significance levels, which help in understanding the strength and significance of each predictor's effect.

- The **constant (intercept)** has a coefficient of **-0.221** with a **p-value of 0.702**, which is not statistically significant. This means that when all independent variables are zero, the predicted value of building construction outcomes is not significantly different from zero, but the intercept itself is less relevant for interpretation here.

- **Implementation Process (IP)** has an unstandardized coefficient of **0.474** and a standardized beta of **0.342**, with a **t-value of 3.073** and a **p-value of 0.004**. This indicates that Implementation Process has a **positive and statistically significant effect** on building construction outcomes. Specifically, holding other variables constant, a one-unit increase in Implementation Process score is associated with a 0.474 increase in the predicted construction outcome. The standardized beta suggests a moderate effect size.
- **Durability and re-usability (DR)** shows the strongest positive effect, with an unstandardized coefficient of **0.697** and a standardized beta of **0.526**. The t-value is **4.672** and the p-value is **0.000**, indicating a highly significant relationship. This implies that improving durability and re-usability has the greatest impact on enhancing construction performance.
- **Material and Resource Requirements (MRR)** has an unstandardized coefficient of **0.420** and a standardized beta of **0.034**, with a **t-value of 2.000** and a **p-value of 0.042**. This suggests that MRR has a **positive and statistically significant**, but relatively small, effect on building construction outcomes. Even though the effect size is small (based on the standardized beta), it still contributes meaningfully.
- **Flexibility and Design Adaptability (FDA)** shows an unstandardized coefficient of **0.039** and a standardized beta of **0.037**, with a **t-value of 0.212** and a **p-value of 0.833**. This variable is **not statistically significant**, indicating that flexibility and design adaptability do not have a meaningful direct impact on the construction outcomes in this model.

Summary of interpretation

Predictor Variable	Significance (p-value)	Interpretation
Durability and re-usability (DR)	significant	Most influential predictor; highly significant and positively impacts construction
Implementation Process (IP)	significant	Statistically significant; contributes meaningfully to construction outcomes
Material and Resource Requirements (MRR)	significant	Significant but weaker impact compared to DR and IP
Flexibility and Design Adaptability (FDA)	not significant	Does not significantly influence construction outcomes in this model

5. MAJOR FINDINGS, CONCLUSION, AND RECOMMENDATIONS

This chapter presents the summary of the major findings, draws relevant conclusions, and outlines practical recommendations based on the comparative analysis of conventional and aluminum form-work systems in the context of the Ovid Real Estate construction project in Addis Ababa. The study aimed to assess the impact of these two form-work types on key construction performance indicators including time, cost, quality, safety, and resource efficiency.

Drawing from both descriptive and inferential analyses discussed in the previous chapter, this section distills the essential insights that emerged from the data. The conclusions are derived directly from the research findings and are aligned with the study objectives. Finally, the recommendations are intended to guide industry stakeholders construction firms, project managers, policymakers, and future researchers toward informed decisions that enhance construction performance, promote sustainability, and encourage the adoption of innovative form-work technologies in Ethiopia's construction sector.

5.1 Major Findings

The study compared the impacts of conventional and aluminum form-work systems across key construction performance indicators including cost, time, quality, safety, material usage, and adaptability. Key findings include:

1. **The implementation process:** of kumkang aluminum form-work have eight major steps to erect one floor using the following steps and works for all floors repeatedly.

   Step 1 – Foundation & Ground Floor Setup

   Step 2 – Erecting wall reinforcement.

   Step 3- Erecting Wall and slab form-work

   Step 4- Slab reinforcement and electrical conduit fittings

   Step 5- Completing Electrical and sanitary works and overall checking

   Step 6- Concrete pouring

   Step 7- De-shuttering vertical and Slab form-work

   Step 8- Overall checking and finishing works

2. Cost analysis result between Timber and kumkang aluminum form-work

The total expenditure for conventional timber form-work is 17,832,035.88 ETB, while the innovative Kumkang aluminium form-work proved to be significantly more economical, costing only 9,178,815.05 ETB and The cost savings by utilizing Kumkang form-work over conventional timber form-work amounted to 8,653,220.83 ETB, which represents a 48.54% reduction in costs. This analysis indicates that switching from conventional timber form-work to Kumkang form-work can lead to substantial cost savings while completing major structural activities in building construction.

3. Time analysis result between Timber and kumkang aluminum form-work

The analysis of construction times for major structural activities using conventional timber form-work compared to Kumkang form-work highlights significant differences in efficiency. For the 1st floor, the timber form-work required 21.65 days, while the Kumkang form-work completed the same task in just 7.01 days. When considering the time taken to complete floors 1 to 13, timber form-work took an extensive 281.65 days, whereas Kumkang form-work accomplished this in only 91.39 days.

This results in a remarkable time difference of 190.26 days between the two methods for completing the same number of floors. In terms of efficiency, the use of Kumkang form-work led to a reduction in construction time by approximately 67.6% compared to conventional timber form-work. This substantial time savings underscores the effectiveness of the Kumkang system in expediting construction processes, making it a more efficient choice for large-scale projects.

4. **Durability and re-usability**
   - Aluminum form-work demonstrated significantly greater durability and re-usability (mean = 4.30) compared to conventional systems (mean = 3.60).
   - Durability and re-usability were the most influential factors in improving construction outcomes ($\beta = 0.526$, $p < 0.01$).
5. **Implementation Process**
   - Aluminum form-work was perceived as easier to assemble and disassemble and required less manual labor.
   - The implementation process had a statistically significant positive effect on construction performance ($\beta = 0.342$, $p < 0.01$).

6. **Material and Resource Efficiency**
    - Aluminum form-work was seen as more efficient in terms of material use, transportation, and sustainability (mean = 4.09).
    - The use of timber in conventional systems was viewed as less sustainable and more wasteful.
7. **Safety and Health**
    - Aluminum form-work contributed positively to worker safety due to its ergonomic and lightweight nature (mean = 4.09).
    - Compliance with safety protocols was crucial for maximizing benefits.
8. **Cost Implications**
    - Despite higher initial investment costs, aluminum form-work offered lower maintenance and repair needs, leading to long-term cost-effectiveness (mean = 4.05).
    - re-usability of aluminum was critical in offsetting the upfront costs.
9. **Design Flexibility**
    - Aluminum form-work was more adaptable to complex designs but was less flexible in accommodating mid-project design changes (mean = 3.95).
    - However, this factor was statistically insignificant in predicting overall construction outcomes (p = 0.833).
10. **Challenges in Adoption**
    - High upfront cost, lack of skilled labor, limited technical support, and inadequate local regulations were identified as major barriers to aluminum form-work adoption (aggregate mean = 4.06).

5.2 Conclusion

The study concludes that aluminum form-work significantly outperforms conventional form-work across multiple dimensions including durability, efficiency, safety, and long-term cost-effectiveness. Its re-usability and low maintenance requirements make it ideal for large-scale or repetitive construction projects. However, its successful implementation depends heavily on skilled labor, adequate training, and supportive infrastructure and policies.

While aluminum systems require substantial initial investment and adaptation, their cumulative benefits align well with modern construction goals, especially in urban developments like the Ovid Real Estate project. Conversely, conventional form-work, although cheaper initially, presents limitations in terms of sustainability, flexibility, and efficiency.

Therefore, the choice of form-work should be strategic considering not just the initial cost but long-term project goals, available skill-sets, and sustainability requirements.

5.3 Recommendations

Based on the findings and conclusions, the following recommendations are proposed:

For Construction Firms

- **Invest in Aluminum form-work for Repetitive or Large-Scale Projects**
  - Leverage its re-usability and lower maintenance costs to improve cost-efficiency and project consistency.
- **Provide Technical Training**
  - Train workers and site supervisors to handle aluminum form-work safely and effectively to mitigate the current skill gap.
- **Conduct Cost-Benefit Analysis**
  - Evaluate projects on a life-cycle basis to justify aluminum form-work investment rather than focusing on upfront costs alone.

For Government and Regulators

- **Update Building Standards and Guidelines**
  - Introduce policies that promote and support the use of modern form-work technologies such as aluminum, especially in high-rise or dense urban areas.
- **Encourage Local Supply Chains**
  - Facilitate partnerships with local suppliers and manufacturers to reduce costs and ensure availability of spare parts and technical support.
- **Incentivize Sustainable Practices**
  - Offer tax or permit incentives for construction firms that adopt environmentally sustainable materials like aluminum over timber-based form-work.

For Future Researchers

- **Explore Lifecycle Costing Models**

Conduct more detailed studies on the long-term economic, environmental, and operational impacts of various form-work systems across different building types.

- **Investigate Hybrid form-work Systems**

Explore the feasibility of combining aluminum and conventional form-work to optimize both cost and adaptability in varying project conditions.

References

Argaw Tarekegn. (2010). *Application of Modern form-work Systems In Ethiopia*. ADDIS ABABA UNIVERSITY SCHOOL OF GRADUATE STUDIES ADDIS ABABA INSTITUTE OF TECHNOLOGY.

Ashish P. Waghmare, R. S. H. (2017). Cost and Time estimation for Conventional , Aluminium & Tunnel form-work. *International Research Journal of Engineering and Technology(IRJET)*, *4*(7), 5–8. https://irjet.net/archives/V4/i7/IRJET-V4I7363.pdf

Bereket Amare Sida. (2015). Cost, quality and speed comparison of steel and timber form-work system used for building projects (a case study in Addis Ababa) [Addis Ababa University School Of Graduate Studies Addis Ababa Institute Of Technology School]. In *The ASHA Leader* (Vol. 20, Issue 10). https://doi.org/10.1044/leader.ppl.20102015.20

Bezaye Girma Tamer. (2017). *Cost and Quality Comparison of Different Types of form-work Systems in Concrete Structure Buildings Case Study in Bahir Dar*. http://hdl.handle.net/123456789/10699

Bhargavi S., P., & Shelake, A. G. (2018). Kumkang Aluminium form-work. *International Journal of Creative Research Thoughts (IJCRT) Www.Ijcrt.Org*, *6*(2), 9–15.

Chitra Kendre1*, T. B. (2024). Comparison between Aluminum and Conventional form-work Based of Cost and Time. *International Journal of Research in Engineering, Science and Management Volume 7, Issue 2, February 2024 Https://Www.Ijresm.Com | ISSN (Online): 2581-5792*, *7*(2), 71–73.

Getaw Tessema. (2019). *Study on Current form-work Practices and Trends in Ethiopian Building Construction Industries: Case of Selected Contractors in Addis Ababa* (Issue June). ADDIS ABABA UNIVERSITY ADDIS ABABA INSTITUTE OF TECHNOLOGY SCHOOL.

Harle, S. M. (2018). Comparision of Conventional With Aluminium form-work System. *Eureka Journals*, *1*(1), 1–14. http://www.technology.eurekajournals.com/index.php/GJCRUARP/article/view/262

Loganathan, K., & Viswanathan, K. E. (2016). a Study Report on Cost, Duration and Quality Analysis of Different form-works in High-Rise Building. *International Journal of Scientific & Engineering Research*, *7*(4), 190–195. https://www.researchgate.net/publication/302905135

Meron Tadesse. (2016). *Investigation on the effectts of form-work and scaffolding types in building projects in addis ababa*.

Nawy, D. E. G. (2008). Concrete Construction Engineering Handbook. *Concrete Construction Engineering Handbook*. https://doi.org/10.1201/9781420007657

Rajeshkumar, V., & Sreevidya, V. (2019). Performance Evaluation on Selection of form-work Systems in High Rise Buildings Using Regression Analysis and Their Impacts on Project Success. *Archives of Civil Engineering*, *65*(2), 209–222. https://doi.org/10.2478/ace-2019-0029

Risma Apdeni1*, James Hellyward 2, D. L. S. S. R. . (2024). Comparative Study of Cost and Eco-Efficiency Factors of Aluminum and Conventional form-work in The AYOMA Apartment Construction Project. *Cived*, *11*(1), 174–184. https://doi.org/10.24036/cived.v11i1.508

Sandip.P.Pawar1, P. M. A. (2014). Comparative Analysis of form-work in Multistory Building. *International Journal of Research in Engineering and Technology*, *03*(21), 22–24. https://doi.org/10.15623/ijret.2014.0321006

Sharma, R., Kumar, B., & Choudhury, D. (2024). *Integration of Aluminium form-work in Sustainable and Affordable Housings*. *6*(5).

Swanson, R. A., & III, E. F. H. (2005). *Research In Organizations*. www.bkconnection.com.

Www.kumkangkind.com. (n.d.). *Global Kumkang Kind*.

Www.kumkangkind.com. (2016). *Kumkang Modular Coordination*.

Zinabu, T. (2022). Effect of soaking sample cubes on concrete compressive strength: The case of Ethiopian Construction Industry. *International Journal of Physical Sciences*, *17*(1), 23–31. https://doi.org/10.5897/ijps2021.4962

Appendix-A:

Correlations table

Correlations

		Implementation Process	Durability and Re-usability	Material and Resource Requirements	Flexibility and Design Adaptability	Building Construction time, cost, quality,and Safety and Health
Implementation Process	Pearson Correlation	1	.037	.080	.138	.369**
	Sig. (2-tailed)		.794	.571	.329	.007
	N	52	52	52	52	52
Durability and Re-usability	Pearson Correlation	.037	1	.204	.185	.552**
	Sig. (2-tailed)	.794		.147	.189	.000
	N	52	52	52	52	52
Material and source quirements	Pearson Correlation	.080	.204	1	.766**	.197
	Sig. (2-tailed)	.571	.147		.000	.161
	N	52	52	52	52	52
Flexibility and Design Adaptability	Pearson Correlation	.138	.185	.766**	1	.207
	Sig. (2-tailed)	.329	.189	.000		.140
	N	52	52	52	52	52
Building Construction time, cost, quality, and Safety and Health	Pearson Correlation	.369**	.552**	.297*	.207	1
	Sig. (2-tailed)	.007	.000	.045	.140	
	N	52	52	52	52	52

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix-B:

Questionnaire Survey

ADAMA SCINCE AND TECHNOLOGY UNIVERSITY

OFFICE OF POST GRADUATES STUDIES

A Comparative study on the impact of using conventional and Aluminum form-work on building construction: A case study on Ovid Real Estate project in Addis Ababa

Dear respondent: The purpose of the survey is to collect relevant data for conducting a research entitled" A Comparative study on the impact of using conventional and Aluminum form-work on building construction: A case study on Ovid Real Estate project in Addis Ababa. please kindly answer all question genuinely and to the best of your knowledge. there is no wrong no right response to any of these statement. all responses are collected for academic research purpose and will be kept strictly confidential. Thank you in advance for taking your time to complete the questionnaire and for your cooperation.

Debebe Kubrael Kurka

Tele: +251916146506, Email:- ***debebekubrael@gmail.com***

Thank You for Your Co-operation !

Instruction:

1. There are Three (3) section in this questionnaire and please answer all questions

2. Put your answer using a tick mark (√) in box of you choice

3. Completion of these form will take you not more than 30 minutes

Part A: Personal information of respondents

In this section, please circle the letter of you answer will be kept strictly confidential

1. Gender of the respondent Male ☐ Female ☐

2. Age of the respondent (1- 18] years ☐ (18-30]years ☐ (30-35] years ☐ 35 and above years ☐

3. Marital status Unmarried☐ Married ☐

4. Education level College diploma or level ☐ first Degree ☐ Master's ☐ PH.D or above ☐

5. Work experience (1-5] years ☐ (5-10] years ☐ (10-15] years ☐ above 15 years ☐

6. Stakeholder Project manager☐ Consultant ☐ Quantity surveyor ☐ construction engineer ☐ Accountant ☐ Forman ☐ client ☐

Part B: Detailed information

To what extent the following cause are important for the impact of using conventional and Aluminum form-work.

Section 1: form-work Direct Cost-Related Questions

1.1 Material required for Conventional (Timber) Form-work and its Direct Cost, if there is any other please use blank space and specify them.

SN	Type of material	unit	Unit Rate
1	Timber	pcs	

2	Eucalyptus dia 120mm	ml	
3	Eucalyptus dia 100mm	ml	
4	Eucalyptus dia 60mm	ml	
5	Nail 6-12mm	kg	
6	Black wire 2.5	kg	
7	Mould oil	lit	
8	Morale 50*70cm	ml	
9			

1.2 Kumkang Aluminum Form-work and its Direct Cost, if there is any other please use blank space and specify them.

SN	**Material Type**	**Unit**	**Unit Rate/m2**	**Remark**
1	Kumkang Aluminum form-work	M2		Initial inv. Cost
2	Kumkang Aluminum form-work	M2		Rental Cost/day
3	Kumkang Aluminum form-work	M2		Salvage Value
4	Kumkang Aluminum form-work	M2		Maintenance Cost/-----

1.3 In the above table if there is difference in cost of wall panel,Slab panel and Staircase panel of Kumkang Aluminum form-work , please specify them.

1. Cost of Kumkang aluminum Wall Panel ----------------------ET birr/m2
2. Cost of Kumkang aluminum Slab Panel ----------------------ET birr/m2
3. Cost of Kumkang aluminum Staircase Panel ------------------ET birr/m2

1.4 please Mention the number of repetition that your project or company uses the two type form-work

SN	form-work Type	No. Of Repetition of Use(Re-use)
1	Kumkang Aluminum form-work	
2	Conventional (Timber) Form-work	

1.5 After how many days does your project stripping(disassembly) of the following form-work item starts for Kumkank Aluminium after pouring of concrete :-

A. Wall Panel ------------------------------ days

B. Slab panel ------------------------------- days

C. Staircase Panel ------------------------- days

1.6 Please specify the productivity of skilled labour by one crew for both type of form-work per day on your project

SN	form-work Type	Work Type	Crew Productivity per day
1	Kumkang Aluimnum form-work	Wall Panel Work	
		Slab Panel Work	
		Staircase PaneWork	
2	Conventional (Timber) Form-work	Footing Pad	
		FoundationColumn	
		Grade Beam	
		Elevation Column	
		Floor Beam	

		Floor slab	

1.7 What is the Direct cost of skilled and Unskilled labor per day on your project for both type of form-work, please fill only the required part and mention other labor by trade if there

SN	Labor By Trade	Kumkang Aluminum form-work(Labor cost per day in Birr)	Conventional (Timber) Form-work(Labor cost per Day in Birr)
1	Chief Carpenter		
2	Daily Labor		
3	Ass. Carpenter		
4	Kumkang Specialized		
5	Forman		
6			
7			

Section 2: Safety and Health-Related Questions

SN	Description	1	2	3	4	5
D	**Safety and Health**					
1	How significant is the lightweight nature of aluminum form-work in improving worker safety compared to conventional form-work?					
.2	To what extent does conventional form-work pose greater risks of workplace injuries compared to aluminum form-work?					
3	How important is the ergonomic design of					

	aluminum form-work in reducing worker fatigue and strain compared to conventional form-work?					
4.	How critical is adherence to safety protocols when using aluminum form-work versus conventional form-work?					
5	To what degree does the type of form-work (aluminum vs. conventional) influence the overall safety of construction sites?					

Aluminum and Conventional form-work and their respective attributes that affect the dependent variables (cost, time, quality, and safety/health). These attributes include ease of implementation, durability, re-usability, material requirements, and complexity of design/assembly.

1.Not important 2. Slightly important 3. moderately 4. very important 5. Extremely important cause.

NS	Description	1	2	3	4	5
A	**Implementation Process**					
1	How easy is the assembly process of aluminum form-work compared to conventional form-work?					
2	To what extent does the disassembly process differ between aluminum and conventional form-work?					
3	How critical is the availability of skilled labor for the successful implementation of conventional form-work?					

4	How important is technical training for using aluminum form-work effectively?					
5	To what degree does the complexity of design affect the ease of implementing aluminum form-work?					

NS	**Description**	**1**	**2**	**3**	**4**	**5**
B	**Durability and re-usability**					
1	How durable is aluminum form-work compared to conventional form-work?					
2	To what extent does the re-usability of aluminum form-work influence its selection over conventional form-work?					
3	How often does the re-usability of conventional form-work meet the requirements of large-scale projects?					
4	How critical is the durability of aluminum form-work in ensuring consistent project outcomes?					
5	To what degree does the wear and tear of conventional form-work reduce its effectiveness over time?					

NS	Description	1	2	3	4	5
C	**Material and Resource Requirements**					
1	How significant is the material efficiency of aluminum form-work compared to conventional form-work?					
2	To what extent does the weight of aluminum form-work make it easier to transport and handle?					
3	How critical is the availability of materials for conventional form-work in determining its usability?					
4	How often does material wastage occur in projects using conventional form-work compared to aluminum?					
5	To what degree does the reliance on timber in conventional form-work affect sustainability efforts?					

SN	Description	1	2	3	4	5
D	**Flexibility and Design Adaptability**					
1	How flexible is aluminum form-work in adapting to complex architectural designs compared to conventional form-work?					
2	To what extent does					

	the modularity of aluminum form-work simplify construction processes?					
3	How often do design changes during construction affect the usability of conventional form-work?					
4	How critical is the adaptability of aluminum form-work to different project sizes and types?					
5	To what degree does conventional form-work meet the design flexibility requirements of modern projects?					

SN	Description	1	2	3	4	5
E	**Cost of Initial Investment and Maintenance**					
1	How significant is the high initial cost of aluminum form-work compared to conventional form-work?					
2	To what extent does the low maintenance requirement of aluminum form-work justify its cost?					
3	How often do maintenance costs for conventional form-work exceed the expected budget?					

4	How critical is the ability to reuse aluminum form-work in recovering the initial investment?					
5	To what degree does the cost of repairs and replacements reduce the effectiveness of conventional form-work?					

Section 3: Challenges in Adopting Aluminum form-work

1.Not important 2. Slightly important 3. Moderately 4. Very important 5. Extremely important cause.

No	**Description**	**1**	**2**	**3**	**4**	**5**
1	Finding skilled workers proficient in aluminum form-work installation and handling is difficult.					
2	The high upfront cost of aluminum form-work is a major barrier for our company.					
3	Our team lacks sufficient training to efficiently use aluminum form-work systems.					
4	Transporting and storing aluminum form-work is challenging due to its weight and bulkiness					
5	Maintaining aluminum form-work in good condition over multiple projects is difficult					
6	There is limited local supplier support for spare parts and technical assistance					
7	Aluminum form-work is not suitable for most of the projects we undertake.					
8	Local construction standards and regulations do not fully support the use of aluminum form-work					
9	Aluminum form-work is not flexible enough to accommodate frequent design changes in projects.					

Appendix-C:

Interview

Interview Checklist

General Information

1. Interviewee Details

o Name of Interviewee: ______________________

o Job Title/Role: ______________________

o Company/Organization: ______________________

o Years of Experience in the Construction Industry: ______________________

o Involvement in Aluminum form-work Construction: [ ] Yes [ ] No

o Role in form-work System Design/Implementation: [ ] Yes [ ] No

Objective 1: To identify the challenges in adopting aluminum form-work in Addis Ababa

high-rise building construction industry

2. Perceived Challenges in Adoption

o What do you believe are the primary challenges in adopting aluminum form-work for high-rise construction in Addis Ababa?

*____

o How do you perceive the cost of aluminum form-work compared to traditional methods in terms of short-term and long-term benefits?

*____

o Are there significant challenges regarding the availability of aluminum form-work in the local market? If so, what are they?

*____

o To what extent does the lack of local expertise in aluminum form-work affect its adoption?

*____

o What are the technical difficulties faced by workers or engineers when using aluminum form-work?

*____

o How do you think the transition from traditional form-work to aluminum can impact existing construction practices and workforce management?

*____

Challenges in Adoption:

o What were the main challenges faced in adopting aluminum form-work for this project?

*____

o How did the project team overcome issues related to cost, material availability, or local expertise?

*____

o Was there any resistance to the use of aluminum form-work? If so, how was it addressed?

*____

Implementation Process:

o How was the aluminum form-work system integrated into the construction process?

*____

o What steps were taken to train workers and contractors in using aluminum form-work?

*____

o Were there any technical or logistical issues encountered during the installation and use of aluminum form-work?

*____

o How was the supply chain for aluminum form-work managed?

*____

6. Lessons Learned and Future Implications

Lessons Learned:

o What key lessons were learned from implementing aluminum form-work in the project?

*____

o Would the project team recommend aluminum form-work for similar projects in the future?

*____

Recommendations for Policy or Industry Change:

o What policy or industry changes would you recommend to facilitate broader adoption of aluminum form-work in Addis Ababa?

*____

o How can construction companies and stakeholders better prepare for the transition to aluminum form-work?

*____