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COMPARISON OF ALUMINUM FORMWORK SYSTEM WITH CONVENTIONAL FORMWORK SYSTEM: IN THE CASE OF GERJI FEDERAL HOUSING PROJECT

BY:

YEMISRACH SELESHI

March, 2022

Addis Ababa, Ethiopia

Addis College

School of Graduate studies

Department of Construction Technology and Management

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A Thesis Submitted to Addis College the School of Graduate Studies in Partial Fulfillment of the Requirements for the Degree of Master of Science in Construction Technology and Management

By:

Yemisrach Seleshi

Advisor: Denamo Addissie (PHD)

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Endorsed by:	Signature	Date
1. Advisor		
Denamo Addissie (PHD)	___________	___________
2. Chairperson		
___________	___________	___________
3. Internal Examiner		
___________	___________	___________
4. External Examiner		
___________	___________	___________
5. School Dean		
___________	___________	___________

Declaration

I, the undersigned, declare that the study entitled “Comparison Of Aluminum Formwork System With Conventional Formwork System: In The Case Of Gerji Federal Housing Project” is the result of my own effort and study that all sources of materials used for the study acknowledged. I have conducted the study independently with the guidance and comments of the research advisor.

This study not been submitted for any degree in any other university. It is all sources of material used for thesis has been fully acknowledged and conducted for the partial fulfillment of the Degree of Master of Science in Construction Technology and Management.

Name: Yemisrach Seleshi

Date of submission: March, 2022

Place, Addis Ababa, Ethiopia.

Statement of Certification

This is to certify that YEMISRACH SELESHI WOGAYEHU has carried out her project work entitled "Comparison Of Aluminum Formwork System With Conventional Formwork System: In The Case Of Gerji Federal Housing Project". This work is original in nature and is suitable for submission for the award of Master of Science in Construction Technology and Management.

Denamo Addissie (PhD)	__________	___________
Advisor	Signature	Date

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Acronyms

1. FHC Federal Housing Corporate
2. OVID Our Vision Is Development
3. CID Construction Industry Development

Abstract

In building construction there are key parts that are necessary for the success of a project with different parameters like quality, time, cost and safety. From its many components concrete work is very crucial and critical part of the construction. In concrete work; formwork material, concrete quality and workmanship have influence on the above parameters. Concrete Formwork which a temporary structure used to shape and support concrete until it could hold its own weight is responsible for several concrete issues. The conventional formwork system has major impacts like poor quality with discolorations, staining, and dusting on the quality aspects and others has to be thoroughly identified and analyzed. Managing these defects has a high impact on cost and time. The main objective of this research is to Compare Aluminum Formwork System with Conventional Formwork System. This study takes on explanatory research type with quantitative research strategy by employing primary data. To collect the primary data, the researcher prepared self-administered and close ended questionnaire with pre-determined 5-poit Likert scale. Accordingly, the questionnaires were distributed to 190 employees of Federal Housing Corporate (FHC) and OVID Group using random sampling technique. Out of the distributed questions 179 usable responses were collected and used for the analysis process. The analysis process is done with software named SPSS V26 and Microsoft Excel. The results suggest that using an aluminum formwork system is less expensive than using a conventional formwork system. When compared to a conventional formwork system, it saves 25% on costs. Different proportions for main construction components are also acquired, which can be used to get a comparable estimate of per m^2 *cost, which can be used to budget important operations. The study also discovered that traditional formwork systems are more time taking than aluminum formwork systems in terms of work pace, implying that the type of formwork system utilized will influence project completion time. When it comes to the quality of the concrete surface finish, the use of an aluminum formwork system produces the greatest results. The study's final conclusion concerns workplace safety. When compared to traditional formwork, the aluminum formwork system provides a safer working environment.*

Key Words: *Formwork, Aluminum formwork, conventional formwork, speed of work, quality surface finish.*

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Chapter One: Introduction

1.1.Background of the study

Construction is one of the significant sectors of Ethiopian economy and is an integral part of modern Ethiopia. This fact directly relates the concept that the success of the construction industry with the growth of the economy. There are different factors that have direct or indirect relation to the success and growth of the construction industry. One of the major factors which have a great role in the success and growth of the construction industry is the formwork system (Sinesilassie *et al*., 2019).

Formwork is the most important aspect of any building project. It is a mold or matrix pattern into which new concrete is poured and which protects it until it hardens. It is primarily divided into two types of support: horizontal support and vertical support. Formwork carries a variety of loads, including dead and live loads (Sivapriya, and Senthamilkumar, 2016). Formwork is a temporary structure that gives the structure the necessary shape and dimensions. Shuttering is a type of vertical support, while centering is a type of horizontal support. Bellies, props, and jacks are used to provide vertical and horizontal support in the form of staging (Wani, 2017).

Ethiopia has a long history of construction of churches, palaces, statues including Axum, Lalibela, Gonder, etc. from stones. The Lalibela churches are carved in soft ignimbrite, and the Gondar castles are built of local, easily available rock types. Despite pioneering in traditional construction this does not develop to modern construction technology and we are still struggling with conventional building system which is constrained by various problems. With a high investment plan to the construction industry, the country needs to practice ways that other developed countries are practicing. This can be done by improving the challenges that are stated above like collaboration and professionalism for the development of the industry. This could be practiced through time and with education.

Construction projects, consider being successful on the basis of objectives that are completion on time with desired quality, within cost and safety is prime requirement. There are many components of a construction project like material, labor and equipment. It has to be worked hard on each to prepare a strategy to achieve these objectives effectively also add value to the construction project with the complementary functions of time and cost as now a day' (Tarekegn, 2010) s. According to Ajiambo et al., (2017) best way to minimize the cost is complete the project in short time without compromising the safety and quality.

One of the main sub-components comes under material component is a temporary support for the structure; which is formwork. Effective formwork system is one of the key factors to ensure the success of a construction project and achieve objectives as planned. The current formwork Technology in the world is being progressed with different options. The options have mainly changed with respect to the parameters of time, cost and quality. Ethiopia is mainly using the conventional building system which includes cast in-situ column-beam-slab frames.

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. This system is most suitable for Indian condition as a tailor–made aluminum formwork for cast–in–situ fully concrete structure (Lim, Kim, Cho, & Kang, 2013).

1.2.Statement of the problem

The structural building systems have been progressing for the last several decades. Even though, Ethiopia has experimented most of the systems, it has been stuck to the conventional formwork system. The conventional building systems are constructed through four operations, namely, erection of timber/steel formwork and scaffolding, erection of steel bar, pouring of fresh concrete into form and dismantling of formwork and scaffolding. These operations are labor intensive, costly, tedious, environmental impact with high wastage and require a lot of on-site coordination (Ismail, 2001). The availability of the raw materials is also at risk which makes it expensive.

As discussed above when employing a conventional formwork system, the construction's cost and duration are influenced by the materials we use and the labor it requires. The conventional formwork technique requires a lot of specialized labor during erection and must be put together piece by piece, which adds to the time and cost of the overall construction project. Due of the steel/timber's low repeating behavior after use, more formwork materials are required, which by itself add the cost of the project for the additional material. Therefore, a new formwork system must be found that is less expensive, requires less trained labor, and is simple to install and disassemble.

In Ethiopia most of the construction materials are conventional and time taking. So, Ethiopia needs construction systems that would improve challenges, inability to deliver projects on time (time over run), inability to finalize the project within the budget (cost overrun) and poor quality of executions. Every aspect of the construction industry with the method of construction should be checked to improve the problems that are now becoming a trend.

In previous studies, the Aluminum formwork system has found to be cost, time, and quality effective and in addition labor intensive. This research deals with the effectiveness of the new Aluminum formwork system in Ethiopia by comparing it to the Conventional formwork system with parameters like cost, time, quality and labor intensity for the future development of the system. If the system is found to be successful with minimized time and cost and maximized quality; it would be a beginning to a new technology for better success of the construction industry.

1.3.Objective of study

1.3.1. General Objective

The general objective is to investigate the suitability of Aluminum formwork system as a modern construction method when compared with the conventional Formwork system with respect to cost, time and quality parameters.

1.3.2. Specific Objectives

- To investigate the current practice of conventional structural building formwork system.
- To identify the suitability of the new and modern Aluminum formwork technology system with respect to Cost, Time, Quality and safety parameters.
- To compare the conventional formwork with the modern Aluminium formwork technology system with respect to Cost, Time and Quality parameters.
- To point out the effect of the newly adopted formwork technology on safety and environmental issues.

1.4.Research Questions

The research would raise and try to answer the following questions

1. What are the current practices of using conventional structural building formwork system for concrete work?
2. What are the merits and demerits of the modern Aluminum formwork technology system with respect to Cost, Time and Quality parameters?

3. What is the special thing with the Aluminium formwork when compared to the conventional formwork system with respect to Cost, Time and Quality parameters?
4. What is the effect of the newly adopted formwork technology on safety and environmental issues?

1.5. Scope and delimitation of the research

The scope of the research is to study the feasibility and advantages of the practice of the Aluminum formwork System as a modern construction system when compared to the conventional column-beam-slab frame system with timber, ply-wood and steel as formwork for Ethiopia. The research considers the Federal Housing Corporation; Gerji Housing Project as a case project for comparison purposes. The study compares the two systems with the parameters of time, cost and quality.

1.6. Limitations of the study

Due to the fact that the aluminum formwork system is new to the country; there are major and expected potential limitation of the study;

- The research could only be addressed from the perspective of only one project in Ethiopia; the Federal Housing Corporate, Gerji Housing Project.
- There is high shortage of references and similar researches conducted on the system in Ethiopia.
- There is a potential knowledge gap to the system in Ethiopia due to lack of exposure to the Aluminum formwork system.

1.7. Significance of the study

The practice of conventional column-beam-slab frame system with timber, ply-wood and steel as a formwork has been practiced in Ethiopia for a long time. There have not been any major breakthrough structural construction methods that have been practiced to the construction industry in Ethiopia to take it to the next level in which other countries have now reached. Therefore, the outcome of the research would have significance for different stakeholders in taking the decision to incorporate and practice the system to our county.

Some of the significances of this study for different stakeholders includes:

- **For contractors –** it helps in choosing between the conventional column-beam-slab frame system with timber and ply wood as a formwork and Aluminum formwork system with respect to time, cost, quality and labor intensity specially for Design build projects they will be conducting.

- **For Designers, Government and Public Housing Agencies, Real Estate Developers, Private Investors, client/owners and other stakeholders** – it will be able to have research-based evidence on the pros and cons of the Aluminum formwork system when compared to the conventional system with respect to the volume of work they are planning to invest.
- **Future researchers:** As an opening study on performance of the Aluminum formwork system in Ethiopia, this research is believed to open the door for further and more detailed studies on another advanced formwork system application and performance that enhance performance of the Ethiopian construction industry.

1.8.Organization of the document

Chapter one mainly deals with introduction, objective of the study, the question to be addressed, scope and limitation of the study. The rest of the thesis is structured as follows: chapter two reviews extant literature including the history of construction, formwork system, and technologies related to formwork as well as the current trends in Ethiopia. The third chapter discusses the research methodology including the research approach, research design, research method, data collection instrument, sampling technique, and method of data analysis. Chapter four presents the results and discussion of the study. The final chapter captures the summary of findings, conclusions, and recommendations.

Chapter Two: Literature Review

2.1.Introduction

The purpose of this chapter is to carry out a detail literature review about formwork system and its influence on the cost, quality and speed of construction of building projects. A review of books, thesis, standards and relevant website are carried out to develop this chapter.

Construction is one of the most important industries on the planet. This industry makes a significant contribution to global GDP, and it has long been used as a benchmark for assessing the economic growth of developing countries (Jones and Stead, 2020). The construction sector has seen enormous growth in recent years as a result of globalization and technological advancements. Ethiopia is a developing country with a burgeoning construction industry that accounted for 18% of the country's GDP in the 2017-2018 fiscal year (Jones and Stead, 2020). Despite the construction boom, the housing situation is deteriorating due to the ever-increasing demand for houses. These calls for the task of providing affordable housing to the mass by adopting modern and cost-effective technologies. “Innovative technologies capable of rapid construction and capable of delivering good quality and lasting structures in a cost-effective way are required for executing mass housing projects.” (Anon, 2010)

Concrete is the most prevalent building material for both load-bearing and non-load-bearing parts. Its capacity to be molded and reflect the surface against which it is put allows it to create a wide range of ornamental and architectural off-form finishes, obviating the need for additional, and often costly, applied treatments using other materials (Jones, 1985). For concrete building, cost-effectiveness is critical. The overall cost of building could be reduced by identifying the factors that influence cost and quality. One of the most factor that could control the overall cost of construction is a formwork system.

Formwork is a type of mold that incorporates all supporting structures and is used to shape and support concrete until it can hold its own weight. Formwork consumes more than half of the time used in RC construction. Because of frequent reuse of formwork and poor support of formwork, the cost of formwork varies between 15 and 25% of the cost of reinforcing concrete structural systems (Ramshankar, et al , 2020).

2.2. Formwork Systems

2.2.1. Definition

Concrete is in a plastic state when it is laid. Until it develops strong enough to sustain its own weight, it must be supported by temporary supports and casings of the proper shape. The formwork, often known as forms or shuttering, is a temporary casing. A form is a temporary structure or mold used to hold concrete while it is curing and develops enough strength to sustain itself (Kazi and Parkar, 2016). Formwork encompasses the entire system of support for freshly put concrete, including the mold or sheathing that comes into contact with the concrete, as well as all supporting components, hardware, and necessary bracing. Concrete building requires the use of forms. They manage the location, alignment, and surface contour of concrete by molding it to the required size and shape (Awad & Hanna, 1999).

2.2.2. History

The use of formwork begins in ancient times and the first country to use formwork systems is Rome. Roman engineers use the first formwork system to construct concrete slab in 1900. As stated above, concrete is poor to resist its own weight when it is initially casted until it cures. Therefore, temporary scaffolding or false work or formwork is required to give the future shape and to mold it properly. After the initiation of the Roman engineers, the use of formwork techniques has raised as the use of concrete construction increased. At the beginning plywood was used as formwork material till the advancement is expanded.

Formwork materials, which used to be predominantly wood, have expanded to include plywood, metals, plastics, and aluminum, as well as specific accessories and hardware. The traditional process of erecting formwork in place for each use and then destroying it has been replaced by reusable pieces. This includes pre-fabricated standard or modular panels and accessories including assembly and erection by manual or mechanical means and reusing the forms several times (Badir et al., 1998).

Large scale developments in formwork technology took place mainly during the last 50 years. The construction of formwork takes the Pantheon in Rome. To molds this structure, temporary scaffolding and formwork or false work was built in the future shape of the structure. Even though, formwork techniques have developed keeping pace with the growth in concrete construction. The material for formwork which was at one time, primarily timber now includes a wide range such as plywood, metals, plastics and aluminum along with specialized accessories and hardware. Age old methods of erecting formwork in place, for each use and destroying it thereafter have now been changed to reusable items. This includes pre-fabricated standard or modular panels and accessories including assembly and erection by manual or mechanical means and reusing the forms several times. Large scale developments in formwork technology took place mainly during the last 50 years. The construction of formwork takes time and involves expenditure up to 20 to 25% of the cost of the structure or even more (Badir et al., 1998).

2.2.3. Types of Formwork Systems

According to the Badir-Razali building system classification (Badir et al., 1998) there are four main categories:

1. conventional building system;
2. cast in-situ formwork system – table or tunnel formwork;
3. prefabricated system; and
4. composite system as shown in Figure 1.

The last three building systems are termed as IBS. Junid (1986) expound that an IBS in the construction industry includes the industrialized process by which components of a building are conceived, planned, fabricated, transported and erected on site. The system includes a balanced combination between the software and hardware components. The software elements include system design, which is a complex process of studying the requirement of the end-user, market analysis, development of standardized components, establishment of manufacturing and assembly layout and process, allocation of resources and materials and definition of a building designer conceptual framework. The software elements provide a prerequisite to create the conducive environment for industrialization to expand. On the other hand, the hardware elements are categorized into three major groups. These include frame or post and beam systems, panel system, and box system. The frame structures are defined as those structures that carry the loads through their beams and girders to columns and to the ground whilst in panel systems, loads are distributed through large floor and wall panels. The box systems include those systems that employ three-dimensional modules (or boxes) for fabrication of habitable units capable of withstanding load from various directions due to their internal stability (Ismail, 2001).

The conventional building system is divided into two major components. The first component is the structural system, which includes cast in-situ column-beam-slab frames. These frames are constructed through four operations, namely, erection of timber formwork and scaffolding, erection of steel bar, pouring of fresh concrete into form and dismantling of formwork and scaffolding. These operations are labour intensive, tedious and require a lot of on-site coordination.

The second component consists of brick and plaster as the non-structural infill material. Cast-in-situ building systems utilize lightweight prefabricated formwork made of steel, fiberglass or aluminium in order to replace the existing conventional timber formwork. The method is suitable for large numbers of housing units that require repetitive utilization of formwork. The formwork can be reused as many times as possible with minimal wastage. Careful planning of cast in-situ work can improve productivity, speed, and total cost (Ismail, 2001).

Fully prefabricated building systems can be classified into two main categories, namely on-site prefabricated and off-site prefabricated (factory produced). On-site prefabricated method involves casting structural building elements within site before erecting to actual location. On-site precasting provides several advantages over cast in-situ construction. These include mass production of units, cost and time reduction and improved quality of work (CIBD, 1992). Off-site prefabricated method involves transferring building operations from site to factory.

Prefabrication allows a component to be built whenever convenient, so long as it is delivered on time. The composite construction method involves casting some elements in the factory while others are cast on site. Types of precast elements usually produced are floor slabs, infilled wall, bathrooms, and staircase. These elements are placed for incorporation into main units, column and beams, which are usually, cast in-situ (Ismail, 2001).

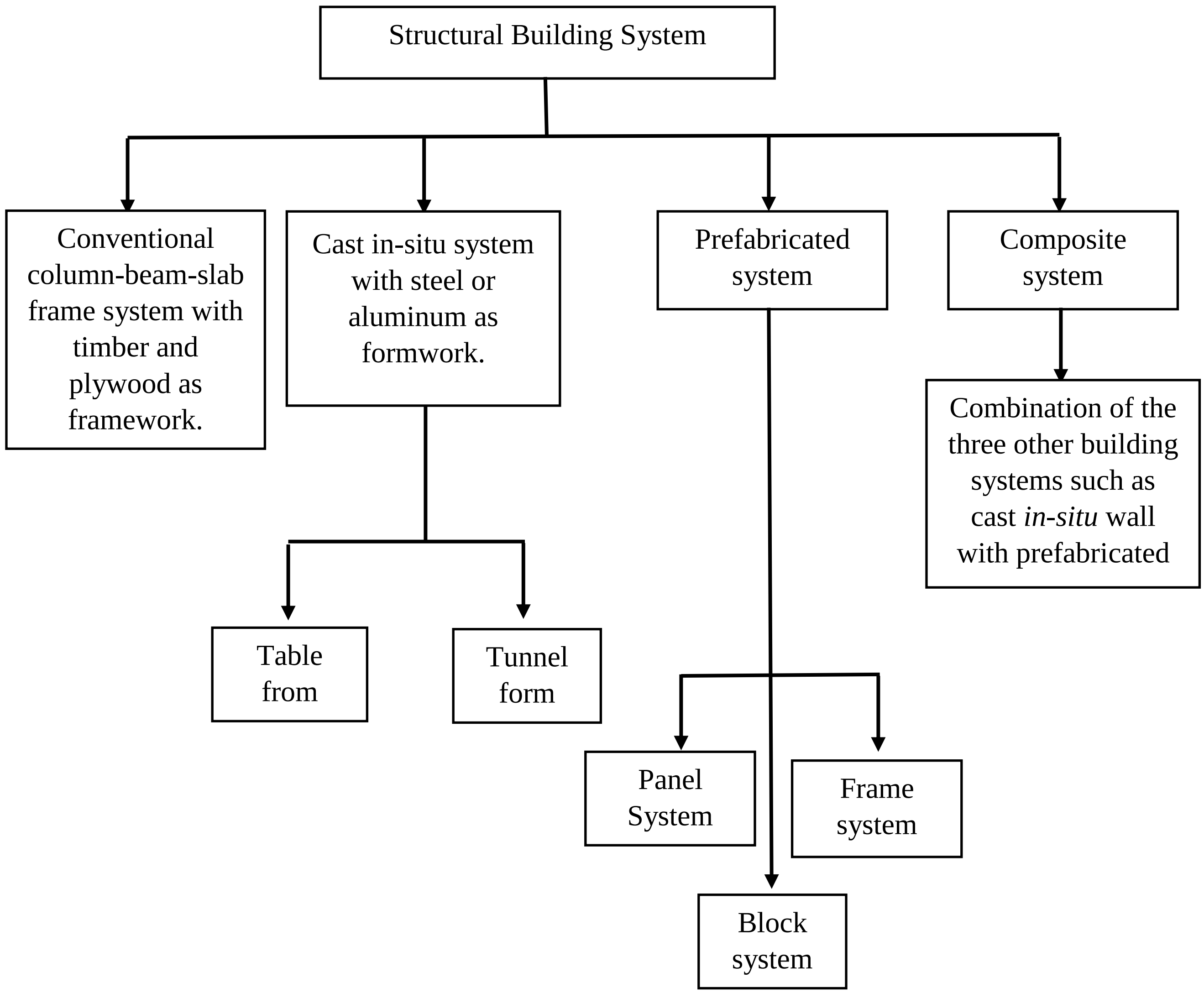


Figure 2. 1 Main formwork categories. (Source; Mydin, Sani, and Taib, 2014)

2.3.Conventional Formwork System

Conventional wood or metal systems are classified as hand-set systems. In hand-set systems, different formwork elements can be handled by one or more laborers (Awad and Hanna 1999). Conventional wood or metal systems for horizontal concrete work are made of plywood, lumber, steel and aluminum sheathing for decking. Sheathing is supported by horizontal members called joists or runners. Joists are supported by another set of horizontal members perpendicular to the joists, called stringers. The stringers are supported by vertical members called shores (Badir et al., 1998).

The conventional building system usually consists of standard framed panels tied together over their backs with horizontal members called waling. The waling is provided with the basic function of resisting the horizontal force of wet concrete. One side of the wall formwork is first assembled ensuring that it is correctly aligned, plumbed and strutted. The steel reinforcement cage is then placed and positioned before the other side of the formwork is erected and fixed. Plywood sheet in combination with timber is the most common material used for wall formwork (Awad and Hanna 1999). The usual method is to make up wall forms as framed panels with the plywood facing sheet screwed on to studs on a timber frame. This allows for the plywood to be easily removed and reversed and used on both sides so as to increase the number of reuses. The wall forms are susceptible to edge and corner damage and must be carefully handled. Special attention must be given to comers and attached piers since the increased pressures applied by wet concrete could cause the abutments to open up, giving rise to unacceptable grout escape and a poor finish to the cast wall (Badir et al., 1998).

2.3.1. Advantage and Disadvantage of Conventional Formwork System

According to Asadi and Praneeth, 2017, the advantage and disadvantage of conventional formwork system are presented here under:

A. Advantage of Conventional Formwork System

- ✓ Durable, light weight, economical, flexible for easy erection.
- ✓ It exhibits good thermal insulation so it can be used in cold climates.
- ✓ Its reusability varies from 10 to 12 times.
- ✓ It can be built piece by piece so capable enough to form any concrete shape as per architectural design.
- ✓ This system is economical for small scale projects with limited potential reuse.
- ✓ It has low initial cost and make up cost.
- ✓ Good for restricted site conditions less storage area and use of crane is difficult.

B. Disadvantage of Conventional Formwork System

- ✓ High labor cost.
- ✓ Usually varies from 30 to 40% of total cost of concrete slab per floor.
- ✓ High waste generation 5% of waste is produced for a single use of formwork.
- ✓ Erection and dismantling are to be done piece by piece.
- ✓ Very highly skilled labor force is needed.
- ✓ Spans are limited as timber has low strength compared to metal formworks.

2.4.Cast In-situ System with Steel or Aluminum Formwork System

2.4.1. Aluminum Formwork System

Aluminum formwork system is formwork construction, cast – in – situ concrete wall and floor slabs cast monolithic provides the structural system in one continuous pour. Large room sized forms for walls and floors slabs are erected at site. These forms are made strong and sturdy, fabricated with accuracy and easy to handle. They afford large number of repetitions (around 250). The concrete is produced in RMC batching plants under strict quality control and convey it to site with transit mixers (Kim, 2013). Formwork systems for buildings are classified as either horizontal or vertical formwork. Horizontal formwork systems are those used to form the horizontal concrete work (slabs or roofs), while vertical formwork systems are those used to form the vertical supporting elements of the structure, e.g., columns, core walls, and shear walls. Due to the fine tolerances achieved in the machined metal formwork components, consistent concrete shapes and finishes are obtained floor after floor, building after building, confirming to the most exacting standards of quality and accuracy. This allows plumbing and electrical fittings to be prefabricated with the certain knowledge that there will be an exact fit when assembled. The dimensional accuracy at the concreted work also results in consistent fittings of doors and windows. 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. This system is most suitable for Indian condition as a tailor–made aluminum formwork for cast–in–situ fully concrete structure (Lim, Kim, Cho, & Kang, 2013).

Advantage and Disadvantage of Aluminum Formwork System

Advantage of Aluminum Formwork System

- ✓ Less requirement of heavy lifting equipment’s
- ✓ Final output of the construction is with good quality and accurate dimensions especially for openings.
- ✓ Can be used for large number of repetitions, the repletion's are obtained from the materials durability.
- ✓ The monolithic walls and slabs produce a superior structural quality (Earthquake resistance of the resulting structures increases manifold and crack free structures are obtained.
- ✓ Plastering and block works are removed, cost and time is saved.

- ✓ Most components are de-shattered immediately after casting except the vertical props.

Disadvantage of Aluminum Formwork System

- ✓ High initial investment cost.
- ✓ More number of components.
- ✓ High repair cost of aluminum forms.
- ✓ Probability of theft is more.
- ✓ Segregation and stocking required more space.
- ✓ No flexibility in the architecture.
- ✓ Due to speed of work, planned running capital is required.

Figure 2. 2 Installation system of aluminum Formwork System (Kumkang Kind Formwork production Company Manual)

2.4.2. Tunnel Formwork System

It is a highly efficient Industrialized System of On-Site Construction, which enables putting-up stable structure on a 24-Hour cycle basis Tunnel form is a formwork system that allows the contractor to build monolithic walls and slabs in one operation on a daily cycle. It combines the speed, quality and accuracy of factory/offsite produced ready-mix concrete and formwork with the flexibility and economy of cast in-situ construction. This fast-track method of construction is suitable for repetitive cellular projects, such as hotels, apartment blocks and student accommodation. It offers economy, speed, quality and accuracy, as well as utilizing the inherent benefits of concrete, such as fire and sound resistance. Tunnel Formwork System: Tunnel formwork system is one type of construction techniques used for multi storied building construction to reduce cycle time and also the slab & the wall are cast monolithically. Its components are made of steel. Its usefulness also stems from the fact that no starter concrete is required for walls; it allows easy alignment and de-shuttering, hot air curing to enable early stripping and favors a standardized working sequence to improve labor productivity (Lim, et. al., 2013).

Advantage and Disadvantage of Tunnel Formwork System

According to Kim, 2013, the advantage and disadvantage of tunnel formwork system are presented here under:

Advantage of Tunnel Formwork System

I. Time Advantages

1. A production cycle of 1-3 days can be achieved.
2. The project can be completed in a short time.
3. Due to accelerated production, effects of climatic conditions on productivity are minimized.

II. Quality Advantages

1. Higher precision in production of walls and slab units
2. Smooth surfaces for the walls and slabs are obtained that can be covered with wallpaper right after easy and quick cleaning.

III. Cost Advantages

1. Formwork cost per m^2 (or per housing unit) can be reduced by using formwork up to number of times.
2. Due to smooth surfaces, walls and slabs do not need any additional finishing such as plaster.
3. Early completion of project provides financial opportunities such as rental incomes.
4. Repetitive nature of buildings provides effectiveness in production and minimization of labor costs.

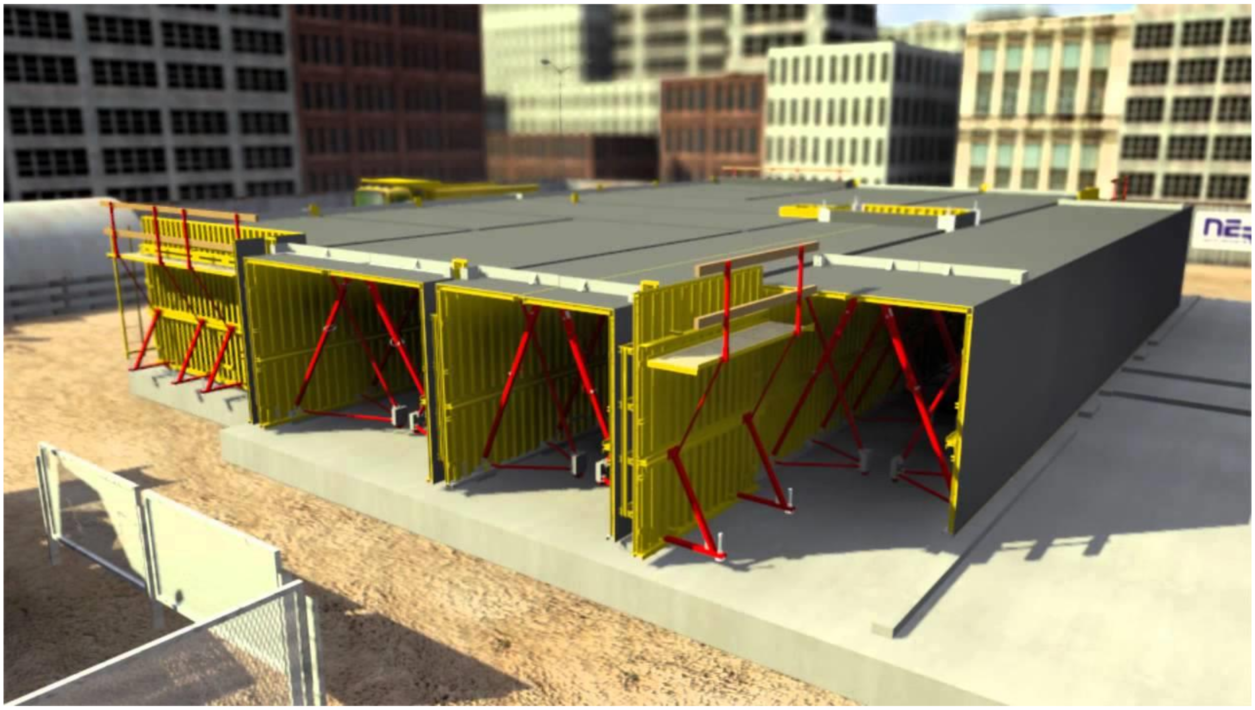


Figure 2. 3 Installation system of Tunnel Formwork system (Kim, 2013)

Tunnel form can accommodate room widths from 2.4 to 6.6m. When rooms are wider (up to 11m), a mid-span table is incorporated between the tunnels. The main component of the system is the half tunnel. Manufactured entirely from steel, including the face of the form, the half tunnel provides the rigidity and smooth face necessary to produce a consistently high-quality finish to the concrete. When two half tunnels are put together this creates a tunnel. The tunnel sections come in two lengths, 1.25 and 2.5m. These are fixed together to produce a tunnel length that suits either the building dimensions. The tunnel is tailored to the room width and height by the inclusion of infill sections which are sacrificed at the end of the job. These are not loose fittings but are an integral part of the tunnel (Kim, 2013).

Disadvantage of Tunnel Formwork System

The limitations of the formwork can be seen as:

1. Design Phase Limitations
2. Construction phase limitations

Design Phase Limitations

1. Low degree of modular flexibility (105 cm+1,2,3...n X 30 cm for a half tunnel formwork)
2. Min. Room size 210 cm.
3. Approximately. 12 m depth, and 6 m width since ribbed or waffle slab cannot be applied)
4. Min. 20 cm thickness of wall and slabs
5. Tunnel formwork system is not convenient for some building types such as music halls, theaters, etc., that contains large spans.
6. Lowered slab is not allowed since it prevents the removal of formwork.
7. Load bearing walls must be designed continuously on the same axial system due to the resistance requirements against horizontal forces.
8. Basement stories cannot be constructed by using tunnel formwork system, removal of formwork is not possible.
9. Distances of blocks facing each other must allow removal of formwork.
10. Continuous footing or mat foundation is required.
11. No geometrical forms angles that prevent removal of formwork is not allowed.

Construction phase limitations

1. Tower cranes are required for the erection, removal and carriage of formworks, scaffolds, and pre-cast components.
2. A workshop is required for the production of pre-cast components such as façade, partition wall, stairs, and parapets walls.
3. A crane can serve max. 2 blocks at the same time.
4. Movement of cranes has difficulties according to some topographic conditions.

Comparison of Aluminium formwork system with Tunnel Formwork System

The processes of planning formwork is separated into three stages (Ketan Shah, 2005) Stage 1: Gathering information, gathering data, and examining limiting factors.

Stage 2: System analysis and selection based on information gathered

Stage 3: Implementation of the system in the construction process.

Various types of formwork systems are chosen depending on the purpose of use and the technique of erection. For various applications, numerous types of formwork are available. In general, wall forms are used for vertical concreting, while slab or floor forms are used for horizontal concreting.

These formwork systems range from traditional to modern MIVAN and TUNNEL systems, with slab cycles ranging from 1-3 days (Ketan Shah, 2005).

A half Tunnel is a half-room-sized L-shaped structural steel manufactured form used to cast RCC walls and floor slabs as a monolithic structure in a continuous pour. Two half tunnels combine to form a whole tunnel the size of a room. For rapid concrete curing, hot air blowers are sometimes used to heat the forms. When the structure consists of a large number of identical units, this approach is cost-effective. In order to accomplish a one-day slab cycle, the mix design should be such that the initial setting time is longer (Mandal, 2006).

After that, concrete is poured, the forms are covered, and hot air blowers are placed inside. The forms are removed the next day and cranes are used to transport them to the next location. Tunnel form is best used in multiunit shear wall structures with identical floor layouts on all levels.

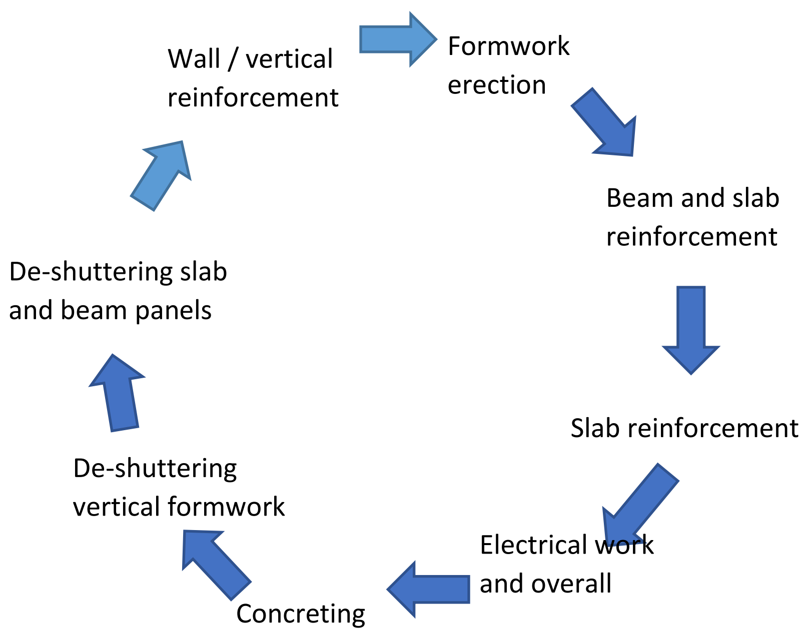


Figure 2. 4 Typical slab cycle of Tunnel formwork (Source: Mayank Patell et al. 11th April, 2015)

The formwork is built of aluminum sheets, as the name implies. Because aluminum is lighter than steel, it is used to create lightweight formwork. This system is quick, easy, and inexpensive. Aluminum formwork can be used to cast many types of construction elements, including walls, slabs, columns, beams, and staircases. Aluminium formwork does not necessitate the use of any heavy or specialized equipment; all that is required is a hammer.

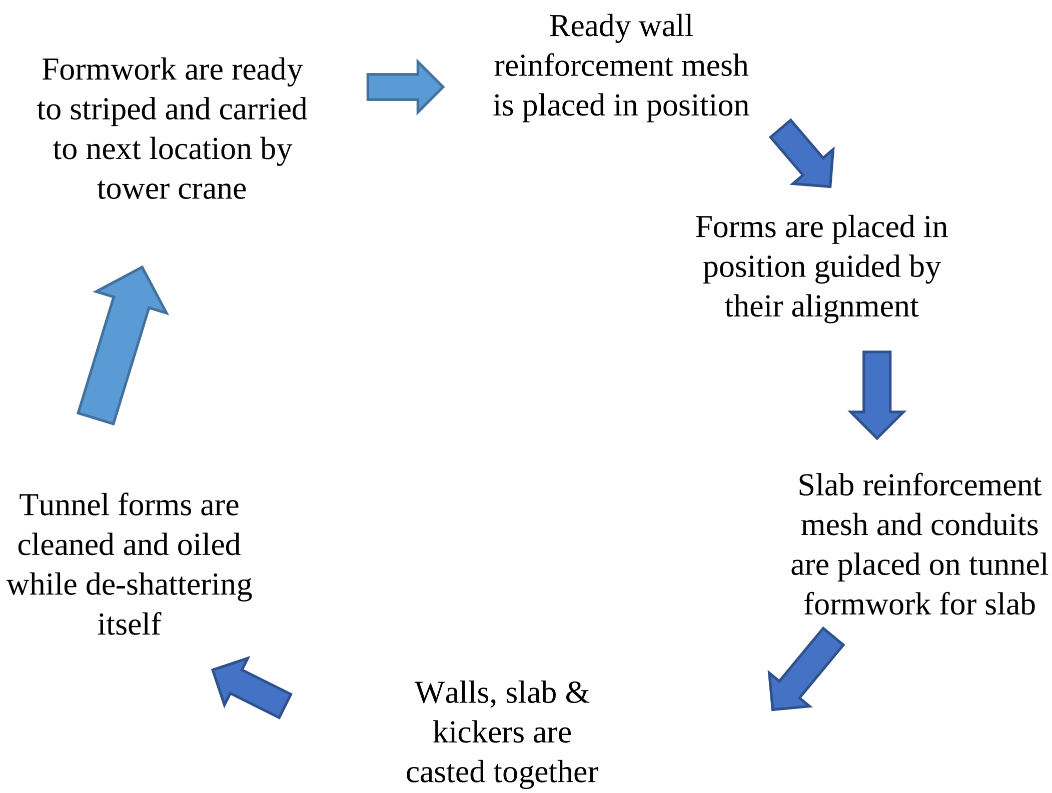


Figure 2. 5 Typical slab cycle of Aluminum formwork (Source: Mayank Patell et al. 11th April, 2015)

The aluminum formwork's finish is so good that it eliminates the need for plastering. Aluminum Formwork enables monolithic construction by allowing the walls and slab to be cast in the same pour. This improves efficiency while also resulting in a building that is extremely sturdy and has a beautiful concrete finish.

Consistent concrete shapes and finishes are attained floor after floor because to the excellent accuracy achieved in the machined metal formwork components. This enables plumbing and electrical fittings to be prefabricated with the assurance that they will fit perfectly when put together (Mayank Patell et al. 11th April, 2015).

Comparison:

1. Initial cost for tunnel form is very high
2. Accuracy is very good in tunnel form construction than aluminum form construction.
3. Generally, no plastering required in construction with tunnel form, whereas it is required in Aluminum formwork.
4. Design changes/ design flexibility is very less in tunnel form but it is easily possible in aluminum form.

5. As both technologies need skilled labors, cost of labor is high in both systems. But with proper equipment it can be reduced in tunnel form system.
6. Slab cycle can be actually 1 day in tunnel form, whereas it will be around 10-12 days with aluminum form.
7. As Steel is stronger than Aluminum, it can be reused more than 500 times and Aluminum shuttering can be used around 150 times.
8. Speed of construction is very high in tunnel form than Aluminum form.
9. Equipment's/ machineries like Tower crane, hydras etc. is more in tunnel form than Aluminum form, because heavy tunnels that cannot be shifted without machinery.
10. Skilled staff as well as skilled labors are required in tunnel form system than Aluminum form system.

2.5.Selection Criteria of Formwork system

As it is stated in literatures, there are many components of a construction project like material, labor and equipment. One of the main sub-components comes under material component is formwork. Selection of effective formwork system is one of the key factors to ensure the success of a construction project and achieve objectives as planned (Ganar and Patil, 2015).

Formwork system is the key factor determining the success of a concrete construction project in terms of quality, cost, time and safety of the project on hand. Formwork system plays a major role in finishing the structure with in stipulated time bound, specified quality, budget and safety.

Due to the above stated reason great care gas to be taken for selecting the type of formwork for the structure to be built. The expenditure on formwork is occupying a major part in the total cost of construction. Therefore, the selection and proper planning the system of form work will reduce the cost of construction, time of construction, the wastages and labor requirement which reduces the total cost of construction (Ingle, & Waghmare, 2015).

Selecting the formwork system for cast in place reinforced concrete is a critical decision that can affect cost, safety, quality, and speed of construction. Many factors must be considered for the proper selection of the formwork system (Tarekegn, 2010). Among these are:

- Factors related to building architectural and structural design, which include slab type and building shape and size.

- Factors related to project (job) specification, and schedule, which includes the speed of construction.
- Factors related to local conditions, which include area practices, weather conditions, and site characteristics.
- Factors related to the supporting organizations, which include available capital, hoisting equipment and availability of local or regional yard supporting facilities.

More over according to (Tarun, & Lokeshwaran, 2017). Requirement of good form work is: -

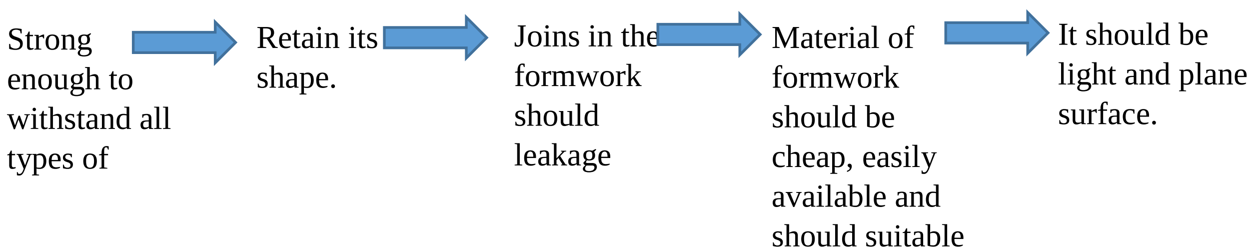


Figure 2. 6 Requirements of good formwork (Source: Mayank Patell et al. 11th April, 2015 Tarun, & Lokeshwaran, (2017).

2.5.1. **Building Design and Shape**

Except in exceptionally large buildings, the cost of constructing slabs is frequently more than half the cost of constructing structural framing systems. As a result, to save money, it should be paid close attention to the slab formwork technique you choose. The choice of a formwork system should be based on the floor system that best meets the structural loading requirements. The type of slab chosen has an impact on the cost of formwork. Construction of two-way slabs supported by drop beams, for example, is more complicated and expensive (Sonawane & Ambre, 2019).

Special buildings, such as industrial buildings and power plants, typically have complex electrical and mechanical requirements that do not lend themselves to any advanced formwork system. As a result, traditional formwork should be used to construct them. The contractor can determine whether to employ a formwork system or a conventional forming process based on the following shape factors (Sonawane & Ambre, 2019):

- Variation of column and wall location
- Variation of beam depth and location
- Variation of story height

- Existence of openings for windows and doors
- Extensive HVAC requirements.

Designers play great role in minimizing the cost of formwork. Ease of construction should be considered besides safety, aesthetics and other design requirements Sonawane & Ambre, 2019). Considering the following three things could ease up the Building construction methods.

1. **Job Specification**

The most significant benefit of employing a modern formwork system is the speed with which it may be built. Construction speed has an impact on cost because it dictates when the structure will be ready for use and also saves financial costs. The floor cycle time is the most important component in determining construction speed. Casting two floors or more each week in high-rise buildings has been achieved in recent years, particularly in metropolitan locations.

Only complex formwork techniques like as flying forms and tunnel formwork, which can form one story every two days, can achieve this quick floor cycle (Tarun, & Lokeshwaran, 2017).

2. **Area Practice**

The employment of formwork "systems" can significantly lower the cost in locations where the labor force is expensive and unskilled. Even if the building characteristics are compatible with a sophisticated formwork system, a traditional formwork system is an economical choice in places where the labor force is inexpensive and skilled. As a result, some geographic areas rely on preassembled formwork systems due to a scarcity of low-cost trained labor (Tarun, & Lokeshwaran, 2017).

3. **Site Characteristics**

Because of site constraints and accessibility for construction operations, the choice of a suitable forming system may be influenced by the construction site itself. For example, the practicality of adopting flying forms is determined by site factors such as (Kazi and Parkar, 2016):

- Accessibility to the site.
- Availability of a fabrication area.
- Property lines, adjacent buildings, electricity lines, and major streets are all limits in the surrounding region. All forming systems are viable in open and unrestricted suburban areas, and some other considerations should be evaluated to determine the most efficient

and cost-effective system. In congested areas of the city, ganged units that may be transferred from floor to floor may be the only option.

2.6.Design and Construction Considerations of Formwork Systems

2.6.1. Design consideration of formwork system

1. **Strength:** Dead weight, living load, and hydrostatic pressure must all be supported by forms and shutters. Sheathing must be sufficiently stiff to prevent bulging.

Pressures on the form face are applied to formwork for vertical concrete elements, such as columns and walls. The fluid motion of the new concrete is to blame for this. The pressure of the fluid concrete on the vertical faces rises in direct proportion to the concrete depth. The form's maximal pressure is found near the bottom. The hydrostatic pressure for concrete is the maximum pressure for full depth fluid concrete, and it usually happens when the concrete is laid very quickly. The bracing should not be able to be displaced by impact or wind coming from any direction (Sonawane & Ambre, 2019).

2. **Speedy erection and dismantling:** To save time during erection and dismantling, the formwork design and assembly processes must be as basic as feasible. The formwork should be easy to take down without damaging the concrete.
3. **Tightness of joints:** The formwork's liquid retention characteristics must be sufficient to prevent cement and fine aggregate leaks from the concrete.
4. **Rigidity:** Brace and support the formwork to ensure that it does not move under wind pressure or when the concrete is being put and vibrated. The shutters must be stiff enough to maintain the concrete member within the tolerances set by the manufacturer.
5. **Reuse:** If at all possible, design for unit construction so that you can strike and reuse as quickly as possible. Hold portions of formwork in place with clamps, wedges, and other similar devices. Avoid nailing as much as possible; nail holes and bruising of the wood will ruin the formwork and prevent it from being used again. The formwork material must be long-lasting and able to produce a smooth finish.
6. **Ease of handling**: Forms and shutters must be of a size and weight that the labor and equipment on hand can handle.

2.6.2. Construction considerations of formwork systems

The type and materials of formwork for structural elements should be chosen based on the building's nature and purpose. Different elements must be addressed when selecting a formwork system for a certain building project, in order for the construction process to go smoothly and the contract document to be agreed upon. For best results, proper formwork system selection should be a priority for all parties involved (Hanna, Willenbrock, & Sanvid, 1992).

To pick formwork, one must first understand the sequence of formwork building activities, procedures or phases, and methods that must be followed so that the project can be completed on time and on budget. Following construction methods and, or steps, will always aid in understanding the interdependence of activities, specifications, and other requirements in the placement of concrete. This will enable us to use appropriate formwork technologies that meet building standards.

Because the formwork cycle finishes when the concrete cures and gains enough strength to sustain itself, the life-cycle of formwork is frequently integrated with the life-cycle of concrete construction, particularly in horizontal building structural parts such as slabs, beams, and flat roofs. In concrete construction, formwork is used to mold or lay fresh concrete until it reaches self-supporting strength. As a result, the formwork and concrete life cycle are tightly linked (Hanna, et al, 1992).

However, after the removal of formwork in vertical structural elements such as columns and shear walls, concrete has mostly begun to cure. The integrated concrete/formwork life cycle is depicted in Figure 2.4, with the left circle representing the formwork life cycle and the right circle representing the concrete construction life cycle. The beginning and end of the concrete construction life cycle are represented by the two intersecting locations.

The formwork life cycle begins with a feasibility study (gathering all necessary information) and ends with repair, then reuse/storage, whereas the concrete construction life cycle begins with placing reinforcement bars and ends with curing the concrete so that the forms are ready to be stripped off the concrete.

In the construction of high/mid-rise buildings with reinforced concrete structures, formwork has a considerable impact on project quality, safety, cost, and completion time. As a result, managing the formwork construction in one way or another might have an impact on the whole project's success. The effective and efficient management of formwork construction throughout its life cycle aids in achieving the required quality, safety, cost, and time. When the concrete placed in the form is sufficiently cured to stand alone, one of the most effective techniques to reduce the form work duration is to strip the forms as soon as possible (Hanna, Willenbrock, & Sanvido, 1992).

The cost is one of the most important factors in selecting which formwork method is best for a certain construction project. In nations with high labor costs, the cost of formwork may be half, or even more, than the cost of concrete constructions. On average, formwork accounts for around 35% of the overall cost of every finished concrete unit or element; of this, little over 40% can be attributed to material for formwork and 60% to labor (Patil, 2017). For a typical multistory reinforced concrete construction, formwork is the most expensive component.

As a result, when planning the formwork for a concrete structure, cost should be taken into account. The cost of materials, the cost of labor in building and removing the forms, and the cost of equipment necessary to handle the forms all play a role in the economy of formwork. The number of reuses of the form materials, where designing formwork for maximum reuses can save money, the probable salvage value of the forms for use elsewhere, and the cost of polishing concrete surfaces after the forms are removed are all factors that go into the cost of formwork.

2.7.Formwork Construction Systems in Ethiopia

2.7.1. Introduction

The technology of formworks in Ethiopia is at an infant stage. This situation is attested through reviewing the construction practices of sites in all sub cities of Addis Ababa. Since the construction methods and materials used in all sub cities in particular and country in general is similar, representative sites in Addis Ababa are selected for review. As there are few literatures written on the formwork construction practices in our country, investigations from sites are considered as a review and presented in subsequent sections. Formwork construction practices for footing, column, slab and beam will be reviewed from quality, safety and environment aspect (Tarekegn, 2010).

2.7.2. Footing Pad and Foundation Column Construction Systems

Formworks for footing pads can be either timber or steel panel. The steel panels are joined using black wire and supported from back by timber (see figure 2.4). In case of timber boards, the members are nailed together and supported from back in the same manner as that of steel panels. Formwork release agents, mainly burnt oil is usually applied on the panels and boards before placing of the formworks. Lean concrete is casted to form hard surface beneath the formworks which minimizes the settlement of the forms (Sharmila & Christober, 2016).

Figure 2. 7 Footing pad formwork construction system in Addis Ababa (Gerji Federal Housing Project)

Column forms can be either timber or steel like that of footings. The members are oiled and tied together using timber yokes supported by diagonal props. Wooden ladder is provided as an access for concreting. The following picture is taken from one of the high-rise buildings in Addis Ababa which is constructed by local grade one contractor.

Figure 2. 8 Column formwork construction systems in Addis Ababa (Gerji Federal Housing Project)

Spacing of yokes differs from contractor to contractor. Some provide very closely which is not economical while others provide at relatively larger spacing which is not safe. This might be due to the lack of guidelines for the formwork design. As the timber is used intensively for yokes, ladder and props, the construction system is not environmentally friendly unless rapid replacement of trees is made. The platform system for concreting is not suitable to properly consolidate concrete. Vibrators are sometimes inserted diagonally as the working condition is not suitable for labor. This will result in segregation of concrete. Moreover, failure of the ladder may occur while concreting which make unsafe working conditions for the workmen (Sharmila & Christober, 2016).

Slab and Beam Formwork Construction Systems

Steel panels of different sizes such as 0.9m*2m, 1m*1m etc are used as forms for slab construction. Almost all contractors use wooden shores (see figure 2.9). A few contactors use steel in combination with wooden props. Some start to modify wooden props by providing metal shoes in which the props are inserted. This system will help them to easily remove the props. Few contractors in Addis Ababa have started to use modern formwork, Doka systems, for slab construction. It is possible to say that the current construction systems in Ethiopia are threatening the environment as mainly timber is deployed for slab and beam props. In most sites the props are very closely spaced and make the circulation underneath difficult (Sharmila & Christober, 2016).

Figure 2. 9 Slab formwork construction systems in Addis Ababa. (Gerji Federal Housing Project)

Concerning beam formwork, the construction system is not different from others members. Timber boards and/or steel panels are used as sheeting material. Timber, mainly eucalyptus tree, props are used in Addis Ababa in particular and Ethiopia in general (see figure 2.10). The quality of concrete for beam and slab might be affected unless very experienced man power is employed in construction of beams and slab. The depth of the beam will be different at different points if all props for beam and slab are not precisely cut and placed. This problem is recurrent in most construction sites in Addis Ababa. More over the width of a particular beam might be different owing to the bulging of forms. Bulging may occur if the form ties are not properly designed. This phenomenon is also observed in most of our construction sites.

Figure 2. 10 Beam Formwork Construction Systems in Addis Ababa. (Gerji Federal Housing Project)

Ethiopian standards recommendations for formwork removal

The most common Ethiopian standards in building construction are BATCODA (1991) specification and EBCS. The minimum periods required to strip formwork for building structures are indicated in Tables 2.3 and 2.4 as per BATCODA and EBCS-2 respectively. The time of form removal is determined mainly by the strength development of the concrete and the function of the formwork. ―No undue deflection or damage whatsoever shall be caused to a structure by the removal of formwork. No formwork shall be removed until the concrete has hardened sufficiently (BATCODA, 1991). In the absence of more accurate data, the following minimum periods are recommended

Table 2. 1 Minimum periods for Formwork Stripping as per BATCODA (1991)

Vertical formwork to columns, walls & beams	16 hours
Soffit formwork to slab	21 days
Props to slabs	14 days
Soffit formwork to beams	21 days
Props to beams	14 days

Table 2. 2 Minimum periods for Formwork Stripping as per EBCS-2 (1995)

For non-load bearing parts of formwork	21 days
(e.g. vertical formwork of b~; formwork for columns and walls) For soffit formwork to slabs	7 days 14 days
For props to slabs	14 days
For soffit formwork to beams	21 days
For props to beams	

2.8.Aluminum Formwork system

The Aluminum Formwork System is one of the technologies that has been identified as being particularly well suited to Indian circumstances for mass construction, where excellent quality and speed may be accomplished. Aluminum Formwork is successfully employed in the construction of low- and high-rise residences and structures in Japan, Singapore, Malaysia, and the Middle East. This system's construction speed will be faster than most other construction methods and technologies. This method is efficiently handled by the labor to speed up the construction process while also ensuring quality control and durability. The structure's overall cost is reduced by using this system (Sonawane & Ambre, 2019).

Because the formwork is composed of aluminum, it contains portions that are large enough to be functional but light enough for a single worker to manage. Individual personnel can handle all of the components needed to put the system together without the use of heavy lifting equipment or specialized labor. The approach can introduce assembly line techniques to the construction site and ensure excellent work by unskilled or semi-skilled workers by ensuring regular repetition of labor activities.

The formwork is trial-erected in factory settings to check that all components are made correctly and that no components are missing. They're also numbered and packed in a way that makes site erection and disassembly a breeze (Sharmila & Christober, 2016).

2.8.1. Different Types of Aluminum Formwork:

Generally, aluminum formwork is classified according to the manufacturer, firm, or brand name. MIVAN was the first company to introduce aluminum formwork. Mivan is a formwork system made of aluminum that was developed by a European construction company. Mivan Company Ltd, a Malaysian company, began producing similar formwork systems in 1990. They now operate more than 30,000 square meters of formwork around the world. Another type that began in Korea in 1992 is the Kumkang sort. Kumkang is a new technology that has aided and encouraged large-scale construction projects all around the world (Deshmukh and Shalgar, 2016).

Components of Aluminum Formwork:

Because aluminum is not a very robust material, the panel, which is a formwork of extruded Aluminum pieces welded to an Aluminum sheet, is the foundation of the formwork system. It is made up of high-strength aluminum components. When subjected to the force of weight concrete, this results in a light weight panel with an excellent stiffness to weight ratio, generating negligible deflections. The pan sizes with non-standard parts are made to the exact size and shape necessary for the job. Stress is distributed on the shear wall in aluminum formwork rather than the traditional framed structure of columns and beams (Deshmukh and Shalgar, 2016)

The aluminum formwork panels are comprised of a high-strength aluminum alloy with a 4mm thick skin plate and 6mm thick ribbing behind them to reinforce them. The panels are held in place by a simple pin and wedge arrangement system, with high-strength wall ties connecting the walls and beams and props supporting the decks.

Other countries, including Europe, the Gulf States, Asia, and the rest of the world, have made substantial use of the technology. The use of room-size forms to construct walls and slabs in one continuous pour on concrete allows for the construction of a large number of houses in a short amount of time. Hot air curing / curing ingredients can help to remove forms sooner. This allows for quick building, such as two flats each day. All activities are scheduled in an assembly line fashion, resulting in more precise, well-controlled, and high-quality production at the lowest possible cost and in the shortest possible time (Durmisevic, 2006).

Cast-in-situ concrete wall and floor slabs cast monolithically supply the structural system in one continuous pour in this type of formwork construction. At the job site, large room-sized forms for wall and floor slabs are built. These forms are meant to be strong and durable, as well as accurate and simple to handle. They allow for a lot of repeats (around 250). RMC batching facilities manufacture the concrete under stringent quality control, while transit mixers transport it to the job site.

Before the form is concreted, the window and door frames, as well as service ducts, are installed. The building also includes staircase flights, façade panels, and other pre-fabricated elements. When compared to other modern construction processes, this shows to be a significant benefit (Magdum, Kumthekar and Jadhav, 2017).

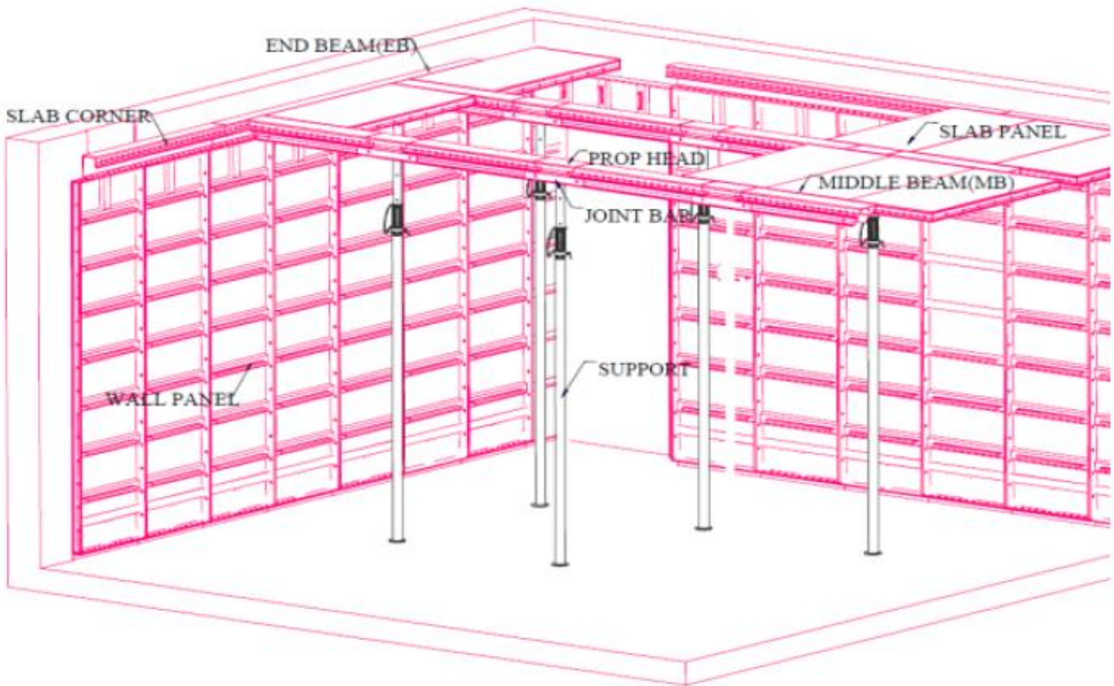


Figure 2. 11 Assembling of components of Aluminum Formwork. (Kumkang Kind Formwork Production Company Manual)

2.8.2. Construction Activities with Aluminum Formwork:

Pre-concrete activities, concreting activities, and post-concrete activities are the three types of building activities. The list is as follows (Durmisevic, 2006):

A. Pre – Concrete Activities:

1. Receipt of Equipment on Site – The equipment is received in the site as ordered.
2. Level Surveys – Level checking are made to maintain horizontal level check.
3. Setting Out – The setting out of the formwork is done.
4. Control / Correction of Deviation – Deviation or any correction are carried out.
5. Erect Formwork – The formwork is erected on site.
6. Erect Deck Formwork – Deck is erected for labors to work.
7. Setting Kickers – kickers are provided over the beam.

After the above activities have been completed it is necessary to check the following.

I. All formwork should be cleaned and coated with approved realize agent.
II. Ensure wall formwork is erected to the setting out lines.

III. Check all openings are of correct dimensions, not twist.
IV. Check all horizontal formwork (deck soffit, and beam soffit etc.) in level.
V. Ensure deck and beam props are vertical and there is vertical movement in the prop lengths.
VI. Check wall ties, pins and wedges are all in position and secure.
VII. Any surplus material or items to be cleared from the area to be cast.
VIII. Ensure working platform brackets are securely fastened to the concrete.

B. On Concrete Activities:

During concreting, at least two workers should be on standby to inspect pins, wedges, and wall ties as the pour progresses. The absence of pins, wedges, or wall ties could cause the formwork to slide, potentially causing damage. Following the striking of the formwork, this impacted region will require remedial work (Durmisevic, 2006).

Things to look for during concreting:

1. Dislodging of pins / wedges due to vibration.
2. Beam / deck props adjacent to drop areas slipping due to vibration.
3. Ensure all bracing at special areas slipping due to vibration.
4. Overspill of concrete at window opening etc.

C. Post – Concrete Activities:

1. Strike Wall Form- It is required to strike down the wall form.
2. Strike Deck Form- The deck form is then removed.
3. Clean, Transport and stack formwork.
4. Strike Kicker Formwork – The kicker is removed.
5. Strike wall – Mounted on a Working Platform the wall is fitted on next floor.
6. Erect Wall – Mount Working Platform and the wall is erected.

2.8.3. Speed of Construction:

Aluminum Formwork is a scheduling and control system for other related construction trades including steel reinforcement, concrete placements, and electrical inserts. As a result, the work on the job site is done in a specific order. The de-shuttering of the panels kicks off the work cycle. It takes between 12 and 15 hours. After that, the brackets and platforms are placed on the level. It takes roughly 10-15 hours at the same time.

The panels that have been de-shuttered are removed and secured to the floor. The activity will take 7-10 hours to complete. In 7 hours, the kicker and external shutters are installed. In 6-8 hours, the wall shutters are built. One of the most important activity reinforcements takes 10 to 12 hours. It takes about 10 hours to install the electrical conduits, and then concrete is poured into them.

This is a 7-day work cycle that is well-synchronized. After concreting, the concrete is allowed to acquire strength for 10-12 hours before the next cycle begins. This work schedule calls for 1010-1080 square meters of formwork, 72 to 25 cubic meters of concrete, and estimated reinforcement. The installation of formwork on the job site is a simple and rapid process. All panels are precisely identified when they leave the Kumkang factory, ensuring that they are immediately identifiable on site and can be seamlessly joined together utilizing formwork modulation drawings. All formwork starts at the corners and works its way outward.

2.9.Empirical basis of the study

2.9.1. Method of Analysis

2.9.2. Method of construction cost comparison between conventional and formwork technology in construction industry

According to different articles on related topics to study and research in, there are three distinct principles that are used to compare the costs of construction projects Rahim, M.S.M. and Haron, N.A. (2013).

1. Comparison of standardized identical buildings
2. Comparison of standard buildings with local modifications
3. Comparison of functional similar buildings

1. Comparison of standardized identical buildings

The first approach uses the same drawings and specifications to price the exact same construction work. This is only theoretically possible, owing to international (or even national) variations in design, standards, product availability, and so on. While the structure and costs will be similar, they will not necessarily be representative.

2. **Comparison of standard buildings with local modifications**

When adaptations for local contexts, such as building codes, standards, and specification levels, are taken into account, better representation can be achieved.

3. **Comparison of functional similar buildings**

The third method compares typical, functionally similar buildings: that is, building types that are representative. Not only are local differences in circumstances and quality standards considered, but also various performance and architectural parameters that represent typical client or tenant expectations for a building in that sector are considered. While the structures and costs are representative, they are not necessarily equivalent.

In previous studies, the Aluminum formwork system has found to be cost, time, and quality effective and in addition labor intensive. However, this doesn't actually mean that the conducted researches in other countries will apply to under developed country like Ethiopia. Therefore, a research should need to be conducted to check if the findings could be applied.

This research deals with the effectiveness of the new Aluminum formwork system in Ethiopia by comparing it to the Conventional formwork system with parameters like cost, time, quality and labor intensity for the future development of the system. If the system is found to be successful with minimized time and cost and maximized quality; it would be a beginning to a new technology for better success of the construction industry.

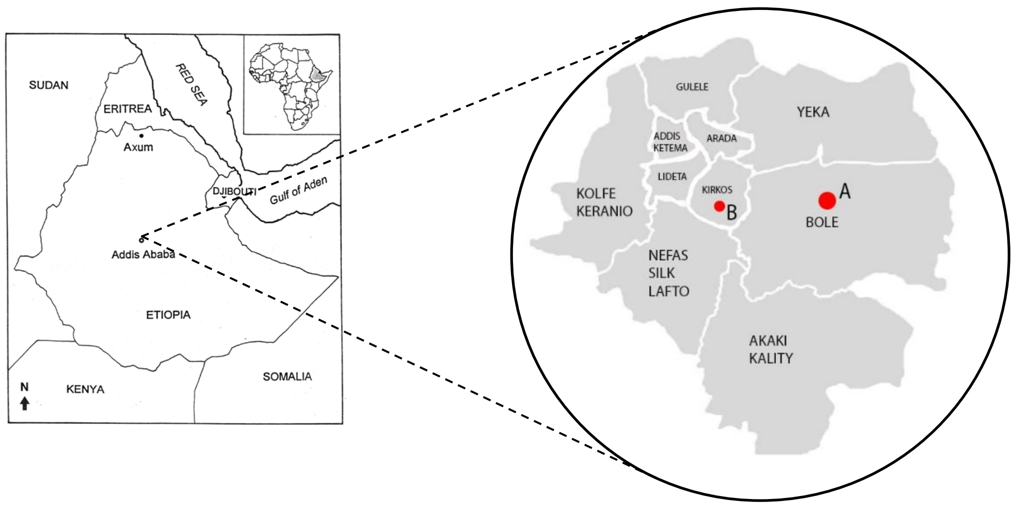
2.10. Research Gap

In previous studies, the Aluminum formwork system has found to be cost, time, and quality effective and in addition labor intensive. This research deals with the effectiveness of the new Aluminum formwork system in Ethiopia by comparing it to the Conventional formwork system with parameters like cost, time, quality and labor intensity for the future development of the system. If the system is found to be successful with minimized time and cost and maximized quality; it would be a beginning to a new technology for better success of the construction industry.

Chapter Three: Research Methodology

3.1.Study Area

In Ethiopia, Aluminum formwork technology is currently being used in two projects. Both projects are being built by OVID Construction PLC, a local Grade One contractor. OVID Construction PLC is Ethiopia's first company to use the technology. The Federal Housing Corporation (FHC) project and the Kazanchis project are two projects that use Aluminum formwork technology. The FHC Gerji project is constructed to house Ethiopian higher officials. The project site is located in Addis Ababa City Government, bole sub city at Gerji, with a plot size of approximately Twenty-Seven Thousand One Hundred Twenty-Two Square meter (27,122.00 m2).



A. Gerji Site

Figure 3. 1 Location for FHC Gerji Project Site (N8^{0}59’20.76”, E38^{0}48’57’’)

3.2.Research Design

A research can be grouped into three based on the purpose of the research, exploratory, descriptive, and explanatory (Bhattacherjee, 2012). Exploratory research engages with describing things which are not known before but has existence. Descriptive research engages with describing the characteristics of variables in a particular situation. Explanatory research primarily focuses on developing relationships and uses correlations to explain relationships. Since descriptive research is used to describe different properties and characters of a particular situation the researcher used descriptive research.

3.3. Data Types

3.3.1. Approach

There are three types of research approaches: deduction, induction, and abduction. The study adopted the deduction approach because the conceptual framework is built based on the previous studies and aimed to empirically test theoretically proposed relationships (Saundres, 2012). The deductive approach can be explained by the means of hypotheses, which can be derived from the propositions of the theory. In other words, the deductive approach is concerned with deducting conclusions from premises or propositions (Wilson, 2014).

3.3.2. Strategies

A research has different components such as research topic the research standpoint, the research design and research method. These components of research are organized with a research strategy. The four research strategies are: case study, qualitative interviews, quantitative survey, and action-oriented research Johnson, R. B., & Onwuegbuzie, A. J. (2004). Since descriptive research is used, the research strategy applicable is a case study and quantitative survey. In addition to the case study an interview was made to get pure information on the theoretical comparison between conventional formwork and Aluminium formwork technology.

3.4. Sources of Data

Researchers use different sources of data for the analysis and discussion of the targeted objective. The source of data used by the researchers can be grouped into two: primary data and secondary data. A primary source of data is a raw data which is collected by the researcher. Primary source of data gives the access to the main source of the research. Secondary data is a data that is already exists and collected by someone else. A secondary source describes, interprets, or synthesizes primary sources Summers, J. O. (2019). Both primary data and secondary data is employed for this research based on the main objectives.

3.5. Sampling Design

3.5.1. Target Population

Study population is a collection of all the people or items with certain common characteristics of interest to be studied (Rahi, 2017). As the issue under investigation is a technical matter, the participants should have an exposure to such issue in the case project. Accordingly, the researcher used preliminary observation to identify the right respondents who had pertinent knowledge, experience, and ability to provide response for the research questions. Thus, the researcher has grouped the studied population as Professional, Semi-professional or technical employees and non-professional employees. Professional employees refer to employees who have supervisory, administrative, or strategic and major technical exposure in the construction industry and possess at least degree in educational qualification. These groups of labels are resident engineers from the client side, internal resident engineers, site managers and assistant site managers. On the contrary, those employees having limited / no exposure to strategic and administrative decisions in construction sector but have technical knowledge are labeled as semi /non-professional employees these group contains office and site engineers. And those who have no administrative and strategic exposure but have technical knowledge are grouped as technical employees and grouped as technicians.

Moreover, non-professional employees are those who are engaged in low level tasks which have very no administrative and no strategic decision exposure. These groups of employees are bar benders, carpenters, assistant carpenters, and daily labors. Incumbents of these positions are not part of the study due to the fact that they have no exposure to strategic issues with very limited involvement in administrative decisions and majority of them have Certificate or lower.

3.5.2. Sample Size

Since the technology is new and it is not practiced well in Ethiopia it is difficult to get sufficient respondent, therefore it is planned to use the following targeted population.

Table 3. 1 Target Population by division

Title	Male	Female	Total	Percentage (%)
FCH Resident Engineers	15	5	20	10.53%
OVID Internal Resident Engineers	10	5	15	7.89%
OVID Office and Site Engineers	40	25	65	34.21%
OVID Technical crews	70	20	90	47.37%
Total	135	55	190	100%

3.5.3. Sampling Frame

Sampling frame of the study is, out of the total employee of Federal Housing Corporate (FHC) and Ovid Construction, the study focuses on professional staffs who are located at Gerji project at the site.

3.6. Method of Data Collection

There are different kinds of data collection techniques, from those questionnaires are the most widely used tool for comparative researches Cope, J. (2005). A questionnaire is developed with different standardized question in which the respondents supposed to answer. The data collection technique for this research is a questionnaire since the research is descriptive research. As a result, a self-administered, closed-ended questionnaire with a pre-determined 5-point Likert scale for response will be distributed to the OVID building target sample workers and the Federal Housing Corporate supervision team members.

3.7. Method of Data Analysis

In this study, analysis of data collected by questionnaire survey have been undertaken using statistical package for social science (SPSS) to display findings and it helps make it easier. Using computer programs and software's help in reducing the occurrence of different errors. Besides, it is fast and more accurate.

The quantitative data to be collected from sample respondents will be analyzed by descriptive statistics and graphs and some nonparametric inferential statistics to analyze the collected data. A descriptive method has been used for the analysis of the data which provides a general overview of the results in order to make interpretations and discussions based on the results percentages, tables and figures and the qualitative data's that has been gathered from general comments case studies and interview are analyzed separately but presented in combination with the quantitative information.

3.8. Method of Presentation

3.8.1. Reliability, Validity and checking missing data

Reliability

Measurement of any construct should provide stable and consistent result, the consistency and stability of the measurement is checked by its reliability (Oluwatayo, 2012). Consistency across the parts of any instrument is measured using test for reliability (Huck, 2007). A consistent instrument is that with high internal consistency and the items of the scale measure the same construct (Huck, 2007, Whitley, 2013). Internal consistency or reliability mostly measured using Cronbach Alpha Coefficient. Especially for Likert scales measuring reliability with Cronbach Alpha Coefficient is the most appropriate. The cutoff point or the minimum internal consistency that most researchers agreed is .70. Reliability of the questioner will be tested using SPSS v26 software.

Table 3. 2 Test for reliability

Constructs	No. of Items Proposed	No. of items dropped	No. items retained	Cronbach's alpha
Speed of construction and formwork system	7		7	0.778
Formwork system and work quality	9		9	0.823
Health and safety risk factors Conventional Formwork System.	109		109	0.8450.763
Health and safety risk factors Aluminum Formwork SystemHealth and safety risk factors Conventional Formwork System	1010		1010	0.820.845
Health and safety risk factors Aluminum Formwork System	10		10	0.82

As can be seen in Table 4.1 the measure of ‘Speed of construction and formwork system’ began with 7 items, no Items were dropped. Hence, using 7 items Cronbach alpha for ‘Speed of construction and formwork system’ was 0.778. Looking for ‘Formwork system and work quality’ it began with 9 items, of which no item was dropped. Cronbach alpha for ‘Formwork system and work quality’ was 0.823. Similarly, ‘Health and safety risk factors Conventional Formwork System’ have not dropped items and its Cronbach’s alpha was 0.845. ‘Health and safety risk factors Aluminum Formwork System’ dropped no item, resulting in Cronbach’s alpha of 0.820. From this one can decide that the data collected is reliable and can be used for further study.

Validity

Validity is the extent to which the results really measure what they are supposed to measure. Valid research produces a result that resembles real properties, features, and variation in physical world. Validity can be described in different forms such as content, external (criterion) and construct (convergent and discriminant) validity Briñol, P., Petty, R. E., & Wagner, B. (2009). To test the validity of the questionnaire some respondents that work in both organizations (Federal Housing Corporate (FHC) and OVID Group) form different departments were selected and given the questionnaire. From their response the measures of the constructs are covered, the arrangement of the questionnaire is good and easy to understand means that the instrument fulfills content validity. Additionally, from the response of the selected respondents, the researcher found that their scores on measures are correlated from variables to variables which are known to be correlated implying that the instrument fulfills criterion validity. Additionally, the sample size is ample to generalize about the population from the sample. Since all validity criterions are full filled validity test have been accomplished for this study.

Validity is the extent to which the results really measure what they are supposed to measure. Valid research produces a result that resembles real properties, features, and variation in physical world. Validity can be described in different forms such as content, external (criterion) and construct (convergent and discriminant) validity Briñol, P., Petty, R. E., & Wagner, B. (2009). To test the validity of the questionnaire some respondents that work in OVID Group form different departments were selected and given the questionnaire. From their response the measures of the constructs are covered, the arrangement of the questionnaire is good and easy to understand means that the instrument fulfills content validity. Furthermore, the researcher discovered that the selected respondents' scores on measures are associated from variables to variables that are known to be correlated, demonstrating that the instrument meets criterion validity. Additionally, the sample size is ample to generalize about the population from the sample. Validity of the questioner will be tested using SPSS v26 software.

Assessing Missing Data

Missing data are a serious issue in quantitative research. Missing data leads to biased estimates, will produce decreased statistical power with an increased standard error, and weakened generalizability of findings. Enders (2010) stated that a missing rate of 15% to 20% was common in educational and psychological studies but variable with more than 50% of missing data should be omitted. Since there were some missing data's in the variables, the researcher tried to fill the missing values with using the method of replacing the missing values with the mean of nearby values. The missed values by respondents are shown in table below. The researcher uses SPSS V26 software to assess and fill the missing values. There are several techniques of filling missing values, including substituting the missing value with the mean/median/mode strategy, which was employed in this study.

Table 3. 3 Missing values from each respondent for the given questions.

	Cement Bag for AF WS	CSF1 for CF WS	CSF2 for CF WS	CSF5 for CF WS	CSF8 for CF WS	CSF1 for AF WS	CSF2 for AF WS	CSF3 for AF WS	CSF4 for AF WS	HSRF8 for CF WS	HSRF10 for CFWS	HSRF1 for AF WS	HSRF4 for AF WS
Valid	176	177	177	177	175	176	177	177	177	177	176	177	176
Missing	2	1	1	1	3	2	1	1	1	1	2	1	2

3.9.Ethical Consideration

Since Ethical considerations in research are critical, the data collected from respondents used only for the research purpose and kept confidential. The researchers do not reveal the names of the respondents and all the respondents have participated voluntarily. The researcher also attempted to properly acknowledge their work in the acknowledgement section of the publication, as well as to state each referenced document in the referring section of the study.

Participants were highly advised and encouraged to give an honest and genuine answer, opinion, suggestion in the course of the study. Drawings, work methodologies, manuals, policy, procedures, and other relevant documents collected from the selected companies are kept confidential and are not disclosed to the third party in any form. Generally, the data were collected in a way that did not harm the participants' wellbeing and privacy.

Chapter Four: Results & Discussion

4.1. Introduction

The section is structured in a manner that aids in answering each research question and research objective. After collecting data using a questionnaire, this chapter presents quantitative statistics to analyze data. The chapter has four major sections. Section 4.1 introduction, section 4.2 discusses about profile of respondents, section 4.3 is about suitability of aluminium formwork system over the conventional formwork system, section 4.4 is about summary of respondents.

4.2. Profiles of Respondents

As shown in Table 4.2, respondents to the returned questionnaires have 2 to 25 years of experience in the construction business in various positions. 72 percent of respondents, the highest rate of responses, are females where as 28 percent of the respondents are males.

Table 4. 1 Gender Profiles of Respondents.

Title	Male	Female	Total
FCH Resident Engineers	15	4	19
OVID Internal Resident Engineers	10	4	14
OVID Office and Site Engineers	38	23	61
OVID Technical crews	66	19	85
Total	129	50	179

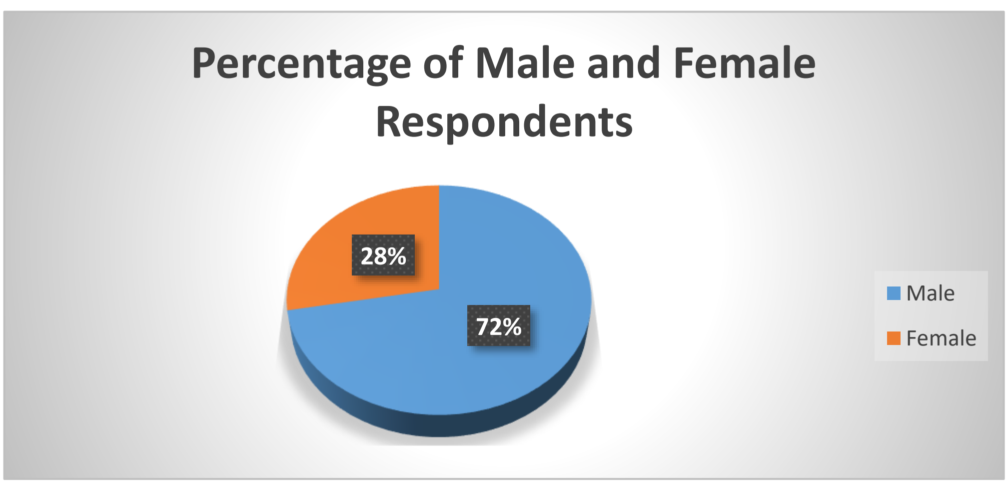


Figure 4. 1 Comparison of male and Female respondents.

From the total respondents the majority of the respondents are from OVID construction, (90%) whereas the rest are selected from Federal Housing Corporate (FHC) counterpart office (10%) working at Gerji project. work as site engineers, and they were the only ones to respond to nearly every question in the survey. From the selected respondents working for OVID 53% is taken from the technical crew since the technical crew has details of the work.

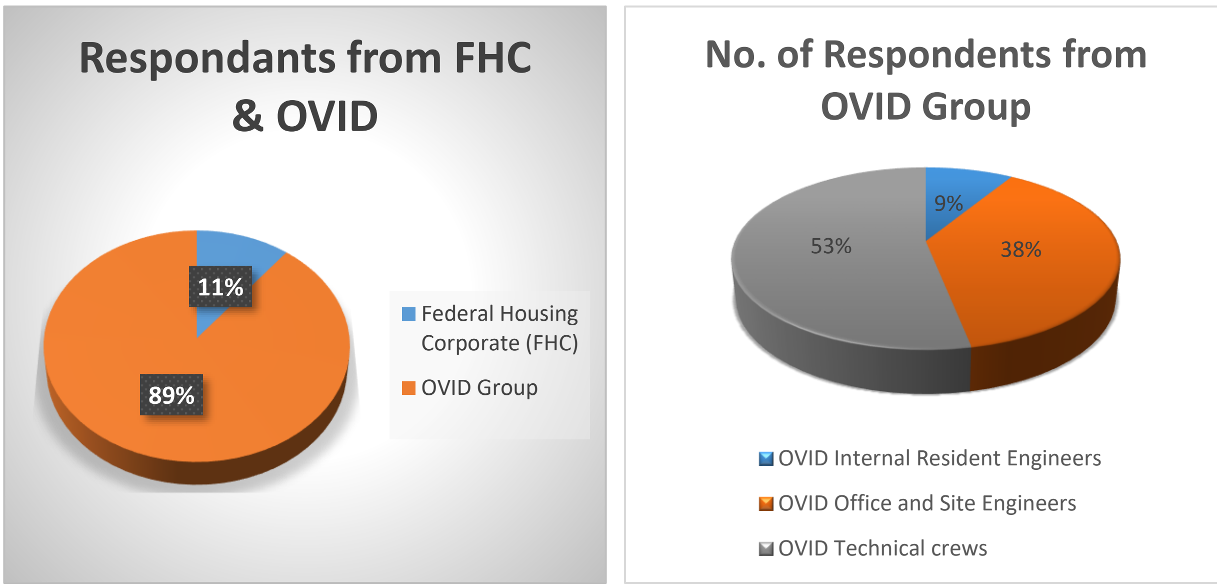


Figure 4. 2 Number of respondents from FHC and OVID Group.

4.3. Suitability of Aluminium formwork System Over the Conventional Formwork System

4.3.1. Cost Analysis

The majority of large construction projects in Ethiopia are carried out using conventional methods. OVID Construction PLC is a construction industry pioneer in adopting current formwork technology based on the experience of foreign corporations to disrupt the traditional construction process and introduce a new technology that saves time, money, and improves quality. OVID Construction plc has acquired new formwork technology from Kumkang Kind plc, a well-known Korean company. At Gerji and Kazanchis sites, the new formwork technology is vividly demonstrated. From January 2021 to March 2021, Aluminum formwork was used on the two projects in Ethiopia, which were structurally completed in three months and had a total of twelve stories. Every week, one new narrative is created.

Hence, the traditional formwork system has been in use for a long time and is familiar and the percentage cost proportion for each work content is well-known. However, because Aluminum formwork is a new technology, it requires a thorough evaluation and identification of its cost proportion by work contents. As a result, the primary goal of this research is to determine the percentage cost proportion of each work content under the new formwork technology and to compare it to the conventional formwork system.

In Addis Ababa, apartment towers developed using the conventional approach that are comparable to those erected using modern technology were chosen for the cost comparison method, with the unit being a percentage of major construction contents (actual construction is done with Aluminum formwork framework, but the design is adopted to local design trend in this analysis). The cost comparison takes into account both Aluminum formwork and conventional formwork constructions. In fact, both projects that use Aluminum Formwork technology and projects that use the traditional approach are

subjected to a desk case study. An interview was conducted in addition to the desk case study in order to obtain a theoretical contrast between the two formwork systems. The Gerji FHC initiative, which includes the development of six sky villa and ten apartment buildings to house Ethiopian higher officials and Kazanchis G+16 Real Estate, are the subject of a case study.

The key focus of the case study is on the expense of various construction work contents (Foundation works, Structural works, Electrical works, Sanitary works, and Finishing works). After a thorough analysis, the total percentage of each construction work content is calculated from the total construction cost for both formwork systems.

Table 4.4 breaks down the percentage of different building works into conventional and Al-formwork methods. The work percentages for the conventional formwork method were calculated using data from six identical buildings in the city and a simulated building from the Gerji FHC project.

Table 4. 1 Work Percentage for different buildings for both conventional and Aluminum formwork.

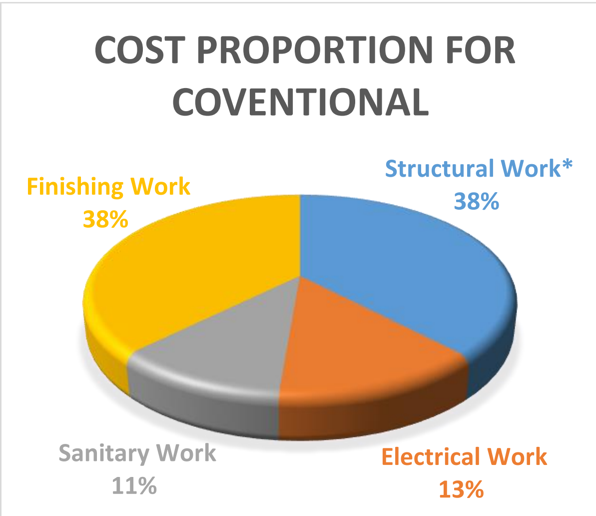
	Buildings in Addis Conventional	Work Content				Total cost
		Structural Work*	Electrical Work	Sanitary Work	Finishing Work	
Conventional Formwork	Project B+G+11 (Simulated)	61,577,124 (35%)	21,468,652 (12%)	23,112,527 (13%)	67845242.7 (39%)	**174,003,545.70**
	Apartment 2B+G+12	86,745,112.5 (38%)	32,233,145 (14%)	22,958,750 (10%)	86372411 (38%)	**228,309,418.50**
	Apartment 2B+G+8	76,283,589.26 (39%)	28,100,600 (14%)	23,213,458 (12%)	68329845 (35%)	**195,927,492.26**
	Apartment B+G+10	88,305,930 (39%)	30,740,871.25 (14%)	23,740,871.25 (11%)	81005710 (36%)	**223,793,382.50**
	Apartment 2B+G+9	76,401,813.83 (39%)	25,645,984 (13%)	20,431,524.64 10%)	75845242.7 (38%)	**198,324,565.17**
	Apartment 2B+G+10	65,069,810.88 (36%)	22,789,877 (13%)	21,570,385.24 (12%)	69417785 (39%)	**178,847,858.12**
Aluminum **Formwork**	Gerji Project Sky Villa B+G+9	54,036,675.71 (46%)	15,905,187 (14%)	16,467,617.27 (14%)	31327407.17 (27%)	**117,736,887.15**
	Gerji Project Apartment B+G+11	61,609,775 (45%)	17,947,148.6 (13%)	18,557,422.35 (14%)	37554526.1 (28%)	**135,668,872.05**

*Including conduit

Table 4. 2 Cost proportion for both conventional formwork and Aluminum formwork.

	Structural Work*	Electrical Work	Sanitary Work	Finishing Work	Total
Average Cost for Conventional	75,730,563.41	26,829,854.88	22,504,586.02	74,802,706.07	199,867,710.38
Cost Proportion	**37.89/62.11**	**13.42/86.58**	**11.26/88.14**	**37.44/62.56**	**100.00**
Average Cost Al-Formwork	57,823,225.36	16,926,167.80	17,512,519.81	34,440,966.64	126,702,879.60
Cost Proportion	**45.64/54.36**	**13.36/86.64**	**13.82/86.18**	**27.18/72.82**	**100.00**

The cost proportions for various building tasks are shown in the table above, based on the results for both formwork systems. The cost proportion of structural work to the remaining work is 37.8/62.11 and 45.64/54.36 for conventional and aluminum formwork systems, respectively. For electrical and sanitary work, the cost proportions are approximately 13.42/86.58 and 11.26/88.14 for traditional formwork systems, and approximately 13.36/86.64 and 13.82/86.18 for aluminum formwork systems, respectively. For finishing work, the cost proportions for conventional and aluminum formwork systems are 37.44/62.56 and 27.18/72.82, respectively.



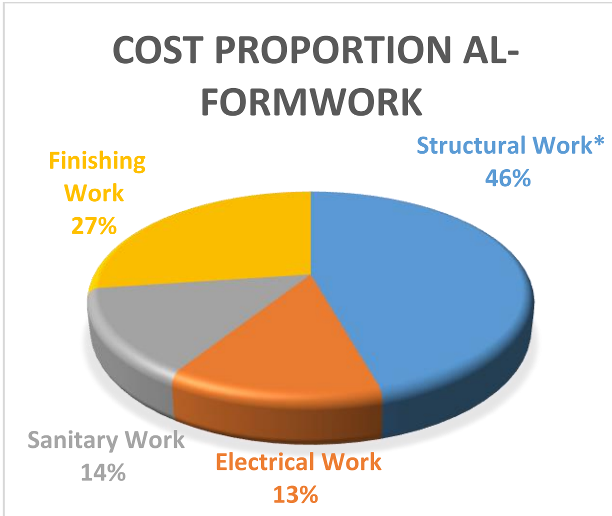


Figure 4. 3 Cost percentage for different works

Table 4. 3 Mean difference between average cost of works for conventional and Aluminum formwork system.

Paired Samples Statistics

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	Conventional	49,966,927.59	4	29,269,353.49	14,634,676.75
	Aluminum formwork	31,675,719.90	4	19,230,913.96	9,615,456.98

Table 4.4 shows the mean difference between the average cost of different works for conventional and Aluminum formwork system. The mean cost of conventional system is 49,966,927.59ETB per

work content, while for the Aluminum formwork system, the mean cost is 31,675,719.90ETB per work content. From this the difference is about 18,291,207.69ETB per work content. This shows that there is a wide difference in cost between the conventional formwork system and Aluminum formwork system, the former being very expensive.

The t-test analysis is a statistical analysis to test the difference between two variables. The purpose is to show the significance level of the building cost comparison of building using conventional system with that of Aluminum formwork system.

The present study used a two-tailed test and the underlying reason for choosing the two-tailed test over one-tailed test is to ensure that the result obtained is compatible. If only one-tailed test is used, then the result obtained might not be the same with that of a two-tailed test. If the result shows the difference between conventional and Aluminum formwork system is not significant, then the study cannot conclude that conventional formwork system is more expensive than the Aluminum system.

Table 4. 4 Significant of difference between one B+G+10 apartment building of conventional system and aluminum formwork system.

Paired Samples Test

		Paired Differences							
					95% Confidence Interval of the Difference				
		Mean	Std. Deviation	Std. Error Mean	Lower	Upper	t	df	Sig. (2-tailed)
Pair 1	Conventional – Aluminum FW	.25	5.91	2.95	-9.15	9.65	.085	3	.162

Table 3.7 shows the results of the t-test conducted using conventional and Aluminum formwork system. It has been found that there is a 0.162 (last column) or 83.8 percent confidence level. This confirms that the cost of building using conventional formwork system method is more expensive compared to the Aluminum formwork system. The means difference of 25 percent per work content also shows that conventional formwork system is more expensive compared to the

Aluminum formwork system. This implies that the Aluminum formwork system will save about 25% cost than that of the conventional formwork system.

In addition, when considering the time value of money and the number of repetitions the Aluminum formwork will be used, the outcome will be drastically different, clearly indicating that using Aluminum formwork will produce better results. Unlike traditional formwork, which must be discarded after 5-10 repetitions and steel formwork after a maximum of 50 repetitions, aluminum panels can be reused for over 300 times Pujari Bharagvi, S., et al., 2018.

Beside this, construction waste, like many other industrial activities, has become a significant environmental concern in the business. Increased waste production is another key issue that each project must manage in order to keep the cost of removing all unwanted materials from the working site, such as used lumber and other materials, as low as possible.

As a result, it's obvious that Aluminum formwork would save time and money. Material waste is nearly non-existent when Aluminum formwork is used. As a result, adopting Aluminum formwork reduces the expense of removing material waste. The Following figure gives an idea about the proportion contribution of each component in the generation of construction waste. From the chart the biggest waste is generated from formwork in the case of conventional formwork system, while in employing Aluminum formwork system the waste generated owing to the formwork is almost forgotten.

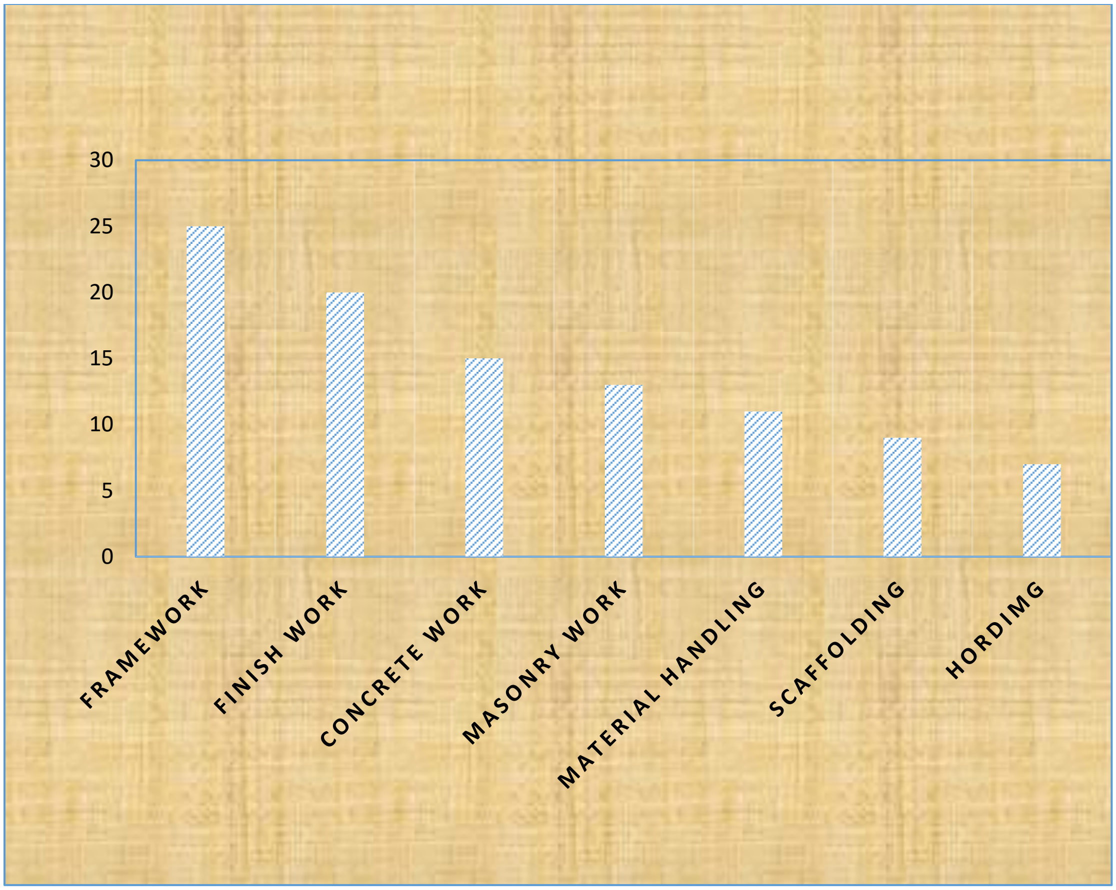


Figure 4. 4 Construction waste generation (Renuka Hangarge, A. and Waghmare, S.P., 2017)

4.3.2. Speed of construction analysis

Having the structure of a typical floor completed in the quickest period is one way to reduce the cost of a building project while also speeding up construction activity to achieve a very fast floor cycle. Again, from a production standpoint, the key to achieving this is the adoption of an efficient and suitably constructed formwork system.

The notion of erection time, stripping time, and productivity of construction work was asked in the questionnaire in the sense of comparing each type of formwork system in order to compare the pace of construction done by conventional formwork and Aluminum formwork systems. In the following paragraph, we analyze the responses of the respondents: -

With respect to the erection time of formwork respondents responded their observation about the time difference in constructing conventional formwork and Aluminum formwork systems in their respective project, if there is difference, they responded which one is faster and which one is slower. Results of the analysis are given below in Fig. 4.6. From the result obtained about 95% agreed on that there is erection time difference between conventional formwork and Aluminum formwork systems. From the respondent's response on can understand that Aluminum formwork system is faster than conventional formwork systems. Thus, generally the type of formwork used in the projects affects erection time of formwork.

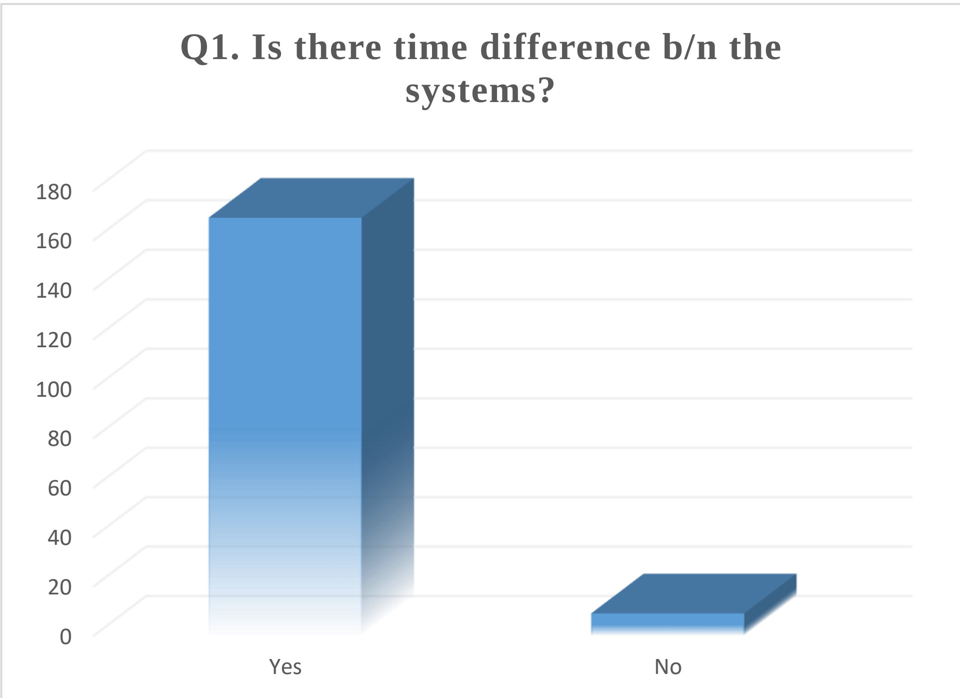


Figure 4. 5 Erection time comparison between the two systems.

The other question related to speed of work is the stripping time of the formwork. Regarding to stripping time of formwork, for how long one has to wait to remove the form from concrete, respondents were asked to response whether type of formwork used their respective project affects the stripping time of the formwork. Graphical analysis of their response is given below in Fig. 4.7.

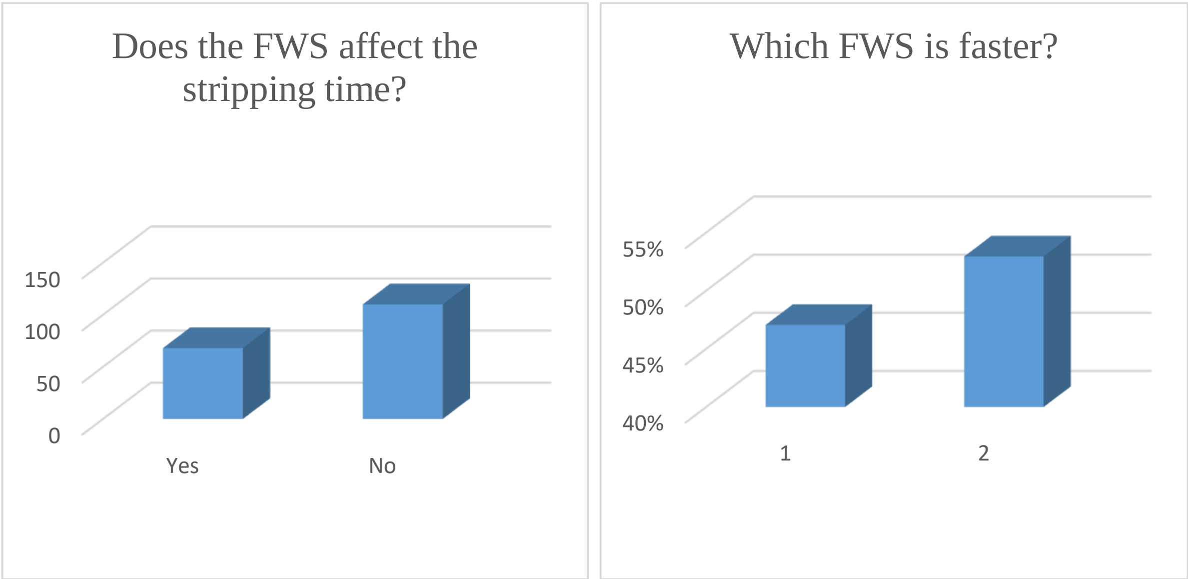


Figure 4. 6 Stripping time of formwork system

From the above graphs we can see that more than 62% of the respondents feel that type of formwork used in their projects did not affect the stripping time of formwork from the casted concrete, whereas only 38% feel that the formwork system can affect the tripping time of formwork from the casted concrete. The second graph reveals that 43 percent of people who responded that the formwork system affects stripping time of the formwork from the casted concrete, said that an aluminum formwork system may be stripped faster than a conventional formwork system and 36% of respondents feel that conventional formwork can be stripped faster than Aluminum formwork system. Those respondents that said there is no time difference in stripping the formwork from the concrete feel that length of time that required to remove the formwork actual depend on the type of cement and other environmental factor of the site.

A table was provided for responders to fill out in order to determine the stripping time of their projects. For both types of formwork systems, the response range is nearly identical for almost all respondents. Table 4.8 shows the average range of stripping time provided by respondents.

Table 4. 5 Stripping Time for steel and timber formwork

Structural elements	Waiting time for stripping	
	Aluminum FWS	Conventional FWS
Beam	21 Days	21 Days
Column	12-24 Hours	12-24 Hours
Slab	21-28 Days	21-28 Days
Stair	21 Days	21 Days
Walls	12-24 Hours	12-24 Hours

Table 4.6 shows that the type of formwork employed in construction projects has no bearing on the time it takes to remove the form. However, stripping time is determined by how soon the concrete achieves the desired strength, which is determined by the cement and additives used in the project. As a result of this research, we can deduce that the type and condition of the formwork utilized in the project can have an impact on the crew's productivity. Most respondents believe that current formwork systems (Aluminum formwork system), increase crew productivity since they can cover a larger area, are lighter in weight, and are easier to handle for employee. Furthermore, the formwork system includes unique props that are separate from the main slab formwork panels, allowing the slab formworks to be dismantled and reused for upper floors in as little as 2-3 days.

In terms of productivity and kind of formwork, respondents were asked to answer which type of formwork employed affects worker productivity. Table 4. Figure 4.12 shows the results of the analysis.

Table 4. 6 Respondents results on increasing productivity by using the formwork systems

	Which FWS increase productivity
Aluminum Formwork Systems	175
Conventional formwork Systems	3

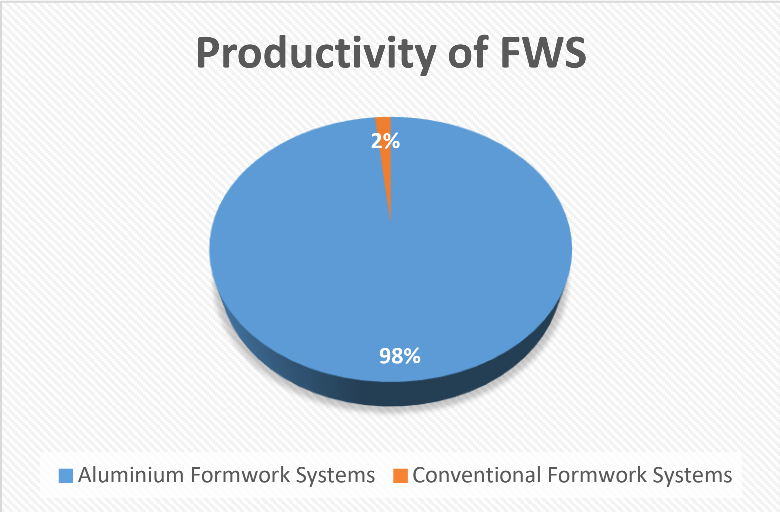


Figure 4. 7 Shows percentage of respondents for increasing productivity by using the formwork systems.

We can see from the table and the graph that the majority of respondents (98%) believe that the type of formwork employed in their projects has an impact on worker productivity, while only 2% believe that the type of formwork has no impact on worker productivity. We may deduce from these figures that the sort of formwork utilized in any project has an impact on work productivity. By providing a greater covering area for casting concrete, the modern aluminum formwork system increases the productivity of the project.

The last question related to speed of work is about the supporting props. Almost 100 percent respondents respond that Aluminum formwork system is convenient for supporting props left after slab members are stripped. According to the response of the respondents they have attempted to re-shore the slab and remove the formwork sheets while lifting the props. Aluminum formwork system has unique prop system which is an isolated system from the slab panel. Propping is a system of structural members used temporarily to support loads during construction. The forces arising from these loads must be fully resolved, using props or columns to provide all the support needed for the work under construction, such as beams, formwork, etc.

4.3.3. Formwork system and work quality

When comparing the quality of completed concrete created by Aluminum formwork and conventional formwork systems, respondents were asked different questions on discoloration, dimensional accuracy, smoothness and regularity of the concrete surface, and serious quality problems that occurred during the stripping process. The following is an analysis of the respondent's responses to each question:

The first question addressed which type of formwork system creates more fair finish of the finished concrete. From the result most of the respondents believe that aluminum formwork system creates better fair finish that that for conventional formwork system. About 29% of the respondents answered that conventional formwork system creates better finish than that of aluminum formwork system. The result of the finish area that will be seen after aluminum formwork is dismantled will create vertical and horizontal grooves in every 60cm. for that matter the finish area needs additional surface preparation.

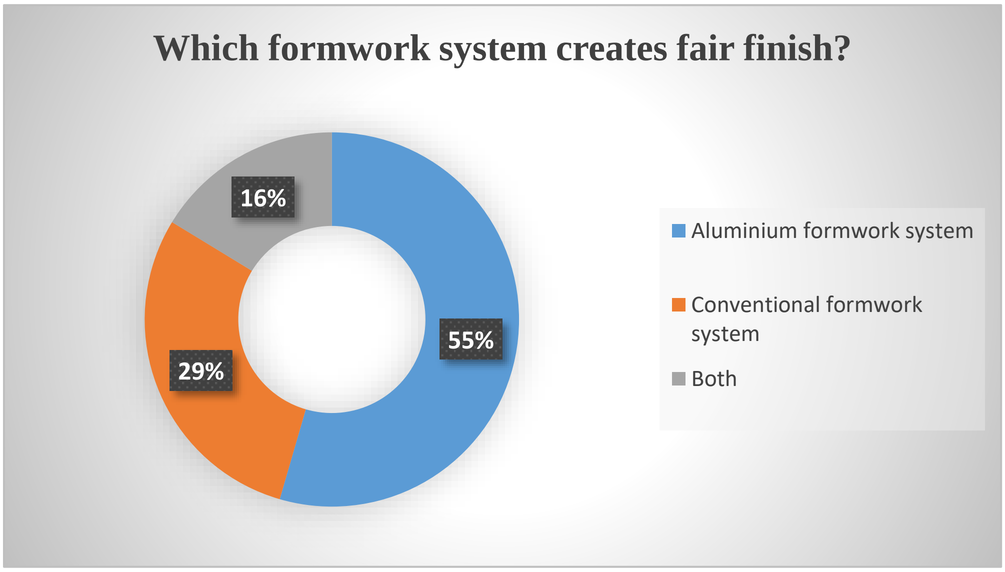


Figure 4. 8 Respondents percentage for fair finish

The second topic raised for the respondents in respect to the issue of quality of finished concrete created by the kind of formwork systems is how to maintain dimensional correctness in casted concrete. The size, shape, and alignment of structural parts are all factors in dimensional accuracy. The respondents were provided this verification and asked to choose which type of formwork system maintains the most dimensional accuracy among the options presented (Conventional and Aluminum formwork systems). The findings of the analysis are depicted in Fig. 4.9.

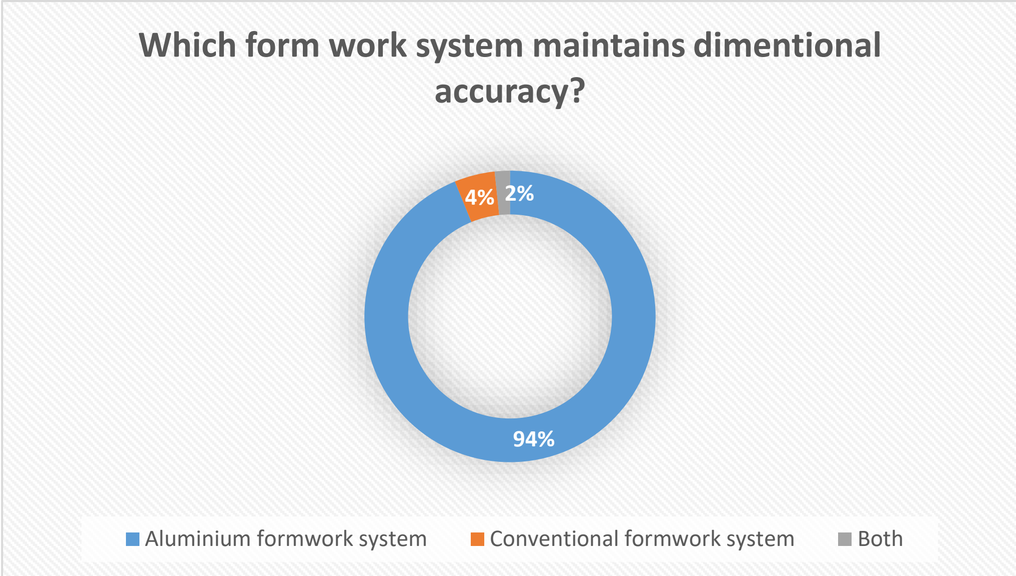


Figure 4. 9 Dimensional accuracy

The main trait required from any formwork system used in the construction of building elements is maintaining design size, shape, and alignments of structural elements, with about 94 percent of respondents preferring Aluminum formwork systems. Aluminum formwork system creates the most accurate design size, shape, and alignment since the design is developed after the final structural and architectural design is completed properly. Only small percentage of respondents respond that only 4 percent choose the conventional formwork system. In order to ensure dimensional accuracy of final concrete, some responders choose both Aluminum formwork and conventional formwork systems. As a result, we can infer that there is large difference between Aluminum formwork and conventional formwork systems when it comes to maintaining dimensional accuracy of casted concrete.

The following two questions about the quality of formwork systems were asked of respondents: which type of formwork system addresses the smoothness and regularity of the finished surface, and whether they are satisfied with the quality of concrete surface after stripping the formwork that they are using.

As one of the quality measurements of the formwork system, the other question in this category addresses the smoothness and uniformity of the completed surface. Respondents are asked to write the type of formwork system they would propose for building projects based solely on the smoothness and regularity of the final concrete based on this concept. The analysis' findings are depicted in Fig. 4.10.

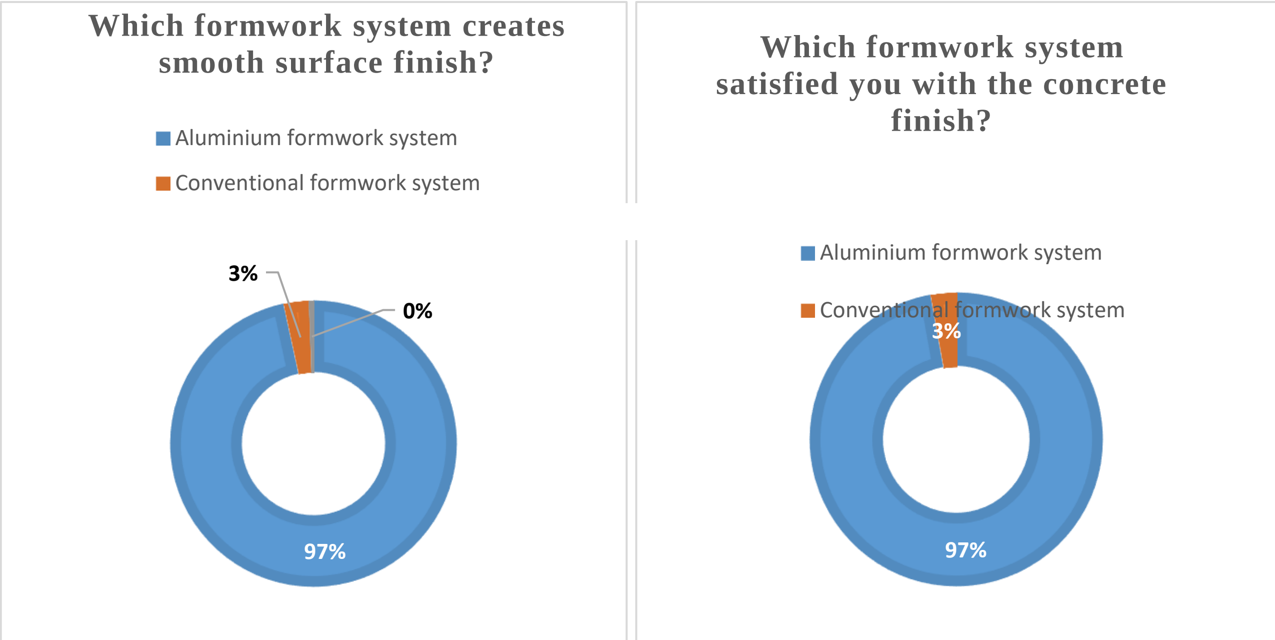


Figure 4. 10 Respondents results for smooth surface finish and their preference of formwork systems.

The majority of responders (97%) prefer the aluminum formwork system, while the remaining 3% prefer the conventional formwork system. 97 percent of respondents chose Aluminum formwork systems for smooth surfaces and regularity, whereas only 3% prefer conventional formwork systems. The majority of responders chose the Aluminum formwork system because it produces a smoother and more regular surface. Furthermore, 97 percent of those polled prefer an aluminum formwork system for concrete finishing. The completed surface created by the aluminum formwork system is nearly flawless and provides a better surface finish.

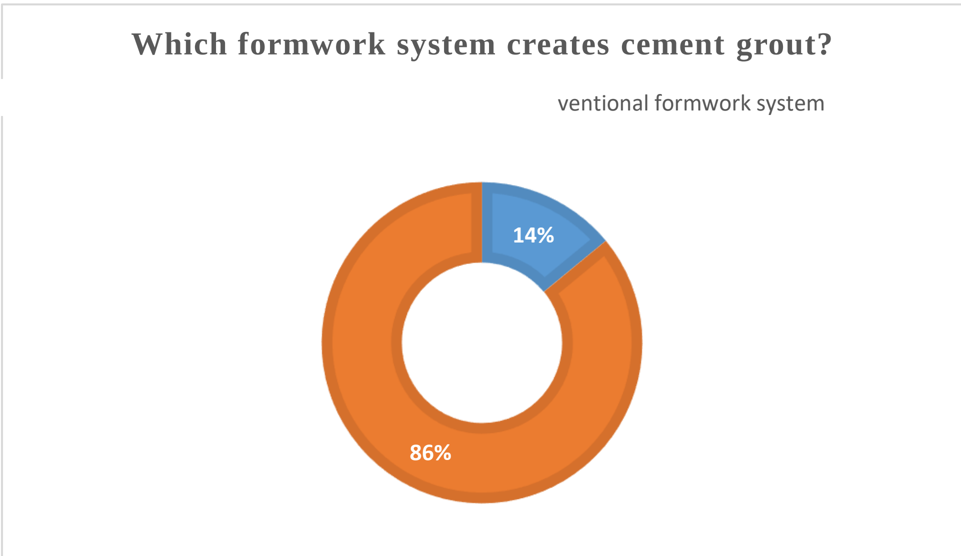


Figure 4. 11 Respondents result for question of formworks system that creates cement grout.

According to the survey results, around 86 percent of respondents believe that typical formwork systems produce cement grout and require additional treatment to control and avoid the cement pest that emerges from the formwork. Cement pest or grout that comes out of the formwork is typical in most construction sectors, and most workers use cement bags to prevent the cement from spreading. The next question for respondents was about using a cement bag to keep the cement grout that comes out of the formwork. Similar to the results of the previous question about cement grout, roughly 86 percent of respondents say they use cement bags to keep cement pest at bay while utilizing conventional formwork systems.

The next question given for respondents was about treating the applied loads on the formwork. About 58 percent of the respondents did consider the applied load on the formwork while preparing it. From the result while using conventional formwork most of the engineers doesn't consider the applied load that will be applied on the formwork until the concrete attains its strength and the formwork is dismantled. But the suppliers of Aluminum formwork system the props as well as the whole system is designed to sustain for the applied loads on the formwork. Regarding to the design loads Aluminum formwork system is much better than that of conventional formwork system.

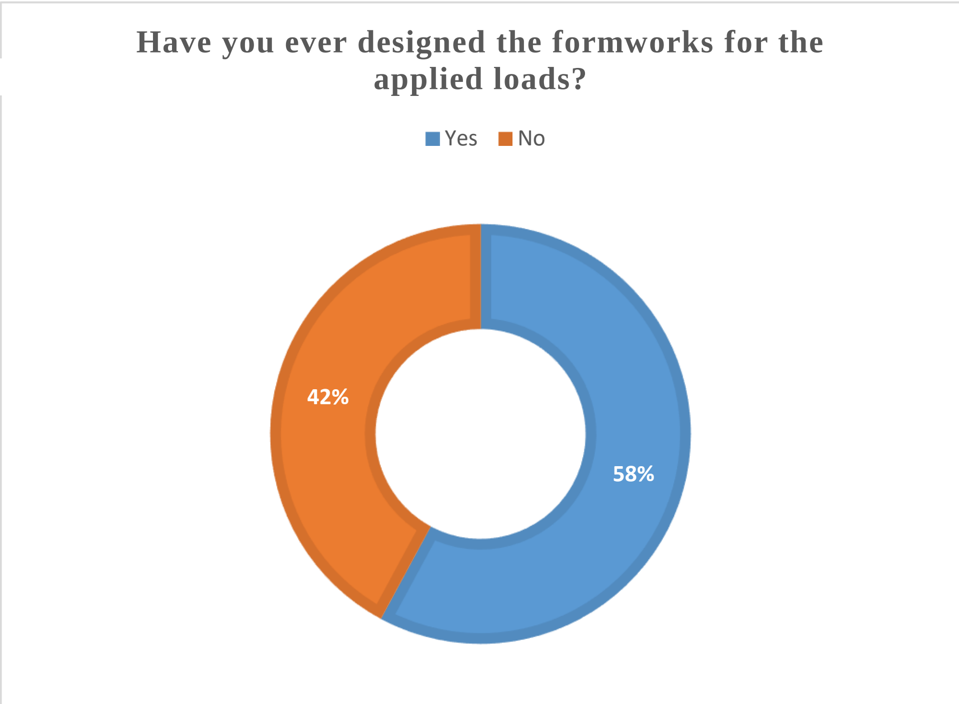


Figure 4. 12 Respondent results for the applied loads for formworks.

The last two questions are related to props of that will used as support for slabs, beams and other suspended structural elements. The first one asks about which type of props for slab and beam do they often use. From the result show in the figure below, 48 percent of the respondents respond that as they are using Aluminum props and 28 percent of the respondent respond as they are using wooden props to support the slabs and beams while they are constructing the formwork. And 24 percent of the respondents use steel props. While using Aluminum formwork system the props used are also Aluminum but for other works in the specified project used both wooden and steel props.

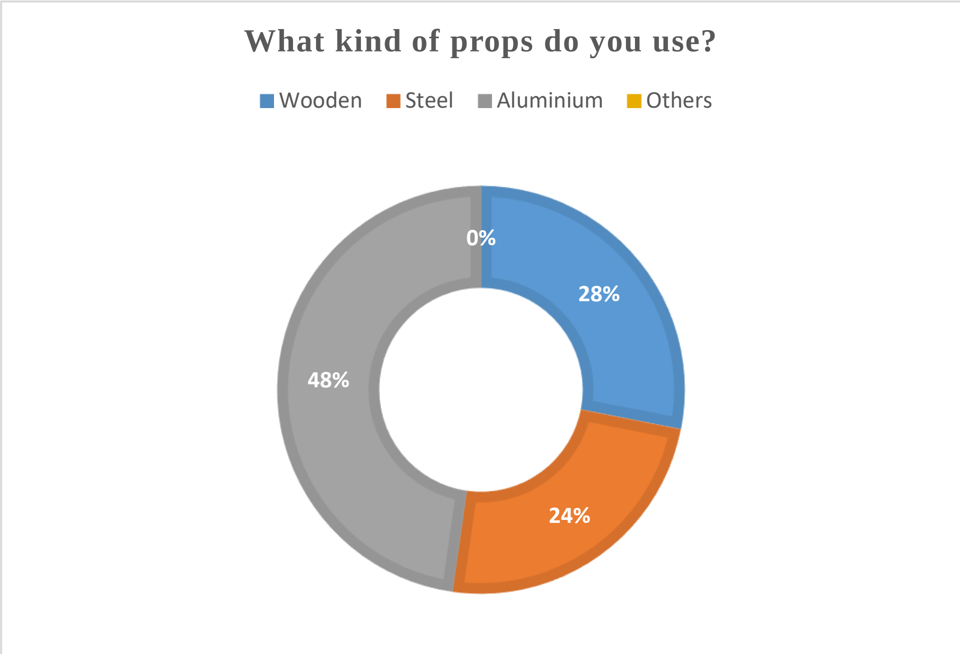


Figure 4. 13 The types of props that are used by respondents.

The other question regarding formwork props is about the specific design for the props. From the result 76 percent respondents answered as they have designed for the props before starting the activity. Especially for Aluminum formwork system the props are placed with the designed aspect and will be placed according to the design that the suppliers provide. And also, most steel props have design for the props used. And in some case wooden props are also placed in a designed manner to get good support and to protect the formwork form failure.

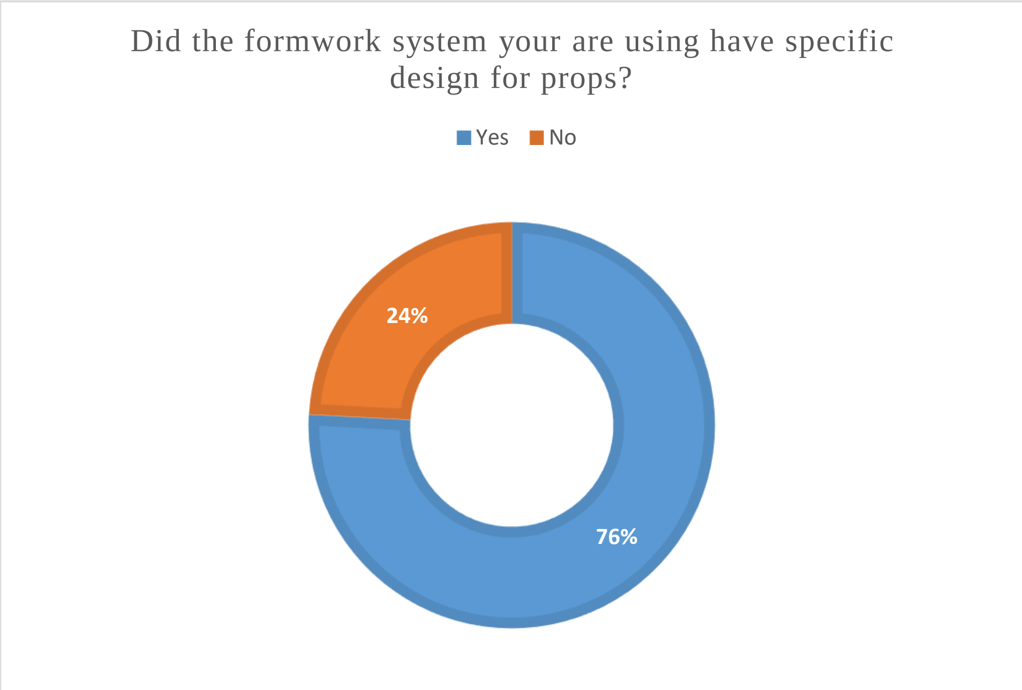


Figure 4. 14 Respondents response about specific design for props.

4.3.4. Health and Safety Risk Factors

Health and Safety Risk Factors

The environment should not be jeopardized by construction activity. One of the environmental hazards is the usage of wood props and forms without a promise of replacement. Aluminum formwork systems do not require the use of wood props, making them environmentally friendly. As a result, it is feasible to conclude that construction utilizing modern formwork technologies is environmentally friendly. It is critical for site safety, orderly equipment storage, compact stacking, simple access, and safer movement with a forklift truck and/or crane. Modern site equipment, such as aluminum formworks site accessories, can help achieve these goals. At all levels of work, there are also safety guard rails and working platforms. Some formwork systems are completely enclosed, preventing workers from looking down and providing wind protection. The major unique systems of the aluminum formworks system are safety brackets. They offer a separate design and drawings that show how to install the safety bracket and enclose it. Everything is under control in terms of work environment security.

In the next paragraphs, the practice of safety and environmental issues during formwork construction for both formwork systems was evaluated and described. Because of the well-designed brackets for safety purposes, roughly 88 percent of the respondents feel that there is no risk of falling from height while working with an aluminum form work system. However, while employing a conventional formwork system, there is a risk of falling from a great height, as 90 percent of the respondents agreed. Aluminum formwork outperforms conventional formwork systems in terms of working platforms, safety belts, and other factors. 100 percent of respondents believe that an aluminum formwork system offers a better working platform than a conventional formwork system. When using the conventional formwork approach, about 85 percent of respondents say there is no acceptable working platform. In terms of noise production, the opposite is true. The use of an aluminum formwork system generates greater noise than a conventional formwork system. During installation, an aluminum formwork system makes greater noise, according to 81 percent of respondents.

According to the respondents' responses, employing an aluminum formwork system poses nearly little danger of pain or damage. However, nearly 75% of respondents believe that employing conventional formwork systems poses a risk of discomfort and damage. Because hammers and other tools are used so frequently in most construction projects with conventional formwork system, there is a danger of pain and damage. Because there are numerous wood scraps and other debris everywhere around the working environment, slips, trips, and falls due to an untidy work environment are most common when using a conventional formwork system. Around 95% of respondents believed that an aluminum formwork system does not cause falls because there are no untidiness or scraps to cause them. And roughly 65 percent of respondents believe that utilizing conventional formwork systems increases the risk of slipping and falling owing to the dirty working environment.

When employing a conventional formwork system rather than an aluminum formwork system, there is a risk of exposure to asbestos and toxic compounds. The components of an aluminum formwork system are most likely carefully structured and within a safety margin, whereas conventional formwork systems mostly used wood and wooden materials. Asbestos is produced, as are hazardous falling objects. When employing an aluminum formwork system, roughly 95% of respondents believed that there is no risk of exposure to asbestos or hazardous substances, however when using conventional formwork, 70% of respondents agreed that there is a risk of exposure to asbestos and harmful substances. When employing a conventional formwork system rather than an aluminum formwork system, there is a risk of being struck by falling objects, similar to the risk of being exposed to asbestos and hazardous compounds. However, the same thing happens when using an aluminum formwork system.

When working with both formwork systems, the majority of the respondents did not suffer and saw no record of mortality. When both formwork systems are used, 100 percent of the respondents say there is no record of death. However, from a technical standpoint, they concurred that the conventional formwork technique is more likely to cause mortality than the aluminum formwork system. In a similar vein, the majority of respondents agreed that when an aluminum formwork system is installed, panels will fall from height.

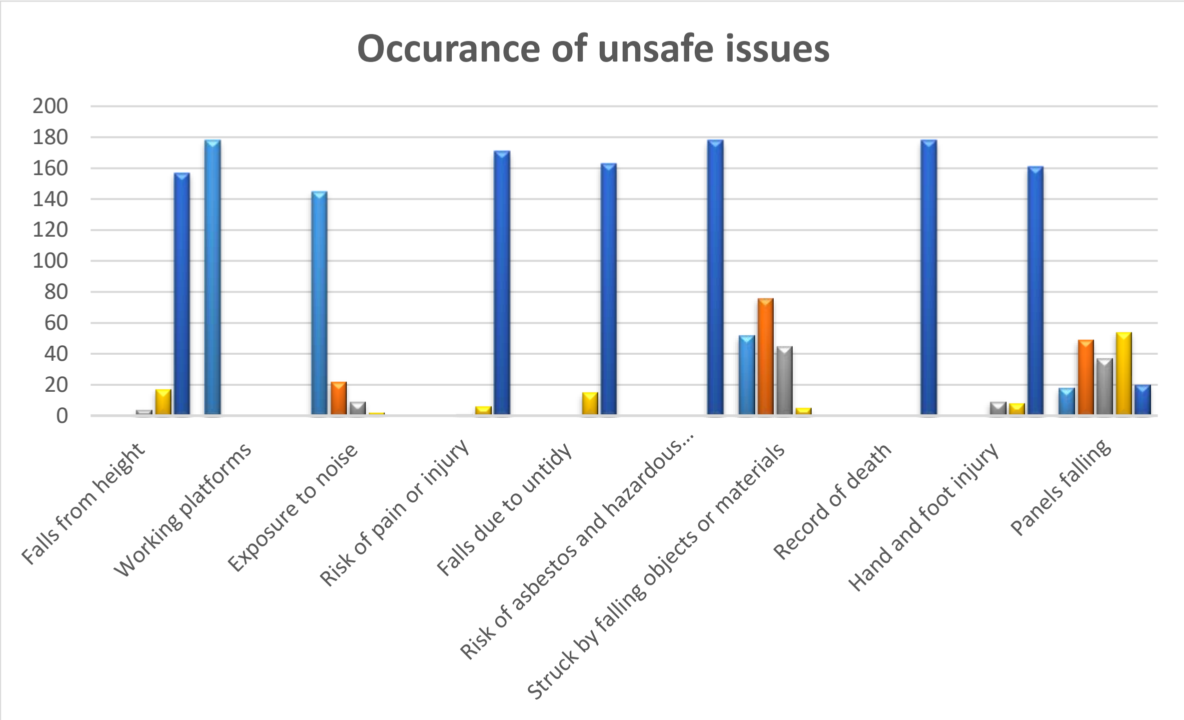


Figure 4. 15 Safety issues regarding aluminium formwork system.

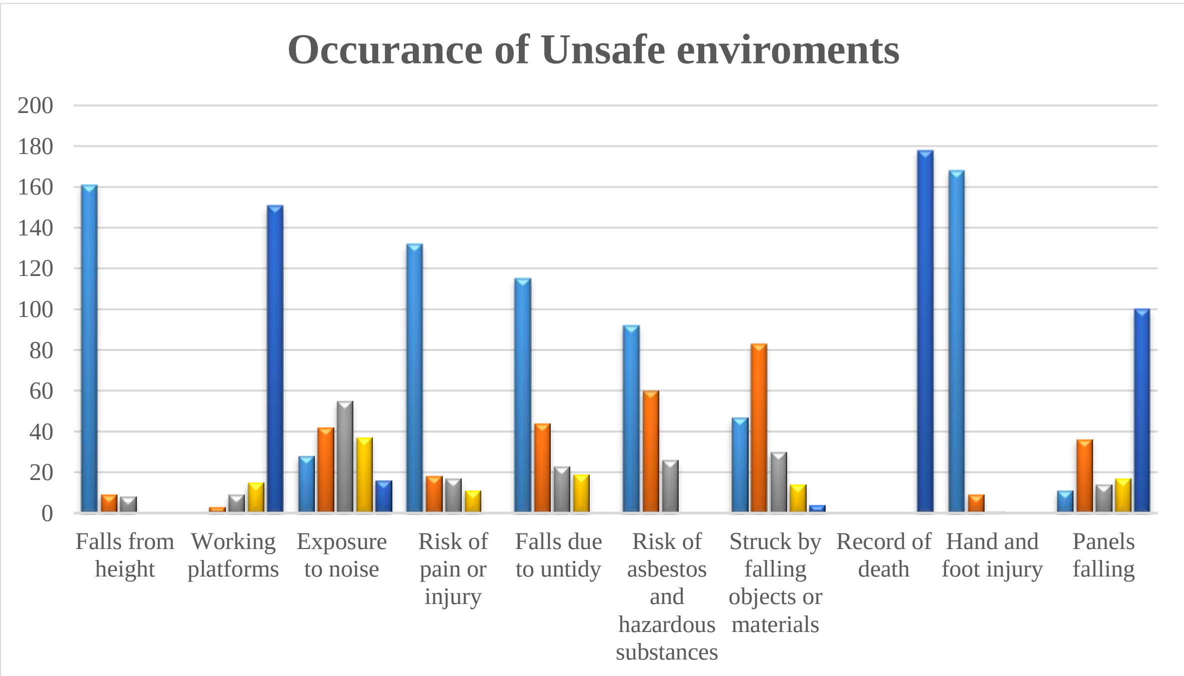


Figure 4. 16 Safety issues regarding Aluminum formwork system.

The construction industry, with its conventional formwork system, is the leading cause of tree deforestation. Many trees were felled to make way for formwork, scaffolding, and other construction needs. For example, if a cast concrete slab has a surface area of $100m^2$ and dimensions of 10m*10m*0.15m, the quantity of timber supports is calculated as follows:

- Average spacing in both sides of the props is 60cm.
- Average diameter of timber props varies from 8cm to 12cm.
- Average height of props is taken as 3.0m
- Props are reused for maximum of three times.

As a result, a minimum of 324 props and a horizontal member length of 540m are required. The total length of the timber is approximately 1512m. With a five-meter tree length, a minimum of 302 trees must be cut down to cast concrete for a 100-square-meter slab. At least 604 trees are required to complete slab concrete work on one G+6 structure. The number of trees that must be cut down grows in proportion to the slab's size. Furthermore, the pace of deforestation is linked to the rate of construction. It is apparent that Addis Ababa's present construction rate is tremendous, and many trees are being cut down. As a result, the existing forest coverage of 3% is anticipated to decline in the near future if deforestation for construction and other purposes continues.

All respondents believe that contractors should not be allowed to use wood for formwork construction. To prevent deforestation caused by the building industry, regulatory bodies should establish policies forbidding contractors of grade 1 to 3 from using lumber as formwork material. The policy will progressively be extended to other contractor classes. The idea can be easily executed because higher-grade contractors have more financial resources. The policy's execution not only helps to protect the environment, but also improves the safety and quality of the country's building. Eighty-two percent of contractors propose using alternate formwork materials such as steel, plastic, glass reinforced fiber, and precast concrete rather than cast-in-place concrete. Only 18% of those polled want to keep using lumber as a construction material. Lower-class contactors contend that the initial cost of new material may be more than the one they currently use. As a result, it is plausible to conclude that contractors will accept policy changes if they are implemented.

In general, the factors of time, safety, and the environment outlined in previous sections are some of the factors that force Ethiopia's building sector to employ modern formwork technologies. Formworks are left in place for lengthier periods of time before striking, and delays are prevalent in Ethiopia's building industry. Construction safety is undervalued in Addis Ababa and Ethiopia in general, posing a threat to the construction industry. Because there is no emphasis on the design and construction of correct formwork systems, failure of formworks or associated false works is expected. Many trees are taken down without being replaced, which is bad for the ecosystem. The building industry is a significant contributor to tree destruction. As a result, the usage of current formwork technologies is required to address the aforementioned issues.

There is no need to start from scratch in order to solve the difficulties; the systems adopted by industrialized countries such as Korea, Germany and Turkey and others would make things easier. As a result, the current formwork systems of Aluminum Kumkang, Korea, are examined from this standpoint. Labor costs in affluent countries are obviously much higher than in poor ones like Ethiopia. As a result, the criteria for selecting formwork systems for developing countries should be based on how the system uses both manpower and equipment. Currently, equipment-intensive formworks are not favored in Ethiopia due to the large number of laborers in the country in general, and in Addis Ababa in particular, when compared to developed countries like Korea and Germany.

Conventional labor-intensive formworks in Ethiopia must be partially or completely replaced with a contemporary formwork system that balances the use of both labor and machinery. As a result, Aluminum formwork products are evaluated for material and labor costs, concrete surface quality, and product longevity. In addition to the company's document evaluation, the inspection included a visit to the building site.

4.4. Summary of results

The major aim of this study was to assess conventional and Aluminum formwork systems for building projects in order to determine which system is more favorable in terms of cost, quality, time and safety. In chapter four, a study of these four parameters were conducted, and based on the findings, the following results were obtained: -

- The study discovered that Aluminum formwork system is more cost-effective than conventional formwork system. The advantages of utilizing or applying the Aluminum formwork approach become obvious when it is used frequently. Buildings with a repeated design are more efficient to produce and have reduced labor expenses.
- For Al-formwork and conventional formwork, the proportion of structural work to remaining works is 38/62 and 45/55, respectively. In addition, the proportions for electrical and sanitary works are 13/87 and 12/88 for conventional and 13/87 and 13/87 for Al-

formwork system, respectively. For the conventional and Al-formwork systems, the proportion of finishing work to remaining work is 37/63 and 27/63, respectively. Budget for significant activities can be computed using this proportion and analogues estimate of per m^2 cost.

- There is a difference in erection time between conventional formwork and aluminum formwork systems. Conventional formwork system is slower than aluminum formwork system. As a result, the type of formwork employed in a project has an impact on the time it takes to erect it.
- Stripping time is determined by how soon the concrete achieves the desired strength, which is determined by the cement and additives used. No time difference in stripping the formwork from the concrete length of time that required to remove the formwork actually depend on the type of cement and other environmental factor of the site.
- The sort of formwork utilized in any project has an impact on work productivity. By providing a greater covering area for casting concrete, the modern Aluminum formwork system increases the productivity of any project.
- It is preferable to use an Aluminum formwork system over a conventional formwork system such as MDF or ply wood for the greatest quality of finished concrete. The smooth surface of the aluminum formwork system aids in the removal of the formwork from the concrete surface.
- Aluminum formwork system creates the most accurate design size, shape, and alignment since the design is developed after the final structural and architectural design is completed properly.
- When an aluminum formwork system is employed, no cement grout or cement pest is created during concrete casting because the aluminum formwork system is appropriately designed and act as a monolith.
- The findings suggest that early commitment to the selected formwork system in the project, detailed planning and assessment of the suitability of the selected formwork system for the given project based on project, specialized skills, and industry conditions, and collaborative design with manufacturers are all required for successful implementation and management of the early stages of any project lifecycle.
- The federal, state, and local governments should prepare and pass regulations, design standards, and code of practices that order the type of formwork and materials used in

formwork constructions in consideration of building height and safety as well as proper safety measures to be implemented in any project.

- For the safety of the building structures and labor, as well as to reduce environmental effect by saving trees, wooden materials, particularly those used for supporting and bracing elements, should be substituted with steel or equivalent materials in building projects that require higher repetitions.

Chapter Five: Conclusion and Recommendation

5.1.Conclusion

- When compared to a conventional formwork system, Aluminum formwork system saves roughly 25% on costs.
- Aluminum formwork system is faster than that of conventional formwork system. Hence, the type of formwork utilized in any project has an impact on work productivity.
- Regarding quality it is better to use Aluminum formwork system for better surface finish and it gives accurate size.
- From safety point of view, Aluminum formwork system has good safety conditions than conventional formwork.
- Environmentally friendly.

5.2.Recommendation

The following significant recommendations are made in light of the various issues mentioned in the study as well as the present construction trend in Ethiopia.

- Ethiopia's government should assist local contractors in importing modern formwork systems duty-free and provide loans to contractors so that they can buy the formwork they want. Most contractors' liquidity concerns in owning new formwork systems will be alleviated by long-term loans with reasonable interest rates from both government and private banks.
- Regulatory organizations, such as the Ministry of Works and Urban Development, should provide standard specifications that include information on formwork materials, release agents, stripping time, and strength requirements for various structures, among other things. Such committees should establish minimum norms that are appropriate for the Ethiopian situation.
- The temporary applied loads on the formwork should be considered during the design stage of any project. Contractors should be provided with various design standards and guidance for designing and installing formwork.

5.3.Further Study

- The effects of different types and applications of form release agents on the surface finish of concrete.
- Assessing the effect of the concrete type used on the formwork system.
- Assessing the methodology and the procedures for Aluminum formwork system.

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Appendix

ADDIS COLLEGE

DEPARTEMENT OF CONSTRUCTION TECHNOLOGY AND MANAGEMENT

QUESTIONARY SURVEY

Dear Sir/Madam:

First and utmost I would like to express my appreciation for your assistance in providing relevant information on a research I am currently working on “Suitability of Aluminum Formwork System for Provision of Affordable Houses: In the case of Gerji Federal Housing Project”. This research survey is intended to fulfill an academic requirement for Master of Construction Management and Technology program.

OBJECTIVE

The objective of this survey is:

- To study the current practice of conventional structural building formwork system.
- To identify the merits and demerits of the new and modern Aluminum formwork technology system with respect to Cost, Time and Quality parameters.
- To analyze the technical advantage and suitability of the new and modern Aluminum Formwork technology system rather than the conventional structural building formwork system in Ethiopia with respect to cost, time and quality parameters.

Therefore, I kindly request you to use your knowledge and expertise to answer the questionaries’ since your response is going to be the input for the achievement of the study.

CONTACT DETAILS

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

Mrs. Yemisrach Seleshi

Phone Number: +251-911-53-62-89

Email: miser2801@gmail.com

Thank You in advance for your assistance and co-operation

Section 1: Respondent`s (personal) Information

1. Job position \ level in the company or project:

Project manager ☐ Project Supervisor ☐ Site Manager ☐

Site engineer ☐ Office engineer ☐ Technical Crew ☐

2. Academic status:

Ph.d ☐ Master's ☐ Degree ☐ Diploma ☐

3. Experience in construction industry:

<5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐

4. Experience in building construction: years.

<5 ☐ 5-10 ☐ 10-15 ☐ 15-20 ☐

5. Number of building projects you have participated:

<5 ☐ 5-10 ☐ >10 ☐

6. Highest number of stories (tallest building) you have practiced: G+_____

Section 2: General Company Profile

1. Name of the company_______________________
2. How long the organization being operating _______________
3. Category or class of the company_______________________
4. Number of projects executed in the last five years__________
5. The formwork types used in current project_______________

Section 3: Personal Opinions of respondents on the advantage and disadvantage of conventional formwork system and Aluminum formwork.

1. The advantages of conventional formwork system
   - ✓
   - ✓
   - ✓
   - ✓
   - ✓
   - ✓
   - ✓

2. Disadvantage of conventional formwork system
    - ✓
    - ✓
    - ✓
    - ✓
    - ✓
3. Advantages of Aluminum formwork system
    - ✓
    - ✓
    - ✓
    - ✓
    - ✓
    - ✓
    - ✓
4. The disadvantages of Aluminum formwork system
    - ✓
    - ✓
    - ✓
    - ✓
    - ✓
    - ✓
    - ✓

Section 4: Speed of construction and formwork system

1. It is better to give answers for the related formwork system that your company is using. Therefore, which formwork system is your company using? ______________________
2. In the erection or construction of Conventional and **aluminum formwork** system; is there any time difference you observe in any project where you are involved? **Yes / No**

   If yes which one is faster and which one is slower? Underline your choice.

   - Conventional formwork **(faster/ slower)**

- Aluminum formwork **(faster/ slower)**

3. Did the type of formwork used, affect the dismantling time? **Yes / No**

   If yes, please specify which type of formwork dismantle faster. Underline your choice.

   - Conventional formwork **(faster/ slower)**
   - Aluminum formwork **(faster/ slower)**

4. Slab and beam soffit formworks, how long a minimum day do you wait to remove? For,

   - Conventional formwork ___________days
   - Aluminum formwork _____________days

5. Does the type of formwork used in your project affect productivity of the work? **Yes/ No**

   If yes, which formwork system creates more productivity? Underline your choice

   A. Conventional formwork **B. Aluminum formwork**

6. Did you attempt to re-shore the slab and remove the formwork sheets early? **Yes /No**

   If yes, which type of formwork system is convenient for supporting props left after slab members are dismantled? Underline your choice

   B. **Conventional formwork** **B. Aluminum formwork**

7. How many days the supporting props can be left before slab members are dismantled?

   - Conventional formwork ___________days
   - Aluminum formwork _____________days

Section 5: Formwork system and work quality

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

☐ Conventional Formwork ☐ Aluminum Formwork

2. Which type of formwork system maintains dimensional accuracy in casted concrete?

☐ Conventional Formwork ☐ Aluminum Formwork

3. Which type of formwork system address the smoothness and regularity of finished surface?

☐ Conventional Formwork ☐ Aluminum Formwork

4. Which method of erecting and dismantling formwork is used in your company? (tick in the box)

☐ Using labor only in transporting, erecting and dismantling

☐ Using labor and Cranes in transporting, erecting and dismantling

☐ Using labor and other hoisting equipment's in transporting, erecting and dismantling

5. Are you well satisfied with the quality of concrete surfaces after dismantling of formwork?

☐ **Yes** ☐ **No**

If yes, what is the possible reason for achieving good quality concrete surfaces?

____

____

____

____

If No, what is your opinion in achieving good quality concrete surfaces

____

____

____

____

6. For the formwork type you are using, is the grout (cement slurry) loss from column formwork, beam formwork or other members controlled?

☐ **Yes** ☐ **No**

7. Do you use cement paper bag or other material in controlling the loss of grout at the junction of formwork elements?

☐ **Yes** ☐ **No**

8. Have you ever designed the formworks for the applied loads? (please tick in the box)

☐ **Yes** ☐ **No**

9. Which type of props for slab and beam do you often use? Please rank in order of usage, if you use more than one material?

☐ Wooden ☐ Steel ☐ Aluminum ☐ other, specify

____

10. Did the formwork system you're currently using have specific design for props for slabs?

☐ **Yes** ☐ **No**

11. What is the average spacing and height of props for slabs?

____

____

Section 6: Health and safety risk factors

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

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

No.	**Health and safety risk factors on Aluminum Formwork system**	**Degree of Occurrence**				
		5	**4**	**3**	**2**	**1**
1	Falls from height					
2	Climbing steps and working platforms					
3	Exposure to noise					
4	Risk of pain or injury from performing repetitive tasks					
5	Slips trips and falls due to untidy work area					
6	Risk from exposure to asbestos and hazardous substances					
7	Struck by falling objects or materials					
8	Record of death					
9	Hand and foot injury					
10	Panels falling over during installation					

No.	Health and safety risk factors on Conventional Formwork system	Degree of Occurrence				
		5	4	3	2	1
1	Falls from height					
2	Climbing steps and working platforms					
3	Exposure to noise					
4	Risk of pain or injury from performing repetitive tasks					
5	Slips trips and falls due to untidy work area					
6	Risk from exposure to asbestos and hazardous substances					
7	Struck by falling objects or materials					
8	Record of death					
9	Hand and foot injury					