American Journal of Construction and Building Materials
2024, Vol. 8, No. 1, pp. 9-19
https://doi.org/10.11648/j.ajcbm.20240801.12

Research Article

Assessment of Concrete Formwork Practices in Bahir Dar City, Ethiopia

Shumet Getahun Reda*, Biruk Yenehun Lemlem

Lecturer at Faculty of Civil and Water Resources Engineering, Bahir Dar University, Bahir Dar, Ethiopia

Abstract

Formwork is among the most determinant factors affecting the cost and completion time of construction projects. In this study, the erection practices, challenges, types, quality and cost of formwork on active building construction projects in Bahir Dar were assessed. The study uses, Questionnaires, site observations and oral interviews with project managers, office and site Engineers, construction managers and carpenters were used to organize and analyse data. From assessment, most of the contractors have given less attention to formwork erection and safety issues. Since the principal criteria for formwork selection are cost and traditional formwork erection, it impacts construction safety and reduces the concrete finishing and quality. Formwork erection is left as the task of carpenters and labourers. There is no proper supervision of the quality of formworks that guarantees construction workers' safety so it is vulnerable to physical injuries and affects employee's health. From the study, timber formwork is the most dominant type of formwork used for the construction of slabs, beams, columns and stairs due to its availability and low cost. Burnt oil is used as a releasing agent in all construction projects that causes undesirable outputs in concrete surfaces.

Keywords

Concrete, Formwork, Plywood, Prop, Steel

1. Introduction

Concrete structural members do not gain the desired shape by themselves, and thus need supporting elements. Concrete formwork used as a mould to produce concrete elements having a required dimension and shape. Formworks are erected for this purpose and then deshuttered after the concrete has gained an adequate strength [1, 17, 18].

Formwork cost comprises 30% to 60% of the total cost of the project. The sizes and shapes of the elements of the structure should be chosen after considering the forming requirements and costs, without compromising strength requirements. The cost of formwork should be get an attention during design and planning phase of projects [2, 3, 19, 20].

Shoring and bracing support the forms that carry the wet concrete. Formwork are supporting the temporary weight of material such as bundles of reinforcing steel and live loads of workers and equipment [4, 9, 16, 21].

Formwork components can be generally classified as Vertical Systems (wall and column) and Horizontal Systems [5, 6].

Horizontal formwork systems are used to support horizontal concrete beams and slabs. The sheathing is supported by horizontal members called joists. Joists are made from dimension lumber spaced at same spacing that are affected by

*Corresponding author: shumgeta@gmail.com (Shumet Getahun Reda)

Received: 23 July 2024; **Accepted:** 13 August 2024; **Published:** 30 August 2024

applied loads and the type of lumber. The stringers are supported by shores. Shores are vertical elements rested on timbers, called mudsills, to transfer the vertical loads to the ground. In the case where a slab-on-grade exists, shores are directly rested on them [6, 22-24].

Formwork for beams comprises a bottom and two sides and supporting members. The bottom is supported by and fastened to horizontally. Having side of the beam form is constructed, the bar is placed inside the beam and then the other side of the beam is erected. Column forms are fixed by braces in the whole direction to improve the resistance of plates and supported by diagonal shores. Braces are fixed to the panel by the constant spacing each other through the height of the column [7, 23-25].

Wall forms designed to resist the lateral pressures due to fresh concrete as a liquid or semi-liquid material. Wall form design usually comprises narrowly spaced supported members. The contact surface of the wall form is called as sheathing and is supported by vertical members called studs (vertical soldiers) and then studs are rest on props [8, 23, 24, 26].

Timber, Plywood, Steel, Aluminum and plastic are the common types of formwork material used in concrete construction. Timber is a common formwork material and suitable for constructing concrete forms due to its availability in a variety of grades and sizes. Concrete formwork made by using only timber or combining timber with other types of formwork material. The timber is lightweight and convenient to fix and dismantle [8, 23, 27].

Plywood is strong, durable and lightweight wooden manufactured material. The thickness plywood ranges from 7 mm to 32 mm. The standard size of plywood mostly used in building construction is 1220 mm x 2440 mm. It can easily cut into small sizes and reused more times than timber shuttering [8, 23, 27].

Aluminium formwork is emerging in the construction industry due to its easiness to assemble and remove thus increasing worker productivity. It is also reused many times compared to other materials. Aluminium stems have a lighted weight which reduces handling costs [8, 23, 25, 27].

Time is a critical factor during selection of formwork type. Amount of labour required to strip, set, pour, and control the system, availability, adaptability, cost, erection and dismantling and erection are the factors considered in the selection of formwork [6, 23, 24, 28].

Forms must be simple to erect and dismantle, modular dimensions should be used. The economy in formwork design depends partly on the experience of the form designer and contractor. Judgment concerning the development of a forming system could rush a project or reduce costs [27, 28, 30].

To build the most economical design, the designer should analyze load of each member to make easier, narrower or shallow. This is done under the consideration of the minimum size and least weight result in the optimal design [9, 10, 30].

Forms has to be built with sufficient strength and factors of safety. They are supposed to be capable of supporting all dead and live loads without collapse or danger to workers and the concrete structure [10, 28].

There are risks in the construction of erecting and dismantling forming systems. Precaution should be taken to ensure a safe working environment. Forms should be strong, sound, and avoid bending and the formwork from erection to stripping cycle would allow for faster removal of shoring and re-shoring [10, 29].

The loads applied on the form consist of dead and live loads. The weight of formwork, reinforcement and freshly placed concrete is a dead load. On the other hand, live load includes the weight of the workers, material, equipment, and impact [8, 11, 29].

Formwork and falsework shall be designed and constructed so that they are capable of carrying all loads which may occur during the construction. They shall remain fixed until the concrete has gained sufficient strength to bear the loads to which it will be subjected on stripping, with an acceptable level of safety [12, 29].

Modular formwork systems are usually lighter weight and need less physical effort than traditional systems because they are constructed from aluminium instead of steel and they eliminate the need for repetitive hammering [13, 29].

Plywood and other sheet materials can be challenging to handle in the wind. The added and uncertain extra load imposed by a sudden blow of wind can throw a worker off-balance and lead to a fall [13, 15].

Stripping formwork is one of the hazardous phases of concrete construction. While falling objects are the main causes of hazard, there may also be fall of debris as a result of floor, scaffold or formwork collapse, as well as manual task hazards from a person working in awkward physical standing, repetitive handling of materials and others [12, 18].

A proper work platform with safe access must be provided for workers stripping forms at any height. If workers are stripping forms in an area with a fall hazard, fall protection must be provided and applicable [10, 18, 29].

According to Ethiopian Building Code of Standard (EBCS-2), removal of formwork shall be removed slowly, as the sudden removal of wedges is equivalent to a shock load on the partly hardened concrete. Provided the concrete strength is confirmed by tests on cubes stored as far as possible under the same conditions, formwork supporting cast-in-situ concrete may be removed when the cube strength is 50% of target. If the nominal strength or twice the stress to which it will then be subjected whichever is greater, provided that such earlier deshuttering will not cause in undesirable deflections due to change in volume [14, 29].

British Standards recommends 18 hours, 7 days, 14 days and 21 days for column formwork, slab soffits, slab props and beam props for removal respectively. ACI Recommends 12 hours, 4 days, 10 days and 14 days for column formwork, slab soffits, slab props and beam props for removal respectively.

Higher grades of concrete made for faster construction scheduling operations. Construction planning and sequencing could be improved with the knowledge of 'what time' a given strength should be achieved for a mixture-specific concrete. Developed models could be used to estimate stripping time, removal of props and accommodation of construction loads for members in flexure irrespective of size and type of formwork used [15, 29].

Form-release coating (form oil) is applied when the construction of the form is complete, and before placing reinforcing steel. Applying form oil immediately after stripping increases the likelihood of contaminating the workers handling and re-locating the form, and also makes the pieces more difficult to handle [12].

Few studies have been done related to practices and challenges of formwork and its application in Bahir Dar. This paper aims to indicate different directions to solve identify problems of construction formwork and practices in Bahir Dar.

2. Methodology

2.1. Data Collection Method

In this study, data was collected using both primary and secondary sources. The primary data was obtained through a questionnaire directed to the representatives of contractors, consultants and clients who are involved in building projects and observation of sites. The secondary data was obtained from previously done research (literature), journals, books and different articles in published documents. The secondary data was used as a source for problem identification and as a criteria for developing and analyzing the primary data.

2.2. Research Population and Sampling

Formwork quality and cost affect all contractors and clients directly or indirectly. However, the study focuses only on building construction companies and projects because construction of buildings without formwork is almost impossible even in small unit works. Therefore, the study populations included in this study are building construction projects which are active in 2018 in Bahir Dar. While doing this project we visited active building construction sites in Bahir Dar and the projects were selected random sampling technique for questioner interview and observation.

2.3. Data Analysis Method

Stakeholders were interviewed; project managers, site and office Engineers, consultants, formwork carpenters and personnel who work there share about their practice. A literature review is also done to see the standard practices that shall be followed during the erection of the formwork. By collecting the data from the site that we have seen and asked for, the Percentage technique have taken to analyze the results that are collected.

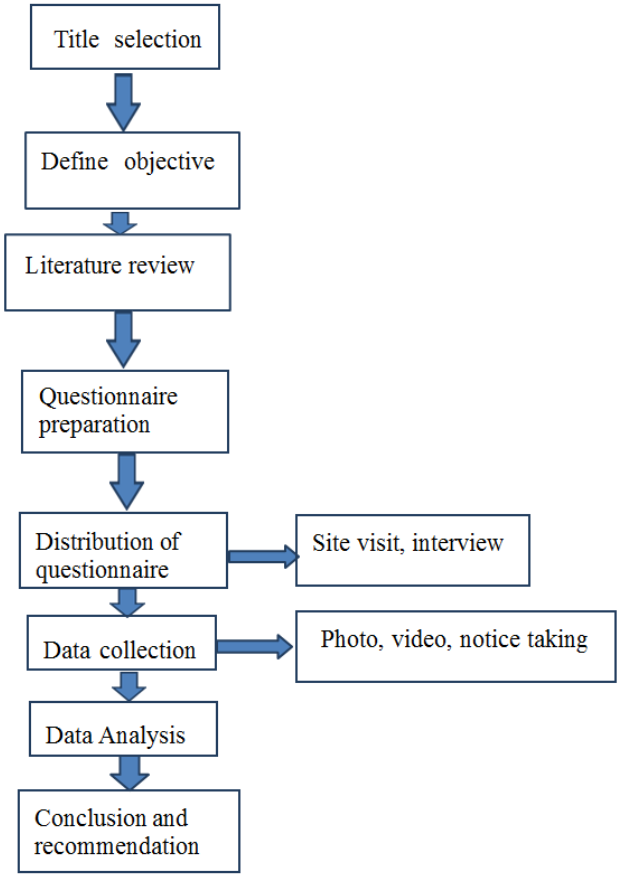

Figure 1. *Methodology Flow Chart.*

3. Results and Discussion

3.1. Data Analysis

Data from questionnaire, interview and observation are analyzed to find out the response on the practice of formwork with different considerations of safety, cost, stripping, material types and other factors in order to achieve the prescribed objective. Using random sampling technique, Out of 13 questionnaires distributed using random sampling; 11 questionnaires were returned and those responses were valid.

Table 1. *Statistical Data of Questionnaire Distribution.*

Questionnaire	Number	Percentage
Total received questionnaires	11	85%
Non returned	2	15%

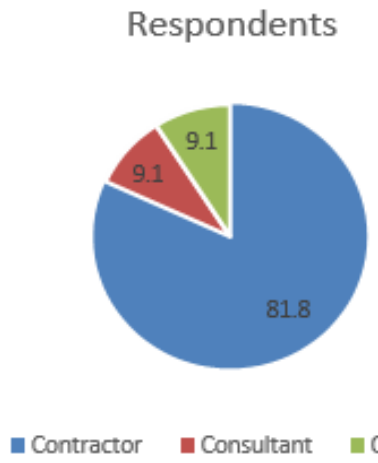

Figure 1. Percentage of Each Stakeholder Respondents.

3.2. General Information About the Responding Projects

Based on the Figure 4, most of the respondents have used both timber and steel formworks for beam, shear wall and column construction. Stairs are usually constructed by using timber formworks, and in one site it is observed that the contractor uses plywood formwork within internal canvas cover (shera) for footing pad. It is investigated that, they use timber because of its cheap cost and availability. Some high grade contractors used ply wood formworks. Lamera form work is common type of formwork used for slab and stair soffit made of old barrel metal sheets. But it is rough surface is not convenient for slab construction and produces undesirable concrete outputs.

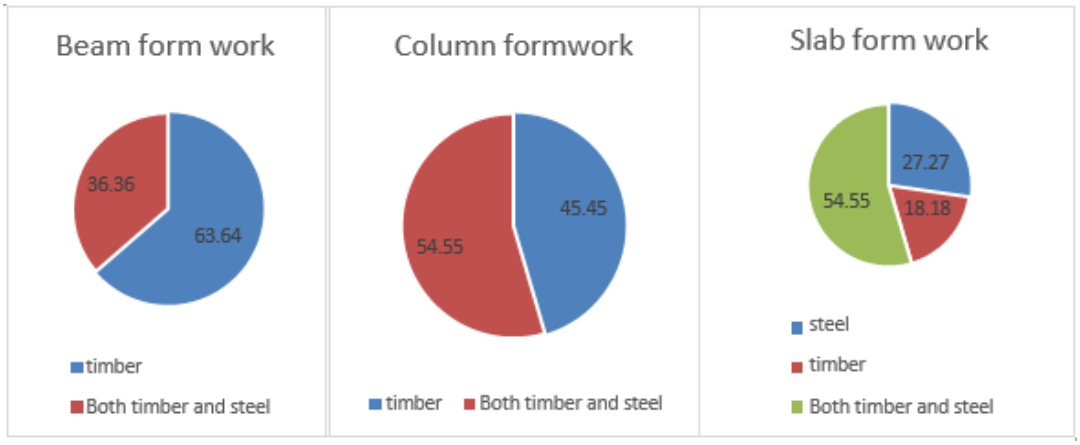

Figure 2. Materials Used For Formwork of Different Concrete Structural Components.

Table 2. Project Information.

No.	Project type	Grade of contractor	Cost of project (ETB)	Location
1	CBE Bahir Dar district office (2B+G+12)	GC 1	888,000,000	Bahir Dar
2	Land and land related administration (G +4)	GC 2	47,000,000	Bahir Dar
3	Industrial shade	GC 5	8,944,269	Bahir Dar
4	Commercial building (G+6)	GC 4	52,740,363	Bahir Dar
5	Adada water work	GC 1	16,669,225	Bahir Dar
6	Mixed use building (G+7)	BC 5	52,422,821	Bahir Dar
7	EITEX lot 7	GC 1	220,000,000	Bahir Dar
8	Leadership Academy	BC 1	280,000,000	Bahir Dar
9	Gibrna college upgrading	GC 7	4,200,000	Bahir Dar
10	EITEX lot 5	GC 1	251,731,000	Bahir Dar
11	EITEX lot 4	GC 1	235,564,200	Bahir Dar

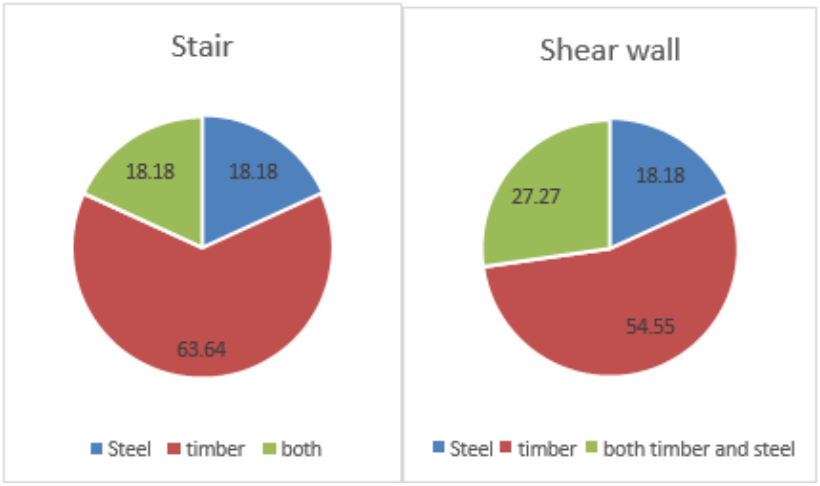

Figure 3. *Material of Form work.*

3.3. Period of Formwork Dismantling

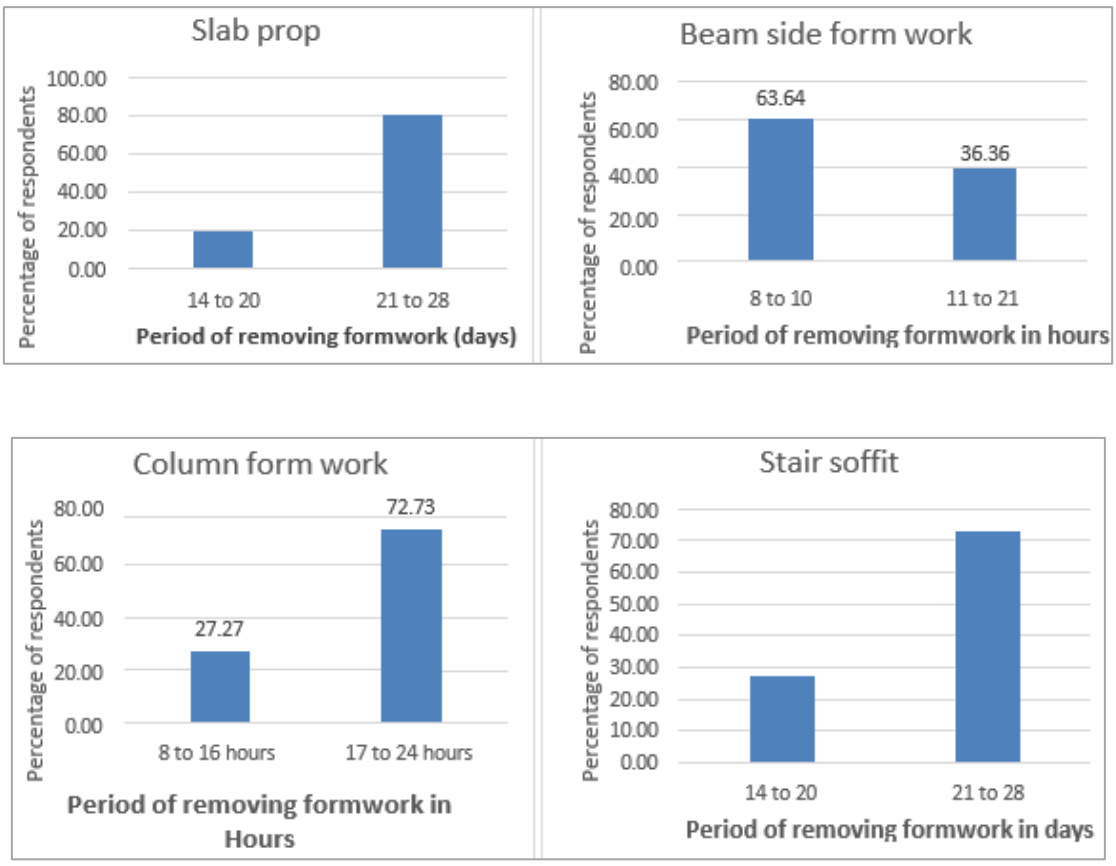

Figure 4. *Period of Form Work Removal.*

As seen in Figure 4, the stripping period of formwork for slab prop is 21 to 28 days which most of the respondents says and some of them remove the formwork within 14 to 20 days. The 63.64% respondents used a stripping period for beam side formwork is 8 to 10 hours and 36.36% respondents removed the formwork within 11 to 21 hours. It is also described that the 72.73% of respondents used stripping period of column formwork is 17 to 24 hours and some of them remove the formwork within 8 to 16 hours for the beam side the formwork. It is investigated that stair soffit stripped within 21 to 28 days by 71% of the respondents and 29% of them remove the formwork within 14 to 20 days. 72% of contractors respond

that formwork erection is controlled by contractors.

The difference is resulted because of the cement type, size of concrete member, availability of form work, required strength and admixture used, re-using and cost of formwork. Re using is the main consideration of cost of formwork on the construction sites seen Table 3.

From the Table 3, it is shown that the contractors reuse timber formwork not more than ten times and steel formwork can be used for more than thirty times. So steel-form works are preferable for large projects to reuse many times.

Table 3. Re-use of Formwork.

No.	Number of repetition	Responses number		
		Timber	Steel	Others
1	1-10	9	2	--
2	11-20	---	2	1
3	21-30	---	--	--
4*	>30	---	4	--

3.4. Cost of Formwork

Formwork selection is mainly depends on cost. The cost is listed as follows:

1) Costs of Chinese Plywood (2.40 m x 1.20 m) which is costs 1,600 Ethiopian Birr (ETB) which are used in some construction sites.
2) Cost of plywood manufactured in Debre Birhan (2.40 m x 1.20 m) area which costs 750 ETB.
3) Timber and Lamera = 300-400 ETB/m^2

3.5. Qualitative Data Analysis

3.5.1. Releasing Agents Used

All respondents are using burnt oil as a releasing agent because of its low cost and availability. They spread burnt oil over the formwork before the erection of the formwork. Since they don't use a proper releasing agent, they face formwork stripping problems and this affects the quality of concrete structure and the formwork.

3.5.2. Quality Problems Resulted During Stripping

The stripping practice in Bahir Dar construction sites is not assisted by advanced technologies. Because of these different problems in both concrete structures and formwork itself are occurred. Those are; concrete surface scratching, formwork cracking, and nailing of workers. Excessive use of force to dismantle formwork shortens the life of formwork and affects concrete strength.

3.5.3. Appearance and Stability

Using steel formwork makes the workers more confidential in dimension, alignment and shape of accuracy due to its high steel strength. Timber formwork is joined by nailing whereas, steel formworks are connected by bolts and wiring. So steel formwork is more stable than timber formwork. Even though steel formwork has a high initial cost, it is advantageous in terms of construction safety, speed and long-term cost.

3.5.4. Training Program for Workers

Almost all of the construction firms don't have regular training programs about the erection of formwork, how to protect from accidents during construction and how to use safety tools. Also, the workers don't have a professional license; experienced carpenters are employed to erect formworks.

(a)

(b)

(c) (d)

Figure 5. *Materials for form work a. Shear wall plywood (1200*2400*20 mm^3) form work, b. "Lamera" slab, formwork c. Circular column formwork, d. steel false work.*

(a) (b)

(c) (d)

Figure 6. *a. Footing pad form work construction, b. Plywood for shear wall construction, c. Stair formwork construction, d. Column formwork construction.*

Figure 7. Beam Formwork.

Figure 98. Steel Props.

3.6. Some of the Problems in Formwork Construction

From the assessment, the following problems have been identified during formwork casting.

1) There is no proper design
2) Its unskilled labor based
3) It lacks safety cover (shoes, proper wearing)
4) Material defects (breaking, reuse several times)
5) There is no properly defined releasing agents (use black oil)
6) Sometimes formworks are not properly aligned in direction and dimension

Black or burnt oil was used as a releasing agent. Information about formwork design. There is no design for formwork rather they use trial and error methods. But some of them have shop drawings that used to show how to assemble formworks.

3.7. Advantages of Steel Formwork

Selection of steel scaffoldings saves time (no need for nailing, it is connected by bolts), easy for erection (flexible and less injury risk than wood scaffoldings), provide enough working space, high initial cost but it is economical for high-rise buildings and has less wastage than timber, it can be reused many times by welding damaged sections.

2cm thick plywood is used in the construction of shear wall formwork for slab and column, they use 2.5cm thick plywood. If the dead load of the slab is anticipated higher, the prop spacing is reduced to increase load resistance.

4. Conclusion

74% of the contractors in Bahir Dar construction projects use timber formwork and some of the contractors used steel and timber formwork simultaneously. The formwork type varies depending on the financial capability of the contractor. Steel form work has good strength and provides a smooth surface which is used by high-grade level contractors. Local contractors have no proper formwork design but they have their work methodology. Most of the contractors' formwork selection is based on cost and construction of formwork is left as the task of carpenters and labourers. Safety issues are not considered a major concern of construction works. From assessment, burnt oil is widely used as a formwork-releasing agent which affects the colour of the concrete surface.

Generally, to maximize the profit margin of specific projects, contractors have to pay attention to formwork system quality and safety based on project size and complexity. Constructors should update the Traditional formwork system to a modular formwork system to reduce construction risks and improve the quality of work. Formwork erection should be done by specialized (licensed) personnel. Training programs should be prepared to upgrade formwork carpenters' technical knowledge. The contractor's formwork selection should prioritize quality rather than cost. The government should prepare legal regulations that strictly control contractors' formwork systems.

Abbreviations

BC Building Contractor
GC General Contractor

Acknowledgments

We would like to thank all parties involved in the questionnaire and interview. We would like to thank Ayalsew Aemiro, Birhanu Derib, Fasika Abiy, Samson Worku, and Yalem Birhan for their help during the data collection process.

Author Contributions

Shumet Getahun Reda: Conceptualization, Methodology, analysis
Biruk Yenehun Lemlem: Editing

Data Availability Statement

All materials and data are available in the hands of the authors.

Conflicts of Interest

The authors declare no conflicts of interest.

Appendix

Questionnaire

Here, we have included open and closed questions to assess the formwork practices in Bahir Dar city. Cost, challenges and safety issues are the main targets of questionnaire. After reading carefully the questions, please write your opinion by relating to your specific project and experience.

1) General

Firm type

a. consultant b. contractor c. if any other
i. company name
ii. Project cost
iii. Project location
iv. Project manager name
v. Grade of contractor/consultant

2) Who controls the erection and installation of formwork?
a. contractor b. consultant c. owner d. other--------

3) Which type of formwork you often use for your construction?
a. Timber b. Steel
c. Combination of both
d. Other

4) Type of formwork is used in your current project, Indicate by (√) in each cell?

Type	Beam	column	Slab	Stair	shear wall
Timber					
Steel					
Aluminum					
Other					

Repetition (reuse) of formwork used? Indicate by tick (√) in each cell.

Repetition	Timber	steel	Aluminum	Other
1-10				
11-20				
21-30				
>30 specify				

5) What are the factors for selecting the type of formwork (can select more than one)?
a. Cost
b. Finished concrete quality
c. project completion time
d. Formwork availability

e. all

6) Preference of your company for the structural element from cost perspective?

Element	Steel	Timber	Other / don't know
Beam			
Column			
Slab			
Stair			
Shear wall			

ii) Most likely time of deshuttering formwork and props

Type of formwork	Duration (days)
Slab	
Slab prop	
Beam soffit and prop	
Beam side	
Column	
Stair	
Shear wall	

7) The Mean cost of formwork per square meter (ETB/m ^{2}) used in your project for
   a. beam
   b. column
   c. Slab
   d. Stair
   e. Shear wall
8) What is the number of laborers used to construct steel and timber formwork in terms of cost per meter square? Specify
9) Which type of formwork system you suggest to reduce cost in the Ethiopia construction industry? Why?
10) What type of formwork system creates more undesirable products on finished concrete, discoloration?
   a. Steel
   b. Timber
   c. Both of them
11) Type of formwork system to maintain dimensional accuracy and alignment during concrete placing
   a. Steel
   b. Timber
   c. Both of them
   d. Neither of them
12) What is the basic difference in the erection of steel and timber formwork?
13) Type of releasing agents do you use for your construction?
   a. water-soluble emulsions
   b. chemical releasing agents
   c. neat oil list if any
14) Is there any training and awareness programs for laborers and carpenters about the installation and safety of formwork? If yes, specify a time interval
15) Have you ever faced a formwork failure accident in your career life? If yes, how do you mitigate/control it? What is its consequences? If any general about formwork and construction safety comments write here…….

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