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Review Article

Comparative Assessment of Formwork Systems used in Construction Projects in the Tamale Metropolis of Northern Ghana

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Abstract *- Construction is one of the major continuous activities of man in every society. The need for infrastructure in our communities keeps increasing. As such, both the state and private individuals have different levels of demand for infrastructure. As a result of this, the sector requires different levels of input in order to achieve its desired goals. One key component of the construction sector is formwork which seeks to provide grounds for creating molds on structures. This study examined the major types of formwork used among contractors in the Tamale Metropolis of Ghana. Simple Random Sampling (SRS) was employed to select eighty (80) respondents from the construction industry in the metropolis. Data were expressed in terms of frequencies for purposes of analyses. It was found that contractors in the metropolis use both timber and steel formwork. However, both timber and steel formwork are challenged differently. These challenges ranged from poor containment, issues of leakages and accuracy challenges, as well as the cost of acquisition. As such, the respondents' preference for the timber formwork was quite high, mainly due to the cost of acquiring the steel formwork even though it is seen to be more appropriate. In sum, the awareness of the appropriateness of steel formwork is high among respondents, but its usage is hindered by the cost of acquisition. The industry players should endeavour to make steel formwork accessible so as to ensure excellence in the construction industry of the Tamale Metropolis.*

Keywords *- Construction, Formwork, Scaffold,Tamale, Project.*

1. Introduction

Construction is one of the dynamics of human enterprises in the 21st Century. It consists of related activities with subtle interdependence, which is more or less organized systematically [1]. Construction covers the makeup of different infrastructures, and for this reason, its input demands cut across an array of building materials, tools, and equipment meant to facilitate the progress of work [2]. As a result of the wide range of inputs demand of construction projects, most developed countries employ a plethora of assessment tools to enable them to achieve a desirable with respect to time and cost in order to obtain value for money and reap other economic benefits. One of the ways in which the above assertion can be achieved is through the deployment of appropriate techniques with the use of the right building materials [2] [3].

According to [4] formwork basically describes the structural formation used in support of constructing molds. This is usually temporal, and it's meant to give support to casting molded shapes that otherwise couldn't have been easily done by routine masonry works. The idea is to support moulded concrete to become hardened enough to gain a permanent stay. Formwork receives concrete in its plastic form and weight for the continuation of chemical reactions until its substantial strength is achieved. Owing to its temporary nature, it is not normally shown on drawings but accounts for a significant amount of project time, and cost [5]. [6] Posits that formwork ideally takes some time to be done and accounts for about 20-25% of projected expenditure of construction projects.

[7] Argues that construction in developing economies does not usually aspire to international standards, and this reduces the quality of construction output. Poor usage of formworks also affects construction outputs' competitiveness. In order to increase the quality of construction output, industry players are encouraged to use cost-effective but quality tools and equipment in the process of construction. According to [8], one of the most challenging resulting in deferments of projects in most

developing countries is the choice, type, and shortage of the right building materials. Ghana's situation is not exempted as significant difficulties, especially with regards to formwork abound [2]. This explains why management of construction projects has implored to ensure quality output of projects while also ensuring the safety of artisans during project execution. This, according to [6] [11], can only be achieved when appropriate tools and equipment are used [9].

One of the material resources which directly affect the finishes of concrete structures of buildings in developing economies like Ghana is the quality and selection of appropriate shuttering or formwork by contractors. Most building contractors in Ghana, especially those in the northern region, are used to traditional timber formwork with bamboo props for the concrete casing [4]. To achieve a good finish with this type of formwork, the quality of skill and workmanship required must be the best available, which is in short supply in this part of the country. This often leads to undesirable output, which leads to delay in project delivery owing to rework of such surfaces, thus causing extra swelling of the project cost and further opportunity cost to the client for the usage of the facility on time [10].

Across the world, major actors in the construction sector consider the nature of the formwork to use before the construction [5]. The principal factors clients consider before initiating projects are cost and time [11]. In Kumasi, a huge pile of timber waste is often seen on construction sites after using formwork and scaffolding, which is a contribution to the depletion of forest resources. Available records at the Town and Country section of the Kumasi Metropolitan Assembly (2000) indicate a cadre of about 1,200 construction firms in the various categories of D1, D2, D3, and D4 use timber formwork and scaffolds in varying quantities for construction works in the metropolis.

This assertion is in tandem with an initial cursory survey on the use of timber formwork and scaffolding in the Tamale metropolis prior to the organization of this study. The continuous use of timber for formwork of scaffolding in Ghana's evolving construction industry, if not properly addressed, will contribute to serious sustainability issues in our environment [12]. Some studies opine that poorly output in construction work output has been one of the challenging factors in the Ghanaian construction sector, and this affects development in general. The quality of materials mostly used for formwork does not only lead to poorly finished work but also the convenience and safety of artisans are compromised.

The experience of the artisans or carpenters has been identified as another factor for the waste of timber. On some sites, the carpenters engaged in the construction of scaffold and formwork do not have the required experience to enable them to cut the timber pieces with precision. Most often, trial and error methods are used, resulting in poor sizing, shaping, cutting, and eventual waste of the timber pieces. In fact, this situation is ongoing on most construction sites in Kumasi [11]. This assertion is one that can have negative consequences on the placing of plastic concrete as well as the durability, shape, and final finish of soffits of beams and slabs.

Usually, the class one construction firms D1 mostly use the steel or metal components with a small fraction of timber as formwork and scaffold for construction activities producing less waste and rework to concrete surfaces. [11] Argues that this class of construction firms forms only 5% of the various classes of firms in the construction industry in Ghana. This paper compares the works of construction firms working in the Tamale metropolis using timber formwork and scaffold with firms using metal shuttering with respect to their relative delivery times and cost-effectiveness.

2. Literature Review

Globally, studies have identified concrete as a key component material in the sector. Concrete infrastructure accounts for about sixty per cent of construction projects [13]. The use of concrete is not recent and traceable to the ancient Egyptian Civilization. Its role in providing shape and strength to the building structure has never been contested. In this modern era, concreting is still responsible for the construction of a building in the construction sector [14]. Other authors in the field of construction have revealed that the use of concrete in buildings forms part of the basic requirement in modern times [11][15].

The technology is by now well established, but the production of concrete of consistently good quality is by no means simple. One of the basic materials needed to support the production of quality concrete is formwork [16]. Even though several types of formwork exist, the commonest in Ghana and most developing countries is timber (wood) and steel. Its appropriate functionality is based on the tightness of the frame so as to prevent the escape of wet material concrete of distortion of form shape [4]. Emphasis on formwork is on the reusability since the intention of reducing is prime for all project managers. Formwork systems as a component of the construction can cost up to twenty-five per cent of the project cost depending on the design [17].

3. Concept of Formwork

According to [5] [18] the constructability assessment of formwork in the construction industry is very important. This is because formwork provides the opportunity for a permanent structure to derive its shape. Concreting is an important component of construction. Trends in its development have always been key to its success. These trends result directly from the choice of materials that have been used for the project. While the initial stages of concrete

formwork were dominated by direct labour, recent attempts have reduced its labour intensity. The use of timber formwork, in particular, requires a lot of labour, and this has been the practice for a long time even though recent technologies demand otherwise. Technology has given a chance to a more rapid and efficient process of doing concreting. Studies such as [19] [2] noted that the advent of recent materials such as steel and aluminium has not quickened the pace of formwork but also resulted in excellent finished work. This further led to developments in new forming materials such as aluminium, steel plywood, plastics and glass fibre, among others. With this, the burden of site managers and carpenters has lessened [4] [19].

The art of formwork results from the use of several related components that are usually arranged or ordered depending on the chosen design. Common among the most used ones are wood, bamboo, steel, wailings, metal bars, and plates. In a typical design process, a component is chosen, and its arrangement within the formwork assembly is assumed [20]. This is followed by some analyses in order to determine the capacity of the form to cast the kind of form being conceived [3]. The demands of formwork are quite repetitive as the materials needed are often not enough for a whole piece of output, especially in large projects. [20] noted that while doing this, factors that need careful scrutiny are the safety of the scaffold, the output of the formwork, and the materials [1].

[1] [21] also emphasized the importance of formwork and scaffold of which they assert that their construction cannot be overlooked, substituted, or avoided in any way once concrete structures are involved and analysed the functions of each. Formwork functions as the moulder or former of desired shapes, size and finish of concrete slabs, beams and columns, while scaffolds provide the working platform for both workers and materials at required heights onsite [22]. [5] also argue that the construction of formwork is quite critical for overall project success, in that well-designed formwork appropriately constructed using the right materials will result in a very good concrete structure both in terms of durability and aesthetics. On the other hand, any formwork which is inappropriately designed using undesirable materials has the tendency to provide defective concrete. According to [22] the following are the requirement of good formwork in the construction. Few are identified below;

- Formwork materials should be relatively cheap, accessible and suitable,
- Accuracy should be the hallmark of the formwork,
- Materials should be resistant to the vagaries of the weather,
- The base of the formwork should be resistant to the expected weight,
- Formwork materials should be disassembled easily without causing significant damage to the concrete.
- The joints in the tight formwork fit to avoid leakages,
- Formwork should be firm with appropriate braces, both horizontal and vertical,
- The formwork should be strong enough to withstand all types of dead and live loads

3.1. Timber Formwork

According to [1] the comparison between conventional and formwork systems identified timber for formwork to have the following requirements;

- well-seasoned for any purpose
- Free from loose knots
- Easily workable with nails without splitting
- Light in weight

From empirical studies, timber formwork is used for shuttering for exposed concrete work, which should have a smooth and even surface on all faces which come in contact with concrete [3].

3.2. Steel Formwork

This is a formwork made out of steel with a careful fix in order to assist in the moulding of concrete. It uses steel as the main material, carefully constructed with light metal plates well fitted to each other in the frame. There are bolts and knots usually fixed at the adjustable edges where measurements can be controlled. Steel formwork is noted for being quite fast in terms of output and accuracy of finishing. It also allows for reuse since it is faster informing and dismantling [22]. This type of shutter is considered most suitable for circular or curved structures.

3.2.1. Comparison between Steel and Timber Formwork

- Steel forms are stronger, durable and have a longer life than timber formwork
- Easy to mount and dismantle that timber formwork.
- Nice finishing is produced as compared to timber.
- Steel formwork does not absorb moisture from concrete as compared to timber formwork
- Steel formwork does not shrink or wrap, but timber formwork does.

3.3. Formwork System

Formwork systems consist of the general formation of the formwork. This encompasses the supports, equipment, materials, moulds and every other thing necessary for its formation. It was and has been widely used in the latter part of the 20th century. The significance of its usage has come of age in the industry and will thus continue to be at the forefront in terms of concrete. [21].

As technology advances, engineers and artisans have always braced themselves for a concomitant advancement in formwork. This is to maintain the quality of output of construction projects. These developments are in keeping

with the increasing automation of production in construction sites and other fields [14]. Formwork usually takes the lion's share of the cost, especially in multi-storey structures. Studies have estimated formwork cost to range about 10% of the total construction cost. This does not matter the type of formwork is used [12]. However, the reduction in the cost of labour has proved to be the number of ways of reducing the general cost of formwork. Significant cost savings could be achieved by reducing labour costs. Formwork costs are not the only significant component of the formwork life cycle. Other important aspects of the formwork operation include speed, safety, and quality [3].

Literature has also emphasized a lot on the safety of formwork scaffolds. The risks involved in operating from a height has been a major concern. The general nature of it has exposed workers to conditions that are not safe [13]. Although usually not preferred, few cases of collapse of concrete works have led to irreversible damages to the sector [23]. Additionally, the stage of the dismantling of formwork has also been linked to injuries. Structural collapses and failures involving concrete structures account for 25 per cent of all construction failures. Records show that nearly half of construction-related accidents are associated with formwork [22] [3].

Key among the causes of these stem from faulty formwork structural design, poor shoring and re-shoring, lack of adherence to safety practices, weak bracing, weak support system, and insufficient concrete strength [23]. Contractors are generally responsible for the stability and safety of concrete formwork. Contractors are guided by several federal, state, and local codes and regulations that regulate formwork safety [22]. The quality of concrete has also been among the regular causes of accidents [3] [23].

3.4. Erect Formwork, Place Inserts, and Reinforcement

There are several ways in which formwork can be erected for placement and reinforcement purposes. This may, however, be determined by the availability of devices for lifting equipment and cages for reinforcement. In some instances, forms are manually handled where a small derrick or crane may be used in some other cases. Key among the processes are lifting, positioning, and alignment of the different formwork elements [19]. This activity also includes the process of applying the form release agent or coating that prevents the bonding of concrete to forms. The logical sequencing of erecting formwork and its relation to placing inserts and reinforcement is:

- Set lines a template is generally set in place on the floor slab or footing to accurately locate the column floor.
- Erect scaffolding
- Install column reinforcement
- Provide forms for column
- Erect outside forms for walls
- Install wall reinforcement
- Erect inside forms for walls
- Install ties
- Provide bracing for walls
- Erect forms for beams
- Install beam reinforcement
- Erect forms for slabs
- Place inserts for mechanical and electrical connections, openings for ducts and conduits, and supporting bars for reinforcement
- Place secondary and main reinforcement

A form coating or release agent is often applied to the inside surface of formwork to prevent the concrete from bonding to the formwork elements. The coating can be applied by spraying, brushing, or by a roller. Form coating enables the operation of removing the formwork after the concrete has gained enough strength to support itself. Another function of the formwork coating is sealing the surface of the wooden elements, which prevents the water in freshly placed concrete from being absorbed by the wood. Form release agents should not affect or react with the finished concrete in any way [5].

4. Materials and Methods

The study was conducted in the Tamale metropolis. The metropolis is found within the central portion region, and it's bounded by the Sagnerigu Municipality to the West and North Mion district in the East, Savannah region to the South-West [24]. Geographically, the metropolis lies between latitude 9º16 and 9º 34 North and longitudes 0º 36 and 0º 57 west. The metropolis is a nodal town linking other major towns up north to south. Additionally, the metropolis is also the number one entry point for landlocked countries such as countries like Burkina Faso, Niger, Mali, and the northern part of Togo in the sub-region. This makes the Tamale Metropolis one of the fast-developing cities in the country. This also explains why there is a surge in construction projects in the Tamale Metropolis.

The study employed the survey research design where a section of the public constructors was studied using quantitative data collection strategies. The questionnaire was administered directly to the respondents. A probability sampling procedure was used to select respondents for the purposes of the study. The study population included subcontractors, contractors, engineers, quantity surveyors, and architects who have been directly involved in construction project works in the region. A list of contractors in the region was solicited from the Association of Building Contractors, Tamale branch, and with this, simple random sampling was used to select eighty (80) respondents for this study. The selection of the respondents reflected and covered contractors with varied experience obtained in the industry at the time of the study. The result from the study was analyzed

using Frequencies Distribution Tables (FDT). The choice of the FDT was to allow for easy comparison of trends of respondents relative to the topic of study.

5. Results and Discussions

5.1. Challenges Associated with Timber and Metal Formwork and Scaffold

The challenges that were associated with timber and steel formwork were elicited from the study respondents. The study requested respondents to examine the challenges of using timber as formwork with particular reference to elements such as the inadequacy of containment, leakages, weakness, and inaccuracy. In Table 1, it was revealed that the majority of the respondents representing 81.3%, indicated that timber formwork was poor in its ability to properly contain concrete. This gives an indication that timber formwork is not adequate for containing the weight of concrete. This may result in poorly finished concrete output. With reference to the perception of weakness, 93.8% perceived timber formwork to be weak. The fact that a greater percentage of respondents mentioned timber formwork being weak mans that respondents will be more likely not going to use it provided a better alternative can be afforded. This assertion is in direct agreement with the findings of [13] that timber made scaffolds are generally weak and stands a chance of distortion of concrete if care is not taken. Similarly, 96.3% identified timber formwork to be prone to leakages when used. This suggests a major challenge since such leakages could result in wastage and weakening of concrete material. As a result of this, timber formwork has loose joints and edges, which are often sealed with tape to hold sealant from leaking. Concrete grout leakages cause honeycombing of the surface and also result in reduced compressive strength.

Also, 55% of the study respondents perceive timber formwork to be inaccurate compared with other formworks. Unlike steel, timber formwork is not standardized in terms of measurement. This affects the accuracy of work since irregular sliced timber has a greater tendency of being inaccurate. Additionally, [24] noted that timber formwork contracts, when exposed to the weather and can lead to inaccuracy relative to measurement. The study further revealed that timber formwork was not capable of safely withstanding the dead weight of the plastic concrete placed on it, weight, equipment weight, and any other environmental loadings.

In Table 2, challenges with the usage of steel formwork are presented. In terms of handling, 95% of the respondents indicated their challenge with that, with only 5% dissenting. This means that most artisans have difficulty in handling steel formwork. This will more likely result in difficulty in its adjustment unless a crane is used. Usually, steel forms do not include facilities for adjustments, levelling, easing and striking without damage to the formwork or concrete, as pointed out by [9]. Respondents also complained about the cost involved in the acquisition of steel formwork. Nearly all respondents (97.5%) perceived the cost to be colossal. This means that, in designing a steel formwork, formwork, consideration must be given to the maximum number of times that any form can be reused, but also produce a design that will minimize the amount taken for erection and striking.

Table 1. Challenges associated with timber formwork and scaffold

Variable	Response	Frequency (n=80)	Percentage (%)
Inadequate containment	Yes	65	81.3
	No	15	18.7
Weak	Yes	75	93.8
	No	5	6.2
Leakages	Yes	77	96.3
	No	3	3.7
Inaccuracy	Yes	44	55.0
	No	36	45.0

Source: Author, 2022.

Table 2. Challenges associated with steel formwork and scaffold

Variable	Response	Frequency (n=80)	Percentage (%)
Not easy to handle	Yes	76	95.0
	No	4	5.0
Expensive	Yes	78	97.5
	No	2	2.5
Leakages	Yes	78	97.5
	No	2	2.5
Inaccuracy	Yes	34	42.5
	No	46	57.5

Source: Author, 2022.

5.2. Comparative Statement of the Two Formworks

Various studies [2] [23] are of the view that the commonest formwork found in most developing countries is the timber and steel made formwork. The study, therefore, sought the views of respondents relative to the two. The two were compared in line with elements such as the cost of investment, durability, surface finishing, material wastage and labour requirement. In Table 3, 47.3% of the respondents mentioned that the initial investment cost for the timber formwork is low, while 67.3% tend to see the steel formwork to be high. This gives an indication that respondents in the metropolis perceive the steel formwork to be high. This will therefore have some implications for its adoption and usage.

In terms of durability, 84.7% see the steel formwork to be durable, with 20.2% seeing the timber formwork to also be durable. Similarly, 78.4% of the respondents will rate the finishing of the steel formwork to be high as compared to 31% of the timber. Also, the level of material waste for the timber formwork was rated to be very high (58.8%) as against 2.1% of material wastage. Lastly, it was revealed that material wastage of the steel was low as compared to that of the timber. In effect, aside from the perceived cost of initial investment, all other elements examined favoured the steel formwork.

It is seen that the estimation of cost elements involved in the use of timber and metal formwork and scaffold in projects in the Tamale metropolis has been the main driver of adoption and use of formwork scaffold. The findings in terms of cost signify that the estimated rate of cost of formwork construction projects in the study area is not the same for both timber and metal formworks. However, cost savings and opportunity cost on the use of the steel formwork over timber formwork would inure to the benefit of contractors directly executing the works in the long term in terms of cost and time as steel formwork will produce little to no rework on concrete surfaces.

Formwork systems and formwork technologies basically determine the speed of construction labour intensity of concreting operations [15]. Therefore, it is also possible to achieve the goal of reducing the construction time and labour intensity of works performed by improving the technology of formwork systems used. Steel formwork with competent artisan is easily assembled and struck when concrete is properly cured compared to timber formwork. This has a direct impact on the time and duration of projects with huge volumes of concrete works and high-rise buildings.

Table 3. Comparative statement of the two formworks

Elements	Timber Formwork				Steel formwork			
	L	M	H	Total (%)	L	M	H	Total (%)
Initial Investment	47.3	35.7	17.0	100.0	3.3	29.4	67.3	100.0
Durability	18.5	61.3	20.2	100.0	-	15.3	84.7	100.0
Surface Finishing	33.8	35.2	31.0	100.0	-	21.6	78.4	100.0
Wastage of materials	-	41.2	58.8	100.0	51.3	46.6	2.1	100.0
Manpower requirement	-	44.6	55.4	100.0	62.5	25.8	11.7	100.0

|*L=Low, M=Moderate, H=high*

6. Conclusion

Based on the results, the majority of the respondents preferred timber formwork systems to steel formwork systems due to cost. But in terms of durability, finishing, and labour demand, the preference level of steel formworks are desirable. Alternatively, even though respondents pointed out the availability of steel formwork on a rental basis, there was still some difficulty associated with the rent as the steel formwork scaffold were not readily available in the metropolis. The type of formwork used in building projects affects the productivity of the labour force. Steel formwork has a faster rate of erection during construction as compared to timber formwork systems. Although this assertion is highly dependent on the productivity of the erection crew, it still boils down to the rate of acquisition. In a nutshell, even though the study did not segregate respondents into their abilities, it stands to reason that the rate of adoption and use of a particular formwork scaffold will more or less depend on the size of the executed project. Steel and timber formwork should therefore be integrated often in the casting of slabs, beams and columns, proper adherence to standards and specifications for the use of any type of formwork could also be advocated based on the construction needs. Also, the weighing of the advantages and disadvantages of each type of formwork relating to the scale of construction before the choice is made could be ideal.

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