KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY KUMASI

COLLEGE OF ARCHITECTURE AND PLANNING

FACULTY OF ARCHITECTURE AND BUILDING TECHNOLOGY

DEPARTMENT OF BUILDING TECHNOLOGY

EFFICIENT UTILIZATION OF TIMBER FOR FORMWORK AND SCAFFOLD CONSTRUCTION: A CASE STUDY OF CONSTRUCTION FIRMS WITHIN KUMASI METROPOLIS

A Thesis submitted to School of Graduate Studies, Kwame Nkrumah University of Science and Technology Kumasi, in partial fulfilment of the requirement for the degree of Master of Philosophy In Building Technology

By

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DECLARATION

I, the undersigned have declared that this project work is the result of my individual effort under the guidance of my supervisor and all relevant materials and sources of information have been dully acknowledged.

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DEDICATION

I dedicate this project to my wife Anas, my daughter Josephine and my son Dela

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. I am very thankful to God Almighty for the provision of life and sustenance of health to complete the project.

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ABSTRACT

This dissertation investigated how timber used for formwork and scaffold on construction sites within the Kumasi metropolis has been identified with waste. It also identifies strategies necessary to be adopted to minimise the waste. The study reflects on previous observations and research on various appropriate strategies and other relevant issues of timber formwork and scaffold construction. Samples of construction firms: D1, D2, D3 and D4 were surveyed through site visits, observation, interviews and questionnaires to identify the factors associated with the waste. Experiments were conducted on samples of some timber species to determine their strength properties and durability in the service life, and viability of such species. Development of prototype of prefabricated timber formwork and scaffold provides a possible solution to enhance economic use of timber.

The main findings of the study reflected on timber usage, supply schedule of timber to the sample sites, the different construction methods being used and the subsequent destruction occurring demonstrated the seriousness of timber wastage through formwork and scaffold construction on sites. Timber consumption in this regard, constitutes a notable depletion rate of Ghana's forest resources. The study concludes that, the prototype of prefabricated timber formwork and scaffold developed and the recommendations are appropriate strategies devised to promote efficient utilization of timber in the building industry in Ghana.

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1.0 INTRODUCTION

1.1 Background of the Study

Timber exploitation in various forms has become a global issue. The negative effects of the exploitation are due to man's action and inactions in the past and today. According to Timberlake (1987) the destruction of the forests, especially in Africa, has resulted in the reduction of agricultural land and fall in food production. Continuous consumption of timber through various activities, have resulted in deforestation and soil erosion. In the construction industry, formwork and scaffold construction is the responsibility of the contractor. The contractor usually requests the service of a supplier to supply timber consignment to the site.

In Ghana, the construction of formwork and scaffold is heavily dependant on timber. This is as a result of the fairly large timber resources which the country could boast of in the past. Unfortunately, that is not the case today. The increasing population and subsequent demand for more buildings for housing have necessitated the continuous use of large consignment of timber. Such a situation poses a threat to the limited forest resources. According to Ghana Forestry Commission (2003), the annual allowable cut of round log to ensure sustainability of Ghana's forest was set at 1 million cubic metres. However, the actual volume of timber consumed in 1999 was 4 million cubic metres, which is 300% over consumption.

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The demand for timber in Ghana is on the ascendancy. This situation can be described as alarming since the timber used for construction purposes, constitute a substantial volume of timber for construction. In this case, the practice of using the timber pieces for firewood after they have been used for the construction of formwork and scaffold for building projects is equally a waste of timber resources. Formworks and scaffolds are indispensable and extensively used in construction in Ghana. However, observation of the construction of these structures at sites usually shows that timber is not used economically (Building Road Research Institute 1996).

Provisional research findings by the Ghana Forest Commission from 1990 to 2000, revealed that close to about 38% of forest resources have been depleted through various activities of consumption. Timber for temporary structures involving formwork and scaffold accounted for a quarter of the total depletion rate (FORIG 2000). As a precautionary measure against this problem of forest depletion due to various consumption activities including the use of timber for formwork and scaffold, the Forestry Commission, has embarked on a nationwide tree planting exercise to replenish the forest. However, since it takes a long time for a tree to mature for use as timber, the huge volumes consumed annually cannot be replaced in a short time (Ghana Forestry Commission 2000).

On most sites in Africa, especially in the West African sub-region of which Ghana is a member, approach to construction of formwork and scaffold has been identified as a major cause of timber wastage. This is amply demonstrated on the construction sites where the irregular sizing of the component parts has resulted in excessive and unnecessary of shapes, angles and joints. Usually, the employment of inappropriate joints at the sides, ends and angles, has resulted in the construction of defective formwork and scaffold. Also lack of dimensional co-ordination by contractors in the construction process has necessitated unnecessary cutting of timber pieces. Most often, defective formwork and scaffold become a waste as they fail in use. The reconstruction of such damage or defective structures always require additional use of timber (Addai et al 1995).

Another issue of great concern involving the construction of formwork and scaffold is the prevailing common sight of excessive volumes of timber off cuts, not suitable for use, which are left on the sites (Ayarkwa 1994). Meanwhile, the harvesting of trees in the forest for timber to meet various consumption demands including timber for formwork and scaffold is on the increase. Mostly, the waste of timber on sites in such circumstances, are due to the employment of wrong methods of work. The formulation of an efficient method to check and prevent wastage of timber in the construction of formwork and scaffold will reverse the negative trend of continuous waste and increases in forest depletion rate.

A study on efficient utilization of timber for formwork and scaffold construction through Prefabrication can be an appropriate strategy to change the prevailing tide. Though timber for formwork and scaffold do not account for the whole consumption rate, such strategy, would reduce the national forest depletion rate substantially, and promote an improvement in the production of formwork and scaffold.

1.2 Statement of the Problem

. In Kumasi, the huge pile of timber waste seen at the construction sites after using formwork and scaffold is a contribution to depletion of the forest resources. According to records section of Town and Country planning of Kumasi Metropolitan Assembly (2000), close to about 1,200 construction firms with the classifications of D1, D2, D3 and D4, use timber in varied quantities in their constructional works involving formwork and scaffold within the Metropolis. The Kumasi Metropolitan Assembly building inspection report (2002) gave a yearly timber consumption rate of the firms regarding formwork and scaffold at 40% of the total consumption for construction works.

The issue however, of timber waste on construction sites in Kumasi, if not addressed, is capable of worsening the forest depletion in Ghana. At the moment, the huge volume of timber waste found on sites after using them for either formworks or scaffolds is very disturbing. Though the rate of timber waste varies between the classes of firms, the total waste of all the firms is quite huge. Usually, the D1 construction firms, use mostly metal components with just a little fraction of timber members. However, the waste of timber for formworks and scaffolds in Kumasi is linked mostly to the D3 and D4 construction firms who make up 95% of the firms. These firms are the ones, who use timber solely for all types of formwork and scaffold on their sites.
The causes of timber waste by firms in Kumasi can be attributed to many factors as expressed by the carpenters on the sites visited. According to the

operatives, any attempt to prevent waste would help cut down on the firms' expenditure on new consignments of timber for every project. The scenes on the sites suggest that, the idea of temporary status about the structures has influenced the choice of poor quality timber.

There is also the incidence of using inappropriate construction methods which is rendering most of the timber pieces beyond the scope of reuse. For instance, most artisans involved in the construction of the structures when interviewed, said that, they never consider shaping and sizing of timber members as a priority when working. The practice accounts for irregular sizes and shapes of timber pieces that deteriorate after the first use and are discarded. Visits to most construction firms in Kumasi revealed the huge pile of timber pieces being disposed of.

The experience of the artisans or carpenters has been identified as another factor for waste of timber. On some of sites, the carpenters engaged on the construction of scaffolds and formworks do not have much experience to enable them 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 on going on most construction sites in Kumasi metropolis.

Another factor of inefficient use of timber and subsequent waste is the operative's lack of knowledge of suitable timber. Knowledge of the working properties and conditions of good working timber is important for effective selection of the material. Physical survey of the firms on construction of formworks and scaffolds, showed that most of the timber pieces, being used are not seasoned, thus exposing them to undue physical changes. The timber pieces therefore become so deformed that they can not be reused after the first use.

The few D1 construction firms used for this case study, by their resource status, use a different approach to the construction of formwork and scaffold. Combination of metal and timber members usually enabled these firms to minimize the rate of timber waste on their sites. However in some instances, the large firms or D1, use mostly timber, but the treatment of the timber pieces render them good and still usable for some time.

Considering the situation of formwork and scaffold construction on sites in Kumasi, it is clear that improper use of timber is causing waste. Also, the timber waste issue is a contributing factor to the national problem of forest depletion. Exploring the available construction materials and technologies can enhance efficient use of timber for formworks and scaffolds construction in Kumasi.

1.3 Aim and Objectives

The aim of the study is to develop efficient means of utilizing timber for formwork and scaffold construction in Ghana.

The objectives of the study are to:

1. Review current designs and methods of constructing and removal of formwork and scaffold on sites.

2. Develop appropriate design of formwork and scaffold through prefabrication to facilitate repetitive use of the components.
3. Identify appropriate methods of combining timber with other constructional materials to enhance the efficient use of timber for formwork and scaffold.

1.4 Justifications for the study

The efficient use of timber for formwork and scaffold through prefabrication is an appropriate study for several reasons. The depletion of the forest of Ghana has become a crucial national issue, due to the alarming rate of timber exploitation. In this connection the Government's concern about timber consumption and wastage in the building industry through the construction of formwork and scaffold will be addressed.

The study's aim at developing pre-fabricated timber formwork and scaffold will enhance economic use of timber thereby promoting the concept of conservation. By this it has become clear that it is possible to conserve timber for construction purposes.

The use of inappropriate methods of construction has been a major cause of timber waste for formwork and scaffold. Irregular sizing of timber pieces, cutting poor shaping, lack of dimensional coordination of component parts, angles, and joints have often contributed to the inefficient use of timber. The avoidance of nail to use angle plates, and bolts and nuts to prefabricate timber pieces will ensure the repetitive use of formwork and scaffold on sites.

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The need to combine timber with other construction materials for formwork and scaffold can assist the construction industries to minimise their over dependence on timber. In this way, the timber pieces combined with other materials will become valuable and use repetitively.

1.5 Method and Scope of the study

The study was conducted through survey of construction firms, sites and personnel involved in the construction of formwork and scaffold within Kumasi metropolis. Experiments were also conducted on timber species to determine strength properties and durability of treated timber. Design and development of prototype prefabricated timber formwork and scaffold were undertaken to verify their efficiency in timber utilization.

In scope, the study covered scaffolds and formworks for floors, beams and columns in building construction. It included the analysis of designs of both dependent and independent scaffolds. Other types of scaffolds like the jack and ladder scaffolds used by the D3 and D4 construction firms. The formworks for columns, floors and beams were closely observed and discussed. Also included, are issues concerning the use of timber for the structures namely; design concerns and strategies to enhance economic use of timber, dimensional coordination in the sizing, cutting and shaping of timber pieces and joints suitable for formworks and scaffolds.

The exploration of the varieties of constructional materials especially; metal and plastics have been analysed to identify their properties, characteristics and suitability to combine with timber for formwork and scaffold.

1.6 Research questions

The research seeks to address the following questions:

1. What roles do formwork and scaffold play in the construction process?
2. Do the design and construction methods of formworks and scaffold promote repetitive use of timber pieces?
3. Can timber pieces be developed into prefabricated units to ensure multiple uses?
4. How can timber be efficiently used in the construction of formwork and scaffold to reduce waste?
5. Is it possible to explore other materials that can be combined with timber to construct scaffolds and formworks to reduce the over-dependence on timber?

CHAPTER TWO

2.0 PREVIOUS OBSERVATIONS AND RESEARCH

2.1 Introduction

Following the discussion of the over view of the study in chapter one, an attempt has been made to discuss the relevant previous observations and research in this chapter. The observations and research on formwork and scaffold in building construction, reflects on approaches, purposes, dimensional coordination, sizing, cutting and shaping of timber pieces, as literature review for the study. In addition, information on materials for formwork and scaffolds and sustainable methods of timber utilization has widened the scope of the study in exploring the variety of solutions. The construction methods of formwork and scaffold have presented the ideal situation for which inefficient methods can be easily identified on sites.

The consideration of Asian, African and European perspective has helped in understanding timber utilization by the construction firms on sites in Kumasi. Extensive observations and research exposition on timber was resourceful in identifying the fact that, quality plays an important role in efficient utilization of timber pieces. Also, the potentials of plastics and metal as suitable materials have been established to show how their use with timber in the construction of scaffolds and formworks can be an efficient method of timber utilisation. Issues raised and discussed are vital towards ensuring that timber utilization for formwork and scaffold are made economical in Kumasi.

2.2 Timber Formwork and scaffold in Building Construction

Timber Formwork and Scaffold are very important structures in the building process. As Arora and Gupta (2003) put it, "They are temporary structures which are means to an end, in that they serve as caretakers, who ensure that the desired permanent structure is obtained".

According to Walton (1985) and Nash (1990) formwork and scaffold are inevitable in all aspects of the building process. For instance, the making of concrete slabs is possible through the use of formwork and scaffold is used to ensure that construction work progress vertically to the desired heights.

Chudley and Greeno (1998) expressed the importance of formwork and scaffold for which they suggested that the design and construction must lead to a successful end product. They pointed out that since formwork and scaffold play important roles, their construction can not be overlooked, substituted or avoided altogether as analysed in the following points:

- Formwork: functions as a moulder or a former of desired shapes and sizes of concrete slabs.
- Scaffold: Provide safe working platform for both workers and materials at a height on site.

Observations of timber formwork and scaffold at sites, confirmed that they are constructed with the aim of obtaining the desired concrete structures and building up to convenient heights respectively. Nevertheless, how timber formwork and scaffold are constructed, used and dismantled rather destroy them after first use.

2.3 Purpose of Formwork and Scaffold

Very often, the scene at most sites especially the D3 and D4, firm sites in Kumasi concerning the construction of timber formwork and scaffold have created doubts about their purposes. The quality of materials used, and construction methods employed by the personnel on the sites give negative impressions about the essence of the formworks and scaffolds. Usually, the use of poor timber pieces on D3 and D4 sites has produced defective formwork and scaffold. Such defective formwork and scaffold are made of decayed timber pieces, split end and side timber pieces which can not be reused. Also the concrete structures obtained are not of good quality. A look at the pictures in figures 2.1 and 2.2 show the inappropriate construction methods for which the purposes of formwork and scaffold can not be effectively achieved. Since about 80% of construction projects in Kumasi are undertaken by D3 and D4 firms, the knowledge and application of the purposes for formwork and scaffold will provide the right orientation for a successful construction.

Studies by Seeley (1987), Walton (1995) Chudley (1983), Arora et al (2002) acknowledged formwork and scaffold are very important temporary structures which can enhance the successful function of the permanent structures. They emphasised that, any attempt to engage in the construction of these structures must first and foremost be backed by adequate knowledge and interpretation of their respective purposes. This is because; the knowledge of the purposes will guide the possible design, construction strategies and selection of suitable materials. In analysing the opinions of the construction experts, the following purposes have been outlined to guide the construction and uses of formwork and scaffold:

- To act as a caretaker in the realisation of the permanent structure. This implies that the need to make concrete slabs or to work at a height can only be achieved through a formwork and scaffold respectively.
- Another purpose of a temporary structure is to ensure the provision of a permanent structure. For instance, a formwork indicates the desired final position of a concrete slab, whilst the position of a scaffold, will enable work to be continued at a height or repair work at a desired position.
- The construction of formwork and scaffold serves as the provider of a convenient working environment to achieve the ultimate result of the desired structures. Formwork is the only appropriate temporary structure that can contain wet concrete to achieve its shape and size. Temporary platforms or scaffolds are the only appropriate and convenient means by which construction works can be done to a higher level.
- The purpose of a scaffold as an offer of safety to workers as they use it to construct the permanent structure is a very essential consideration in construction works.

- Also be it concrete works or working at a height or a repair works, formwork and scaffold are expected to serve as safe structures for the materials being used.
- Though formwork and scaffold play short lived roles in construction, the experts emphasised that they should be constructed to ensure a consistent high standard of work.

2.4 Classification of Construction Firms (Contractors)

According to the Ministry of works and housing (2000) building contractors or firms are classified into four namely: D1, D2, D3 and D4. The D1 class of construction firms refer to very large type and undertakes very huge projects which are usually state funded. The D2 class is also of a large scale but less in project size compared to D1 class. Class D3 construction firms are best described as the medium scale type of firms. Some of such firms are operated by sole proprietors. They undertake projects which are medium and need short periods of completion. The D4 class of firms are usually operated by the sole proprietors with no defined organisational structures are always involved in small projects financed by individuals.

All these classes of construction firms construct timber formwork and scaffold at their sites for which they form part of the study.

Timber wastage on sites due to formwork and scaffold construction is evident in the activities of all construction firms.

Table 2.1 Classification of Building contractors (2000) in Ghana

Region/ Class	Ashanti	Brong Ahafo	Central	Eastern	Greater Accra	Northern	Upper East	Upper West	Volta	western
D1	11	4	9	4	80	6	1	3	7	7
D2	69	18	47	31	309	28	52	29	39	25
D3	355	140	180	232	1,228	255	137	142	155	131
D4	410	163	185	248	940	355	140	149	132	128

2.5 Personnel Responsible for Formwork and Scaffold

In a construction project, the party responsible for formwork and scaffold on sites is the contractor. Nash (1990) and Walton (1995) identify the site engineer as the contractors' team technical director at site who plays very significant roles in formwork and scaffold construction. As shown in Table 2.1 there are various personnel involved in the construction of formwork and scaffold. The action and inaction of the individual personnel has an effect on the outcome of the project.

Personnels roles for the construction as analysed in table 2.1, is in line with the ideas of Walton (1985), when he acknowledged that personnels contribute immensely towards successful construction. In the case of Kumasi metropolis, the personnels especially on the D1 construction firm sites undertake roles as indicated in table 2.2. On the D4 sites however, the project is usually undertaken by one or two persons who perform roles that other personnel are expected to do.

Table 2.2 Personnel with various roles in the construction of formworks and scaffolds.

Type of Personnel	Role in Construction of formwork and scaffold.
Project Consultants	Give suggestion on various construction methods. Determine suitability of construction methods. Approve of safety of formwork and scaffolds on site.
Site Engineers	Apply technical ideas to meet consultant's suggestions and request. Direct and guide construction of formwork and scaffold through the foremen. Examine the suitability of the construction prior to consultants' evaluation.
Clerk of Works	Liaise with site Engineer and foremen to ensure appropriate methods of construction are used for formwork and scaffold. Inspect the construction methods on sites.
Foremen	Direct headmen and carpenters in the construction of formwork and scaffold. Inspects the construction work as it progresses.
Headmen	Follow the instruction of the foreman to guide the carpenters in the selection of timber pieces Guide the carpenters in the construction processes. Cross check the suitability of the construction works . Guide the carpenters in the striking and dismantling of the formwork and scaffold.
Carpenters	With the guidance and supervision of the headman, construct formwork and scaffold. Undertake corrections on the formwork and scaffold when directed by the foreman, engineer or consultant. Strike or dismantle formwork or scaffold under the guidance of the headman.

2.6 Approaches to Construction of Formwork and Scaffold

Survey of construction sites and observation of approaches to formwork and scaffold construction among the classes; D1, D2, D3 and D4 of construction firms in Kumasi metropolis vary. Responses from the sites identified among others that the differences are influenced by the following factors:

- Class of the construction firm
- Size of project
- Construction personnel and resources
- Standard of work done by firm
- Constructional methods
- Quality of timber
- Monitoring and supervision schedules
- Striking and dismantling schedules
- Storing of timber pieces after use

The D1 and D2 construction firms are large in size and usually undertake state funded or corporate body projects for which the formwork and scaffold are constructed to standard. Due to their resources and financial status, they use timber boards and prefabricated metal tubes in formwork and scaffold. Site observations revealed that even though some of the D1 and D2 contractors use timber solely for formwork and scaffold construction, most of the timber pieces are destroyed on these sites through striking and dismantling methods. The D3 and D4 construction firms generally employ timber for formwork and scaffold construction on their sites. Factors that will normally enhance standard works in formwork none exist on D3 and D4 sites. Right from construction stage, usage and striking, the formwork and scaffold members are destroyed and discarded on the sites. The diagrams of figure 2.1 and 2.2 show a typical inappropriate construction of formwork and scaffold and possible destruction of timber pieces.

The submissions of Whitney et al (1987), stressed on careful consideration of manufacturing processes to ensure effective utilization of timber formwork and scaffold. To minimise possible destruction and discarding of timber pieces after striking and dismantling, the emphasise should be placed on the use of non-destructive joints and have good storage for formwork and scaffold, after stripping the same.

Figure 2.1 a scene of inappropriate construction of scaffold which will lead to subsequent discarding of timber pieces.

Figure 2.2 a scene of inappropriate construction of formwork for a floor which will lead to subsequent discarding of timber pieces.

2.7 Formworks

In the building industry, concrete structures at every stage of the building are very necessary and important. In view of this concern, Walton (1995) regarded the construction of formwork, the sole mould for any size and shape of concrete structure to be purposeful. A formwork which is well designed and constructed appropriately using the desired materials will result in a very good concrete structure. On the other hand, any formwork which is inappropriately designed and constructed using unsuitable materials will provide a defective concrete structure. Observations of the sites visited in Kumasi metropolis revealed the realities in quality of formworks based on the construction methods employed.

Ceca (1979), a concrete practice group, in its findings, consider the importance of formwork as central to the functions of the resultant concrete slab. Their purpose of formwork stated that:"it is to contain the freshly placed and compacted concrete until it has gained enough strength to be self supporting, to produce the desired finish to the concrete." This is in line with the views of Chudley and Greeno (1998), Seeley (1987) and Arora et al

(2002), when they stressed that, both the materials for formwork and construction strategies are given serious consideration. For a formwork to achieve the desired purposes on the sites, the concrete practice group (Ceca 1979) formulated the following construction requirements:

- The formwork should be sufficiently rigid to prevent undue deflection during the placing of the concrete.
- It should be of sufficient strength to carry the working loads and the weight or pressure of the wet concrete and to withstand incidental loading and vibration of the concrete.
- It should be set to line and level within the specified tolerance and include any chamber, which may be required.
- The joints should be sufficiently tight to prevent loss of mortar from the concrete.
- The size of panels or units should permit easy handling. The design should permit an orderly and simple method of erecting and striking.
- The arrangement of panels should be such that they are not "trapped" during striking, and it should be possible to strike side forms from beams without disturbing the soft formwork.

Formworks in general play significant roles in ensuring that the obtained concrete structures meet the expected functional requirements. In achieving good concrete products, materials required and appropriate design and construction strategies for the formwork must be identified. It is in following these steps that the firms can be assured of success. Experiences of formwork construction in other parts of the world have revealed observations that are worth noting. Arora and Gupta (2002) have done extensive and comprehensive studies on formwork construction in Asian countries. They stressed that formwork construction whether for precast or insitu must be well co-ordinated. The studies observed that formwork cost about one – third or even more of concrete structures. For this reason, it is imperative that economic designs and construction methods are seriously employed. Though formwork may be made of either timber or metal or other materials, Arora and Gupta again, stressed the need for requirements of a good formwork and suggested the following to avoid wasting of materials:

- It should be strong enough to support the dead and live loads during construction.
- Its construction should be such that it can be easily removed.
- It should be water tight as far as possible.
- It must be so designed that it can be used several times.
- It should have plain surfaces so that they may provide good finished surfaces.

In viewing the formwork as a mould, Chudley and Greeno (1998), considered its role in containing the concrete in a fluid state to retain the required shape, size and position. They observed that the actual formwork is the reverse shape of the concrete member, which is to be cast. It is therefore important that, the formwork as a mould perform its roles economically to enhance efficient design and construction of a formwork, Chudley and Greeno devised the following basic principles to serve as a guide:

(1) Formwork sides can be design to offer pressures as a single or alternatively they can be designed to use or thinner material, which is

adequately strutted. For economic reasons, the later method is usually employed.

(2) Grout tight joints formwork can be designed to offer all the necessary resistance to the imposed loads as a single member or alternatively they can be designed to a thinner material, which is adequately propped. For economic reasons the latter method is usually employed.

The Technical Brochure of Ghana Cement, (GHACEM) formulated the following guidelines concerning formwork for cement works:

- The joints in the formwork should be tight against leakage of cement grout.
- The formwork should be constructed in such a manner that it may permit the removal of the various parts in the desired sequence without damaging the concrete.
- The formwork should be rigidly constructed and efficiently propped and braced so as to retain its shape without undue deflection.

2.7.1 Types of formwork

There are various concrete slabs for which formworks are designed and constructed. Among the types of formwork that are constructed on sites are for floors, beams, columns, lintels, stairs and others. They are identified as moulds for the various concrete slabs which have distinctive shapes, sizes and are engaged at the appropriate stages Chudley and Greeno (2000).

A survey of the construction sites in Kumasi metropolis showed that the construction of formwork for various concrete slabs is an on going activity.

Depending on the stage of the building process, every site has a type of formwork construction in progress. The diagrams of figures 2.3, 2.4, 2.5, 2.6 and 2.7, show typical examples of formwork in use on the sites. The illustrations show that the formworks are different in shapes and sizes and are solely intended to mould the distinctive concrete slabs namely; beams, floors and columns.

- The diagrams of figure 2.3 shows the role of a typical formwork for a beam in ensuring that the expected shapes and sizes of the, beams are obtained.

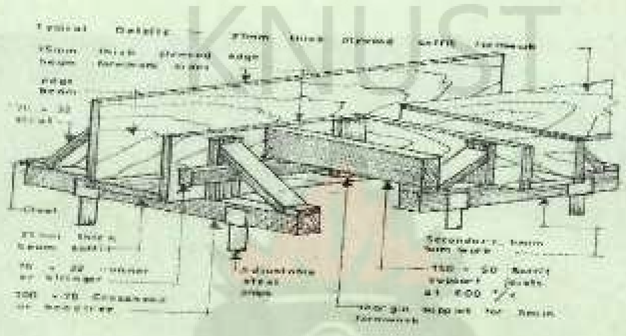


Figure 2.3 a typical timber formwork for a concrete beam.

The type of a formwork is determined by the type of concrete unit or slab and the shape it is to construct. Among the types of formwork identified by Chudley and Greeno (1998) are: formwork for columns, floor and beans, lintels, open drains, stairs and others. Concrete slabs obtained from formworks, vary in design and serve different purposes. For this reason, it is important that basic principles of formwork design and construction are observed. The illustrations following exposed the different types of formwork and methods of construction as observed on the sites within Kumasi metropolis.

Figure 2.4 a typical formwork for concrete floor at a construction site

Figure 2.5 a typical timber formwork for a concrete column at a D 4 Site.

Figure 2.6 a typical timber formwork for a lintel at a D 4 site

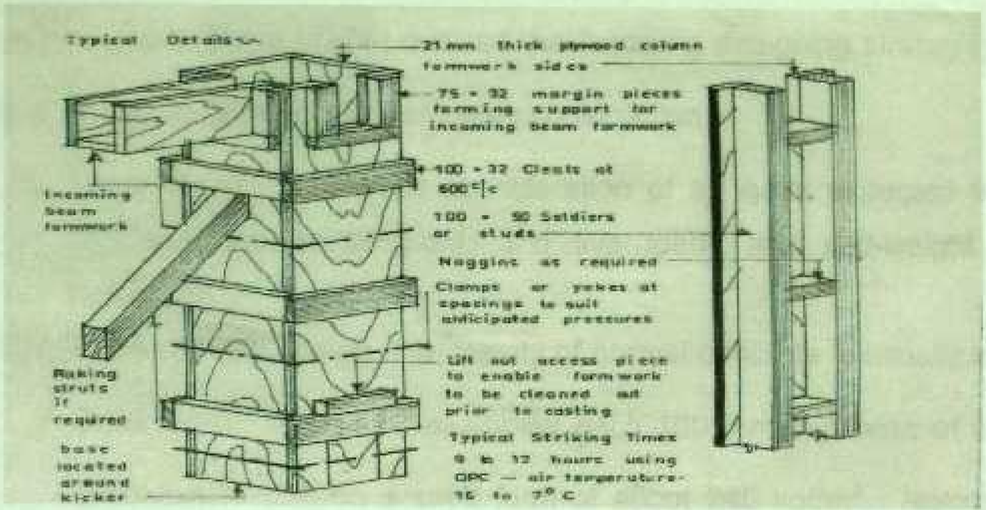


Figure 2.7 a typical formwork for column.

Figure 2.8 a typical formwork for concrete beam

2.7.2 Designing strategies for formworks

Formworks for concrete slabs need to well designed, to ensure effective construction. The ability to develop the desired shape and correct sizes of the concrete slabs will depend on the appropriate use of designing skills for the formwork. A good design of the formwork usually enhances efficient and successful concrete product. The success or failures of formworks on sites have been closely linked to the design strategies employed. To ensure that formworks function effectively to achieve the expected results, the concrete practice group, Ceca (1979) outlined the following designing strategies which have served as guideline for formwork construction:

1) There should be serious consideration of all loads expected from the concrete, the environment, and live loads and self-weight of the formworks.

2) For formwork design, the density of normal concrete is usually taken as 2400 kg/m^3, so that for examples each 100 mm thickness of concrete produces a load on a soffit form of about 240 kgf/m^2. Normally, the calculation will help in determining the types of soffit that can resist the load up thrust.

3) The resistance from the environment is said to mean the stress that the form will endure when placing concrete, and when compacting it. At sites where no due consideration is given this factor, the forms open up in the tamping process. It is very important to note this point is useful to all formwork design process.

4) A live load of the formwork is normally assumed to be the whole weight of the concrete in direct contact with the form. The design must cater for this factor.

5) As the concrete sets, it gives a horizontal pressure against the vertical forms depending on the rate of filling the form and the thickness of the concrete section.

The sight of irregular projections on face alignment of columns, beans, stairs and others was due to the point that the forms used were not strong enough to counteract the horizontal pressure of the concrete in fresh state. At all cost the forms must be sufficiently strengthened to prevent such irregularities.

Consideration of the stress in relation to the design aspect of the forms can effectively enable the builder to have a successful job done.

2.7.3 Considerations to Prevent Timber Wastage in Formwork Construction

A lot of timber pieces used for formwork construction go to waste after first usage and can not be reused. Several factors account for this unfortunate situation which is very common on most sites, especially of the D3 and D4 firm sites. Studies have shown that, due to the hydroscopic nature of timber, it is liable to deteriorate in strength and size when in contact with wet concrete. As a result of this condition, most timber pieces used for formwork will warp, twist, crack, break and bow and can not be reused. The timber pieces in such cases are usually discarded. The diagram of figure 2.9 shows the usual sight of piled up waste timber pieces obtained from formwork construction on the sites. The scene confirms the reality of timber waste on sites in the Kumasi metropolis.

Chudley and Greeno (1998) identified wastage of timber pieces on construction sites to be associated with formwork construction. They developed some considerations which have prevented timber wastage greatly on most construction sites in England and Wales. Their considerations are:

- The stress imposed by fluid concrete should be analysed and the minimum safe sizes of timber and maximum spacing of supports obtained
- Timber should be ordered in the most convenient lengths to avoid wastage in cutting.

- All longer lengths should be cut first and short lengths cut from waste materials.
- Shutters should be made to strip easily without damage, thus permitting maximum re-use.
- All shutters or loose boards which are striped should be immediately cleaned, loose nails removed and the shutters stacked in neat, wedges, bolts, and other loose parts should be thrown into separate boxes as they become free.

Fig2.9 A typical site scene of piled up of timber wasted after formwork construction.

2.7.4 The need for Economic planning in formwork construction

Looking at the important roles that concrete structures play in the construction of buildings, Chudley and Greeno (1998), (Ceca 1975) and Walton (1985) in their opinion indicated that formwork construction need careful planning. Lack of planning can bring about over expenditure in the purchase of the materials which can then cause economic crisis in the construction firms. They therefore suggested that formwork must be carefully handled and economically used and maintained in serviceable condition since it is a very important part of the construction process and at same time expensive. Research has shown that, the call for economic planning is due to the fact that, the total cost of formwork operations can be as much as one third of the cost of the completed concrete structure. Even on a well-organised job, the cost of the formwork may be as much as one –fifth of the total contract. It is therefore essential that every one on the job should keep these costs to a minimum by considering wastage of materials and labour Chudley and Greeno (1998).

Formwork sides should have limited width and shape of wet concrete if it has to resist the hydrostatic pressure of the wet concrete, which will diminish to zero within a matter of hours depending on settings and curing rate. It is expected that base or soffit limits depth and shape of concrete and has to resist the initial dead load of the wet concrete and later the weight of the dry set concrete until it has gained sufficient strength to support its own dead weight which is usually several days after casting depending on the curing rate. In view of these concerns, therefore it becomes very obvious that, Austin (1966), Nash (1990) and Chudley and Greeno (1998) declared that the design and construction be given a serious attention when planning for formwork construction

2.8 Scaffold

Scaffold is defined as a temporary structure made from poles of wood or metal tubes that can enable workers reach parts of a building above the ground level Walton (1995). A common phenomenon in the building enterprise is that as the work develops on upward direction, it becomes impossible for the workers to advance up if he/she should remain at the initial level. The use of scaffolds is therefore necessary on every building construction site. Though scaffolds enable workmen reach their work at a height, there has been doubts about the ineffectiveness of those made of timber. Defects associated with timber scaffolds are linked to irregularities in design and construction processes (Nash 1976). Among the irregularities observed on most sites are; the lack of dimensional co-ordination regarding the sizes of timber pieces, shapes, inconsistency in the dimensions and quality of timber used. Also identified as a contributing factor to defective scaffolds are the joints employed and the cutting methods on the timber pieces.

The general observations about the defects are that they render the timber members not reusable but rather promote continuous use of new consignments of timber on every new project. This is exactly what is prevailing on most sites in Kumasi. The concern of the study is to explore strategies of ensuring an efficient use of timber through effective design and construction methods. It is therefore necessary that scaffolds as temporary structures must satisfy certain requirements to function effectively for high productivity in the construction industry.

Nash (1976) and Walton (1995) observed that, applying the requirements for scaffold construction have been important guidelines for successful contractors. These requirements play a dual role in the process as a guideline and after construction as a checklist. This approach brings to the fore that, requirements for scaffolds can be classified into two categories for easy interpretation and implementation. The two are identified as general requirements of scaffolds and the constructional requirements of scaffolds. The general requirement, should suggest what is expected of a scaffold as a unit in terms of functions and outlook. Whereas the constructional requirements should indicate what is expected in every procedural stage of the construction of the scaffold. This consideration is in accordance with Nash (1990) and Chudley (1998), as presented in the following points:

- It is strong enough to carry all loads that will be placed upon it. Standards should not be placed too far apart, and a single tube should not carry too much weight.
- It is stable and will not bend or move in any direction. It is most important that sufficient bracing is provided both across the scaffold and along its elevation.
- Platforms are safe to work on and no traps are left in the boarding. Precautions should be taken against the accidental dislodgement of boards by wheelbarrows etc.
- Materials or tools do not fall off working platforms.
- The safety of all personnel on site is safeguarded by taking safety precautions at every point where an accident is liable to happen.

Nash (1990) also considers the following construction regulations about scaffolds very necessary. To him, the followings points derived from the construction regulation will enable the builders to carry out scaffold construction efficiently. The diagram of figure 2.10 shows tubular scaffold of independent and dependent scaffold as identified by Nash and Chudley. All the D1 construction firms in Kumasi possess tubular scaffolds and use them on their sites. Observation on such sites revealed that, when erecting the tubular scaffolds, the firms use the following regulations as directed by Walton (1995) Nash (1990) and Seeley (1987).

- All materials used shall be of good quality and in sound condition.
- Every scaffold shall be of good construction.
- Every scaffold shall be properly maintained.
- No scaffold shall be partly dismantled unless it complies with these regulations or a notice is prominently displayed, warming that the scaffold is not to be used, and any access is effectively blocked.
- Standards shall be either vertical or slightly learning towards the building, and fixed sufficiently close together to secure the stability of the scaffold.
- The foot of a standard shall be on a firm base.
- Ledgers shall be as horizontal as possible and securely fastened to the uprights.
- Putlogs shall be securely fastened to the ledgers or to the standards. Where they are supported by the wall they shall extend into the wall sufficiently to provide an adequate support.
- The distance between putlogs shall not as a general rule exceed:

  1m for 31 mm planking

  1.5 m for 38 mm planking

  2.5m for 50 mm planking.
- Scaffolds shall be securely supported and properly strutted and braced or rigidly connected to the building to ensure stability.

- Loose bricks, drainpipes, chimney pots or other unsuitable material shall not be used for the construction of scaffolds.
- Bricks or blocks, however, may if they provide a firm support, be used to support a platform not more than 600 mm above the ground or floor.
- No part of a building shall be used to support a scaffold unless that structure is of sound material and good construction

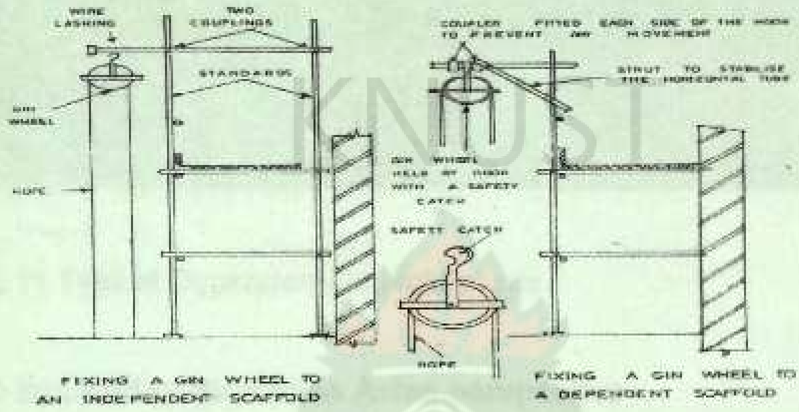


Figure2.10 Typical examples of tubular independent and dependent scaffolds.

2.8.1 Type of Scaffold

Apart from the tubular scaffolds that are seen on most D1 and D2 sites in the Kumasi metropolis, there are several types in use on all D3 and D4 sites. The scaffolds erected on these sites are of timber. On these Depending on the type of work and the extent of level to work at, the firms employ different designs of scaffold on their sites. The methods used in the erection of any type on D3 and D4 construction sites, have resulted in great waste of timber pieces. The lay down regulations on scaffold construction are not used on most construction sites. All irregularities associated with the construction of scaffolds on D3 and D4 sites have resulted in the waste of timber through cutting, sizing excessive nailing and joints. The diagrams of figure 2.11 illustrate the different types of timber scaffolds usually erected on most sites within the Kumasi metropolis.

Figure 2.11 Typical Dependent Scaffold at site.

2.8.2 Scaffold construction Asian perspective

Scaffold construction in Asia, especially in India has witnessed rapid innovations since 1980.This is so, because of the sudden shift from the use of traditional timber species which were becoming depleted, to the use of bamboo. The specie was identified as the sole inspiring factor in the process of construction works. Arora and Gupta (2002) in their exposure have kept track of the rate of scaffold construction. They acknowledged the abundance of bamboo in the Asian region for which most aspect of scaffold were done with it, especially in the rural areas where most building works go on. What is really fascinating about the Asian style is the application of the principles of construction in the use of bamboo, despite its lacking of predetermined sizes and shapes.

With the successful construction of scaffolds, on most sites using bamboo wood, Arora and Gupta (1987) undertook extensive studies to identify the resourcefulness of the Asian approach. They discovered that despite the non use of traditional timber, various types of scaffolds are being appropriately constructed using bamboo as the main material. Among the types of scaffold used are:

- Bricklayers scaffold
- Masons scaffold i.e. This is similar to independent scaffold
- The ladder scaffold i.e. this is an improved type of masons scaffold in that, bolts and nuts are incorporated.
- Cantilever or needle scaffold i.e. this type is used for on upper floors
- Suspended scaffold i.e. This is used for light work but generally it is hanged from the roof by means of wire ropes

One factor which made the Asian perspective sustainable is the cautious attempt made to avoid using nails to form joints for bamboo. They devised the use of rope to tie the bamboo pieces to form rigid and strong joints. As Arora and Gupta summed it up, the use of bamboo and employment of appropriate methods is helping to ensure an efficient management of the forest resources in the Asian region.

The Asian approach is relevant to this study in view of the challenges that Ghana is faced with, trying to check the alarming forest depletion rate. The continuous practice of procuring large consignment of timber for formwork and scaffold construction on sites for every project is putting the forest reserve of the country at great risk of depletion. Also the discarding of timber pieces used for formwork and scaffold construction and subsequently used as firewood is a waste of the timber resources. There is therefore, the need to devise an efficient means of utilizing timber through appropriate methods to construct formworks and scaffolds on building sites in Ghana.

2.9 Materials for formwork and scaffold

Site surveys of materials used for formwork and scaffold construction showed that timber and metal are suitable. Between the two materials, timber is the most predominantly used on sites. This is because, timber in general, is in abundance and affordable. Metals, on the other hand, are the most suitable material for formwork and scaffold. This is in view, of the fact that, metal as a material, possesses properties that can make its products withstand the conditions of usage Walton (1995). Despite its advantage over timber in terms of strength and durability, metal is too expensive for every category of construction firm to use. From this point of view, it has become clear that the D1 construction firms are financially resourced and are the ones who use metal formwork and scaffold on their sites. The scene on these D1 construction sites in Kumasi metropolis is a clear manifestation of their financial stand. Timber usage for formwork and scaffold construction is very well associated with the D3 and D4 construction firms. The availability of timber and at a reasonably low price compared to the tubular scaffold has made it to be more patronised by the D3 and D4 construction firms.

2.9.1 Timber

Studies have shown that, throughout the ages, the unique characteristics and comparative abundance of timber have made it one of the most widely used natural building materials. For this reason, it is extensively used for the construction of homes and other structures in most developing countries especially in Africa. However, the over reliance on some specific species for building projects is posing a great threat to the resources.

Okoh and Addo-Ashong (1977), in their study, identified timber as one of Ghana's most readily available natural resources. The study also revealed that timber producing forest of Ghana occupied an area of approximately 78 square km (about 30,000 sq miles), which represented about one-third of the total, area of the country. However, the situation has changed drastically over the years to the extent that currently, the timber forest is about 52 square km. Further more, the timber resources are estimated at about 350 million cubic metres (about 12,000 million cubic metres), of which about 140 million cubic meters is in the immature stock.

Studies showed that timber has limitations for which most D1 building firms will prefer metal as a material for formwork and scaffold. For instance it is susceptible to decay and insect attack. Also moisture movement of concrete through formwork deteriorate the texture of the wood fibres they discovered that, even though timber has its limitations, of susceptible to decay and insect attack, there are a number of inherent factors which keep timber in the forefront of the building materials. Some of the chief attributes are, its availability in many species, sizes, shapes and conditions to suit almost every demand. It has a high strength to weight ratio and remarkable record for durability and performance as a structural material.

On the other hand, the dry nature of wood can enhance its use effectively. For instance, dry wood has good insulation properties against heat, sound and electricity. Because of grain patterns and colours, wood is inherently an aesthetically pleasing material. Its appearance may be easily enhanced by paints, stains, varnishes, lacquers and other finishes. An extensive study of B.R.R.I (1989) report observed that timber is a very versatile material.
It is easily shaped with tools to any desired size as boards, battens and scantlings. Timber pieces ability to fasten well with adhesives, nails, screws, bolts and nuts and dowels was confirmed. The study however discovered that when timber pieces are damaged, they could be easily repaired. Also timber structures are easy to remodel or alter.

2.9.2 Timber Species for Construction of formwork and scaffold

Studies have shown that, there are over 300 timber species that have been identified in Ghana and grouped into primary and secondary species. According to Okoh et al (1977), the classification into primary and secondary species is intended to help users of timber to become aware of the highly competitive species and the less known ones which are also very suitable for construction. For lack of ideas about the lesser known species, no one goes for them. The studies revealed that the primary species are made of about 14 major species of economic value which are linked to export potentiality, while 12 species are of lesser economic value. However most of the lesser economic value species are very durable timber, but their properties are not known, so they are not well patronised locally.

On the other hand, the secondary species of timber is made of 23 species of future economic value. However over 200 species in this category are not well known, as their properties are still under various studies. Unfortunately, these large varieties of lesser known timber species are the ones in abundance and not being used. The fact that their properties are not known has caused their exploitation to the background. It is this situation that has created the over reliance of construction works on a few timber species. It is possible that these lesser known timber species have the potential of being a great source of materials for the building industry in Ghana. The situation on the sites, where all construction requests for timber for formwork and scaffold construction is depended on only Obechie (wawa). The continuous over reliance on wawa for construction of formwork and scaffold on the sites of especially medium and small scales can be reversed, if a second look is taken at the lesser known but potentially suitable timber species for construction.

2.9.3 Timber Utilization for Construction

Knowledge of Timber technology is a perquisite for timber utilization globally. Getting to know much about timber can help in making well-informed choices about its usage. Walton (1995) stressed that the knowledge of the two main types of wood into softwood and hardwood is very necessary.

He therefore outlines the main features and general characteristics of softwood and hardwood. Since wood is used at various stages of construction, Walton believes that the following analysis will provide a good working knowledge of the type of woods.

Softwood

- They have an open grained texture, which is easier to work on than hardwood.
- They have a lighter colour than hardwood.
- The timber they provide needs to be protected from the weather by paints, varnish or preservatives.
- They also need to be protected from insect attack (on the structural timbers)

Hardwood

- They are harder to work with hand tools than softwoods.
- They are darker in colour or have distinctive colours.
- They are more expensive to use for timber.
- They are usually left undercoated except for varnish or polish.

2.9.4 Sustaining the Utilization of Timber for Construction

As to how timber utilization for construction can efficiently be ensured, Barrit(1994), identified two main considerations which he stressed are very necessary. He sees seasoning and preservation as the key to enable successful use of timber in any construction situation. Seasoning of timber makes the timber piece workable and prevents it from defects in service like warping, twisting shrinkage and others. Preservation of timber is intended to maintain the service condition of the timber piece thereby preventing any changes on moisture content due to its exposure. He therefore recommended impregnation and surface coating as reliable preservation methods suitable for timber use for construction works. Normally the defects associated with timber affect their efficient use. However, the consideration of the defects and how the could be corrected, will ensure an economic use of timber pieces in construction. For study, Barrit's discoveries are useful and relevant. The timber pieces used for formwork and scaffold are exposed and expected to function under the effect of rain and sunshine. This condition is likely to affect the strength of the timber pieces and their effective function. The piece may possibly decay and get discarded. Also the effect of the atmosphere through defects could shorten the service life of the timber.

According to Taylor (2000), a well seasoned and preserved timber has the potential to withstand the weather when in use. Considering the conditions of formwork and scaffold, it has become imperative that Barrit's suggestion for seasoned and preserved timber for construction is a possible strategy.

2.9.5 Timber Utilization Asian perspectives

Lee et al (1993) observed that timber does not deteriorate spontaneously. It is possible that, timber could last indefinitely if not attacked by certain external forces. Though the causes of timber failures whether structural or non-structural are numerous, initial measures taken during procession is important. To this end, Lee et al, concluded that, if preventive measures are taken at the design, construction and post construction stages, efficient use of timber can be enhanced.

In their work, concerning timber utilization in the Asian sub-region of Singapore, Hong Kong and Malaysia, Lee et al (1993) analysed the importance of the following factors in enhancing efficiency of timber:

- Moisture Content of Timber: is considered to ensure that the moisture content is removed before the timber is used. Various forms of distortion will develop in timber when it is not seasoned before use.
- Mechanical strength of timber: is considered because it is affected by factors such as density, moisture content and grain structure. Features like density suggest how strong the timber is, as well as the thickness of the cellular walls and the growth ring is closer together.

Durability is an important issue when looking at uses of timber. Lee et al again identified physical factors like moisture, heat, radiation and mechanical wear which can affect the durability of timber, and explained as follows:

- Moisture: the atmospheric moisture whether in liquid or vapour form has the greatest effect on the durability of timber in external situations. Timber absorbs moisture becomes saturated and swells. This is followed by surface drying, which causes shrinkage and eventual opening up of timber grains during drying periods. The moisture then penetrates greater depths. It is this slow disintegration of the timber surfaces that cause decay of the inner parts of timber. This is a factor, which seriously affects timber structures like formwork and scaffold and subsequent spoiling and waste of the timber pieces.
- Heat: This reflects on dry heat which reduces moisture content and causes shrinkage. Evidence of this factor is seen as the splitting and cracking that occurs near the ends of boards and batter. It is this factor

which usually befalls timber pieces used for formwork and scaffold since they are exposed the heat of the sun.

Defects of timber

According to Lee et al (1993), defects occur in timber at various stages, mainly during its growth and during the conversion and seasoning processes. Defects as factors of durability can affect timber either by reducing its strength or marring its appearance.

Conversion defects of timber

The main methods of conversion namely: radial or quarter sawing, tangential or plain sawing and slab sawing, are intended to produce appropriate size and shapes of timber pieces for use in construction. However inappropriate conversion methods can result in distortion of timber boards during seasoning. Conversion defects due to unsound milling practice or attempts to economise during conversion of the timber have resulted in the wasting of huge consignment of timber pieces on construction sites.

- **Seasoning Defects of Timber**

These defects are caused by movement which occurs in timber due to changes in moisture content. Excessive or uneven drying, exposure to wind, rain and poor stacking during seasoning can cause distortions in timber. Since seasoning defects are mostly irreversible and usually results in high wastage of timber, preventive measures are considered very important issues.

Lee et al (1993) also discovered that, in the Asian region, fungi attack has been a major cause of decay of timber. As timber use for construction works come into contact with moisture and therefore liable to fungi attack, Lee et al formulated very effective precaution. The following precautions helped in preventing timber used in construction from fungi attack and possible decay in the Asian region:

1. All timber used for building projects should be sound and well seasoned with moisture content not exceeding 20 per cent.
2. The timber must be kept dry while in use. It is for this reason that dampness in buildings must be avoided. If the timber should be in contact with moisture like formwork, special treatment should be given to the timber members.
3. The surfaces of the joints use in timber structures must be well treated and protected against moisture penetration.

2.9.6 Selection of Timber

Though timber utilization at specific stages is inevitable and can not be avoided, its selection is a major challenge Everett (1994). Site observations, revealed that, the choice for most timber pieces used especially for formwork and scaffold are not based on suitability. For this reason, timber pieces generally classified as off cuts are used to construct formworks and scaffolds, which is normal practice on most sites. The failure of such timber pieces and the huge pile of wasted timber pieces suggest that, timber selection can not be avoided, if efficient use is to be enhanced. Everett explained the importance of selection of timber is in every construction project in which they are used. He therefore suggested that, adaptation of selection factors will ensure efficient utilization of timber for all construction works including formwork and scaffold. These factors should depend on:

- The strength, moisture movements and dimensional stability of the timber spice
- Availability of the timber spices, sizes and sections (this various from place to place and time to line)
- For external uses: natural durability and ease of preservation.

2.10 Plastics in the construction

In recent times, new innovations concerning the use of materials in the construction industry have emerged. One of such materials gaining ground, and functioning well is plastic. According to Everett et al (1994), plastics have ranges of properties which make them a suitable choice for construction works. Further, plastics were identified as light in weight, have good strength and low thermal conductivity. Everett, however identified phenol laminate and melamine laminates as the most effective and successfully used plastics to coat timber surfaces for constructional works.

Evidence of plastics being used as construction materials has been established through observation on some D1 construction firm sites. In such cases, the boards used for the soffit and side of the formwork are surface coated with plastics. The surface treatment made the boards maintained their shape and also provided smooth plastic surface. Usually, ordinary timber boards used for formwork get spoilt by wet concrete passing through the wood fibre, swelling and drying shrinkage. The plastic surface therefore acts as a seal thus preventing any moisture transmission through the wood fibre. The surface smoothness of the boards also enables easy striking of the formwork as the board surface does not stick to the concrete surface.

The success of using plastic materials in construction especially in formwork construction is real. This was reflected in the concrete structures observed on Barbisoti and son's construction site at Okomfo Anokye teaching hospital, Kumasi and K+H construction firm's college of engineering complex block project site at Kwame Nkrumah University of Science and Technology Kumasi. Apart from the good quality of concrete products, there is the ensuring evidence concerning the boards being used again. According to the personnel of the two firms, the boards coated with plastics do not undergo any change or transformation when in content with wet concrete. These boards are constantly used for the formwork soffit and side. They are never wasted through twisting or warping. The repetitive use of such timber pieces suggest that plastic can be effectively used to ensure efficient use of timber for formwork. The site evidence of the outcome of plastics materials on the two sites visited affirms the findings of Everett et al (1994).

In analysing the effectiveness of plastics in Construction, Everett (1994), noted that it is a capable material. The ability of plastics to resist passage of moisture, makes them good choice for use in the construction of formwork and scaffold. For instance, the use of a plastic material as formwork sheeting or in combination with timber pieces can give a good result. This is due to the fact that the plastics do not corrode and will generally resist most chemical normally encountered in building work.

2.10.1 Improving timber with plastics

There are various means by which plastics could be used to enhance the efficiency of timber in the building industry. Everett et al (1994) and Taylor (2000) did extensive studies on possible means by which plastics can be used in the construction of some building structures. The results of their findings have started gaining grounds, as most building firms in England and Germany who previously use only timber, now prefer those with plastic combination. Some of the means by which timber can be improved with plastic products for efficiency have been identified as:

- Timber products of the various sizes are impregnated with plastic resins and subject to heat and pressure. By this process, the products become highly impermeable to moisture movement. Timber members treated in this way are being used for formwork, scaffolds, hutments and floor.
- The edges and sides of timber products are lipped with a thin layer of plastics to provide basis for fabrication between the pieces.
- Speed frame systems are formed like tubes which are designed to fit timber pieces to form joints.

2.11 The use of Metals in construction.

Site surveys of materials used for formwork and scaffold construction showed that, timber and metal are suitable. Between the two materials, timber is the most predominantly used on sites. This is because, timber in general, is in abundance and easily accessible to the construction firms. Metals on the other hand are the most suitable material for formwork and scaffold construction. This is in view of the fact that metal as a material; possess properties that can make its products withstand the conditions of usage (Walton 1995). Despite its advantage over timber in terms of strength and durability, metal is too expensive for every category of construction firm to use. From this point of view, it has become clear that, the D1 construction firms are financially resources and are the ones who use metal; for formwork and scaffolds on their sites. The scene on some D1 c sites in Kumasi Metropolis is a clear manifestation of the situation.

Taylor (2002) confirms that, the suitability of metals for construction works is based on several properties and characteristics they possessed. He therefore summarised the properties of metal by emphasising that, they possess high compressive and tensile strength and are very durable in construction works. Among the applications for metals that he identified are:

- Steel frames and angle plates for roof structures.
- Square, rectangular circular tubes for scaffold and props for formwork.
- Sheet metals for soffit and sides of formwork.

2.12 The use of metals to prefabricate timber structures in construction

According to Son et al (1993), Walton (1995), Seeley (1987) and Chudley (1983), metal is the most suitable material for formwork and scaffold. For instance, many years of the use of framed scaffolds in construction firms in Europe and across the world have been very successful. For this reason, metal remains an undisputed material for effective and efficient construction of formwork and scaffold.

However in most areas of Africa and Asia where timber is in abundance, excessive consumption including the construction of formwork and scaffold on sites is depleting, the forest resources. Son et al (1993), in their research on reducing over reliance on timber for formwork and scaffold, discovered the possibility of combining timber with metal to ensure efficiency through prefabrication. They therefore formulated the following methods of prefabricating timber pieces with metal to enhance economic use of timber in Singapore:

- Using metal fish plates to connect new and existing sections of timber with the aid of thread rod and nut. This can promote frequent use of the timber pieces without any difficulty. The use of nails will cause a split to the edges of the piece rendering it not good for use again. The diagrams of figure 2.12 show some effective methods of joining timber pieces without nailing.

- To reinforce the timber pieces, Son et al (1993), devised that, steel plates are inserted into the timber pieces. Then holes drilled at noted spots to enable the use of bolts and nuts with ease. As shown in the diagram of figure 2.13, the use of bolts and wing nuts can enhance the effective strengthening of timber pieces. The use of bolts and nuts will not have any adverse effect on the timber pieces.
- To enhance effective formation of joints between timber boards, the edges and ends are lipped with metal sheet. By this method, the splitting of the timber pieces at ends and edges are prevented.

The use of steel hangers or steel angle plates can serve as a useful support for the ledger, transom or putlog when constructing a timber scaffold. The holes through the hanger or plate and timber piece can be used several times to erect and dismantle the bolts through the hanger timber can be tightened with nuts.

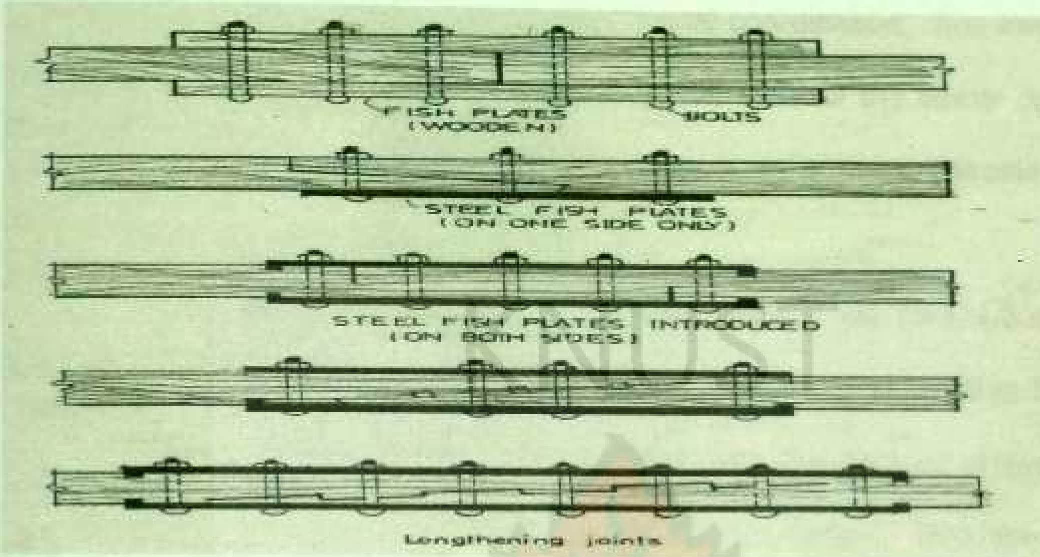


Figure 2.12 methods of using different types of metals plates, bolts and nuts to join timber members.

Figure 2.13 Bolt and wing nut as a method of joining timber pieces.

2.13 Dimensional Coordination of Timber Members:

One of the main factors which contribute to inefficient use of timber for formwork and scaffold is lack of dimensional coordination. Site investigations of temporary timber structures revealed that, most of the timber pieces used are of irregular shapes and dimensions, and as a result become damaged after striking, and can not be reused.

In the construction of the structures, timber pieces are continuously wasted due to lack of dimensional co-ordination. This trend of wasting the timber, continued as local builders believe that, once the desired project is done without any dimension co-ordination, it does not matter. Also, the prevailing practice of buying new consignment of timber for every project has a negative effect on any dimensional consideration for timber members. Chudley and Greeno (1998) identified Modular coordination as a model that can be defined as a basic dimension, which could form the basis of planning the grid for standards. They further emphasised that, Dimensional coordination as a practical concept, can enhance efficiency through:

- Sizing components so as to avoid the wasteful process of cutting and fitting on site.
- Obtain maximum economy in the production of
- Reduce the need for the manufacture of special sizes.
- Increase the effective choice of components by the promotion of interchangeability.

2.14 Design concerns for formwork and scaffold

According to Ostrowsk (2004), the frequent collapsing of temporary structures, especially during formwork and scaffold Construction are due to ineffective design considerations. The high risk of serious injuries, death and substantial property loss clearly suggested the short comings of design for such structures. Clearly the design of such structures is a critical function. He therefore, stressed the need to always consider the essential elements of design and construction of these structures to ensure efficiency. The following principles that he generated to guide the designing of all types of temporary structures is very important

- Allowable stresses vs. limit states design be seriously noted
- Performance criteria, safety, strength, tolerance, cost efficiency must all influence the designing
- Strength, stability and serviceability requirements, must be the checklist for designing and construction
- Short versus long, -term exposures, wind, soil and hydrostatic, material storage etc. be central to the general requirements for efficient design and construction.
-

Considering the waste of timber for formwork and scaffold construction especially on the medium and small scale sites, the design concerns expressed, can bring great relieve. If the design principles are adopted and practice, the prevailing waste of timber on the sites in Kumasi can reversed. Also Ostrowsk's further suggestions that, Formworks and scaffolds are so important and central to the success of construction works that, their design issues should never be ignored. To keep the constructions in touch, he called for an annual programme, which should be held to address issues on temporary structures in general and in particular formworks and scaffolds. An attempt to have a similar programme in Ghana can have far reaching effects on efficient timber utilization in construction in Ghana.

2.15 Cutting of Timber Members

Cutting of timber pieces for all types of construction works need to be co-ordinated to avoid irregularities in shape. Walton (1995), in his studies, acknowledged the importance of cutting timber pieces according to the required sizes and shapes. In his opinion, conversion of timber at the initial stage helps in deciding the purpose for the resultant timber. Knowledge of the different methods of conversion of timber is a necessary factor when considering timber for construction purposes like formwork and scaffold.

Studies have showed that, close observation of the various types of timber pieces in their full length is very important. The presence of the different type of pieces will ensure appropriate selection of timber piece thereby avoiding irregular cutting. One main problem about the cutting of timber members has been the tendency to substitute any type of timber piece in the construction of formwork and scaffold. Any irregular piece cut to substitute the normal size piece will eventually become wasted. As the work progresses, the compilation of these irregular timber pieces off cuts contribute to the huge piles of timber waste seen on most sites. There is a close relation between factors like poor designing, cutting and sizing of timber members in the construction of temporary structures. This is because the negative result of these factors, narrow down to timber wastage. The practice of irregular cutting of timber members for formworks and scaffolds is on the increase on sites. The results of this activity, is the huge volume of timber pieces being wasted after using them for the structures. This situation posses an economic issue which need to be seriously addressed.

2.16 Sizing of Timber members

Walton (1995) suggested that, timber members meant for any particular structure should be sawn into standard size pieces. He observed that, sizing of timber members is an efficient means of using timber. In obtaining timber pieces for formwork and scaffold construction, lack of proper sizing of the parts, has contributed to the rejection of the pieces for reuse. The situation on the D3 and D4 sites in Kumasi, where most timber pieces are discarded, can be attributed to improper sizing. A close examination of most rejected pieces indicated that, they were not sized before cutting, hence the irregular shapes. Walton again, suggested that, there are certain processes which can render the sizing of timber more efficient. These are:

- Ensuring the timber is well seasoned i.e. as this will take care of the possible defects like warping, twisting and others.
- The converting of log into expected size should be done to have the pieces properly shaped.
- The preservation of timber should be considered, to ensure that, the sizes are maintained in constant shape. The preservations are in twofold:
    - Treatments to resist attack by rot fungus and wood eating insects, which most often render the pieces useless.

- Treatments such as paint; polish or varnish is to protect the timber from moisture and pollution.

The application of the processes as suggested by Walton is relevant towards devising efficient use of timber for formwork and scaffold in Ghana. Though correct sizing of timber pieces is good, the service condition of the timber piece retarding exposure can deteriorate it to become a waste. Keeping the sizes and shapes of timber pieces through the preservative processes will enrich quality of the pieces. The adaptation of sizing of the pieces in the construction of formwork and scaffold on sites in Kumasi, can lead to a drastic reduction in timber waste. However, the preservation can make the pieces to give a long term service.

CHAPTER THREE

3.0 RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the instruments and methods used to gather information for the research. The research aims at developing efficient means of utilizing timber for formwork and scaffold construction in Ghana.

3.2 The Survey of Construction firms and Sites

The methodology started with a two week reconnaissance survey which was planned and conducted on construction firms and sites situated within Kumasi metropolis. The purpose of the survey was to enable the researcher to identify the relevant populations for the study. First, a visit was undertaken to the development section of Kumasi Metropolitan Assembly to enquire about the number of registered construction firms operating in the metropolis.

Information from the K.M.A revealed the different types of construction projects in progress and the classification of the construction firms (i.e. D1, D2, D3 and D4). In addition, information from the development section of K.M.A assisted the researcher to locate the offices of the various construction firms within Kumasi. From the offices, the project sites were easily located and visited. Construction sites that have formwork and scaffold work at the period of the study were visited.

The formwork and scaffold construction on the sites visited were observed and studied. This involved the study of the construction methods employed by the D1, D2, D3 and D4 construction firms. Methods employed by the construction firms to strike formworks and dismantle scaffolds after use and how these are kept for reuses were also studied. Pictures were taken of these structures in use, and striking of the timber members after use.

Among the personnel identified were; project consultants, site engineers, clerk of works, foremen and headmen. Their supervisory roles in the construction of formworks and scaffolds were enquired into, to enable the researcher have an insight into their working activities.

During the survey, timber supplies to the construction sites for formwork and scaffold construction were examined. This was done to find out the quantity of timber used for formwork and scaffold. The survey also helped to identify the various sizes of timber pieces and shapes used at the sites. From the survey, it was possible to examine by measuring some of the pieces to verify if the sizes correspond with what is stated on the schedule. Where schedule on timber sizes and dimensions were not available, the researcher prepared one and filled it with the assistance of the foreman. Also the cross-section of the timber pieces was examined to see whether the shapes were regular or irregular.

3.3 Sampling and Sample Sizes

From the two weeks survey of construction firms and sites, it was possible to identify the relevant populations which would help in addressing the issues regarding efficient use of timber for formwork and scaffold construction. The following were identified for the collection of the research data:

- Construction firms in Kumasi.
- Construction sites.
- Timber species used for formwork and scaffold.
- Timber sizes and dimensions used for formwork and scaffold
- Project Managers involved in formwork and scaffold construction.
- Project consultants involved in formwork and scaffold inspection
- Site Engineers involved in supervision of formwork and scaffold construction.
- Foremen involved in the supervision of formwork and scaffold construction.
- Carpenters involved in the construction of formwork and scaffold.
- Institutions involved in timber preservation and utilization.

The sampling method used for the study is the stratified random sampling. This choice was based on the fact that the study involved construction firms which are in four classification groups of D1, D2 D3 and D3 and D4. These four classes of construction firms vary in sizes, practices of organisational structures and are of different financial standing.

Considering the size of Kumasi metropolis and the number of different construction firms of the various classes, there is forty five firms with sites in the metropolis were selected as shown in table 3.1.

For the D1 construction firms, eleven of them were groped into five and one firm randomly selected from each one of the five groups. The fifty D2 construction firms in Kumasi metropolis were grouped into five and two firms randomly selected from each of the five groups. One hundred and fifty D3 construction firms were identified by the researcher and grouped into fifteen groups and one firm randomly selected from each of the fifteen groups. For the D4 construction firms, three hundred were identified but due to the fact that the practice of firms in this class is the same, fifteen of them were randomly selected.

Table 3.1: Classification of Construction Firms (Contractors)

Class of Firm	No. of Sites selected	Percentage
D1	5	11.1%
D2	10	22.3%
D3	15	33.3%
D4	15	33.3%
Total	45	100%

The study also covered all categories of personnel who play supervisory roles in the construction of formworks and scaffolds within the D1, D2, D3 and D4 firms, as indicated in table 3.2.

firms use wawa mostly to construct formwork and scaffold. Due to high demand for wawa and coupled with limited supply, other species are occasionally used. These other timber species are lesser known and used for the construction of formwork and scaffold. As shown in table 3.4, these species have been identified to explore their suitability as good substitute for wawa

Table 3.4: Timber Species used for Formwork and Scaffold Construction.

Class of firm	Timber species				
	Wawa	Bamboo	Onyina	Afina	Coconut
D1	√	√	-	-	-
D2	√	√	√	√	
D3	√	√	√	√	√
D4	√	√	√	√	√

The construction of formwork and scaffold involved the use of different sizes of timber pieces. These sizes are very important in the construction of the desired shape of either formwork or scaffold. The content of table 3.5 shows the various sizes of timber pieces used to construct scaffold and formwork.

Table 3.5: Timber Sizes used for the Construction of Formwork and Scaffold

Type of Work	Sizes of Pieces						
	25 x 300 (mm)	25 x 200 (mm)	50 x 50 (mm)	50 x 75 (mm)	50 x 100 (mm)	50 x150 (mm)	25 x25 (mm)
Formwork	√	√	√	√	√	√	√
Scaffold	√	√	√	√	√	√	√

Apart from the personnel directly involved in construction on sites, institutes whose roles are related to the study were also selected. These institutes are: Building Road and Research Institute (BRRI), Forestry Research Institute of Ghana (FORIG)and Busi and Stephens Timber Treatment Plant as shown in table 3.6.

Table 3.6: Institutions involved in timber preservation and utilization

Name of Institution	Types of Role
Building Road Research Institute	Timber utilization i.e. permanent and temporary structures.
Forestry Research Institute of Ghana	Determining mechanical properties of timber species.
Busi and Stephenson Ltd Timber Treatment centre	Timber preservation e.g. impregnation

3.4 Data Collection Instrument

Data for the study were obtained from two main sources; namely the primary and secondary sources. The primary sources are the structured, unstructured interviews, general observations and examination of the formworks and scaffolds on sites. On the other hand, the secondary sources of information for the study are the systematic questionnaire, literature, laboratories and documentary searching. The objective for combining both the primary or participatory processes with the secondary sources of questionnaire and literature is to make use of all advantages and to minimize their respective weakness.

3.4.1 Interviews

Both structured and non-structured interviews were personally conducted face to face with the site engineers, foremen, artisans directly involved in the construction of formwork and scaffold.

The structured interview was developed to seek specific information from site engineers, project consultants, managers, supervisors and contractors about their roles in the construction of formworks and scaffolds the sites selected for the study. The interview reflected on issues concerning materials selection, supervision of work regarding designing, construction, dismantling of the structures after use and general classification of timber pieces as good or bad for repetitive use.

In their view, Bell (1997) and Cohen et al (1995) are inclined to the effectiveness of the structured interview since it is one in which the content and procedures are organized in advance. They contended that it can take the form of a questionnaire or checklist which is completed by the interviewer.

On the non structured interview, the group of personnel who are directly involved in the construction processes of the structures on the sites identified and visited, were deem appropriate. The group consists of foremen, artisans or carpenters on the site. The suitability of the non structured interview stems from the fact that the construction of formwork and scaffold on going and issues which come up unexpectedly could be addressed.

Table 3.2: Categories of Personnel who play supervisory roles in the Construction of Formwork and Scaffold.

Type of Firm	Categories of Personnel						
	No of projects	Project Consultancy	Site Engineers	Clerk of Works	Foremen	Headmen	Total
D1	5	5	5	5	5	10	35
D2	10	10	10	5	5	20	60
D3	15	-	15	8	15	15	53
D4	15	-	-	-	10	15	25
Total	45	15	30	18	35	60	173

Carpenters are the personnel who carry out the construction of formworks and scaffolds. Table 3.3 shows the number of carpenters selected for the four classes of contractors operating in the metropolis.

Table 3.3: Carpenters involved in Construction of Formwork and Scaffold

Class of Firm	No of Projects	No. of Carpenters	Percentage
D1	5	20	16.7%
D2	10	40	33.3%
D3	15	30	25%
D4	15	30	25%
Total	45	120	100%

The construction firms used variety of timber species to construct formwork and scaffold. Within Kumasi metropolis the D1, D2, D3 and D4 construction

Though time consuming, the specific roles, expectations and opinion of each stakeholder was taken note of. Through the non structure interview, the concern of the study which is about timber wastage and the aim to reduce waste through efficient means was laid bare to the interviewees. Contributions in the form of their responses to issues raised are worthwhile for the study.

3.4.2 Visits and Observation

The personal visits and observations were undertaken to the sites that have been identified and chosen for the sampling of the large, medium and small scale construction firms within the Kumasi metropolis. Initially, the visits were undertaken to the sites to review the types of formwork and scaffolds being used on the sites. This formed the basis upon which the subsequent visits were made. The following were the schedules for which the visits and observations were made:-

- Identification of the type of structures being constructed and pictures taken of them.
- Observation of the type of timber used for the structures: the species and quality and species being used.
- Observation of the construction methods employed to construct formwork and scaffold and pictures taken. This included the joints sizing and cutting of the timber pieces.
- Observation of the method of dismantling after and storing after the use of the formwork and scaffold.
- Visit to consider the amount of waste.
- Observation of the attempts made for re-use of the timber members.

3.4.3 Questionnaires

Questionnaires were administered to institutions including (I) Building and Road Research Institute (BRRI), (ii) Forestry Research Institute of Ghana (FORIG) and (iii) Busi and Stephenson Limited Timber Treatment Centre, Kumasi. These institutions were selected based on their general functions and specific roles linked to the use of timber in the construction Industry.

The issues in the questionnaire refer to:

a) Knowledge of construction methods for formworks and scaffold.

b) Problems associated with the construction formwork and scaffold.

c) Personnel and experience needed in the construction of formworks and scaffolds.

d) Use of timber for the structures.

e) Techniques for non-destructive stripping of formwork and scaffold.

f) Design considerations for formworks and scaffolds.

g) Incorporation of other materials such as metals and plastics for wooden formwork and scaffold construction.

h) Pre-fabrication of timber members for the construction of formworks and scaffolds.

The questionnaires were developed to allow the respondents the opportunity to express their opinion on the issues as well as select the responses from the options.

3.5 Assessment of Suitability of Formwork and Scaffold for reuse after first usage

The condition of the formwork and scaffolds on the site were assessed. The assessment was conducted in twofold. The first part involves, close observation and examination of the structures during the construction process. This included the cutting, shaping and jointing methods for the formwork and scaffolds. Irregularities in cutting of timber pieces and shapes were examined from site strength and function ability was examined.

The second part of the assessment of the formworks and scaffolds was based on the condition of the structures after use. On sites that the structures have already been used, the formwork and scaffold component parts were assessed to clarify the state of the timber pieces. Deformations like splits, twists and bow, were closely examined. The condition of formwork and scaffold members were then classified as good or bad using the following criteria.

- A. **GOOD** implies that the timber pieces have the following characteristics after use:
    - Maintain their original shape and sizes after use.
    - Surfaces and angles are devoid of rupture.
    - Show no distortion across the section of the piece.

For the timber pieces to be classified as being in bad condition and cannot be reused; the pieces should have the following characteristics:

B **BAD** implies that the timber pieces have the following characteristics after use:

- Original sizes and shapes are distorted after use

- The entire surfaces of the pieces are punched due to moisture movement and striking.
- The pieces are twist and bow along the length.

3.6 Determination of Strength Properties of Samples of Timber Species used for Formwork and Scaffold

To verify the strength properties of the different types of timber species used for formwork and scaffold construction, twenty samples each of wawa, odum, dahoma and kusia, Teak, Afina Oniyna, Makore, Esa and Coconut were selected. The wood samples were prepared based on BS 373:1957 methods of testing small clear specimen of timber at Forest Research Institute of Ghana,(FORIG) Fumesua. The strength tests conducted were modulus of rupture (MOR), modulus of elasticity (MOE), shear parallel to the grain and compression parallel to the grain.

The number of samples, species and dimension of the test specimen are shown in Table 3. 7

Table 3.7: Number of samples and dimensions of test specimen

	Speciment of Timber										Dimension(mm)		
Test	Wawa	Odum	Dahoma	Kusia	Kaku	Afina	Onyina	Makore	Esa	Potrodo	W	D	L
Bending	20	20	20	20	20	20	20	20	20	20	20	20	20
Compression	20	20	20	20	20	20	20	20	20	20	20	20	20
Shear	20	20	20	20	20	20	20	20	20	20	20	20	20
Total	60	60	60	60	60	60	60	60	60	60	-	-	-

Immediately after the preparation of test specimen, all strength properties were determined on a Universal (Multiple) 50 ton Avery machine. The straining rate of Modulus of Elasticity (MOE) and Modulus of Rapture (MOR) was 0.26 in/min while shear and compression were each strained at the rate of 0.025in/min. After loading of each sample test, the load that caused each wood sample to fail was recorded and the sample was immediately placed in polythene to prevent moisture content changes.

The moisture content of each wood sample was immediately determined after the strength test. Small portions of wood samples (2cmx2cmx2cm) near the portion of rupture (of test pieces for MOR) were used to determine the moisture content. However the whole test piece for compression and shear strength parallel to the grain were used for moisture content (MC) determination. The moisture content of each specimen of a particular test conducted was recorded with the results of the particular test to which it refers. The strength values at various MC were converted to strength values at 12%mc. The already existing results on strength properties of timber species at FORIG, were used to cross check the results of the experiment.

3.7 Experiment to Determine Durability of Timber Samples Through Impregnation

Literature on impregnation suggests that, it is one of the possible means to ensure high strength and durability of timber. To determine the service life of different species used for formwork and scaffold, 120 samples each from Wawa, Odum, Dahoma, Kusia, Kaku, Afina, Onyina, Makore, Esa and potrodom were prepared according to specification as shown in table 3.8.

Table 3.8: Number of Samples and Species for impregnation

Test	Species of Timber and Number of Species										Dimensions(mm)		
	Wawa,	Odum,	Dahoma,	Kusia	Kaku	Afina	Onyina	Mokore	Esa	Potrodom	Width,	Depth	Length
Impregnation (Full Cell Process)	120	120	120	120	120	120	120	120			120	120	300

After preparing the test specimen, the impregnation plant was set in place for the operation which is also known as full cell process. The impregnation process involves four main stages through which a durables service life of the timber specie can be assured. The diagram of figure 3.9 shows the four processes involved in the impregnation process.

Table: 3.9: Four Processes of Impregnation of Timber

Vacuum Stage — Flooding Stage — Pressure Stage — Final Vacuum

The ten different types of timber species were separately impregnated employing the four stages of the full cell processes as shown in figure3.9. Ten days were used for the experiment with one day allocated for each of the ten species. The ten timber sample species were separately impregnated with the chemical, Chromated copper Accinate (C.C.A).

Table 3.10: Rate of Vacuum and Flooding Process of Impregnation for different Timber species.

Timber Species	Scientific/Botanical Names	Vacuum Stage	Flooding Duration
Wawa	Truplochiton scleroxylon	12 ins per mercury/25mins	15mins
Odum	Chlorophora excelsa	22 ins per mercury/1hr	25mins
Dahoma	Piptadeniastrum Africanum	20 ins per mercury/11 hr	18mins
Kusia	Nauclea diderrichii	18 ins per mercury/35mins	18mins
Kaku	Lophira alata	18 in per mercury/30mins	20mins
Afina	Strombosia glaucescens	19 in per mercury/28mins	16mins
Onyina	Ceiba pentandra	20 in per mercury/32mins	20mins
Makore	Tiegliemella heckeli	16 ins per mercury/30mins	17mins
Esa	Celtis mildraedii	18 in per mercury/28mins	22mins
Potrodom	Erythrophleum africanum	15 ins per mercury/30mins	17mins

Vacuum Stage:

The tank was closed tightly and all entry tubes sealed except the section pump. The pressure of the section pump was operated at different rates of ins of mercury for each of the timber species as shown in table 3.10. For the respective species, the vacuum pressure was applied to make the wood devoid of moisture. Table 3.10 also shows the rate of vacuum and flooding process of impregnation for different timber species.

Flooding Stage:

This is the second stage of the impregnation process. During this operation, the suction pump used for the vacuum was sealed. The valve leading to the chemical (C.C.A) Chromated Copper Accinate was released to fill the tank. The duration of the flooding stage varied according to the type of timber species as shown in table 3.10.

Pressure Stage:

The pressure stage involved the use of the pressure to fill the timber samples with the chemical C.C.A. The pressure rate at which the timber samples were filled with the chemical is 28ins of mercury. However, the duration for the pressure varies according to texture and density of the timber species. Table 3.10 shows the rate of pressure per duration of the various species.

Final Vacuum Stage:

This is the last stage of the impregnation process. The pressure that is applied results in the draining of excess chemical of the impregnated timber specie. A uniform pressure rate of 5ins per mercury was applied during the turn of each of the four species but the duration varies from specie to species as indicated in table 3.10.

Table 3.11: Rate of Pressure and Final Vacuum Processes of Impregnated per Type of Timber

Timber Species	Pressure Impregnation	Final Vacuum
Odum	28ins per mercury/4hrs.	5ins per mercuy/15mins
Wawa	28ins per mercury/2hrs.	5ins per mercury/5mins
Dahoma	28ins per mercury/2hrs.20mins	5ins per mercury/8mins
Kusia	28ins per mercury/2hrs.10mins	5ins per mercury/5mins
Kaku	28 ins per mercury/2hrs 30mins	5in per mercury/10mins
Afina	28 ins per mercury/2hrs 40mins	5ins per mercury/8mins
Onyina	28 ins per mercury/2hrs 35min	5ins per mercury/8mins
Makare	28 ins per mercury/2hrs 50mins	5ins per mercury/8mins
Esa	28 ins per mercury/2hrs 25mins	5ins per mercury/7mins
Potrodom	28 ins per mercury/2hrs 50mins	5ins per mercury/10mins

3.8 Suitability of plastic to coat Timber surfaces to enhance repetitive use

In considering efficient use of timber for formworks and scaffolds, another possible material to combine with timber is plastic. No doubt, in these modern times, plastic products have become the basic choice due to the wide ranges of properties they possess. Everett et al (1994), in their study, identify that plastics have ranges of properties for which they are suitable for construction works. Among the properties which make plastics suitable for construction are its good strength and low thermal conductivity.

To determine the suitability of timber pieces coated with plastics for formwork and scaffold, the researcher was involved in the trial use of such materials on the K+H construction site at KNUST, using the following procedures:

- The position for the concrete slab was identified and marked.
- The plastic coated timber pieces were sorted out to erect the formwork
- A formwork for column and beam was constructed using the plastic coated timber pieces to form the decking sides, the yokes etc.
- All the frames needed to brace the plastic coated pieces were affected.
- The internal surfaces were checked for sizes, shapes. The foreman and site engineer inspected the formwork and confirmed.
- The concrete was mixed and cast into the formwork to form the column and beam.
- After four days, the formwork was struck and the plastic coated pieces were well arranged for observation.

CHAPTER FOUR

4.0 PREFABRICATION OF TIMBER FOR FORMWORK AND SCAFFOLD

4.1 Introduction

This chapter discusses the prospects of prefabrication as an appropriate strategy to utilize timber economically to construct formwork and scaffold. Son et al (1993) concluded that, metals can be successfully combined with timber in construction works. The use of metals in conjunction with timber to pre-fabricate formworks and scaffolds has always ensured effective and easy construction, effective support and enabled easy striking with least damage to timber members. For instance, formworks for columns made of timber in conjunction with bolts and nuts are strong and durable.

4.2 Survey to verify pre-fabrication of timber for formwork and scaffold on construction sites.

To verify the possibility of combining timber pieces with metal units to pre-fabricate formwork and scaffold, the researcher participated in the construction of a column formwork and a scaffold, at the Consar Limited site at University of Education Kumasi Campus.

(A) The following steps were used in the construction of the formwork.

- The position of the column to be constructed was identified, measurement taken and set out. In this case, the setting out was done on the Kicker.

The timber members of the required sizes, length and shape were sorted out. The members identified were: the boards, scantlings, cleats, yoke, bolts and nuts, steel wedge and metal clamps.

- The edge and ends of the timber members had small groove provided were lipped with metal sheets which are shaped according to the sizes and shapes of the edge and ends.
- This was to ensure that, smooth joints are maintained.
- The timber pieces were assembled to form the required shapes and sizes of the expected columns.
- The positions for the applications of the yokes identified were provided and used to tighten up the formwork. This involved the use of bolts and nuts to tighten the joints at the edge of the boards and at the corners of the yokes.
- The column formworks were inspected and certified by the site Engineer and foreman and the concrete cast in.
- After four days, the formworks for the columns were struck by loosing the joints and the pre-fabricated timber members easily removed and well arranged and the researcher observed the pre-fabricated members used.
- The same prefabricated timber members were used on four occasions to construct formwork for columns and concrete cast.
- After each session of usage and striking the pieces were arranged and observed closely.

(B) For the erecting of pre-fabricated timber independent scaffold, the following steps were used:

- The stages of the project at that moment which required the erecting of scaffolds were identified.
- The foreman then consulted the site engineer concerning decision on what type of scaffold and which spots they are to be erected.
- Scaffold type decided on, is independent scaffold.

- Metal tubes constituting the frame of independent scaffold were sorted out and arranged according to their specific sizes, shapes and length.
- The metal hooks for joining the boards, angle plates with bolts and nuts for framing the angles, were all sorted out and arranged according to sizes and shapes.
- The positions for the various scaffold members for instance; standard, ledger etc were identified and marked. The researcher then joined the workers in erecting the pre-fabricated independent scaffold.
- The erected independent scaffold was used for one week during which the work to be done was successfully completed.
- The pre-fabricated timber pieces were dismantled and arranged according to sizes, shapes and length.
- The researcher was involved in the erecting of the pre-fabricated independent scaffold on four other locations on the site.
- Each time the scaffold was dismantled the pre-fabricated timber pieces were arranged and observed before next use.

4.3 Development of a prototype prefabricated timber pieces with metals to construct formwork and scaffold.

As a follow up to the trial construction of prefabricated formwork and scaffold which was undertaken at the Consar site, the researcher designed prefabricated timber members with metal angle plates, bolts and nuts for formwork and scaffold.

(A) For the formwork, a proto type prefabricated formwork for column was designed using the following steps:

- The shape of any given column was considered by deciding on different width sizes of boards e.g. 100mm, 150mm, 200mm and 300mm. With the different board width sizes, it will be possible to select any width sizes to design any column width.

- The edge joint of the boards is designed with metal angle plates with holes drilled through to enable bolts and nuts to be used to tighten the underside of the boards at intervals of 1.2 metres.
- The yokes which will be used to tighten up the formwork are designed 80X40 (mm) cross-section battens. They are up to the length of 600mm with slots provided at 50mm intervals to enable the erecting of any size of column ranging from 100mm to 400mm. The yokes are to be positioned at 1.2m height intervals

The diagrams of figures 4.1 to 4.4 show the designs of the prefabricated formwork for columns.

(B) The prefabricated independent and Jack scaffolds were designed using the following steps:

For the Independent Scaffold

The shape for the proposed design was considered by deciding on possible sizes of the standard regarding the height and cross section of the piece. The cross section size was 80 x 50(mm) and the height was up to 2.5metress with platform points at 1metre, 1.5metres and 2metres.

- The ledger was designed to have the same cross-section as the standard 80*50(mm) and the length up to 800mm with provision made for 600mm and 450mm width of platform.
- The distance between the standards was at 1.5 metres centres
- The base plate was designed to hold the standard in position with the aid of bolts and nuts to tighten up.
- The boards for the platform were designed to cater for any width size. Angle plates were designed to be fixed at intermediary points to tighten the boards using bolts and nuts.
- Bolts and Nuts are designed as the main jointing material.

For the Jack Scaffold

- The shape for the proposed design was considered by deciding on the size of the vertical and horizontal battens which are joined at ninety degrees.
- The cross section size was 80 x 50mm while the vertical and horizontal battens were designed to the length of 600mm.
- The design for the brace battens was also based on 80 x 50 mm. cross section.
- The angle plate was designed to secure the vertical and horizontal battens of the Jack in position at all times.
- The bolts and wig nuts are designed as the main joints instead of nail.
- The boards for the platform were designed to cater any with size.
- The angle plates for the boards will enable a secured joining of the boards. The diagram of figure 4.7 shows the expected design of a prefabricated Jack scaffold.

Figure 4.1 Pictorial view of the prefabricated formwork for column.

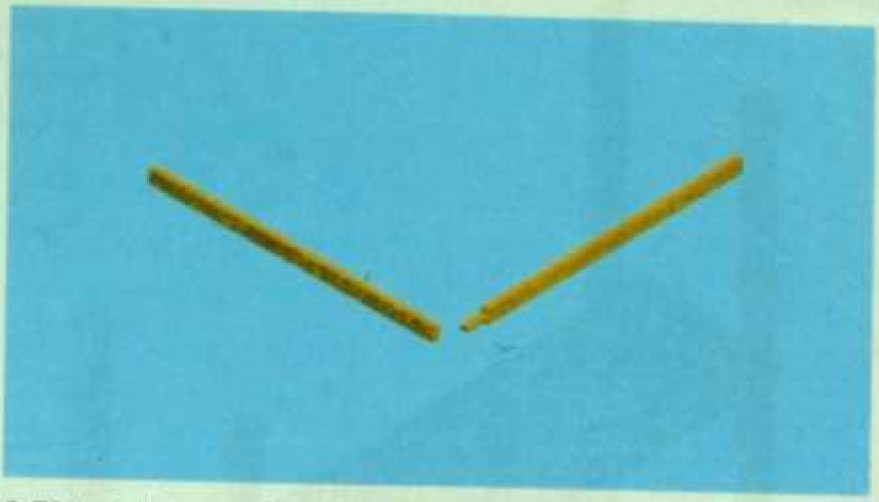
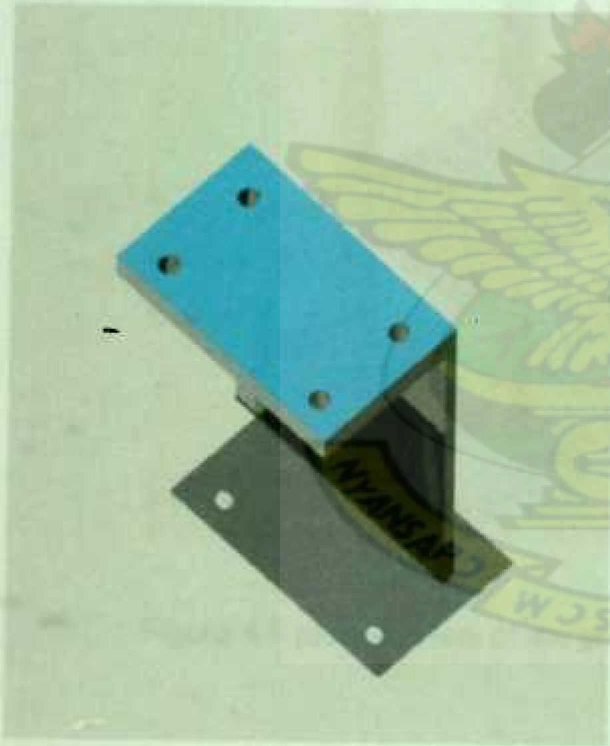


Figure 4.2 Pictorial views of prefabricated yoke of the formwork.



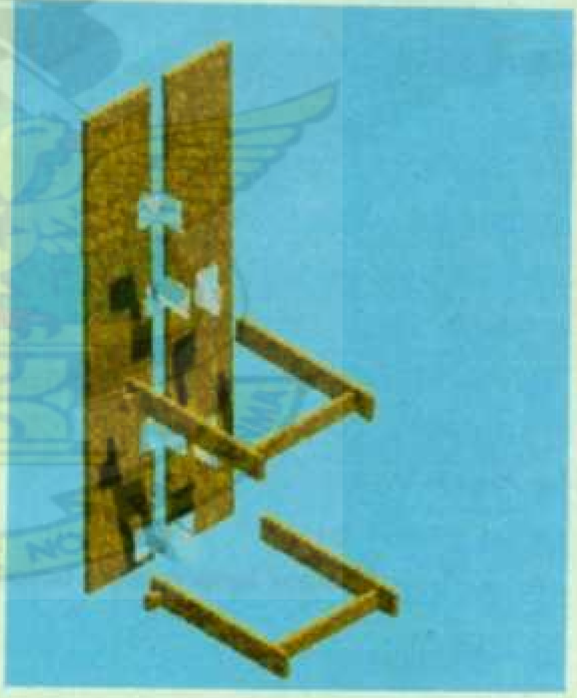


Figure 4.3 Angle plate for joining boards. Figure 4.4 view of formwork parts

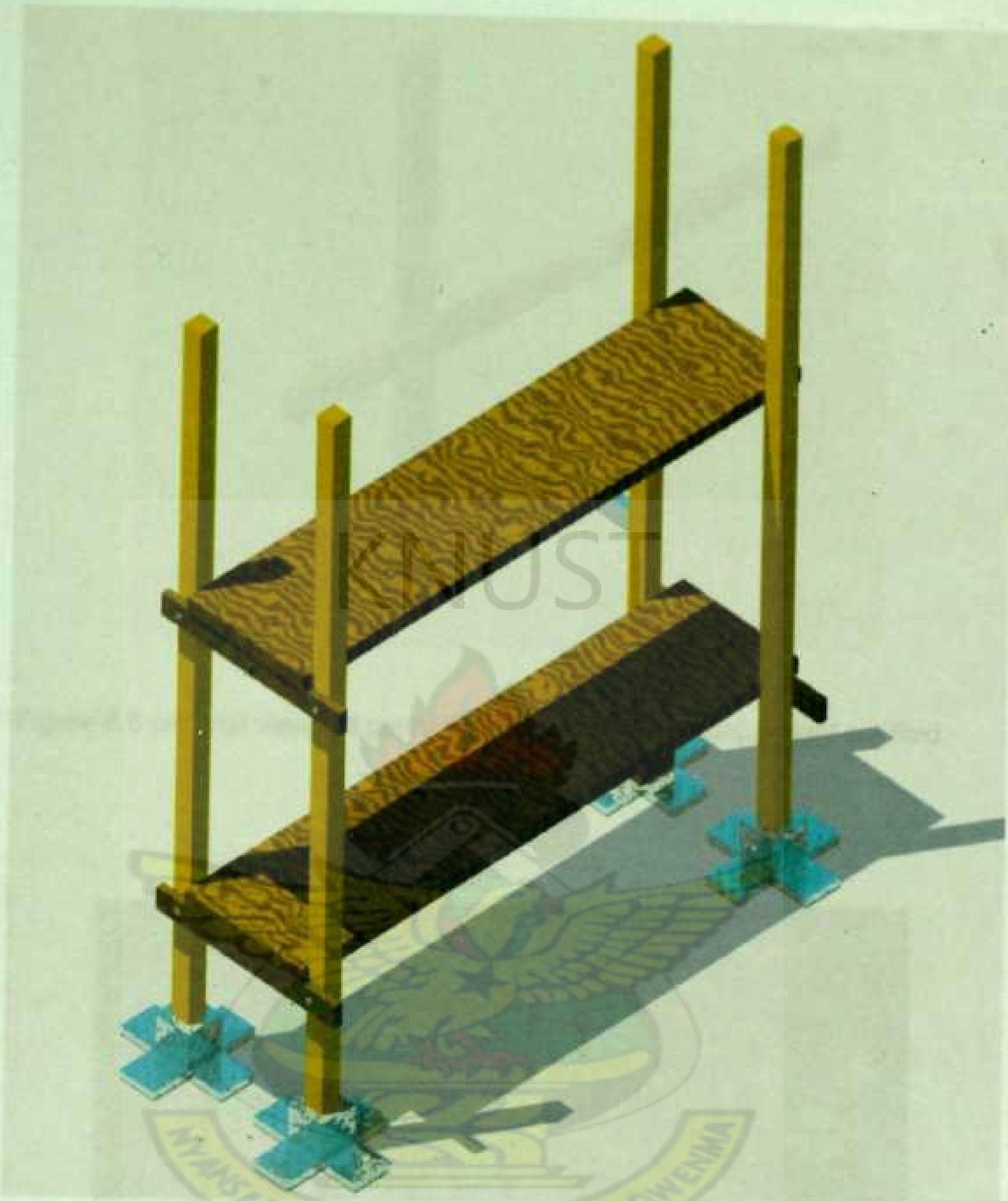


Figure 4.5 pictorial view of the prefabricated independent scaffold.

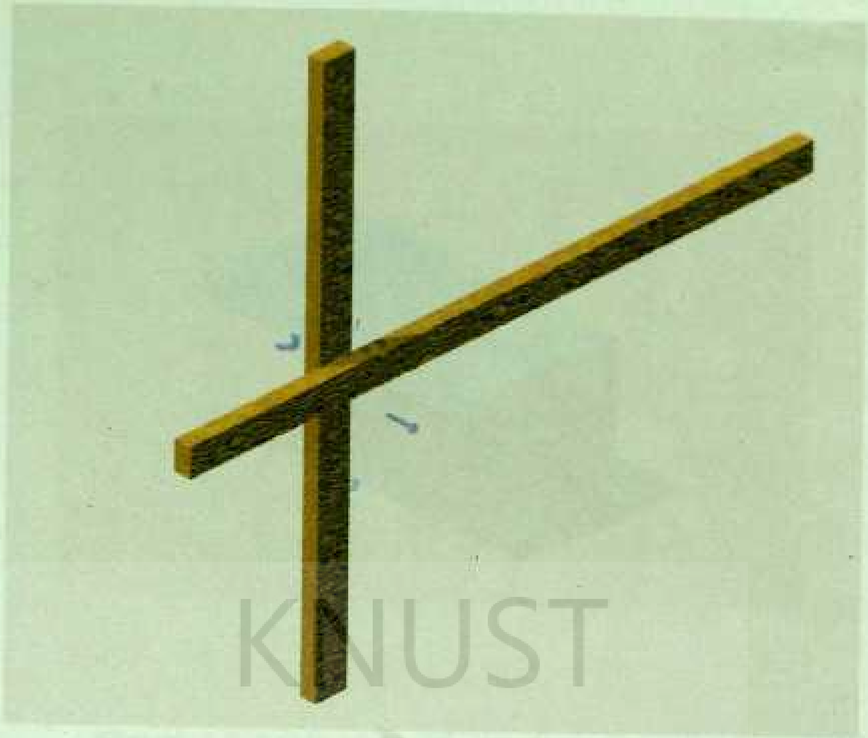


Figure 4.6 pictorial views of prefabricated parts of the independent scaffold.

Figure 4.7 Pictorial view of the prefabricated Jack scaffold.

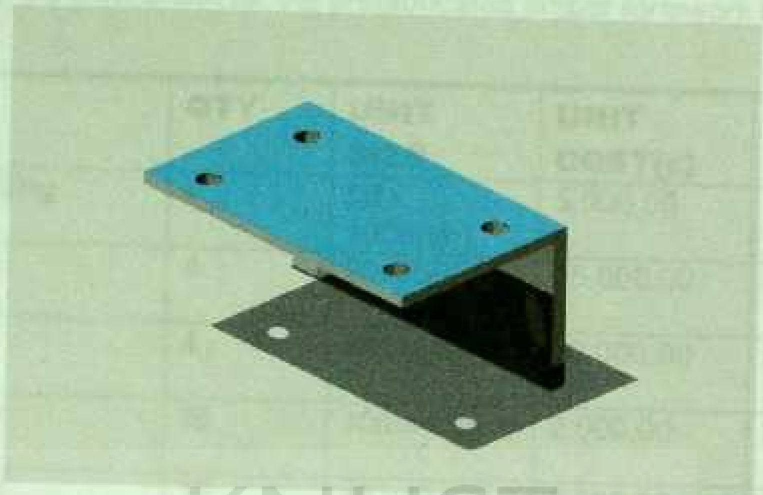


Figure 4.8 Angle plates for joining jack scaffold

Figure 4.9 Pictorial views of the prefabricated boards for the scaffold.

Table 4.1 Cost sheet for the prefabricated timber formwork for column

S/N	ITEM	QTY	UNIT SIZE	UNIT COST(¢)	TOTAL COST(¢)
1	yoke scantling	4	50 x 100(mm)	5,000.00	20,000.00
2	board	4	20x250(mm)	15,000.00	60,000.00
3	board	4	20x150(mm)	20,000.00	80,000.00
4	Bolts/Nuts	16	10mmDia	2,000.00	32,000.00
5	Angle plate	12	40 x40 (mm)	5,000.00	60,000.00
6	Bolts/Nuts	16	15mm Dia	3,000.00	48,000.00
7	Screws	1pkt	18(mm)	40,000.00	40,000.00
8	**SUB-TOTAL**				**340,000.00**
9	LABOUR				100,000.00
10	TRANSPORTATION				50,000.OO
11	TREATMENT OF PIECES				150,000.00
12	HANDLING AND PROCESSING OF WOOD				100,000.00
13	**SUB-TOTAL**				**400,000.00**
14	**GRAND TOTAL**				**740,000.00**

Table 4.2 Cost sheet for prefabricated timber jack scaffold

S/N	ITEM	QTY	UNIT SIZE	UNIT COST(¢)	TOTAL COST(¢)
1	Brace	2	80x50(mm)	20,000.00	40,000.00
2	Top piece	2	80x50(mm)	10,000.00	20,000.00
3	Side piece	2	80x50(mm)	10,000.00	20,00.00
4	Board	2	20x250(mm)	30,000.00	60,000.00
5	Board	2	20x150(mm)	20,000.00	40,000.00
6	Angle plate	6	40 x40 (mm)	5,000.00	30,000.00
7	Bolts/Nuts	4	10(mm)Dia	3,000.00	12,000.00
8	Screws	1/4pkt	18(mm)	10,000.00	10,000.00
9	**SUB-TOTAL**				**232,000.00**
	LABOUR				60,000.00
10	TRANSPORTATION				50,000.00
	TREATMENT OF PIECES				150,000.00
	HANDLING AND PROCESSING OF WOOD				60,000.00
	SUB-TOTAL				**320,000.00**
	GRAND TOTAL				**552,000.00**

Table 4.3 Cost sheet for prefabricated timber independent scaffold

S/N	ITEM	QTY	UNIT SIZE	UNIT COST(¢)	TOTAL COST(¢)
1	standard	4	80x50(mm)	20,000.00	80,000.00
2	Ledger	4	80x50(mm)	10,000.00	40,000.00
3	Transoms	4	80x50(mm)	5,000.00	20,000.00
4	Board	4	20x250(mm)	20,000.0	80,000.00
5	Board	2	20x150(mm)	20,000.00	40,000.00
6	Angle plate	4	40 x40 (mm)	5,000.00	20,000.00
7	Screws	1/4pkt	18(mm)	10,000.00	10,000.00
8	Bolt/Nut	8	15mmDia	3,000.00	24,000.00
9	Bolt/nut	4	10mmDia	2,000.00	8,000.00
10	**SUB-TOTAL**				**322,000.00**
11	LABOUR				150,000.00
12	TRANSPORTATION				60,000.00
13	TREATMENT OF THE PIECES				150,000.00
14	HANDLING AND PROCESSING OF WOOD				100,000.00
15	**SUB-TOTAL**				**460,000.00**
16	**GRAND TOTAL**				**782,000.00**

4.4 Manufacturing the prototype prefabricated Formwork and Scaffold.

The design of the prototype formwork and scaffold was realised through the following procedure:

- A survey was conducted to the various timber processing firms to know the prices of the species and prices of the size.
- Costing sheets were prepared to help ascertain an effective cost of the product.

- Treated teak pieces were procured from Busi and Stephenson's limited Kumasi for the construction.
- The metal parts namely: the angle plates, bolts and nuts were also procured.
- The realisation of the proto type prefabricated formwork for columns, independent and Jack scaffolds were undertaken according to the designs in figures 4.1 to 4.9.

For the prefabricated formwork for column, the following procedures were used:

- The formwork components were assembled and fixed. The angle plates were marked and holes drilled on them for screw and bolts and nuts.
- The initial assembly of all the formwork components was done using the bolts and nuts as the main jointing item. The yokes were placed in position and used to tighten up the formwork.
- A suitable spot was identified and a sample concrete cast into the formwork and left for four days before striking the formwork. The pre-fabricated timber members were well arranged for observation.
- On four different occasions, a week interval was allowed for close observation of the pre-fabricated timber members after which they are assembled and concrete cast into the formwork.

The diagram of figure 3.10 shows the proto type Formwork being tested on a construction site at University of Education-Kumasi campus. The use of bolts and nuts to tighten the boards ensured that, the formwork looked water tight.

Figure 4.10 The Proto type of Prefabricated Formwork for Column on test at C. Deck Construction site at U.E.W. –Kumasi campus.

The construction of the proto type Independent and Jack Scaffolds were undertaken using the following procedures:

- The components for both independent and jack scaffolds were marked and cut to required shapes. They include the standard, ledger, transom, vertical and horizontal jack pieces and brace pieces.
- The metal parts like, angle plates were cut to the required shapes and sizes.
- The points for holes on both the timber pieces and metal pieces were marked and drilled.

- The angle plates design for the sole piece, angles of the jack and angle plates for joining the boards for platforms were marked cut and holes drilled at the required spots.
- The boards for the platform were prepared to size and the edge side well straightened to ensure a smooth joint in between. The angle plates with holes drilled through, were fixed to the underside of the boards to enable easy tightening with bolts and nuts.
- The initial assembly was done to erect the proto type prefabricated independent, and jack scaffolds. The various angles and joints of the scaffold were tightened.
- A suitable site was identified and the two proto type scaffolds were assembled and used for 3 days then dismantled.
- After dismantling the scaffold, the pre-fabricated timber pieces were well arranged for observation.
- The proto type was erected and used on 3 different occasions, after which the pieces were each time arranged for observation.

The diagram of figure 4.11 and figure 4.12 show the proto type prefabricated independent and jack scaffolds being tested on a construction site.

Figure 4.11 the prototype prefabricated Independent Scaffold being tested at Cdeck construction Ltd site on U. E. W- Kumasi campus.

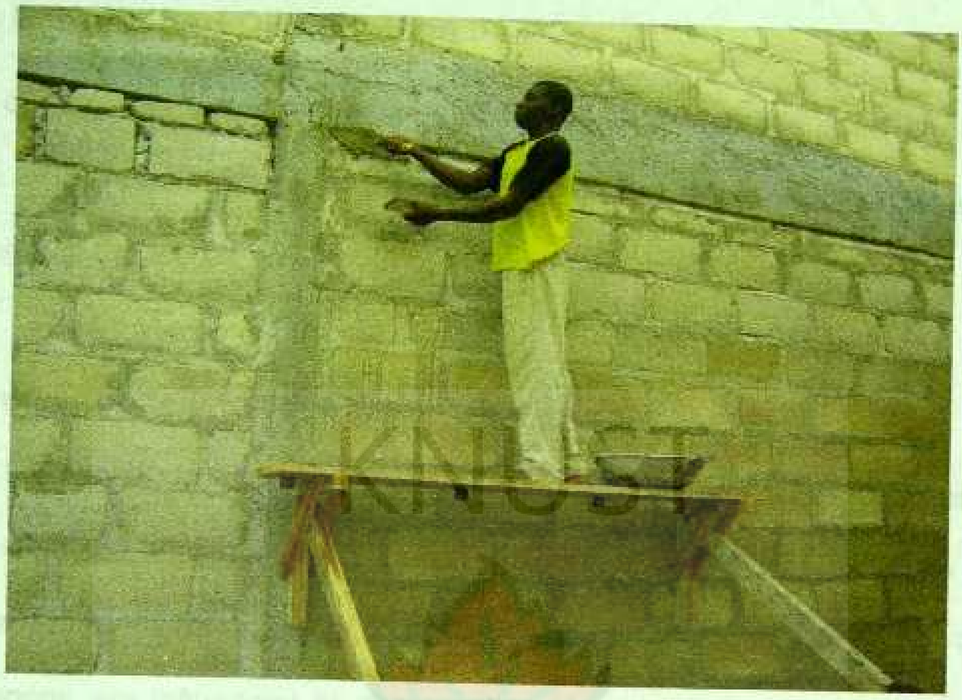


Figure 4.12 the proto type prefabricated Jack Scaffold being tested on a construction site.

CHAPTER FIVE

5.0 Results and Discussions

This chapter discussed the results of the various methods used in chapter three. The results reflect on the situation and the discussions explained the meaning of the issues arising out of the methods.

5.1 Survey of Construction Firms

From the survey, four classes of construction firms namely; D1, D2, D3 and D4 were identified. Observation of the current formwork and scaffold at the sites, showed differences in materials used and construction methods. These differences are influenced by the number of workers, the financial standing and the size of project being undertaken by the respective firms. The numbers of workers per the classified construction firms as observed are as follows:

- D1 firms 60 persons and above
- D2 firms 25 to 40 persons.
- D3 firms 15 to 25 persons
- D4 firms 4 to 10 persons

5.1.1 D 1. class firms

All the five D 1 construction firms representing 11.1% of the forty five construction firms have a lot in common. They have variety of suitable materials from which appropriate choices can be made. For the construction of formwork and scaffolds, not all D1 firms, depend on timber as the sole material for formwork and scaffold. Among the variety of materials they used are:

- Metal tubes used for scaffold and props for formwork.
- Metal sheets as decking for formwork
- Timber beams and built-up timber beams specially made to support formwork decking and platforms of scaffold.
- Timber pieces treated with surface painting e.g. Walnut treated with surface painting
- Timber pieces covered with sheet metal
- Pre-fabricated metal tubes and timber board.

Close observation of the materials at sites of five construction firms clearly showed that, the materials are not new. They have been in use from between one to six or eight years. Because of the reuse intention, the materials are well cleaned classified into sizes and well stored after use. The usual cutting of butt joints and nailing which characterized construction of timber formwork and scaffold was not the common. The use of pre-fabrication in the construction accelerated easy construction and striking of formworks and scaffolds on the sites. Timber pieces treated with surface painting survived the weather effects of twist and bow. After the forth or fifth use, the pieces were in good condition. On the other hand, timber pieces shield with metal sheets, were in good condition after several use. From their several use and continues usage, it is worth noting that quite a huge volume of timber has been saved. In addition, the financial benefit to the firm through the reusing of the materials can not be over emphasized.

5.1.2 D 2. Class firms

The D 2 class firms used for the study were ten; representing 11.1% of the total number of forty five firms. A common feature with all the D 2 class firms is that, they all use timber for formwork and scaffold. However, three of the firms sometimes combine the timber members with metal frames or tubes. According to the foremen, these firms use metal tubes to make frames and timber boards for the deck whenever they are undertaking quite sizeable projects. This approach according to the contractors is usually influenced by time schedule within which a project would have to be completed. Though the D 2. Construction firms have their formworks and scaffold constructed under supervision, timber pieces were discarded after first use. This could suggest that, there is no intention of reuse of the timber at the design and construction stages, hence the littering of sites with discarded timber pieces. Looking at the size of projects they undertake, and the huge piles of timber pieces left on sites, it can be said that, the activities of this category of firms, is contributing to timber waste.

5.1.3 D 3 and D 4 class firms

The D 3 and D 4 construction firms, used for the study are fifteen each totalling thirty in number and this represented 66.6% of the forty five firms. Construction practices on the sites of these classes of firms are very similar. Prominent among the similarities are the small size of projects, number of workers on site, materials used for formworks and scaffolds and the construction methods. The routine of formwork and scaffold construction was based on the fact that, timber pieces once used are discarded. Majority of timber pieces used on the sites could not be reused due to irregular sizing and shaping. Also most of the timber pieces are green wood which get deteriorated during and after use. Nailing of the timber pieces as the only jointing method and irregular cutting of timber pieces is a common sight. Due to the small size of project, the volume of timber used by individual firms in this category is less compared to the D 1 and D 2 class of firms. However, with the majority of the firms in this group, the volume of timber used is about 40% of the total quantity of timber used for formwork and scaffold as indicated in tables 5.2 to 5.7. The undesirable sight of wasted timber pieces scattered on the sites awaiting collection for firewood, has characterized all the thirty sites visited. One important factor is that the green timber pieces being used are unsuitable and could not be used again.

5.2 Selection Of Timber For Formwork And Scaffold Construction

The questionnaire on the role project consultants' play in the selection of timber for formwork and scaffold showed that, all the fifteen respondents are aware of the importance of selection. For this reason, they always advise and insist on the usage of timber that will ensure the desired outcome. According to the site engineers, timber selected and supplied to site is usually checked to:

- Ensure that the pieces are of strong texture
- Detect irregularities like shakes, spat, etc
- Ensure that the timber pieces are well seasoned
- Verify the straightness of the pieces.

To minimise failures of formwork and scaffolds on sites due to the use of inferior timber, all the site engineers confirmed that timbers used are selected based on the check list.

All the clerk of works, eighteen in number, agreed that, they always play a role in the selection of timber for formwork and scaffold and that their role in the selection of timber, is normally done by their advice to the contractors concerning the type of timber needed. They all stated that, their role is seen in instructions which serve as a guideline for the contractor to follow when purchasing timber. To all the thirty-five foremen, selection should be based on straightness, surface quality, and maturity and seasoning quality of timber pieces.

However, the carpenters and the headmen expressed their worry about the large quantity of green timber which is usually supplied to the site for formwork and scaffold construction. They wished to be involved in the selection process to reduce the rate of timber wastage.

As to their view on the need to select timber for formwork and scaffold construction, all the headmen interviewed have the same opinion. They agreed that selection of timber pieces is necessary to always ensure that seasoned and good quality timber is used. They view the selection being done by suppliers as the cause of the increasing supply of green timber, which deteriorates very fast after a few days in use. They are of the view that, contractors should let their foremen or headmen assist the suppliers in the selection of timber pieces for formwork and scaffold.

One hundred and twenty carpenters were interviewed for the study concerning their roles in the selection of timber for formwork and scaffold that they involvement. The site engineers said, they supervised the construction of formwork and scaffold from time to time. This, they do to ensure that the constructions are done according to the designs and that the desired results are achieved. However, there was mixed reaction as to whether they always ensured that, the construction can enable reuse of the timber pieces. Four site Engineers representing 13.3%, were of the view that, supervision and inspection of formwork and scaffold should enhance repetitive use of timber pieces. The practice of destroying the timber pieces after use overshadowed the essence of supervision and inspection. The remaining twenty-six site engineers representing 86.7% of the respondents do see the relevance of linking the supervision and inspection to ensure that the timber pieces can be reused. However, they also see the practice of using the timber pieces for firewood to cook as equally important and necessary. To them using the pieces to set fire to cook food is useful.

The responses of the eighteen clerks of work about the importance of supervision and inspection when constructing formwork and scaffold, was positive. As representatives of the clients, they usually through their presence ensured that the construction methods use for the structures appropriate and yield the desired outcome. They all agreed to the suggestion that, efficient timber utilization should influence supervision and inspection in the construction of formwork and scaffold. This can be of economic advantage to clients.

5.4 Construction of Formworks And Scaffolds

All the one hundred and twenty carpenters representing the D1, D2, D3, and D4 construction firms are responsible for the construction of formworks and scaffolds on sites. The sixty carpenters in the D3 and D4 construction firms representing 50% confirmed that, they undertake formwork and scaffolds construction without supervision and inspection. Since they operate as the sole contractors, formwork and scaffold are designed and constructed by them. They therefore employ all methods that are appropriate to construct the structures' considering the temporal role of formwork and scaffold, these carpenters decided on whatever method they think is possible. Whether there is any provision made to ensure reuse of the timber, the carpenters responded in the negative. Discarding of timber pieces after using them for formwork and scaffold is a usual practice which some clients usually request for discarded timber pieces to use for firewood. They contended that, reusing timber pieces can be economically beneficial to the clients but the latter's interest in timber pieces for firewood has influenced the carpenters approach. Issues about excessive timber consumption and its negative effect on rapid depletion of the forest cover are not known to the clients and carpenters of D3 and D4 firms. The D3 and D4 firm carpenters agreed that, their lack of adequate information on timber consumption and exposure to inappropriate strategies, has contributed negatively to their approach to timber utilization. Two scenarios have been created by the activities of carpenters operating under D1, D2, D3, and D4 construction firms. Carpenters in the D1 and D2 firms because of regular routine of supervision and inspection, worked with care and skill to meet desires of employers. While carpenters in the D3 and D4 firms most often work on as their own supervisors and inspectors and therefore do not have any check on the construction of formworks and scaffolds to promote economic use of timber.

5.5 Timber for Formwork and Scaffold Construction

Enquiries about timber species that are used for formwork and scaffold construction on the forty five construction sites have revealed the type of timber species use as shown in table 5.1. This result was realized through the surveys, questionnaires and interviews conducted on the sites.

Table 5.1 Species of timber used for formwork and scaffold construction.

Species of timber	Number of site using specie	Percentage
Wawa	45	100%
Onyina	6	13.1%
Afina	10	22.2%
Odum	6	13.1%
Teak	6	13.1%
Bamboo	33	71.1%
Coconut wood	2	4.4%

Though the survey showed disparity in the use of timber species among the three categories of sites, Obeche locally known as Wawa was found on all the forty five sites (100%) visited as shown in table 5.1. The high patronage of wawa as revealed through the interviews was due to the following reasons:

- It is available in huge volumes.
- Very easy to work with i.e. nailing
- Very affordable cost

A species like Odum was seen on only six sites representing 13.1%. Giving the background that, Odum has a better service condition than the other timber species, its low patronage might looked surprising. However, one main reason which respondents indicated for its low patronage is its very high cost and scarcity in the timber market. Respondents also said that odum is now among the endangered timber species in Ghana for which, it may be unlawful using it for formwork and scaffold. Information from the six sites where some amount of odum was in use suggested that, the timber pieces were purchased about a year ago. They were used for specific aspects for which wawa could not have been most appropriate. Timber species like Dahoma, Kusia and Teak are in comparable abundance like wawa for which they can be well patronized. Their respective percentage patronage on sites as shown in table 5.1 suggested that, they are less known timber species for formwork and scaffold construction. For example respondents on sites where Dahoma and Kusia were used, gave very good account of the service condition of the species. Their observations are confirmed by Ghana Forestry Commission report (2001) which expressed the appropriate and suitable uses and reliable state of durability. Respondents on the six sites where teak was used intimated that, based on the following reasons they decided to use teak for formwork and scaffold.

- Available in large quality
- It is treatable to withstand moisture movement.

- It is affordable in cost
- Can be grown with in a short time.

One outstanding feature which respondents on the use of teak emphasized was its unfailing endurance. As a pole, for carrying electric wires, teak has survived changing weather conditions. With the over dependence on wawa, and its gradual depletion, teak with its encouraging service condition, will soon emerge as a popular replacement for wawa. Table 5.1 also revealed that, thirty-three (33) sites representing 71.1% of the forty-five sites used, bamboo in one way or the other for the construction of formwork and scaffold. The bamboos were used mostly as props to support the decks of the floors and also as standard and putlog for the scaffolds on the medium and small scale sites. Respondents agreed that the popularity of bamboo is linked to its availability and strength. All the thirty-three firms who used bamboo explained that, because of its hard texture, compressive strength and its length, bamboo is very ideal for formwork and scaffold construction. They even hope that with technology advancement, it should be possible that bamboo can be processed into boards and other pieces. They are also of the view, that bamboo can be cultivated any where and its cost is far more affordable than the traditional timber species. According to table 5.1, coconut wood was used for the construction of formwork and scaffold on two sites, representing 4.4% patronage. With the upsurge of the Cape St Paul disease, quite a huge number of coconut tree logs are going waste. Ghana forestry commission report (1998) showed that it is viable and can be used as a substitute for the endangered timber species. Actually it was a surprise to see coconut wood being used for construction. Nevertheless, the coconut wood scantlings used as props were equally strong and able to support the formwork decking successfully. The few boards obtained from the wood even though not very wide, were strong enough to contain the fresh concrete until it became dry and hard. The coconut wood pieces used for formwork and scaffolds looked very good and strong and can be reused. Because it is less known timber specie, many firms especially the D1, D2, D3, and D4 are not aware of its suitability. Though the indications in table 5.1 on coconut wood showed that, it is the least used, the out come of the concrete slabs obtained showed that, it can be successfully used.

5.6 Timber supply to the construction sites for Formwork and Scaffold Construction

Following the visits, observation and interviews on the sites concerning the schedule of timber supply for formwork and scaffold construction, a detailed analysis has been obtained. The analysis of various sizes of timber supplied to the D1, D2, D3 and D4 firm sites are shown in tables Table 5.3, 5.4, 5.5, 5.6, 5.7, and 5.8.The presentations of each section reflected on the average supply of timber to the sites.

5.6.1 Timber supply to D1 firm sites

Even though the survey on the five D1 construction firms indicated that, they mostly use metal tubes and sheets for formwork and scaffold, quite a substantial quantity of timber is used. This situation is sometimes attributed to urgency of the project for which, there is the need to use timber in addition to metal tubes to meet deadlines. The content of tables 5.2 and 5.3 present list of various sizes and length supplied to the large scale sites. Quantities of the respective timber size pieces have been stated. Also stated is the analysis of percentage of the respective timber pieces in good condition after first use. On the other hand, the percentages of timber pieces in bad condition after first use are also analyzed in the two tables. Table 5.2 compiled the timber schedule for formwork construction. On the use of wawa boards 25x300(mm) the five firms' altogether, used a total of 5,200 pieces timber on their project sites. Of that quantity of timber, 22% was certified to be in good condition after the first use. Large percentage of the timber pieces, (i.e. 78%) were in a bad condition after the first use and could not be reused. According to the personnel on site, the sizes sometimes account for the high or low percentage of timber pieces in bad condition after first use. The timber board of size 25x200(mm) used on the sites were 8,450 pieces. After the first the time use, 53% of the timber pieces were in good condition whilst 47% pieces were in bad condition. This occurrence proved the personnels observation about the influence of sizes on the condition of timber pieces after first use. The good and bad condition percentage rate of (50x50mm) batten piece was also influenced by size and indicated a close percentage of 46% in good and 54%in bad conditions. A total amount of 1,640 50x75(mm) timber battens were used of which 62% were in good condition whilst 38% were in bad condition Similarly, of the 3,200 50x100(mm) timber batters used, 6.16% were in good condition whilst 38.4% were in bad condition. Plywood is used in formwork for special shapes and curves. Of the 640 (6mm) plywood used on the five sites, 18% was in good condition after first use whereas 82% was in bad condition after the first use.

The use of bamboo is not very common on the large scale sites since the metal tubes are appropriately used.

Table 5.2: Timber schedule for formwork on D1 sites

Material & size Description	Total Qty.	Qty. of Wood in Good condition after first use	Percentage of timber in good condition after first use	Qty. of Wood in Bad condition after first use	Percentage of timber in bad condition after first use
0.025 x 0.030 x 4.20(m) Wawa board	5,200	1,144	22%	4,056	78%
0.025 x 0.020 x 4.20(m) board	8,4,50	4,478	53%	3,972	47%
0.050 x 0.050 x 4.20(m) batten	3,650	1,679	46%	1,971	54%
0.050 x 0.075 x 4.2 (m) Batten	1,640	1,016	62%	624	38%
0.050 x 0.010 x 4.2 (m) scantlings	3,200	1.971	61.6%	1,229	38.4%
6mm plywood sheet	640	115	18%	523	82%
18mm plywood sheet	230	74	32%	156	68%
Bamboo (4.20)m length	600	522	87%	78	13%

Table 5.3: Timber schedule for Scaffold on D1 sites

Material &size Description	Total Qty.	Qty. of wood in good condition after first use	Percentage of timber in good condition after first use	Qty. of wood in Bad condition after first use	Percentage of timber in bad condition after first use
0.025 x 0.030 x 4.2 (m) Wawa board	865	450	52%	415	48%
0.025 x 0.020 x 4.2(m) Wawa board	415	261	63%	154	37%
0.050 x 0.050 x 4.2(m) batten	660	429	65%	231	35%
0.050 x 0.075 x 4.2(m) batten	350	235	67%	115	33%
0.050 x 0.010 4.2(m) Scantlings	580	371	64%	209	36%
0.050 x0.015 x 4.2(m) Scantlings	160	122	76%	38	24%

However, in times when the volume of work over burdens the available equipment and materials, other equally effective materials are used. No doubt, the D1 firms used a total of 600 bamboos as props for formwork. As shown in table 5.2, 87% of bamboos were still in very good condition for reuse whilst 13% were in bad condition and could not be reused. Close examinations showed that, the bad ones were obtained as a result of inappropriate striking methods.

The quantity of timber used for scaffold on the five D1 sites was less, compared to that used for formworks. This trend from the site observation was due to large quantity of metal tubes used for the scaffold frames. Timber members were however used for the platforms and carriage ways to the scaffolds. Details of table 5.3 showed that, the quantity of timber retained in good condition for scaffolds was considerably higher than that of formwork. For example, of the 865 25x300(mm) wawa boards used, 52% were retained in good condition after first use. The 25x200(mm) wawa boards used, also recorded an encouraging good percentage retained of 63%. The 37% of boards in bad condition were due to inappropriate dismantling which caused the breaking of the timber pieces. The rate of good timber pieces retained for 50x50(mm), 50x75(mm) and (50x100(mm) wawa pieces were similar to the 25x300(mm) wawa boards. Table 5.3 also showed that the rate of good pieces retained for 50x150(mm) battens were considerably the highest. This high rate of good pieces retained was due to the cross- section of the timber pieces.

5.6.2 Timber supply to D2 firm sites

Observation of formwork and scaffold construction on the 10 D2 firm sites showed that, timber is the main material used. The schedule of timber supplied to the sites as indicated in tables 5.4 and 5.5 showed the quantity of various sizes for formwork and scaffold. Details of table 5.4 highlighted on the quantity of various sizes of timber pieces used, and the percentage in good and in bad condition after first use. Of the 1,620 wawa boards used for formwork, 308 wawa boards representing 19% were in good condition after first use, whilst 1,312 wawa boards representing 81% were in bad condition and could not be re-used.

Table 5.4: Timber schedule for formwork on D2 sites

Material &size Description	Total Qty.	Qty. of wood in Good condition after first use	Percentage of timber in good condition after first use	Qty. of wood in Bad condition after first use	Percentage of timber in bad condition after first use
0.025 x 0.030 x 4.2(m) Wawa board	1,620	308	19%	1,312	81%
0.025 x 0.020 x 4.2(m) Wawa board	2,050	451	22%	1,599	78%
0.050 x0.050 x 4.2(m) batten	1,200	564	47%	636	53%
0.050 x 0.075 x 4.2(m) batten	630	340	54%	290	46%
0.050 x 0.10 x 4.2(m) Scantlings	1,800	1,134	63%	666	37%
6mm plywood sheet	50	7	13%	43	87%
18mm plywood sheet	60	19	32%	41	68%
Bamboo	1,340	1,126	84%	214	16%

The 0.025 x 0.020 x 42(m) type of wawa boards were also used in greater quantity. Like the 0.025 x 0.030 x 4.2(m) boards, 1,599 boards representing

78%, were in bad condition after first use. On the other hand, the higher rates 57% and 58% of good condition for 0.050x0.075 (m) and 0.050x0.1 (m) types of scantlings respectively after first use can be associated with the sizes. Among the timber pieces supplied to the D2 sites, bamboo has the highest number of 1,126 representing 84% in good condition, after first use. The 16% rendered in bad condition were due to poor striking methods. Plywood of 6mm size has a few number of 7 representing 13%, were in good condition after first use whilst 43 boards representing 87% were rendered in bad condition. However the plywood of 18mm size has a better good condition rate of 33% and 67% in bad condition as compared to the 6mm plywood as shown in table 5.4.

Table 5.5: Timber schedule for scaffold on D2 sites

Material &size Description	Total Qty.	Qty. of wood in Good condition after first use	Percentage of timber in good condition after first use	Qty. of wood in Bad condition after first use	Percentage of timber in bad condition after first use
0.025 x 0.030 x 4.2(m) Wawa board	520	322	62%	198	38%
0.025 x 0.020 x 4.2(m) Wawa board	190	108	57%	82	43%
0.050 x 0.050 x 4.2(m) batten	155	59	38%	96	62%
0.050 x 0.075 x 4.2(m) batten	135	97	57%	38	43%
0.050 x 0.1 x 4.2(m) Scantlings	250	145	58%	105	42%
0.050 x 0.015 x 4.2(m) Scantlings	142	91	64%	51	36%
Bamboo	410	353	86	57	14%

The analysis of table 5.5 showed the total number of timber pieces of different sizes used for scaffolds on the 10 D2 sites. Of the 520, 0.025x0.3 (m) boards used for scaffolds, 62% was retained in good whilst 38% was in bad condition.

The 38% in bad condition according to the personnel the on sites was due to over nailing and inappropriate dismantling. As shown in the table, the good percentage of 57% and bad percentage of 43% for 0.025x0.2 (m) boards can be compared to that of 0.025x0.3 (m) boards. The percentages of timber in good condition for 0.050x0.075 (m), 0.050x0.1 (m) scantlings were 57%, 58% and 64% respectively. The marginally low rate of timber in bad condition was quite substantial as indicated in table 5.5. Irregular cutting of the pieces into lengths, nailing at random and wrong methods of dismantling the scaffolds accounted for the timber pieces in bad condition. Bamboo has a high retainable percentage in good condition after first use. Of the total number of 410 bamboos used, 86% were retained in good condition for reuse. Fifty seven bamboos representing 14% were in bad condition and can not be reused. Observation has shown that the bad condition of the bamboos was due to split which occurred during nailing and cutting.

5.6.3 Timber supply to D3 and D4 sites

The survey and observation of timber of various size used on the D3 and D4 construction sites for the construction of formworks and scaffolds are analysed in quantities of timber used on these sites are small. However observation of the construction of formwork and scaffold revealed the use of inappropriate methods, which has caused wastages of timber on the sites. Table 5.6, highlighted the compilation of timber supplied for the 30 firms to construct formworks. All the 30 sites used a total of 1,080, 0.025x0.3 (m) wawa boards of which only 132 representing 12% were retained in good condition after first use. The greater numbers of the boards representing 88% were in bad condition and can not be reused. The table showed a similar trend of high wastage concerning 0.025x0.2 (m) wawa boards. Out of a total of 365 boards used on the twenty sites, just 58 boards representing 16% were retained in good condition. However, as many as 307 boards representing 84% were spoiled after first use. Table 5.7 showed that Bamboo was the second highest quantity supplied to the sites after 0.025x0.3 (m) wawa boards. It's used as prop formwork deck was worthwhile since quite a large number can be used several times. Of the 428 bamboo used for formwork, 56 pieces were spoiled and in bad condition whilst 372 pieces were retained in good state representing 87%. The table showed the details of timber supply for scaffold construction on the 30 D3 and D4 construction sites used for the study. Two types of boards, 0.025x0.2 (mm) sizes have similar percentages retained in good and bad conditions. A total of 210 0.025x0.3 (m) wawa boards were used of which 38% was in good condition and 62% was in bad condition after first use. With the 0.025 x 0.2 (m) wawa boards, 96 pieces were supplied to the sites, 35% were in good condition and 65% in bad condition after first use. The high percentage of the 0.025x0.3 (m) and 0.025x0.2(m) boards in bad condition according to respondents, was due to the weather effect. Because of their small thickness, temperature changes and moisture affect their strength. For scaffold construction, 0.050x0.1 (m) and 0.050x0.15 (m) scantlings used, as shown in table indicated high percentage retained in good condition. The 0.050x0.1 (m) scantlings have 61% in good conditions, and 39% in bad condition respectively. The 0.050x0.15 (m) scantlings have a higher percentage of 72% retained in good condition and 28% in bad condition. Bamboo usage was not very high but as much as 92% of the 102 bamboos were retained in good condition and 8% in bad condition after first use. Respondents at the sites said that the few bamboos spoilt were due to irregular cutting and wrong dismantling.

Table 5.6: Timber schedule for formwork to D3 and D4 sites

Material &size Description	Total Qty.	Qty. of wood in good condition After first use	Percentage of timber in good condition after first use	Qty. of wood in good condition	Percentage of timber in bad condition after
0.025 x 0.030 x 4.2(m) Wawa board	1,080	130	12%	950	88%
0.025 x 0.020 x 4.2(m) Wawa board	165	26	16%	139	84%
0.050 x 0.050 x 4.2(m) batten	86	31	36%	55	64%
0.050 x 0.010 x 4.2(m) Scantlings	372	216	58%	156	42%
0.050 x 0.15 x 4.2(m) Scantlings	135	72	53%	63	47%
Bamboo	428	372	87%	56	13%

Table 5.7: Timber schedule for scaffold on D3 and D4 sites

Material &size Description	Total Qty.	Qty. of wood in good condition after first use	Percentage of timber in good condition after first use	Qty. of wood in bad condition after first use	Percentage of timber in bad condition after first use
0.025 x 0.030 x 4.2(m) Wawa board	210	80	38%	130	62%
0.025 x 0.020 x 4.2(m) Wawa board	96	34	35%	62	65%
0.050 x 0.010 x 4.2(m) Scantlings	178	109	61%	69	39%
0.050 x 0.15 x 4.2(m) Scantlings	104	75	72%	29	28%
Bamboo	102	94	92%	8	8%

5.7 Strength properties of timber species used for formwork and scaffold

The determination of strength properties of wood samples from the ten timber species at 12% moisture content are presented in table 5.8. Details of the table showed that the ten species have different strength properties. However there is close similarity between the strength properties of the timber species. This suggests that, the less known timber species can be effectively used for formwork and scaffold construction. Whilst Dahoma recorded 717 kg/m^3 density, showing a difference of 41 kg/m^3 density, Iroko (Odum), which is considered as the strongest among the ten species, recorded a density of 652 kg//m^3 whilst Obeche (Wawa), considered to be non durable timber specie recorded a lower density of 384 kg/m^3. Kaku, which is not a known timber for formwork and scaffold construction, recorded the highest density of 1,040 kg/m^3. Looking at mechanical properties, the differences of the species, Iroko (Odum) and Makore have compression parallel to grain values of 52 N/m^2 each, Dahoma and Esa have the same value of 60 N/mm^2. The table showed that, again Kaku has the highest value of 91 Nmm^2, whilst Onyina and Obeche (wawa) recorded lowest values of 35 N/mm^2 and 28 N/mm^2 respectively.

Makore with 118 N/mm,^{2} and Esa with 104 N/mm^2, Iroko (Odum) recorded 86 N/mm^2, whilst Dahoma a less known timber specie for construction purposes, recorded 97 N/mm^2 value, which is 11 N/mm^2 higher than that of Iroko. Obeche (wawa) and Onyina recorded lower values of 53 N/mm^2 and 55 N/mm^2. The results of modulus of rapture of the ten sample timber species as indicated in the table, suggested that, less known or use timber species possessed very viable strength properties for which they can be employed for construction works. Eventhough, Iroko (Odum) is considered a very durable timber specie, its modulus of rupture value is lower than that of Dahoma which is lesser considered for construction of formwork and scaffold. Also Kaku, Afina, Makore, Esa and Potrodom, all less known and used for construction recorded far higher modulus of rapture values than Odum. This is an indication that timber species which possess good strength properties can be used in very challenging situations.

It is not surprising that, obeche (wawa) which according to table 5.8, is classified as non durable but has a modulus of rapture value of 53 N/mm^2 as compared to Iroko (odum) classified as very durable with 86 N/mm^2 value. The difference of 33 N/mm^2 value between the two species of very durable and non durable showed that Obeche (wawa) as a non durable can be enriched in standard and employed as a durable timber piece.

The modulus of elasticity results of the species as shown table 5.8 also indicated variations in value. Potrodom (missanda) which is a lesser recorded the highest value of 20,094 N/mm^2 values followed by Kaku, Kusia and Dahoma with values 16,079 N/mm^2, 13,695 N/mm^2 and 12,883 N/mm^2 respectively. Iroko as usual, a very durable timber specie recorded elasticity value of 10,041 N/mm^2 whilst Esa, a specie considered perishable under natural durability, recorded a value of 12,749 N/mm^2. Though Makore, is a less known and used timber specie, its record of favourable mechanical properties value, and very durable status, signified its suitability for construction works. Onyina according to table 4.8 is classified perishable but has an elasticity value of 6,880 N/mm^2. This situation indicates that, with the quite substantial property values of onyina even though perishable, its service life and strength can be improved upon. Obeche (wawa), a non durable timber specie but the most widely used on construction sites for lowest elasticity value of 5,762 N/mm^2. The results concerning the natural durability and moisture movement in service of the timber species are indicated in table 5.8. Some of the species have different natural durability and movement in service as compared to their mechanical properties and density. For instance, Obechie (wawa) has the lowest density and mechanical properties, has small moisture movement in service and is non durable. Iroko (odum) a known and used timber for formwork and scaffold scarely has a small moisture movement in service and very durable just like the following less known and used species; Kusia Makore and Potrodom. Kaku, with a high mechanical property values, has a medium moisture movement in service and is very durable in nature.

The strength properties of values of the ten species vary and have significant considerations. For example, quite a number of the less known timber species namely Kaku, Potrodom, Makore, Afina and Kusia have higher strength values, suitable moisture movement in service and very durable. This is likely to serve the basis for which, these less known species could take up the pressure of the over reliance on Obechie (wawa) as the most desirable choice. As clearly shown in the table, Obechie (wawa) has very low strength property values for which it may not be very suitable for constructing the structures. However, the survey on the sites especially the D3 and D4 construction sites revealed that, Obechie is extremely used to construct formwork and scaffold.

Some important issues have been identified as contributing factors for the high patronage of some particular timber species. The first factor is based on financial considerations. Obeche (wawa), because of its very low strength properties, small moisture movement in service and non durable nature, is considered far cheaper than other timber species. It is subsequently sold cheaper in cost. Based on the lean financial standing of the D2 and D3 construction firms, Obeche (wawa) has become the obvious choice. Though, Iroko (odum), is a well known timber specie with considerable strength properties, for which it could be used several times, its high cost is the major cause of low patronage. On the other hand, less known and used species like Kaku, Makore, Potrodom and Afina which may cost less are not used, due to lack of knowledge about them. The second factor for the continuous high patronage of Obeche (wawa) is its availability in abundance. It appeared to be widely harvested than other timber species owing to the high demand for it for formwork and scaffold construction. According to the firms, as they keep on getting supply of Obeche (wawa) on demand without hindrance, its consumption will continue. What the firms have not considered is whether their over dependence on this particular specie could be sustained to the near future?

Table 5.8: Results of strength properties of timber species

Timber species	Density kg/m^3	Mechanical properties n/mm^2			Moisture movement in service	Natural durability
		Compression	Rapture	elasticity		
Wawa	384	C 11 – 28	B – 53	E – 5,762	Small	No Durable
Odum	652	C 11 – 52	B – 8	E – 10,041	Small	Very Durable
Dahoma	717	C 11 – 60	B- 97	E – 12,883	Medium	moderate
Kusia	758	C 11 –,68	B – 120	E- 1395	Small	Very Durable
Kaku	1,040	C 11 – 91	B – 186	E – 16,079	Medium	Very Durable
Afina	896	C 11 – 78	B –146	E -17,044	Small	Durable
Onyina	320	C 11 – 35	B – 55	E – 6,880	Medium	Perishable
Makore	624	C 11 – 52	B – 118	E – 11410	Small	Very Durable
Esa	757	C 11 - 60	B -104	E- 12,749	Medium	Perishable
Potrodom	885	C 11 – 66	B – 122	E – 20,094	Small	Very Durable

Experiment results concerning the natural durability and moisture movement in service of the species are also indicated in table 5.8. Iroko (Odum) has a high standing of being very durable and having a small moisture movement in service. Obeche (wawa) on the other hand has a poor record of being non durable and medium moisture movement. Opepe (kusia) is also very durable and has small moisture movement in service. The natural durability of Dahoma however is moderate and moisture movement in service is medium.

Strength properties of timber

The strength properties values of the ten timber species showed that,Kaku, Afina Esa, Kusia and Potrodom have higher values. This indicated that, considering the construction of formwork and scaffold, these timber species are most suitable. Obeche (wawa) according to the results has very low values for which, it may not be very suitable for constructing the formwork and scaffold However, the survey on the sites especially the medium and small scale revealed that Obeche (wawa) is extensively used for construction of formwork and scaffold. The graph of figure 5.1 showed that all the 45 sites covered in the study use Obeche. Some, issues have been identified as the contributing factors. First, obeche (wawa) because of its low strength properties, is far cheaper in cost than the others. Based on the lean financial standing of the D3 and D4 construction firms, obeche (wawa) has become the obvious choice. Though Iroko (odum), possess considerable strength properties for which it can be used several times, its high cost is the major cause of low patronage. The second factor for the continuous high patronage of Obeche (wawa) is its availability. Obeche (wawa) appeared to be widely harvested than other species of timber. According to the firms, the specie can be easily accessed and is affordable compared to the other species.

5.8 Suitability of Timber pieces Coated with Plastics to enhance repetitive use

During the three times use of plastic coated timber pieces for formwork and scaffold, the following were observed:

The concrete slabs that were obtained from the formwork with timber members coated with plastics were of a high quality out look. There was no sight of pores on the concrete surfaces. Rather, the surface textures of the slabs were very smooth and looked solid.

- The film of the plastic which is covering the timber surfaces, served as a barrier and prevented any traces of moisture absorption from the fresh concrete. When using ordinary timber, it is possible for moisture movement to take place through the wood fibre.

- All the pieces after each usage were still in good condition. Usually, one factor which leads to the deterioration of timber pieces, after being exposed to the atmospheric pressure, is the constant seepage of moisture and swelling. This eventually leads to decay of timber pieces. In this case, there was not the slightest entry point for moisture to be contained in the timber pieces.
- Even the exposure of the pieces to the heat of the sun in the open for two days on each occasion, has no adverse effect on the pieces. Normally any timber member is it seasoned or exposed to the sun will experience some amount of drying shrinkage. Again, in this situation the plastic film has maintained a constant condition of the timber thereby promoting its continuous use. Since most timber pieces are not able to maintain their strengths when exposed and will warp and twist, plastics ability in protecting timber can not be over emphasised.
- The usual struggle, getting to clean timber pieces after using the formwork, with wire brush is not needed with the plastic surface pieces. The smoothness of the plastic surface prevented any paste of concrete from sticking to the surface. In this regard, maintenance of plastic coated timber will be manageable and therefore ensure several uses of the timber pieces for formwork without any difficulty.
- Further visit to K+H site, revealed that, the same plastic coated pieces have been used on other sites of the company to cast concrete. There is evidence of efficient utilization of timber for formwork by the K + H

Company through the employment of plastic coated timber pieces. Within a period of four months these pieces have been used for twelve times, and the pieces were still observed to be in good shape and have smooth surfaces.

- In view of the experiences observed with the timber pieces coated with plastics, it is envisaged that, such pieces can be used repetitively for so many years.

5.9 Suitability of Metal to Prefabricate Timber Pieces for Formwork and Scaffold

During the four times used and observation of the prefabricated formwork and scaffold on the Consar site at University of Education Kumasi campus the following observations were made:

For the prefabricated formwork for column, beam and floor, on Consar site at U.E.W-Kumasi, the researcher made the following observations:

- Because of the pre-fabrication nature of the formwork, it was very easy to strike the boards from the concrete slab. The only problem identified was that moisture moved through the wood fibre, slightly which made the boards to swell. Some parts of the boards' surfaces have concrete paste stuck to them. Though pre-fabricated with metal pieces, the board were not spared the effect of the wet concrete. This observation clearly confirmed, the high rate of boards that are wasted on large scale sites, even though, they employ pre-fabricated pieces.
- The metal parts used to join the timber members were easily struck and in good state for reuse. Also the timber yokes used to tighten the

formwork for columns were dismantled and the bolts and nuts removed.

- The observation of the pre-fabricated boards after striking revealed that there were some physical changes. As a result of the moisture movement and swelling of the boards, twisting, warping and bowing was visible. The issue now is that pre-fabrication of timber pieces with metal is appropriate in reducing the waste but will be more effective if the timber is treated against moisture movement.

For the prefabricated scaffolds, on Consar site at U.E.W-Kumasi, the following were observed:

- The standards, putlogs, transoms and the ledgers are metal members of the scaffold which were easily fixed and stabilised. The platform of the scaffold was made of timber boards.
- After the scaffolds were used for working at a higher level, the metal members were easily dismantled. The shapes of and sizes of the metal members were still in good condition.
- The timber boards used for the platform were observed with visible changes. Because of the exposure to the atmosphere, some of the boards bowed, twisted and warped slightly. Some of the boards also appeared to have swelled a bit due to moisture absorption from mortar droppings. With greater part of the scaffolds made of metals, the very few timber boards which are usually used and get defective through exposure to the weather, is not viewed as a serious problem by most D1 construction firms.

For the Proto Type Prefabricated Formwork for Column, tested on C. Deck site at U.E.W-Kumasi, the following observations were made:

- During the casting of concrete, the timber boards appeared wet, but there was no sign of swelling, which usually results through moisture intake.
- The yokes were conveniently used to tighten the formwork. Also the angle plates through which the bolts and nuts were used to join the boards ensured an effective joint for the formwork without using nails.
- Striking of the proto type prefabricated formwork was done with ease and within a short period of time, by undoing the tightening of the bolts and wing nuts at the noted points. This method appears to be beneficial in terms of limited time spent in striking and its non destruction to the timber pieces, which is of great economic value. The striking of nailed formwork is usually accompanied with forceful removal and breaking of timber pieces to a condition that they can not be reused.
- Observation for days of the proto type prefabricated formwork after striking revealed that, the timber pieces do not have any noticeable defects on them. The good condition of the timber pieces after the striking can be attributed to the impregnation treatment undergone. The improvement of the condition of timber pieces in this situation

has resulted in no moisture intake and no physical changes seen after been in contact with water.

For the proto type prefabricated independent and jack scaffolds tested on C. Deck site at U.E.W-Kumasi, the following observations were made:

- The Erecting of the Proto Type Prefabricated Independent Scaffolds was done with ease. The various parts were identified and the fixing was done within a short time. The use of bolts and nuts resulted in stable fixing of both scaffolds.
- In use, the standards and transoms of the independent scaffold were effectively joined using the bolts and wing nuts and giving room for tightening up the system whenever the need arose. The usual means of readjusting timber independent scaffolds through excessive cutting and nailing to ensure stability always lead to timber waste.
- The vertical and horizontal timber pieces of the jack scaffold fixed at a rigid angle with an angle plate with screws through into the timber pieces. Attachment of braces to the sides, with bolts and wing nuts made the proto type prefabricated jack scaffold very strong in use every time. Normally the use of nails in the construction of traditional jack scaffolds could not provide a reliable strength for long term use.
- Working on both proto type scaffolds was very successful. This was realised in view of the stability noticed through the

prefabrication methods of bolts, nuts and angle plates. The absence of nails in the erecting of the scaffolds can be identified with absence of cracks resulting at nail holes and irregular cutting of timber pieces.

- Even though the proto type prefabricated scaffolds were exposed to the atmosphere during the period of testing, there were no physical changes noticed on the timber pieces. Timber pieces exposed to the atmosphere usually show signs of warping, swelling, twisting and decaying.

5.10 Durability of timber samples through impregnation

The experiment on the ten selected sample species of timber showed that timber materials properties especially of the less durable timber species can be enhanced and put to various uses in construction. After the full cell impregnation treatment of the ten sample species, the following were observed:

After exposing the samples to the open air for ten days, it was observed that the surface texture of the species did not show any sign of crack.

- The surface texture also look more compacted than before the impregnation process was carried out. Usually the exposure of the species will have resulted into rapid drying out of the moisture and shrinkage which will give rise to cracks or twist to e observed on the samples. Another point of different sample species of timber we expected some signs of shrinkage especially with the less durable ones and those with loss fibre. It can be stated that, the treatment has the potential of improving the tissue texture of timber irrespective of the strength properties.

- The samples after being immersed in water for five days, did not show the possible signs expected of timber pieces when exposed to water for such a long period. When timber is immersed in water, is it expected that depending on the closeness of the tissues, there will be some amount of moisture movement. This will then result in swelling of the timber and then decay.

- In considering the weight of the samples before the immersion and after the immersion, there were some slight differences in weight. The weights ranged between 0.002gm and 0.005gm, which have negligible effects on the condition of the species.

  Generally, all the samples of the timber species can be said to in a stable condition after being exposed to the weather and immersed in water for the stated number of days. The compact nature of the tissues of the species after the treatment revealed that even species with loose fibres can be improved in quality for construction works. Impregnation though expensive, can be cost effective regarding the long term service that, treated, less durable timber specie, will give when used for construction of structures like formwork and scaffold.

CHAPTER SIX

6.0 FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

6.1 Introduction

The analysis and discussions which have been made, were based on the data which were obtained from the various processes. The key findings from this study and their developmental implications have been presented in this chapter. Based on these finding, it has been possible to identify means by which, timber can be efficiently utilised for formwork and scaffold construction.

6.2 Findings

6.2.1 The Construction Firms and Timber Usage for Formwork and Scaffold

The rate of timber usage for formwork and scaffold construction is closely linked to the type or category of firm. The study revealed the classification of the contractors (firms) into D1, D2, D3, and D4. The D1 and D2 firms are well resourced and financially sound. Whereas the D3 and D4 firms do not have the resources and are of low financial standing. Due to their unfavourable financial condition, these D3 and D4 firms are only able to undertake small projects. The dependence on timber for formwork and scaffold is 100% among the D3 and D4 firms, while usage of timber for formwork and scaffold among the D1 construction firms is different from the former. With the use of pre-fabricated metal pieces on a D1 construction sites, just a small amount of timber is usually used. Even though the result of supply of timber to D1 sites appeared higher than that of D3 and D3 firms, because of the huge nature of the projects their timber usage is about 30% to 40% of the total timber supplied.

6.2.2 Timber Supply to Construction sites

Results on timber supply schedule to the four categories of sites used for the study provide basis to identify waste. The supply of timber schedules to the firms for formwork and scaffold construction as shown in tables 5.3, 5.4, 5.5, 5.6, and 5.7, are huge. From the details of the supply schedule, it is clear that, wawa (obechie) is the only timber specie mostly used for formwork and scaffold Construction. Wawa accounted for about 70% to 80% of timber supplied to the sites.

Bamboo, which are usually used as props in formwork construction were also supplied to the sites, they were about 10%of the total supply to the sites. Plywood accounted for the least supply of timber materials to the sites, they were about 3%.

Timber members supplied to sites for formwork are far more than for scaffold as indicated in the tables of the firms. Generally, boards are the most deteriorating material after first use. Most of the boards used for formwork deteriorated beyond 50%. The rate of deterioration of scaffold members like standard, ledger and putlog was low as shown in the tables 4.3, 4.5 and 4.7.

6.2.3 Methods of Constructing Formwork and Scaffold on Sites

The results and discussions on methods of constructing formwork and scaffold revealed that the four categories of construction firms use different approaches in construction.

D1 Construction firms

The D1 construction firms follow a laid down routine to construct formwork and scaffold. This starts from the design stage to the construction stage which is closely monitored and supervised by personnel responsible at the respective stages. These firms used a considerable amount of prefabricated metal members as a supplement. Due to the technique of combining timber with metal members to construct formwork and scaffold, the D1 and D2 construction firms waste less timber as compared to the D3 and D4 construction firms. Striking and dismantling of formworks and scaffolds respectively are considered as equally important as the construction stage. The timber and metal pieces are stacked according to their dimensions and sizes, and kept at a convenient place for use another time. Timber pieces that become bad due to cutting or nailing effect are discarded.

D2 construction firms

The following findings are identified with the D2 construction firms which have a smaller work force as compared to the D1 construction firms. There is laid down rule that designs and constrution methods of formwork and scaffolds should be adhered to, but it is not seen, as on D1 construction sites. These firms rely on timber solely for formwork and scaffold constructions. They do not have any high financial background and therefore procure low quality timber which can not last long. The extensive use of nail renders the timber pieces not suitable for reuse. The concept that formwork and scaffold are for a short period of time, has influenced their decision on striking and dismantling of formwork and scaffold. Most timber pieces are destroyed beyond reuse as a result of uncoordinated striking and dismantling methods. The practice of procuring new consignment of timber for formwork and scaffold on every project is normal. The D2, firms are not aware of the negative effect their practice is having on the national forest resources.

D3 and D4 Construction firm sites

These firms are in the majority of construction companies, but most often have membership ranging from one to ten. They are not of any sound financial status and therefore are mostly engaged on domestic projects. The type of timber employed for formwork and scaffolds by D3 and D4 firms on sites are mostly off cuts. Since the firms are usually, "one man" there is no laid down procedures for the design and construction methods of formworks and scaffolds. Nails are mostly relied on, to ensure the strength of formwork and scaffold instead of the quality of the timber. Because of the poor quality and condition of the timber pieces, irregular cutting, sizing and shaping are employed in the construction methods of the D3 and D4 construction firms. Due to the poor quality timber used, most of the pieces break, twist and are discarded after first time use. On D3 and D4 sites, timber pieces after striking and dismantling are given out for firewood.

6.2.4 Timber Wastage on Sites Due to Formwork and Scaffold Construction

Timber wastage on construction sites in Kumasi due to formwork and scaffold construction is prevalent. Though so many factors account for the waste, it is a common sight on every site after striking and dismantling of the structures. On the D3 and D4 construction sites, poor irregular cutting of the timber pieces has led to defective formwork and scaffold construction. This has often necessitated reconstruction of the structures which is a great waste. Poor quality timber especially green timber pieces are often employed by D3 and D4 construction firms. After construction and striking, the timber are discarded and used for firewood.

Dimensional co-ordination of the timber pieces is never practiced by D3 and D4 firms and this has resulted into irregular cutting. On the D3 and D4 sites, most timber pieces were not arranged according to sizes and lengths. Instead they were placed in a disorderly manner which necessitated the uncoordinated cutting of the timber pieces at different stages of the formwork and scaffold construction. Most D1 firms maintain the practice of dimensional and size coordination of timber pieces before and after construction and therefore experience less waste. It is therefore a normal practice on the D1 sites that, immediately the structures are struck or dismantled, bays are specially created according to various dimensions and sizes where the appropriate timber pieces are kept for next use.

Nailing as a jointing method is a major cause for the wastage of timber pieces in formwork and scaffold construction. All timber pieces used in the construction of formwork and scaffold are secured tightly with nails. The scenarios on the sites suggest that, it is the most reliable jointing method used for formwork and scaffold construction. Nail holes on timber pieces in most cases, cause splitting especially at the edges. Also the holes created on timber pieces through nailing, are permanent and cause puncture on the timber tissue and can not be nailed through at the same points. Every discarded timber piece on site has a nail hole or multiple holes on it. In order to avoid the same nail holes, the timber pieces are cut irregularly to obtain new lengths and sizes. Attempt by some of the firms to reuse the same nail holes on timber pieces has never been successful. It was also found out that, the firms are ignorant of the effect that, timber waste on sites, has on the depletion of forest resource on Ghana. The call by the Ghana Forest Commission in 2000, on all users of timber for economic consumption was relevant. However, there is little or no awareness among the firms especially the D3 and D4 about the depletion of the forest due to various practices including construction of formwork and scaffold. There was therefore no demand or need for measures to be taken on sites to check timber wastage activities. In this direction, the pilling of the sites with pieces of off cut timber pieces used for formwork and scaffold was a normal sight.

The perception that characterised formwork and scaffold as temporary structures has contributed immensely towards the prevailing waste of timber on sites. Since formwork and scaffold are always considered short-lived, the tendency to discard or destroy the materials after use is inevitable. It is not surprising that, Obechie (wawa) a timber specie of low strength properties and of low cost is the most predominantly used. The prevailing wastage has also been identified with the fact that, the timber pieces are not well seasoned. A well seasoned timber piece, even though of low strength properties can be of a considerable quality of work for sometime. On the other hand, green or non seasoned timber deteriorates further when used for formwork or scaffold. The texture of the timber piece becomes soft and weak. Any nailing of such pieces caused cracks and splitting along the edges and ends.

Another cause for timber wastage on sites has been identified, with how the timber pieces are scattered and exposed to the weather for days. Due to the haphazard placement of timber pieces on sites, some get broken when walked over or moved over by vehicles. In the open, the pieces are also exposed to rain and heat of the sun despite all these, quite a reasonable number of timber pieces have been retained and can be reuse for the second time. It can be stressed that, due to the perception that, the formwork and scaffold are temporary structures, the expected care and maintenance needed to enhance the service life of the timber pieces is ignored. As a result, it appears that, the prevailing attitude of wasting timber pieces used for formwork and scaffold will continue. It may take a consented effort and time to change attitudes and thereby reverse the trend of waste on the construction sites.

6.3 CONCLUSION

In conclusion, it was evident through the study findings that, the wastage of timber due to the construction of temporary structures like formwork and scaffold is real and a disturbing issue. Again it is also true that the main factor in the waste is the method of construction and the quality of timber being used. This implies that practice of procuring new consignments of timber for formwork and scaffold for every project is due to inefficient timber utilization.

By categorising the construction firms into D1, D2, D3 and D4 it was possible to identify their operation styles. Knowledge of the personnel and their roles on the respective sites has revealed the construction standard that prevails among the firms.

In deed, the routine supply of timber to construction firms for the construction of formwork and scaffold on building projects, constitute a notable consumption of the Ghanaian forest resources. The continuation of this practice together with other timber consumption activities may lead to eventual depletion of our forest resources. Identification of the practices through which the timber pieces are wasted on the sites has brought to the fore, the need to explore possible strategies.

Through the methods of study, very prospective strategies to address both the construction methods and the material quality have been adequately explored. These strategies together with the designed and developed proto type prefabricated formwork and scaffold, are expected to provide the basis, for the adoption of prudent polices on economic usage of timber on sites.

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The results and discussions exposed the realities of the causes of timber waste and how these could be resolved. The findings of the study therefore emphasised the concerns that should be addressed to eradicate timber wastage on sites. The recommendations that were developed to meet the findings are expected to promote efficient utilization of timber for formwork and scaffold construction in Kumasi metropolis. The effects of this economic practice, will eventually affect a national approach to timber utilization in Ghana.

6.4 RECOMMENDATION

On the basis of the findings, these recommendations are made to address the issues of devising economic and efficient means to use timber for formwork and scaffold construction. I must say that, in making these recommendations, lessons from the survey of sites visited and the research institutions where experiments were conducted on timber utilization inspired me. It must be stated that, adequate recognition has been given to the findings of the roles and activities of the categories of construction firms namely; D1, D2, D3 and D4. The various experiments also provide basis for the consideration of alternative options that can be employed, to enhance the efficient and repetitive use of timber for formworks and scaffolds.

6.4.1 Identification of less known and Used Timber Species for Formwork and Scaffold

One crucial strategy of addressing efficient utilization of timber for formwork and scaffold construction will have to do with, reducing over dependence on

Obeche (wawa) as the only timber specie for that purpose. The reports of FORIGH (2000) identified many timber species which are less known but very suitable for construction. While the over dependence on the known timber species will lead to their depletion in the forest, the less known species are in abundance and under utilized. The results and discussion of the strength properties, natural durability and service life of the following less known and used species have showed that, they are very good and should be used for formwork and scaffold: Kusia, Kaku, Afina, makore, and Potrodom. As these species are not popular and not often used, they are low in price and can be easily procured.

Studies have shown that, bamboo as timber specie has become the most extensively used in the Asian sub-region for formwork and scaffold construction. This is attributed to its availability and good working strength properties. In Ghana, bamboo is used on a mild note for props in formwork. However, recent discoveries and development about the potentials of the timber material being processed, into boards and scantlings for various structural works should be explored. Because of its high mechanical properties, bamboo which is processed into boards, battens and scantlings of various sizes and length, should be used to construct formwork and scaffold. This will help reduce the over dependence on the endangered timber species especially Obechie (wawa) for construction.

6.4.2 Improving the Quality of Timber Species for Long Service

It is natural a phenomenon that, any timber material exposed to the atmosphere when in use will deteriorate. The moisture in concrete may be absorb by the formwork timber pieces and thereby weaken the structure of the tissues. Also scaffold members exposure to the heat of the sun and absorbing of dew and rain water may equally swell the timber pieces. The study results on the use of plastic to coat the surface of timber pieces revealed that the surface protection of timber pieces is very vital to ensure their long term use. Even though it may be expensive using plastics to coat timber surfaces, its long term effect is cost effective. Timber pieces used on most of the D1 construction sites have all the surfaces painted to protect them from the effect of the weather and moisture. With this treatment the pieces were used at least four to six times before discarding them. In a short term, the D3 and D4 firms can ensure the economic use of timber for formwork and scaffold construction. The usual habit of procuring consignments of timber for every project will reduce thereby ensuring economic use. Considering the period of time that timber pieces used for formwork and scaffold are left in contact with moisture and the sun, it may also be necessary to treat the whole piece from inside out. The treatments of timber, through the full cell processes of impregnation can improve the strength properties and fortify the tissues against moisture penetration. Since the results of the study on that the timber species used for the full cell examination on, both strong and weak timber species, shows that they maintained constant size, length and weight after being left in water for some days the treated timber pieces are highly recommended. The full cell processes through impregnation is expensive but may be cost effective in view of the fact that treated timber pieces duration range significantly between twenty to thirty years service. For a long service life of the timber species for formwork and scaffold, it is recommended that all timber pieces either strong or weak should be treated with full cell processes.

6.4.3 Dimensional Co-ordination of Timber Pieces

Lack of arrangement of timber pieces on sites according sizes, shapes, and lengths have contributed immensely to the wastage of D1 volumes of timber. As the timber pieces to be used or formwork and scaffold are left anyhow on the site, sorting becomes difficult. A situation like this has often necessitated uncoordinated and irregular cutting of timber pieces. The provision of sheds with bays which are identified with the timber pieces of various sizes and lengths as observed on the D1 construction sites were very desirable. It helped in co-ordinating the dimensions of all timber pieces and checked the uncontrolled cutting and sizing which would have wasted timber. The D2, D3 and D4 firms should institute as part of their practice, means of ensuring that timber pieces are always arranged according to their sizes and length. This will promote easy identification of the timber pieces in good or bad condition.

6.4.4 Prefabrication of timber pieces

The use of nails in the construction of formwork and scaffold on sites has always caused deterioration of most timber pieces. However, nails are the only means use to join timber pieces for formwork and scaffold on all D3 and D4 construction sites. On D1 sites, the use of pre-fabricated timber with metal pieces ensures efficient utilization of timber through repetitive use.

In this case, the timber pieces are effectively joined and angles secured without using nails. The use of metal angle plates, sheet metals and bolts and nuts enabled an easy assembling and dismantling of the structures without spoiling any timber pieces. To ensure that, the timber pieces are not destroyed through nailing, and cutting, it is recommended that the pieces be prefabricated with metal pieces. This will enhance the repetitive use of timber for the construction of formwork and scaffold. In addition, the sides and edges of the timber pieces, are usually liable to split and break during the construction of formworks and scaffolds. The lipping of the sides of and edges with metal sheets will provide the needed reinforcement against any puncture. Observation on D1 construction sites revealed that, the prefabrication of timber pieces with metal pieces to construct formwork and scaffold is an efficient method. For the five consecutive projects, that the prefabricated timber pieces were used, the timber pieces are still in good service condition. It is possible to use these pieces for more than ten projects without deteriorating. The successful design, construction of prefabricated proto type timber formwork and scaffold and subsequent testing in real situation has proved that the strategy is commendable.

LIST OF REFERENCES

1. Addai S. and Amoah-Mensah (1995) Technical Report on Timber Utilisation for building. Building Road Research Institute (BRRI).

2. Alan E. (1994) Materials, Longman Group Ltd. UK. Pp 32—60.

3. Allan J. (1997) Research Methods Study Material, University of Wolverhampton U. K.

4. Ambuja Cement (1998) Formwork: Construction and Inspection. Technical Services India.

5. Amoakohene, S.K. et al (1998) Technical Skills and Drawing, Unimax/ Macmillan Publishers Ltd London.

6. Arora and Gupta (1997) Building Construction seventh Edition, Sumitra Handa New Delhi India.pp 8.2—8.9.

7. Austin C.K. (1966) Formwork to Concrete, Macmillan and Co. Ltd 2nd Edition, London.

8. Ayarkwa J. (1994) Technical Report on Timber Utilization Forest Research Institute of Ghana (FORIG).

9. Barnbrook et al (1975) Concrete Practice, Cement & concrete Association of U.K.

10 Barry R. (1999) The Construction of Buildings. East West Press PVT Limited New Delhi India. pp.130-158.

10. Bell, J. (1997) Doing Your Research Project Open University Press.

11. Brown C. R. (1998) Research in Science and Technology Education Volume 8, 16 No Carfax.

12. B. R. R. I. (1996) Report on effective use of timber in Ghana

13. Chudley R. and Greeno, (1998) Building Construction Handbook, Butter Worth Heinemann London.323—327.

14. Chudley R. (1983) Construction Technology Vol 1&.3, Longman Group Ltd England.

15. Concrete practice Association (Ceca) (1974-79) special report on requirements for formwork construction U.K.

16. Crunden, F. and Cosyn, F. (1991) Design for Residential Construction, McGraw-Hill Ryerson Limited, Canada. Pp 325-333

17 Everett A and Barrit C. (1994) Materials 5th edition, Pearson Education Limited Edinburgh. U K. pp.213 -230

18 GHACEM (2002) Technical bulletins for formwork construction.

19. Ghana Forestry Commission, (2000) Utilization of Timber Species in Ghana.

20 .Ghana Forestry Commission, (2003) Technical reports on allowable timber harvest In Ghana.

21. Ghose D. N. (2001) Civil Engineering Drawing and Design C.B.S. Publishers and Distributors New Delhi, India. Pp 53—60.

22. Hans Banz (2001) Building Construction Details, CBS Publishers, Delhi India.25—45.

23. Kelsely W.E. (1954). Carpentry, Joinery and Woodcutting Machinery, Macmillan & Co Ltd. London. pp 16-43

24. Kumasi Metropolitan Assembly (2002) Town and Country Planning Report on Building Projects in Kumasi Metropolis.

25. K.M.A. (2003) Building Inspection Report on Projects in Kumasi Metropolis.

26. Lee H.S .and Yuen G.C.S (1993) Building Maintenance Technology, the Macmillan Press Ltd, London.

27. Mckay: (1996). Building Craft services, Carpentry, The Dabrien Press Limited Edinburg.

28. Nash W.G. (1975) Brickwork1, (vol.2) Hutchison Educational Limited, London.

29. Okoh K. and Addo-Ashong (1977) Technical report on Wood as a building material in Ghana (FORIG).

30.Ostrowski P. (2004) Annual Ontario State Workshop Seminar paper on Temporary Structures in Building, Ontario U S.A.

31. Seeley: I. (1986) Building Technology third Edition Macmillan Education Ltd London.

32. Taylor G. D. (2000) Materials in Construction Pearson Education Limited U.K.

33. Timberlake, L. (1987) Only One Earth, living for the Future, London Earth scan limited

34. Walton, D. (1995) Building Construction Principles and Practices, Macmillan Education Ltd London.

35. Whitney, C.H. and Mickadeit, R. E. (1987) Building Construction, Fifth Edition, John Wilsey & Sons New York.

36. Winden, J., Pforte, W., and Hohnerlein, F. (1980) Technical Report on Rural Building Construction Stitching Kongregatic F.I.C. Ghana /Germany

APPENDIX 1

INTERVIEW WITH THE ARTISANS

Title: Efficient Utilization of Timber for Formwork and Scaffold Construction: A case study of Construction firms within Kumasi Metropolis.

Aim: The aim of the study is to develop efficient means of utilizing timber for scaffold and formwork in building construction in Ghana.

The objectives of the study are to:

1. Review the current designs and methods of constructing and removal of scaffold and formwork on sites.
2. Develop appropriate design of formwork and scaffold through prefabrication to facilitate repetitive use of the components.
3. Identify appropriate methods of combining timber with other constructional materials of combining timber with other constructional materials to enhance the efficient use of timber for formwork and scaffold.

Preamble

Timber is a very important material, use in Building construction for various purposes. The construction of formwork and scaffold like formwork and scaffolds is one of the constant uses of timber. The practice of discarding the timber pieces after using them and procuring new consignment of timber for every project is a waste. The national concern about Forest resources depletion through various activities of timber consumption poses a challenge. It is expected that the project will be able to identify and develop appropriate means to efficiently use timber in the construction of formwork and scaffold on sites. The knowledge of formwork and scaffold, problems associated with methods of construction, the need to ensure efficient use of timber and type of materials are issues that the artisans need to be interviewed on.

Knowledge of Formwork and Scaffold

2. What is your idea about formwork and scaffold?
3. Do you know the purposes for which formwork and scaffold are used
4. Which type of formwork and scaffold do you construct on the sites?
5. In all cases, do you realise that the formwork is serving the role of means to an end?
6. Do you think the practice of always procuring new consignment of timber for the construction of formwork and scaffold for every project is justified?

Problems associated with Formwork and scaffold

Do you encounter problems with the formwork and scaffold you construct?

7. What are some of the problems you have encountered?
8. How do you normally solve the problems?

Design Considerations

9. How many years have you been involved in the construction of the scaffold?
10. Do you consider designing of formwork and scaffold as a necessary requirement?
11. Do you prepare designs or sketches of the structures before constructing them?
12. Have you observed that, lack of design consideration has led to waste of timber in the construction of the structures?

Efficient Methods to Enhance Repetitive Use

13. Is it possible to use the timber pieces repetitively?
14. Do you also think it is possible to enhance the repetitive use of the structures through the following?
    - Use of appropriate joints
    - Incorporating timber with other material for the temporary
    - Developing pre-fabricated formwork and scaffold
15. Will the idea of the economic use of timber through your construction of an efficient pre-fabricated structure is effective?