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COLLEGE OF ARCHITECTURE AND PLANNING

DEPARTMENT OF BUILDING TECHNOLOGY

THE POTENTIAL OF BAMBOO AS A MATERIAL IN BUILDING CONSTRUCTION IN GHANA

BY

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DECLARATION

I hereby declare that, this thesis is a presentation of my original research under the guidance of my supervisor and that it has not been submitted anywhere for any award. Wherever contributions of others are involved, every effort is made to indicate this clearly, with due reference to the literature, and acknowledgement of collaborative research and discussions.

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ABSTRACT

Timber plays an immeasurable role in Ghana's economy by contributing immensely to the building construction industry. Nonetheless, the acute dwindling supply of timber to the local market and the overexploitation of the common species have called for the need for an alternative forest product to supplement timber in building construction in Ghana. Bamboo has been exploited and has gained popularity in building construction in China, and other Asian countries. It has been identified to have constructional properties similar to that of timber but its potential has not been fully realised as a material in the building construction in Ghana. This research assessed the extent of utilization of bamboo as a material by identifying the various areas of bamboo usage, factors influencing the use of bamboo and the trend of bamboo usage with respect to volumes in building construction. The study employed structured questionnaire survey with data gathered from Building Contractors in the Kumasi metropolis and Architects in Accra and Kumasi. Data analysis was based on the Relative Importance Indices method of analysis to identify respondents perception on the areas of bamboo usage, the level of influence of different factors on the use of bamboo and also whether areas of bamboo usage in construction for the past ten(10) years has seen any significant increase or decrease. The Chi-Squared method of analysis was also used to assess the relation between the responses of the different respondents on the factors influencing the use of bamboo.

The results showed that all areas of bamboo usage have not been exploited except in the areas of props and landscape which were increasingly gaining popularity in building construction. Respondents were of the view that bamboo is used as a material in Ghana as a result of its availability, affordability, durability, multiples uses, and easy of use in its natural state among others. The Architects not specifying bamboo for use, lack of bamboo details, limited knowledge on bamboo and lack of expertise to use it, lack of processing technique and

insufficient cooperation from government among others were identified as barriers to the use of bamboo in building construction. It was recommended that Architects should consider bamboo as a primary material in building construction, and specify it for use to help spearhead its promotion in building construction. The research further suggested that the government should give the needed support to the bamboo sector in Ghana. This is to promote the extension of its areas of attention further to the construction industry. Industries which will treat and produce bamboo products for use in building construction should be established. Additionally, it was also recommended that promotion of bamboo usage in less used areas in building construction should be giving the needed hype to create the awareness of its potential as a building material. Additionally, research into bamboo in construction should be encouraged in building construction institutions to enhance grass root promotion of bamboo in building construction.

DEDICATION

I dedicate this research work wholeheartedly to God Almighty, My parents and to all my friends.

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"I will enter His gate with thanksgiving in my heart" (Psalm 100:4a)

I'm very grateful to the Lord Almighty for his guidance and protection throughout this research work. He is the reason behind the successful completion of this research.

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INTRODUCTION

1.1 BACKGROUND OF THE STUDY

The role that the construction industry plays is immeasurably great in national developmental agenda of developing countries. The immense demand of construction in developing countries has created ready market for construction firms. It has been identified in research that during periods of acccleration economic growth, construction output grows at a faster rate than the economy as a whole. Ofori (2012) reiterated that building construction contributes to the socio-economic development of nations. Inadequate construction capacity could act as a constraint on capital investment programmes. Investment and the rate of growth will be slowed down and may eventually grind to a halt (Lopes, 2012).

Ahadzie (2009) indicated that there is no doubt that the Ghanaian Construct Industry (GCI) (as in many other construction economics) holds the key to the development of the nation. Construction contributes to the national socio-economic development by providing significant employment opportunities at non-skilled and skilled levels.

The construction industry is characterized by different issues which affect the industry. Fapohunda and Stephenson (2010) indicated that the construction phase of every developing country is faced by four different issues which are categorised into management, capital, labour, and materials. Though all the categories mentioned above are of import, the impact of the material aspect of these categories should not be undermined. The demand for materials either locally obtained or imported has pulled an array of different industries to play roles in the construction industry and the list of these industries is not complete without mentioning the

timber industry. Timbers produced by the timber industry have various uses and these uses could be categorized into furniture and decorative purposes, building and general construction, and heavy construction (Ayarkwa, 1998). For the purpose of this research, emphasis will be made on the timber being used for general construction to bring to bear the relevance of this research.

With the rapid increase of population associated with developing country, there is an outburst demand for construction and this is coupled with increase demand for timber for the industry. It is anticipated by the Food and Agriculture Organization (FAO) in related research that the demand of order for wood and wood products will increase by thirty percent (30%) by 2013 (FAO, 1997).

According to Cardoso et al. (2007), in recent years there has been a growing concern for the protection of gazetted Forest Reserves (FR) as long held assumptions about Ghana's forest wealth are no longer valid. The situation is aggravated by the fact that the non-gazetted forests which encompass some 5.4 million ha, locally known as Off-Forest Reserves (OFR), are seriously degraded and can be considered as largely gone since what is left are merely isolated large trees in a vast agricultural landscape. This however has placed doubt on the future survival of the timber industry.

Ghana's forest timber production area is declining in an increasing manner in both size and productivity due to unecological logging practices and over utilization of the traditional timber species. The extreme exploitation of the forest has beckon on authorities to put strict regulation which has eventually reduced the quantity of timber supplied to the furniture and construction industries (Ayarkwa, 1998).

According to the Ministry of Land and Forestry (1996), the annual allowable cut (AAC) of timber of 1.0 million cubic meters, comprise of five hundred thousand meter cube (500,000m^3) from the reserved forest and five hundred thousand meter cube (500,000m^3) from off-reserves. With the data on the Annual Allowable Cut (AAC), Ayarkwa (1998) indicates that timber obtained from the forest will be insufficient to the expanding timber processing and the construction industries. It is also an indication of a gloomy future for raw material supply to the local wood processing industries.

To alleviate the problem of insufficient and extinction of the timber species allowable to the market especially to the construction industry, it is expedient that other forest resources that can serve as alternatives to timber must be exploited. Bamboo, a giant woody grass, is one of such alternative resources to support the local timber industry. Bamboo has been identified and tested by many countries and proven to have the qualities which make it a very good material for the building and construction industry. According to Gutiérrez (2000), there has been an ancient exploration of bamboo for construction and this is due to the fact that it appears to be a tailor-made material for use as a building component. Bamboo appears round, straight, smooth, strong and beautiful.

Bamboo recently has gained a huge attention as a material which can be an alternative timber due to its ease of cultivation. It has the ability to grow almost everywhere in various seasons and has short rotation (Liese, 1985 and Power, 2004).

Like wood bamboo also possesses high residual strength to absorb shocks and impacts–this makes it a highly suitable material for construction of houses to resist seismic and high wind forces (Shyamasundar et al., 2008)

Building materials accounts for nearly 60 to 65% of the cost of house construction. With the constant rise in the cost of traditional building materials and with the poor affordability of large segments of our population the cost of an adequate house is increasingly going beyond the affordable limits. This calls for wide spread technology dissemination and availability at decentralized locations of cost-effective building materials and construction techniques (Deshwal, 2011).

1.2 PROBLEM STATEMENT

The Ghana construction industry has greatly been affected by the current situation the timber industry is going through. Due to the dwindling nature of the supply of timber species and the high cost of the little quantity supplied to the building construction industry, there is an urgent call for an alternative forest product which can serve as a substitute to timber by making high quantities available to the GCI (TIDD, 2011).

The current situation of timber supply to the construction industry can be solved by the introduction of a material that can be used for construction, which is readily available in the country, relatively cheap, have satisfactory structural properties for construction, and can be renewable (Hutchful, 2002). Bamboo stands out tall among most material to replace timber in its current situation. But the question is to what extent has bamboo been adopted as a material to the building industry in Ghana (Solomon-Ayeh, 2004).

Related research shows that, apart from the fast growing nature of bamboo which can easily meet the demand of its use when exploited as compared to timber, it also possesses many positive quality of modern engineering materials in the construction industry. Among these qualities

include, high tensile strength compared to that of mild steel and also has a high strength to weight ratio and high specific load bearing capacity. Bamboo cannot be mentioned without the acknowledgement of its Physical-mechanical properties and the short maturity period of 4 to 5 years as compared to the favorably hardwood which requires 40 to 50 years to attain maturity (Janssen, 2000).

Bamboo has been extremely exploited as a construction material to the construction industry by South-Eastern Asia and the Latin America. However, though bamboo is grown in larger quantities in Ghana, its exploitation is the reverse of that of the above mentioned areas of the world. It is only used as props in the construction industry (Tekpetey, 2006).

Bamboo possesses constructional properties like high tensile strength, high strength to weight ratio and high specific load bearing capacity hence, making it a potential material for building construction industry.

The research seeks to find out the potential bamboo has as a material for building construction in Ghana.

1.3 RESEARCH QUESTIONS

In the quest of achieving a very good research, the research seeks to ask some question which will help bring the needed solution base on the answers that would be obtained for the said questions.

- What is the current state of timber supply in Ghana to warrant the promotion of a supplement in building construction?
- Which areas in the Ghanaian building construction industry are bamboo used?
- What are the factors influencing the use of bamboo in building construction in Ghana?

- What is the trend of bamboo usage with regards to volumes over the last decade in Ghana?

1.4 AIM AND OBJECTIVES

1.4.1 Aim

This research is aimed at assessing the extent of bamboo utilization as a material in building construction in Ghana.

1.4.2 Objectives

In order to achieve the above mentioned aim of the research, these objectives must be adhered to:

- To identify areas in building construction where bamboo is used in Ghana.
- To identify the factors influencing the use of bamboo in building construction in Ghana.
- To ascertain the trend of bamboo usage with regard to volumes over the last decade in Ghana.

1.5 SCOPE

In reference to the topic, the study will focus on Kumasi as a metropolis. The intention of this study was to cover a wider scope in Ghana. However, the study will be restricted to Kumasi. This should not minimize the importance of the findings because, Kumasi is Ghana's second largest city and capital of the Ashanti region, and it is an important commercial centre (KPMG, 2008).

According to Obiri and Oteng-Amoako (2007), the Ashanti region is the second largest region to Eastern Region where bamboo is grown and collected on commercial scale. Kumasi's location, climate and safety, combined with Ghana's increasing access to foreign markets, make Kumasi a

city among others to attract investment in a number of sub sectors. Investment in these sub sectors has called for the expansion of some existing facilities such as business centres, retail shops, warchousing, storcs and thc construction of ncw oncs such as Sokoban Wood villagc, thc affordable housing project at Asokore Mampong, the cocoa processing plant by Archer Daniels Midland. The whole country is undergoing a face lift in construction with the sprouting of building constructions in the major cities of which Kumasi is no exception. Indeed there are a lot of construction works going on in thc Kumasi mctropolis hcncc, thc high dcmand for construction materials of both foreign and local materials. Bamboo is one local material gaining popularity in building construction in Ghana and with Kumasi being a major city where bamboo can bc found and a lot of construction going on, it is rclcvant to choosc Kumasi as thc study arca. This will help to outline the potential of bamboo as a material in building construction in Ghana.

1.5 OUTLINE OF METHODOLOGY

The desired outcome of the research depends on the appropriateness of the research methods cmployed. Hcncc, thc rcscarch will cmploy a rangc of complcmcntary rcscarch mcthods ovcr some phases. In the preliminary phase, background information on timber, the state of timber industry to construction in the world and Ghana and also the contribution of bamboo to the construction industry will be gathered from literature. This will help in identifying contractors' awareness of bamboo and the extent of its use as a material in the construction industry. Following this, closed ended questionnaires and structured interviews will be developed for collecting data from the fieldwork. The structured questionnaire will be administered to contractors and other consultants (Architects) areas they apply and specify bamboo to be used in buildings, the trend of the use of bamboo and the challenges they face in the use of bamboo

Personal observation for collecting of information from various sites would also be used to identify the use on various sites.

The research will employ purposive sampling technique to seek the views of architects on bamboo usage. The snowball sampling technique will be use to identify the sample size of the registered small scale contractors. This is because the researcher is not getting the list of contractors and their contact information.

Due to the large population of building contractors, an appropriate means of calculating the sample size of the research will be employed. The researcher will collect data from active construction sites to assess the extent of the use of bamboo.

The third phase of the research will be focused on analysis, using Statistical Package for Social Sciences (SPSS), which help collate and interrogate the large volume of data collected during research and the use of relative index as an analytical tool would be employed to rank data. The use of simple descriptive data analysis tool will also be used. Interviews would also be conducted to ascertain the views of contractors, bamboo sellers and probably bamboo farmers about certain specific areas which could not be captured in the questionnaire. Personal survey will also be conducted on construction projects sites to identify the extent of the used of bamboo on projects.

Chi Square would be used to determine whether there is difference between the responses on the factors influencing the use of bamboo by the two respondents. Here the stated hypothesis as stated below would be tested to outline the difference:

- Null hypothesis (H_0): there is no difference between the responses of the respondents on the factors preventing the use of bamboo.

- Alternative Hypothesis (H_1): there is a difference between the responses of the respondents on the factors preventing the use of bamboo.

The analysis of the findings would then be expressed in figures, tables, charts, graph and the like, directed at developing a research to evolved at attaining the potential of bamboo as a materials in building construction in Ghana.

1.7 EXPECTED OUTCOME AND BENEFITS

At the end of this research, the expected outcome will be:

- An identification of the extent of use of bamboo and its areas of application in the construction industry.
- An outline of the current state of timber would be identified at the end of this study.
- An outline of the areas of bamboo usage that contractors can exploit in Ghana.
- Addition to literature information about bamboo relevant for academic purposes for the built environment.

1.8 DISSERTATION CONTENTS

The study has been organized into five chapters.

- Chapter one is the general introduction of the study which include the background to the study, problem statement, the research questions, aim and objectives of the study, the outlined methodology and the scope of the study

- Chapter two of this study deals with literature review on overview of Ghanaian construction industry, current state of timber supply in Ghana, bamboo usage and areas of application: world, Africa and Ghanaian perspectives, and constructional properties of bamboo
- Chapter three dwells on the methodology to achieve the research.
- Chapter four forms the core part of the study and it consists of analysis of data and its discussions expressed in texts, figures, tables, charts graph and the like.
- Chapter five is the concluding part and hence the end product of the study. Some recommendation would be made in this chapter base on the outcome of the findings.

CHAPTER TWO

LITERATURE REVIEW

2.0 INTRODUCTION

This chapter deploys literature on bamboo in building construction in order to bring out the extent of its contribution as a material. The chapter presents the overview of Ghanaian building construction industry (GBCI), followed by the state of timber supply to the construction in Ghana and the world at large. Understanding the need to give attention to bamboo as a material is necessary for a push greatly into the GBCI as a replacement for timber in some areas of building construction. The above mentioned will be supported by insight into bamboo and the construction industry. The chapter will also look at the areas in building construction that bamboo can be used and the sources of bamboo to construction.

Additionally, this chapter will help in identifying the constructional properties of bamboo making it a good material to replace timber due to its dwindling supply. The outline of various factors influencing the use of bamboo in building construction would also be looked at in this chapter.

2.1. OVERVIEW OF GHANAIAN BUILDING CONSTRUCTION INDUSTRY

The performance of the construction industry to every country especially the developing countries are undoubtedly great and the needed attention to the industry must not be under played. Due to the immense demand of construction in developing countries, there has been the availability of ready market for contractors (construction firms) who are partners in the solving of construction needs of these developing countries. Construction in literature has been

acknowledged that, during periods of accelerated economic growth, construction output grows at a faster rate than the economy as a whole. Inadequate construction capacity could act as a constraint on capital investment programmes. Investment and the rate of growth will be slowed down – and may eventually grind to a halt (Wells, 1986).

The construction industry, according to Anaman et al (2007) adopted from Lange and Mills (1979), is defined as a group of firms with closely related activities involved in the construction of real estates, building, private and public infrastructure. It also deals with all economic activities directed to the creation, renovation, repairs or extension of fixed assets in the form of buildings, land improvements of an engineering nature and other such engineering constructions such as roads, bridges, railways, ports, dams. In Ghana, Civil Engineering firms undertake some of the aforementioned projects which involves heavily engineering characteristics such as bridges, roads, railways and dams, while the Building Construction Firms (BCF) also undertake projects such as the construction of schools, hospitals, health centres, hotels, offices. BCF also undertake external works which sometimes involved "simple" engineering construction such as drive ways.

Contractors and construction works are classified according to various factors and the contractors' ability to meet the demands of these factors to achieve the desired construction work whether sophisticated or simple. The assets of a contractor to execute a particular work help in easy classification of that contractor. Kirmani (1988) stated that, for a given work, the value-added in construction depends on many factors, such as design, construction technology, use of equipment and labour, equipment performance, price and wage levels, temporal works and processing of materials during construction.

According to Ayiah (2004), scale of building construction works could be categorized into three main sectors; the large scale, medium scale and small scale construction works. The classification of these various scales is as a result of the simplicity or complexity and the financial involvement of the work in question. The nature of construction work calls for the involvement of particular plant and equipment, human resources (labour with specialist personnel), and material resources. The large scale constructions which are predominant complex or large in nature will call for heavy duty plant and equipment, a large pool of human resources and large quantum of material for its execution. The complexity of work reduces from the large scale to medium scale. The small scale construction basically deals with simple building which does not require as much resource as there are for the large scale building construction. These classifications could be simply said to be the consideration of the financial involvement for the execution of the particular work. The scale of work and the resources necessary for the execution has hence called for the classification of contractors to execute these works.

The Ghanaian building construction firms comprises of a large number of enterprises of various sizes as registered and categorised by the Ministry of Water Resources, Works and Housing (MWRW&H) as D1K1, D2K2, D3K3 and D4K4. There are four financial sub-classifications within these categories: 1, 2, 3 and 4 which set the limitations for companies in respect to their asset, plant and labour holdings, and the nature and size of projects they can undertake. Class 1 has the highest resource base, decreasing through Class 2 and 3 with Class 4 having the least resource base (MWRWH, 2004). Ayarkwa et al. (2010) confirmed that the D3 and the D4 contractors dominate the Ghana construction industry and out of the 7095 construction firms registered in 2002, ninety percent (90%) belong to the D3 and D4 classes. According to Egmond

and Erkelens, (2007) and Owusu-Tawiah (1999 the small construction firms (D3 and D4 contractors) have insufficient funds and the appropriate technological capabilities, plant, key personnel to handle projects properly and the needed equipment to execute a project. The D1 class of contractors handles large scale works, the D2 handles construction works within the medium scale and D3/D4 contractors handles small scale works and cannot go beyond that scale unless they have graduated to an upper class through the upgrading of their resource base.

2.2 STATE OF TIMBER SUPPLY IN GHANA

The Ghana timber industry contributes greatly to the national economy. According to a study by Mhango (2010), the timber industry contributed about nine percent (9%) to the nation's Gross Domestic product (GDP) as at the year 2009. Despite the immense contribution of the Ghanaian forest in the supplying timber to other industries, it is faced with challenges in that its timber supply to both the local and foreign markets is dwindling (Tekpetey, 2006). According to Solomon-Ayeh (2004), there is an increasing realization in Ghana that both primary and secondary timber species (Lesser Used Timber Species, LUS), are becoming difficult to find, and where they are available, they are expensive. It is realized that, illegal logging and over utilization of the main traditional timber species has contributed to the reduction in about one million and two hundred hectors (1.2 million ha.) size timber production area (Ayarkwa, 1998).

2.2.1 State of timber export in Ghana

The classic policy-declined as a result of the free fall which affected Ghana's economy before the adoption of adjustment of policies in 1983 (Hutchful, 2002) affected all sectors of the economy including the timber industry (Owusu, 2001). The pre Economic Recovery Programme

(EPR) era (especially the years from 1970 to 1982), was characterised by sharp decline in GDP. The period was characterised by sharp decline in both domestic and export production. To arrest the situation, the then military government embarked upon the World Bank and IMF sponsored Economic Recovery Programme which was, among others, to halt the economic decline and stabilise the situation, promote economic growth and export recovery through a realignment of incentives towards productive activity and the habilitation of economic and social infrastructure (Hutchful, 2002). The programme, as indicated earlier, rekindled the export sector and consequently natural resources, particularly minerals and timber came under intensive exploitation. It is within the above background that the timber export in Ghana has been discussed. The timber industry which comprise of three categories of operation: primary (logging), secondary (sawmilling, ply milling and veneer milling) and tertiary (furniture, doors, flooring, profile/ moulding and toys) constitute an important component of the economy (Inkoom, 1999).

Currently, the overexploitation of some particular species of timber has affected the supply of timber to the foreign market. According to the timber export report by the Timber Industry Development Division (TIDD) of Ghana as shown in Table 2.2 (a), there has been a decline in the volumes of timber exported from 2008 to 2011. The report also shows that, the volumes of timber supplied to foreign market from 2001 to 2007 have been fluctuating (TIDD, 2011).

Table 2.2(a): Volumes of timber exported from 2001 - 2011

YEAR	VOLUME OF TIMBER EXPORTED PER YEAR (m^3)
2001	476,500
2002	472,427
2003	444,388
2004	455,180
2005	466,155
2006	451,608
2007	528,570
2008	545,915
2009	426,222
2010	403,254
2011	319,843

Source: Timber Industry Development Division (TIDD, 2011)

2.2.2 State of timber supply to the local market

Whilst export trade in timber and wood products has been encouraged over the years little or no attention has been paid to the supply of local market which is dominated by illegal operators (Gayfer et al. 2002). It has been argued by Inkoom (1999) that the domestic consumption of timber for industrial application is on the increase. The reduced volume of timber supply to the local market has become detrimental to the construction industry and other industry in high demand of timber.

Even though government has set policies to arrest the issue less attention to the local market by supplying twenty percent(20%) of sawn timber to the local market, there is still the problem of dwindling supply of timber to the local market (Forestry Commission of Ghana, 2004).

Table 2.2(b): Volumes of timber supplied to the local market from 2001 - 2011

YEAR	VOLUME OF TIMBER SUPPLIED TO THE LOCAL MARKET (m^3)
2001	119,125
2002	118,107
2003	111,097
2004	113,795
2005	116,539
2006	112,902
2007	132,143
2008	136,479
2009	106,556
2010	100,814
2011	79,961

Source: Timber Industry Development Division (TIDD, 2011)

The volumes of timber supplied to the local market as presented in the table 2.2(b) above fluctuated from the year 2001 to 2007 and declined from the year 2008 to 20011. The report shows dwindling supply of timber supply to the local market hence, the need for an alternate forest product.

Different species of timber available in Ghana have specific features which make them suitable for specific use. The wide range of Ghanaian timber includes some of the most durable species in

the world, suitable for use in bridge construction, sea defense and railway sleepers, as well as lighter woods for interior domestic use (Lyonsdown Media Group).

On the contrary to the many species available in the forest of Ghana, Ayarkwa (1998), mentioned that the excessive exploitation of the common species of timber like mahogany, Wawa and other species by the furniture and the construction industry has attributed to the current problem of shortage of timber supply to the said industries. It is added that the cost of the final products from these industries are also measured high beyond the reach of the average person. This problem has therefore called for attention to be directed to the less used unpopular species.

In a related research, it is identified that trade and export of timber revolve around only twenty species. Among these species seven of them have a dominance of about eighty percent (80%). The seven species which dominate timber species are Teak, Wawa, Mahogany, Asanfina, Ceiba, Ofram, and Chenchen. The research stated that the implication of the above mentioned species situation is that, the future of these species will soon become endangered (Oteng-Amoako et al., 2004).

2.2.3 Summary

In summary there has been a general decline in the volume of timber supplied to both the local and foreign markets and this has caused an increase in the cost of the little supplied. The dwindling supply of timber could be attributed to many factors of which include the overexploitation of common species, less attention to other timber species and forest products with properties comparable to that of timber (bamboo), illegal logging of timber from forest etc.

The current situation of timber supply in Ghana has affected building construction greatly and to help arrest this problem, certain forest products like bamboo should be given the requisite attention to supplement timber by replacing it in some of its uses in building construction.

2.3 HISTORY OF BAMBOO USAGE AS A CONSTRUCTION MATERIAL

Bamboo has been exploited as an ancient construction material and this is due to the fact that it appears to be a tailor-made material for use as a building component. Bamboo appears round, straight, smooth, strong and beautiful Gutiérrez (2000). The Chinese Academy of Sciences correlates the use of bamboo as construction material with the end of the Stone Age and the beginning of agriculture and animal husbandry in the Neolithic Age about 8,000 years ago (Small, 2010). Bamboo poles in ancient times were use for simple structure where the poles form the structural members and the split bamboo poles used for the roofing.

According to Brink and Rush (2000), bamboo has been used as a construction material in certain areas for centuries. Rural construction has seen predominant use of bamboo in many countries over the years and the uses for construction are increasingly gaining popularity. In some part of America, Australasia, sub-Saharan Africa, Eastern and South Eastern Asia, bamboo as a plant has been tag to have a high economic importance, especially it being a crucial material for building.

In related study of bamboo in construction, Shrestha (2006) reiterated that the low cost houses in Nepal which were made with round pole bamboo with cement plaster on woven mat is definitely an improvement on shanty shacks some decades ago. Their simple yet effective intervention of having a good foundation and roof provides a new value to bamboo because of increased

durability and a modern look. Their policy of engaging the owners in the construction process not only empowers them but also creates employment and imparts them with skills to maintain thc houscs in futurc.

Though initial use of bamboo was for simple construction in rural areas, it has now gain great attention and has been engineer to meet modern standard building material for construction. the status of bamboo has grown to the extent that it has been accepted in modern sophisticated buildings in the city centres.

Decades of research by bamboo practitioners has validated that, when treated and used properly, bamboo is a sound structural and cngincering matcrial (Janssen, 2000), which, duc to its strcngth, flexibility and versatility, is a suitable material for use in housing. Recently, the International Network for Bamboo and Rattan (INBAR), the world's only intergovernmental organisation dedicated to the sustainable development of bamboo and rattan, and Chinese partners have also dcmonstratcd that laminatcd bamboo can bc uscd in structural applications, prcscnting ncw opportunities to standardise bamboo-based construction and produce modern modular housing designs that are potentially suitable for East African markets (Xiao et al., 2009 and Xiao et al. 2010).

2.4 CONSTRUCTION PROPERTIES OF BAMBOO

Bamboo is a forest product which exhibits constructional properties comparable to that of other building matcrials likc timbcr and stccl. Its propcrtics makc it a vcry good construction matcrial that could be exploited and be used as supplement to timber and in some instance steel.

2.4.1 PHYSICAL PROPERTIES OF BAMBOO

In a study by Recht and Wetterwald (2001), bamboo range from ground cover bamboo that will reach several inches at maturity to giant bamboo that can reach over 100feet in the tropics and from quick spreading species to clumping types that expand outward only a few inches a year. Some types of bamboo thrive in that hot, humid rainforests while others are cold hardy, surviving in temperatures as low as twenty degrees Celsius (20°C). Bamboo comes in many colours, sizes and textures.

2.4.2 MECHANICAL PROPERTIES OF BAMBOO

Bamboo, being a circular, hollow structure has certain mechanical and structural merits and demerits as compared to a rectangular solid timber of the same cross-section. These advantages/disadvantages are, in other instances, complemented or accentuated by the cellulose fibre make-up of the bamboo (Solomon - Ayeh, 2004).

2.4.2.1 Tensile strength

The tensile strength of bamboo can reach up to 370 N/mm^2. This makes bamboo an alternative to steel when the issue of tensile strength is necessary for its applications. According to Amanda et al. (1997), the comparative analysis of bamboo to steel is because the ratio of tensile strength to specific weight of bamboo is six times greater than that of steel. Ghavami (2005) found the strength distribution at the bottom of the bamboo culm to be more uniform than at the top. The strength of bamboo also increases with age and the maximum strengths are realized at age 3-4years, after which strength begins to decrease (Amada and Untao, 2001). In the nodes, the

average fracture toughness is lower than the minimum value of the entire culm. Hence the fibres in the nodes do not contribute any fracture resistance.

2.4.2.2 Compressive strength and density of bamboo

Bamboo has relatively high axial compression strength, but this is often offset by a lack of straightness resulting in buckling long before the crushing load is reached. On average the density of bamboo is greater than timber. For most bamboos, density is 700-800kg/m3. The density is dependent on the species, the position in the culm and other environmental factors. There is a direct relationship between density and strength. The higher the density of bamboo, the higher the strength exhibited for a particular use (Paudel, 2003).

2.4.2.3 Elastic modulus

The elastic modulus of bamboo is much smaller than that of mild steel. Considering the flexural rigidity which controls the deformation of the bending members, it is therefore necessary to use a larger section of bamboo where the bending occurrences would be great (Tada et al. 2010). According to Yao and Li (2003) like the elastic modulus of solid wood, that of bamboo also decreases 5 to10% with growing stress. The enormous elasticity makes bamboo to be a very useful building material in areas with high risk of earthquakes.

2.4.2.4 Stiffness

In a related research by Van der Lugt et al. (2005), shows that in the comparism of the strength and stiffness (mass per volume) of some building materials (ie. Concrete, steel, wood and bamboo) bamboo stood out to have the highest stiffness of mass per volume, followed by steel, wood then concrete. In the aspect of the strength of mass per volume their research shows that bamboo is second to steel followed by wood then concrete.

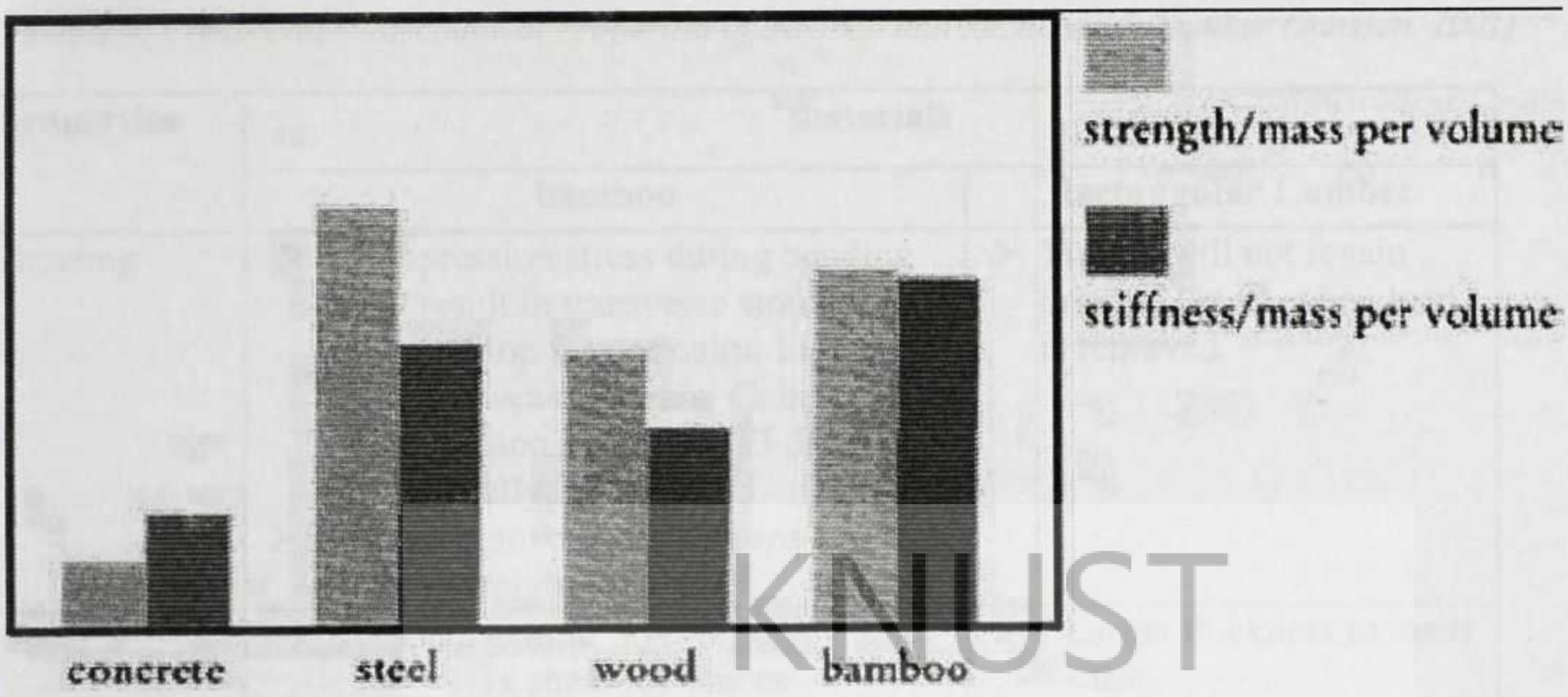

Fig.2.4 (a): Comparison of the stiffness and strength of various building materials

Bamboo also possesses high residual strength to absorb shocks and impacts - highly suitable material for construction of houses to resist seismic and high wind forces

In a study carried out by Lo et al. (2004) on the mechanical properties of bamboo, it was concluded that both physical and mechanical characteristics of bamboo vary with respect to diameter, length, age, type, position along culm and moisture content of bamboo. Different bamboo species perform differently for the same set of test (US Naval Civil Engineering, 1966, 2000 and Iyer, 2002). Bamboo will perform differently depending on the specie and maturity.

As their external using properties, construction materials should have the ability to withstand the stresses of shrinkage or swelling due to the changes of temperature and moisture. If we adopt the unique hot- press technology, waterproof adhesives and make best of the physical properties of bamboo, bamboo based panels will have a better stability in shape and size compared with other building materials making them also suitable to serve as construction materials.

Table 2.4: Comparative Mechanical Properties of Bamboo and Rectangular Lumber (Janssen, 2001)

properties	**materials**	
	bamboo	**Rectangular Lumber**
Bending	➢ Compression stress during bending may result in transverse strain in fibres of top face of culm. Lignin in fibres is weak in strain. Coherence in cross section is lost and EI drops dramatically. ➢ If load removed culm returns to original straight form.	➢ Timber will not regain original length when load is removed.
Shear	➢ Shear in neutral layer = 1.3x shear for timber ➢ Smaller thickness to resist shear. ➢ Larger forces on bolt fastness at joints. ➢ Advantage of not having a ray structure is nullified by hollow nature.	➢ Larger thickness to resist shear. ➢ Has rays. Rays are mechanically weak. Hence, timber material is weaker in shear than bamboo material
Torsion	Better torsional resistance due to circular shape.	Poorer torsional resistance because of sharp corners.
Wind Resistance	➢ Bending stress due to wind is constant over height of culm. ➢ At top (near skin) vessels decrease and cellulose replaces vessels, leading to increase resistance to bending stress.	
Compression	➢ Because of hollow nature and thus greater distance of solid mass from center, longitudinal shortening is greater and thus greater the likelihood of lateral strain in lignin. ➢ Friction due to clamping at top and bottom of culm reduces lateral strain. ➢ Amount of lignin determines Compressive strength not cellulose.	➢ Solid nature makes for better compression resistance and reduced lateral strain.
Density	700 – 800kg/m^3	850kg/m^3

Invariably, the mechanical and physical properties of bamboo will help the researcher identify the various areas in building construction where bamboo will be applicable hence identify the potcntial of its usc in construction.

2.5 USES OF BAMBOO IN CONSTRUCTION

The use of bamboo for building construction has metamorphosize from simple pole construction to morc sophisticatcd construction. Bamboo can scrvc as a matcrial for thc wholc or part of a construction of a building. Bamboo is greatly considered by several countries in Asia and Latin America as an important source of building material not only for construction of rural houses but also for pucca houscs and public buildings in towns and citics (Shyamasundar and Vcngala, 2008).

According to Malin and Bochland (2006) the use of bamboo in construction could be classified into its temporary or permanent usage. The temporary use of bamboo is when the material is disposed off after the completion of the building and they normally form part of the formworks of construction. Thc pcrmancnt usc is whcn thc bamboo matcrial whcthcr cnginccrcd or raw (in its natural state) form part of the building throughout it life cycle.

2.5.1 TEMPORARY USE OF BAMBOO

This section will review literature to outline the extent of the temporary use of bamboo in construction to hclp in idcntifying thc potcntial of bamboo in building construction. Tcmporary use of bamboo is the use during construction and is disposed off after the completion of the construction of the particular project. It does not form part of the building when completed.

2.5.1.1 Props

Indigenous material like the bamboo has proven in some countries through the extensive use of it and has exhibited characteristic of steel or metal in the use as props and also ensuring cost effectiveness (Jiang, 2008). Bamboo props are used as support for reinforced concrete floor elements (floor slabs and beams). According to Tekpetey (2006), bamboo in Ghana has gain massive introduction into the modern construction by its use as props though not with any special technology but applied in the raw state. This restrictive use as props does not exploit the full potential of bamboo as a construction material.

2.5.1.2 Bamboo scaffolding

Bamboo scaffolding serves as a rich tradition in many Asian countries' construction industry such as China, India and Thailand. Bamboo has been used for centuries as scaffolding in Asian countries and, despite competition with many metal scaffolding systems, remains one of the most preferred system in both China and Hong Kong (Fu, 1993). Owing to its high adaptability and low construction cost, it can be constructed to any layout to follow various irregular architectural features of a building within a relatively short period of time (Chung et al., 2003). They are used in construction sites to provide temporary access, working platforms for construction workers and supervisory staff, and to prevent construction debris from falling on passers-by. In Hong Kong, they are used as Single Layered Bamboo Scaffolds (SLBS) for light work and Double Layered Bamboo Scaffolds (DLBS) for heavy work (Chung and Sin, 2002).

It is argued by Janssen, (2000) that Bamboo scaffolding and hoarding is well known for its capacity to resist hurricanes. Cases are known wherein bamboo scaffolds survived hurricanes

that blew away steel ones as if they were matchsticks. The Bamboo scaffolding is exposed to competition with other materials scaffolding like steel and this is because the latter is an industrial product with standardized dimensions, which make it quick to erect and dismantle. In this respect, bamboo scaffolding needs some technical and industrial upgrading. Bamboo poles lashed together have been used as scaffolding in high rise structures due to their strength and resilience. The timber planks can be replaced with bamboo culms and these can be lashed to the vertical culms (Jayanti and Follet, 1998).

2.5.1.3 Ladder and workers shed

In a study by Chung et al., 2003, they identify that bamboo has been extensively used as ladders on construction sites in China and other Asian countries. Bamboo's construction properties make it easy for use as a ladder in construction. It can easy be formed and demounted when needed with less cost as compared to materials like timber and steel. The exploitation of bamboo in China has seen its popularity in the areas of formwork and hording as well.

2.5.2 PERMANENT USE OF BAMBOO

2.5.2.1 Bamboo reinforcement

Bamboo has the quality to be used as reinforcing material in concrete. The application of bamboo for reinforcement has some advantages though its disadvantages cannot be overruled. According to Jiang (2007), the high tensile strength of bamboo gives it an advantage to be used as reinforcement. Jensen (2000), also added that many structures have been built with bamboo reinforcement decades ago and are still standing, but with a factor of safety much less than required.

2.5.2.2 Bamboo flooring

Bamboo as a material is considered as a durable floor material for any floor whether traditional building or modern buildings or any area that is repeatedly exposed to moisture (Xiao et al, 2009). According to (Haregewoin, 2007) in related bamboo research, bamboo floors has proven to be an ideal for humid climates because it has low absorption properties and its good performance in drier climates. Bamboo flooring is not only a good choice for its moisture resistance, beauty, affordability, and ease of installation, but it is a green material. Bamboo floor finished comes in Carbonized finish, Natural finish or Stained finish.

Bamboo flooring is a quality product that can be used widely and has a large, global consumer market. It has certain advantages over wooden floors due to its smoothness, brightness, stability, high resistance, insulation qualities and flexibility. Bamboo flooring has a soft natural luster and maintains the natural gloss and elegance of bamboo fibre. This flooring is attractive to the demanding markets in Europe, Japan and North America. The estimated annual production of bamboo flooring in China was 17.5 million m^2 in 2004. Exports account for some 65 percent of total production (Customs General Administration of China, 2004).

2.5.2.3 Trusses

Fabrication of roof trusses is about the most promising use of bamboos. Literally, any span of truss is possible due to the fact that bamboo has strength comparable to that of teak and sal. It is proven in related research that, an experiment with the construction and testing of a 4m span truss made of round bamboo and different jointing techniques for web-chord connections gave results that were matching with the strength of timber (Paudel and Solomon-Ayeh, 2004).

2.5.2.4 Ceiling

Bamboo is rapidly becoming a popular decorating medium. More and more people in bamboo growing areas are making efforts to use sustainable goods when building and remodeling their homes. Hence, bamboo ceilings have gained much attention to give the needed aesthetic (Petty, 2009). Ceilings can be made from small, closely spaced culms, split or flattened bamboo, bamboo boards or bamboo mats in a manner similar to that for floors. Woven mat ceilings are sometimes applied as sarking to the topside of the rafters or purlins, separated from the roof covering by battens (Bandara, 1990).

2.5.2.5 Bamboo Doors and Windows

Bamboo frames can replace timber frames appropriate to function. This is capable when the bamboo is taken through industrial processes to ensure durability. Research shows that, Bamboo mat shutters fixed to bamboo frame or a panel of bamboo board fixed to the frame which is hinged to the wall can be used as door. Small framed openings hinged to the top in the wall can serve as windows.

2.5.2.6 Bamboo roofing

The BMTPC in collaboration with Indian Plywood Industries Research & Training Institute (IPIRTI), Bangalore, have jointly developed a technology for manufacturing of Bamboo Mat Corrugated Sheet (BMCS) which is durable, strong, water-proof, and decay-insect-fire resistant. The product has been accepted by the consumers and is becoming increasing popular as a roofing option in the north east part of India. The graph below shows the load bearing strength of BMCS compared with that of aluminium, Asbestos Cement Corrugated Sheet (ACCS), and Corrugated Galvanized Iron Sheet (CGIS).

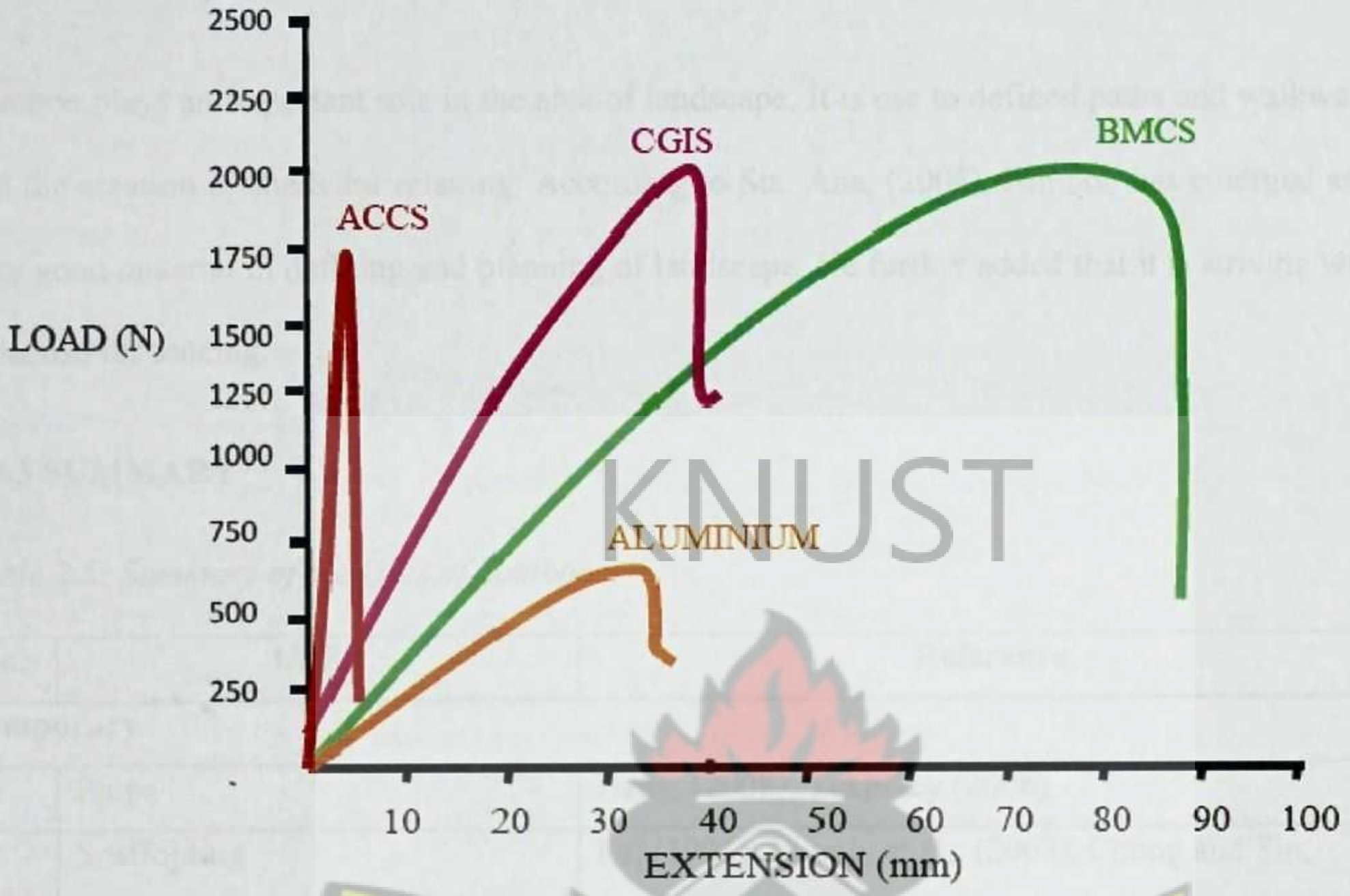

Fig. 2.5: load bearing strength of BMCS compared with that of aluminium, ACCS, and CGIS

Source: Shyamasundar, K. (2005)

2.5.2.7 Walls

According to Punhani and Pruthi (1992), an extensive use of bamboo in construction is for walls and partitions. The major elements of a bamboo wall (posts and beams) generally constitute part of the structural framework. As such they are required to carry the self-weight of the building and also loadings imposed by the occupants, the weather and, occasionally, earthquakes. An infill between framing members is required to complete the wall. The infill should also be designed to allow for light and ventilation. Not least is its architectural and aesthetic function.

2.5.2.7 Landscape

Bamboo plays an important role in the area of landscape. It is use to defined paths and walkways and the creation of sheds for relaxing. According to Sta. Ana, (2006), bamboo has emerged as a very good material in defining and planning of landscape. He further added that it is striving well in its use for fencing.

2.5.3 SUMMARY

Table 2.5: Summary of the Uses of bamboo

No.	USES	Reference
Temporary		
1	Props	Jiang, (2008), Tekpetey (2006)
2	Scaffolding	Fu, (1993), Chung, et al., (2003), Chung and Sin, (2002), Janssen, (2000), Jayancti and Follet, (1998)
3	Workers shed	Recht et al., (2001)
4	Ladder	Chung, et al., (2003)
5	Formwork	Recht et al., (2001)
6	Hoarding	Jiang, (2008), Tekpetey (2006)
Permanent		
1	Bamboo Reinforcement	Iyer (2002)
2	Trusses	Paudel and Solomon-Ayeh, (2004)
3	Ceiling	Bandara, 1990
4	Doors and windows	Gangopadhyay (2003)
5	Roofing	Shyamasundar, K. (2005)
6	Bamboo floor	Xiao et al, (2009), Haregewoin, (2007), Customs General Administration of China, (2004)
7	Partition walls	Punhani and Pruthi (1992)
8	Landscape	Sta. Ana, (2006)

Knowledge of the various uses of bamboo in construction will help contractors to be aware of what bamboo product to go for, applicable to the particular project being undertaken. Literature on this area will help the researcher identify the uses of bamboo beneficial to building construction. This will eventually help in the identification of the potential of bamboo in construction.

2.6 FACTORS INFLUENCING THE USE OF BAMBOO IN BUILDING CONSTRUCTION

2.6.1 REASONS FOR CHOOSING BAMBOO

Contractors and consultants' choice and specification of bamboo as a building material respectively are due to various factors influencing positively. Other researches and produces have outlined some of these factors as follows:

2.6.1.1 **Availability**

Bamboo has a short period of attaining maturity as compared to timber and a cluster of it shows a lot of culms. In Ghana it is identify to be readily available and easy accessible in growing areas (Epatko, 2011; Obiri and Oteng-Amoako, 2007).

2.6.1.2 **Affordability**

With high cost of building materials in Ghana currently as a result of high percentage of building material imported, research into local material especially bamboo shows that bamboo is cheaper and when invested into it will promote reduction in the cost of building material (Paudel and

Solomon-Ayeh, 2007). It is easily grown and harvested, making it one of the most cost effective construction materials (Janssen, 2000)

2.6.1.3 Shortage of timber supply to the local market

With the current state of timber supply to the construction industry in Ghana, there is the need for attention to be given to some other forest products which have properties comparable to that of timber. Bamboo has been identified in related research to be a very good alternative and supplementary material to timber (Janssen, 2000, Solomon-Ayeh, 2007and Bonsi, 2009). Hence, the shortage of timber supply has been a considerable factor influencing the choice of bamboo in building construction.

2.6.1.4 Bamboo is Easy to erect

Bamboo for temporary activities in building construction has been identified to be easy to erect with very low technical requirement (Gutiérrez, 2000). However, bamboo for permanent activities has to go through treatments which require technical knowhow though not as cumbersome as that of other materials.

2.6.1.5 Bamboo is durable

The structure and nature of bamboo makes it have very good constructional properties very durable especially when treated. Bamboo has good strength properties (Sumardi et al., 2006; Hershey, 2004). In a recent test at the Central Power Institute of India at Bangalore, a full-scale bamboo building fixed to the shake table was found to withstand a series of earthquake simulations and showed no sign of structural rupture (Brown, 2004). Remarkably, bamboo is

tensile or cellulose fiber strength is similar to that of steel and is non-porous when processed as cardboard, making it a reliable material for building.

2.6.1.6 Bamboo is reusable and easy to use in its natural state

Bamboo with its structural properties makes it easy to be reused. It can be transferred from one project to the other. Bamboo is susceptible to insect attack after a period of time when not treated and in its natural state, however, it can withstand a number of projects in its natural state and when treated has a very long lifespan making usable (Brown, 2004). For temporary uses, bamboo is a material that is easy to use in building construction directly from the forests or farms they are harvested from without going through any processing of sawmilling. Specific sizes of bamboo could be harvested for specific uses (Mankin, 2007).

2.6.1.7 Bamboo as good material for a sustainable green building construction

Bamboo is identified as a very good material for sustainable Green building. Green building is about making the best use of resources during all stages of construction. Bamboo can combine with other building material and in harmony with one another (Jim, 2011).

2.6.1.8 Bamboo is easy to obtain in any quantity required

According to Obiri and Oteng-Amoako (2009), bamboo is grown in almost every region in Ghana, both the northern Ghana and southern Ghana. The concentration of the growing area of bamboo is mainly in the southern Ghana. Though the resources are largely available in the country, it is poorly managed unlike other Asia countries where bamboo is properly managed as a major resource for building construction.

2.6.1.9 Bamboo has multiple uses in building construction

Bamboo as a matcrial can bc uscd in so many arcas in thc building construction. Thc uscs can bc categorized into temporary and permanent. the popularity of it usage in Ghana is dominantly for temporary usage, however, in Asian countries like Japan, China, India and other Latin American, bamboo has greatly been exploited and used permanently in building construction. Some of the uscs havc bccn outlincd in subsccctions 2.5.1 and 2.5.2 (Tckpctcy, 2006).

2.6.1.10 **Bamboo is beautiful**

According to Gutićrrcz (2000), thcrc has bccn an ancient cxploration of bamboo for construction and this is due to the fact that it appears to be a tailor-made material for use as a building component. Bamboo appears very beautiful especially when treated and polished for permanent usage.

2.6.2 BARRIERS TO THE USE BAMBOO IN BUILDING CONSTRUCTION

In as much as bamboo possesses many advantages when used as a building material for either temporary or permanent use, its usage in building construction is faced with some constraints. According to a study by Mardjono (2002), the constraint of using bamboo in construction deter some contractor and consultants from using and specifying bamboo respectively for building construction. Below are some factors from related literature on bamboo deterring contractors and architects from using and specifying bamboo respectively (Roach, 1996; Mankin, 2007; Carrere, 2008; Obiri and Oteng-Amoako, 2009; Tekpetey, 2006; Gangopadhyay, 2003 and Madhab, 2003).

- Limited knowledge of bamboo and lack of expertise to use it.

- Problem of social acceptability (bamboo is considered for the poor).
- Lack of management skill in the use of bamboo.
- Competition with other building materials.
- Insufficient cooperation from government.
- Poor processing techniques in Ghana.
- Treated bamboo is expensive.
- Less specification attention in the designs by architects.
- Bamboo is highly susceptible to fire if not treated.
- Treated bamboo is not readily available.
- Irregular shape of bamboo culms makes it difficult to work with as compared to timber.
- Bamboo is less durable if not treated for permanent use.
- Architects (consultants) do not specify them for use by contractors for building projects.
- Lack of knowledge in bamboo detailing.
- Lack of bamboo processing companies in Ghana.

BAMBOO SOURCES AND MARKET

Depending on the nature of bamboo required for use, one specific source cannot be mentioned being the only viable source for the acquisition of bamboo as a material for building construction. According to Obiri et al. (2007), the primary sources (in the natural state) of bamboo are community farms, fallow fields, farm lands or forest reserves. According to a report by FRA (2005), the primary bamboo source ownership of bamboo could be classified into three;

the public (land owned by the state or government-owned institutions), the private (land owned by individuals, families, private cooperatives, corporations, industries, religious and educational institutions, pension or investment funds and other private institutions) and others (land that is not classified as one of the two previous classes). Bamboos are easily obtained and in higher quantity in most of the southern regions in Ghana and most of these culms are obtained from the community farms.

From a research conducted by Obiri et al. (2007) on the bamboo sources in the southern regions in Ghana, about sixty five percent (65%) of bamboo culms collectors obtain the bamboo from the community farms, twenty five percent (25%) from fallow farms and the rest from both farm lands and forest reserves. Access to the bamboo resource for household and commercial purposes by non-owners in most cases attracts a fee ranging from GH¢5 to GH¢ 10 or more on community and private lands for 100 pieces of culms in the south. In the forest reserve a permit is issued for GH¢10 for a months' collection during which about 100 to 150 head loads of culms are harvested. In the north GH¢ 0.10 - 0.50 may be paid per culm.

Other researches in Ghana show that Bamboo in its natural state could also be obtained from retailers aside from the farms or forest reserves directly. These retailers mount their stands along high ways and in areas where new buildings are sprouting out (new sites). While some retailers display their bamboo culms under shelves, others are exposed in opened air. Some of the retailers also showcase just a few to attract the market and as per the quantity demanded by the contractors for construction, the retailer refer to their representatives in the bamboo growing area (farms and reserved forest areas) for the supply the quantity demanded.

Bamboo could also be obtained in a secondary state (that is factory treated form) for different purposes. These states come in the form of laminated or ply bamboo which could take different form applicablc to thc building construction industry (Zhong and Liu, 1999)

CHAPTER THREE

MATERIALS AND METHODS

3.0 INTRODUCTION

The focus of this chapter is to combine the observations, assertions and conventions that emerged from the literature review to develop a structured questionnaire for the study. This will serve as a pivot to evaluate the potential of bamboo as a material in building construction. The literature review was captured through the identification of the various uses of bamboo in building construction, the current state of timber supply in Ghana, the constructional properties of bamboo, the factors motivating the use of bamboo, barriers to the use of bamboo and finally to outline the trend of use of bamboo with regards to the volume of usage by contractors and it specification by architects in building construction. Following this, an appropriate research instrument for eliciting the relevant data was established. The chapter also discusses issues relating to how the sampling frame was established and the data used for the analysis.

3.1 METHODOLOGY

As noted earlier, the aim of this research is to assess the potential of bamboo as a material in building construction in Ghana. According to Naoum (2007), to arrive at the appropriate aim of a study, the important area that ought to be given a requisite attention is the kind of method adopted. For this reason, a range of complementary research methods will be employed by the researcher for the study. The three phases upon which these methods will be applied to are;

- preliminary phase;
- second phase;
- analysis of data phase

➢ 3.1.1 PRELIMINARY PHASE

The background information on the potential of bamboo as a material in building construction was gathered from literature and the sources of the reviewed literature were in two categories:

- **Primary source:** - These include field survey, both formal and informal, face to face unstructured interviews, administering of close-ended structured questionnaires and discussions with architects and contractors on building projects.

- **Secondary source**: - These include desk review of both published and unpublished material about the subject matter being considered including policy documents, newspapers, internet, journals, articles, reports, bulletins, newsletters, and site safety text books available in KNUST main library and libraries in other universities outside the country.

The secondary source was to get a deeper understanding of the state of the timber supply situation in Ghana, the uses of bamboo in building construction, the factors influencing the use of bamboo and the trend of the volumes used building construction. The information gathered from the preliminary phase helped guide the second phase of the fieldwork, which is distribution of questionnaires and collection of data from key respondents.

3.1.2 SECOND PHASE

The second phase of the study includes:

- design of research instrument;

- data collection

3.1.2.1 Design of Research Instrument

In order to achieve the aim and objectives of the study, a well structured close-ended questionnaire was designed to gather information from building construction sites (registered contractors) in the study area (Kumasi Metropolis) and consultants (Principal Architects in Registered Architectural Firms) in Ghana. The questions were without bias and provided multiple choice options which gave the respondents the opportunity to present their ideas by way of selecting from the options provided. Close-ended questionnaires as indicated by Glasow (2005) are easy for respondents to answer and the analysis of the data collected from the respondent by researchers could be made easily. Further research on the use of close-ended questions has shown that it helps to direct the respondent answers towards the required response needed by the researcher. Salant et al (1994), are of the school of thought that closed-ended questions with unordered choices, for example the multiple choice questions are useful for ranking items in order of preference. Additionally, close-ended questionnaires are used to gauge the respondents' ability to provide informed responses or to identify respondents who believe they are informed and compare their responses to those who do not believe they are informed as suggested by Fowler et al (1995).

The way a closed-ended questionnaire is structured is very important and the level of understanding of the subject matter of the respondents must be considered. There are further assertion that, researchers must avoid questions that ask the respondent for data they cannot or do not have answers to, including questions that assume the respondent knows something about the subject and are more so personal questions. Objectionable statements that reflect the researcher's personal bias and leading questions that call for difficult and intense calculations should be eliminated in the case of wording and structuring of research questionnaires (McIntyre 1999,

Fowler et al 1995, and Salant et al 1994). These researchers further observed that, questions with predisposition type, either for or against a particular perspective should be avoided, because such questions may be leading or may include assumptions that may not be true.

3.1.2.1.1 The content and the rational of the research questionnaires

The content of the questionnaires was structured for the two groups of respondent (Contractors and Architects) and structured into four different sub-headings. The same set of questions was addressed to two groups of respondents.

SUB-HEADINGS	RESPONDENTS	
	Contractors	Architects (Consultants)
A	Background to construction firm	Background to Architect and architectural firm
B	Uses of bamboo or bamboo products in building construction	Uses of bamboo or bamboo products in building construction
C	Factors influencing the choice of bamboo or any bamboo product for building construction projects	Factors influencing the choice of bamboo or any bamboo product for building construction projects
D	Trends of bamboo usage with respect to the volumes	Trends of bamboo usage with respect to the volumes

Generally, the first sub-heading (A) was to help identify the period of operations of the construction companies and the categories they belong as a construction firm. The sub-heading (A) of the Architects questionnaire was to seek out for the period of operation of the

Architectural firm and also to identify the experience of the principal architects in the profession with regards to the number of years. This indeed was to establish the credibility of the data.

The sub-heading (B) was to help ascertain the various areas, in which bamboo was specified by Architects and used in building construction by contractors. From the literature review a list of the various areas bamboo has been used in building construction (BC) was extracted and the various respondents were to express the extent of bamboo usage in BC.

Additionally, the sub-heading C of the questionnaire was designed to outline the various factors influencing the use of bamboo as a material in BC. The factors will focus on what influence the choice of bamboo and what also deter the usage of it.

Finally, the sub-headings D was designed to identify the trend of bamboo usage with regards to the volumes used in BC. This will help the researcher to ascertain whether bamboo over the past ten years has gained popularity in BC in GhanaIn most of these sub-headings in the questionnaires, the respondents (the Contractor and the Architects) were to respond by scoring based on the Likert scale.

3.1.2.2 Data Collection

3.1.2.2.1 Population and Sample size

- **Building Construction Firms (Contractors)**

Ahadzie (2007) in a study outlined that there are over 20,000 registered "building contractors" with Ministry of Water Resources, Works and Housing (MWRWH) in Ghana. According to a list of building contractors published by the MWRWH as cited by Ahadzie (2007), the total number

of registered building contractors in Ashanti Region is about 2400 making up 12% of the total number of registered contractors in Ghana.

With the scope of the research focusing on building contractors in general and the Ashanti region being the study area considered, there was the need to use an appropriate sampling technique to achieve the needed sample size for the research. To determine the minimum sample size of these registered contractors in the Kumasi metropolis, Kish's (1965), formula which gives a procedure for calculating minimum sample size had to be applied.

$$n = \frac{k}{1 + \frac{k}{N}}$$

Where n = sample size, $k = \frac{S^2}{V^2}$ N = Population Size

S = Maximum standard deviation in the population element (total error = 0.1 at a confidence level of 95%)

V = Standard error of sampling distribution = 0.05

P = the population elements

$S^2 = P(1-P) = 0.5(1- 0.5) = 0.25$

Therefore in determining the minimum sample size of small scale contractors in Ashanti regions given that N = 2400

$$k = \frac{0.25}{0.0025} = 100$$

$$n = \frac{k}{1 + \frac{k}{N}}$$

$$n = \frac{100}{1 + \frac{100}{2400}}$$

$$= 96$$

n = 96 represent, the minimum sample size of building contractors in the Ashanti region (Kumasi metropolis) to be used for the purpose of this study was approximately ninety-six (96). For the sake of irregularities such as refusal to respond to questionnaires, incligibility to respond to questionnaires, inability to locate respondent which occur during distribution and collection of data the total sample size for building contractors was rounded to 100.

Oladapo (2005), Newman and Idrus (2002), Ellhag and Boussabaine (1999) among other researchers, have indicated that a response rate of 30% was good enough in construction studies.

- **Architectural firm (Architects)**

With specification on building designs done by the Architects (designer) it is necessary to establish the views of architects on the use of bamboo as a material in building construction. According to the Architect Registration Council / Ghana Institute of Architects (ARC/GIA), there are about one hundred and fourteen (114) registered architectural firms in good standings in Ghana. Out of the total number of firms, Eighty-four were located in the Accra and Kumasi metropolis being the two major cities in Ghana. With the focus of the research on the cities with large pool of construction on-going, the researcher considered the 84 firms as the population for the architects. Twenty four of the firms could not be located hence, the sample size was narrows to 60 firms forming 71% of the total population.

3.1.2.2.2 Sampling method

The sampling techniques applied for the selection of the Contractors and the Architects were purposive and snowball sampling. The purposive sampling technique according to Erbil et al (2010), allows the researcher to select the individual who have good knowledge on the subject matter under discussion. The architects specified the material (bamboo) for use, whereas the contractors use the material in achieving the desire building designed. In the selection of the various building contractor in the study area, the Kumasi metropolis was zoned into the four main sub-metros and then the questionnaires were allocated to active construction sites and offices in the sub-metro. This is to ensure an evenly distribution of the questionnaire to building contractors and it will help attain a broader spectrum of respondent to handle the subject matter.

The snowball sampling technique according to David (2008) is a sampling method which uses a small pool of initial informants to nominate, through their social networks, other participants who meet the eligibility criteria and could potentially contribute to a specific study. It wass difficult to locate the architectural offices, hence, the location of the unknown offices were obtained from the known ones.

3.1.2.2.3 Distribution and Data collection

Data collection as clearly defined by Danso (2009), is a term used to describe a process of preparing and collecting data. The aim of these processes was to obtain necessary information to keep on record, to make assertions about important issues, and to relay the acquired information on to interested individuals. The developed questionnaires to the contractors were distributed and retrieved from construction firm offices and active construction sites. The questionnaires to the architectural firms were distributed to their offices both in person and the internet by e-mailing.

One very important area of a research is the methods developed to distribute and retrieve questionnaires. Ahadzie (2007) indicated the importance of distributing and retrieving questionnaires in person. He outlined two main reasons for doing that which was first of all, to make sure that the questionnaires get to the intended recipients and secondly, to help improve the response rate. The contractors with active sites were given a set of questionnaire for a response and on the other hand, principal architects who are practicing in reputable firms and are in good standing as according to the Ghana Institute of Architects (GIA) were also given another set of questionnaires to respond to.

3.1.2.2.3 Response Rate

Out of the sixty (60) questionnaires distributed to consultants (Principal Architects of Architectural firms), Fourty (40) questionnaires were retrieved out of which five (5) were found not to have been answered. This brought the responses effectively to thirty-five (35), representing a response rate of 58.3%. Out of the 100 questionnaires issued to contractors with active sites, 75 of them were retrieved. Twenty (20) of the returned questionnaires however were found not well completed to be useful for the analysis and were therefore discarded. This brought the responses of contractors effectively to fifty-five (55), representing a response rate of 55%. In reacting to the response rate obtained for the research, Oladapo (2005), Newman & Idrus (2002) and Ellhag and Boussabaine (1999) in a related study, outlined that a response rate of thirty percent (30) in construction studies was good enough to draw conclusions from.

3.2 ANALYSIS OF DATA

Another important aspect of any research is the means of analysing the data collected to be able to make good conclusions and recommendations. The Statistical Package for Social Sciences (SPSS) was used to analyse the data collected and the statistical tools employed were the measure of central tendency and relative importance index to establish the significant importance of the various factors influencing the use of bamboo in building construction. The SWOT means of analysis was also employed to categorize the identified factors influencing the use of bamboo in building construction under strength, weakness, potential and threat of bamboo in building construction.

3.2.1 Relative importance index

The Relative Importance Index (RII) method of analysis was employed to help identify the significance of the factors which influence bamboo in building construction (BC). According to Adnan et al. (2007), to analyse data on an ordinal scale (e.g Likert scale 1-5) as used in this research, the application of Importance Index (II) is suitable and this helped in coming out with various ranking in the research. Ranking as defined by Fowler et al. (1995), is a comparison among given options, within pairs of options, by cardinal of importance (first, second, third, etc). Additionally, he asserted that, ranking is scoring items one at a time using a common scale, and it also determines the importance of factors. The Importance Index (II) as computed by Adnan et al. (2007) is

$$Importance\ Index = \frac{5n5 + 4n4 + 3n3 + 2n2 + n1}{5(n + n2 + n3 + n4 + n5)} x100$$

It is also expressed by Tam et al, (2000) as

$$\text{RII} = {\Sigma W}/{(S * N)}$$

Where: $\sum$ W = the summation of the weight given to a variable

S = the number of scales to which the factors were ranked

N = number of respondent

n1 – number of respondents who answered "strongly disagree";

n2 – number of respondents who answered "disagree";

n3– number of respondents who answered "neutral ";

n4 – number of respondents who answered "agree";

n5 – number of respondents who answered "strongly agree"

The nearer the value of importance index of the identified factor is to one (1) or 100%, the more significant it is and hence, a greater impact on the rest of the variables

3.2.2 Chi-squared (X^2) Test on the factors influencing the use of bamboo in Building Construction (BC)

The Chi-Squared test of the contingency table is used to determine whether differences exist in response between two or more populations (Keller et al, 2004). In this study, Chi-Squared test was used because the analyses of response of the two respondents were considered separately. The result of Chi-Squared test is achieved by stating the hypothesis, computing the observed and expected values from the responses, computing X^2 statistic and p-value. The X^2 statistic measures how far away is the observed values from the expected one and it is the sum of each of the contributions from each variable. The p-value is computed by looking under the Chi-square table with the degrees of freedom. In this study, the chi-squared test was used to ascertain if there

existed any differences in the response of respondent on the various areas of bamboo usage and the various factors which influence the use and specification of bamboo in BC.

The Chi-squared test is achieved by:

- Stating the hypothesis;
- Computing the observed and expected values from the responses;
- Computing X^2 statistic; and
- P-value

Hypothesis

H_0: there is no difference between the responses of the respondents on the factors preventing the use of bamboo.

H_1: there is a difference between the responses of the respondents on the factors preventing the use of bamboo.

Where H_0 denotes the null hypothesis and H_1 denotes the alternative hypothesis

Significant level (α) = 0.05

We reject the H_0 if $X^2_{cal} > X^2_{0.05}$

X^2 Statistics

After stating the hypothesis, the next step is to calculate the X^2 statistic and it is computed from the relation:

$$X^2 = \sum_{i=1}^{n} (Observed\ proportions - expected\ proportion)^2 / Expected\ proportions$$

The observed and expected proportions values are generated from the SPSS as a result of entering data. However, X^2 for all the factors is calculated from the equation above.

3.2.3 Spearman Correlation

This inferential statistics method was also used to find out whether the difference in the ranking of the two groups of respondent on the factors influencing the temporary use of bamboo and the permanent use were statistically significant or not.

3.2.4 SWOT analysis

The SWOT is an acronym for the strength, weakness, opportunities and threats for bamboo in building construction. The strengths and weakness are the resource advantage and the inadequacy or paucity respectively of bamboo in BC. The opportunities and the threats are respectively complimentary and adverse or impeding issues affecting the use of bamboo in BC. The SWOT analysis was considered as a structured approach that helped in systematical analysis of issues that affect the fulfillment of an intended goals or objectives. For the purpose of this research, the SWOT analysis would help in classifying all identified factors influencing the use of bamboo in BC (Rabin et al., 2000 and Macmillan et al., 2000).

3.3 SUMMARY

This chapter precedes the literature review where related literature on the subject matter was reviewed. Questionnaires have been developed by employing number of research methods. Again, the chapter has presented the distribution and retrieving of questionnaires. The next stage is to analyse and discuss the results obtained.

CHAPTE FOUR

RESULTS AND DISCUSSIONS

4.0 INTRODUCTION

The purpose of this study is to identify the extent to which bamboo has been used in building construction projects in Ghana. In order to achieve the purpose of the study, a methodology consisting of a review of literature and a survey to address the various objectives of the research was depicted. This chapter therefore presents the survey results, analyses of the results and discussions of thc findings of thc study.

4.1 BACKGROUND TO RESPONDENTS' FIRMS

The period of operation of a firm according to Frimpong (2002), has great influence in decision making which affect the firm, hence, the researcher considered outlining the year groups of the various respondents and their firms.

As indicated in Table 4.1(a) below, the majority of building contractors (36.0%) with active construction sites responding to the questionnaire had a working experience of 16 - 20 year and was followed by 11-15 and 6-10 with 30% and 18% respectively. On the whole, the contractors responded to a higher response rate of 78% for year group between 6-20 years.

Majority of principal Architects who responded to the questionnaire were between the year group of 11-15 as shown in the table 4.1(a) below. About 23% of architects were within 6-10 ycars and abovc 20 ycars. About 6% of architccts had bccn working for 1-5 ycars. This rcsult mcans that thcir rcsponscs would bc tangiblc and thcn a good conclusion may bc madc.

Table 4.1(a): Years of experience of Respondents

Years	Contractor		Architects
	Frequency	Percentage	Percentage
1 - 5	7	12.0	5.7
6 - 10	10	18.0	22.9
11-15	16	30.0	34.3
16-20	19	36.0	14.3
Above 20	3	4.0	22.9
Total	55	100	100

Source: Study Survey

4.2 USES OF BAMBOO IN BUILDING CONSTRUCTION (BC)

As demonstrated in the literature review (see chapter two), the areas of usage of bamboo in Building construction (BC) can be categorised in two. These usages are the temporary and permanent uses.

In Fig. 4.2 (a) below, out of the 55 responses of the questionnaire (to Building contractors) collated , it was identified that, there are 100% building contractors responded they have used bamboo or bamboo products at least in an area in building construction. About Ninety-four (94%) of architects responded they have specified bamboo for use at least in a building project and about six percent (6%) had not specified bamboo for use before.

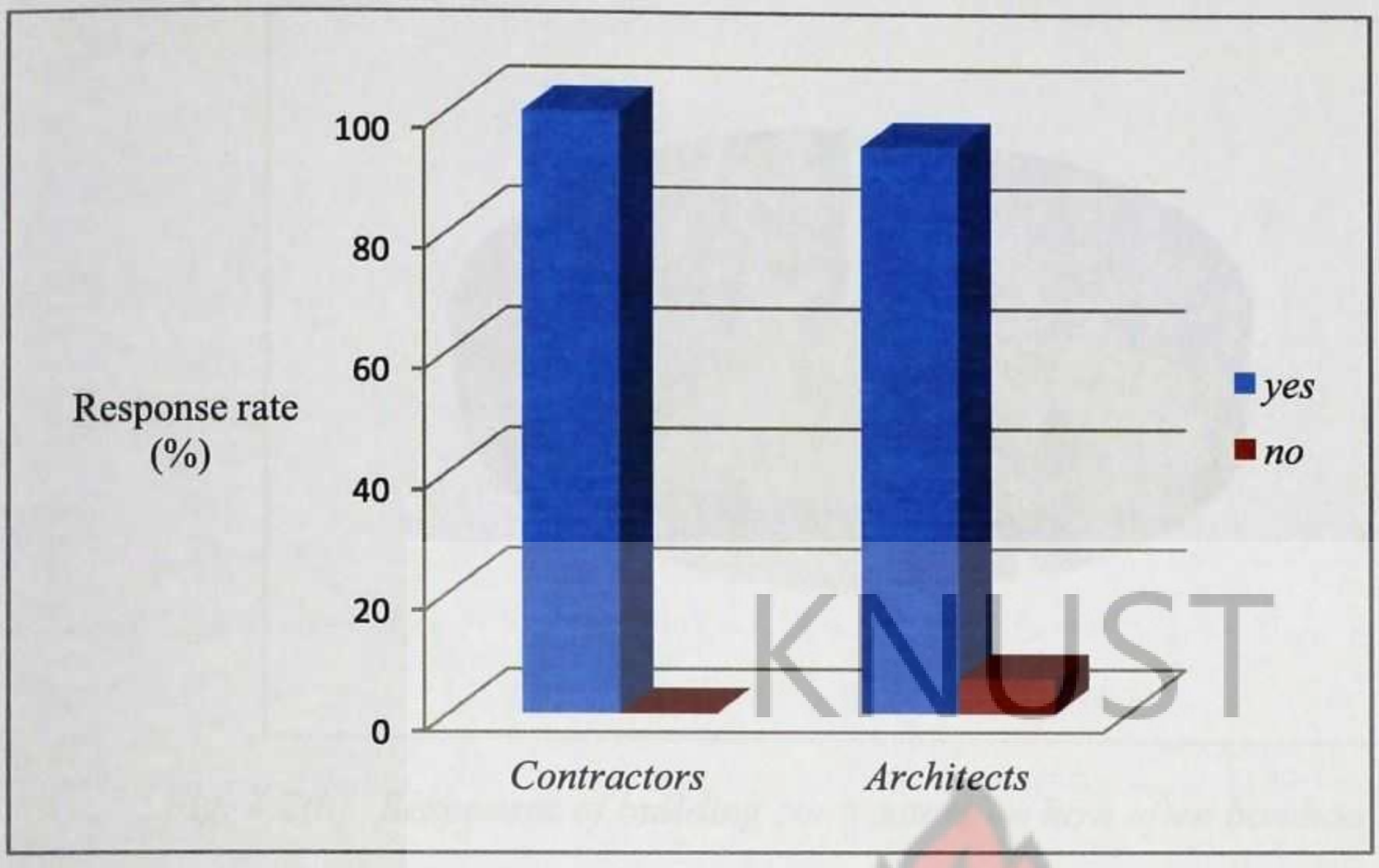

Fig. 4.2(a): Response to the use of bamboo

4.2.2 How often bamboo is used

The general view of the various respondents was sought to find out how often bamboo was used and specified by contractors and architects respectively. Fig. 4.2 (b) below shows that 32% and 20% of building contractors in the study area use bamboo not often and often respectively in Building construction (BC). Eighteen percent (18%) of contractors use bamboo very often, with 12% using bamboo in areas in construction quiet often.

The results from the response of Architects as shown in Fig. 4.2 (c) also reveal that, 60% of architects specify bamboo not often for use in Building construction. About 26% and 6% specify bamboo quiet often and very often respectively. About 3% of architects specify bamboo often.

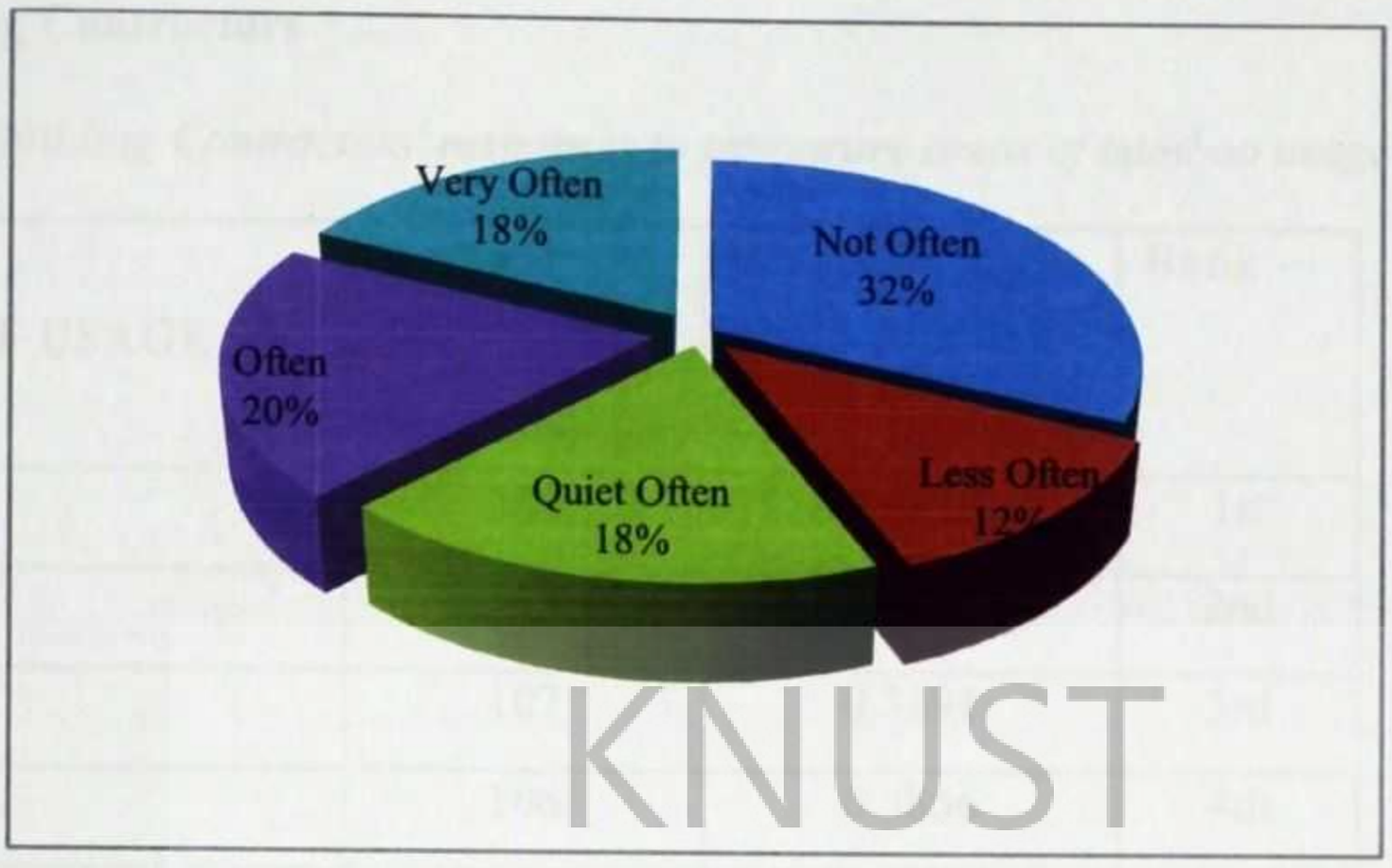

Fig. 4.2(b): Responses of building contractors on how often bamboo is used BC

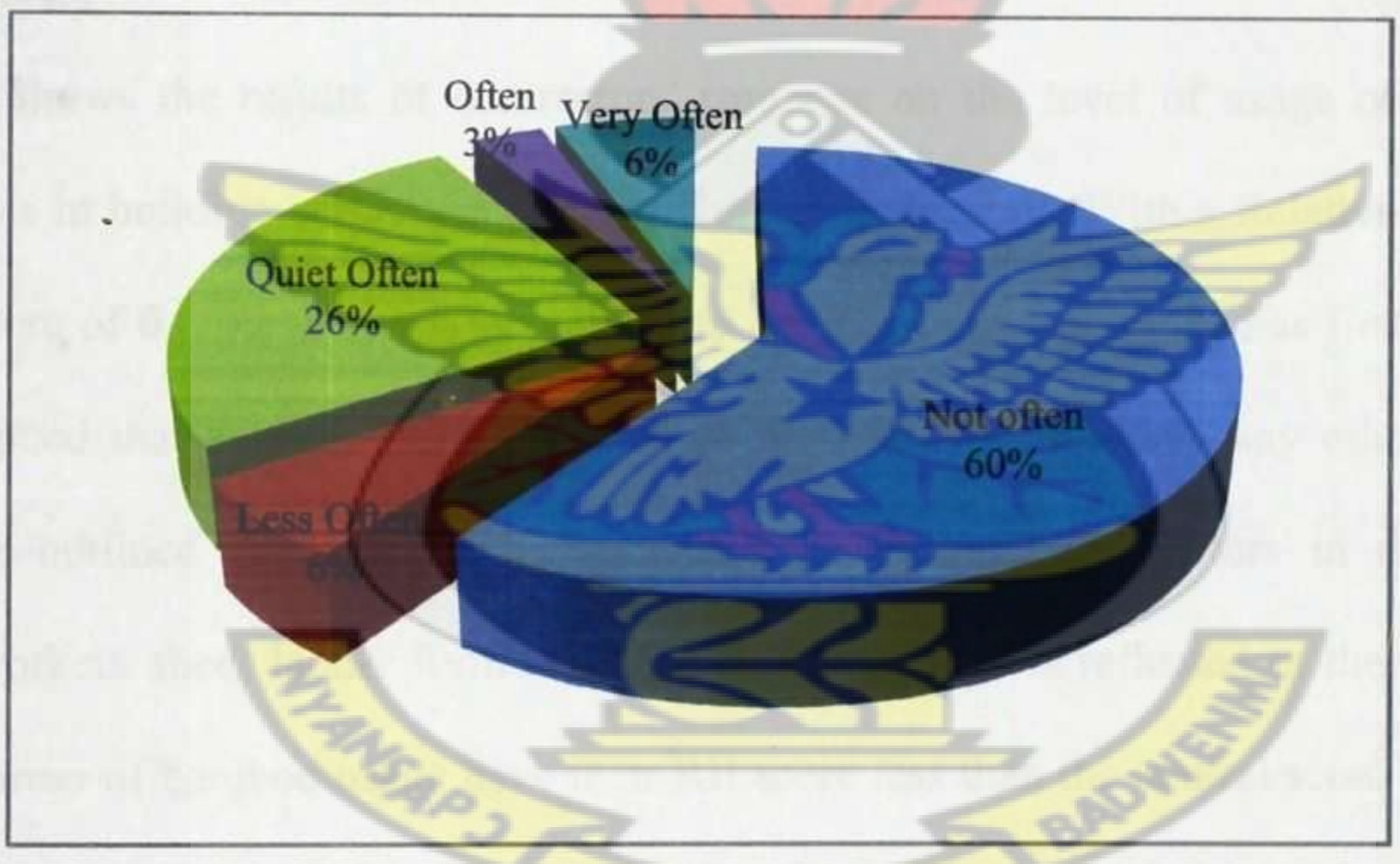

Fig. 4.2(c): Architects' responses on how often bamboo is used Building Construction

4.2.3 Areas of bamboo usage in building construction

This survey was carried out on registered contractors with active sites and principal architects in registered architectural firms. The Tables 4.2 (c) and 4.2 (d) show the reaction of the respondents on the areas they use bamboo in BC, temporary and permanent respectively.

- **Building Contractors**

Table 4.2 (a): Building Contractors' responses to temporary areas of bamboo usage

AREA OF USAGE	∑W	RII = $\sum W / (S * N)$	Rank
Props	236	0.8582	1st
Workers shed	115	0.4182	2nd
Scaffolding	107	0.3891	3rd
Ladder	106	0.3856	4th
Hoarding	104	0.3782	5th
Formwork	89	0.3236	6th

Source: Study Survey

Table 4.2 (a) shows the results of contractors' response on the level of usage of bamboo in temporary areas in building construction in the Kumasi metropolis. With a Relative Importance Index (RII) score of 0.8582 which is very close to one (1) and being ranked as first means that contractors agreed that bamboo is highly used in the area of props than any other area. The results further outlined that bamboo is less used by building contractors in the areas of scaffolding, workers shed, ladder formwork and hoarding. This is reflected in the table above where others areas of bamboo usage have their RII score less than the neutral score (0.5). Thus, with the exception of props, the uses of bamboo for other temporary areas have not been exploited by contractors.

Table 4.2 (b): Building Contractors' responses to permanent areas of bamboo usage

AREA OF USAGE	∑W	RII = $\sum W / (S * N)$	Rank
Landscaping	84	0.3055	1st
Doors and Windows	81	0.2946	2nd
Bamboo Reinforcement	78	0.2836	3rd
Trusses	77	0.2800	4th
Bamboo floor	74	0.2691	5th
Cciling	71	0.2582	6th
Partition Walls	70	0.2546	7th
Roofing	66	0.2400	8th

Source: Study Survey

The research reveals that bamboo is less used by contractors in permanent areas in building construction. The Relative Importance Index (RII) score obtained from the analysis of contractors' responses for the various areas as shown in Table 4.1(b) were below the neutral score (0.5). The implication is that bamboo is rarely used in the area of reinforcement, trusses, ceiling, doors and windows, roofing, flooring, partition walls and landscape. Although the area of landscaping was ranked as the area bamboo is mostly used permanently, its RII score was below the neutral score.

- **Architects**

Table 4.2 (c): Architects' responses to temporary areas of bamboo usage

AREA OF USAGE	∑W	RII = $\sum W / (S * N)$	Rank
Props	146	0.8343	1st
Hoarding	67	0.3829	2nd
Scaffolding	66	0.3771	3rd
Workers shed	65	0.3714	4th
Formwork	55	0.3143	5th
Ladder	52	0.2971	6th

Source: Study Survey

Architects were made to evaluate how bamboo is used in six (6) temporary areas in building construction and the results is as shown in the Table 4.1(c) above. The Relative Important Index (RII) scores of all the areas of use except one-the area of props, were found to be less than the neutral score (0.5). Thus, architects were of the view that bamboo is highly used in the area of props whereas in the areas of scaffolding, workers shed, ladder, formwork and hoarding were less specified. Bamboo specified for props was ranked the first by the respondents followed by the rest as outlined in the Table 4.1(c). The results also buttress the fact that architects have also contributed to the less exploitation of bamboo on construction site because the fail to specify them for use in the industry (Tamakloe, 2012).

Table 4.2 (d): Architects responses to permanent areas of bamboo usage

AREA OF USAGE	∑W	RII = $\sum W / (S * N)$	Rank
Landscaping	92	0.5257	1st
Partition Walls	68	0.3886	2nd
Bamboo floor	64	0.3657	3rd
Ceiling	57	0.3257	4th
Roofing	56	0.3200	5th
Doors and Windows	54	0.3086	6th
Trusses	51	0.2913	7th
Bamboo Reinforcement	48	0.2743	8th

Source: Study Survey

Specification of bamboo for permanent areas in building construction has not seen any increase as Architects responded that bamboo is less specified for use in building construction. The relative Importance Index (RII) score of all the areas of bamboo usage as shown in the table 4.1(d) except one-landscape was less than the neutral score of 0.5. The results shows that the RII score for landscape is 0.5257 as shown in the table above implies that the specification of bamboo for use in the area of landscape is more than that of the neutral score, hence, bamboo is responded to have been highly specified for use in the area of landscape by Architects. There had been less specification of bamboo for the areas of reinforcement, trusses, ceiling, doors and windows, roofing, flooring and partition walls.

4.3 FACTORS INFLUENCING THE USE OF BAMBOO IN BUILDING CONSTRUCTION

As demonstrated in the literature review (see chapter two) the use or unuse of bamboo in some areas in Building construction is contributed by various factors. Building contractors' and Architects' decisions to use bamboo are greatly influenced by these factors outlined in the preceding chapters. For bamboo with all its potentials in the BC industry to gain the acceptance into BC in Ghana as in some Asian countries, the impact of the afore mentioned factors on bamboo usage was identified from the two main stakeholders the research considers. The emphasis on this section was to analyze the level of influence the factors have had on the two main respondents in their decision to use bamboo. Section 4.3.1 of this chapter epitomized contractors' response to the factors influencing the use of bamboo and Barriers to the use bamboo in building construction. Section 4.3.2 dealt with architects' responses on the assessment of the factors influencing the specification of bamboo in BC.

4.3.1 BUILDING CONTRACTORS

This section relates to contractors putting weight on some factors with respect to showing the level of agreement to how the identified factors affect decision to use bamboo temporarily. For this reason, Ghanaian contractors especially those in Kumasi were to respond to this assertion by ticking an appropriate cell to indicate whether they agree or disagree to that assertion.

Table 4.3 (a): Factor influencing the temporary uses of bamboo by Building Contractors

FACTORS	∑W	RII = $\Sigma W/_{(S*N)}$	Rank
Bamboo is readily available	225	O.8182	1st
Bamboo is cheaper to use	221	0.8036	2nd
bamboo can be reused	218	0.7927	3rd
Bamboo is easy to use in its natural state with less processes go through	205	0.7593	4th
Bamboo is durable	208	0.7564	5th
Bamboo has multiple uses in building construction	204	0.7418	6th
Bamboo is Easy to erect	197	0.7164	7th
Bamboo does not break easily	196	0.7127	8th
Low technical requirements in its application	190	0.6909	9th
Easy to obtain in any quantity required	188	0.6836	10th
It is a very good material for a sustainable building construction	177	0.6436	11th
Shortage of timber supply to the local market	154	0.5704	12th

Source: Study Survey

Factors that motivates Building Contractors to use bamboo temporarily include 'bamboo is readily available', 'bamboo is cheaper to use', 'bamboo can be reused' and 'bamboo is easy to use in its natural state with less processes go through' (Table 4.3 (a)). The Relative Importance index (RII) score of all twelve (12) factors evaluated are significantly greater than the neutral score of

0.5 (50%). Thus, Building contractors agree that 'bamboo is readily available 'and 'bamboo is cheaper to use' are the first and second major factors influencing the use of bamboo for temporary areas in building construction. Building contractors who use bamboo temporarily, primarily considers the factors in the order of ranked more important than the lower ranked as reiterated by Tekpertey (2006) and Solomon-Ayeh (2004). They outlined that in Ghana and other bamboo growing countries, bamboo is used because it is readily available, it is cheaper to use, it can be reused, Bamboo is easy to use in its natural state with less processes go through and followed by the rest as ranked in the table above.

Table 4.3 (b): Factor influencing the permanent uses of bamboo by Building contractors

FACTORS	∑W	RII = $\Sigma W / (S * N)$	Rank
Bamboo is readily available	225	0.8182	1st
Bamboo has very good constructional properties	225	0.8182	1st
Bamboo is cheaper to use	223	0.8109	3rd
Very beautiful in its appearance	218	0.7927	4th
Bamboo can be reused	218	0.7927	4th
Bamboo is easy to use in its natural state with less processes go through	207	0.7527	6th
Bamboo is durable	206	0.7491	7th
Bamboo has multiple uses	204	0.7418	8th
Resistance to pests and fungi attack due to preservation and treatment	196	0.7127	9th
Bamboo does not break easily	196	0.7127	9th
Bamboo is Easy to erect	193	0.7018	11th
Low technical requirement in its application	191	0.6945	12th
Easy to obtain in any quantity required	189	0.6873	13th
It is a very good material for a sustainable building construction	177	0.6436	14th
Shortage of timber supply to the local market	154	0.5704	15th

Source: Study Survey

The Relative Importance Index scores (RII) of fifteen (15) factors influencing the permanent use of bamboo in building construction by building contractors are presented in Table 4.3 (b). The factor 'bamboo has good constructional properties' was indicated by contractor to be the number one factor that influences the use of bamboo in permanent areas. All the factors had their RII scores significantly greater than the neutral score (0.5). Thus, contractors were of the view that all the factors listed in Table 4.3(b) are influential in their decision to use bamboo as a material for permanent areas.

The results also reflect that contractors who use bamboo permanently, primarily considers the factors in the order of ranked very important. This is to say that they use bamboo because it is readily available, it has a very good constructional property, it is cheaper to use and followed by the rest as ranked in the table above. From the ranking it is identified that the factor 'shortage of timber supply to the local market' was ranked (15th) though contractors were of the view it significantly influence their decision to use bamboo.

4.3.2 PRINCIPAL ARCHITECTS (CONSULTANTS)

This section of this chapter relates to some factors which influence Architects to specify bamboo for both temporary and permanent uses. Lists of assertions were made and the architects were asked to indicate whether they agreed or disagree. Tables 4.3.2 (a) and 4.3.2 (b) show the result of the question.

Table 4.3 (c): Factor influencing the specification of bamboo for temporary uses by Architects

FACTORS	∑W	RII = $\Sigma W / (S * N)$	Rank
Bamboo has multiple uses in building construction	141	0.8057	1st
Bamboo is cheaper to use	138	0.7886	2nd
Bamboo is readily available	131	0.7486	3rd
Bamboo is a very good material for a sustainable building construction	127	0.7257	4th
Bamboo is durable	125	0.7143	5th
Bamboo does not break easily	124	0.7086	6th
bamboo can be reused	120	0.6857	7th
Low technical requirements in its application	120	0.6857	7th
Bamboo has good constructional properties	117	0.6686	9th
Bamboo is easy to use in its natural state with less processes go through	113	0.6457	10th
Bamboo is Easy to erect	112	0.6400	11th
Easy to obtain in any quantity required	109	0.6229	12th
Shortage of timber supply to the local market	98	0.5600	13th

Source: Study Survey

All the factors as shown in Table 4.3 (c) were agreed upon by Architects to be significantly important in their decision to specify bamboo for use in building construction. The Relative Importance Index score of all the thirteen listed factors were found to be significantly greater

than the neutral score of 0.5 ($p = 0.05$). Thus, the respondent were of the view that they were significantly influenced by the factors ' bamboo has multiple uses in building construction', 'bamboo is cheaper to use', ' bamboo is readily available', 'bamboo is a very good material for a sustainable building construction', 'bamboo is durable' and the rest as shown in Table 4.3(c) in their decision to specify bamboo for temporary uses.

Though Architects considers 'Shortage of timber supply to the local market' to be a significant factor in their decision to specify bamboo, it was ranked the Thirteenth (13th).

Table 4.3 (d): Factor influencing the specification of bamboo for permanent uses by Architects

FACTORS	∑W	RII = $\Sigma W / (S * N)$	Rank
Bamboo has multiple uses	141	0.8057	1st
Very beautiful in its appearance	133	0.7600	2nd
It is a very good material for a sustainable building construction	130	0.7429	3rd
Rcsistancc to pcsts and fungi attack due to preservation and treatment	126	0.7200	4th
Low tcchnical rcquircmcnt in its application	125	0.7143	5th
Bamboo is durable	121	0.6914	6th
Bamboo can be reused	120	0.6857	7th
Bamboo is Easy to erect	120	0.6857	7th
Bamboo has very good constructional properties	118	0.6743	9th
Bamboo does not break easily	115	0.6571	10th
Bamboo is easy to use in its natural state with less processes go through	115	0.6571	10th
Bamboo is chcapcr to usc	115	0.6571	10th
Bamboo is readily available	111	0.6343	13th
Easy to obtain in any quantity required	107	0.6114	14th
Shortage of timber supply to the local market	97	0.5543	15th

Source: Study Survey

From Table 4.3 (d), 'Bamboo have multiple uses' in building construction turned out to be the most important factor which influences the permanent use of bamboo. This means that architects in Ghana specifics bamboo greatly because of it versatility in the construction industry (Tekpertey, 2006). Another important highly ranked factor is the fact that 'bamboo is Very beautiful' in its appearance. According to Gutierrez, (2000), in areas of use for permanent purposes bamboo enhances aesthetics and has appearances which do not need too much enhancement to be aesthetically pleasing as a material. The result shown in the table above indicates that the Relative Importance Index values of the various factors were significantly greater than the neutral score and this implies that respondents agreed to all the factors to be influential in their decision making

Architects according to the ranking were of the view that, the specification of bamboo for use has a very minimal influence by the factor "there is shortage of timber supply to the local market." as compared to the other listed factors though it is significantly greater than the neutral score. Hence, it is ranked the fifteenth (15th).

4.4 BARRIERS TO THE USE OF BAMBOO

This section outlines how some listed factors deter respondents to use and specify bamboo for use in building construction. Building Contractors and Architects responses are shown in sections 4.4.1 and 4.4.2 respectively.

4.4.1 BUILDING CONTRACTORS

Table 4.4 (a): Building contractors responses to barriers to temporary uses of bamboo

FACTORS	∑W	RII = $\sum W / (S * N$	Rank
Architects (consultants) do not specify them for building projects	232	0.8593	1st
Insufficient cooperation from government	229	0.8481	2nd
Less durable if not treated for permanent use	208	0.7704	3rd
Poor processing techniques	211	0.7673	4th
Lack of knowledge in bamboo detailing	199	0.7370	5th
Limited knowledge of bamboo and lack of expertise to use it	199	0.7370	5th
Highly susceptible to fire	202	0.7345	7th
Irregular shape of bamboo culms makes it difficult to work with as compared to timber	192	0.6982	8th
Difficult in controlling the quality of bamboo because of different species	177	0.6556	9th
Problem of social acceptability (bamboo is considered for the poor)	168	0.6222	10th
Competition with other building materials	159	0.5782	11th

Source: Study Survey

Building contractors were asked to respond to how eleven (11) factors listed in Table 4.4 (a) deter them from using bamboo temporarily in building construction. Factors which deter them from using bamboo include 'Architects (consultants) do not specify them for building projects', 'Insufficient cooperation from government', 'less durable if not treated for permanent use', 'poor processing techniques' and 'lack of knowledge in bamboo detailing'. The Relative Importance index (RII) score of all the factors were significantly greater than the neutral score of 0.5 or 50% ($p = 0.05$). thus, respondents agree that 'Architects (consultants) do not specify them for building projects' and ' Insufficient cooperation from government' are the first and second major factors contributing to why contractors do not use bamboo for some areas in building construction. Though respondents agreed that all the factors significantly affect their decision to use bamboo, they were of the view that the factor 'bamboo faces Competition with other building materials' is ranked the eleventh (11) among all the factors.

Table 4.4 (b): Building contractors responses to barriers to permanent uses of bamboo

FACTORS	∑W	RII = $\Sigma W / (S * N)$	Rank
Architects (consultants) do not specify them for building projects	236	0.8906	1st
Lack of bamboo processing companies in Ghana	219	0.8264	2nd
Insufficient cooperation from government	219	0.8264	2nd
Problem of social acceptability (bamboo is considered for the poor)	218	0.8226	4th
Limited knowledge of bamboo and lack of expertise to use it	222	0.8222	5th
Lack of knowledge in bamboo detailing	212	0.8000	6th
Lack of management skill in the use of bamboo	210	0.7925	7th
Poor processing techniques in Ghana	211	0.7925	7th
Highly susceptible to fire	202	0.7623	9th
Less durable if not treated for permanent use	201	0.7585	10th
Treated bamboo is expensive	178	0.6717	11th
Not readily available	162	0.6113	12th
Competition with other building materials	148	0.5585	13th

From Tables 4.4 (d) above, it can clearly be seen that the five most important factors (in order of importance) which deterred contractors from using bamboo for permanent purposes in Ghana are as follows:

1. Architects (consultants) do not specify them for building projects
2. Insufficient cooperation from government
3. lack of bamboo processing companies in Ghana
4. Problcm of social acccptability (bamboo is considcrcd for thc poor)
5. Limited knowledge of bamboo and lack of expertise to use it

4.4.2 PRINCIPAL ARCHITECTS (CONSULTANTS)

This section outlines how some factors deter Architects from specifying bamboo for both temporary and permanent uses. Lists of factors were made and the architects were asked to indicate whether they agree or disagree.

Table 4.4 (c): Architects responses to barriers to temporary uses of bamboo

FACTORS	∑W	RII = $\Sigma W/(S * N)$	Rank
Lack of knowledge in bamboo detailing	143	0.8171	1st
Limited knowledge of bamboo and lack of expertise to use it	139	0.7943	2nd
Insufficient cooperation from government	131	0.7486	3rd
Less durable if not treated for permanent use	127	0.7257	4th
Poor processing techniques	125	0.7143	5th
Competition with other building materials	122	0.6971	6th
Highly susceptible to fire	116	0.6629	7th
Irregular shape of bamboo culms makes it difficult to work with as compared to timber	116	0.6629	7th
Difficult in controlling the quality of bamboo because of different species	110	0.6286	9th
Problem of social acceptability (bamboo is considered for the poor)	110	0.6286	9th
Problem of social acceptability (bamboo is considered for the poor)	110	0.6286	9th

The views of architects concerning the barriers to the use of bamboo for both temporary and permanent uses were ranked using the Relative Important Index (RII) and the results are as shown in the Tables 4.4. (c) and 4.4 (d). 'Lack of knowledge in bamboo detailing' was identified

as the major factor which serves as a barrier to the specification of bamboo for use by architects. It was ranked the first in both temporary and permanent areas of usage. Though the material is availablc and casy to afford, thc tcchnical knowhow of its application is not availablc to architects. Hence, they will go in for other material commonly used and with available details (Mardjono, 2002).

All the factors responded to have their RII score significantly greater than the neutral score of 0.5 (50%). thus, respondent agree that all the factors listed the Tables 4.4(c) and 4.4 (d) are significant in deterring them from specifying bamboo for use as a material in building construction.

Additionally, architects outlined that, 'Limited knowledge of bamboo and lack of expertise to use it' in building construction is one other very important factor which deters them from specifying bamboo for use. Hence, it was ranked second (2nd) in both the temporary uses and permanent uses. This shows that, not much in terms research of bamboo in construction has been carried out in Ghana, hence, the need for attention to be directed to bamboo as a material.

The result of the ranking also shows that, insufficient cooperation from government is one other major factor contributing to non specification of bamboo by architect for temporary uses in Ghana. for permanent use, it is reveal that, lack of bamboo processing companies in Ghana has also contributed immensely to the non specification of bamboo in BC as shown in tables 4.4.2 (d). Architects acknowledged that, if bamboo is not treated it is less durable. Hence, bamboo does not last long especially for temporary use.

The lowest ranked factors according to results in Tables 4.4.2 (c) and 4.4.2 (d) are the Problem of social acceptability (bamboo is considered for the poor) (9th) and bamboo not readily

available respectively (12th). This means that architects decision not to specify bamboo for use are least influenced by the two mentioned factors.

Table 4.4 (d): Architects responses to barriers to permanent uses of bamboo

FACTORS	∑W	RII = $\Sigma W / (S * N$	Rank
Lack of knowledge in bamboo detailing	154	0.8800	1st
Limited knowledge of bamboo and lack of expertise to use it	146	0.8343	2nd
Lack of bamboo processing companies in Ghana	140	0.8000	3rd
Less durable if not treated for permanent use	137	0.7829	4th
Competition with other building materials	132	0.7543	5th
Problem of social acceptability (bamboo is considered for the poor)	131	0.7486	6th
Poor processing techniques in Ghana	129	0.7371	7th
Lack of management skill in the use of bamboo	129	0.7371	7th
Highly susceptible to fire	125	0.7143	9th
Insufficient cooperation from government	121	0.6914	10th
Treated bamboo is expensive	121	0.6914	10th
Bamboo is not readily available	106	0.6057	12th

4.5 Chi-squared (X2) Test on the barriers to the temporary use of bamboo

The Chi-Squared test of the contingency table is used to determine whether differences exist in response between two or more populations (Keller et al, 2004). In this study, Chi-Squared test was used because; consultants (Architects) and Contractors have been identified as the population and because of the use of descriptive statistics. The result of Chi-Squared test is achieved by stating the hypothesis, computing the observed and expected values from the responses, computing X^2 statistic and p-value. The X^2 statistic measures how far away is the observed values from the expected one and it is the sum of each of the contributions from each variable. The p-value is computed by looking under the Chi-square table with the degrees of freedom.

Table 4.5: Chi-squared values between respondents on barriers to the temporary use of bamboo

	FACTORS	Chi-Squared value X^2_{cal}
1	Problem of social acceptability (bamboo is considered for the poor)	8.43E-05
2	Limited knowledge of bamboo and lack of expertise to use it	0.049
3	Competition with other building materials	0.002
4	Poor processing techniques	0.041
5	Highly susceptible to fire	0.043
6	Less durable if not treated for permanent use	0.005
7	Insufficient cooperation from government	0.047
8	lack of knowledge in bamboo detailing	0.040
9	Difficult in controlling the quality of bamboo because of different species	0.287
10	Irregular shape of bamboo culms makes it difficult to work with as compared to timber	0.461

Hypothesis

H_0: there is no difference between the responses of the respondents on the factors preventing the usc of bamboo.

H_1: there is a difference between the responses

Where H_0 denotes the null hypothesis and H_1 denotes the alternative hypothesis

Significant lcvcl (α) = 0.05

Wc rcjcct thc H_0 if $X^2_{cal} > X^2_{0.05}$

From the Chi-Squared values calculated in the table above, there is enough evidence to infer that some of the factors associated with the prevention of temporary uses of bamboo as responded to by contractors and architects are related where as two of them are not. This is to say that, to some factors we accept the null hypothesis that there is no difference between the responses of the respondents on the factors preventing the use of bamboo temporarily in BC and to two, we reject. From the Table 4.5, the response of the underneath stated factors are related since their calculated X^2 values were less than 0.05:

- Problcm of social acccptability (bamboo is considcrcd for thc poor)
- Limited knowledge of bamboo and lack of expertise to use it
- Poor processing techniques
- Highly susceptible to fire
- Lcss durablc if not trcatcd for pcrmancnt usc
- Insufficient cooperation from government
- Lack of knowledge in bamboo detailing

The response of the respondent on the factors "Difficult in controlling the quality of bamboo because of different species" and "Irregular shape of bamboo culms makes it difficult to work with as compared to timber" are not related since the calculated X^2 values are greater than 0.05. The relationship or the extent of agreement is significant. This underscores the reasons why there were high frequencies for "agree" in the tables 4.3.1(c) and 4.3.2(c). This means the listed factors actually deter contractors and architects from using and specifying bamboo in building construction hence less popularity in the areas of use in BC.

4.6 SPEARMAN CORRELATION

After obtaining these results as shown in the tables above, the Spearman rank correlation coefficient which is a non-parametric test was used to measure the difference in ranking between any two of the three contact groups. This was used to highlight as accurately as possible whether there is a significant difference in the rankings. The rankings of the individual groups are shown in Tables 4.5(a) and 4.5(c)

Table 4.6 (a): Ranking of Each Group of Respondent on Factors Influencing Temporary Use of Bamboo

	FACTORS	**RANKING**	
		Contractors	Architects
1	Bamboo is readily available	1	3
2	Bamboo is cheaper to use	2	2
3	Shortage of timber supply to the local market	12	12
4	Bamboo is Easy to erect	7	10
5	Bamboo is durable	5	5
6	Bamboo can be reused	3	7
7	Bamboo is easy to use in its natural state with less processes go through	4	9
8	It is a very good material for a sustainable building construction	11	4
9	Easy to obtain in any quantity required	10	11
10	Low technical requirements in its application	9	7
11	bamboo does not break easily	8	6
12	Bamboo has multiple uses in building construction	6	1

Source: Study Survey

Table 4.6 (b): Ranking of each group of respondent on factors influencing temporary use of bamboo

	FACTORS	RATING	
		Contractors	Architects
1	Bamboo is readily available	1	13
2	Bamboo is cheaper to use	3	10
3	Bamboo is Easy to erect	11	7
4	Bamboo has very good constructional properties	1	9
5	Bamboo is easy to use in its natural state with less processes go through	6	10
6	Bamboo is durable	7	6
7	Easy to obtain in any quantity required	13	14
8	Very beautiful in its appearance	4	2
9	Resistance to pests and fungi attack due to preservation and treatment	9	4
10	Shortage of timber supply to the local market	15	15
11	Bamboo can be reused	4	7
12	It is a very good material for a sustainable building construction	14	3
13	Low technical requirement in its application	12	5
14	Bamboo does not break easily	9	10
15	Bamboo has multiple uses	8	1

According to Table 4.5(c), the rank correlation coefficient for the 12 factors influencing architects and contractors to specify and use bamboo temporarily in BC is 0.5178. The rank correlation coefficient for contractors and architects on the factor influencing the permanent use of bamboo in BC is 0.0186. This indicates that architects and contractors agree more on the ranking of the factors influencing the use of bamboo temporarily in BC than the factors influencing the use of bamboo for permanent purposes.

Table 4.6(c): The rank correlation coefficient (Using Microsoft Excel 2007)

	Temporary uses		Permanent uses	
	Contractor	**Architect**	**Contractor**	**Architect**
Contractor	1	0.5178	1	0.0186
Architccts		1		1

Source: Study Survey

4.7 TREND OF BAMBOO USAGE WITH REGARDS TO VOLUME

In order to achieve the aim of this research, the trend of bamboo usage with regard to volume over the past ten years (10) was sought from the group of respondents. This helped outline the state of bamboo usage in the various areas of application as mentioned in the literature review. This section of this chapter deals with two parts, the first being the response of contractors on the average bamboo culms they use per building project. The second also deal with contractors and consultants expressing their views on the level of increment of the various areas bamboo are applied in building construction.

4.7.1 Quantity of bamboo culms per building project

Figure 4.7(a) shows that about 38% contractors use average bamboo culms of about 100 - 200 for a single building project. This quantity relates to the temporary use of bamboo and as shown in Table 4.2 (a), the majority of contractors in Ghana uses bamboo predominantly as props. 25% contractors also responded that they use an average of 201-300 bamboo culms per project. However, contractors responded that, even though bamboo culms are used regularly on building sites, there is no contractor who has used more that 500 bamboo culms per project. According to

Tekpertey (2006), bamboo culms below 100 pieces are mainly used for activities which do not require a lot of time to complete. In relation to BC, the use of bamboo culms below 100 are for small building projects which require a very short time of execution.

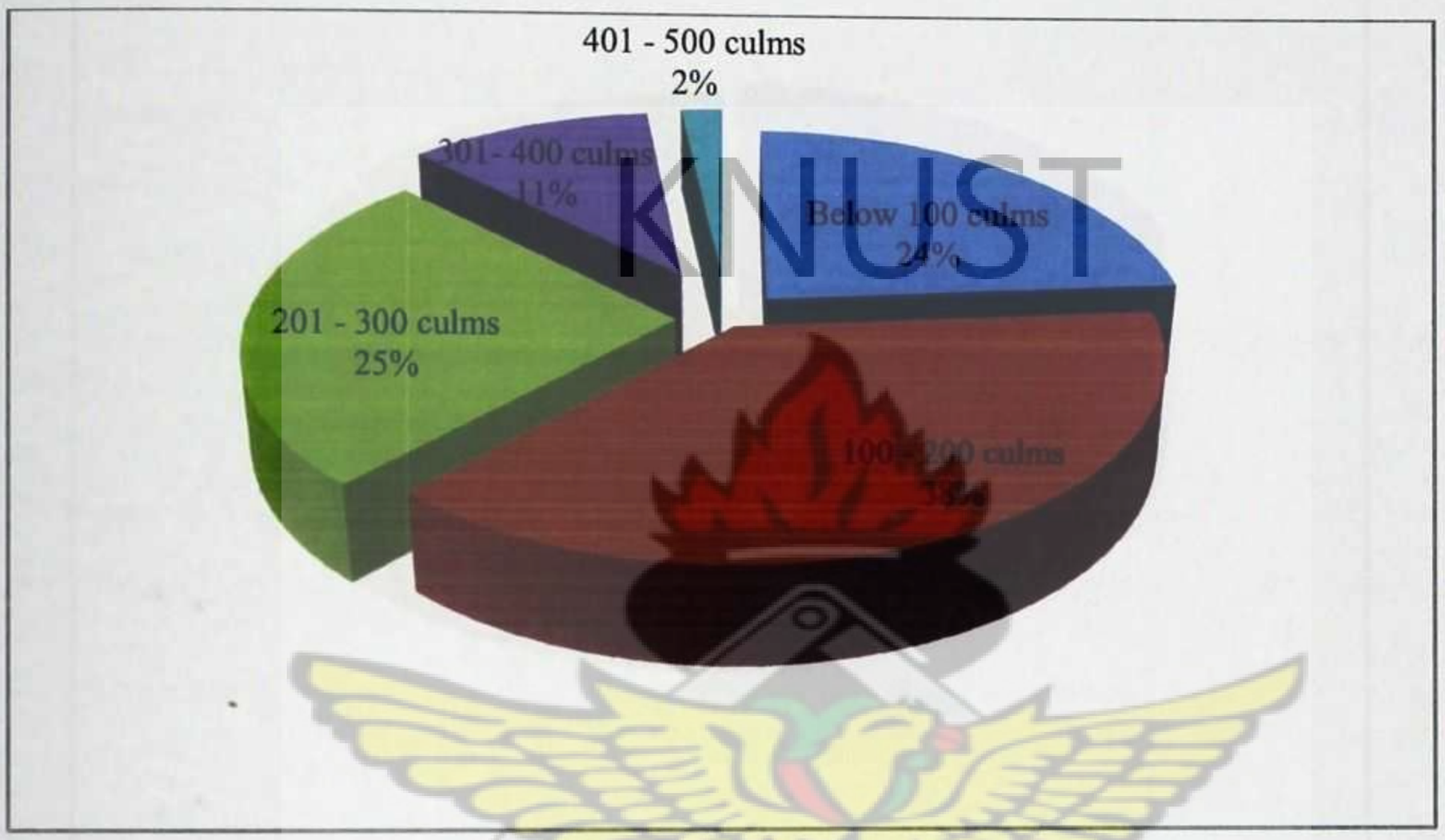

Fig. 4.7(a): Contractors response to the average quantity of bamboo culms per project

4.7.2 Perception of respondent on the trend of bamboo usage over the past 10year

This section was intended to ascertain the trend of bamboo usage by respondent over the last 10years for both temporary and permanent uses. The Tables 4.7(a) and 4.7(b) are the result obtained from the respondents.

From the evaluation of the perception of respondents on the trend of bamboo usage as shown in Fig 4.7(b), averagely, about 62% of contractors reiterated that, their usage of bamboo temporarily in BC has neither seen increment nor reduction in the volumes. About 22% of

contractors responded there is an increase in the temporary use of bamboo for BC and 16% also responded there is a significant decrease in the various temporary uses of bamboo.

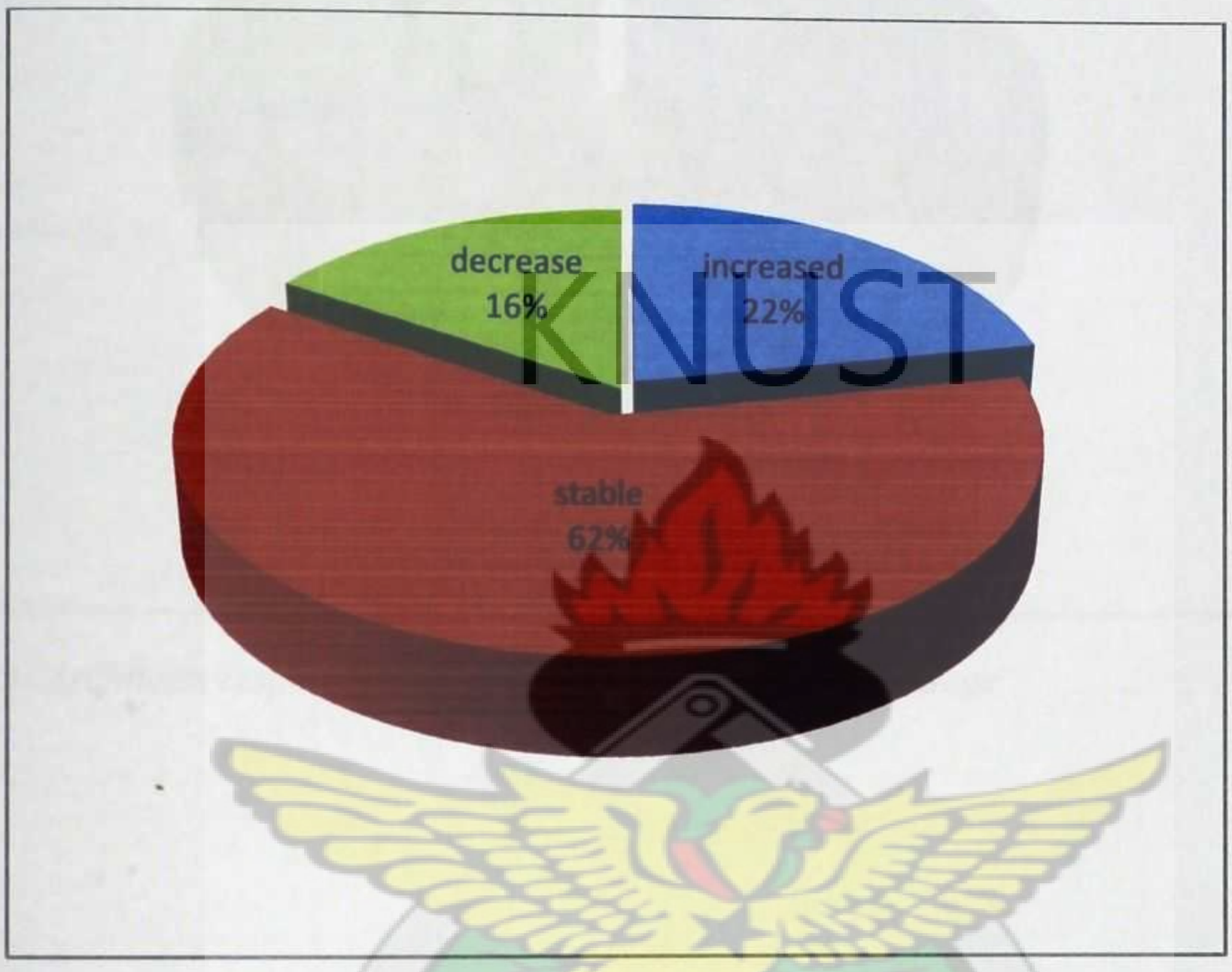

Fig. 4.7 (b): Contractors' response to the trend of volume of bamboo usage

Majority of the Architects responded that the volume of bamboo props has seen a great increase (83% architects responded to an increase in volumes) over the past 10years. This is to say that bamboo in building construction is gaining popularity in its usage for props than any other areas of application. Averagely, majority (40%) of Architects responded that the trend of bamboo usage in building construction has been stable as shown in Fig. 4.7(c). about 31% and 29% of Architects also indicated the used of bamboo in building construction had increased and decreased respectively.

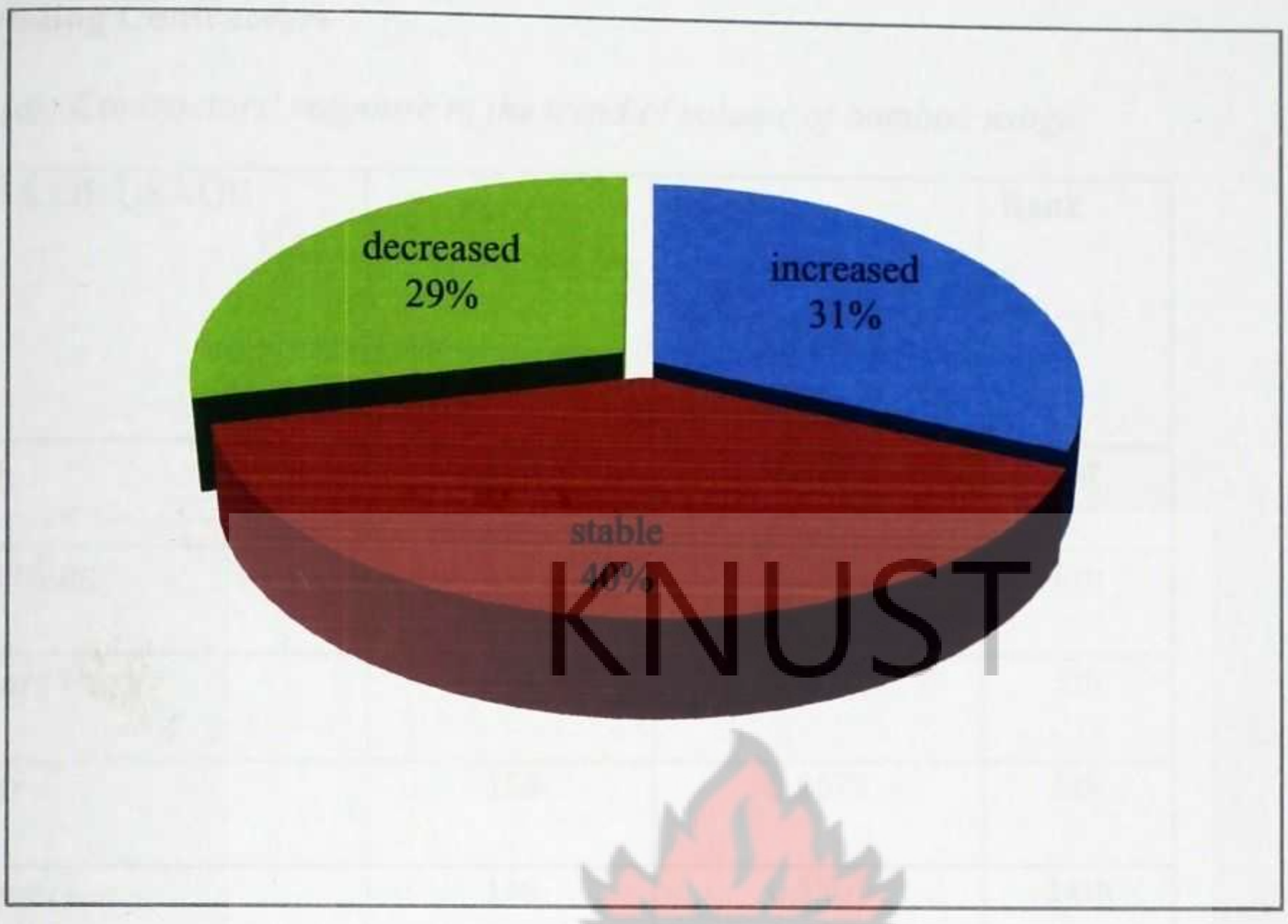

Fig. 4.7 (c): Architects response to the trend of volume of bamboo usage

- **Building Contractors**

Table 4.7 (a): Contractors' response to the trend of volume of bamboo usage

AREA OF USAGE	∑W	RII = $\Sigma W / (S * N)$	Rank
1. Props	245	0.8909	1st
2. Scaffolding	155	0.5636	6th
3. Workers shed	154	0.5600	7th
4. Ladder	156	0.5673	5th
5. Formwork	146	0.5309	14th
6. Hoarding	162	0.5891	4th
7. Bamboo Reinforcement	153	0.5564	9th
8. Trusses	163	0.5927	3rd
9. Ceiling	152	0.5527	11th
10. Doors and Windows	152	0.5527	11th
11. Roofing	150	0.5455	13th
12. Bamboo floor	154	0.5600	7th
13. Partition Walls	153	0.5564	9th
14. Landscape	169	0.6146	2nd

- **Architects**

Table 4.7 (B): Architects' response to the trend of volume of bamboo usage

AREA OF USAGE	∑W	RII = $\Sigma W / (S \bullet N)$	Rank
1. Props	152	0.8686	1st
2. Scaffolding	96	0.5486	8th
3. Workers shed	103	0.5886	3rd
4. Ladder	97	0.5543	7th
5. Formwork	92	0.5257	13th
6. Hoarding	102	0.5829	5th
7. Bamboo Reinforcement	83	0.4743	14th
8. Trusses	96	0.5486	8th
9. Ceiling	95	0.5429	10th
10. Doors and Windows	98	0.5600	6th
11. Roofing	95	0.5429	10th
12. Bamboo floor	93	0.5314	12th
13. Partition Walls	103	0.5886	3rd
14. Landscape	114	0.6514	2nd

Respondents were asked to evaluate whether the use of bamboo in various areas in building construct has decrease or increased over the last ten (10) years. the results as shown in tables 4.6(a) and 4.6(b) above shows that the temporary use of bamboo in the area of props in building construction has seen significant increase and this relate to the finding of Tekpertey (2006)

which acknowledge the fact that bamboo is largely used in the area of props in building construction . Permanent use of bamboo in the area of landscape has also seen an appreciable increase as it is ranked second by both respondents. averagely, respondent were neutral about their response in bamboo use areas such as scaffolding, workers shed, ladder, formwork, hoarding, trusses, ceiling, doors and windows, roofing, bamboo floor and partition walls. the result also shows that, the use of bamboo in the areas of reinforcement and formwork have seen a decrease in their usage over the last ten (10) year as it is ranked thirteenth (13th) and fourteenth (14th) by both respondents.

4.8 SWOT ANALYSIS OF BAMBOO IN BUILDING CONSTRUCTION IN GHANA

STRENGTHS	WEAKNESSES
➢ Bamboo is readily available in Ghana	➢ lack of knowledge in bamboo detailing
➢ Bamboo is durable and easy to use in its natural state with less processes go through	➢ It is Difficult to controlling the quality of bamboo because of different species
➢ It is Easy to obtain bamboo in any quantity for temporary uses	➢ Highly susceptible to fire if not treated to be fire proof
➢ Using bamboo for temporary areas in building construction requires low technical know how	➢ Untreated bamboo is prone to fungi and insect attacks
➢ Bamboo does not break easily	➢ Irregular shape of bamboo culms makes it difficult to work with as compared to timber
➢ Bamboo is very beautiful in it appearance	
OPPORTUNITIES	**THREATS**
➢ Bamboo has multiple uses in building construction	➢ Bamboo faces Competition from other building materials
➢ Shortage and high cost of timber makes bamboo a promising material to be considered in building construction	➢ bamboo is considered as a material for the poor
➢ Contractors and architects are ready to embrace bamboo as a popular building material in building construction	➢ There is insufficient cooperation from government to support bamboo in building construction
	➢ There is poor bamboo processing techniques
	➢ There is Limited knowledge of bamboo and lack of expertise in building construction
	➢ There is lack of knowledge in bamboo detailing in Ghana

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

5.0 INTRODUCTION

This chapter presents the conclusion of the study made to address the main findings obtained from the analysis in the light of the objectives of the study. the objectives of the study was to identify the areas where bamboo can be used in building construction in Ghana, to identify the factors influencing the use of bamboo in building construction in Ghana and to identify the trend of bamboo usage in Ghana with regards to the volume. The chapter also presents recommendations of the researcher based on the findings of the study and also outlines recommendations for further research.

5.1 CONCLUSIONS

5.1.1 Areas of bamboo usage in Building Construction

At the end of the study, the respondents - Building contractors and Architects indicated that they have used and specified bamboo for use respectively in at least an area in building construction. Basically, bamboo is mostly used for temporary works than permanent works in building construction in Ghana, with the most popular area of usage being props. About eighty eight percent (88%) of building contractors and seventy seven Percent (77%) architects responded that bamboo is highly used and specified respectively in building construction for props.

It can further be concluded that, bamboo has not gained popularity in the areas of use for permanent purposes in building construction except in the area of landscape. Nonetheless not many respondents use bamboo in that area, even though it was ranked used than any other area

of usage. It can further be deduced that, bamboo has a potential to thrive in the building construction industry in Ghana but the various areas of usage have not been exploited with the exception of the area of props which even need further attention to be able to survive through many building projects and made sustainable.

5.1.2 Factors influencing the use of bamboo

The findings of the research show that there are two main groups of factors which influence the use of bamboo in building construction in Ghana. These are factors contributing to the promotion of the use of bamboo (that is to say factors which will cause building contractors and Architects to use or specify bamboo for use respectively) and the barriers to the use of bamboo in building construction.

Respondents agreed that 'the availability of bamboo', 'the affordability of bamboo', 'the Bamboo has multiple uses', the durability of bamboo' and 'bamboo being a very good material for a sustainable building construction' were among the major factors which contributes to the promotion of the use of bamboo by the respondents.

The results further outlined that respondent agreed that 'insufficient cooperation from government', ' poor processing techniques', and 'lack of knowledge in bamboo detailing', lack of bamboo processing companies in Ghana' were among the major factors which deter the respondents from using bamboo. Building contractors further agreed that the number one factor which serves as a barrier to the use of bamboo was 'lack of specification of bamboo as a material by Architects'. The unpopularity and under exploitation of bamboo in the Ghanaian construction industry are as a result of the impact of the barriers to the use of bamboo during decision making to consider bamboo as a material by Architects and building contractors. It can be concluded that, for the potential of bamboo to be harness in the building construction sector of Ghana,

critical attention to reduce or eliminate the impact of the factors that deter the use of bamboo must be devoted.

The table 5.1 below shows five (5) major critical barriers to the use of bamboo outlined from the results which the respondents agreed are paramount to the used of bamboo in Building construction.

Table 5.1: Conclusion on Barriers to the use of bamboo in building construction

	Contractors	Architects
Temporary Uses		
1	Architects (consultants) do not specify them for building projects	lack of knowledge in bamboo detailing
2	Insufficient cooperation from government	Limited knowledge of bamboo and lack of expertise to use it
3	Less durable if not treated for permanent use	Insufficient cooperation from government
4	Poor processing techniques	Less durable if not treated for permanent use
5	lack of knowledge in bamboo detailing	Poor processing techniques
Permanent Uses		
1	Architects (consultants) do not specify them for building projects	lack of knowledge in bamboo detailing
2	Insufficient cooperation from government	Limited knowledge of bamboo and lack of expertise to use it
3	Lack of bamboo processing companies in Ghana	lack of bamboo processing companies in Ghana
4	Problem of social acceptability (bamboo is considered for the poor)	Less durable if not treated for permanent use
5	Limited knowledge of bamboo and lack of expertise to use it	Competition with other building materials

5.1.3 Trend of bamboo usage with regard to volumes

The results of the research show that, generally, over the past ten (10) years, the different areas of bamboo usage in building construction has not seen any increase with respect to the volumes of usage except in the areas of props for temporary use and landscape for permanent use. Respondents agreed that the above mentioned areas are the only two which have gained popularity in building construction.

5.3 RECOMMENDATION

At the end of the study, the researcher found out that, indeed, bamboo as a material in the building construction has a lot of potential but has not been exploited. Hence, it needs the involvement of the various stakeholder related to bamboo in construction to spearhead the potential into feasible uses. As a result of this, some specific recommendations were made to help in the promotion of bamboo in building construction:

- The government should give the needed support to the bamboo sector in Ghana to promote the extension of it areas of attention further to the construction industry. Industries which will treat and produce bamboo products for use in building construction should be established.
- Established institutions in the building construction industry such as Department of Building Technology, KNUST, Department of Architecture, KNUST, The building and road Research Institute (BRRI) and some Non Governmental Organisations (NGOs) could be funded to organise training programmes and workshops towards the promotion of the use of bamboo and itS potential in building construction.
- Architects should consider bamboo as a primary material in their specification for building designs and during construction.
- Promotion of bamboo usage in less used areas in building construction should be giving the needed hype to create the awareness of its potential as a building material.
- Research into bamboo in construction should be encouraged in building construction institutions to enhance basic promotion of the potential of bamboo.

5.4 FUTURE RESEARCH

The following are some areas suggested for future research:

- Extend the research to identify cost benefit analysis of bamboo and other building materials in specific areas of application in Ghana.
- The research covered building contractors in the Ashanti region. There is the need to repeat the research for other contractors in the other nine regions in Ghana.
- Studies into specific details in bamboo construction.

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APPENDIX A: SURVEY QUESTIONNAIRE

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF ARCHITECTURE AND PLANNING

DEPARTMENT OF BUILDING TECHNOLOGY

QUESTIONNAIRE

TOPIC: THE POTENTIAL OF BAMBOO AS A MATERIAL IN BUILDING CONSTRUCTION IN GHANA

A. BACKGROUND TO CONSTRUCTION FIRM

1. Tick [√] to indicate how long your firm has been in the building construction industry`

a. 1 – 5 years [ ]
b. 5 – 10 years [ ]
c. 11 – 15 years [ ]
d. 16 – 20 years [ ]
e. 21 years and above [ ]

B. USES OF BAMBOO OR BAMBOO PRODUCTS IN BUILDING CONSTRUCTION

1. Indicate if you have used bamboo for any purpose as a material for building construction.

Yes [ ] No [ ]

2. Please tick [√] to indicate how often you use bamboo in your building construction.

Not often [ ] less often [ ] Quiet often [ ]

Often [ ] very often [ ]

3. Rank on a likert scale of 1-5 which of these areas bamboo is used in your building construction activities.

Not used = 1 **Less used = 2** **Neutral = 3**

Used = 4 **Highly used = 5**

USES					
	Not used (1)	**Less used (2)**	**Neutral (3)**	**Used (4)**	**Highly used (5)**
Temporary use					
1. props	[ ]	[ ]	[ ]	[ ]	[ ]
2. scaffolding	[ ]	[ ]	[ ]	[ ]	[ ]
3. Workers shed	[ ]	[ ]	[ ]	[ ]	[ ]
4. ladder	[ ]	[ ]	[ ]	[ ]	[ ]
5. formwork	[ ]	[ ]	[ ]	[ ]	[ ]
6. Hoarding	[ ]	[ ]	[ ]	[ ]	[ ]
Others (Specify) 7..... 8..... 9..... 10.....	[ ] [ ] [ ] [ ]	[ ] [ ] [ ] [ ]	[ ] [ ] [ ] [ ]	[ ] [ ] [ ] [ ]	[ ] [ ] [ ] [ ]
Permanent use					
1. Bamboo Reinforcement	[ ]	[ ]	[ ]	[ ]	[ ]
2. Trusses	[ ]	[ ]	[ ]	[ ]	[ ]
3. Ceiling	[ ]	[ ]	[ ]	[ ]	[ ]
4. Doors and windows	[ ]	[ ]	[ ]	[ ]	[ ]
5. Roofing	[ ]	[ ]	[ ]	[ ]	[ ]
6. bamboo floor	[ ]	[ ]	[ ]	[ ]	[ ]
7. Partition walls	[ ]	[ ]	[ ]	[ ]	[ ]
8. Landscape	[ ]	[ ]	[ ]	[ ]	[ ]

C. FACTORS INFLUENCING THE CHOICE OF BAMBOO OR ANY BAMBOO PRODUCT FOR BUILDING CONSTRUCTION PROJECTS

1. Rank on a likert scale of 1-5 your level of agreement to the extent to which the following factors influence your decision to use bamboo **temporarily** in building construction.

Strongly Agree = 5 **Agree = 4** **Neutral = 3**

Disagree = 2 **Strongly disagree = 1**

FACTORS	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
	5	4	3	2	1
1. Bamboo is readily available	[ ]	[ ]	[ ]	[ ]	[ ]
2. Bamboo is cheaper to use	[ ]	[ ]	[ ]	[ ]	[ ]
3. shortage of timber supply to the local market	[ ]	[ ]	[ ]	[ ]	[ ]
4. Bamboo is Easy to erect	[ ]	[ ]	[ ]	[ ]	[ ]
5. Bamboo is durable	[ ]	[ ]	[ ]	[ ]	[ ]
6. bamboo can be reused	[ ]	[ ]	[ ]	[ ]	[ ]
7. Bamboo is easy to use in its natural state with less processes go through	[ ]	[ ]	[ ]	[ ]	[ ]
8. It is a very good material for a sustainable building construction	[ ]	[ ]	[ ]	[ ]	[ ]
9. Easy to obtain in any quantity required	[ ]	[ ]	[ ]	[ ]	[ ]
10. Low technical requirements in its application	[ ]	[ ]	[ ]	[ ]	[ ]
11. bamboo does not break easily	[ ]	[ ]	[ ]	[ ]	[ ]
12. bamboo has multiple uses in building construction	[ ]	[ ]	[ ]	[ ]	[ ]
Specify others:					
13.	[ ]	[ ]	[ ]	[ ]	[ ]
14. .	[ ]	[ ]	[ ]	[ ]	[ ]
15. .	[ ]	[ ]	[ ]	[ ]	[ ]

2. Rank on a likcrt scalc of 1-5 your lcvcl of agrccmcnt to thc cxtcnt to which the following factors influence your decision to use bamboo **permanently** in building construction.

Strongly Agree = 5 **Agree = 4** **Neutral = 3**

Disagree = 2 **Strongly disagree = 1**

FACTORS	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Bamboo is readily available	[ ]	[ ]	[ ]	[ ]	[ ]
2. Bamboo is cheaper to use	[ ]	[ ]	[ ]	[ ]	[ ]
3. Bamboo is Easy to erect	[ ]	[ ]	[ ]	[ ]	[ ]
4. Bamboo has very good constructional properties	[ ]	[ ]	[ ]	[ ]	[ ]
5. Bamboo is easy to use in its natural state with less processes go through	[ ]	[ ]	[ ]	[ ]	[ ]
6. Bamboo is durable	[ ]	[ ]	[ ]	[ ]	[ ]
7. Easy to obtain in any quantity rcquircd	[ ]	[ ]	[ ]	[ ]	[ ]
8. Very beautiful in its appearance	[ ]	[ ]	[ ]	[ ]	[ ]
9. rcsistancc to pcsts and fungi attack due to preservation and treatment	[ ]	[ ]	[ ]	[ ]	[ ]
10. shortagc of timbcr supply to the local market	[ ]	[ ]	[ ]	[ ]	[ ]
11. bamboo can be reused	[ ]	[ ]	[ ]	[ ]	[ ]
12. It is a very good material for a sustainable building construction	[ ]	[ ]	[ ]	[ ]	[ ]
specify others					
13.	[ ]	[ ]	[ ]	[ ]	[ ]
14.	[ ]	[ ]	[ ]	[ ]	[ ]
15.	[ ]	[ ]	[ ]	[ ]	[ ]
16.	[ ]	[ ]	[ ]	[ ]	[ ]

3. Plcasc idcntify by ticking (in thc scalc of strongly agrcc to strongly disagrcc) how thc following factors dctcr you from using bamboo as a matcrial in building construction.

Strongly Agree = 5 **Agree = 4** **Neutral = 3**

Disagree = 2 **Strongly disagree = 1**

a. Temporary use

FACTORS	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Problem of social acceptability (bamboo is considered for the poor)	[ ]	[ ]	[ ]	[ ]	[ ]
2. Limited knowledge of bamboo and lack of expertise to use it	[ ]	[ ]	[ ]	[ ]	[ ]
3. Competition with other building materials	[ ]	[ ]	[ ]	[ ]	[ ]
4. Architects (consultants) do not specify them for building projects	[ ]	[ ]	[ ]	[ ]	[ ]
5. Poor proccssing tcchniqucs	[ ]	[ ]	[ ]	[ ]	[ ]
6. Highly susceptible to fire	[ ]	[ ]	[ ]	[ ]	[ ]
7. Less durable if not treated for pcrmancnt usc	[ ]	[ ]	[ ]	[ ]	[ ]
8. Insufficient cooperation from government	[ ]	[ ]	[ ]	[ ]	[ ]
9. lack of knowledge in bamboo detailing	[ ]	[ ]	[ ]	[ ]	[ ]
10. Difficult in controlling thc quality of bamboo because of different species	[ ]	[ ]	[ ]	[ ]	[ ]
11. Irregular shape of bamboo culms makcs it difficult to work with as compared to timber	[ ]	[ ]	[ ]	[ ]	[ ]
specify others					
12.	[ ]	[ ]	[ ]	[ ]	[ ]
13.	[ ]	[ ]	[ ]	[ ]	[ ]
14.	[ ]	[ ]	[ ]	[ ]	[ ]

b. Permanent use

FACTORS	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
1. Problem of social acceptability (bamboo is considered for the poor)	[ ]	[ ]	[ ]	[ ]	[ ]
2. Limited knowledge of bamboo and lack of expertise to use it	[ ]	[ ]	[ ]	[ ]	[ ]
3. Competition with other building materials	[ ]	[ ]	[ ]	[ ]	[ ]
4. Architects (consultants) do not specify them for building projects	[ ]	[ ]	[ ]	[ ]	[ ]
5. Less durable if not treated for permanent use	[ ]	[ ]	[ ]	[ ]	[ ]
6. Highly susceptible to fire	[ ]	[ ]	[ ]	[ ]	[ ]
7. Insufficient cooperation from government	[ ]	[ ]	[ ]	[ ]	[ ]
8. Treated bamboo is expensive	[ ]	[ ]	[ ]	[ ]	[ ]
9. Not readily available	[ ]	[ ]	[ ]	[ ]	[ ]
10. Lack of management skill in the use of bamboo	[ ]	[ ]	[ ]	[ ]	[ ]
11. Poor processing techniques in Ghana	[ ]	[ ]	[ ]	[ ]	[ ]
12. lack of knowledge in bamboo detailing	[ ]	[ ]	[ ]	[ ]	[ ]
13. lack of bamboo proccssing companies in Ghana	[ ]	[ ]	[ ]	[ ]	[ ]
specify others					
14.	[ ]	[ ]	[ ]	[ ]	[ ]
15.	[ ]	[ ]	[ ]	[ ]	[ ]
16.	[ ]	[ ]	[ ]	[ ]	[ ]
17.	[ ]	[ ]	[ ]	[ ]	[ ]

D. TRENDS OF BAMBOO USAGE WITH RESPECT TO THE VOLUMES

1. Please indicate by ticking the volume (number of culms) of bamboo you averagely use temporarily for building project.

a. Below 100 culms [ ]
b. 100 -200 culms [ ]
c. 201-300 culms [ ]
d. 301-400 culms [ ]
e. 401 - 500 culms [ ]
f. Above 500 culms [ ]

2. Please indicate by ticking how you would classify the trend of bamboo usage with respect to volumes in building construction over the past ten (10) years. (In a scope of highly increased to highly decrease only indicate the areas you have used bamboo)

AREAS	SCOPE				
	Highly increased	Increased	stable	Decreased	Highly decrease
Temporary					
1. props	[ ]	[ ]	[ ]	[ ]	[ ]
2. scaffolding	[ ]	[ ]	[ ]	[ ]	[ ]
3. Workers shed	[ ]	[ ]	[ ]	[ ]	[ ]
4. ladder	[ ]	[ ]	[ ]	[ ]	[ ]
5. formwork	[ ]	[ ]	[ ]	[ ]	[ ]
6. hoarding	[ ]	[ ]	[ ]	[ ]	[ ]
Others (Specify) 7.....	[ ]	[ ]	[ ]	[ ]	[ ]
8.....	[ ]	[ ]	[ ]	[ ]	[ ]
9.....	[ ]	[ ]	[ ]	[ ]	[ ]
10.....	[ ]	[ ]	[ ]	[ ]	[ ]

Permanent					
1. Bamboo Rcinforccmcnt	[ ]	[ ]	[ ]	[ ]	[ ]
2. Trusses	[ ]	[ ]	[ ]	[ ]	[ ]
3. Ceiling	[ ]	[ ]	[ ]	[ ]	[ ]
4. Doors and windows	[ ]	[ ]	[ ]	[ ]	[ ]
5. Roofing	[ ]	[ ]	[ ]	[ ]	[ ]
6. bamboo floor	[ ]	[ ]	[ ]	[ ]	[ ]
7. Partition walls	[ ]	[ ]	[ ]	[ ]	[ ]
8 Landscape	[ ]	[ ]	[ ]	[ ]	[ ]
Others (Specify)					
9.....	[ ]	[ ]	[ ]	[ ]	[ ]
10.....	[ ]	[ ]	[ ]	[ ]	[ ]
11.....	[ ]	[ ]	[ ]	[ ]	[ ]