**UNIVERSITY OF EDUCATION, WINNEBA**

**COLLEGE OF TECHNOLOGY EDUCATION**

**FACULTY OF TECHNICAL EDUCATION**

# SUSTAINABLE AFFORDABLE HOUSING DELIVERY IN GHANA: FOCUSING ON APPROPRIATE DESIGN AND TECHNOLOGY

**A DESSERTATION IN THE DEGREE OF WOOD SCIENCE AND CONSTRUCTION TECHNOLOGY, FACULTY OF TECHNICAL EDUCATION, SUBMITTED TO THE SCHOOL OF GRADUATE STUDIES, UNIVERSITY OF EDUCATION, WINNEBA IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MASTER OF PHILOSOPHY IN CONSTRUCTION TECHNOLOGY**

**BY**

**EMMANUEL TEKPE**

**(8171760021)**

**MPHIL CONSTRUCTION TECHNOLOGY**

**ACKNOWLEDGMENT**

First I would like to thank God Almighty for His grace and mercies throughout my studies. It is by His mighty hand held of me, wisdom and protection upon my life, I have been able to reach this far, all I have to say is that he will continue to be my God, creator and King.

I would also like to give my sincere thanks to my supervisor Dr. William Gyadu Asiedu, a lecturer at university of Education Winneba for his greatest support toward my project, aside all his busy schedules.

I also extend my gratitude to all my course lecturers for their supports and directions. My appreciation also goes to Mr. Samuel K. Ansah a lecturer and HOD of the Building Department of Cape Coast Polytechnic my mentor who always inspired me and had supported me both financially and in all aspect, which has contributed much success to my education and my life.

Much gratitude also to my friends on campus Frank Ackon, Benjamin Harrison, Simon Ofori Ameterpey, Elisha Badu for their supports.

I want to acknowledge the support and prayers of my precious family especially to my parents Mr. and Mrs. Tawiah, and my siblings Georgina Obeng, Christina Obeng, Janet Tawiah, Prince Tetteh, Benjamin Larwah, John Kwame Tei and Abraham Narh.

## DEDICATION

This research work is dedicated to my Heavenly father, my Lord and saviour Jesus Christ and the Holy Spirit.

I also dedicate it to my dear Parents Mr. and Mrs. Tawiah, and my siblings, not forgotten my senior brother, in the person of David Lartey.

Much thanks also goes to Mr. Samuel K. Ansah and His family, I appreciate all your support toward both my life and education, May the Lord richly bless you and protect you.

I dedicate this work to all my friends, especially Helena Narh, Helena Ama Eshun, Antoinette Y. B. Gabrah, Michael Awuah, and John Nketsiah. David Amanor and Comfort Thompson.

My final dedication goes to my friends on campus Simon Ofori Ameterpey, Frank Ackon, Elisha Badu, and Benjamin Harrison for their supports toward my work, may the Lord richly bless you.

## ABSTRACT

Housing undoubtedly remains one of the essential needs of man among food and clothing from creation. From the Paleolithic era, interventions for housing delivery have been a challenge and still remain unresolved and fallen short in demand in the world, especially in the developing countries like Ghana. From pre- and post- independence several interventions and researched has been done by many researchers to resolve the housing provision challenges that existed in the country, nevertheless this seemly solutions to resolve the housing challenges in the country does not tackle the issues of home or domestic grown solutions. Furthermore, these solutions had in fact culminated into severe negative impacts and catastrophes on the environment and economic life of people, because these interventions and solutions are not domestic based solutions to support housing sustainability and are therefore not affordable to the average income earners to afford. To address the issues of affordability is therefore a necessary condition towards housing sustainability. Yet housing affordability is not enough, because the so-called affordable houses cannot be considered sustainable if they create negative impacts on the environment, or on the social life, hence the need to marry housing affordability with sustainability, and provides sure solutions for their implementation.

This study presents the major factors or challenges to sustainable and affordable housing delivery in Ghana, it‟s also seeks to find the local available building materials that are potentials for sustainable affordable housing in Ghana. It finally attempt to presents the innovative solutions to resolve housing challenges through the questionnaire survey, interviews and observation such as appropriate technologies (Hydrafoam, Local Modular and efficient Eco-affordable, Adobe bricks, I-section floor beams-trassacco

floors, Compressed earth, Rammed earth technologies etc.), local materials (Clay pozzolana cement, Clay bricks, Unburnt clay bricks, Bamboo, Stones, Wood, Land crete blocks, Laterite, thatch etc.) and good designs qualities to achieved appropriate or alternative designs for sustainable housing and development in Ghana (Designs that must always be economical and socially sustainable, Must based on locally or community strategies, Must uses renewable resources, Must encourage cyclic construction process instead linear construction processes, Must encourage conservation of scarce materials, Must encourage the uses smaller but portable designs, Must encourage the use of solar energy systems, Must encourage the renovation of old buildings etc.). Descriptive statistics such as frequencies, percentages, mean and tables presentations was used to summarize information or results from respondents.

Principal Component Analysis (PCA) was also adopted to establish the major problems associated with the existing housing delivery schemes in Ghana, and good housing designs qualities for the achievement of sustainable affordable housing in Ghana. The Analysis of variance one way ANOVA was used to establish the relationships between construction firms in Ghana and their designs, technologies, and materials adopted for construction of housing and relationships of respondents and their awareness on the housing sustainability and affordable in Ghana to promote sustainable development.

# TABLE OF CONTENT

**CHAPTER TWO**

**CHAPTER FOUR**

**DATA PRESENTATION AND ANALYSIS**

**CHAPTER FIVE**

**DISCUSSIONS OF RESULTS**

**CHAPTER SIX**

**SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS**

# LIST OF TABLE

# LIST OF FIGURE

**CONTENT** **PAGES**

# CHAPTER ONE

## 1.1 Background of the Study

Housing undoubtedly remains one of the essential needs of man among food and cloth from creation (Kwofie, Adinyira and Botchway, 2011). It‟s the basic needs of mankind, a pre-requisite to survivals of man (Onibokan, 1983: UN, 1992). From the Paleolithic era, interventions have taken the forms of caves, make shift tents nomadic artifacts, traditional mud houses, wooden house etc.

Despite the universally acknowledged, fact that housing is necessary for the physical and social well-being of mankind, its provision, accessibility, affordability and sustainability remains a seemly insurmountable problem for the nations in Africa and remains the most in short supply or deprived to demand in many countries in the world (Werna, 1998). In Ghana the rate of housing delivery has been erratic and often fallen short of the demand (Kwofie et al., 2011). This has culminated into several developmental problems such as high unaffordable rent, development of slums and ghettos and huge housing shortfall or deficits that will take sustained effort over long periods to correct (Kwofie et al., 2011).

The 2000 Ghana population and housing census reported the existence of about 3.88 million dwelling units in Ghana. In addition, 74,000 kiosks and containers housed several hundred thousand of people, and a large number of people in urban areas sleeps on pavements, walk ways and on streets due to lack of accommodation to house them. The report added that Ghana has 3.7 million households and growing at 2 percent and is expected to reach 6 million by 2025. That is 2.3 million new households will be

generated, each expected to be sheltered in a housing unit. The home finance company limited (HFC – now HFC Bank Ltd) also estimated in 2002, that the country had an estimated unsatisfied housing need of 1,232,835 units with an estimated new annual demand of 133,000 units. However, only 25,000 units are produced annually leaving an unsatisfied annual demand of 108,000 units. More than 52% of houses in Ghana accommodate between two (2) and four (4) households (Ghana Statistical service, 2002). Most household are unable to consume housing with adequate standards, good environmental factors, and also meet other basic necessities of life (Boamah, 2010).

Statistics show that the country"s housing deficit is projected to be around 1.2 million house-units as against an annual purported delivery of 37,000 house units which is dominated by individual self-house projects (Amoa-Mensah, 2003). The records and statistics of housing statistics in Ghana confirm that the country has huge housing deficit and therefore need to make provision for adequate housing, to enhance its economic development pursuits and facilitate its dreams of becoming middle in-come state. The delivery of housing in the country has witness many challenges such as the interest rates, income levels, and construction cost, land supply, cost of materials, materials availability, and housing prices. The problems are many and they are all interwoven. One of the biggest problems low income households face today is finding affordable cost of housing, the type of materials to be used and design and technology type to be incorporated.

In spite of the many factors affecting housing delivery, provision of houses in the country should not be of substandard in terms of quantity, quality, cost effective and adequate size. Houses should be affordable and sustainable in order to support

sustainable development irrespective of building forms, location and the materials used for its construction (Ebsen and Rambol, 2000).

Sustainable affordable housing is therefore a form of housing that incorporates environmentally friendly and community based practices (construct with locally based materials and technology). It attempts to give hope to the future or the unborn generation by attempting to reduce the negative impacts that homes can have on the environment through choosing better building materials, environmental friendly or sustainable designs and appropriate technologies. Housing that is cheaper to construct by low income group of people and it also poses less negative impacts on the environments (Gilkinson, 2010). Sustainable affordable housing originates from the concept of sustainable development. It is generally used to describe the application of sustainable development to the construction industry or the built environment. Sustainable affordable housing therefore, could be best described as a subset of sustainable development, which encircles matters such as tendering, site planning and organization, materials acquisition, selection and usage, recycling, and waste minimization (Ding , 2001).

Technology on the other hand, is the tools, instruments, knowledge and culture to enhance human ability to shape nature and solve problems (Vergragt, 2010). According to Hard and Jamison, (2005) culture and technology, has permeated society to such an extent that separation between technology and culture is no longer meaningful. Thus all human activities, like housing, nutrition, transportation, work, leisure, even art and imagination, become heavily entangled with technology. However, technology, since its inception especially science-based technology, has offered the promise of a better world through the elimination of disease and material improvements to standards of living. On

the other hand, resource extraction, emissions of dangerous materials, and pollution of air, water, and soil have created conditions for unprecedented environmental catastrophe and have already caused irreversible damage to the biosphere. While the future might promise a vast acceleration of technological innovation, the scale and impact of environmental degradation may reflect this vast acceleration as well. A related painful paradox is that, despite the ongoing technological revolution, the majority of the world population still lives in hopeless poverty with inadequate food, housing, and energy, plagued by illnesses that could be easily cured if clean water and simple drugs were made available (Vergragt, 2006). Hence the need for appropriate technology, the technologies that is simple and appropriate with little or no impacts on the environments on the entire earth, but support all matters of sustainable development, which give hope to both present and future generations.

The benefit of focusing on sustainable design and appropriate technology for affordable housing to every nation is extremely massive as it provides shelter for sleep, serve as a shield against elements of the weather and other hazards, it affects efficiency and stability of a whole economy and financial markets and hence has a sufficient impact on the productivity and growth of all nations. However for the benefit of this basic good to be attained by any country, it needs to be affordable by many households. But, this is not the case in Ghana. Ghana‟s housing delivery and access to decent accommodation in any part of the country is at a crises level (Agyemang, 2001).

Since Ghana‟s independence, numerous initiatives have been pursued by succeeding governments to resolve the housing deficit but these interventions have failed to make a dent in Ghana‟s growing housing crisis. It is however not for lack of effort on

the part of successive governments to address the problem of housing shortages. A critical analysis of the situation from pre- independence to date poses that Ghana‟s housing deficit is a problem which is spawned and fuelled by host of factors notably, ever increasing cost of building materials, rapid population growth, urbanization, deterioration of fabric of existing structures, absence sustainable affordable housing delivery policy framework and poor managerial system (Kwofie et al 2011).

There has been many researched done by many scholars also to investigate into how people can build low, but quality and affordable housing as their shelter.

Nevertheless, priority and efforts have not been placed upon sustainable affordable housing delivery, which are houses of low cost and are environmentally friendly and built with local available building materials. Furthermore, the use of alternate designs such as sustainable design, and appropriate technologies in providing houses in other jurisdictions has not been considered as a way to reducing the housing crisis in Ghana. Houses constructed of local or traditional materials and with appropriate technologies are affordable and sustainable in Ghana but are rather unpopular and faced with challenges such as its durability, aesthetics, strength and quality because not much research has be done to improve it.

**1.2 Problem Statement**

A full supply of proper decent sustainable and affordable housing for low/average – income people is still an unresolved issue in many notable cities throughout the world (Werna, 1998).

Furthermore, the pressure on the increasing demand of housing and it associated cost and materials have become a challenge and problem to authorities, beneficiaries/users, suppliers, engineers, contractors and nature (source). This means there is the need to be much more focus on using appropriate technologies and alternative designs in resolving Ghana‟s housing crises to some extent.

Various governments and the private sector in Ghana have on a number of times constructed affordable houses for the public. However, the cost of these affordable houses does not make it affordable for the low income earner or the average Ghanaian. These seeming affordable houses end up being purchased and owned by the higher income earners, because it is not affordable to the low in-come earners as claimed. Hence, the need to derive some means, of providing housing for the low income earners, other than the use of the existing approaches, which also do not support sustainable development in Ghana. With the ever increasing cost of building materials, there is the need to identify alternative building materials which are less expensive and also alternative engineering designs and appropriate technologies which will reduce the cost of the building drastically. Findings show that up to 60 % of the total cost of a low-income house is allocated to engineering design and construction materials (Ballerino, 2002). A lot of savings can be made every step of the way when houses are built small and incorporate appropriate technologies, initial building costs are lower, and home owners save money on operations and long-term maintenance (Abdul, 2011).

The use of local natural building materials is a key part of affordable housing and sustainable development. According to Kwofie et al. (2011), before Ghana‟s contacts with the European and influence of capitalism, building in Ghana was predominantly

locally based materials in the form of thatch, mud, wood, earth, bamboo and bricks. Currently about half of total dwellings in Ghana are constructed with local or traditional materials such as Mud bricks, earth, thatched roof, bamboo etc (2000 population and censuses).

Instead of transporting materials from hundreds of thousands of miles away, it is far better to improve and utilize what is at hand or home. It is significance to note that in most African countries popular materials for construction of houses are imported from outside Africa with high transportation cost, high embodied energy, not environmentally friendly and also inadequate supply (Atiemo, 2009). According to Boadi et al., (2009) cement and its related products and materials alone constitute about 60% of total cost of construction and the average increases in the price of cement between 2005 and 2008 was 140%. The use of local available materials or improving them, and adapting sustainable designs, and appropriate technologies for construction of houses can promote sustainable affordable housing, better quality of building structures, faster construction solutions and foster economic development as against those materials that are imported from elsewhere into the country for construction.

There are numerous local building materials available in Ghana. Also, minimally processed, low– embodied energy natural building materials are locally available. Examples are clay pozzolana cement, clay bricks, landcrete blocks and stabilized mud that already exist. However, most construction activities are still undertaken with mostly imported materials and for that matter expensive material. The challenge is to mainstream the use of local materials, and make them more acceptable either through legislation like other countries has done and intensive education and extension (Abdul, 2011).

There are numerous researches on affordable housing by many researchers across the world (Berry, 2006; Burke, et al 2007; Wendell, 2005; Yates and Gabriel, 2006; Yates et al 2007; Lloyd-Sherlock, 2000; Witehead, 2006). These studies were generally addressing one of the housing affordability, issues such as fiscal / economic implications, housing finance, problems of housing, which has an affordability problem policy, planning etc. However, there are few studies that have specifically tried to find solutions with sustainable affordable housing to low income earners or the average people. Unfortunately, some of the solutions proposed by these researchers have been implemented but the problem of sustainable affordable and adequate housing still lingers on. This is because there is not much research that concentrates on sustainable affordable housing which focuses on using local available building materials, alternative designs and appropriate technologies to address the issue of housing affordability and sustainability.

Hence, the main focus of this research is to investigate into the various housing delivery schemes and exploring an innovative solution for sustainable affordable housing in Ghana through the use of appropriate design technology and locally based building materials.

**Table 1:1 Housing Deficit from 1980s -2010.**

| YEAR | DEFICIT | DELIVERY | % OF DELIVERY | NEED |
|---|---|---|---|---|
| 1980'S | 250,000 | 70,000 | **22%** | **133.000** |
| 1998 | 300,000 | 30,000 | **25%** | **140,000** |
| 2000 | 700,000 | **25,000-30,000** | **21%** | **199,000** |
| 2008 | 1,000,000 | **37,000** | **22%** | **150,000** |
| 2010 | 1,200,000 | **199,000** | **23%** | **300,000** |

**Source: Kwofie et al, (2011) Literature.**

### 1.3 Aim and Objectives of the study

The main aims of this research is to investigate into the various housing delivery schemes in Ghana, as a measure of exploring an innovative solution for sustainable affordable housing in Ghana through the use of appropriate design, technology and locally based building materials, and to develop a framework guide to improve the existing linear construction process for the implementation of cyclic construction processes to support the achievement of sustainable affordable housing and development in Ghana.

### 1.4 Objectives of the Study

The specific objectives that will help achieve the aim of the research are:

1. To identify the various housing delivery schemes in Ghana.
2. To identify the major problems associated with it and how it‟s preventing the achievement of sustainable affordable housing delivery in Ghana.
3. To identify the most appropriate designs and technologies for achieving the goal of sustainable affordable housing delivery in Ghana.
4. To formulate framework guide for implementing cyclic construction process for sustainable affordable housing delivery in Ghana, and recommendations on how to use most appropriate technologies and designs for sustainable affordable housing for low- income earners in Ghana.

## 1.5 Research Questions

1. What are the existing housing delivery schemes in Ghana?

2. What are the main problems with it?

3. What are the most appropriate designs and technologies for sustainable affordable housing in Ghana?

4. How can sustainable affordable housing delivery be achieved through a framework guide and by the use of most appropriate technologies and designs?

## 1.6 Significances of Study

The importance of conducting this research therefore, are to promote the construction of sustainable affordable housing in Ghana, through the use of local available building materials, the adoption of alternative designs and appropriate technologies, houses which will be cost effective for every Ghanaian. Affordable housing (low- income) housing is a basic need for mankind, and a basic human right. It is fundamental to human dignity, physical and mental health and overall quality of life. It provides shelter for sleep, serve as a shield against element of the weather and other environmental hazards, it affects efficiency and financial markets and hence has a sufficient impact on the productivity and growth of all nations. The benefits of housing for low- income earners for developing country are extremely massive as it has impacts on the economic, socio-cultural and political life of people.

Housing that is affordable and sustainable is cardinal to all households and the economic development pursuits of nations. Promoting and provision of adequate and

affordable housing to Ghanaians or to the world at large is moral and economic imperative and development. Hence the need to research into this topic to alleviate the housing challenges, to benefit the average people. The research will also be used to fill academic gaps, by reducing the huge housing deficits, assisting low-income earners in Ghana afford to build houses, and to help Ghanaians developed taste for the use of local available building materials for construction of houses, to support sustainable development to benefits future generations and to formulate framework policies to governments and stakeholders to overcome the challenges on provision of sustainable affordable housing for Ghanaians. This research when undertaken successfully will serve as a guide and an informative document that can be used by all to reduce the cost of housing, drastically for all Ghanaians.

**1.7 Research Scope**

In terms of geographical coverage, this research will centre on only Ghana and will again be on construction industry firms and their professionals, and private institutions in Ghana. In order to achieve the objectives of the research, the researcher deems it necessary to select population for the study on members of construction industry of Ghana. Thus building professionals such as architects, structural engineers and Quantity Surveyors. The primary role and business of the building professionals are to conceive Administrate, supervise and execute housing for the general public as shelter and as habitat for mankind, hence the reason for their selecting. Some public institutions in Ghana will also include the Ghana Building and Road Research Institute (BRRI-Ghana) and Habitat- Ghana. Due to the nature of their works.

There are 171 registered numbered of architect as it stand now (Registered General –Ghana, 2014). Also there are 75 Quantity Surveyors and only 5 registered Structural Engineers firms in Ghana, of which over 90% of these firms and professionals are registered and operate in the Accra, Kumasi and some few reside at Takoradi, Tema, and Koforidua. Given the relatively significant size of the membership in the other regions of the country, the survey was conducted in the entire nation (Registered General – Ghana, 2014).

The research was undertaken throughout the country, thus Ghana at large to capture the needed data and information for the research under study.

The study area was chosen because the researcher wants the findings to be implemented and benefits of entire country. And also wants to study the housing challenges in the country holistically not in fragmented to reduce the housing deficit to some extent.

**1.8 Outline of Methodology**

This research use mixed method approach, spanning on five processes. In the early stage preliminary process was conducted an extensive review on the subject matter of the study was also undertaken. The literature review covered the housing delivery schemes that existed in Ghana, the major challenges associated with it, sustainable construction, and development, and designs to achieve sustainable affordable housing for average Ghanaians. Good housing qualities to be adopted, existing construction process, technologies and local available natural material to be improved and adopted for sustainable housing delivery in Ghana. Based on the literature review, a standardized questionnaire was developed to collect data from members of Ghana construction

industry thus construction or consultancy firms about their effort and perception on housing delivery in Ghana especially the constructions of sustainable affordable housing for low-income earners in Ghana. The targeted respondents were Architects, Quantity Surveyors and Structural Engineers that are registered and of good standing. A total of 156 constructions consultancy firms (respondents) were targeted to respond to a set of close – ended questionnaires.

The third process, qualitative approach was also adopted to collect adequate information for the study. Interview Guide and observation guide was used under this approach to secure data by setting structured interviews questions to be responded by selected firms, and personal observation was conducted to selected site to observed the construction processes of housing in Ghana.

The fourth process was data analysis. The data were analyzed using statistical package for social scientist (SPSS 16). Descriptive tables, Ranking, Factor Analysis and one way **Anova** statistics were employed.

Finally, the information which was obtained regarding the achievement of housing sustainability and affordability in Ghana, through the use of appropriate designs, technologies and materials and improvement of the existing construction processes, was use to develop framework guide for improving and implementation the existing linear construction processes for sustainable and affordable housing for average Ghanaian which is the aim of the research, and suggested also solutions for housing delivery challenges in Ghana. The methods employed are well detailed out in chapter three, four, and five of this thesis.

## 1.9 Organization of the Thesis

The thesis comprises of six chapters and these have been organized as following:

1. Chapter one deals with the background to the study, statement of the problem, aim and objectives of study, research questions, scope of research, significance of study, outline of methodology and organization of the research.
2. Chapter two address and gives an overview of the various housing delivery schemes in Ghana, the problems associated with the housing delivery schemes. The chapters also discuss into details the available appropriate technologies, designs and potential designs and technologies to achieve sustainable affordable housing for Ghanaians. Finally the chapter reviews the sustainable construction and development around the globe and its importance and how it could be achieved; and local available buildings materials that can be improved for decent housing to support sustainable development and offer homes that can be easily affordable by low-income earners as well as favors the future unborn generations in Ghana, and reviewed the existing linear construction processes and how to improve it.
3. Chapter three discusses the research methodology employed. The research methods described including the designs of the study, research instruments and methods for collecting data, sample and sampling techniques employed and data analysis and presentation.
4. Chapter four presents data analysis of the result on how to achieve housing sustainability and affordability for low-income earners in Ghana, and the need to improve on the existing construction framework guide to support effective

achievement of sustainable construction and development. From these discussion a proposed conceptual framework guide would be develop to improve and implement the achievement of sustainable affordable housing delivery in Ghana.

5. Chapter five discusses the results obtained and design of framework guide for implementation of cyclic construction processes for sustainable affordable housing delivery in Ghana was considered.
6. Finally, chapter six presents the summary, conclusions of the study and suggestions for implementation and for future studies in line of this research.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Introduction

This chapter gives general details and an overview of the various housing delivery schemes that existed in Ghana, and the problems associated with it delivery in Ghana. The chapter also discusses into details the available appropriate technologies, designs and potential designs and technologies to achieve sustainable and affordable housing to every Ghanaian, especially to the low – income earners group in Ghana. The chapter finally discusses sustainable developments around the globe and its importance, sustainable construction and how it can be achieved, affordable housing, sustainable designs and appropriate technologies and local available materials that can be improved for decent housing that can support sustainable development and offer homes that can be afforded by low-income earners as well as favours the future generations in Ghana.

## 2.2 Various Housing Delivery Schemes in Ghana

Housing schemes are plans, policies, developments and frame work for the provision of housing and organizing houses by government or individuals for the public or private purposes. This in Ghana can be mainly divided into two that is during the era of pre-independence and after post-independence housing scheme.

In Ghana, the foregoing reviews suggest a continuous effort by private individuals, the real estate sectors, and the public sector on ways and means to provide houses or shelter for the citizenry. This intervention for creations and provision of houses for Ghanaians started during pre and post-independence Ghana until now. According to

Agyemang (2001), all the housing schemes initiated by various governments from pre to post independence era failed due to a host of factors.

### 2.2.1 Pre-Independence Housing Schemes

Pre-independence witnessed the direct involvement of government in public housing.

The emphasis on developing the housing industry gained prominence in Ghana probably from the late 50s to the 60s as it attained independence from colonial rule (Bank of Ghana, 2007).

The housing interventions during the pre-independence era took the form of provision of houses likes

- **Staff bungalows for senior officers**
- **Staff quarters for teachers**

These houses were provided most by the colonial governments in many parts of the country especially in the regional capitals, towns and mining areas through direct funding by the colonial government (Agyemang, 2001). These housing schemes were provided only to their working class at that time, and no consideration was made for the average, poor and non-working class until 1920s and after the occurrence of the 1939 earthquake in Ghana (Agyemang, 2001). The then governor Sir Frederick Gordon Guggisberg of Gold Coast first recorded direct involvement in native housing was 1920s when **Dispossessed persons housing Scheme** was introduced to provide housing for the dispossessed as a result of government development programs such as road, rail way and housing construction. Under the scheme, which begun in 1923, affected persons were advanced with building materials loans to commence their own houses. This scheme can

be named **Dispossessed persons housing scheme** (Kwofie et al, 2011). From this time onwards, little attention was paid to housing until the 1939 earthquake.

On the 22nd June, 1939 Ghana experienced her first earthquake in the capital city called Accra, and due to the damages cause by earthquake, the then government called for direct intervention in the provision of affordable housing scheme for the affected population, by providing funds to build about 1250 bedroom unit houses at the affected areas like Osu, Mamprobi, Chorkor, North-West Korle Gonno, Kaneshie and Abbosey Okai. These housing units were completed and existed up to date being occupied by civil servants and the armed forces (BRRI, 1970). Therefore the name of this particular housing scheme can be call **affordable housing scheme to replace the affected ones.**

The Alan Burns government also introduced two housing schemes and policies as part of his four year developmental plan. The first was to implement the construction of inexpensive but well built houses, with much local building materials for the construction. This housing scheme can also be called **affordable housing scheme build with local materials** and this was to be built by the department of social welfare. Under the scheme 3, 2, and 1 bedroom dwellings were to be constructed and rented to all people at economic price.

The second housing scheme was termed and named **town and council housing** to be concentrated in Accra, Kumasi and Sekondi Takoradi. Under this scheme, a person could apply for financial assistance to build within the Municipal on his own designs, but both plans and contractors must be approved by Town Council (Agyemang, 2001). This event occurred within the years 1942 to 1947 when Gold Coast first political party was formed and called UGCC.

### 2.2.2 Post-independence housing delivery schemes

In the post-independence era also, several intervention were also undertaken but considered unsuccessful by experts and stakeholders. Under the reign of Dr Kwame Nkrumah, the first president of Ghana, three intervention or plans were formulated which aimed at provision of adequate housing to shelter majority of Ghanaians. The interventions by Dr Nkrumah to provide houses were:

The five year plan from 1951-1956 for the establishment of **Tema Development Corporation (TDC).** This plan led to the creation communities of Tema (Communities 1 to 8 contributing over 2255 units), and the **State Housing Corporation (SHC)** –under the Ministry of Works Housing.

The **Schockbeton Housing Scheme** was targeted to provide 168 houses in Accra, Kumasi, and Sekondi Takoradi. It was contracted to the then Dutch firm, and the scheme became expensive than estimated and was abandoned (Nelson and Ayeh, 2009).

After Dr Kwame Nkrumah the first president was over thrown all the military government that succeeded him continued with his plans and development on housing and added some quota to it through Dr Nkrumah initiative until PNDC/NDC era under J.J Rawlings.

Under the era of J.J Rawlings between 1979 to 2001, there was the implementation of many schemes in an attempt to solve the housing problems. These were:

- The National Housing Shelter Strategy (NSS)
- Ghana vision 2020 and the structural adjustment programme (SAP)
- Economic Recovery Programme (SAP/ERP) (Bank of Ghana, 2007).

The National Shelter Strategy was initiated in 1986 by forming a National Housing Policy Committee by the Ministry of Works and Housing (MOWH) to examine the housing situation in the country. The main focus of the committee was on the challenges of housing delivery and other contributing factors that undermined the provision of housing to the sector. The issues that the committee focuses on were land, building materials, housing finances, infrastructure, and management efforts toward housing delivery. This policy and strategy covered the period 1987 to 1990 (Agyemang, 2001; Bank of Ghana, 2007).

The Ghana Vision 2020 housing scheme had the First Medium-Term Development plan from 1997-2000 target the provision of low-income housing as reported by (Bank of Ghana, 2007); MOWH, 2001). It sought to bring housing within the domain of the poor to enhance their living standards. The plan introduced a new facility under the Social Security Scheme which permitted contributors to withdraw part of their contributions to purchase a house. Unfortunately, due to lack of funds, private sector participation, and political will by government, none of these housing strategies under this schemes were implemented( Bank of Ghana, 2007).

Structural Adjustment programmes (SAP) was establish between Ghana and of world bank and the IMF in order to secure much needed cash flows for the country inclusive of the housing construction industry. This was as a result of Ghana‟s financial crisis had peaked in the 1980s. This initiative required the country‟s participation in trade liberalization initiatives which opened its market to importation of building materials and necessitated the loosening of rent control (Benjamin, 2007). This challenge grew up and resulted in high cost of building materials, high cost of construction, high rent rates and

loosening the government‟s grip on the housing market. This also increased the creation of slums and ghettoes in many cities and urban areas due high cost of renting houses that time and lingered on to date ( Gyabaah, 2009).

During this times, thus from 1985 onward no considerable additions of public houses was made or provided until the year 2000 when the new government NPP sought to reduce the crisis situation of the housing sector through the initiation of about 20,000 NPP **affordable housing units** 2001 (Kwofie et al, 2011). In 2007 about 4,500 units out of the 20,000 was started at Borteyman and Kpone in Accra, Asokore Mampong in Kumasi Ashanti region, Tamale in Northern region, and Akwadum Koforidua in the eastern region, to be completed by June, 2009 (GOG, 2007). The main groups targeted by this scheme were the civil and public servants. Unfortunately not a single unit remains completed up to date and most have been taken over by squatters. This scheme was discontinued by the new NDC government in 2009 (Ahadzie et al, 2010; Nelson and Ayeh, 2009; Ayeh, 2011; Kwofie et al 2011).

The effort of Social Security and National Insurance Trust (SSNIT) for the provision of housing for Ghanaians cannot be overlooked. This interventions and program took placed within the 1980-1990. The initiative was to build mass housing scheme for its staff across the country. Though this was originally targeted at its staff, it was expanded in 1988 in a significant investment in housing at social and not market prices, providing a lower option for the general public. However, SSNIT could not attain its objective for the poor and low-income. The project benefited the middle and upper class (Benjamen, 2007). This was called **SSNIT mass housing scheme**.

SSNIT housing schemes built 1637 units at Sakumono, and extended the policies later to other parts of the country such as Anaji-Takoradi, Koforidua, Wa, Adenta-Accra, Kumasi etc (Amoa- units at a loss and that even its reduced rents were higher than what most Ghanaians could not attain afford. Today they have sold out almost more than 92% of its housing units (Kielson, 2010). The NDC two administrations which was led by late Prof John Evans Atta Mills also initiated to build about 200,000 affordable housing by some Korean Company but never materialize due to lack of fund raising internally and the failure on the agreement with the Korean company to finance

Aside the various housing schemes Ghana has ever had, there has been other ways and efforts through which Ghana‟s housing deficit or gap to facilitate its economic, social and political development.

This includes the following:

- Individuals self-help housing schemes
- Non -governmental organization housing schemes
- Private partnership housing delivery schemes
- Private housing delivery schemes(real estate developers)

Through self-Built housing finance such as Self accumulated income, Remittances from relatives and friends, Access to home loans from non-banking institutions (SHC, SSNIT etc), and Credit from Banks (Kwofie et al., 2011). The country housing schemes has no consistency in terms of delivery between those carried out before and after independence and aside majority was carried out in a fragmented manner, and due to the lack of clear cut plans and government efforts to make this schemes works effectively in eradication of the housing delivery challenges. This has resulted in the huge

housing deficit we face in the country today. Hence there is the to find out the home grown solutions through appropriate technologies, designs and with local materials.

**Table 2.1 Further details of the various housing schemes that has existed in Ghana**

| GOVERNMENT | VARIOUS HOUSING SCHEMES IN GHANA | PERIODS |
|---|---|---|
| During early colonial rules | Staff bungalows for senior officers | 1890-1919 |
| During early colonial rules | Staff quarters for teachers | 1890-1919 |
| During early colonial rules | Compound houses | 1890-1919 |
| Sir F. G. Guggisberg | Dispossessed persons housing scheme | 1919-1927 |
| Sir F. G. Guggisberg | Affordable housing scheme to replace the affected ones. | 1939-1942 |
| Sir Allan Burns | Affordable housing scheme build with local materials | 1942-1950 |
| Sir Allan Burns | Town and council housing | 1942-1950 |
| Dr Kwame Nkrumah | Tema Development Corporation (TDC). This plan led to the creation communities of Tema (Communities 1 to 8) | 1951-1966 |
| Dr Kwame Nkrumah | State Housing Corporation (SHC) – under ministry of works housing. | 1951-1966 |
| Dr Kwame Nkrumah | The Schockbeton Housing Scheme | 1951-1966 |
| J.J Rawlings through Quasi-Gov"t inst. | SSNIT mass housing scheme. | 1980-1990 |
| J.J Rawlings | The housing shelter strategy (NSS) | 1987-1990 |
| J. J Rawlings | Ghana vision 2020 and the structural adjustment programme (SAP) | 1997-2000 |
| J. J Rawlings | Economic Recovery Programme (SAP/ERP) (Bank of Ghana, 2007) | 1979-1980 |
| J. A. Kuffour | 20,000 NPP affordable housing units | 2001-2009 |

| | | |
|---|---|---|
| J E A Mills | 10 billion dollars XTS proposed affordable housing | 2009-2011 |
| Land lords | Individuals self-help housing schemes | When Ghana emerges |
| NGO | Non -governmental organization housing schemes | 1990s to date |
| Real estate developers | Private partnership housing delivery schemes | 1970s to date |
| Real estate developers | Private housing delivery schemes(real estate developers) | 1970s to date |

**S**ources: Authors compilation from several literatures

### 2.3 Problems Associated With The Various Housing Delivery Schemes In Ghana.

In reviewing the various literatures relevant to the topic under study, the following were found to be the major problems associated with the housing delivery schemes and also delivery of sustainable affordable housing in Ghana and in other part of the world especially with the developing countries. The problems are many and they are all interwoven. The main problems include the type of materials to be used, the design type and technology to be incorporated, the interest rates, income levels, and construction cost, land supply and acquisition, land litigation, materials availability, and housing prices, ever increasing cost of building materials, rapid population growth, urbanization, deterioration of fabric of existing structures, absence of sustainable affordable housing delivery policy framework, failure to championing the use and improving local building materials and poor managerial systems (Kwofie et al 2011).

The other challenges associated with the huge housing deficit include the following:

- Lack of good Governance and political will by various governments.

- Lack of Public Awareness on construction of sustainable affordable housing
- Public Perception
- Lack of Funding / inadequate funding
- Lack of Skills personnel"s
- Technology
- Failure to Plan
- Supply
- Safety
- Lack of strategies (Akanbi et al 2012).

**2.4 Sustainable development**

The awareness about sustainable development is growing around the globe for last few decades (The UN Summit on Environment and Development in 1972). The concerned for protecting the environment for the future generations is on the increase or growing wide (the UN Earth Summit in 1992).

In the ideal world, it is painted, there exists a society in which people everywhere live in peace and security, breathe fresh air, drink clean water and eat uncontaminated food. They have livelihoods that allow them to enjoy life, raising healthy, contented and educated children. They leave behind them a stock of wealth comprising man made and environmental assets for the next generation, no less than they inherited from the previous generation. The real world, however, is far from these ideals (Malik, 2002). There is a growing concern about the long-term future, the resources of the planet, the environment and high levels of poverty, which are linked with the spread of disease, social unrest, population growth and environmental degradation (Chaharbaghi, 1999).

**2.5 Definition of sustainable development**

There are many definitions to describe sustainable development. A few of them can be present here.

Sustainable development is a process which enables all people to realize their potential and improve their quality of life in ways that simultaneously protect and enhance the Earth‟s life support systems (Parkin, 2000).

According to DETR(Green Minister Report, March 2000), literature, sustainable development is all about ensuring a better quality of life for everyone, now and for generation to come, through:

- Social progress which recognizes the needs of everyone.
- Effective protection of the environment.
- Prudent use of natural resources.

There is also a common definition for sustainable development, which was formulated by the World Commission on Environment and Development (WCED), led by the Norwegian Prime Minister Gro Harlem Brundtland, in 1983 (Chaharghi, K. and Willis, R. 1999). It states that:

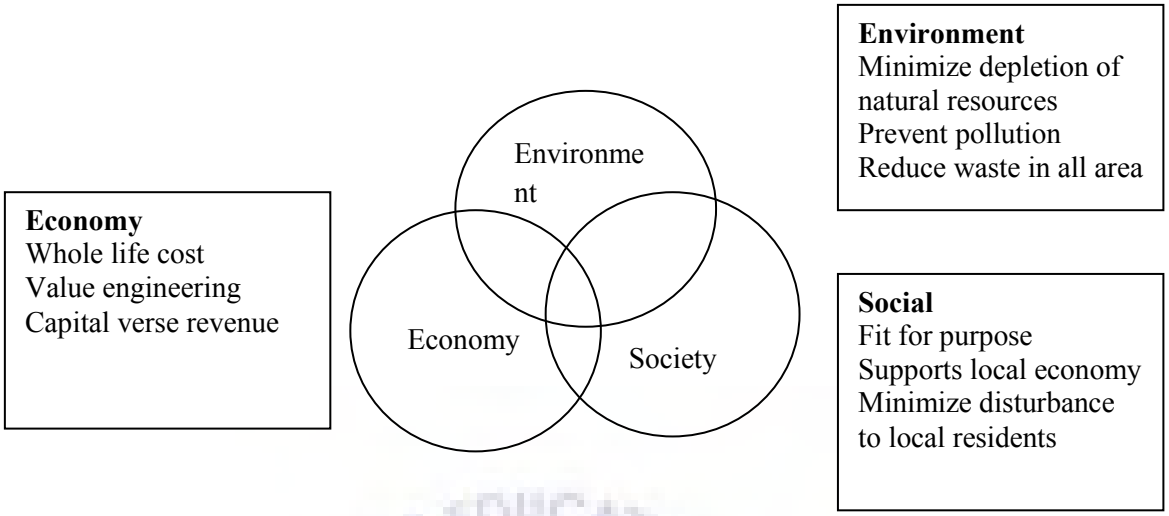
“Sustainable development is development, which meets the needs of the present without Compromising the ability of future generation to meet their own needs.”

**2.6 Factors affecting the achievement of Sustainable development and construction**

Sustainable development often depends on three broad factors or themes. In fact sustainability cannot be achieved without considering these factors. When these factors are considered, then sustainability is also ensured. This includes:

* Environment * Society * Economy

**Fig.2.1 Details of Factors Affecting the Achievement of Sustainable Development**




Source: (Neil, 2008)

### 2.6.1 Sustainable Communities (society)

The following are issues that fall under this factor: Education, Food, Health, Water, Poverty, Housing, Fuel Planning, Employment, Transportation, Construction of buildings that work well, Settlement and growth of community, Meeting local needs locally, Skills development, Empowering community, Opportunities for cultural, leisure & recreational activities, Worker health and safety, Impacts on local communities, Quality of life, Benefits to disadvantaged groups e.g. disabled, Reduce level of crime, etc. This is how a sustainable communities and societies will or should portray for the benefits of our communities (Malik, 2002).

### 2.6.2 Sustainable Environment

The philosophy of environmental sustainability is to leave the Earth in as good or better shape for future generations than we found it for ourselves. By a definition, human activity is sustainable when it can be performed or maintained indefinitely without

depleting natural resources or degrading the natural environment. This includes Resource consumption to be minimal, Materials consumed should be made entirely of 100% post consumer recycled materials or from renewable resources (which were harvested without harm to the environment and without depletion of the resource base), Recycling of waste streams should be 100%, Energy should be conserved and energy supplies should be entirely renewable and non-polluting (solar thermal and electric, wind power, bio-mass, etc.), Use of natural resources efficiently, Minimization of waste and pollution, Protect natural diversity,

Reduce greenhouse gases‟ emission, Reduce road traffic, Good quality of rivers; Population of wild birds, Building new homes on brown field, Reduced waste, effluent generation, and emissions to environment, Reduced impact on human health, Use of renewable raw materials, Elimination of toxic substances, etc. Surely when these practices are ensured by the inhabitant on earth, then sustainable environment for future generations can be assured (Malik, 2002).

### 2.6.3 Sustainable Economy

Sustainable economy is consist of sub-themes, such as Investment in people and equipment for a competitive economy, Job opportunities, Vibrant local economy, Services are accessible which reduces use of car, Creation of new markets and opportunities for sales growth, Cost reduction through efficiency improvements and reduced energy and raw material inputs, Creation of additional added value, etc. Sustainable development should not be at the cost of spending more in order to achieve all above-mentioned and much more (Malik, 2002).

## 2.7 Ways of achieving sustainable development

Sustainable development is being significantly addressed all over the world; however, the concept is often achieved or addressed only on partially manner. The reasons for this are as follows

- Problems in providing quantitative estimates of savings which can be gained;
- Problems in the attribution of accurate economic costs to these products; and
- Problems in identifying the regulations and laws which provide suitable guidelines to new buildings and refurbishment (Khalfan, 2002).

According to Dincer and Rosen (1999), a society seeking sustainable development ideally must utilize only energy resources which have no environmental impact, e.g. which release no emission to the environment. They have also discussed relation between energy efficiency and environmental impact since, for the same services or products, less resource utilization and pollution is normally associated with increased energy efficiency. Since energy is the central theme to achieve the goals of sustainable development, therefore, the main thrust of sustainable development is the maintenance of these valuable assets (Rogner et al., 2001).

Achieving solutions to environmental problems that this world is facing today requires long-term potential actions for sustainable development. In this regard, renewable energy resources appear to be the one of the most efficient and effective solutions. That is why there is an intimate connection between renewable energy and sustainable development. The renewable energy resources also have potential to reduce acid precipitation, stratospheric ozone depletion and the greenhouse effect (Dincer, 2000).

### 2. 7.1 The use of Agenda 21

Agenda 21 is a comprehensive plan of action to be taken globally, nationally and locally by organizations of the United Nations System, Governments, and Major Groups in every area in which human impacts on the environment in order to achieve sustainable development (http://www.un/agenda21) .

The Commission on Sustainable Development (CSD) was created in December 1992 to ensure effective follow-up of UNCED, to monitor and report on implementation of the agreements at the local, national, regional and international levels. It was agreed that a five year review of Earth Summit progress would be made in 1997 by the United Nations General Assembly meeting in special session.

Agenda 21 explains that population; consumption and technology are the primary driving forces of environmental change. It sets out what needs to be done to reduce wasteful and inefficient consumption patterns in some parts of the world while encouraging increased but sustainable development in others. It offers policies and programmes to achieve a sustainable balance between consumption, population and the Earth‟s life-supporting capacity. It describes some of technologies and techniques that need to be developed to provide for human needs while carefully managing natural resources (Malik, 2002).

### 2.8 Sustainable Construction

Sustainable construction could be defined as the creation and responsible management of a healthy built environment based on resource efficient and ecological principles (http://www.arch.hk/research/BEER/sustain.htm).

Sustainable construction is therefore the application of sustainable development to the construction industry. The construction industry is all who produce, develop, plan, design, build, alter, or maintain the built environment or the industry, and includes building materials suppliers and manufacturers as well as clients, and users or occupiers. Sustainable construction could therefore, be best described as a subset of sustainable development, which encircles matters such as tendering, site planning and organization, material selection, recycling, and waste minimization(Ding, 2001).

A more meaningful definition for sustainable construction is the need to find a balance between economic, environmental and social factors in the design, construction and use of buildings: (Neil, 2007).

In UK for instance, buildings are responsible for almost half of it carbon emissions, half of the water consumption, about one third of landfill waste and one quarter of all raw materials used in the economy. The construction industry has also a central role in driving the sustainable development agenda (Malik, 2002). In the case of Ghana it is different because, the country has no means or frameworks of measuring the impacts of construction activities and also already existing buildings and their impacts on the environment and on the future generations.

Therefore, sustainable construction practices, is that which minimize environmental impact throughout the life of a building, by designing for minimum energy and water use and waste production, preventing pollution and preserving and enhancing biodiversity.

## 2.9 Principles of Sustainable Construction

According to Kibert (1996), there are six principles for sustainable construction, and these are:

1. Minimization of resource consumption;
2. Maximization of resource reuse;
3. Use renewable and recyclable resources;
4. Protect the natural environment;
5. Create a healthy and non-toxic environment; and
6. Pursue quality in creating the built environment.

## 2.10 Ways of realizing and achieving sustainable construction

There are three main ways by which the construction industry and civil engineering can act to realize and achieve sustainable constructions. These are:

- By creating built environments
- By restoring damaged and or/polluted environmental and
- Improving arid or dry environments (Miyatake, 1996).

Miyatake (1996), suggests that, everybody has to realize now that in order to achieve sustainable construction, the industry must change the processes of creating the built environments. How, this could be coined as bringing change from linear processes of construction to cyclic processes of construction within the construction industry or built environments. This means that the industry has to change the way in which all the construction activities are undertaken. The industry is using energy, material, and other resources to create buildings and other civil engineering projects, and the end result of all

these activities is huge volume of discharge waste during and at the end of the facility‟s life.

Therefore, changing this linear process into cyclic process will bring increased use of recycle, renewed and reused resources, and decrease in significant use of energy and other natural resources.

On the other hand, in order to restore damaged and polluted environments, efforts have been made such as treatments of damaged and contaminated soils, water and air. The idea behind improving arid or dry environments is to improve large scale arid environments like deserts and making them habitable for plants, animals and human beings. But it is suggested according to Miyatake, (1996) give priority to improve the built environments in order to transform it‟s from linear process into cyclic Processes. Thus, source the materials locally, minimized process or manufactured it, use them and re-use by recycling them for another constructional purposes.

**2.11 The Existing construction processes**

Construction processes refers to the phases or stages that a complete and successful project undertaken and this includes pre-construction or contract phase, construction phase and post construction phase, hence the name is call linear processes (Neil, 2007). To achieve and also ensure sustainable construction, which give hopes for the future generations, a comprehensive design to sustainability have to be incorporated in all these phases and if possible change it from linear construction stage or phase to cyclic construction phase to ensure effective sustainable development. In effect there are three types of construction processes that already exist almost all over the world.

### 2.11.1 Pre- construction stages

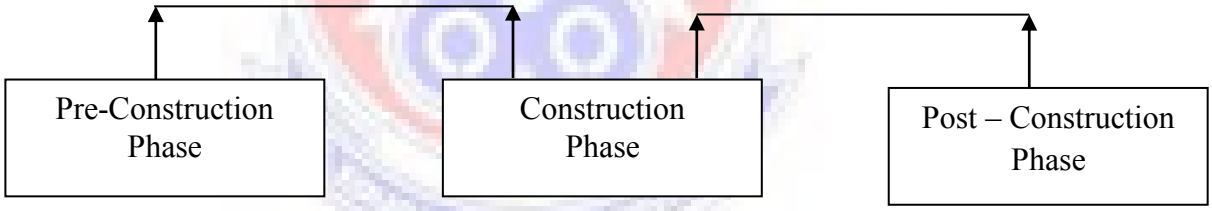
This includes the clients brief, investigation, sketch, design, procurement process, the costing of the project, quantity surveying, user‟s requirements, client‟s awareness and involvement, etc.

### 2.11.2 Construction stage

This phase includes the On-site Construction Process, Waste Management and Re-cycling, Suppliers and Management of Construction Materials, etc. This also includes Involvement of whole Supply Chain during the Construction of the Project.

### 2.11.3 Post-construction stage

This phase involves the Maintenance Period of a facility, life-cycle cost/economy and efficiency, including the demolition of a facility (Khalfan, 2002)




**Linear Construction Process**
Source: (Khalfan, 2002)

**Fig. 2:2 shows the existing or linear construction phases**

### 2.12 Strategies for Sustainable Construction by other countries

The UK Government for instance has taken sustainable development on board for the structure industry. The government considers sustainable construction as asset of processes by which a profitable and competitive industry delivers built assets (building,

civil engineering structures, supporting infrastructure, and their immediate surroundings) which

- Enhance quality of life and offer customer satisfaction;
- Offer flexibility and the potential to cater for user changes in the future;
- Provide and support desirable natural and social environments; and
- Maximize the efficient use of resources (Raynsford, 2000).

The strategies or plans developed for sustainable construction highlights the importance of design in order to achieve greater sustainability, because buildings or any other facility are the end product of all the design decisions taken at the onset of a project. Therefore sustainable design factored into construction works is the key part of planning or strategizing the achievement of sustainable construction.

According to Raynsford, (2000) designs, impacts in a variety of ways. For example, the choice of material and their applications have a significant environmental impact, depending on the sources of materials, their durability, and potential reuse. Civil engineers should also build on their strengths of design of the environment grounded in physical science, by analyzing the entire environmental management system, thinking in terms of outcomes, and considering a broad range of alternatives. For example, civil engineers need to attend more closely to sustainable development and pollution prevention as substantive areas for engagement beyond the traditional design of waste treatment systems (Emison, 2001). Like UK and other developed countries in the world have done, the forthcoming nations must learn to replicate them to ensure and enhance sustainable designs and construction for future unborn generations.

Here are UK Governmental initiatives towards sustainable designs and construction. The initiatives or the policies and strategies are reflected from the following examples.

- Sir John Egan‟s Construction Task Force published **‘Rethinking Construction’** in 1998 (Parkin, 2000).
- Movement for Innovation (M4I) was launched after the above mentioned report to identify and disseminate examples of good practice. One such example is the Queen Margaret Hospital in Swindon (http://www.m4i.org.uk).
- A Government‟s sectoral strategy for construction industry came out in April 2000;
- Report: „A better quality of life‟; Foreword by the Prime Minister Tony Blair (http://www.sustainable-development.gov.uk).
- Work done by „Green Ministers‟, including the publications produced by DETR-Sustainable development report in March 2000.
- The Government target of 60% of new homes to be built on previously developed land is a significant initiative to encourage brown-field sites redevelopment with its aim of reducing development pressure on the green-field, initiating urban regeneration, and achieving a more sustainable programme (Smith, 1999).

These practices by other countries for sustainable construction, even though are not common in Ghana and in most part of Africa, but the construction industries can begin to draw up its own principles to ensure effective sustainable construction or better still can copy the develop countries to implement them here in Africa to support the achievement of sustainable development through sustainable construction strategies.

## 2.13 Formal techniques for Achieving Sustainable Construction

To achieve sustainable construction and designs, there are formal techniques that had to be observed and adopted, and these techniques include:

1. Introduction of Green Building construction.
2. Integration of Sustainable Designs, when designing.
3. Implementation of sustainable constructional tools and quality standards for assessing the project life cycle, thus from commencement of project until completing and after completion, through BREEAM, Eco Home techniques etc (Malik, 2002).

### 2 .13.1Green Building

Buildings have a tremendous impact on the environment-both during construction and throughout their operation, this need to be curbed to enhance sustainable construction and developments. Green building techniques is one of the main solutions that can curb or reduce this situation at hand. "Green building" therefore is a loosely defined collection of land-use, building design, and construction strategies that reduce these environmental impacts (http://www.buildinggreen.com). The green building approach to the built environment involves a holistic approach to the design of buildings.

The Green Building practice expands and complements the building design that concerns of economy, utility, durability, and comfort (U.S. EPA, 2009).The common objective of green buildings is that, they are designed to reduce the overall impact of the built environment on human health and the natural environment by:

- Protecting occupant health and improving employee productivity

- Reducing waste, pollution and environmental degradation
- Reduction of human exposure to noxious materials (U.S. EPA, 2009).
- Conservation of non-renewable energy and scarce materials;
- Minimization of life-cycle ecological impact of energy and materials used;
- Use of renewable energy and materials that are sustainably harvested;
- Protect and restore local air, water, soils, flora and fauna; and
- Support pedestrians, bicycles, mass transit and other alternatives to fossil-fuelled Vehicles (http://www.arch.hk/research/BEER/sustain.htm.)

### 2.13.2 The Integration of Sustainable Designs when designing

This is a very essential section so long as the achievement of sustainable construction is concern. It is an important subject in the building community to study the contribution to improving the earth environment and sustainable development from an architectural perspective (Bai, 28).

Incorporation of Sustainable designs into buildings is the first step towards the achievement of sustainable construction and development.

Sustainable design requires innovative solutions to technical problems. These solutions should always take into account the impact upon the environment.

Innovative solutions which cost less conserve energy, and natural materials, reduce pollution while providing healthier, more comfortable internal environment can only meet with success.

Therefore, it could be said that sustainable design is a thoughtful integration of architecture with electrical, mechanical, and structural engineering. In addition to concern for the traditional aesthetics of massing, proportion, scale, texture, shadow, and light, the

facility design team needs to be concerned with long term costs: environmental, economic, and human (Architecture: Is change required, Building,( Feb. 1995).

According to the Rocky Mountain Institute there are five elements for sustainable design planning. Sustainable design is "front loaded" compared with traditional design. Early decisions have the greatest impact on energy efficiency, passive solar design, day lighting, and natural cooling.

Sustainable design is more of a philosophy of building than a prescriptive building style. Sustainable buildings do not have any particular look or style.

Sustainable buildings do not have to cost more, nor are they more complicated than traditional construction.

Integrated design that is design where each component is considered part of a greater whole is critical to successful sustainable design.

Minimizing energy consumption and promoting human health should be the organizing principles of sustainable design. The other elements of design can be organized: energy saving architectural features, energy conserving building envelope, and energy-efficient and health-promoting mechanical, electrical, and plumbing systems.

Sustainable designed buildings aim to lessen their impact on the environment through energy and resource efficiency and include the following principles, minimizing non-renewable resource consumption; enhancing the natural environment; and eliminating or minimizing the use of toxins (http://www.arch.hk/research/BEER/sustain.htm)

### 2.13.2.1 Five Principles of Sustainable Designs

According to Fisher, (1992) there are also five principles of sustainable design and environmental architecture, and every intended sustainable building should possess these.

### 2.13.2.2 Healthy Interior Environment

All possible measures are to be taken to ensure that materials and building systems do not emit toxic substances and gasses into the interior atmosphere. Additional measures are to be taken to clean and revitalize interior air with filtration and plantings.

### 2.13.2.3 Energy Efficiency

All possible measures are to be taken to ensure that the building's use of energy is minimal. Cooling, heating and lighting systems are to use methods and products that conserve or eliminate energy use.

### 2.13.2.4 Ecologically Kind Materials

All possible measures are to be taken to use building materials and products that minimize destruction of the global environment. Wood is to be selected based on non-destructive forestry practices. Other materials and products are to be considered based on the toxic waste output of production.

### 2.13.2.5 Environmental Form

All possible measures are to be taken to relate the form and plan of the design to the site, the region and the climate. Measures are to be taken to "heal" and augment the ecology of the site. Accommodations are to be made for recycling and energy efficiency. Measures are to be taken to relate the form of building to a harmonious relationship between the inhabitants and nature.

### 2.13.2.6 Good Designs

All possible measures are to be taken to achieve an efficient, long lasting and elegant relationship of use areas, circulation, building form, mechanical systems and construction technology. Finished buildings shall be well built, easy to use and beautiful.

### 2.13.2.7 Good design practices to ensure sustainable construction and development.

**Designs**

*** Smaller is better:** Optimize use of interior space through careful design so that the overall building sizes-and resource use in constructing and operating it-are kept to a minimum.

**Design an energy-efficient building**: Use high levels of insulation, high-performance windows, and tight construction. In southern climates, choose glazing‟s with low solar heat gain.

**Design buildings to use renewable energy:** Passive solar heating, day lighting, and natural cooling can be incorporated cost-effectively into most buildings. Also consider solar water heating and photovoltaic‟s-or design buildings for future solar installations.

**Optimize material use:** Minimize waste by designing for standard ceiling heights and building dimensions. Avoid waste from structural over-design (use optimum-value engineering/advanced framing). Simplify building geometry.

**Design water-efficient, low-maintenance landscaping**: Conventional grasslands have a high impact because of water use, pesticide use, and pollution generated from mowing. Landscape with drought-resistant native plants and perennial groundcovers.

**Make it easy for occupants to recycle waste:** Make provisions for storage and processing of recyclables: recycling bins near the kitchen, under sink compost receptacles, and the like.

**Design for durability:** To spread the environmental impacts of building over as long a period as possible, the structure must be durable. A building with a durable style ("timeless architecture") will be more likely to realize a long life.

**Design for future reuse and adaptability:** Make the structure adaptable to other uses, and choose materials and components that can be reused or recycled.

**Avoid potential health hazards: radon, mold, pesticides:** Follow recommended practices to minimize radon entry into the building and provide for future mitigation if necessary.

Provide detailing that will avoid moisture problems, which could cause mold and mildew growth. Design insect-resistant detailing that will require minimal use of pesticides.

**Renovate older buildings:** Conscientiously renovating existing buildings is the most sustainable construction.

**Locate buildings to minimize environmental impact:** Cluster buildings or build attached units to preserve open space and wildlife habitats, avoid especially sensitive areas including wetlands, and keep roads and service lines short. Leave the most pristine areas untouched, and look for areas that have been previously damaged to build on. Seek to restore damaged ecosystems.

**Provide responsible on-site water management:** Design landscapes to absorb rain water runoff (storm water) rather than having to carry it off-site in storm sewers. In arid

areas, roof top water catchment systems should be considered for collecting rainwater and using it for landscape irrigation.

**Materials**

**Avoid ozone-depleting chemicals in mechanical equipment and insulation:** CFCs have been phased out, but their primary replacements--HCFCs--also damage the ozone layer and should be avoided where possible. Avoid foam insulation made with HCFCs. Reclaim CFCs when servicing or disposing of equipment.

**Use durable products and materials:** Because manufacturing is very energy-intensive, a product that lasts longer or requires less maintenance usually saves energy. Durable products also contribute less to our solid waste problems.

**Choose low-maintenance building materials:** Where possible, select building materials that will require little maintenance (painting, retreatment, waterproofing, etc.), or whose maintenance will have minimal environmental impact.

**Choose building materials with low embodied energy:** Heavily processed or manufactured products and materials are usually more energy intensive. As long as durability and performance will not be sacrificed, choose low-embodied-energy materials.

**Buy locally produced building materials:** Transportation is costly in both energy use and pollution generation. Look for locally produced materials. Local hardwoods, for example, are preferable to tropical woods.

**Use building products made from recycled materials:** Building products made from recycled materials reduce solid waste problems, cut energy consumption in

manufacturing, and save on natural resource use. A few examples of materials with recycled content are cellulose insulation, Homasote, Thermo-ply, floor tile made from ground glass, and recycled plastic lumber.

**Use salvaged building materials when possible:** Reduce landfill pressure and save natural resources by using salvaged materials: lumber, millwork, certain plumbing fixtures, and hardware, for example. Make sure these materials are safe (test for lead paint and asbestos), and don't sacrifice energy efficiency or water efficiency by reusing old windows or toilets.

**Seek responsible wood supplies:** Use lumber from independently certified well-managed forests. Avoid lumber products produced from old-growth timber unless they are certified. Engineered wood can be substituted for old-growth Douglas fir, for example. Don't buy tropical hardwoods unless the seller can document that the wood comes from well-managed forests.(Khalfan, 2002).

### 2.13.3Environmental Assessment (Tools and Standards) for sustainable construction (BREEAM)

BREEAM (Building Research Establishment Environmental Assessment Method) is a tool that allows the owners, designers, and users of buildings to review and improve environmental performance throughout the life of a building. It is a widely accepted and respected scheme that sets a benchmark for environmental performance and provides a wide range of benefits. It is independent and authoritative, being based on many years of construction and environmental research carried out at the Building Research Establishment(BRE) together with the input and experience of the construction and property industries, Government and building regulators. BREEAM is regularly updated

to take advantage of new research, to reflect changing priorities in regulations and in the market place and to build on experience gained. The aim is to ensure that BREEAM continues to represent current best practice, going beyond what is required by regulations (http://products.bre.co.uk/breeam.html).

This latest version of BREEAM Offices (BREEAM 2002), launched in August 2001, includes major changes in the way BREEAM operates, and incorporates several major environmental issues. To achieve sustainable construction, BREEAM can be one of the contribution factors to be considered (Building Engineer, Dec. 2001). In Ghana, schemes of this nature are not considered greatly into our construction industry (thus majority of Ghanaian constructional work do not consider BREEAM) as a way to attain sustainable construction and development, hence the need to assess the construction of building performance against the environment through the use of BREEAM and any other approve schemes which can be of great importance towards the achievements of sustainable construction and developments in Ghana.

**2.14 Standards for sustainable quality**

Following are some of the examples of 14000 series standards for environmental management (Sustainable development and sustainable construction): also environmentally responsible design and construction. Examples of these standards are:

Environmental management systems – Specification with guidance for use (ISO 14001:1996). Environmental management – Life cycle assessment – Principles and framework (ISO 14040:1997)

Environmental management – Life cycle assessment – Goals and scope definition and Inventory analysis (ISO 14041:1998)

Environmental management – Life cycle assessment – Life cycle impact assessment (ISO14042:2000)**http://www.ISO14000.org**(http://www.buildinggreen.com/ebn/checklist.html)

**2.15 EcoHomes**

EcoHomes are straightforward, flexible and independently verified environmental assessment method for homes, with environmental performance expressed on a scale of Pass to Excellent (http://www.bre.co.uk/sustainable/ecohomes.html). BREEAM leads the world in setting benchmarks for the environmental performance of buildings. It is independent, authoritative and based on many years of construction and environmental research carried out by BRE, the construction industry and Government.

EcoHomes is an easily understood, credible label for new and renovated homes including houses, apartments and sheltered accommodation. It rewards developers who improve environmental performance through good design, rather than high capital cost solutions (Khalfan, 2002). Hence EcoHomes is one of the schemes and technique for attaining sustainable construction.

**2.14.1 Benefits of EcoHome schemes and designs**

- Demonstrating sustainability credentials to planning authorities to assist a smooth passage through the planning process;
- Demonstrating "green" credentials to investors helps to minimize investment risk and increase the appeal to ethical investors;
- Demonstrating superior environmental design to customers, resulting in:

- Reduced running costs through greater energy and water efficiency, and reduced maintenance;
- Healthy, comfortable and flexible internal environments;
- Access to local amenities (Khalfan, 2002).

**2.16 Affordable Housing in Ghana**

The benefit of focusing on sustainable design and appropriate technology for affordable housing to every nation is extremely important as it provides shelter for sleep, serve as a shield against elements of the weather and other hazards, it affects efficiency and stability of a whole economy and financial markets and hence has a sufficient impact on the productivity and growth of all nations.

Various governments and the private sector also in Ghana, have on a number of times constructed affordable houses for the public. However, the cost of these affordable houses does not make it affordable for the low income earner or the average Ghanaian. These seeming affordable houses end up being purchased by the higher income earners, because it is not affordable to the low or middle income earners as claim (Agyemang, 2001).

**2.17 What is affordable housing**

Housing affordability in itself involves the ability of households to consume other basic necessities of life such as food and clothing in addition to accessing adequate housing. It includes the ability of households to consume housing that permits reasonable standard of living, ability of mortgagors to effectively meet mortgage obligations, and households‟ access to adequate standard of housing without denying them access to other basic necessities of life (Addai, 2010-National Rental Affordability Scheme).

According to Arman et al., (2009) Affordable housing or dwelling can be defined as the following product:

- A product where the rent or mortgage repayments do not exceed 30% of household incomes for the bottom 40% of income groups.

**2.18 Types of affordable housing**

- subsidized housing
- mixed-income housing
- senior housing
- supportive housing
- rent stabilized housing
- public housing
- housing for social rent
- housing for mid-rent
- shared ownership
- Shared equity or home stake (www.ghana.gov.gh)

**2.19 Technologies**

Technology in simple terms is the study of machines and the way things works to solve problems of humanity.

Hard and Jamison, (2005) suggested that we are living in a "culture technique" in the sense that our deepest and most private knowledge and emotions are permeated by technology.

The transition from technology as tool use to knowledge began around the emergence of the first industrial revolution, more than two centuries ago. The transition to technology as culture accelerated after the Second World War, and is closely related to the rise of information and communication technologies, biotechnology, computers, and

the Internet. In contrast to technology, science is seen as an organized search for "truth" and objective knowledge" about reality and the laws of nature. In spite of the enormous merit that the introduction of technology has brought to humanity in the world, it also posits great effect and challenges to the globe.

Technology, since the Enlightenment, especially science-based technology, has offered the promise of a better world through the elimination of disease and material improvements to standards of living. On the other hand, resource extraction, emissions of dangerous materials, and pollution of air, water, and soil have created conditions for unprecedented environmental catastrophe and have already caused irreversible damage to the biosphere. While the future might promise a vast acceleration of technological innovation, the scale and impact of environmental degradation may reflect this vast acceleration as well (Vergragt, 2006).

A related painful contradiction is that, despite the ongoing technological revolution, the majority of the world population still lives in abject poverty with inadequate food, housing, and energy, plagued by illnesses that could be easily cured if clean water and simple drugs were made available. Hence the need to focus on technology that is appropriate, and based on simple techniques and materials and above all sustainable in nature. Fortunately a significant number of former "developing" countries are now on the threshold of development, helped by technology transfer and technological innovations that have benefited large parts of their populations.

Some countries, such as China, India, Korea, Taiwan, Singapore, and, to a certain extent, Brazil, have followed their own technological trajectories. However, for large populations in Africa, Asia, and Latin America the benefits of technology remain a

dream, even if new technologies like photovoltaic cells, cellular phones, and the Internet could help them "leap-frog" towards the twenty-first century (Vergragt, 2006).

The persisting contradictions between better lives created and supported by technology for the wealthy few, and increasing environmental degradation and persistent poverty for the vast majority calls for a deeper exploration and understanding of the nature of technology and its relationship to society, especially to a sustainable society. Societies in the world must exert effort to catalyze a Great Transition to a sustainable global society, in which deep changes in culture, values, consumption patterns, governance, business, and institutions are envisaged (Raskin et al.,2002).

**2.20 Types of technology**

- ✓ Nanotechnology
- ✓ Biotechnology and health technology
- ✓ Information and communication technologies
- ✓ Appropriate technologies
- ✓ High technologies

**2.21 Types of appropriate technology**

- Capital-saving technology
- Alternative technology
- Self-help technology
- Village-level technology
- Community technology
- Progressive technology
- Indigenous technology
- Adaptive technology
- Soft technology

### 2.21.1 Appropriate technologies

One of the aims of this report is to envision a sustainable affordable housing and equitable global society through reflecting or focusing on the role of appropriate technologies for such an aim for all people.

In a Great Transition society, through appropriate technology, will support and enhance a good life for all of its citizens, in both rich and presently poor countries, without compromising the Earth‟s ecosystem or the prospects of later generations.

Thus, considering technological innovation in the context of the good life and how it can be supported or threatened, depending on the way technological innovations are influenced and steered by human decisions and institutions.

Appropriate technologies however, is a small scale, energy efficient, environmentally sound, labor intensive, and controlled by the local community, and usually with local available materials. The breadth of the paradigm or pattern of appropriate technology is suggested by the many terms used to describe it: intermediate, progressive, alternative, light-capital, labor-intensive, indigenous, and low-cost, community, soft, radical, libratory, and convivial technologies (Akubue, 2000).

Intermediate technology and its kinds of appropriate technologies can be considered as a subset of appropriate technology that focuses on technology that is more productive than inefficient traditional technologies, but less costly than the technology of industrialized societies. In contrast to the areas of so-called high-tech innovation and development that has been considered so far, there is a very different strand of technologies, often called appropriate technology (Schumacher, 1973). At present, these are found primarily in the rural third world, but also in pockets of the “developed”

countries (Vergragt, 2003). As Schumacher described it, "such an intermediate technology would be immensely more productive than the indigenous technology but it would be immensely cheaper than the sophisticated, highly capital-intensive technology of modern industry" (Schumacher, 1973, p. 180).

Appropriate technology has been advocated as a solution for rural development problems, but has also gained support as a direction for sustainable technologies.

However, it has often been identified as "cheap", "second hand", or second best by adherents of massive Western technology transfer to developing countries and by ideologues who believe in modernization by technological innovation (Vergragt, 2006). Many elements of intermediate or appropriate technology could be used in the development of technologies for a sustainable society, especially when used in synergy with high-tech developments. These elements include an orientation toward human needs, control by and empowerment of local communities and materials, small scale and distributed, energy efficient, local techniques , environmentally sound, low cost or cost effective(at affordable cost), and labor intensive. The renewable energy movement in the USA and Western Europe, UN Earth Summit and other movement in the world has emphasizes some of these elements. The challenge now is going forward to learn from our past mistakes, and to combine elements of appropriate technology with some aspects of high-technology into a new paradigm or adapt appropriate technology solely where necessary to ensure sustainable technology, with the aspect of sustainable construction (Vergaragt, 2006).

## 2.22 Appropriate technologies to achieve sustainable construction/development in Ghana

- Local, modular and efficient Eco-Affordable housing technology for Ghana
- Hydrafoam/interlocking blocks technology
- I-section beam for floor technology
- Micro-concrete roofing tiles(MCRT) technology
- Adobe brick technology
- Wattle and Daub technology
- Compressed Earth Blocks technology
- Earthships technology
- Hybrid Structures technology
- Straw-Clay (Leichtlehm) technology
- Straw Bale Construction technology
- Living Roofs technology
- Rammed Earth technology (Kennedy, 2011).

These techniques/technologies are being validated by modern structural and other code tests, which also point out directions for further research and improvement to ensure their durability and strength.

### 2.22.1 Local, modular and efficient Eco-Affordable Housing innovation (new tech.) for Ghana Emerging Ghana affordable housing concept.

This is a piece of new eco/sustainable housing in Ghana. The concept of houses or home to be built which was published at Inhabitant. The design was done by Lisbon-based Blaanc in collaboration with Architect Joao Caeiro, the emerging Ghana is a plan for an

eco-affordable middle class of Ghana. The design recently won first place in the international design competition open source house, a non-profit organization that aims to provide better, more sustainable housing in low-income or middle income countries. Emerging Ghana is modular single –family home design to be built with local materials, local labor, and with all the best sustainable design strategies. The house can cost about $12,500 USD which is equivalent to GHC 25,000. The home will be constructed based on the Ashanti compound, a courtyard building with a deep structure and large overhangs that encourage natural ventilation. Modular by nature, the home can grow as funds allow and as the family expands. All the construction materials are locally source-rammed earth walls, dahoma wood and bamboo can all be found nearby to construct the home.

It is intended to be taught to all local people that are interested a house especially eco affordable housing and sustainable in nature.

Energy efficient was a primary design goal to improve the homes over all sustainability, but more importantly to create a more comfortable living environment with minimize cost.

Low- tech energy solutions would be capitalized onto minimizes energy use and maximizes comfort. Solar passive design with south-surfacing structure and large overhangs provides shades for the interior. A solar hot water tank on the large roof provides hot water for the kitchen and bath room. Orientations of the home improve natural ventilation, while rain water is collected for use within the home and for the garden in the courtyard, which helps provides some of the family‟s food. A small scale

septic tank manages the household‟s waste, while organic waste is composted in the yard. The concept was to be built somewhere in 2010.

Fig 2.3 Typical local-modular and eco-affordable housing for Ghana.

http://inhabitat.com/local-modular-and-efficient-eco-affordable-housing-for-ghana

http://inhabitat.com/architecture

http://www.blaanc.com

**2.22.2 The use of Interlocking Masonry Blocks and Bricks (hydrafoam )**

Building materials constitute the largest input in housing; about sixty (60) percent of the total housing expenditure goes for the purchase of building materials (Adedeji, 2012). Ogunsemi (2010) opened that building materials form the main factors that restricts the supply of housing and ascertained that they account for between 50-60 percent of the cost of buildings. Adedeji (2012)rightly observed that one main barrier to the realization of effective housing in the most developing African countries as has been revealed in successive government efforts has been the high cost of building materials in our age. He continued to argue that in the early periods, shelter in sub-Saharan Africa which Ghana is included was at easily affordable cost. Technology also was readily

available with commensurate simple techniques But contact with the outside world (Western countries) through inter-regional and international training of professionals in foreign countries as occasioned by colonization, brought changes to tastes and hence outlook to house forms. These changes rendered the undeveloped local building materials inadequate while there was an increased demand for exotic ones. Ideally building material for construction of houses must be of low cost, environmentally friendly and less energy consuming. The other factors that greatly affect the selection of building materials are their costs and social requirements such as thermal comfort, good mechanical properties (strength and durability), aesthetic characteristics and an ability to construct quickly, and easily accessibility. It is in this line that the construction industry in Ghana should involve varied kinds of construction materials, and building systems with local available materials, environmental condition and simple techniques. One of such system is the adaptation of interlocking masonry block as a local material into the building industry which is the one of the technologies to be focus of this research.

Interlocking or “dry stayck” masonry system in construction requires the development of efficient, easy to handle, use thus very compact and yet versatile blocks (Adedeji, 2012).

**2.22.2.1Types of interlocking Block**

There are varied interlocking blocks developed for use, and this includes:

1. Separlock system
2. Mecca no system
3. Spiffily system

4. Header system

5. Solid interlocking Block (SIB)/Hydrafoam block (Adedeji, 2012).

While interlocking blocks are made of laterite, it can also be made of cement and sand content only. The blocks can have geometric size of 225 by 225 by 112mm.The blocks are made both by machines and by hand thus manual procedure, the machine type produces interlocking blocks of composition mainly and stabilized with cement of ratio 1:20, thus one part of cement and twenty part of laterite (Adedeji,2012).The major environmental burdens and effect associate with building materials(conventional and innovative types)include embodied energy of building materials and greenhouse emissions originated from each stage of their life cycle. According to the Thormark (2006) ),he indicated that embodied energy in traditional building can be reduced by approximately 10-15%.Through the proper selection of building material with low environmental impacts, to save the environment but produce affordable housing. Although, the values of embodied energy can vary widely (sometimes by as much as 100%,depending on the numbers of factors like country, manufacturing process, recycling technologies, methodology analysis, fuel cost and destination),they can be considered as reasonable indicators of an overall environmental impact of builders materials. The usage of interlocking block of any type in place of conventional fired ones can significantly reduce the energy use and also cut down $Co_2$ emissions there by reducing the environmental degradation of the environment but will ensure low cost housing to Ghanaians. Interlocking blocks are manufactured by hydraulically compressing a soil and cement mixture (stabilizer) in a blocks-making machine.

Fig2 .4 Typical machine for making blocks.

Fig2.4Hydraulic Machine developed for hydrafoam block moulding.

Source: NBRRI-Lagos March, 2014

**2.22.2.2 Types of materials for making interlocking Blocks are:**

1. Laterite or soil
2. Straw
3. Water

**2.22.2.3 Production Processes of moulding hydrafoam blocks**

The production process involves:

- Preparation of soil
- Preparation of mix
- Compression of mix by machine
- Stacking and curing of blocks

The results of several studies (Harris, et al, Anand and Ramamurthy) Showed that increase in durability and strength over studies blocks and unfired blocks occurred when cement is added to stabilize solid interlocking blocks. The mix requires a ratio of 1:20, of cement to soil. This means that for one bag of 50kg cement you will need about 10 wheelbarrows of soil. This mix yields or produces about 75 blocks, with engineering standards acceptable for wall construction (Adedeji, 2012).

**2.22.2.4 Advantages of using interlocking blocks.**

- It can be used as both internal and external wall construction
- They can be used as external wall elements without plastering
- It is lighter in weight and easily to work with.
- It is cost effective as compared to other alternative
- It is environmental friendly materials and support sustainable construction and development
- It is made of low embodied energy
- It uses simple methods and processes in manufacturing. Thus it supports appropriate technologies.
- It is durable and reduced about 85% of cement contents use for ordinary block making.

**Fig.2.5 Stacking of Solid Interlocking blocks/ Hydrafoam Blocks on a project site**

**2.22.2 .5 Details of Advantages and Benefits of using interlocking Blocks**

In solid interlocking blocks, substantial cost savings can be achieved due to elimination of bedding mortar in the superstructure, except in rings beams and high gables, accelerates or speed up construction, thereby reducing workmanship and cost. Hydrafoam blocks are there times as efficient as concrete and almost twice as efficient as fired clay bricks in terms of the thermal insulation they offer. Attractive, face bricks finishes in a variety of natural colures derived from the soil found at individual sites. The production of interlocking blocks such solid interlocking blocks (SIB) does not require firing as in the case of burnt bricks nor expensive factory processes associated with cement products. Hence, energy consumption is reduced considerably. Besides, the cost of using interlocking blocks in construction is lower than that of conventional blocks as

its operation does not require special skilled labor as it is in the case of conventional blocks. Above all the gang output of 1 mason +1 labor for laying interlocking blocks is 3times higher than 1mason +1 labor for laying conventional masonry block.(Adedeji,2o12).

**Fig 2.6** Interlocking / hydrafoam Masonry blocks at the finishing stage of a housing project

### 2.22.3 Adobe brick technology

Adobes are sun-dried mud bricks stacked with a mud mortar to create thick-walled structures (Kennedy, 2011). According to him, **adobe** is also a sun dried brick derived from a yellow silt or clay deposited in the soil and by rivers. These thick earthen walls provide what is known as "thermal mass" which helps to modulate interior

temperatures by absorbing excess heat during the day and slowly releasing it at night. Adobe houses are houses built from bricks made primarily of clay and straw. It is a sun-dried mud that has great energy saving. Adobe and its houses are found in many parts of the world. Adobe houses are still being built, either a multistory buildings or smaller single-story homes. Adobe homes have been used in both North America, South American and in Africa for thousands of years.

Adobe bricks were one of the most ancient and widely used building materials by humans. Adobe is material and technique for delivery affordable (low-income) housing, but quality housing, sustainable and in areas which are labor-rich and capital-poor, because it is labor intensive, using local materials and simple tools (http://en.wikkipidia.org-building).

**2.22.4 Wattle and Daub technology**

The technique of weaving branches (wattle) as a support for mud plaster (daub) is perhaps the oldest of earth building techniques and is still used for traditional architecture in many parts of the world. Uncommon in the U.S., it can be used in mild climates to create thin earthen walls, but lacks the thermal mass or insulation desirable in other climates. An intriguing use of wattle and daub is to create interior partition walls, with a recent experiment using pulped paper to replace the daub. Michael Smith has recently created inner and outer wattle and daub walls which are filled with an insulating straw-clay mixture (livingearth62@hotmail.com)

### 2.22.5 Compressed Earth Blocks technology

Compressed earth blocks are similar to adobes, with the main differences being that, they are not fully saturated with water, are denser than adobes, and are usually significantly more uniform. These blocks are created using a variety of machines. Some, like the Cinva-Ram invented in South America, use human labor and are relatively inexpensive. Expensive fuel-powered machines, on the other hand, can produce thousands of bricks in a day.

Because of their uniformity, compressed earth blocks need little mortar, and can even be dry-stacked. This uniformity also speeds up the laying process and results in straighter walls (livingearth62@hotmail.com).

### 2.22.6 Earthships technology

"Earthships" are the name for the independent living structures utilizing passive-solar design and recycled materials developed by Michael Reynolds of Solar Survival Architecture. While not exclusively reliant on "natural" materials, Earthships replace some conventional materials with recycled trash which is found all over the planet.

The building is framed in wood on the south side and roofed to collect rain water. Other systems include integrated wastewater treatment, photovoltaic electrical systems, solar hot water and passive-solar heating.

Advantages of the system include near-total self-sufficiency, the use of recycled materials and local soil, and technical and aesthetic sophistication. Disadvantages include the complexity of building such a structure and the sometimes-overwhelming amount of labor required. Summer overheating can also happen (Kennedy, 2011).

### 2.22.7 Hybrid Structures technology

Hybrid buildings are a fascinating outgrowth of the efforts of a few visionary natural builders and the sharing of ideas in the Natural Building Colloquia. The basic concept is that several techniques can be combined for increased building efficiency or unique artistic effect. An example is to combine a thermal-mass technique such as cob or rammed earth on the south side of a house, with an insulative system such as straw bales or straw-clay on the north, east and west sides, taking advantage of the best qualities of each system. New solutions to common problems have begun to evolve from such creative combinations (Kennedy, 2011)

### 2.22.8 The straw bales technology

The use of baled straw to create super insulated walls has become an extremely popular method of construction in recent years. Most common in North America, bale buildings have been built around the world. Originally used by the pioneers of the Nebraska sand hills, straw bales are cheap to buy and easy to build with, lending themselves to "barn-raising" parties, where structures and community are created at the same time.

Straw bales are commonly used as infill in a post-and-beam structure, or as a load-bearing system, where the bales themselves support the weight of the roof. Bales are secured to a concrete, stone or (experimentally) an earthbag foundation with pins or strapping. They are laid in a running bond and pinned together using rebar, wood stakes or bamboo. The roof is then attached to a top plate. The bales are commonly wrapped

with stucco netting and plastered with mud, lime-sand or cement plaster. In many cases, the netting has been found to be unnecessary, and plaster is applied directly to the bales.

Structural, fire, and moisture tests have been done on the system with great success, leading to easier code approvals. Several insurance companies have insured bale buildings (often at preferred rates), and bank financing is becoming available. The system is also gaining acceptance with HUD and Fannie Mae (a federal home loan program), as well as with large home building organizations as Habitat for Humanity. (www.strawhomes.com)

**2.22.9 Living Roofs technology**

The Archibio architecture group in Quebec as well as rammed-earth builder David Easton has updated the ancient sod roof of Europe with a concept called the "living roof." This type of roof has several advantages: it is an aesthetic feature, helps the house blend into its environment and provides climatic stabilization. While it is particularly useful in wet snowy areas, it has limited applicability in dry climates.

A living roof is built on top of a sufficiently strong frame with carefully applied waterproofing, as it is very difficult to locate leaks once the growing medium is in place. The living roof itself is a compost-based system, usually a base of straw left to decompose, within which native or introduced plants can then take root. The living roof will need ongoing tending, and it could be a fire hazard in hot dry climates. It also doesn't provide much insulation value when wet, which must be considered for heating needs. It is advantageous in that it protects the waterproofing from

damage by ultraviolet radiation, and precludes the need for tiles or other shingles.livingearth62@hotmail.com

**2.22.10 Rammed Earth technology**

Rammed earth is an ancient earth building technique currently undergoing a renaissance in the U.S. and abroad. It has been revived in France by CRATerre, in Australia by Giles Hohnen and others, while its main proponent is the U.S. is David Easton, author of *The Rammed Earth House*. Usually more expensive than conventional construction, this technique has been updated with improved engineering, sophisticated forms, and innovative design to make rammed earth competitive with conventional construction, even in earthquake-prone California. While rammed earth is in limited use in the U.S., builders in Western Australia have captured up to 20% of the housing market in many areas.livingearth62@hotmail.com

**2.22.11 Earth, Rammed**:

Soils with high clay contents are pulverized moistened and dumped into frames or formed into walls. Compaction is created by ramming. These buildings are allowed to sun dry. Structurally sound and weather resistant, these buildings survive for several hundred years or more note.

Rammed earth has the advantage of excellent thermal mass (which in some climates would be a detriment unless insulated) as well as strength, comfort and beauty. Rammed earth can be built with simple forms and tools with less handling than other earth building techniques, as the material cures in the wall, and can be built in a variety of climates. Walls do not need to be plastered and will last for hundreds, even thousands of

years (the Great Wall of China is partially built of rammed earth). It has been used to build structures of up to seven stories in Yemen.

First setting up forms on top of an appropriate foundation (usually stone or concrete), a soil mixture with a clay content of 20% and a moisture content of 10% is then rammed in layers or "lifts" of 6-8 inches using mechanical or hand tampers. Different soil types can be layered to create decorative effects and the whole is topped by a concrete bond beam which then holds the roof. Procedures are discussed in detail in The Rammed Earth House book.livingearth62@hotmail.com

Almost all these appropriate technologies can be applied in the dry countries, and dry other arid areas. Ghana has dry areas in almost every parts of the country especially from the central parts of the country to the northern parts of the country, and these technologies should be encourage and institute for the construction of houses and shelter. livingearth62@hotmail.com

**Appropriate / Alternative designs**

This simply refer to engineering perspective (structural designing, loading, stability, strength and durability), styles, sizes, shapes-plans (thus the architectural perspective) of a house to be build, that support sustainable construction and development. They greatly rely on local or community base expertise or knowledge for its delivery. Houses constructed with appropriate designs are environmentally friendly, socially and economic sustainable for both present and unborn generations. Both the structural designing (thus loading and members sizing) and architectural designing (drawings-plans, styles, sizes, shapes) are made to reduce construction cost greatly for an average Ghanaians to afford

(Schumacher, 1973 and Kibert, 1996), This in effect will help to close the gap of Ghana‟s huge housing deficit. According to Raynsford, (2000) designs, impacts the delivery of housing in a variety of ways. For example, the choice of designs type, materials and their applications has a significant environmental impact, depending on the sources of materials, their durability, and potential reuse, and this can first ensure environmental comfort but reduce the cost of housing to the extent that low- income earners can afford to own their own house with ease. On the other hand alternative /appropriate designs uses both appropriates technologies and the local available building materials for the delivery.

**Types of Designs**

Luxury/modern designs

Ultra modern designs

Standards/normal designs

Simple and smaller designs

Community/locally based designs (appropriate designs)

**Qualities of good appropriate designs**

Good designs qualities of every appropriate design are as followings:

| GOOD DESIGNS QUALITIES OF APPROPRIATE DESIGNS FOR SUSTAINABLE AND AFFORDABLE HOUSING |
|---|
| It must be locally or community based strategies |
| It must be economical and socially sustainable |
| It must base on appropriate technologies practices |
| It must protect the natural environment |
| It must uses renewable resources |
| It must uses recyclable resources |
| It must create a healthy and non-toxic environment |
| It must encourage maximization of resources reuse |
| It must encourage minimization of resource consumption |
| It must encourage restoration of damage or polluted environment |
| It must improve or make good the arid or dry environment |
| It must encourage cyclic construction processes instead of linear construction processes |
| Must depend on green building construction principles |
| It must always encourage waste minimization |
| It must reduce human exposure to noxious materials |
| It must encourages conservation of scarce materials |
| Must encourage the use of low –embodied energy materials |
| It must reduce energy in use in all aspect of construction |
| It must harvest rain water and conserve it for constructional purposes to reduce pressure on social water supply |
| It must protect water quality |
| It must be flexible in nature |
| Must ensure good sound and thermal comfort |
| It must encourage the re-use of old building materials |
| It must use salvage materials |
| It must always consider low energy designs |
| Designs building that will be cherished but affordable and sustainable |
| Must always ensure safety measures when designing and constructing |

| |
|---|
| Discourage the uses of foreign materials, technologies and styles for housing |
| Must encourage smaller and potable designs |
| Must choose low-maintenance buildings |
| Designs for future reuse adaptability |
| Avoid potential health hazards |
| It must encourage the renovation of older buildings |
| Encourage the use of solar energy and resources |
| Must situate buildings to benefit from existing vegetation |
| Avoid ozone-depleting chemicals and materials for construction |
| It must encourage the production, and selling of locally base materials for construction of buildings |
| It must encourage the use of natural ventilation instead of artificial means of ventilation |
| Minimize the use of pressure-treated lumber/timber |
| It must always be in safer and favour of future generations |
| It must design to preserve and conserve all resources |

The research review that the above strategies and practices can help achieves alternative/appropriate designs for sustainable affordable housing and development (Dincer, 2000, and Malik , 2002).

**2.23 Local and natural building materials that can be used for sustainable affordable housing in Ghana.**

Natural or local building has emerged as a response to an increasing demands and concern for our built environment (housing). Natural buildings or building with local accessible materials are an alternative to toxic substances (materials) which have led to widespread environmental degradation and illness. These techniques and approaches can be used to provide and promote simple delivery of houses to all Ghanaians and the world

at large, and to offer assistance to those seeking to simplify their lives by building their own homes, can use such techniques, with community help and local inexpensive materials (Kennedy, 2011). Examples are pozzolana cement, clay bricks, hydrafoam blocks, adobe, timber, bamboo and stabilized mud that already exist in Ghana which can be improve and used for housing that can cost low for the average Ghanaians.

**2.24 The following are list of some local building materials that can be used in Ghana:**

- Pozzolana cement
- Timber/wood
- Bamboo
- Thatch
- Stones
- Earthbags
- Mud brick
- Earthen floors
- Hemp and other fibres
- Natural plasters and finishes
- Paper blocks/fibrous cement
- Grass and poles/stick
- Plaster and board/timber
- Laterite
- Landcrete blocks
- Un burnt clay bricks
- Clay bricks

### 2.24.1 POZZOLANA CEMENT

The problem of inadequate housing in developing countries, which Ghana is among, has become a very critical one, particularly due to the increasing population, deterioration of existence material, and high cost of building materials ,especially cement, lack of affordable housing policies and less priority place on the use and the development of the indigenous or local materials. In Ghana, ordinary Portland cement is the major type of cement produced for majority of the country construction works (BRRI- Ghana, 1992).info@ghanacement.com.

According BRRI-Ghana, the country spends more than $120million annually to import the raw materials for cement production especially clinker. Consumption of cement will continue to increase because of increased activities of the construction industry. However, the price of cement is very high ranging between GH8.00 and GH9.50 per bag of 50kg, currently it is between GH18.00 and GH20.00. This and other factors have resulted in high cost of housing in Ghana, and it has created a worsening housing situation in the country. According to the 2010 housing and population census, the housing deficit of the country is about 1.7million (2010 housing and population census).

The need to reduce the excessive dependence on imported materials and rather concentrate on production and the use of durable local cementitious materials for housing delivery is therefore essential. This will greatly and drastically reduce the cost of the key building material and thereby making housing more affordable and will also support sustainable construction and development to majority of Ghanaians. One of such local base materials is pozzolana cement.

### 2.24.1.2 What is pozzolana cement?

Pozzolana cement, also known as pozzolana ash (pelvis puteolanus in Latin), is a siliceous and aluminous material which react with calcium hydroxide in the presence of water at room temperature. In this reaction insoluble calcium silicate hydrate and calcium aluminates hydrate compound are formed possessing cementitious properties. The designation pozzolana is from the primary deposits of volcanic ash used by the Romans in Italy, at Pozzudi. Nowadays the definition of Pozzolana encompasses any volcanic materials (Punice or volcanic ash), predominantly composed of fine volcanic glass, that is used as a pozzolana. (Pozzolan-Wikipedi)

Furthermore, Pozzolanic cement is a cement which consists of pozzolanic materials like fly ash, volcanic ash, pumicite, etc., a material which in the presence of lime and water will react hydraulically to form a cemented mass. It contains pozzolanic materials of 10-95% by weight. Pozzolanic cement can be made from 95 % recycled materials it provides many improved performance over OPC. (Ordinary Portland cement) It is generally used nowadays and it is less heat evolved when compared to OPC (www.wikkipia.com - what is pozzolana cement).

Ghanaian type of pozzolana cement is made particularly from clay materials as major materials or ingredient, hence the name clay pozzolana cement (US@ghanacement.com).

### 2.24.1.3 HISTORICAL USE OF POZZOLANA CEMENT

Pozzolana cement, such as Santorin earth was first use in the eastern Mediterranean since 500-400 BC. Although pioneered by the ancient Greeks, it was the Romans that eventually fully the potential of lime–pozzolana past as binder phase in Romans concrete use

for building and under water construction. They vigorously speak of four types of pozzolana cement: black, white, grey and red, all of which can be found volcanic areas of Italy, such as Naples. Typically it was very thoroughly mixed two- to- one, with lime just prior to mixing with water. The Roman port at cosa was built of pozzolana –lime concrete that was poured under water, apparently a long tube to carefully lay it up without allowing any sea water to mix with it. The three piers are still visible today, with the underwater portions in generally excellent condition even after more than 2100years (www.wikkipia.com -Historical use of pozzolana cement).

In Ghana, the Building and Road Research Institute(BRRI), has conducted an extensive research and came out with their funding that pozzolana materials can be produced mainly from clay and other additional materials like palm kneel shell ash, alkaline etc which are locally base raw materials in almost every district. They have also developed and established a plant for pozzolana cement production. The pozzolana cement is then blended with Portland cement to produce pozzolana cement. The institute aimed at producing affordable but durable cement, which will reduce the cost of housing in Ghana. The plants and facilities developed for production has capacity of 1, 200,000 bags of pozzolana cement annually (BRRI, Ghana).

**2.24.1.4 The main targeted groups/clients likely to patronize the products are:**

- District assemblies of Ghana
- Building contractors
- Estate developers
- Individuals that have interest to use the product (BRRI –GHANA).

### 2.24.1.5 Pozzolana cements an Ideal Cost Saver in the Construction Industry for Ghanaian.

Once it is fully hardened, the Portland cement-pozzolana blend may be stronger than Portland cement, due to its lower porosity, which also makes it more resistant to water absorption and spilling. It improves the workability of mortar and concrete, reduces the heat of hydration, bleeding and segregation of concrete and it's an environmentally safe and a natural resource of Ghana. It is cost- effective because it is an alternative it competitors cement, the cement can replace about 40% of ordinary Portland cement (BRRI- Ghana).

### 2.24.1.6 Reasons to adopt and promote pozzolana cement for construction in Ghana.

Ghanaian Pozzolana cement has been developed and approved by the government as a new construction material, perfect for any type of building. The Ghana Building and Road Research Institute (BRRI), conducted extensive research and development activities on the production of pozzolana cement from clay and has exclusively licensed Pozzolana Ghana Limited (PGL) to produce pozzolana cement for building materials.

In light of the critical housing shortages and the rising need for quality construction in Ghana, pozzolana provides a cost-effective alternative to the steadily increasing cost of cement. Pozzolana provides additional strength, protection against water damage and corrosion, and drastically reduces the cost of construction when compared to OPC and other types available. (BRRI, Ghana)

### 2.24.1.7 Some facts about pozzolana cement for construction

- Pozzolana can replace up to 40% of OPC in cement.
- It can reduce the cost of cement by as much as 20%.
- Can be used in all types of construction.
- It improves the technical properties of cement.
- It reduced setting times.
- It can reduce imports (clinker and gypsum) by saving the country about $120,000,000 for purchasing clinker and other products annually (BRRI, Ghana, 2003).

### 2.24.1.8 Benefits of Using Clay/ Natural Pozzolana Cement For Construction Activities

**Lithification:** Once the Natural pozzolana-lime mixture is hydrated, the pozzolanic reaction begins immediately and continues for many years. Eventually, the mass will reach complete lithification, forming a rocky material with some content of magnetite. The compressive strength as well as the flexural strength will continue to increase for a long time. This unique characteristic is one of the main reasons many great ancient structures have lasted for over two thousand years.

**Autogenous Healing:** A unique characteristic of Natural pozzolana is its inherent ability of pozzolanic reaction with the calcium hydroxide freed from the cement hydration reaction. This results in the filling up of most of the gaps inside the hardened concrete matrix

**Reduced Permeability and Voids:** The leaching of water-soluble calcium hydroxide produced by the hydration of Portland cement can be a significant contributor to the formation of voids. The amount of "water of convenience" used to make the concrete workable during the placing process cretes permeable voids in the hardened mass. Natural pozzolana can

increase the fluidity of concrete without "water of convenience," so that the size and number of capillary pores created by the use of too much water can be minimized.

**Reduces Expansion and Heat of Hydration:** Experiments show that replacing 30% Portland cement with Natural pozzolana can reduce the expansion and heat of hydration to as low as 40% of normal. This may be because there is no heat produced when Natural pozzolana reacts with calcium hydroxide and that the free calcium oxide in the cement can hydrate with natural pozzolana to form C-S-H. Natural pozzolana decreases the heat generated by cement hydration and delays the time of peak temperature. The graphic patterns of Natural pozzolana - Portland cement mixture is extended longer and lower to form a much more moderate curve than the heat of hydration curve of Portland cement itself.

**Reduces Creep and Cracks:** While concrete is hardening, the "water of convenience" dries away. The surface of the hardening mass then begins to shrink as the temperature goes down from outside. This results in the formation of creep and cracks. Natural pozzolana moderates the expansion and shrinkage of concrete. It also helps to lower the water content of the fresh concrete. Therefore, the creep and cracks can be significantly reduced without the process of water cooling.

**Reduces Micro cracking:** The expansion and shrinkage mentioned above also create micro cracks inside the hardened C-S-H paste and in-between the aggregate and the C-S-H paste. These microcracks significantly contribute to concrete permeability as well as other concrete defects. The Natural pozzolana- Portland cement mixture expands these shrinks so moderately that there is no micro cracking inside the C-S-H paste after drying.

**Increases Compressive Strength:** The pozzolanic reaction between natural pozzolana and calcium hydroxide happens after the C3S and C2S in the cement begins to hydrate. At the early stage of curing, 30% Natural pozzolana substituting Portland cement mixture is slightly lower than reference OPC [Ordinary Portland Cement} in regard to compressive strength. As time goes by, natural pozzolana continues to react with the calcium hydroxide produced by cement hydration and increases the compressive strength by producing additional C-S-H. After 21 curing days, the 30% Natural pozzolana/ 70% Portland cement mixture begins to exceed reference OPC in compressive strength. After 28 days, it exceeds reference OPC by about 15%. The pozzolanic reaction continues until there is no free calcium hydroxide available in the mass and the compressive strength exceeds the reference OPC by 30-40%.

**Increases Resistance to chloride Attack:** Concrete deterioration caused by the penetration of chloride occurs quickly when chloride ions react with calcium. The expansion of hydrated calcium oxy-chloride enlarges the micro cracks and increases the permeability that causes quicker chloride penetration and more damage from freezing and thawing action. The 30% Natural pozzolana added into cement can react with almost all the free calcium hydroxide and form a much denser paste. Thus, the penetration of chloride can be minimized and the few penetrated chloride ions cannot find free calcium hydroxide with which to react.

**Increases resistance to sulfate attack:** There are three chemical reactions involved in sulfate attack on concrete: 1) Combination of free calcium hydroxide and sulfate to form gypsum (CaSO4-2H2O). 2) Combination of gypsum and calcium alumina test hydrates (C-A-H) to form ettringite (C3A-3CaSO-32H2O). 3) Combination of gypsum and calcium carbonate with C-S-H to form thaumasite (CaCO3-CaSiO3-CaSO4-15H2O). All these reactions result in the

expansion and disruption of concrete. Thaumasite in particular is accompanied by a very severe damaging effect which is able to transform hardened concrete into a soft mass.

**Reduces alkali-aggregate reaction:** Because Natural pozzolana is shattered into such a fine particle size resulting in dramatically increased reactive surface area, it can react quickly with calcium hydroxide and can trap the alkali inside the cement paste. Thus, it helps to form a denser paste with almost no alkali aggregate reaction at all.

**Protects steel reinforcement from corrosion:** The preceding discussions make it very clear that concrete made from 30% Natural pozzolana/ 70% Portland cement mixture can protect steel reinforcement because it creates an environment so densely packed that no liquids or gases can penetrate through it to cause corrosion to the steel.

**Increases abrasion resistance:** Natural pozzolana increases the compressive strength of concrete and makes the concrete matrix stronger and denser. It also prevents the formation of pulpy or softy, crispy, or water-soluble materials created by chemical attack. Therefore, it helps the concrete to durably resist abrasion.

**Lowers water requirement with high fluidity, self-leveling, and compression:** In normal operations, the bulk volume of concrete in the constructions are placed and compacted by use of high frequency poker vibrators. The rapid vibration induces segregation phenomena of all orders of magnitude in the fresh concrete, e.g., stone segregation, internal bleeding giving bonding failures, and inhomogeneous cement paste and air-void systems. Under proper use of vibratory compaction, Natural Pozzolana minimizes or eliminates these problems due to the amorphous structure of the pozzolana particles.

**Improves Durability:** The benefits and characteristics of Natural Pozzolana mentioned above clearly explain why the ancient structures built by the Greeks have survived over 2000 years of weathering (BRRI, Ghana).

### 2.24.1.9 Use of clay pozzolana

A lot of successful projects have been enhanced with pozzolana cement for Ghana, including the following:

- Sandcrete blocks
- Floor beds
- Pavement blocks
- Rendering and plastering
- Culverts
- Kerbs
- Drains
- Biogas tanks (BRRI-GHANA)

**Fig. 2.7 typical structures at Accra build with Pozzolana Cement**

**Source: info@ghanacement.com – June, 2014 GNA**

**2.25 The use of Bamboo as local building materials**

Bamboo is the largest of the grass family of plants. It grows very quickly, providing renewable material for building, tools, and utensils as well as edible shoots. Common in the tropics (Africa), many species of bamboo grow in temperate climates as well. Strong and beautiful, bamboo has seen a recent resurgence in popularity with builders (Kennedy, 2011).

Bamboo as a building material is not commonly known in some areas, because of limitations on the import of living plants, lack of knowledge of traditional techniques, and because there are so few native species. This ignorance is beginning to change, however, as timber prices rapidly escalate, and even western builders become aware of innovative uses of bamboo that have originated in Africa, Asia, Central America and South America (livingearth62@hotmail.com).

On Africa continents, bamboo is often used, as the western countries uses wood and steel, for structural purposes. It can replace rebar in certain concrete applications, be used as pins in straw-bale construction, to create trusses and other structural members, as decorative elements, and has even been used as plumbing. In Ghana particularly, bamboo as a local and sustainable building materials are available in almost every district. They are greatly use as floor propping, roofing trusses and as reinforcement agent for traditional or natural building housing (use as post members).

**2.26 Earthbags**

Earthbags are soil-filled fabric sacks or tubes used to create wall components and domes. Commonly used for flood control and by the military to create bunkers, this method of construction has been recently turned to a variety of natural-building purposes. This technique has been used by Gernot Minke of Germany and is currently being pioneered in the U.S. by Persian architect Nader Khalili of the California Institute of Earth Art and Architecture (Cal Earth), who has dubbed the technique "super adobe." The use of earthbags is still in its infancy, but holds much promise as a quick, easy and forgiving technique which uses minimally-processed soil and few tools. To build with this technique, moistened soil is placed into a bag set in place on the wall; the bag is lowered into place, then compressed using a hand tamper.

Heavy earth mixtures can be used with weaker burlap bags as the compressed soil makes the bags redundant once it sets, while stronger, structural polypropylene bags are preferable for sandy soils. The polypropylene deteriorates with prolonged exposure to sunlight, so it is important that the structures are plastered quickly. Long tubes of the bag

material are filled and stacked like a coiled ceramic pot. Recycled sacks are often available free or at minimal cost.

**2.27 Earthen Floors**

The use of tamped or poured earth mixtures to create floors is currently undergoing a renaissance in the Southwest U.S (Kennedy, 2011). In Africa it is still use in some of which Ghana is among, it is common at some rural areas. It consist of palm fronts or raffia fronts, bamboo and sometime timber, which are used to form a decking to receive earthen bales form in between the space created until it dries to support itself. These floors can provide an excellent source of thermal mass in passive solar designs. Methods range from the African use of fresh cow dung sealed to earth mixtures sealed with linseed oil and beeswax as additives to enhance the floors.

The technique involves pouring or tamping one or several layers of an earth mixture over a substrate of gravel, pumice or sand (a sub layer of straw-clay has also been used for insulation by builder Robert Laporte). Hardening agents such as lime, cement or glue may be added. This mixture is allowed to dry and any cracks are filled with more mud mixture.(Kennedy, 2011).

**2.28Thatch**

The use of reeds, grasses, palm fronds or raffia fronds as a roofing material is still common in Europe and many southern countries. In Africa it is of greatly use mostly in the rural areas. It is very common in use in Ghana especially in the coastal and northern part of the country. This "natural" roof is of increasing interest to builders seeking an alternative to

industrial roofing methods. Thatched roofs, if well built, can last up to sixty years, and provide a pleasing counterpoint to many of the wall systems. (Kennedy, 2011).

**2.29 Wood**

Wood is an ideal building material, strong, easily worked and beautiful. It is the most widely used material for building construction in the world. It is light, durable, strong and easily managed. Woods range widely in density and durability. Its major disadvantage is that its use is unsustainable, with current clear-cutting practices leading to widespread deforestation and this really against environmental protection. Natural builders are seeking alternatives to conventional stick-frame construction, where wood is used indiscriminately, and have begun to use wood in new ways, thus is replanting immediately they are cut down, learning to recycle them for reuse etc.

Building with exposed timber-frames surrounded by materials such as straw-clay or straw bales can take advantage of the beauty and structure of wood while eliminating its unnecessary use. In addition, increased popularity of non-wood construction systems can lead to reduced wood use and ecosystem rehabilitation.

Appropriate timber use is closely tied to sustainable forestry practices. Selective cutting can provide ongoing sources of material while saving delicate ecosystems. Using smaller diameter or UN milled lumber can save large old-growth trees; innovative uses of non-traditional species or young, second growth trees can also be an effective strategy (Kennedy, 2011). Ghana has a large forestry reserve, for about two decades ago, but due to indiscriminate cutting down of trees by chain saw operators for both construction activities and commercial purpose by exporting it for money, has led to rapid depleting of these forest

reserves. The way forward is to grow faster growth timbers like other develop country (Brazil, Australia etc) has done to save or reserve our rich forest, and government must also enact strict laws against the illegal cutting of lumber from the both reserve and unreserved forest (livingearth62@hotmail.com)

**2.30 Hemp and Other Fibers**

Hemp and other fiber-producing plants are currently being investigated as potential building products. Commonly used for numerous purposes before drug laws made its cultivation illegal, non-psychoactive hemp is being rediscovered as a source of fiber, oil, and hurd; these can replace less ecologically sound wood or petrochemical products in a variety of building applications.

Examples include a company using hemp to create a pressed board product to replace plywood, and another which uses the inner pith or "hurd" as an additive for a lime-based concrete-like material.(Kennedy, 2011)

**2.31 Natural Plasters and Finishes**

Before the advent of Portland cement, most earthen and masonry structures were protected by mud- or lime-based plasters. While still common in other parts of the world, lime and mud plasters are relatively rare in the U.S. The advantages of these plasters include breathability, softness to the touch, aesthetic qualities, workability and easy reparability, as well as economy of materials. Because they can erode unacceptably in wet vicinities, exterior mud plasters are generally used in drier climates or with wide overhangs of roofs to avoid it eroding or wearing away especially in wet seasons.

Less brittle than cement-based plasters, those based on lime or mud adhere and "move" with the underlying wall, lessening cracks and often making stucco netting unnecessary (wire mesh). They have fallen into disuse in the U.S. and other part of the world because of their disadvantages: slow curing times, the need to renew them every several years and discrimination against their use by some building codes. Proper lime putty traditionally used for building is unavailable in the most part of the world, forcing builders to rely on the much-inferior dried hydrated lime and sometimes depend on other conventional building materials (Kennedy, 2011).

Ghanaians can also develop interest to adopt these systems because it performance overcome some limitations of cement-based plasters and above all support sustainable development and construction.

**2.32 Paper Blocks/ Fibrous Cement**

Printer Eric Patterson of New Mexico rediscovered a use of waste papers. He re-pulps this paper and mixes it with cement, making lightweight, strong and easily-worked paper blocks. Builder Mike McCain is currently advocating the system with low-tech mixers and block-making techniques which can greatly speed the building process. His mixture has also been used to plaster earth bag domes and some walls types. While most recipes call for as much cement as is used in a solid concrete wall, some practitioners are experimenting with clay as a binder to make a lightweight earthen wall. These walls can be extremely susceptible to water damage. Concerns also include flammability with some examples having burned, and the effects of freeze-thaw. (Kennedy, 2011). In Africa at large and in Ghana such materials

and techniques are not common to be use however, it could be research into and practices, since it is affordable and also support sustainable development and construction.

**2.33 Mud brick**

This is different from the normal bricks in that it is made from puddle mud which is later gathered, molded and sun dried. It is durable enough for light load bearing and can be carved fairly easily after drying. All external walls using this material are covered with linseed oil to help prevent weathering. This makes a poor brick in areas with extreme weather, but this challenge can be avoided by providing long overhang roofs over the walls (livingearth62@hotmail.com).

**2.34 Grass and Poles/Sticks**

Popular in very dry areas or countries, these constructions consist of poles and sticks interwoven with grasses and branches to form small structures. Often times these structures are recessed into the ground several feet or more to avoid it deteriorated by wet conditions and also be affected by insect‟s attacks. Policies by governments and non-governmental organizations to adopt these traditions which could be of great help, in terms of insuring the sustainable world with sustainable affordable housing.

**2.35 Plaster & Board/Timber**: Wooden structures are covered in a moistened mud, clay or soil for added protection and insulation. Mud and clay plasters are only use in drier climates. It is recyclable and sustainable in nature.

**2.36 Stone**

Limestone, marble, granite, sandstone and other durable rocks are used for construction. These rocks are altered and polished for specific needs and come in almost any shape imaginable. They are load bearing and durable often lasting thousands of years or more. Stone is used as facing, for internal support and augments or is augmented by brick and timber constructions. It is sustainable building materials, easy to obtain and require little techniques for its usages (Kennedy, 2011). Stone as a local material can almost be obtain in every region of Ghana, it‟s had been already been use for construction of some houses in several areas, like Akywea mountains in Ashanti region of Ghana, it is also use as a composite material for fence walls in several cities in the country, as a decorative materials for ashlars and external walls, for construction of some churches in the urban areas, for roads construction, for bridges and for a gabion retaining walls construction as a sea defense structures. However, no frame work and policies by governments and stakeholders have been issue about it usages and also to create it awareness to the public concerning the importance of the material. (livingearth62@hotmail.com).

# CHAPTER THREE

# RESEARCH METHODOLOGY

## 3.1 Introduction

This chapter seeks to describe the methods that were adopted to realize the aim and the objectives of this study. The methods the chapter places emphasis includes, the study design that was used to plan the study, how data was collected for the research, the study population for the research, the sample and sampling techniques for the research, the research instruments adopted, the data analysis and procedures that were used to discuss and present the results, and finally, talked about the limitations faced by the researcher.

As noted earlier in chapter one, the aim of this research, and generally, to achieve the aim of a study, one of the important areas to consider is the kind of method that is adopted (Naoum, 2001). For this reason, the research methodology adopted in this study is in two distinct phases, but corresponding to each other. The two phases upon which these methods were applied to are;

• Preliminary phase; and

• Second phase

Information on housing sustainability, affordability and sustainable development was gathered from literature and the sources of the reviewed. The literatures were sourced in two means for the study, and they are:

Primary source

Secondary source

• Primary source: This includes review of published materials including framework policy documents, government publications on housing delivery in Ghana, newspapers, internet, journals, articles and reports on sustainable construction and housing affordability delivery.

• Secondary source: This includes textbooks on sustainable construction and development, construction technology and practices.

### 3.1.1 The Preliminary Phase

The Preliminary phase was to recognize, and analyze the deeper understanding of methods and processes related to the achievement of construction of housing sustainability, affordability and development through the use of appropriate designs and technologies. The purpose was to improve on better understanding of the theories and processes regarding the sustainable affordable housing in the construction industry and at the end help the researcher to meet the objectives stated.

### 3.1.2 Second Phase

The second phase of the study, the researcher considered and explored on all the methods and research procedures that will be used to conduct this research. The methods and procedures include:

- Scope of study area
- Target population for the study

- Study designs employed
- Data collection techniques
- Sample and sampling procedures
- Research instruments
- Data analysis, processing and presentation.
- Reliability
- Validity

In order to secure effective and reliable data to address the purpose of the research at this phase, the methods and research procedures employed for the study were significantly selected.

**3.2 Scope of research area**

The research was undertaken throughout the country, thus Ghana at large to capture the needed data and information for the research under study.

The study area was chosen because the researcher wants the findings to be implemented and to benefits the entire country. The geographical location was also selected due to time constraint for the study and the researcher deems it important to use the whole country instead of zoning the country into several parts. And also wants to study the housing challenges in the country holistically not in fragmented to reduce the housing deficit to some extent in a collective manner.

### 3.3 Target Population for the study

For the benefits of the topic under study, the research population used made up of building professionals all within Ghana, and public institutions. For the building professionals, it comprises of registered Ghana institute of Architects (GIA), Structural Engineers, and Ghana Institution of Surveyors (GIS). These respondents are selected because Kumar et al., (1993) has indicated that the selections of key respondents are generally based on those who have knowledge about the problem and subject area being researched into. Indications are that their responses will minimize response error.

In this study Ghana Institute of Architects (GIA), were selected because it has been established by fact that architects assist clients to realize their dreams by being in charge of projects from inception to completion of projects, they have broader knowledge of construction of buildings and are responsible for supervision of project. Also Most structural engineers have the widest exposure to construction projects, and are involved in various project phases including determination of structural loading, initial planning of projects, designing structural members, construction and selection of materials, technologies and advice on designs before implementation. They have a quota to play in realizing the achievement of housing sustainability and affordability in Ghana. Quantity surveyors roles are the determination of project cost and determination of any financial matters with regard to the projects at hand and finally advice on cost of various housing delivery, hence their role are unambiguous and necessary.

The Private institutions such as the Ghana Building and Road Research Institute (BRRI-Ghana) and Habitat- Ghana were considered, by the researcher to capture the needed data for the study at hand. The Ghana Building and Road Research Institute (BRRI-Ghana)

and Habitat were selected because of their wide experience in the delivery of affordable housing for Ghanaians and their advocating for the use of local building materials available (clay bricks, clay pozzolana cement etc.) for construction of affordable housing for Ghanaians over the years, and this support sustainable construction and development, hence the reasons to include them to secure the needed data for the research.

### 3.4 Study Design

The research design that was employed to plan the overall research and to obtain answers to the research questions and to achieve the aim and the objectives of the research was both qualitative and quantitative paradigms (mixed method). Mixed method approach is as a type of research where the researcher combines quantitative and qualitative research techniques, approaches, methods, concepts into a single study (Johnson and Onwuegbuzie, 2004).

### 3.4.1Quantitative Design

The quantitative approach employed a descriptive survey for the study. According to Gay (1992), descriptive survey involves the collection of data in order to test hypothesis or answer research questions concerning the correct status of the subject of study mostly through the use of questionnaires or interviews means.(Agyedu, Donkor and Obeng, 2011) also described descriptive research, as a research involving describing, and analyzing conditions as they exit. It seeks to gather information so that a description of what is going on and can be made, since this particular research also seek to find out or gather information about the use of appropriate designs, appropriate technologies and the use of local available building materials to provide sustainable affordable housing for Ghanaians. The researcher also seeks to make

judgment or evaluate the effectiveness, relevancy, efficiency or desirability of the previous technologies, materials, designs approaches and policies for the provision of the already affordable housing delivery in the country.

Descriptive survey design was also chosen because the study interprets, synthesizes and integrates data, points to implications and interrelationships. Furthermore the method has advantage of producing a good amount of responses from a wide range of people or population (Osuala, 2001), hence the use of descriptive survey design for the research under study.

Questionnaire will be used as a data collection tool to collect perceptive and factual responses (Naoum, 1998).

### 3.4.2 Qualitative Design

Qualitative research is an enquiry process of understanding based on distinct methodological traditions of enquiry that explores social or human problem (Creswel, 1998). The purposes of employing qualitative research is that it‟s more open-ended where the respondents express their own views on issues more than quantitative approaches where more closed-ended items are used(Creswell, 2005). Qualitative data help researchers to understand processes, especially those that emerge over time, provide detailed information about setting or context, and emphasize the voices of participants through quotes. Qualitative methods facilitate the collection of data when measures do not exist and provide a depth understanding of concepts (Johnson, Onwuegbuzie and Turner, 2007). According to Maxwell (1996), the qualitative research model has a number of strengths which provide a suitable framework for achieving research goals.

The qualitative approaches such as interviews, narrative, and observation were used to secure the data not captured in the quantitative approaches and was also used to validate results and findings obtained by the quantitative methods.

### 3.4.3 Justification for using mixed method design

Qualitative and quantitative data are intimately related to each other. On the contrary to the notion that one of the methods is better than the other, both qualitative and quantitative methods rely on systematic empirical evidence and observations. They are both used in evaluation to improve validity of measurement which enrich judgment and interpretation of program or policy been evaluated (Fitzpatrick, Sanders and Worthen, 2004). Creswell (2005) indicated that the idea of combining different methods probably originated as far back as 1968 when Campbell and Fiske used multiple methods to study the validity of psychological trails. Since then, mixed methods have been used in research activities in various fields including education and the industries.

## 3.5 Data Collection Techniques

Data collection is a term used to describe a process of preparing and collecting data and the purpose of these processes is to obtain information to keep on record, to make decisions about important issues, and to pass information on to others (Imbeah, 2012).

Data for conducting this research was collected through primary data and secondary data techniques.

The primary data for the study were obtained from questionnaire survey, interviews guide, and observation guide. This questionnaire developed were distributed and retrieved in

person not by mailing from the constructional consultancy firms in Ghana. The questionnaire was distributed and retrieved in person with the reason to make sure that the questionnaire get to the intended recipients and also help to collect as much as possible for the research. On the other hand structured interviews were considered for some selected firms and BRRI of Ghana to secure adequate information for the research. Personal site observation was also conducted on some selected sites to obtained data for the research.

Secondary data was obtained through statistical department of Ghana reports on housing and population census 2000 and 2010, government publications on housing.

Out of the 156 questionnaires distributed, 71 were returned .However, 15 were found to be invalid and were discarded for the analysis as a result of improper filling, remaining 56, representing an effective response rate of 36%. This response rate is considered adequate as, according to Idrus and Newman (2002), and Oladapo (2005), a response rate of 30% is good enough in construction studies or the construction industry.

## 3.6 SAMPLING AND SAMPLE PROCEDURES

Probability and non-probability sampling procedures was employed to select sample that will represent and exhibits characteristics possessed by the target population of this research. The procedures include simple random sampling techniques, and purposive or judgmental sampling techniques.

With the probability sampling, simple random procedures was applied to select randomly to select respondents such as Ghana institute of architects (GIA), Structural Engineers and Ghana institution of surveyors (GhIS) from the building professionals of the

construction industry. This method was used because the method will gives all elements in the population an equal chance of being selected from the population and avoid sort of bias (Agyedu et al, 2011 p.97).

Purposive sampling or judgmental sampling approach on other hand was employed to sample items from the public institution such as BRRI, and some construction sites to secure the needed data for the study at hand. Specifically data was secured through interviews and personal observation on sites under this sample sizes. Here the sample for the research was chosen arbitrary on the basis of some characteristics possessed by the subjects and deemed important for the research. Thus certain elements of the population were deliberately selected on the judgment of the researcher (Agyedu et al, 2011 p.101). Hence the application of this technique.

### 3.6.1 Sample Frame determination

According to (Neumann, 2007) Sample size is defined as a subset or proportion of the total population, which indicates the characteristics or items a researcher ought to study.

To determine the minimum sample size of building professionals (architects, structural engineers and quantity surveyors) across the country, Kish (1965) formula which gives a procedure for calculating minimum sample size was applied.

The sampling frame for the study was 251 consultancy firms of various classifications. These members were obtained after the list had been screened to eliminate new members and non-active members (Kish, 1965 as Cited by Imbeah, 2012, Isreal, 1992). The table 3.1 below shows the details of sample frame or the study population.

**Table 3.1 Registered construction consultancy firms across the country**

| Architectural firms | Structural Engineers firms | Quantity Surveying firms | Total |
|---|---|---|---|
| 171 | 5 | 75 | 251 |

Source: MWRWH (April 2014)

The sample size was deduced from Kish (1965) formula; the equation is shown as calculated below-

$$n = \frac{n'}{\left\{1+\left(\frac{n'}{N}\right)\right\}}$$ Where

n = Sample Size from finite population

N = Total Population

n′ = Sample Size from infinite population calculated from; $n' = S^2 / V^2$, Where

V = Standard error of sample population equal to 0.05 for the confidence level 95%, t = 1.96

$S^2$ = Standard error variance of population elements,

$S^2$ = P (1 - P); Maximum at P = 0.5.

The sample size of the Architectural firms with good standing can be calculated from the afore mentioned equations as follows;

$$n' = \frac{S^2}{V^2} =$$

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

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

$S^2$= 0.5×0.5

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

Where P = 0.5

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

$S^2$= 0.25

To find $V^2$, let $V$ =0.05 level of confidence.

$V^2$= $(0.05)^2$

$V^2$= 0.0025

$\therefore\ n' = \frac{S^2}{V^2} = \frac{0.25}{0.0025}$

$n'$= 100

Architectural firms

n (Architectural Firms with good standing) = $\frac{100}{\{1+(\frac{100}{171})\}}$ = 63 Firms across Ghana.

Structural Engineers firms

n (Structural Engineers Firms with good standing) = $\frac{100}{\{1+(\frac{100}{5})\}}$ = 5 Firms across Ghana.

Quantity Surveyors firms

n (Quantity surveying Firms with good standing) = $\frac{100}{\{1+(\frac{100}{75})\}}$ = 43 Firms across Ghana.

Therefore the total minimum sample from population as calculated is as follows, thus 63 + 5 + 43 =111

Assume a non response rate of 40% to overcome a low response that threatened to disturb the consistency and the benefits of the study (Enshassi et al., 2007). The adjusted sample size taken into consideration non response was

$\frac{140}{100} \times 111 = 1.4 \times 111 = 156$

The samples sizes for the three respondents were calculated as follows:

n Architectural firms = $\frac{171}{251} \times 111 = 76$

n Structural Engineers = $\frac{5}{251} \times 111 = 2$

n Quantity surveyors = $\frac{75}{251} \times 111 = 33$

The samples from the total population are better presented on table 3.2 below

Table 3.2 Sample size for each registered construction consultancy firms across the country

| **Architectural firms** | **Structural Engineers firms** | **Quantity Surveying firms** | **Total** |
|---|---|---|---|
| 76 | 2 | 33 | 111 |

Source: Field survey, April, 2014

Table 3.2 shows that a total of one hundred and eleven (111) respondents were sampled for the information used in the study, however a total of one hundred and fifty six (156) sample frame after the adjustment of 40%, was adopted to gather information for the research under study.

### 3.7 Research Instruments

The researcher, for the purpose of this study and to gather the needed data, the research instrument employed was field survey, interviews guide and observation guide (Kumar, 2005).

Field survey technique was considered by the researcher through which questionnaire was administered and collects quantitative data for the study. This was conducted to obtained response mostly from the literate respondents. The open- ended interviews and non-participant observation was also used to secure qualitative data as well as cross-check and validate the findings of the quantitative data. This was also used to collect data from the population where majority of its element are illiterate which will not be easier to used quantitative instrument like questionnaires to collect data.

#### 3.7.1 Field survey

The survey participants in this study are Ghana Institution of Architects (GIA), Structural Engineers, and Ghana Institute of Surveyors (GhIS).

With the field survey, questionnaire questions (items) were administered to be answered by the building professionals such as Ghana Institute of Architect (GIA), Structural Engineers, and Ghana Institution of Surveyors (GhIS).

According to Agyedu et al. (2011), Questionnaires are useful for large-scale survey involving collections of data from literate respondents, hence the adoption of this technique by the investigator. The data collection instrument was used to find response and solutions to answer the objectives questions one to three.

### 3.7.2 Interviews

In order to obtain adequate information about housing sustainability and affordability in Ghana, 6 open- ended interviews were conducted (Agyedu et al, 2011 P.108). To learn about firms and building professional‟s perception and effort on housing sustainability, affordability, their technologies and designs and develop a framework policy for cyclic construction process. It was extended to the BRRI of Ghana. The following questions were asked: what are the factors affecting the achievement of the sustainable affordable housing in Ghana? What practices would you adopt to facilitate sustainable affordable housing in Ghana? What, in your own opinion is housing affordability means? What, in your own opinion are appropriate technologies and designs for housing? What do you see as barriers affecting sustainable affordable housing in Ghana? This technique also will be chosen to clarify any ambiguity which might be in the questionnaire delivered to collect quantitative data.

### 3.7.3 Observation

The non-participant observation approach was also used, to capture data which might not be collected by the alternate data collecting techniques and instrument used. This research instrument will be employed because people sometimes behave abnormally in the presence of an observer or an investigator, and this has to be taken into account in this manner (Agyedu et al, 2011). Purposive samplings techniques was conducted to select some construction

companies, sites and other geographical areas within the country to conduct a study to find out the types of structures Ghana adopts or dominate in Ghana, the type of construction materials used and to also find out actual practices on the ground with regards to housing sustainability and affordability situation in Ghana.

### 3.8 Data Analysis, Processing and Presenting.

Statistical package for social scientist (SPSS.16) was used to analyze the data retrieved from the survey thus in the quantitative data, and on the other hand tables and pictures was also used to analyze and present the qualitative data from the interviews and observation guide. Measurement for reliability was done to determine the measurement scale that had been developed. This would produce consistent results if measurement is done on a repeated basis. This study utilized internal consistency method in determining the instrument reliability with the Cronbach coefficient, Alpha, as the relevant coefficient to evaluate. Content validity was determined by consultants and academician to check the accuracy of the items under each Construct in the questionnaire developed.

#### 3.8.1 Processing and Analyzing Quantitative Data

Prior to analyzing quantitative data, a prescribed checklist must be followed? This include: assigning numbers to instrument; giving each entry a name; entering them into relevant statistical package; producing a simple two way matrix of variables versus responses; giving respondents serial numbers to ensure there is no mix-up; and coding the data to allow for statistical analysis. The processing routine will be determined by the nature of the data collection technique, the size of the survey, the composition of the questionnaire, the processing facilities available and the requirements of the computer software package to be

used in the analysis (Bryman, 2004). Agyedu et al., (2011), suggest that after collecting the research data, an analysis is necessary to facilitate the interpretation of the results and the drawing of conclusions. He argued that the purpose of analyzing data to make meaning out of the data collected vis-à-vis the research problem at hand. Without proper analysis, the data collected would be a meaningless heap of information.

Descriptive statistics such as frequencies, percentages, mean and tables presentations was used to summarize information from respondents to identify the dominate housing delivery schemes that existed in Ghana, available local building materials that can be adopted to improve our systems and also to identify the most appropriate designs and technologies for achieving the goal of sustainable affordable housing in Ghana.

Principal Component Analysis (PCA) was adopted to reduce the number factors or major problems associated with the existing housing delivery schemes, and how it‟s preventing the achievement of sustainable affordable housing in Ghana. The analytical tool was also employed to condense or summarize the number of factors of good designs qualities to achieve houses that are sustainable, affordable for the average income Ghanaian to afford or own. The tool was also employed in order to reduce the number of the items in to small components or sets to explain the original set of variables and also to enhance suitable presentation for easy interpretation and understanding of results (Hinton, Brownlow, McMurray and Cozens, 2004). Kim and Mueller, 1978; Imbeah, 2012), suggested that KMOs must be used to screen the presence of correlation among the items and then appropriateness of factor analysis. The range of 0.5-0.6 are considered poor, those in the range of 0.6-0.7 are average, those in the range of 0.7-0.8 are considered good, 0.8-0.9 are great and values greater than 0.9 are excellent. From Appendix C most of the KMO values obtained are greater

than 0.7 which indicate that the data is adequate and appropriate for factor analysis. See Appendix C

On the other hand inferential statistics like Analysis of variance (ANOVA) one way was used to establish the relationships, differences etc. between some variables (Hinton et al., 2004). Thus, the relationships between construction firms in Ghana and their designs, technologies, and materials adopted for construction of housing and relationships of respondents and their awareness on the housing sustainability in Ghana to promote sustainable development.

### 3.8.2 Processing and Analyzing Qualitative Data

Methods of collecting qualitative data results in a large quantity of unstructured textual material hence are not simple to analyze (Bryman, 2004). According to Kusi (2012), qualitative data deals with descriptions and meanings rather than numbers in quantitative data. It occurs in a variety of forms, including interviewing, observation, documentary materials, newspaper reports, field notes, pictures or visual data and others graphical representation. Two basic methods of analyzing qualitative data are Analytical Induction and the Grounded Theory, though others exist such as Content analysis and Narrative analysis. Narrative analysis has however been introduced in qualitative data analysis as an approach to curb the main limitation of the grounded theory (Bryman, 1988). The data collection techniques used was through structure interviews and non participant‟s observation. For the purpose of this research, tables, pictures, and narrative analysis were used to analysis the qualitative data from interviews and observation and present results.

### 3.9 Reliability

Reliability of an instrument concerns its consistency of measurement. Thus reliability refers to the extent to which an instrument measures the same way each time it is used under the same conditions with the same subjects (Agyedu et al., 2011). According to Zhang, et.al., 2000), reliability is a statistical tool to measure how reproducible the surveying instrument data is. Four methods are used in measuring reliability namely; the test-retest, equivalent form, interscorer and internal consistency methods (Agyedu et al., 2011). For the purpose of this research internal consistency this method was employed, because it is the most widely used reliability tool, and it requires simple administration (Zhang, et.al., 2000); Agyedu et al., 2011).The internal consistency of each factor was determined by examining each item inter-correlation and computing the Cronbach‟s Alpha. The minimum advisable level is 0.7 (Agyedu et al., 2011; Imbeah, 2012; Nunnally, 1978; and Cronchbach, 1951) even though it may reduced to 0.6 in exploratory research (Hair et al., 2006) and anything that is less than 0.6 is usually discarded (Imbeah, 2012). The proposed successful factor who‟s calculated Cronbach‟s α was greater than the critical point of 0.70, is said to be highly reliable and internally consistent and therefore acceptable. See Appendix C for further details

### 3.10 Content validity

Content validity is also statistical tool and for the purpose of this research it was adopted. It that which focuses on the extent to which content the instrument corresponds to the concept it is designed to measure (Agyedu et al., 2011). When assessing content validity, the question is to what degree does the content of the instrument measure the objectives of the instrument (Sproul, 1988, p.76). The usual process of establishing content validity is to

examine the objectives of the instrument and compare to its content (Agyedu et al., 2011). Content validity is usually assessed by a panel of experts in the field who judge its adequacy, but there is no numerical way to express it (Best and Khan, 1993). For the purpose of this research questionnaire was sent to experts of the subject, thus Consultants and Academician to check the accuracy of the items under each construct. This will help to improve the content, eliminate ambiguity and ease understanding.

# CHAPTER FOUR

# DATA PRESENTATION AND ANALYSIS

## 4.1 Introduction

This chapter focuses on analyzing the gathered data from respondents through Questionnaire, interviews and observation. The descriptive statistics of the data provide quantitative insight to this research and as such provides a very useful role to the achievement of the aims of this research. To this sight, the analyses presented here are data from the demographics of respondents‟ firms and respondents, designs, materials and technologies practices of respondents‟ firms for construction.

And again, an in-depth analysis is presented to understand the problems or factors which are critical in the preventing of housing sustainability and affordability in Ghana, various housing scheme that existed in Ghana, local available building materials and potential appropriate technologies for sustainable affordable housing as well as presenting good housing designs qualities as critical factors to be considered at the designing stage by the construction industry, to promote sustainable housing and development. The results are actually structured to determine the critical factors and assess the level of importance of the critical factors using Factor Analysis, and descriptive statistics to assess the means, frequencies and percentages of the items. Data captured by interviews and observation were analyze through structured interview questions and answered by respondents and also paying personal visit to selected site to observe actual constructional activities and processes. Results were finally presented on the tables and in the picture format.

The findings are therefore presented here in a statistical format such as tables and charts to make it easy to assess and describe the directions of the responses.

### 4.2 Demographics of respondent

#### 4.2.1 Gender

Table 4.1 reveals that fifty – one (51) of the respondents representing (91.1%) were males, and five (5) of the respondents representing (8.9%) were females.

**Table 4.1 Respondents based on gender.**

| Gender | Frequency | Percentages (%) |
|---|---|---|
| Male | 51 | 91.1 |
| Female | 5 | 8.9 |
| Total | 56 | 100 |

#### 4.2.2 Age

**Table 4.2,** indicates that six (6) of the respondents representing(10.7%) of the respondents were in the age range of 26 – 35 years; Eighteen (18) of the respondents representing (32.1%) of the respondents were in the age range of 36 – 45 years; Twenty six (26) representing (46.4%) of the respondent were also in the age range of 46 – 55years and six (6) of the respondents representing (10.7%) of the respondents were 56years and above range.

**Table 4.2 Respondents based on Age**

| Age | Frequency | Percentages (%) |
|---|---|---|
| Below – 25yrs | 0 | 0 |
| 26 – 35yrs | 6 | 10.7 |
| 36 – 45yrs | 18 | 32.1 |
| 46 – 55yrs | 26 | 46.4 |
| 56 – and above | 6 | 10.7 |
| Total | 56 | 100 |

### 4.2.3 Qualification/Educational level

**Table 4.3**, indicates that nine (9) representing (16.1%) of the respondents were HND graduates; Twenty Two (22) representing (39.3%) of the respondent were BACHELOR Degree graduates and Twenty five (25) representing (44.6%) of the respondents were masters degree graduates.

**Table 4.3 Respondents Qualification / Education Level**

| Qualification | Frequency | Percentages (%) |
|---|---|---|
| HND | 9 | 16.1 |
| BACHELOR | 22 | 39.3 |
| MASTER | 25 | 44.6 |
| PhD | 0 | 0 |
| Total | 56 | 100 |

### 4,2.4 Working Experience

**Table 4.4**, shows that fourteen (14) representing (25% of the respondents had working experience of below 10years; Twenty Two had (22) representing (39.3%) of the respondent had working experience of 11 – 20years; seventeen (17) representing (30.4%) of the respondents had working experience of 21 – 30 years and three (3) representing (5.4%) of the respondents had working experience of 31 – 40years.

**Table 4.4 Respondent based on Working Experience**

| Years of Working | Frequency | Percentages (%) |
|---|---|---|
| Below – 10yrs | 14 | 25 |
| 11 – 20 yrs | 22 | 39.3 |
| 21 – 30yrs | 17 | 30.4 |
| 31 – 40yrs | 3 | 5.4 |
| Total | 56 | 100 |

### 4.3 Firms, works execution and materials used

#### 4.3.1 Works execution

**Table 4.5** shows that fourteen (14) representing (25%) of the respondents works on Building works; six (6) representing (10.7%) of the respondent works on civil works only and Thirty six (36) representing (64.3%) of the respondents works on both Building and civil works.

**Table 4.5 Respondents Based on Work Execute**

| Works Execution | Frequency | Percentages (%) |
|---|---|---|
| Building works | 14 | 25 |
| Civil works | 6 | 10.7 |
| Building and civil works | 36 | 64.3 |
| Total | 56 | 100 |

### 4.3.2 Profession

**Table 4.6** reveals that twelve (12) representing (21.4%) of the respondents were Architects, Twenty Two (22) representing (39.3%) of the respondents were Engineers, and Twenty Two (22) representing (39.3%) of the respondents were also quantity surveyors professionals.

**Table 4.6 Responses of Professionals**

| Professional | Frequency | Percentages (%) |
|---|---|---|
| Architects | 12 | 21.4 |
| Structural Engineers | 22 | 39.3 |
| Quantify surveyors | 22 | 39.3 |
| Total | 56 | 100 |

### 4.3.3 Firm classification

**Table 4.7**, indicates that seventeen (17) representing (30.4%) of the respondents were from the large scale firms; thirty seven (37) of the respondents representing (66.1%) of the

respondents were also from the medium scale firms, and two (2) representing (3.6%) of the respondents were from small scale firms in Ghana.

**Table 4.7 Respondent Based on Firm Classification**

| Firm Classification | Frequency | Percentages (%) |
|---|---|---|
| Large scale | 17 | 30.4 |
| Medium scale | 37 | 66.1 |
| Small scale | 2 | 3.6 |
| Total | 56 | 100 |

### 4.3.4 Type of materials used

**Table 4.8**, indicates that nine (9) of the respondents representing (16.1%) were respondents or firms that uses locally processed materials; twenty three (23) of the respondent representing (41.1%) of the respondents were the firms that uses foreign or imported materials, and Twenty four (24) representing (42.9%) were the respondents or firms that uses combination of both local and foreign materials for construction of houses.

**Table 4.8 Responses on the types of materials that firm uses for construction of houses**

| Type of materials used | Frequency | Percentages (%) |
|---|---|---|
| Locally processed materials | 9 | 16.1 |
| Foreign or imported materials | 23 | 41.1 |
| Combination of both local and foreign materials | 24 | 42.9 |
| Total | 56 | 100 |

### 4.3.5 Type of appropriate technology

**Table 4.9,** shows that fifty (50) representing (89.3%) of the respondents or firms, uses high technological means for construction of houses in Ghana, and six 6) representing (10.7%) of the respondents uses appropriate technologies or local and community based practices for housing in Ghana.

**Table 4.9 Responses on the type of technology that firms used for construction of house**

| Type of Technology | Frequency | Percentages (%) |
|---|---|---|
| High Technology | 50 | 89.3 |
| Appropriate Technology( locally and community based Technology) | 6 | 10.7 |
| Total | 56 | 100 |

### 4.3.6 Firms Awareness

**Table 4.10** indicates that Twenty one (21) of the respondents representing (37.5%) were aware of the construction of sustainable affordable housing, and thirty five (35) of the respondents representing (62.5%) were not aware of the construction of stainable affordable housing in Ghana.

**Table 4.10 Responses based on respondent's awareness on the construction of sustainable affordable housing in Ghana.**

| Respondents Awareness | Frequency | Percentages (%) |
|---|---|---|
| Yes | 21 | 37.5 |
| No | 35 | 62.5 |
| Total | 56 | 100 |

### 4.3.7 Affordable Housing

Table 4.11, shows that Twenty three (23) of the respondents representing (41.1%) were the firms in Ghana who as constructed affordable housing before, and thirty three (33) of the respondents representing (58.9%) were also firms in Ghana who had not constructed affordable housing before in Ghana.

**Table 4.11 Responses of respondents on the construction of affordable housing before by firms in Ghana.**

| Responses of Respondents on Construction of Affordable Housing Before | Frequency | Percentages (%) |
|---|---|---|
| Yes | 23 | 41.1 |
| No | 33 | 58.9 |
| Total | 56 | 100 |

### 4.3.8 Type of designs used

**Table 4.12**, shows that six (6) representing (10.7%) of the respondents or firms uses luxury or modern type of designs for construction of affordable housing in Ghana; Forty seven (47) representing (83.9%) of the respondents or firms uses standard or normal designs type for construction of affordable housing in Ghana, and only three (3) of the respondents representing (5.4%) of the respondents or firms uses simple and smaller designs for construction of affordable housing in Ghana.

**Table 4.12, Respondents based on the firms designs type used for construction of affordable housing in Ghana.**

| Design Types Used | Frequency | Percentages (%) |
|---|---|---|
| Luxury or modern designs | 6 | 10.7 |
| Standards or normal designs | 47 | 83.9 |
| Simple and smaller designs | 3 | 5.4 |
| Total | 56 | 100 |

### 4.4 Various Housing Scheme in Ghana

For the purpose of explaining table 4.13, the following rules shall be applied:

1 – 1.59 : - 1 represent not common housing schemes in Ghana

1.60 – 2.59 : – 2 represent common housing schemes in Ghana

2.60 – 3.0 :– 3represent most common housing schemes in Ghana

From the rules it was indicated by respondents that *Town and council housing schemes* (1.34), *NGO's housing schemes initiatives* (1.27), Dispossessed housing schemes (1.25), Affordable housing schemes (building with local materials (1.23), Ghana vision 2020 structural

Adjustment Programme- SAP (1.18) Economic Recovery Programme – ERP (1.4), 10 billion dollars XTS affordable housing programme (1.14), affordable housing schemes to replace the affected onces (1.05), the Housing Shelter Strategy – NSS (1.05), and the Schocbeton Housing schemes (during colonization (1.00) were found to be "not common" housing schemes in Ghana.

The result further indicated that SSNIT mass housing schemes (2.52) individual self – help housing schemes (2.50) compound housing schemes (2.91), real estate developers housing schemes (2.39), Tema development corporation TDC (2.39) staff quarters housing schemes (2.07), staff bungalows for senior staff (1.95), and NPP 20, 000 affordable housing units were the common housing scheme in Ghana. However, the results also shown that Ghana has no housing schemes "most common" or dominated.

**Table 4.13 Responses of respondent on various housing schemes in relations to most common, common and not common**

| Various Housing Scheme in Ghana | Mean | Ranking |
|---|---|---|
| SSNIT mass housing schemes | 2.52 | 1 |
| Individual self – help housing schemes | 2.50 | 2 |
| compound houses schemes | 2.41 | 3 |
| Real estate developers housing schemes | 2.39 | 4 |
| Tema development corporation (TDC) | 2.39 | 5 |
| Staff quarters | 2.07 | 6 |
| Staff bungalow for senior staff | 1.95 | 7 |
| NPP 20, 000 affordable housing schemes/units | 1.71 | 8 |
| Town and council housing schemes | 1.34 | 9 |
| NGO – housing scheme | 1.27 | 10 |
| Dispossessed housing schemes | 1.25 | 11 |
| Affordable housing school (Building with local materials) | 1.23 | 12 |

| | | |
|---|---|---|
| Private partnership housing schemes | 1.23 | 13 |
| Ghana vision 2020 structural adjustment- SAP | 1.18 | 14 |
| Economic recovery programmed – ERP | 1.14 | 15 |
| 10 Billion dollars XTS affording Housing project | 1.14 | 16 |
| Affordable housing scheme to replace the affected once | 1.05 | 17 |
| The housing shelter strategy – NSS. | 1.05 | 18 |
| The schocbeton housing schemes (During colonization). | 1.00 | 19 |

### 4.5 Housing problems in Ghana

**Table 4.14 Responses of respondents on housing delivery problems that it's preventing sustainable affordable housing in Ghana.**

The results of the principal Component Analysis (PCA) shows that the major problems associated with the various existed housing schemes, and it‟s preventing sustainable affordable housing delivery in Ghana, can be categorized into six major problems/ factors namely: Lack of public awareness on the construction of sustainable affordable housing in Ghana related problems/factors (Lack of public awareness on the construction of sustainable affordable housing in Ghana, increase in housing prices, the interest rate, construction cost, land litigations, and land supply and acquisitions for housing), Absence of sustainable affordable housing policy framework related problems/factors (Absence of sustainable affordable housing policy framework, lack of funding and credits facilities, the ever increasing cost of building materials, materials availability, rapid population growth, and lack of skills and technical know- how personnel‟s), Absence of sustainable affordable housing standards and codes for guidelines related problems/factors, (Absence of sustainable affordable housing standards and codes for guidelines, failure to championing the use and improving local materials, designs and technology for housing, lack of good governance and political will to

construct houses by governments, lack of employment by majority of Ghanaians, and deterioration of fabric of existing structures), Absence of clearly defined national policy for housing related problems/factors (Absence of clearly defined national policy for housing , and absence of quality standards to measures the performance of sustainable affordable housing in Ghana) failure to plan related problems/factors (Failure to plan, and the taste to use foreign materials and designs), and Unable to accept our indigenous style and construction systems related problems/ factors (Unable to accept our indigenous style and construction systems and absence of quality standards to measure the performance of sustainability and affordability of housing in Ghana). The table below further indicated the mean of the problems/ factors in their descending order.

The (PCA) was employed in order to reduce the number of problems or factors that affects and prevents the delivery of housing in Ghana in a simple and better outlook for easily understanding.

**Table 4.14**

| **Housing Problems(Factors) in Ghana** | **Mean** | **Ranking** |
|---|---|---|
| Lack of public awareness on the construction of sustainable affordable housing in Ghana related problems/factors | 0.903 | 1 |
| Absence of sustainable affordable housing policy framework related problems/factors | 0.880 | 2 |
| Absence of sustainable affordable housing standards and codes for guidelines related problems/factors | 0.820 | 3 |
| Absence of clearly defined national policy for housing in Ghana related problems/factors | 0.779 | 4 |

| | | |
|---|---|---|
| Failure to plan related problems/factors | 0.660 | 5 |
| Unable to accept our indigenous style and construction systems related problems/ factors | 0.650 | 6 |

### 4.6 Local Available Building Materials

For the purpose of interpreting the results of Table 4.15, the following rules shall be apply:

1 – 1.59 – 1 representing strongly disagree local building materials use in Ghana

1.060 – 2.59 – 2 disagree local building materials use for housing in Ghana

2.60 – 3.59 – 3 agree local building materials use for housing in Ghana

3.60 – 4.0 – 4 strongly, agree local building materials use for housing in Ghana

According to the rules, the results indicated that Hem and other fibres (1.62), Earthen floor (1.64), Grass and poles / sticks (1.82), paper & board / timber and (1.82), and Earth bags (1.98), were considered the disagree local available building materials for sustainable affordable housing in Ghana, plaster and / fibrous cement (2.70), thatch (2.73), laterite (2.77), Natural plaster and finishes (2.80), mud bricks (2.84) landcrete blocks (3.14), Timber / wood (3.23), stones (3.23) Bamboo (3.25), and unburnt clay brocks (3.39) were considered the Agreed local available building material for sustainable affording housing delivery in Ghana. While as clay bricks (3.89) and clay Pozzolana cement (3.91) were considered strongly Agree local available building materials for sustainable affordable housing in Ghana. However no local available building materials were strongly disagree.

**Table 4.15** Responses of respondent on the use of local available materials for sustainable affordable housing in Ghana

| Local Available Building Materials | Mean | Ranking |
|---|---|---|
| Clay pozzolana cement | 3.91 | 1 |
| Clay bricks | 3.89 | 2 |
| Unburnt clay bricks | 3.39 | 3 |
| Bamboo | 3.25 | 4 |
| Stones | 3.23 | 5 |
| Timber /wood | 3.23 | 6 |
| Land crete blocks | 3.14 | 7 |
| Mudbricks | 2.84 | 8 |
| Natural plaster and finishes | 2.80 | 9 |
| Laterite | 2.17 | 10 |
| Thatch | 2.73 | 11 |
| Plaster and / fibrous cement | 2.70 | 12 |
| Eathbags | 1.98 | 13 |
| Paper and board / timber | 1.82 | 14 |
| Grass and poles /sticks | 1.82 | 15 |
| Earthen floor | 1.64 | 16 |
| Hem and other finishes | 1.62 | 17 |

### 4.7 Appropriate Technologies

For the purpose of interpretation of the table 4.16, the following rules shall be applied:

1 – 1.59 – 1 representing strongly disagree appropriate technologies for housing

1.6 – 2.59 – 2 representing disagree appropriate technologies for housing

2.60 – 3.59 – representing agree appropriate technology for housing

3.60 – 4.0 -4 representing strongly agree appropriate technology for housing

The responses according to the rules indicated that, Hybrid structure technology (2.69), living roofs technology (2.55) and straw bale construction technology (2.59) were considered disagreed appropriate technologies for sustainable affordable housing in Ghana, furthermore wattle and duab technology (2.71), Rammed earth technology (2.71)compressed earth blocks technology (3.27), and 1 – section floor beams / trasacco adopted upper floor technology (3.22) were the agreed appropriate technologies for sustainable affordable housing in Ghana whiles Adobe bricks/blocks technology (3.68). Local modular and efficient Eco – affordable housing technology (3.75) and Hydrafoam (interlocking block technology were the strongly agree appropriate technologies for sustainable affordable housing in Ghana. However, no appropriate technologies were strongly disagreed.

**Table 4.16** Responses of respondents on the appropriate technologies that can be used for construction of sustainable affordable housing in Ghana.

| **Appropriate Technologies** | **Mean** | **Ranking** |
|---|---|---|
| Hydrafoam / interlocking blocks technology | 3.93 | 1 |
| Local modular and efficient Eco – affordable housing technology | 3.75 | 2 |
| Adobe bricks / blocks technology | 3.68 | 3 |
| I- section floor beams / trassacco upper floor technology | 3.32 | 4 |
| Compressed earth blocks technology | 3.27 | 5 |
| Earthship technology | 2.71 | 6 |
| Rammed earth technology | 2.71 | 7 |
| Wattle and duab technology | 2.71 | 8 |
| Straw bale construction technology | 2.59 | 9 |
| Living roof technology | 2.55 | 10 |
| Hybrid structures technology | 2.09 | 11 |

### 4.8 Good housing design qualities

The results of the Principal Component Analysis (PCA) shows that the good designs qualities for sustainable affordable housing in Ghana can be categorized into seven most important factors namely: It must encourage cyclic construction processes instead of linear construction process related design qualities (it must encourages the conservation of scarce resources-materials(it must improve or make good the arid or dry environment, it must encourage restoration of damage environment and resources, it must uses recyclable resources, avoid ozone layer – depleting chemicals and materials for construction and it must encourage the renovation of older buildings), It must encourage maximization of resource reuse related design qualities(it must encourage minimization of resource consumption, it must use renewable resources, it must protect the natural environment, must ensure good sound and thermal comfort and it must use salvage materials), It must always consider low energy designs related qualities( it must protect water quality, it must always encourage waste minimization, must depend on green building construction principles, it must be flexible in nature and it must reduce energy in use in all aspect of construction, Avoid potential health hazards related design qualities (must designs for future reuse adaptability, designs building that will be cherished but affordable and sustainable, must always ensure safety measures when designing and constructing), It must be economical and socially sustainable related design qualities(it must base on appropriate technologies practices and strategies, and it must encourage the re-use of old building materials), It must harvest rain water and conserve them for re-use related designs qualities(must encourage the use of low –embodied energy materials and it must encourage the use of solar energy and resources) and It must always be in safer and favor of future generations related designs qualities(It must always be in safer and favor

of future generations and discourage the use of foreign imported building materials, technologies and designs for housing delivery in Ghana).

The table below further indicated the mean and standard deviations of the good designs qualities /factors for sustainable affordable housing in the descending order.

This statistical tool (PCA) was employ in order to reduce the number of good designs qualities or factors that affects or must be adopted for sustainable affordable housing in Ghana in to look in a simpler way for easily understanding.

**Table 4.17 Responses on the good housing design qualities for sustainable affordable housing in Ghana**

| Good Housing design Qualities | Mean | Ranking |
|---|---|---|
| It must encourage cyclic construction instead of linear construction process related factors | 0.908 | 1 |
| It must encourage maximization of resource reuse related factors | 0.900 | 2 |
| It must always consider low energy designs related factors | 0.801 | 3 |
| Avoid potential health hazards related factors | 0.790 | 4 |
| It must be economical and socially sustainable related factors | 0.770 | 5 |
| It must harvest rain water and conserve them for reuse related factors | 0.750 | 6 |
| It must always be in safer and favour future generations related factors | 0.600 | 7 |

**4.9 ANOVA: Influence of firm size on Type of materials used for sustainable affordable housing in Ghana**.

The results of **Table 4.18** shows that there is no significant difference in mean of type of materials used for sustainable affordable housing by the respondents companies (P > 0.05); The results further indicated that large scale firms uses both local and foreign materials for sustainable affordable than the medium and small firms (M = 3.06, SD = 1.029).

However, the mean for medium firm was (M = 2.62, SD = 1.210). The results also revealed that small scale firms were the least usage of both local and foreign materials for sustainable affordable housing in Ghana (M = 1.00, SD = 0.000).

**Influence of firm size on Type of materials used for sustainable affordable housing in Ghana**.

| Company Classification | Mean | SD | F | Sig. |
|---|---|---|---|---|
| Large scale | 3.06 | 1.029 | 3.118 | 0.052 |
| Medium scale | 2.62 | 1.210 | | |
| Small scale | 1.00 | .000 | | |

(P>0.05)

**4.10 ANOVA: Influence of company size on the Types of technologies used for sustainable affordable housing**.

The results of **table 4.19** reveal that there is significant difference in mean of type of technologies used for sustainable affordable housing by the respondents companies (P < 0.05). The results further indicated that small firms uses more appropriate technology for sustainable affordable housing than the medium and large firms (M = 2.00, SD 0.00). However the mean

for medium firm was (M = 1.11, SD = 3.15). The results also reveals that large scale firms were the least usage of appropriate technology for sustainable affordable housing in Ghana (M = 1.00, SD = 0.00).

**Influence of company size on the Types of technologies used for sustainable affordable housing**

| Company Classification | Mean | SD | F | Sig. |
|---|---|---|---|---|
| Large scale | 1.00 | .000 | 13.293 | .000 |
| Medium scale | 1.11 | .315 | | |
| Small scale | 2.00 | .000 | | |

(P < 0.05)

**4.11 ANOVA: Influence of company size on Design type used for sustainable affordable housing in Ghana.**

The results of the **table 4.20** indicate that there is no significant difference in mean of the Design type used for sustainable affordable housing by the respondents companies (P> 0.05). The results further indicated that medium scale firms use more standard or modern designs for sustainable affordable housing in Ghana than large and small scale firms (M = 2.00, SD = 236);. The mean for large scale firms was (M = 1.88, SD= .600). Finally it was revealed that small scale firms were the least usage of standard or normal designs for sustainable affordable housing in Ghana (M = 1.50, SD = 707).

**Influence of company size on Design type used for sustainable affordable housing in Ghana**

| Company Classification | Mean | SD | F | Sig. |
|---|---|---|---|---|
| Large scale | 1.88 | .600 | 1.842 | 0.168 |
| Medium scale | 2.00 | .236 | | |
| Small scale | 1.50 | .707 | | |

(P>0.05)

**4.12 ANOVA: Influence of building professional (respondents) on the awareness of construction of sustainable affording housing in Ghana**.

The results of **table 4.21**, show, that there is no significant difference in the mean of building professionals awareness on the construction of sustainable affording housing in Ghana (P > 0.05).

The results further indicated that Quantity Surveyors building professionals had the least awareness, as far as the construction of sustainable affordable housing in Ghana is concern, followed by Engineers and Architect (M = 1.78, SD = .456), (M = 1.64, SD = .492) and (M = 142, SD = 0.515). These results indicated that Architectural and Engineers buildings professional were more aware on the construction of sustainable affordable housing in Ghana than the QS building professional.

**Influence of building professional (respondents) on the awareness of construction of sustainable affording housing in Ghana**

| Professionals Awareness | Mean | SD | F | Sig. |
|---|---|---|---|---|
| Architect | 1.42 | .515 | 1.615 | 0.209 |
| Engineer | 1.64 | .492 | | |
| Quantity Surveyor | 1.73 | .456 | | |

P > 0.05

**4.13 ANOVA: Influence based on firm awareness on the construction of sustainable affording housing in Ghana**.

The results of the **table 4.22** indicated that there is no significant difference in the mean of firms‟ type or classification on the awareness of construction of sustainable affordable housing in Ghana.

The results further indicated that medium scale firms were more aware of the construction of sustainable affordable housing Ghana than large scale and small scale firms (m = 1.70. SD = 0.463). The mean for large scale firms was (m = 1.53, SD = 0.514). The results also revealed that small scale firms were the least on the awareness of the construction sustainable affording housing in Ghana.

**4.13 ANOVA: Influence based on firm awareness on the construction of sustainable affording housing in Ghana**.

| Firm Awareness | Mean | SD | F | Sig. |
|---|---|---|---|---|
| Large scale | 1.53 | 0.514 | 2.569 | 0.86 |
| Medium scale | 1.70 | 0.463 | | |
| Small scale | 1.00 | 0.000 | | |

P> 0.05

**4.14 ANOVA: Influence of building professionals / Respondents on the construction of affordable housing before in Ghana**.

The results of the **table 4.23** show that there is no significant difference in the mean of building professionals on the construction of affordable housing in Ghana before. (P > 0.05) The results indicated that the building professional of Quantity surveyors and Engineers were the least respondents who has constructed affordable housing in Ghana (m = 1.59, SD = .503). The mean for Architect was (m = 1.58, SD = .515) and this mean that professional of the Architects has constructed more affordable housing than the Quantity Surveyors and Engineers professionals.

**4.14 ANOVA: Influence of building professionals / Respondents on the construction of affordable housing before in Ghana.**

| Building Professionals | Mean | SD | F | Sig. |
|---|---|---|---|---|
| Architect | 1.58 | .515 | 001 | .999 |
| Engineer | 1.59 | .503 | | |
| Quantity surveyor | 1.59 | .503 | | |

P > 0.05

**4.15 ANOVA: Influence of company classification on the construction of affordable housing in Ghana before.**

The results of the **table 4.24**, revels that there is no significant difference in the mean of firms‟ classification on the construction of affordable housing in Ghana before (P > 0.05). The results further indicated that large and medium scale firm were the more built or practices the construction of affordable housing in Ghana than the small scale firms (M = 1.41, SD = .507) (M = 1.65, SD = .484). The mean for small scale firms was (M = 2.00, SD = 0.000).

**4.15 ANOVA: Influence of company classification on the construction of affordable housing in Ghana before.**

| Company Classification | Mean | SD | F | Sig. |
|---|---|---|---|---|
| Large scale | 1.41 | .507 | 2.119 | .130 |
| Medium scale | 1.65 | .484 | | |
| Small scale | 2.00 | .000 | | |

P > 0.05

**4.16 Interviews**

Structured interviews were conducted to secure adequate information. It was conducted on some Ten (10) selected firms and their respondents of the construction industry to measure issues about housing sustainability and affordability in Ghana. Respondents responded to same structural interview questions to obtain their perceptions concerning the factors affecting the achievements of sustainable and affordable housing, responses given were environmental impacts, economical impacts, social impacts, the use of low – embodied energy products etc. Responses concerning the practices to facilitate the achievement of sustainable affordable

housing in Ghana, were the role of government and their policies for sustainable affordable housing for Ghana, the provisions of framework guide to achieve housing sustainability affordability for Ghana, the role of EPA of Ghana, the role of the construction industry, encourage the use of appropriate technology, and adoption of I – section trassacco beam for floors etc.

The table 5.16 contains the further responses and answers to questions concerning the perception of respondents on housing sustainability and affordability by the construction industry.

**4. 17 Site Observations**

For the benefits of a successful research, a non-participants observation was conducted in some regions of the country based on the researcher own judgment or through purposive sampling techniques. The researcher observed construction processes at many site visited, right from the type of materials, designs and technologies practices for construction of houses in Ghana. Pictures were taking on the works observed such as ongoing project sites and some dwelling places of some community, their housing situation, materials availability, styles, and how dominate these structures were.

Source: Site observation

Source: Three unit class room of complete clay bricks at central region-KEEA district (ESIAMAN- SEPTAMBER 2014).

Source: site observation

A typical fence wall build with clay Bricks at Ashanti region (SEP. 2014)

Source: through personal site observation

A typical complete class room block of hydrafoam brick and technology at Central Region-Assin Kobina.

Fig.2.8 Typical structures made with local available building materials in Ghana

# CHAPTER FIVE

# DISCUSSIONS OF RESULTS

## 5.1 INTRODUCTION

This is divided into two parts. Part 1 focuses on the discussion of the results obtained. Part two also provides a framework for implementing cyclic construction process for sustainable affordable Housing Delivery in Ghana.

## PART 1: DISCUSSION OF RESULTS.

### 5.2 Demographics of respondent

#### 5.2.1 Gender

The results in the table 4.1 imply that construction industry in Ghana is male dominated professionals.

#### 5.2.2 Respondents based on Age

The results show that most of the respondents that responses to the questions were between the ages of thirty (30) to fifty (50) and above. This therefore implies that respondents has the required experience needed to generalizes on the issues and to provides solutions to the research questions posted by the investigator.

#### 5.2.3 Respondents Qualification / Education Level

The results therefore, implies that responses of respondent were from the higher educational scholars, and can therefore answered the questions to the best of their knowledge to achieve the require outcomes for the research understudy.

### 5.2.4 Respondent based on Working Experience

The results shows that in terms of working experience of respondents who response to the questions to solve the problem understudy, majority has working experiences between 10 to 40years, hence the respondents responses can be relied upon to find answers to the challenges of housing in Ghana.

## 5.3 Firms, works execution and materials used

### 5.3.1 Respondents Based on Work Execute

Results show that according to the construction industry of Ghana, the works executed most by building professionals is both civil and building works, followed by only building works and civil works being the least among the works built in the built and environment of Ghana.

### 5.3.2 Responses of Professionals

Results shown implies that Structural Engineers and Quantity surveyors profession were more dominate to the Architectural professionals in the construction industry of Ghana.

### 5.3.3 Respondent Based on Firm Classification

Results show that most of the respondents were from medium scale firm and the implication is that firms and respondent were of well standing and of much experience to depend upon their response to solve the research question posted to be administered. This also means that majority of the respondents about (66 %) were from medium scale firm and professionals.

### 5.3.4 Responses on the types of materials that firm uses for construction of houses

Results show that according to firms‟ classification with regards to materials they used for construction in Ghana, combination of the local and foreign materials are the most used

for construction activities, followed by only foreign imported materials. Locally processed materials was the least materials to be used for construction of houses in Ghana, and this implies that in terms of building materials for sustainability, majority of the firms prefer to use foreign imported materials, and a just a few locally processed materials. Hence the reasons for the lack of sustainable affordable housing in Ghana. Ghana‟s housing delivery and access to decent accommodation or to sustainable housing in any part of the country is at a crises level (Agyemang, 2001).

### 5.3.5 Responses on the type of technology that firms used for construction of house

The results show that according to the classification of firms in Ghana and the technological means used by (large, medium and small scale) in Ghana, almost all of them construct houses or structures with high technological means thus about (90%) with just about (10%) which based on appropriate technologies or locally and community based technological practices for sustainable affordable housing in Ghana. The implication of this had cumulated into huge housing deficit in Ghana, because appropriate technological means were not adopted or practice for delivery houses in Ghana by majority of the construction companies (Akubue, 2000). According to Abdul (2011), a lot of savings can be made every step of the way when houses are built small and incorporate appropriate technologies, initial building costs are lower, and home owners save money on operations and long-term maintenance. Schumacher also suggest that “such an appropriate technologies would be immensely cheaper than the sophisticated, highly capital-intensive technology of modern industry” (Schumacher, 1973, p. 180).

### 5.3.6 Responses based on respondent's awareness on the construction of sustainable affordable housing in Ghana.

Results indicate that great numbers of construction companies" professionals in Ghana are not aware about the shifting of the form of construction in Ghana to support sustainable construction and development. The few that are aware of construction of sustainable housing do not practice it effectively due to lack of proper framework guidelines, codes and standards for improvement and implementation. The UN Summit (1972), suggested that the awareness about sustainable development is growing around the globe for last few decades (The UN Summit on Environment and Development in 1972). This means that construction of sustainable housing in the world is not well known by majorities which Ghana is among.

### 5.3.7 Responses of respondents on the construction of affordable housing before by firms in Ghana.

The results shows implies that majority of houses that are built in Ghana are not affordable to the low-income earners. According to MWRWH records and UN-HABITAT (2012), the said affordable housing is not in them affordable and sustainable because the low-income group cannot afford to own. Furthermore, addressing the issue of affordability is, therefore, a necessary condition for transformation towards sustainable housing. And yet housing affordability in Ghana and most part of the Africa is not enough, because the so-called affordable homes cannot be considered sustainable if they create negative impacts on the environment, social and economic life of the people.

### 5.3.8 Respondents based on the firms designs type used for construction of affordable housing in Ghana.

Results shows, implies that standards or normal designs were the most used designs type for housing in Ghana. It was further reveal that luxury or modern designs were the next dominated design type used for housing. The simple and smaller design type was far less used designs type for housing in Ghana. But the refusal to use alternative designs and appropriate technologies thus the non- use of our local or community practices or technology for housing in Ghana, has contributed to the huge housing deficit and challenges to country. According to Raynsford, (2000) designs, impacts the delivery of housing in a variety of ways. For example, the choice of designs type, materials and their applications has a significant environmental impact, depending on the sources of materials, their durability, and potential reuse, and this can first ensure environmental comfort but reduce the cost of housing to the extent that low-income earners can afford to own their own house with ease.

## 5.4 Responses of respondents on various housing schemes in relations to most common, common and not common in Ghana.

The results show that according to the construction industry in Ghana, SSNIT mass housing scheme, individual self-help housing schemes, compound houses schemes, real estate developers housing schemes, Tema development corporation (TDC) housing schemes, and staff quarters housing schemes were considered the dominant housing schemes in Ghana. Affordable housing schemes to replace the affected once, the housing shelter strategy-NSS, and the Schocbeton housing schemes were also considered far least dominated housing schemes Ghana has had.

**5.5 Responses of respondent on the use of local available materials for sustainable affordable housing in Ghana**

The results shown, implies that clay Pozzolana cement, clay bricks, urburnt clay bricks, bamboo, stones, timber/wood, and landcrete blocks are considered as most used and acceptable available local building materials for sustainable affordable housing in Ghana. Earthen floors and Hem and other finishes were also considered less used local available building materials for sustainable housing delivery in Ghana.

**5.6 Responses of respondents on the appropriate technologies that can be used for construction of sustainable affordable housing in Ghana.**

The results indicated, implies that hydrafoam/ interlocking blocks technology, local modular and efficient Eco-affordable housing technology, Adobe bricks/blocks technology, I-section floor beams/trassacco upper floor technology and compresses earth block technology are considered the most used and acceptable appropriate technologies for construction of sustainable affordable housing in Ghana. Living roof technology and hybrid structure technology are considered to be less important or used for sustainable affordable housing in Ghana.

**5.7 Responses of respondents on housing delivery problems that it's preventing sustainable affordable housing in Ghana.**

The results show that according to the responses by Architects, Structural Engineers and Quantity Surveyors), the three most important problems to sustainable affordable housing delivery in Ghana are a lack of public awareness on the construction of sustainable affordable housing in Ghana related problems, absence of sustainable affordable housing delivery policy

framework related problems and absence of sustainable affordable housing standards and codes for guidelines related problems.

**5.8 Responses of respondents on housing good designs qualities for achieving sustainable affordable housing in Ghana.**

Results indicated implies that according to the respondent in the construction industry of Ghana, the three most important good designs qualities for sustainable affordable housing and development are it must encourage cyclic construction processes instead of linear construction processes, it must encourage maximization of resources re-use and it must always considered low energy designs for housing in Ghana.

**5.9 ANOVA: Influence of company size on Type of materials used for sustainable affordable housing in Ghana.**

The result implies that companies" sizes have no significance influence on materials type used for sustainable affordable housing in Ghana. It reveals that large scale firms were the most to use both locally processed materials and foreign imported materials for construction of sustainable affordable housing in Ghana followed by medium scale.

The results further indicated small scale firms in Ghana uses majority of locally processed materials for sustainable affordable housing than large scale and medium scale firm and it means that small scale firms practices the construction of sustainable affordable housing in Ghana.

**5.10 ANOVA: Influence of company size on the Types of technologies used for sustainable affordable housing**.

The results show that companies, base on their sizes has a significance influence on technological type used for sustainable affordable housing in Ghana. It also implies that most

of smaller scale companies in Ghana use appropriate technologies for sustainable housing than the medium and large scale companies in Ghana. Medium and large scale companies in construction industries uses almost high technological means for construction of houses and this do not favor or save our environment for both present and future generations.

**5.11 ANOVA: Influence of company size on Design type used for sustainable affordable housing in Ghana.**

The result therefore implies that company size has no significant influence on designed type used for sustainable affordable housing in Ghana. It also implies that majority of medium scale companies in the construction industry adopt the use of standard or normal designs type for construction, with the large scale companies next to use standard or normal designs followed by smaller scale companies. Furthermore, the results indicated that smaller scale and large scale companies adopt the use of luxury or modern designs than medium scale companies for delivery housing in Ghana.

**5.12 ANOVA: Influence of building professional (respondents) on the awareness of construction of sustainable affording housing in Ghana.**

Results shows that building professionals used as respondents has no significance influences on the awareness of the construction of sustainable affordable housing in Ghana. This implies that in terms of awareness of sustainable affordable housing in Ghana, building professionals has limited awareness on housing sustainability.

**5.13 ANOVA: Influence based on firm awareness on the construction of sustainable affording housing in Ghana.**

The results shown, implies that construction companies has no significance influence on the awareness of the construction of sustainable affordable housing in Ghana.

**5.14 ANOVA: Influence of building professionals / Respondents on the construction of affordable housing before in Ghana.**

The results indicated, implies that firm awareness has no significance influence on the construction of sustainable affordable housing in Ghana.

**5.15 ANOVA: Influence of company classification on the construction of affordable housing in Ghana before.**

Results shown, implies that building professionals in Ghana has no significance influence on the construction of affordable housing in Ghana before.

**Table 5.16 Interviews results**

| INTERVIEWS QUESTIONS | RESPONSES FROM RESPONDENTS | NUMBER OF RESPONSES |
|---|---|---|
| What are the factors affecting the achievement of the sustainable affordable housing in Ghana? | • Environment impacts<br>• Economic impacts<br>• Social impacts<br>• The use of low-embodies energy products | 10<br>8<br>9<br>7 |
| What practices would you adopt to facilitate sustainable affordable housing in Ghana? | • The role of Governments and their policies for sustainable Housing for Ghana. 8<br>• The prevision of framework guide to achieve Housing sustainability or / affordability 9<br>• The role of the EPA of Ghana 5<br>• The role of the construction industry 6<br>• Discouraging the use of foreign | |

| | |
|---|---|
| | materials, and systems for housing in Ghana. 8<br>• Accept and improve upon our traditional systems of housing in Ghana 7 |
| What, in your own opinion is housing affordability? | • It is housing that are designs to fit into environment, social, cultural and economic live of community and influence peoples" lives in health, security, well being etc. 5<br>• The ability of the developer to continuously develop land for housing4<br>• Housing that it"s element or materials can be re-use for same or other purpose 6<br>• Housing that it"s total cost is about 30% of the owner annual net income.6<br>• It is basically a housing scheme that is designed to meet the "pocket" of the various social and economic classes of the society. 4 |
| What, in your own opinion are appropriate technologies and designs for housing? | • Are technologies and design the posits less environmental impacts and can save both present and future generations 9<br>• They are technology and design that |

| | |
|---|---|
| | support sustainable development 7<br>• Technologies that are locally base, easily to understand and practices and very cheap to afford. 7<br>• They prevent climate change, global warming and ozone laryer depleting6 |
| What do you see as barriers affecting sustainable affordable housing in Ghana? | • Lack of sustainable housing framework guide for housing in Ghana 9<br>• Over dependence on foreign materials, ideas and strategies. 8<br>• Lack of tools for measuring housing sustainability and affordability 5<br>• Poor governance and policies by various government on housing 8<br>• Failure to improve upon our traditional systems of building 7<br>• monopoly systems by some manufacturing companies of building materials 6 |

**5.17 Site observation results**

Results shown that in Ghana, places such as the towns and the villages, and even some part of the urban cities many people dwell in structures that are built with some local materials, technologies and designs such as adobe bricks, clay bricks, thatch roof houses, mud bricks

houses, hydrafoam technology to eradicate schools under tree, traditional mud houses, wooden houses, stone structures etc. This is consistent with Kwofie et al., 2011), which suggested that before our contacts with the European and influence of capitalism, building in (Gold Coast) Ghana was predominantly locally based materials in the form of thatch, mud, wood, earth, bamboo and bricks. Currently about half of total dwellings in Ghana are constructed with local or traditional materials such as Mud bricks, earth, thatched roof, bamboo etc (2000 population and housing censuses report). In view of this Abdul (2011), also suggested that a lot of savings can be made every step of the way when houses are built small and incorporate local materials, and appropriate technologies, initial building costs are lower, and home owners save money on operations and long-term maintenance. Instead of transporting materials from hundreds of thousands of miles away into the country which does not also support housing sustainability as expected, it is far better to research into our own indigenous materials and technologies to improve them and utilize them fully. Thus placing much priority on the use of local"s materials and technologies for housing in Ghana.

The use of local natural building materials, appropriate technologies and designs are the key part of affordable housing and sustainable development.

## PART 2: THE FRAMEWORK

### 5.18 Framework for Implementing Cyclic Construction Processes for Sustainable Affordable Housing in Ghana

This part of the chapter discusses the development of a framework for implementing the cyclic construction processes for enhancing and achieving sustainable affordable housing

in Ghana. It began by looking at the present linear approach, identifies the weaknesses in it and thereby proposes the new framework as a means of improvement.

The frame work is based on the sustainable construction and development literature, critical loop hole or challenges it‟s has posits on the attainment of housing sustainability as a shelter for people in Ghana by majority of registered and practice building professionals and companies of the construction industry of Ghana.

**5.19 The Need for the Framework**

According to Dale (2003), framework is usually a well-liked output which serves as a means of presenting concept, ideas, pointers and plans in a non prescriptive manner. It allows users to choose their own starting to the finishing point and specific course of action, and to improve or implement existing ideas, theories and concept to enhance situations and benefit people with little supervision.

The main purpose of this framework is to provide a detailed breakdown and real outline for sustainable construction and development, to give further directions and improvement of the existing construction processes (linear construction process) to cyclic construction processes of designing and implementing sustainable affordable housing in Ghana. This can ensure once use forever building materials to promote sustainable development and construction. Furthermore, the framework guide will hopefully build capacity which can save massive environmental impacts and catastrophes cause by construction activities such as air and water pollutions, diseases, creation of dust and noise, generation of new construction materials instead of just recycling old building materials and

put them into use, failure to practice maintenance culture and renovations of existing buildings etc.

It will also hammer on the key challenges, identifying the gaps and committing to the actions that are needed to mainstream and deliver sustainable construction and development for affordable housing in Ghana, to put in place effective implementation mechanisms and deliver concrete measures to progress sustainable development.

**5.22 The framework for Existing construction processes (linear construction processes)**

Construction processes refers to the phases or stages that a complete and successful project undergo, and this includes pre-construction or contract phase, construction phase and post- construction phase, hence the name linear construction processes (Neil, 2007 and **Khalfan, 2002** p17). To achieve progress of work and to ensure sustainable construction, which give hopes for the future generations in this process, then the process need to be improve or change from the linear construction processes to cyclic construction processes or phases which would ensure effective implementation of sustainable development and construction than the linear construction processes or stages, hence the need to introduce a framework which will ensure implementation of sustainable development and construction, through cyclic construction process. In effect there are three types of construction processes that already existed almost all over the world.

**5.22.1 Pre- construction stages**.

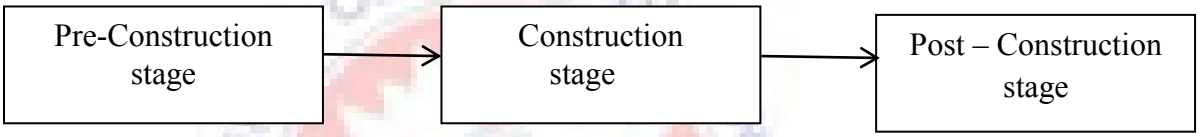
This includes the clients brief, investigation, sketch, design, procurement process, the costing of the project, quantity surveying, user‟s requirements, client‟s awareness and involvement, etc.

### 5.22.2 Construction stages

This phase includes the On-site Construction Process, Waste Management and Re-cycling, Suppliers and Management of Construction Materials, etc. This also includes Involvement of whole Supply Chain during the Construction of the Project.

### 5.22.3 Post-construction stages

This phase involves the Maintenance Period of a facility, life-cycle cost/economy and efficiency, including the demolition of a facility (Khalfan, 2002)




Linear Construction Process
Source: (Khalfan, 2002)

**Figure 5.1** Shows the existing or linear construction process

### 5.23 Short Comings of the Existing Linear Construction Process Framework

According to Miyatake (1996), there are many challenges and deficiency with the linear construction process, in that it does not comprehensively tackle the issues of sustainability well and practically do not have models and framework guide on how to use the existing construction process for achieving effective sustainable construction and development, which the entire world are anxious to attain. Although the system existed but there are still significant impacts and catastrophes it‟s posits and contribute to the destruction of environment, causing climate change, depletion of the ozone layer etc. He further suggested that, everybody has to realize at the present that in order to achieve sustainable construction,

the construction industry must change the processes of creating the built environments. However, this could be coined as bringing change from linear processes of construction to cyclic processes of construction within the construction industry or built environments. This means that the industry has to change the way in which all the construction activities are undertaken. The industry is using high embodied energy materials, and other resources to create buildings and other civil engineering projects and activities, and the end result of all these activities is creating huge volume of discharge waste into the environment during and at the end of the facility‟s life.

Therefore, shifting from this linear process into cyclic process will bring increased use of recycle, renewed and re-used resources, and decrease in significant use of energy and other natural resources to facilitate sustainable construction and development.

On the other hand, to restore damaged and polluted environments, efforts have to be made such as treatments of damaged and contaminated soils, water and air. The idea behind improving arid or dry environments should be accepted to improve large scale arid environments like deserts and making them habitable for plants, animals and human beings. Thus, source the materials through sustainable means (locally based source materials, use low-embodied energy manufactured building products, use them, renewed them by recycling, and re-use them for other constructional purposes).

**5.24 The key challenges and negative effects of the existing process**

Due to the shortcomings of the present‟s construction process practice by almost all the firms, there have been some challenges especially with regards of achieving housing sustainability with the constructional industry. These challenges has some amount of negative

effect to all the sustainability factors (environmentally, socially, cultural and economics pursuits of all nations) and hence there is a need for a change or improvement in our construction processes by all firm to address the housing challenges to some extent. This has generated the following effects such as:

- High demand of affordable housing
- Lack of employment and global poverty challenges
- Environmental impacts such as climate change and hazards
- Natural disasters, slums and global warming
- Much consumption of scares natural resources
- lack of access to sustainable energy, and economic uncertainty,

  Lack of affordable or low – income housing to average people, and huge housing deficit (UN-Habitat, 2012).

**5.25 The Structure of the Proposed Framework**

It is the framework summarized in Tabulated and diagrammatic format that shapes the discussions of this framework guide. This framework is to provide useful methods and guidance to support the application of sustainable framework for the construction industry, the EPA of Ghana in decision making and particularly within the institution and department of Researched in Ghana. However, it is anticipated that external organizations will find this information useful, as well. The concept includes five-stage for implementation process

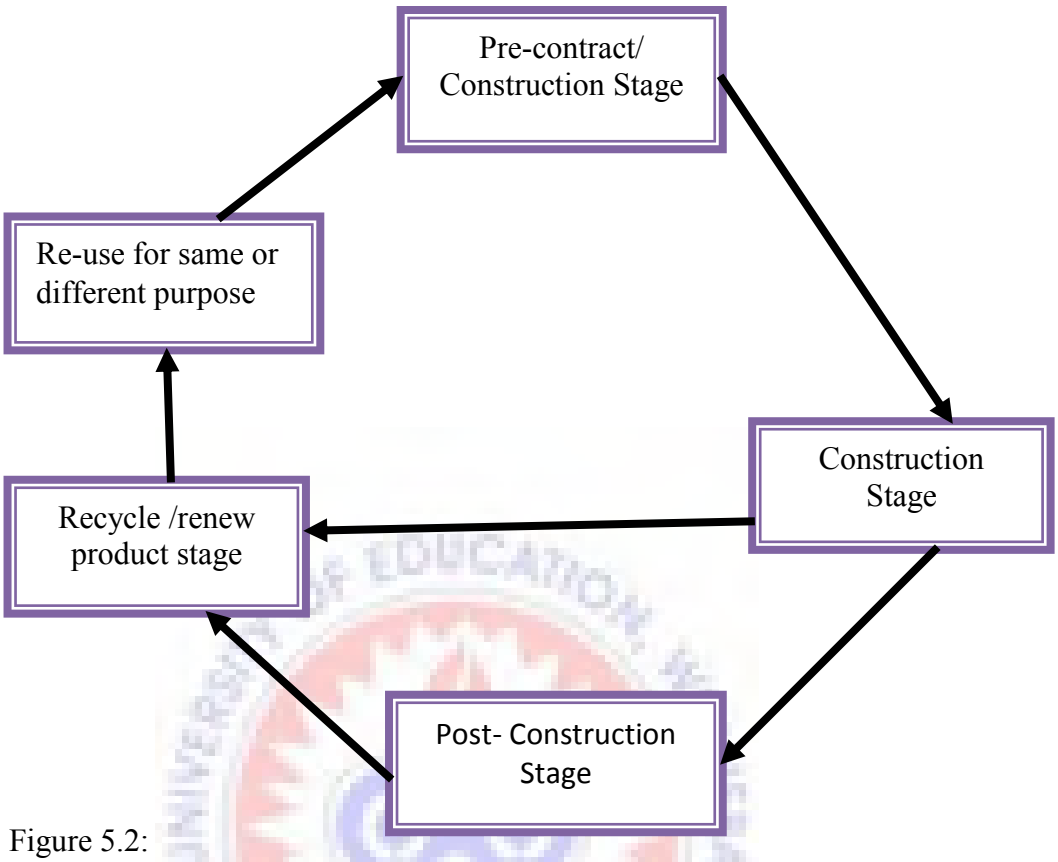



Figure 5.2:

**Fig. 5.2 Proposed cyclic construction process**

## 5.26 Framework Design Requirements

In general, the following criteria can be considered as a guide in developing a good framework to suit the construction industry for improving and implementing sustainable affordable housing (Neil, 2007).The framework should be done systematically and easily understood, simple in structure, represent a road map and tools for implementing issues of sustainability through construction industry in Ghana, answers questions like what is?, why is? and how to? achieve sustainable construction and development, and implement the framework at reasonable cost.

**Table 5.3 Framework for Improving and Implementing Cyclic Construction Processes for Sustainable Affordable Housing in Ghana.**

| Sustainable Construction Processes | Constructional Activities | | Implementation Process |
|---|---|---|---|
| Pre-construction Stage | ➢ User‟s/ client requirement<br>➢ Client‟s brief<br>➢ Client‟s awareness of sustainable construction & Development ( construction impacts on social, economic and environment)<br>➢ Clients awareness on the use of appropriate designs (flexible, environmental friendly designs etc)<br>➢ Clients awareness on the use of appropriate technologies (locally or community based technology). | ➢ Clients awareness on the conservation and preservation of scarce resources (natural & artificial resources- materials, labours, and plants)<br>➢ Investigation of site and feasibility studies<br>➢ Sketches and drawings<br>➢ Costing of the project<br>➢ Procurement / tendering process. | Planning |
| | | | Implementation |
| Construction Stage | ➢ General site/ construction activities<br>➢ Construction according to specifications of sustainable construction, green or eco-home standards, codes and | ➢ Ensuring disposing of waste in the environmentally sound way to avoid extra environmental hazards.<br>➢ Ensuring all safety | |

| | | | |
|---|---|---|---|
| | guidelines.<br>➢ Supply of construction materials that are sustainable in nature.<br>➢ Avoid specifying materials with ozone – depleting potential or which contain other toxic contents.<br>➢ Management of construction materials with the effort to reduce waste. | measurement on site<br>➢ Ensuring all risk management on site<br>➢ The attempt to recycle and manage waste at this stage.<br>➢ Encourage maximization of resource re-use (both recyclable and unrecyclable products).<br>➢ Encourage minimization of resource consumption. | Evaluation |
| Post - Construction Stage | ➢ Creation of maintenance awareness to the users<br>➢ Development of maintenance cultural – attitudes by the following:<br>o construction industry,<br>o government sectors,<br>o Private sectors and individual Ghanaians.<br>➢ Practice of maintenance<br>o Routine and preventive maintenance<br>o plan maintenance | ➢ Consideration/ provision of life cycle cost<br>➢ Encourage the re-use of recyclable products for any repairs and changes at this stage.<br>➢ Renovation of old structures<br>➢ Rehabilitation of old structures both (buildings and civil works). | Improvement |

| | | | |
|---|---|---|---|
| Recycling / Renew Stage | ➢ Encourage recycling at the construction process stage (Khalfan, 2002 )<br>➢ Encourage recycling of old demolishes structure fabrics for construction new buildings to reduce waste going into landfills.<br>➢ Waste management<br>➢ Restoration of damage and polluted environment<br>➢ Improve or make good the arid or dry environment( Savannah and Saharan desert vegetations)<br>➢ Encourage the generation and the use of solar energy resources for processing the entire construction stage. | ➢ Encourage the generation of new energy resources during recycling stage.<br>➢ Harvest rain water for construction activities to reduce pressure on the scarce water resources<br>➢ Encourage the adoption of cyclic construction process instead of linear construction process for sustainable construction & development.<br>➢ Protecting historic buildings and ancient monuments. | Measurement of the effectiveness and performance |
| Re-use Stage | ➢ Encourage the full RE-USE of old and all recycled construction products and materials for same / very new construction projects and purposes. | ➢ Encourage the adoption of one‟s use forever building materials for effective sustainable construction and developments.<br>➢ Re-use existing/old buildings where possible | |

**5.26 Stages of sustainable construction processes**

**5.26.1 Pre – Construction Stages**

The will includes the user‟s / client requirement, client‟s brief, client‟s awareness of sustainable construction, and development client‟s awareness on the use of appropriate design

and technologies etc. further details have been provided in the table above for better understanding.

### 5.26.2 Construction Stages

This phase consist of general site / construction activities, construction according to specification of sustainable construction green or eco-home standards, codes and guideline, supply of construction materials that are sustainable in nature etc. further explanation has been provided in the table above for better understanding.

### 5.26.3 **Post – Construction Stages**

Under this stage creation of maintenance awareness to the users, development of maintenance culture attitude by the following the construction industry, government sectors private sectors and individual Ghanaians etc, further details has been provided in the table above.

### 5.26.4 Recycling/renew stage

The idea of this stage (recycling) is that recycling should begin right from pre-contract stage, construction and post-construction stage, but more emphases should be place at the construction stage that all waste products are recycle and put into use for the same constructional purpose or other purposes which might be different from the project at hand, as well as recycling of building products should also be more focus after the buildings life span are exceeded (deteriorated, demolished, and dilapidated (old structures) stage to re-use them for different constructional purposes or same. This will ensure that no fabric of the defective buildings goes waste, and thus the meaning of ensuring once use forever building materials.

In order to promote the construction sustainability and sustainable development, both the construction and civil engineering industry must learn to become accustomed and stick to the

practices of recycle and re-use of old building materials, thus by trying to recycle or converting materials of existing or demolish buildings and project into the same or alternative construction products and purposes, and after ensure that they are put into use or re-use.

To enhance the construction of sustainable affordable housing within the built environments of Ghana, the construction industry has to pay much attention to all the activities carried out in each of the above mentioned stages in the table.

**5.26.5 Re-use stage**

Thus to be more focus and re-use the recycled old building materials for erecting same or different constructional purpose such as renovation, maintenance and make way for extension of old structures or buildings, thus rethinking construction. Here unlike linear construction process no materials products that are inculcated into the project will go waste such as cement, concrete but the processes and materials used can be brought back through recycling, hence the adoption of re use stage.

**5.27 How to implement the propose framework**

**5.27.1 Planning process**

The planning process requires that top management and government commitment and involvement is consistent for a successful Implementation. It is the driving force for sustainable affordable housing process. It also requires the top management setting up an effective sustainable affordable housing management system. The framework system will serve as a spring board for full implementation of sustainable affordable housing.

Management should convey the firm‟s vision, mission and strategic direction to employees consistently. Its strategies, planning process should effectively prepare the firms environment

for change process from the linear to cyclic construction processes. In a typical construction firms or industry, the management and supervisory role is provided by the firms. The type of planning, managers consider here is strategic and operational planning.

### 5.27.2 Implementation process

The structure and the table of the framework guide identified above consisting of factors manifesting through which the framework can be implemented or practices. It is essential that all the factors necessary for effective implementation, be considered at this stage and the practices should be the concerns of top management to the low management through to the operations or the whole firm of the organization.

### 5.27.3 Methods for improvement and evaluation

The evaluation of the framework implementation practices should be easily and can be done by developing an effective assessment tools for periodical evaluation and improvement. Examples of these tools are as follows **breeam; eco-home and green building principles, (ISO 14000, 14040, 14041, 14042)** etc. The firm and the companies should use the framework guide to identify deviations, problems and plan towards corrective actions.(**http://www.ISO14000.org** (http://www.buildinggreen.com/ebn/checklist.html).

### 5.27.4 Measurement of effectiveness and performance

The firm should develop or use sustainable construction and development codes, standards, BREEAM, guidelines to measure the performance and effectiveness of framework or the system to be adopted. These mechanism of the firm should continually measured performance, and compare with the firm‟s goals and objectives.

**5.28 Benefits of the proposed conceptual framework for sustainable affordable housing**

This framework, when successfully implemented by the industries including construction industry, stakeholders and government will provide all these benefits to Ghanaians in promoting sustainable construction and development. This will include the following:

- Improved quality of life, social equality and dignity of residence (sanitation)
- Affordable access to housing
- Improved health and lower incidents of illness, fatalities and material losses, better labour productivity
- Better conditions for human development, employment, creativity and economic growth
- Durability and low maintenance cost
- Improved efficiency and savings on the use of energy, water and other physical resources
- Better environmental protection and sanitary conditions
- Contribution towards climate adaptation and mitigation
- Social cohesion and political stability (Matthew French/UN-Habitat).
- While mitigating the unstable convergences of the problems related to population growth, urbanization.

Hence the reasons why there is the need for sustainable affordable housing framework to at least address the housing challenges to some extent.

### 5.21 Implementers of the framework policies

This will include people of the following:

- The Construction industry (Architects, Surveyors, Engineers etc)
- Key governmental experts on housing
- Non –government organizations
- The EPA of Ghana
- Individual self –help builders (clients)

### 5.29 Summary

The framework will provide a roadmap for improvement and implementation, of housing sustainability and development through the use of cyclic construction process instead of linear construction processes. From the diagram it can be seen that the framework is very simple and can be easily understood when various stages are implemented.

As shown in fig 5.2, this frame work provides an understanding of the cyclic stages of construction processes for addressing sustainable construction to achieve sustainable affordable housing through the construction industries of Ghana. This frame work considers the pre-construction stage, construction stage, post-construction stage, recycling/renew stage and re-use stage for cyclic construction process.

These feed into the firm‟s commitment to housing sustainability and affordability, by practicing the various construction stages or activities and thus the implementation. When changes are seen and implemented by construction industry from the practice of cyclic construction process, hence the improvement of the existing linear construction process or the framework.

The framework proposed is derived from the construction processes practices of these construction companies, problems they faced in the implementation of housing that are sustainable and affordable and can be afforded by average Ghanaian.

# CHAPTER SIX

# SUMMARY OF FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

## 6.1 Introduction

This chapter presents a summary of the findings from the study, gives overall conclusions based on the findings, and provide recommendations by which the construction industry or built environment and government can improve on the existing construction processes, technologies, design and materials to promote the delivery of housing that are sustainable and affordable for Ghanaians especially the average Ghanaians.

## 6.3 Summary of Findings

The aim of the study was to investigate into the various housing delivery schemes in Ghana, as a means of exploring an innovative solutions for sustainable affordable housing in Ghana, through the use of appropriate designs, technologies and locally based building materials, and develop a framework to implement the cyclic construction process to support the achievement of sustainable construction, affordable housing and development in Ghana. A descriptive study design was adopted to describe the perception of respondents on the various housing schemes existed in Ghana, the use of local available materials and appropriate technologies for sustainable affordable housing in Ghana. One way anova techniques was used to assess the relationships between firms and their awareness of housing sustainability in Ghana, the relationship between firms and their materials, technologies and designs being practiced for housing delivery, while Principal Component Analysis (PCA) was adopted to assess and reduce the number of factors into related/critical factors for easy assessment and presentation of results. A total of 156 building professionals were sampled for the study.

Questionnaires, interviews and observations were used as the instrument for collecting data for the study.

**The findings are outlined below.**

1. The study found that most works executed by building professionals in the construction industry were both civil and buildings work dominated, followed by the only building works and civil works in Ghana. Both civil and building works, only building works, and civil works only were ranked first, second and third respectively by respondents" in terms of works execution by the construction industry professionals in Ghana.
2. The study found that the respondents which response to the issues to seeks solution to the research problems or questions were medium scale firms dominate and large and small firms dominate respectively (66.1%, 30.3% and 3.6%).
3. The study revealed that according to the construction industry, combination of both local and imported materials were the most used building materials for construction activities, followed by foreign imported and locally processed materials only, thus in terms of building materials for housing or for sustainable housing, majority of firms and professional in Ghana prefer to use imported materials than locally processed materials, and this as a result has contributed greatly to the lack of sustainable housing delivery in Ghana.
4. Respondents from all the firms classification (large, medium and small scale firms) agreed that High technological means were the most known, or the most use and practice technologies for housing delivery in Ghana (89.3%) and appropriate or community based technologies were the least housing technologies practice by the construction industry of Ghana for housing.

This practice has culminated into huge housing deficit which will take a very long time to correct. However, the study also found that a lot of savings can be made every step of the way when houses are built with appropriate or with locally based technologies and materials, initial building costs are lowered, and home owners can save money on operational and long – term maintenance.

5. The study indicated that great number of construction companies professional in Ghana were not aware of the shifting from the existing form of construction to support sustainable construction and development. However, the few that were aware of the construction of sustainable housing do not effectively practice them, due to lack of proper framework polices, codes, standards and guidelines for improvement and implementation.
6. The study found that majority of houses in Ghana is not affordable for outright purchase, mortgaged or to be built by low- income earners of Ghana. The study further revealed that addressing the issue of affordability is necessary condition for transformation towards sustainable housing, yet housing affordability in Ghana and most part of Africa is not enough, because the so called affordable homes cannot be considered sustainable if they create negative impacts on the environment, social and economic life of the people.
7. From the study, respondents from the construction industry revealed that most design types used for construction of houses were standard or normal designs method. Whiles modern or luxury designs and the simple and smaller designs type, were the less used design methods for housing in Ghana. Furthermore study revealed that the refusal to place priority on the use of alternative designs and appropriate technologies for housing has been the major factor for the country huge housing deficits, because designs impact

on the delivery of housing in a variety of ways such as environmental, social and economic impacts of the people.

8. The study found that, according to the construction industry of Ghana, SSNIT Mass housing scheme (Mean = 2.52), individual self – help housing schemes (mean = 2.50), compound houses schemes (mean = 2.4), real estate developers housing schemes (mean = 2.39), and staff quarters housing schemes (mean = 1.05) were the dominated housing schemes strategies Ghana had experienced. Whiles affordable housing schemes- housing to replace the affected once, during the time Ghana‟s experience earthquake disaster (mean=1.05), The housing shelter strategy – NSS (mean = 1.05), and the schocbeton housing schemes (mean = 1.00) strategies were ranked last in terms of domination of housing schemes strategies in Ghana.
9. The study found that, respondents from the construction industry, thus the building professional‟s strongly agreed that clay pozzolana cement (mean= 3.91) clay bricks (mean = 3.89), unburnt clay bricks (mean = 3.39), Bamboo (mean = 3.25), stones (mean = 3.23), Timber/wood (mean = 3.23), and land crete blocks (mean = 3.14), were the most acceptable local available building materials for sustainable affordable housing in Ghana; whiles earthan floors (mean = 2.64), and Hem and other finishes (mean = 2.62), were agreed to be less used and acceptable local available building materials for sustainable housing delivery in Ghana.
10. From the study, respondents revealed that Hydrafoam / interlocking blocks technology (mean = 3.93), local modular and efficient Eco – affordable housing technology (mean = 3.75), Adobe bricks /blocks technology (mean = 3.68), I – section floor beams / trassacco upper floor technology (mean = 3.32), and compressed earth block technology (mean =

3.27) were the most considered and acceptable appropriate or local based technology for construction of sustainable affordable housing in Ghana. Living roof technology (mean = 3.55), and Hybrid structure technology (mean = 3.09) were considered less important or less acceptable technologies for sustainable affordable housing in Ghana.

11. Respondents from the construction industry category agreed that the lack of public awareness on the construction of sustainable housing related problems/factors, absence of sustainable affordable housing delivery policy framework related problems/factors, and absence of sustainable affordable housing standards and codes for guidelines related problems/factors, were the three major related problems/factors that had been preventing the construction of housing in Ghana especially the construction of sustainable affordable housing in Ghana.
12. The study found that, respondents of the construction industry of Ghana, agreed that the three most important good housing designs qualities for enhancing and ensuring sustainable affordable housing and development were to encourage cyclic construction process instead of linear construction processes related qualities, encourage maximization of resources re-use, and must always considered low energy designs for housing in Ghana.
13. The study found that there was no significant influence on the type of materials used for sustainable affordable housing and the firms of the construction industry of Ghana ($P > 0.05$, sig = 0.052).
14. The study revealed that there was a significant influence on the type of technologies used for sustainable affordable housing and the firms of the construction industry in Ghana. ($P < 0.05$, sig = 0.000).

15. The study found that respondents of the construction industry in Ghana, has no significant influence on the awareness of the construction of sustainable affordable housing in Ghana, and by their firms (P>0.05, Sig=0.209).
16. The research revealed that, in Ghana, people still dwell in structures build with local building materials, alternative designs and appropriate technologies such as adobe bricks, clay bricks, thatch roof houses, mud bricks houses, hydrafoam bricks or technologies, wooden houses, straw, and stone structures etc., some for sixty years (60yrs) and above, and this was in consistent with Kwofie et al, 2011) which suggested that before Ghana‟s contacts with the European and influence of capitalism, building in Ghana was predominately, locally based materials in the form of thatch, mud, wood, earth, bamboo and bricks, currently about half of total dwellings in Ghana are constructed with local or traditional materials such as mud bricks, earth, thatched roof, bamboo etc. Instead, most building materials in Ghana are transported from hundreds of thousands miles away into the country which are very expensive and does not also support sustainable housing and development, due to lack of knowledge about it negative impacts on both present and future generations.

**6.3 Conclusion**

Provision of adequate sustainable and affordable housing delivery to Ghanaians, especially to average Ghanaians, is proper, social and economic important. For many years, past governments had made several initiatives toward provision of decent, adequate and affordable housing, to close the huge gap of the country housing deficit, but these interventions have failed to make an attempt to resolve Ghana‟s growing housing deficit, because the interventions and the initiatives were narrowly focused and poorly tackle and

implemented. Emulating the foreign ways, thus the use of foreign styles, designs, technologies and materials have missed opportunities for home or domestic grown solutions for eradicating the challenges with regard to the provisions of sustainable affordable housing delivery in Ghana. The research revealed that focusing on the domestic grown solutions, such as the use of appropriate technologies, alternative designs and the use of local natural building materials for housing in Ghana are the key part to sustainable affordable housing, and development. However most construction firms still undertaken most constructional activities with imported products, and still depend on foreign fund, policies and strategies, and for that matter making the provision of housing very expensive but create massive environmental impacts to our world today, making sustainable construction in Ghana impossible. The challenge now is the awareness creation, shifting and developing a taste and accepts to use what we have at home, the role of government and stakeholders to mainstream the use of local materials, alternative designs and appropriate technologies, to improve them to be more acceptable either through research, legislation or intensive education.

**6.4 Recommendations**

1. It is recommended that before Ghana can be successful in both current and future housing policies, the perception of Ghanaians have to be change on use of local natural materials, appropriate or community based technologies and alternative designs for housing delivery in Ghana, especially for achieving the construction of sustainable and affordable housing.
2. The construction industry of Ghana must shift from the use of existing linear construction processes, and adopt to use the cyclic construction processes for effective sustainable affordable housing delivery, which will also ensure sustainable development in Ghana.

3. The study recommends that to enhance and ensure sustainable affordable housing for Ghana, the construction industry which practices building must adopt and implement framework policy for cyclic construction processes for housing delivery propose by this study.
4. Government should set up National Housing Institute with the mandate to draw up effective sustainable and affordable housing policy, and implement these policies without interferences.
5. We should also develop culture to put to use or implement recommendations by experts from academic institutions, private individual to resolve Ghana‟s housing challenges.
6. Governments and stakeholders should establish research institutions and also to equip these research institutions and already existed once, both public and private owned with the needed logistics and funds to conduct critical research into the local building materials to make them more acceptable for construction and exportation for economic development.
7. The study also recommend that Ghanaian can also resolve their housing challenges by developing good housing maintenance and renovation culture and adapt the systems of rethinking construction propose by some other countries like United Kingdom and others.
8. The construction industry would have to place key priorities on the following local materials and technologies by making them more popular to individuals and governments to be use mainly to eradicate the school under tree challenge of housing in Ghana. These important materials are clay pozzolana cement, hydrafoam blocks technology, clay bricks and adobe bricks technology.

9. The study recommends that the construction, industry should put to practice these factors to promote sustainable affordable housing delivery in Ghana. Harnessing the use of renewable energy resources for construction e.g. Solar energy systems, biogas systems for energy generation etc., these can reduced reasonable amount of energy resources use for construction activities in Ghana, Harvesting rainwater and treat them for construction activities, and development codes and standards for guiding the delivery of sustainable affordable housing delivery in Ghana.
10. Construction industry should endeavour to have key performance indicators which measures company policies against meeting housing sustainability and affordability in Ghana.
11. Introducing sustainability into universities for construction students and industries.
12. Innovation in building designs, technologies and materials to the existing once for housing in Ghana.

# REFERENCE

Abdul, M.D. (2011). Developing guidelines for sustainable affordable housing in Ghana.

Adedeji, Y.M.D. (2012). Sustainable Housing Provision Preference for the use of interlocking Mazoning in Housing Delivery in Nigeria.

Agyedu, G.O. Donkor, F. Obeng, S. (2011). Teach Yourself Research methods with 2010 APA updates

Ahadzie, D.K. (2008). Management Practices in Ghanaian House Building industry (unpublished)) pp 1-4, 7-9.

Akubue, A. (2000). "Appropriate technology for socio-economic Development in third World Countries" the journal of Technology Studies XXIV, number 1.

Amoa-Mensah, K. (2003). Housing in Ghana: A search for sustainable Options as the way Forward for Enhanced Output. A paper presented at the international building exhibition seminar, Accra 27th – 28th August.

Bai, L. (200). Sustainable development theory in building domain, Journal of Tsinghua University, Vol. 40, No.9, Sep 2000, pp. 24-27

Bank of Ghana Report- 2007.

Benjamin C. (2007). A Brief History of Housing in Ghana, www.the state manonline.com (accessed 20th August 2014).

Berry, M. (2006). Housing affordability and the economy: A review of macro economic impacts and policy issues, Australian Housing and Urban Research Institute.

Best, J.W. and khan, J.Y. (1993). Research in education (7th ed). Engle wood cliffs, New Jersey: prentice – Hall.

Boamah, N.A. (2010). Housing affordability in Ghana: A Focus on Kumasi and Tamale, Ethiopian Journal of Environmental studies and management, 3(3)

Burke, T. Pinnegars, S. Phibbs, P. Neske, C. Gabriel, M., Ralston, L. & Running, K. (2007). Experiencing the housing affordability Problem. Blocked aspirations, trade-offs and financial hardships, Australian Housing and urban Research Institute.

C.A, Ding, G.K.C. (2001). Sustainable Practices in the built environment, Langston Butterworth- Heinemann, Oxford.

Ghana statistical service (2000). Population and Housing Census.

Dale, B.G. (2003). "Managing quality" Blackwell Publishers Oxford.

Ebsen & Rambol, (2000) International Review of sustainability Low Cost Housing Projects, http://www.builnet.csir.co.za

Emison, G.A. (2001). Civil Engineers and Future Environmental Policies, Journal of Professional Issues in Engineering Education and Practice, Vol, 127, No.3,July 2001, pp. 130-138

Encarta,( 2007). Housing (shelter). Computer Based Microsoft software.

Enshassi, A. Sherif, M. Ziad, A.M. and Peter, E.M. (2007). "Factors Affecting Labour Productivity in Building Projects in the Gaza strip", Journal of Civil Engineering and Management, Vol. XII. No.4

Fisher, T.A. (1992). Principles of Environmental Architecture, AIA, Nov. 1992.

Ghana Building and Road Research institute BRRI – 1970.

Gilkinson, N. (2010) Delivering Sustainable Homes: International Journal for Housing Science, Published in the United States. Vol.34,No.3 pp.175-190,2010

Cronbach, L.J. (1951).“Coefficient alpha and the internal structure of test” Psychometrika.

Gyabaah-Nsiah, K. (2009) urban Housing Challenge and Prospects for meeting the housing Needs, of the Urban poor in Ghana.

Hair, J.F. Anderson, R.E. Tatham, R.L. and Black, W.C. (2006). Multivariate Data analysis with Reading” Prentice – Hall, Engle wood cliffs. NJ

Hard, M. Jamison, A. (2005). Hubris and Hybrids; A cultural History of technology and Science. New York: Routledge, Taylor and Francis Group.

Hinton, P.R. Charlotte, B. Isabella, M. and Bob, C. (2004). SPSS Explained Routledge Taylor and Francis Group. London and New York.

http://www.m4i.org.uk,the movement for innovation

http://www.blaanc.com

http://www.sustainable-development.gov.uk/uk-strategy/content,htm, a better quality of life: A strategy for sustainable development for the United Kingdom

Idrus, A.B and Newman, J.B. (2002). Construction Related Factors Influencing Choice of concrete Floor Systems”, Construction Management and Economic 20, 13-19

Imbeah, K.A. (2012). Framework for the implementation of Total Quality Management (TOM) in Real Estate Firms in Ghana” KNUST-June 2012.

Israel, G.D. (1992). “Sampling the Evidence of Extension program Impact. Program Evaluation and Organizational Development” IFAS, University of Florida.PEOD-6 November.

Kennedy, J. (2011). Overview of natural Building materials for sustainable housing/ housing/livingearth62@hotmail.com.

Kim, J. and Mueller, C. (1978). "Introduction to Factor Analysis, What it is and how to do it" Beverly Hills sage.

Kish, L. (1965). Survey Sampling. New York: John Wiley and Sons, Inc

Konadu-Agyemang, K. (2001). The Political Economy of Housing and Urban Development in Africa: Ghana Experiences from Colonial times to 1998. Praeger Publishers: Westport UK.

Kumar, N. Stern, L. and Anderson, J. (1993) "Conducting Inter-organizational Research Using Key Informants" Academy of Management Journal, 36, pp.1633-1651.

Kumar.R.(2005)Research Methodology(A Step-By-Step Guide For Beginers).SAGE Publications: London

Kwofie, T.E. Adinyira, E. and Botchway, E. (2011). Historical Overview of Housing Provision in Pre and Post Independence Ghana: laryea: Ser. Leiring, b. and Hughes, W. (Eds) Proces West Africa Built Environment Research (WABER) Conference, 19-21 July 2011, Accra, Ghana, 541-557.

Lloyd-Sherlock, P. (2002). „Old Age and Poverty in Developing countries: news Policy. Challenges, World development, Vol.28 (12) pp. 2157-2168.

Malik, M.A.K. (2002). Sustainable Development and Sustainable Construction-Loughborough University.

McCaffer, R. and Harris, F. (2001) "Modern Construction Management" Blackwell Publishing.

Ministry of water, works and Housing Report-2001-Ghana.

Naoum, S.G. (2001). „Dissertation Research and Writing for Construction Students" Butterworth Heinemann, Linacre House, Jordan Hill, Oxford OX2 8DP, 225 Wildwood Avenue, Woburn. MA.

NieL, S. (2008). Sustainable Development guidance for developers and design and construction. www.southampton.gov.uk

Nelson, D. Ayah, S. (2009). Provision of affordable Housing in Ghana Results. Proceeding at the National housing Conference, pps36-37

Neuman W. (2007). "Social Research: Quantitative and Qualitative Approaches, Pearson Education, Inc, USA.

Nunnally, J.C. (1978). "Psychometric theory", 2nd Edition, McGraw-Hill, New York.

Oladapo, A.A. (2005). "An Investigation into the Use of ICT in the Nigerian Construction Industry".

Onibukuw, R. (1998). Urban Housing in Nigeria. NISER: Ibandan

Raynsford, N. (2002), Sustainable construction: the government"s role, proceedings of ICE, Vol 138, June 2014, pp. 6-22.

Schumacher, E.F.E. (1973). appropriate technology.

Sproul. J.L. (1988). Handbook of research methods: A guide to practitioners and students in the social sciences, Metuchen, New Jersey: Scarecrow Press.

Yates, J. & Gabriel, M. (2006). National research Ventures 3: Housing Affordability for Lower Income Australians, Australian Housing and Urban Research Institute.

UN-Habitat (2012), Sustainable Housing for sustainable cities. A Policy Framework for Developing countries www.Unhabitat.org.

Werna, E. (1998). Healthy City Project in developing countires an international Approch to local Problems. London: Earth Scan.

Vergragt, P.J. (2006). How Technology: Could Contribute to a sustainable world, Tellus institute.

Whitehead, C.M.E. (2006). Planning Policies and Affordable Housing; England as a Successful Case Study? Housing Studies, Vol 22 (i) pp. 25-44

www.ghana.goV.gh

Yates, J. Milligan, V. Berry, M. burke, T. Gabriel, M. Phibbs, P. Pinnegar, S. & Randolph, B.(2007). Housing affordability: A 21st Century Problem, Australian Housing and Urban Research Institute.

Zhang, Z. Waszink, A. and Wijngaard, J. (2000). An Instrument for Measuring TOM Implementation for Chinse Manufacturing Companies", international Journal of Quality and Reliability, Vol. 17.

Miyatake Y. (1996). Technology development and sustainable construction, journal of Management in Engineering, Vol. 12, No. 4.

# APPENDIX A

## QUESTIONNAIRES

P. O. Box AD 713
Cape Coast
Mobile: 0244745767

Dear Sir/Madam,

I would be much appreciated if you would answer these questions which forms part of a graduate student thesis. Thank you very much for your assistance and your time. All the information that will be gathered here be kept confidentially and will be used only for the purpose of this research without mentioning the person or company name.

If you need further information or any clarification, kindly contact me on these telephone numbers 0244745767 and 0204027044.

Yours faithfully

Emmanuel Tekpe
(MʹPHIL. Construction Technology (Student).

**TOPIC: SUSTAINABLE AFFORDABLE HOUSING DELIVERY IN GHANA: FOCUSING ON APPROPRIATE DESIGN AND TECHNOLOGY.**

**SECTION A: DEMOGRAPHICS:**

**INSTRUCTIONS**: For this questions, please kindly select by ticking [√ ] all that apply, which is the most appropriate answer to the questions.

1. Please indicate your gender? Male [ ] Female [ ]

2. Please what is your age group?

Below 25yrs [ ] 26-35yrs [ ] 36-45yrs [ ] 46-55yrs [ ] 56+ yrs [ ]

3. Please indicate your highest educational level.

HND [ ] BACHELOR [ ] MASTERS [ ] PhD [ ]

4. Please indicate the number of years you have worked in the construction industry

Below 10 years [ ] 11-20years [ ] 21-30years [ ] 31-40years [ ]

5. What particular work do you normally execute?

Building works [ ] Civil works [ ] Building and Civil work [ ]

Others (Specify)……..……..……

6. What type of profession do you belong?

Architect [ ] Engineer [ ] Quantity Surveyor [ ]

Others (Specify)…… ……

7. What type of classification does your firm belong?

Large scale [ ] Medium scale [ ] Small scale [ ]

8. What type of material does your firm usually use for construction?

Locally Processed Materials [ ] Foreign or imported materials [ ]

Local unprocessed materials [ ] Both local and foreign [ ]

9. What type of technologies does your firm practice for construction of houses? High technology [ ] Appropriate technology (locally and community based) [ ]

10. Are you aware of the construction of sustainable affordable housing in Ghana?

Yes [ ] No [ ]

11. Has your firm built affordable houses that can be afforded by middle and low income earners in Ghana before?

Yes [ ] No [ ]

12 What types of design or style do your firm uses or incorporated for housing?

Luxury or modern designs [ ] Standard or normal designs [ ]

Simple and smaller designs [ ]

**Q14: To what extent are the following housing delivery schemes are most common, common and not common in Ghana.**

Please select an option by ticking [ √ ] in the right column box. Please use this scale:

**3-Most Common 2-Common 1-Not common**

| | Various Housing Schemes in Ghana | Most Common | Common | Not Common |
|---|---|---|---|---|
| 1. | Staff bungalows for senior staff | | | |
| 2. | Staff quarters for staff, teachers and nurses | | | |
| 4. | Compound houses | | | |
| 5. | Dispossessed persons housing schemes | | | |
| 6. | Affordable housing schemes to replace the affected ones( after 1939 earthquake in Ghana) | | | |
| 7. | Affordable housing scheme build with local materials | | | |
| 8 | Town and council housing schemes | | | |
| 9. | Tema development corporation (TDC) | | | |
| 10. | The schocbeton housing schemes (During colonization) | | | |
| 11. | SSNIT mass housing schemes | | | |
| 12. | The housing shelter strategy –NSS | | | |
| 13. | Ghana vision 2020 and the structural adjustment programme –SAP | | | |
| 14. | Economic Recovery Programme-ERP | | | |
| 15. | NPP 20,000 Affordable Housing Units | | | |
| 16. | 10billion dollars XTS affordable housing project | | | |
| 17. | Individual self-help housing scheme | | | |
| 18. | Non-governmental organization housing schemes | | | |
| 19. | Private partnership housing delivery schemes | | | |
| 20. | Private housing delivery schemes (real estate developers). | | | |
| | Please specify any other …….. | | | |

**Q15: To what extent do you agree or disagree with the following statements as problems associated with the various existed housing schemes, and preventing sustainable affordable housing delivery in Ghana**

Please select an option by ticking [ √ ] right column box. Please use this scale:

**4-Strongly Agree 3- Agree 2-Disagree 1-Strongly Disagree**

| | **Problems associated with the various housing schemes** | **Strongly Agree** | **Agree** | **Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| 1. | The type of materials to be used | | | | |
| 2. | The design type and technology to be incorporated | | | | |
| 3. | The interest rate | | | | |
| 4. | Income levels | | | | |
| 5. | Construction cost | | | | |
| 6. | Land supply and acquisition | | | | |
| 7. | Land litigations | | | | |
| 8. | Increase in housing prices | | | | |
| 9. | The Ever increasing cost of building materials | | | | |
| 10. | The taste to use foreign materials and designs | | | | |
| 11. | Rapid population | | | | |
| 12. | Urbanization | | | | |
| 13. | Deterioration of fabric of existing structures | | | | |
| 14. | Absence of sustainable affordable housing policy framework | | | | |
| 15. | Absence of sustainable affordable housing standard and codes for guidelines | | | | |
| 16. | Absence of quality standards to measure the performance of sustainable affordable housing in Ghana | | | | |
| 17. | Failure to championing the use and improving local materials, local designs and technologies | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 18. | Poor managerial systems | | | | |
| 19. | Lack of good governance and political will to construct housing by various government | | | | |
| 20. | Lack of public awareness on the construction of sustainable affordable housing in Ghana | | | | |
| 21. | Lack funding and credits facilities | | | | |
| 22. | Lack of skills and technical know-how personnel‟s | | | | |
| 23. | Unable to accept our indigenous style and systems of construction | | | | |
| 24. | Failure to plan | | | | |
| 25. | Absence of clearly defined national policy for housing | | | | |
| 26. | Lack of employment by majority of Ghanaians | | | | |
| 27. | Materials availability | | | | |
| | Please specify any other…… | | | | |

**SECTION D: To what extent do you agree or disagree with the following, as local available building materials which can ensure sustainable affordable housing delivery in Ghana**.

Please select an option by option [ √ ] in the right column box. Please use this scale:

**4-Strongly Agree 3- Agree 2- Disagree 1- Strongly Disagree**

| | **Local Available building materials** | **Strongly Agree** | **Agree** | **Disagree** | **Strongly Disagree** |
|---|---|---|---|---|---|
| 1. | Clay Pozzolana cement | | | | |
| 2. | Clay bricks | | | | |
| 3. | Unburnt clay bricks | | | | |
| 4. | Land crete blocks | | | | |
| 5. | Mud bricks | | | | |
| 6. | Laterite | | | | |
| 7. | Timber/wood | | | | |
| 8. | Bamboo | | | | |
| 9. | Stones | | | | |
| 10. | Thatch | | | | |
| 11. | Earthbags | | | | |
| 12. | Earthen floor | | | | |
| 13. | Hem and other fibres | | | | |
| 14. | Natural plaster and finishes | | | | |
| 15. | Paper blocks/ fibrous cement | | | | |
| 16. | Grass and poles/ sticks | | | | |
| 17. | Plaster and board/timber | | | | |
| | Please specify any other…….. | | | | |

| **Q16: To what extent do you agree or disagree with the following as appropriate technologies which can ensure sustainable affordable housing delivery in Ghana**. | | | | | |
|---|---|---|---|---|---|
| Please select an option by ticking [ √ ] in the right column box. Please use this scale<br>**4-Strongly Agree 3- Agree 2- Disagree 1- Strongly Disagree** | | | | | |
| **Appropriate technologies** | | **Strongly Agree** | **Agree** | **Disagree** | **Strongly Disagree** |
| 1. | Hydrafoam/ interlocking blocks technology | | | | |
| 2. | Adobe bricks/blocks technology | | | | |
| 3. | Wattle and Daub technology | | | | |
| 4. | Compressed earth blocks technology | | | | |
| 5. | Earthship technology | | | | |
| 6. | Rammed earth technology | | | | |
| 7. | Straw bale construction technology | | | | |
| 8. | Hybrid structures technology | | | | |
| 9. | Living roofs technology | | | | |
| 10. | I section floor beams (Trasacco upper floor technology) | | | | |
| 11. | Local , modular and efficient Eco-Affordable housing technology | | | | |

**Q17: Which of the following statement do you rate (score) most important as good designs qualities for achieving sustainable affordable delivery in Ghana.**

Please select an option by ticking [ √ ] in the right column box. Please use this scale

**4- Most Important 3- Very Important 2- Important 1-Not Important**

| | Good Designs Qualities | Most important | Very Important | Important | Not Important |
|---|---|---|---|---|---|
| 1. | It must be locally or community based strategies | | | | |
| 2. | It must be economical and socially sustainable | | | | |
| 3. | It must base on appropriate technologies practices | | | | |
| 4. | It must protect the natural environment | | | | |
| 5. | It must uses renewable resources | | | | |
| 6. | It must uses recyclable resources | | | | |
| 7. | It must create a healthy and non-toxic environment | | | | |
| 8. | It must encourage maximization of resources reuse | | | | |
| 9. | It must encourage minimization of resource consumption | | | | |
| 10. | It must encourage restoration of damage or polluted environment | | | | |
| 11. | It must improve or make good the arid or dry environment | | | | |
| 12. | It must encourage cyclic construction processes instead of linear construction processes | | | | |
| 13. | Must depend on green building construction principles | | | | |
| 14. | It must always encourage waste minimization | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 15. | It must reduce human exposure to noxious materials | | | | |
| 16. | It must encourages conservation of scarce materials | | | | |
| 17. | Must encourage the use of low –embodied energy materials | | | | |
| 18. | It must reduce energy in use in all aspect of construction | | | | |
| 19. | It must harvest rain water and conserve it for constructional purposes to reduce pressure on social water supply | | | | |
| 20. | It must protect water quality | | | | |
| 21. | It must be flexible in nature | | | | |
| 22. | Must ensure good sound and thermal comfort | | | | |
| 23. | It must encourage the re-use of old building materials | | | | |
| 24. | It must use salvage materials | | | | |
| 25. | It must always consider low energy designs | | | | |
| 26. | Designs building that will be cherished but affordable and sustainable | | | | |
| 27. | Must always ensure safety measures when designing and constructing | | | | |
| 28. | Discourage the uses of foreign materials, technologies and styles for housing | | | | |
| 29. | Must encourage smaller and potable designs | | | | |
| 30. | Must choose low-maintenance buildings | | | | |
| 31. | Designs for future reuse adaptability | | | | |
| 32. | Avoid potential health hazards | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 33. | It must encourage the renovation of older buildings | | | | |
| 34. | Encourage the use of solar energy and resources | | | | |
| 35. | Must situate buildings to benefit from existing vegetation | | | | |
| 36. | Avoid ozone-depleting chemicals and materials for construction | | | | |
| 37. | It must encourage the production, and selling of locally base materials for construction of buildings | | | | |
| 38. | It must encourage the use of natural ventilation instead of artificial means of ventilation | | | | |
| 39. | Minimize the use of pressure-treated lumber/timber | | | | |
| 40. | It must always be in safer and favour of future generations | | | | |
| 41. | It must design to preserve and conserve all resources | | | | |
| 42. | Please specify any other…… | | | | |

## APPENDIX B

**The structured interviewed questions that were response are as follows**:

1. What are the factors affecting the achievement of the sustainable affordable housing in Ghana?

2. What practices would you adopt to facilitate sustainable affordable housing in Ghana?

3. What, in your own opinion is housing affordability means?

4. What, in your own opinion are appropriate technologies and designs for housing?

5. What, in your own opinion are appropriate designs?

6. What do you see as barriers affecting sustainable affordable housing in Ghana?

## APPENDIX C

Reliability and Validity test

**Reliability Statistics table**

| Cronbach's Alpha | Cronbach's Alpha Based on Standardized Items | N of Items |
|---|---|---|
| .951 | .939 | 142 |

**Validity table PCA- Housing problems in Ghana**
**KMO and Bartlett's Test**

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .840 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 1.208E3 |
| | Df | 351 |
| | Sig. | .000 |

**Validity table PCA –Good Housing Qualities Designs**
**KMO and Bartlett's Test**

| | | |
|---|---|---|
| Kaiser-Meyer-Olkin Measure of Sampling Adequacy. | | .709 |
| Bartlett's Test of Sphericity | Approx. Chi-Square | 1.870E3 |
| | Df | 780 |
| | Sig. | .000 |

**PCA Running for the Critical component of housing problems in Ghana**

**Rotated Component Matrix[a]**

| | Component | | | | | |
|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 |
| Increase in housing prices | .792 | .265 | .166 | -.021 | .079 | .170 |
| Lack of public awareness on the constr. of sust. afford. housing in Ghana | .754 | .250 | .292 | .375 | .185 | .004 |
| The interest rate | .730 | .221 | .086 | .145 | .285 | .226 |
| Construction cost | .696 | .279 | .298 | .382 | .088 | .162 |
| land supply and acquisition | .534 | .135 | .308 | .146 | .371 | .359 |
| Land litigations | .519 | .082 | .389 | .062 | .367 | -.025 |
| Income levels | .480 | .320 | .450 | .317 | .051 | .302 |
| Absence of sustainable afford. housing standard and codes for guidelines | .099 | .817 | .061 | .211 | .120 | .080 |
| Failure to champ. the use and improving local mats.,designs and tech. | .327 | .693 | .223 | .001 | -.071 | .124 |
| Lack of good governance and political will to constr. houses by gov. | .420 | .643 | .220 | -.100 | .291 | -.033 |
| Lack of employment by majority of Ghanaians | .069 | .618 | .334 | .114 | .256 | .404 |
| Deterioration of fabric of existing structures | .384 | .551 | .155 | .501 | .029 | .030 |
| Absence of quality standards to measure the performance | .335 | .526 | -.104 | .363 | .189 | .472 |
| The type of materials to be used | .238 | .479 | .258 | .396 | .386 | .189 |
| Absence of sustainable afford. housing policy framewk. | .363 | .058 | .805 | .122 | .183 | .003 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Lack of funding and credits facilities | .241 | .354 | .703 | -.021 | .104 | .344 |
| Rpid population | .183 | .394 | .591 | .306 | .015 | .310 |
| Lack of skills and technical know-how personnel's | .009 | .309 | .586 | .465 | -.111 | .299 |
| materials availability | .125 | .279 | .574 | .334 | .410 | -.102 |
| The ever increasing cost of building materials | .355 | -.231 | .548 | .215 | .328 | .395 |
| The taste to use foreign materials and designs | .106 | .310 | .135 | .706 | .207 | .296 |
| Failure to plan | .246 | -.084 | .357 | .663 | .269 | .082 |
| Absence of clearly defind national policy for housing | .206 | .130 | .185 | .103 | .856 | .182 |
| Poor managerial systems | .199 | .535 | .068 | .201 | .573 | .192 |
| Urbanization | .419 | .073 | .042 | .403 | .548 | .256 |
| Unable to accept our indigenous style and construction systems | .130 | .124 | .270 | .161 | .139 | .789 |
| The design type and technology to be incorp. | .379 | .315 | .050 | .167 | .315 | .541 |

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 13 iterations.

**Running of PCA for the critical factors /good housing qualities designs**

**Rotated Component Matrix[a]**

| | Component | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| It must encourage cyclic constr. instead of linear constr. processes | .908 | .085 | .030 | -.193 | .128 | .040 | .047 | -.123 |
| It must encourages conservation of scarce materials | .867 | .031 | .195 | .070 | .118 | .030 | -.010 | .194 |
| It must improve or make good the arid or dry environment | .829 | .327 | .182 | .068 | .128 | .098 | -.147 | .202 |
| It must encourage restoration of damage environment | .816 | .280 | -.066 | -.149 | .016 | .051 | .198 | -.161 |
| It must uses recyclable resources | .751 | .341 | -.031 | .027 | .141 | .294 | .106 | -.062 |
| Avoid ozone-depleting chemicals and materials for constr. | .529 | .011 | .029 | -.343 | -.191 | .198 | .354 | .412 |
| It must encourage the renovation of older buildings | .506 | .330 | .422 | -.127 | -.024 | .219 | .084 | .157 |
| It must encourage maximization of resources reuse | .204 | .927 | -.009 | -.096 | -.111 | -.025 | .143 | -.087 |
| It must encourage minimization of resources consumption | .163 | .838 | -.134 | -.059 | -.037 | .112 | .098 | -.370 |
| It must uses renewable resources | .163 | .735 | .082 | .089 | .248 | .318 | -.206 | .230 |
| It must protect the natural environment | .381 | .698 | .243 | .122 | .118 | -.009 | .046 | .181 |
| Must ensure good sound and thermal comfort | .048 | .693 | -.146 | .137 | .319 | .129 | -.172 | .325 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| It must use salvage materials | .271 | .504 | .117 | .424 | .164 | -.091 | .014 | .495 |
| Avoid potential health hazards | .064 | .078 | .916 | .065 | .040 | .108 | .143 | .078 |
| Designs for future reuse adaptability | .130 | .074 | .870 | -.010 | .115 | -.097 | .158 | -.052 |
| Designs building that will be cherised but affording and sustainable | .117 | -.106 | .854 | .186 | -.015 | -.148 | -.133 | .097 |
| Must always ensure safety measures when designing and constructing | -.064 | -.062 | .840 | .089 | .072 | .195 | .141 | -.078 |
| It must always consider low energy designs | -.167 | -.084 | -.174 | .801 | .031 | -.040 | .069 | .107 |
| It must protect water quality | -.100 | -.127 | .137 | .726 | .396 | .211 | .016 | .025 |
| It must always encourage waste minimization | .394 | -.009 | .315 | .714 | -.054 | -.086 | -.068 | -.221 |
| Must depend on green building contruction principles | .217 | .146 | .244 | .707 | -.063 | .211 | -.165 | -.249 |
| It must be flexible in nature | -.436 | .231 | -.028 | .695 | .257 | .014 | .021 | .053 |
| It must reduce energy in use in all aspect of construction | -.179 | .089 | .150 | .685 | .161 | -.067 | .070 | .357 |
| It must harvest rain water and conserve them for reuse | -.087 | .176 | .068 | .213 | .862 | -.052 | .184 | -.057 |
| Must encourage the use of low-embodied energy materials | .351 | .048 | .057 | .023 | .823 | .081 | .033 | -.070 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| It must encourage the use of solar energy and resources | .171 | .043 | .091 | .184 | .785 | .118 | -.296 | .236 |
| It must be economical and socially sustainable | .001 | .073 | .199 | .034 | .131 | .842 | -.099 | -.078 |
| It must base on appropriate tech. practices and strategies | .330 | .141 | -.104 | .002 | -.019 | .745 | .368 | -.002 |
| It must encourage the re-use of old building materials | .454 | .146 | -.176 | .117 | -.004 | .602 | .197 | .318 |
| It must always be in safer and favour of future generations | .196 | .081 | .082 | .080 | -.092 | .253 | .731 | .294 |
| Discourage the use of foreign materials, tech. and style for housing | .016 | -.043 | .256 | -.023 | .080 | -.030 | .696 | -.155 |

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

# APPENDIX D

**Typical project build with pozzolana cement at Accra and valley View University**

**SOURCE: info@ghanacement.com**

Structures in Ghana build with local building materials. Source Esiaman K.E.E.A

Hydraufoam blocks technology for building school projects in Greater Accra and Central Region of Ghana. Source Assin Kobina –September, 2014

Typical Clay Bricks self contain house. Source: (Agona Biakwa-central region) Sep. 2014