UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI.

ADOPTION OF APPROPRIATE MEASURES TO MINIMIZE THE EFFECTS OF FLOODS ON HOUSING IN THE THREE NORTHERN REGIONS OF GHANA: THE PERSPECTIVE OF CONSULTANTS

APAYA CHRYSANTUS WEKEM

AUGUST, 2015

UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

ADOPTION OF APPROPRIATE MEASURES TO MINIMIZE THE EFFECTS OF FLOODS ON HOUSING IN THE THREE NORTHERN REGIONS OF GHANA: THE PERSPECTIVE OF CONSULTANTS

BY

APAYA CHRYSANTUS WEKEM

(8121760014)

A Dissertation Submitted in the Department of CONSTRUCTION AND WOOD TECHNOLOGY EDUCATION, Faculty of TECHNICAL EDUCATION, School of Graduate Studies, University of Education, Winneba, in partial fulfillment of the requirements for the award of Master of Philosophy (Construction Technology) degree.

AUGUST, 2015

DECLARATION

STUDENT'S DECLARATION

I, APAYA CHRYSANTUS WEKEM, declare that this Dissertation, with the exception of quotations and references contained in published works which have all been identified and duly acknowledged, is entirely my own original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

SIGNATURE: ………………………………….

DATE: …………………………………………….

SUPERVISOR'S DECLARATION

I hereby declare that the preparation and presentation of this work was supervised in accordance with the guidelines for supervision of Dissertation as laid down by the University of Education, Winneba.

NAME: DR. KHENI ALKANAM NONGIBA

SIGNATURE: …………………………………..

DATE: ……………………………………………..

ACKNOWLEDGEMENT

My first and famous thanks goes to my Dissertation Supervisor; Dr. Kheni, for guiding and supporting me in this work.

I am highly indebted to Dr. Paa-Kofi Yalley, Dr. Martin Amoah, Dr. Francis Bih (Graduate Programmes Co-coordinator) and all of the staff of the Department of Construction and Wood Technology Education, College of Technology Education, University of Education, Winneba, for the immense support given to me during the preparation of this Dissertation.

Mention must be made of some staff of Architectural and Engineering Services Limited, Accra, particularly Mr. Kojo Hohoabu, who rendered support and responded to questionnaires administered. I thank the Honorary Executive Secretary of the Ghana Institution of Surveyors QS Division, Surveyor Humphrey Togbe Amegadoh, for assisting me with the list of members and responding to questionnaires.

I am highly grateful to the Upper East Regional Director of Ghana Highways Authority, Ing. Abdallah Bille (Alhaji), for assisting me in the pilot study.

DEDICATION

To my late mother, Mary Anne Apaya and my lovely wife, Mrs. Beatrice Apaya and my lovely Kids: Cyril, Wilhelmina, Elsie – Cecilia and Venantius for their love, support and encouragement during the compilation of this dissertation. Thanks be to God.

TABLE OF CONTENTS

CONTENT **PAGE**

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

ABSTRACT

Globally, flood disasters increasingly pose severe risk to humanity due to their devastating effects. The built environment is the worst affected sector and often the repercussions of flood events on poorly planned and/or designed settlements leads to crisis situations. In Ghana, floods are major occurrences in the principal cities and towns and settlements along the Volta River Basin. Yearly, the three northern regions of Ghana namely; Northern Region, Upper East Region and Upper West Region experience floods which displace human population. The aim of this study was to examine the effects of floods on housing in the three northern regions of Ghana and strategies for minimizing the effects. The research strategy adopted was a quantitative approach involving the development of survey questionnaires administered to a purposeful sample of 158 consultants (Architects, Quantity Surveyors and Structural Engineers). The findings of the study revealed that the principal effects of floods on housing are destruction of the foundation, collapse of walls and damp penetration. The study also revealed that the enabling factors for adoption of appropriate measures to minimize the effects of floods on housing included; compliance with building regulations and raising the foundation above round level to allow the flow flood water beneath the building. The study revealed key barriers to the adoption of appropriate measures to mitigate the effects of floods included; lack of effective management of risk, design challenges and non-availability of the right materials. The study equally revealed appropriate measures as the adoption of raised piled foundation, stone or burnt clay brick wall and pitch roof with clay tiles as roof covering material to minimize the effects of floods on housing.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

In recent years, Ghana has been facing the most devastating natural disaster; flood, every year in different parts of the country. This disaster culminates in large scale of damage and destructions to houses especially in the three Regions of the North of Ghana. The non-engineered houses constructed by the inhabitants are mostly damaged due to lack of technical guidance (Adelekan, 2010). Considering the growth of non-engineered housing, and the damage level of housing due to flood disasters, it is essential to develop an appropriate housing model which is capable of reducing the disaster effects on housing. Several studies have described methods of constructing housing using low cost techniques (Awour, et al., 2008). The Three Northern Regions of Ghana, namely; Upper East, Upper West and Northern Regions, have been facing flood effects on housing as a yearly affair. Appropriate measures are steps adopted to design and construct a house that will continue to function or requires little maintenance in the event of flood (Lerise et al., 2005). The owner built houses are not durable and get damaged due to heavy rains and wind blows. The projected eaves of the roof are also damaged due to heavy wind velocity. During flood event, the pyramidal shape roofs are damaged due to uplift forces developed by cyclone .The light roof structures having inadequate "J" bolts and absence of wind bracing and lack of ties, inadequate sheet thickness, fastening and insufficient frequency of the fasteners contribute to the damages, even the permanent houses constructed with sandcrete block walls are also affected due to the excessive flood water (Lerise et al., 2005). The reinforced concrete (RC) roof slab having inadequate thickness of roof concrete and low self-weight which causes tension at the top due to the suction. The effect of wind where hair line cracks developed, These RC concrete exposed to the atmospheres are getting rusted and ultimately causes the roof to collapse. The unsymmetrical houses have shown heavy damages when compared to symmetrical plan about its both axes. The National Disaster Management Organisation (NADMO) is often to decide the level of destruction during floods events and to distribute relief items to victims (Lupala, 2002). The unreinforced masonry walls fail due to excessive tension. Sometimes the timber rafter are destroyed by the white ants and losses its section and leads to collapse at the time of disasters. The unscientific installation of roof tiles, the doors and windows latches, hinges and bolts are vulnerable hardware and fasteners all accounts for the annual destruction of houses in the north of Ghana (Adelekan, 2010).

Flood is an eruption of a large volume of water over land but not often submerged (Sheiku, 2010). Ahmed (2003) opines that flood is an extreme weather event naturally caused by rising global temperature which results in heavy downpour, thermal expansion of ocean and glacier melt which in turn results in rise in sea level, thereby causing water to inundate coastal land. Flooding is a house hold name as far as environmental hazards are concerned and often claims more than 20,000 lives annually and seriously affects almost 75 million people all over the world. Adelekan (2013) is of the view that flood costs about one third of all deaths, one third of all injuries and one third of all damages to dwelling houses. The pattern in Ghana is similar to the rest of the world. Flooding in several parts of Ghana has ejected millions of people from their homes, destroyed businesses, polluted water bodies and increase communicable diseases (Baba, et al., 2012). Available record shows that about five thousand people (5000) have lost their homes and properties with three hundred (300) people losing their lives yearly due to flooding (Sheika, 2010). Properties worth billions of Ghana Cedis have been submerged in flood waters across the country (Sheika, 2010). Gyau (2000) laments that for residents of the Three Northern Regions and most Ghanaian towns and villages, the rainy season is by no means the worse time as far as floods in Ghana are concerned. This period is accompanied by perennial events of flooding with its subsequent collapse of residential buildings resulting in the loss of property and human lives. Properties estimated at millions of Ghana Cedis were destroyed in many communities in Tamale and Bolgatanga in 2010 (Sheika, 2010). It has been realized that persistent over flow of the Bagre Dam in Burkina Faso is partly responsible for this disaster (Sheika, 2010). Additionally, the unprecedented rainfall witnessed globally in 2012 has made the Atlantic ocean level rised and in turn forced the White Volta water to rise and spread into the flood prone areas. In the history of floods, a great calamity has always been brought to mankind (Sheika, 2010). The aftermath of floods can be devastating as their physical effects through destruction of basic infrastructures such as housing and breakdown of transport for food, temporary shelter and emergency services (Udarty et al., 2006). Flood also comes with destruction of settlements, properties, hunger and worse of all, loss of lives. Flooding has been identified as one of the main factors that militate against Africa"s growing population of city dwellers from escaping poverty and diseases thereby putting a stumbling block on the way of the United Nation 2020 goal of achieving desirable improvement in the lives of urban slum dwellers (Shieka, 2010). This is so because several African cities lack the infrastructure to cope with the extreme weather conditions (Shieka, 2010).

The world has been trying to give its people decent shelter by 2020 (Blaikie, et al., 2004). A research conducted by Olesya (2013) on global housing deficit indicated that 1 out of the 6 billion world population live in “death trap” houses, susceptible to damage by the least impact of a natural disaster especially floods. Majority of this population live in developing countries. The dream for a total of 227 million people in third world countries to have decent shelter in line with the Millennium Development Goal (M.D.G) according to Opong (2000) will not be achieved as long as the issue of destruction of buildings is not given the needed attention. The introduction of resilient designs have been embraced as it offers lasting solution to damage of houses due to floods and other forms of disaster (Afro, 2009). However, little or no progress is made in developing countries in this direction. Baba et al. (2012) noted that several home owners are left at the mercy of the weather during flood events. Several communities in Ghana suffer from the devastating effects of floods in terms of destruction of houses (IDB, 2011).

It is a well-known fact that Ghana is a flood prone country (Adelekan, 2010). The National Disaster Management Organization according to Afro (2009) has declared that as a result of annual floods, a significant number of houses in the rural areas and along river banks in Ghana will be destroyed in the coming years (Ahmed, 1994). During the 2010 floods, a total destruction was caused to a huge number of houses rendering about 1 million people homeless.

The great percentage of this population can be traced to the three Northern Regions of Ghana namely; Upper East, Upper West (Afro, 2009). Floods have been defined by Opong (2000) and Afro (2009) as an over flow of water which occurs as a result of flash rains or water that comes from a river or other water bodies and brings about devastation damage to life and property. The three Northern Regions according to Benevolo (1980) are the worse affected when the issue of floods impacts are mentioned. Adelekan (2010) argued that floods in the Northern part of Ghana are mostly attributed to the annual spillage of the Bagre Dam in Burkina Faso. Afro (2009) pointed out that since Burkina Faso is up stream, any spillage from a water course will run down to submerge houses and farm lands in the North of Ghana. The White Volta takes its source from neighboring Burkina Faso up stream spilling downstream and causing floods in Ghana (IDB, 2011). Several communities have settled along the white and Black Volta in order to have access to fertile lands for farming purposes (Adelekan, 2010). The river however becomes narrower as a result of backfill of loose soil from the farmlands. The end result of this phenomenon is the fact that houses and farmlands are destroyed in the event of river overflow (Baba, et al., 2012). A survey conducted by Awour, Oridi and Adwera (2010) indicated that a total of 65 communities had their houses completely destroyed in the West Gonja District in the Northern Region and displacing about 6289 persons (Brahmi, et al., 2004).

The yearly occurrences of floods in the North of Ghana have had a negative impact on the settlement of the citizens of Northern Ghana especially those communities along the White Volta basin (Gyau, 2000). Most flood disasters in recent times in Ghana are due to intense rainfall, spillage of the Bagre Dam coupled with indiscriminate disposal of garbage into gutters and land drains (Olesya, 2013). To a large extent, the patterns and causes of destruction seem to result from poor technical knowledge about the concept of resilient design. There is little or no support for housing projects in low income flood prone communities (Olesya, 2013). Dwelling houses in rural areas are often owner built or designed by local artisans (Afro, 2009). Many of these designs are prepared by people who are not construction professionals, hence when implemented, many problems emerge. The usual tendency is to apply the same principle irrespective of the context, soil condition and level of the water table (Satterethwaite, et al., 2007). In most cases, the cost clement is what significantly affects the implementation of best practices. The non-existence of an estate development programme that is geared toward providing subsidized housing to a large number of people who need them is a tragedy (Satterethwaite, et al., 2007). There is the need to develop a housing scheme which is appropriate for flood prone areas where the suggested solutions can be made cost effective as a means of rationalizing the economy.

According to Adelekan (2010) this flood resistant design must be affordable to the local people without compromising on quality. There must be a deliberate attempt to take up initiatives towards improving the performance of new construction by incorporating appropriate flood resilient designs. Cost effective flood resistant design of resilient buildings will make them affordable to the vulnerable people who are a low income group (Afro, 2009). Although, this is the case, very few studies have been done on the possibility of resilient design for flood prone communities (Afro, 2009). Only a handful of research has been conducted on Design of flood resistant houses for poor families, Design of Amphibious structure that is capable of floating in flood water and the causes of destruction of houses during flood events (Gyau, 2000; Baba, et al., 2012 & Afro, 2009). The contribution of built environment consultants, vis-à-vis, minimizing the effects of floods on housing especially in flood prone areas still remains unexploited (Olysya, 2013). The relevance of context knowledge that is knowledge obtained from live experiences of construction professionals such as Architects and Quantity surveyors according to Ahmed (1994) cannot be under estimated. Such designs must be cost effective to meet the needs of the vulnerable communities without compromising on the quality of the product. The use of local building materials to achieve this aim should not be ignore since built environment research have come out lately with lesser known materials to enrich and develop the construction industry (Awou, et al., 2008).

The focus of this research is to minimize the effect of floods through the application of resilient buildings in flood prone areas. It is greatly anticipated that house owners, local masons and small scale contractors will continue to play significant role in the constriction of buildings for low income groups (Awuor, et al., 2008). However, as pointed out by Sheika (2010), it is necessary to upgrade the skills of local Masons by coming out with a frame work for the implementation of resilient designs in flood prone communities. This is a sure way to improving and achieving engineered buildings hence, considerable reduction in loss of human life and property during flood event (Afro, 2009). In the three northern regions, more than 46,000 houses were destroyed and nearly 700 people lost their lives in 2007 as a result of floods (Baba, et al., 2012).

The annual spillage of the Bagre Dam in Burkina Faso makes flooding in the north of Ghana annual event destroying a lot houses and rendering the inhabitants homeless each year (Opong, 2000). There is gross indiscipline in the construction industry in Ghana in recent years. Developers flawed the building codes with impunity. The practice seem to stem up from several factors which when not immediately checked has potential to ground the construction industry to halt and subsequently mitigate against Ghana‟s move towards a high income country in South Sahara Africa. Ahmed (1994) concluded that there is inadequate or lack of moral will to enforce the existing building regulations and bye-law the insufficient number of Building inspectors in the country is another contributive factor. There has been a serious decline in the use of the services of professionals in the construction industry (Kwabena, 2000). In line with this Mayo (2001) pointed out that most of the houses are built with little or no professional advice. Many towns and Cities are not planed or zoned to commensurate the rapid rate of development in the housing industry in Ghana. Building plots and lands are bought and sold indiscriminately without reference to planning schemes (Adelekan, 2010). Many buildings are sited in hazardous or flood plains and on compressible soils with disregards to the soil investigation report (Adelekan, 2010). The most vulnerable or poorest people of society who reside in flood prone areas are they depend only on local materials such as Pozzolana, bamboo and thatch just to mention but a few for construction of dwelling houses (Baba, et al., 2012).Heavy rains that result in floods normally emerged during the months of August and September such floods in northern Ghana of ten displace vulnerable persons and destroys key infrastructure. This is due to inappropriate or wrong construction in an attempt to make use of available local materials (Olesya, 2013). The accumulation of events such as prolonged dry spell, abnormal torrential rains and the spillage of the Bagre Dam in Burkina Faso all aggravated the humanitarian situation in Northern Ghana. Vulnerable communities are also severely affected because of the timing and magnitude of the flood (Sheika, 2010).

The governments of Ghana and other development partners have provided immediate lifesaving assistance to affected population in the most devastated areas (Afro, 2009). However, these are interventions are in the short term. The long term solution to the yearly collapsing of hoses is yet to be addressed (Sharma, et al., 1980). The rapid deterioration and collapse of buildings which have to be rebuilt any other years is a source of great concern not only to the affected people but to the whole country and government in particular (Ericson, 1993). In the aftermath of flooding, many of the flooded areas normally become inaccessible due to breakdown of key infrastructure including roads and bridges making farm produce to go waste in the farmlands (Sieke, 2010). An estimated number of 50,000 people in the north of Ghana are expected to remain vulnerable to collapse of dwelling houses caused by floods and 25,000 are a result of sudden collapse of buildings on the next 15years (Ahmed, 1994). Very high magnitude of about 414.1mm average rain is expected to hit communities such as Tamale, Navrongo, Walewale, Salaga, Zuarungu, Manga, Bawku, Bui, Yendi and Bole all located in the three northern regions in 2014 and 2015 raining seasons (Afro, 2009).

Certain design features must be included in a design meant to resist floods to qualify it as resilient design (Mud, 2012). These features make the design capable of resisting floods. A resilient design will not only be durable but will also remain habitable after a flood situation (Olesya, 2013). Certain critical barriers however mitigate against the choice of resilient designs. These barriers if properly handled Brahmi et al. (1994) will in a sure way increase the believability and confidence of resilient design (Adelekan, 2010). There is clear evidence that the increasing manner of flood disaster occurrence and the devastating effects on the economic progress of Ghana coupled with the cumulative damage to buildings is a source of worry to many Ghanaians (Ahmed, 1994).

Resilient design is almost absent in northern Ghana where the indigenous people are predominantly peasant farmers. They people are classified as a low-income group who cannot afford to pay such colossal amount for a new technological design (Adelekan, 2010). This research is about minimizing the effects of floods on housing through the introduction of resilient designs. The research contributes to the construction of safe houses in the construction industry in several ways. The study provides in depth knowledge on the impacts of floods in flood prone communities (Thomsen, et al., 2010). These impacts will enable the findings of the study to make recommendations to prevent possible floods in flood prone areas in the three northern regions of Ghana.

The study presents a fair understanding on the quantum of destruction in a typical flood event. The findings will also provide a road- map for designing a simple flood resilient design for the study area. A detailed consideration is given to the type of local materials available therein for use in the construction industry and the method of construction. These findings give a theoretical background on how materials can be treated effectively by employing scientific methods to prolong their lifespan. The findings therefore will provide the platform for generating guidelines in developing and transferring technologies of international standards to the socio-cultural settings in Ghana (Adelekan, 2010).

The primary objective of flood-proofing is to reduce or avoid the impacts of flooding upon structures. This may include elevating structures above the floodplain, employing designs and building materials which make structures more resilient to flood damage and preventing floodwaters from entering structures in the flood zone, amongst other measures. The description of this technology originates from Beck and ITN (2003). Flood-proofing of tube wells, boreholes and (hand) dug wells is described in the article 'Flood resilience for protected wells' Flood-proofing measures are widely applied in the USA where two types of flood-proofing are widely recognized: wet and dry. Wet flood-proofing reduces damage from flooding in three ways; first of all, allowing flood waters to easily enter and exit a structure in order to minimize structural damage. Secondly, the use of flood damage resistant materials and thirdly, elevating important utilities. On the other hand, dry flood-proofing is the practice of making a building watertight or substantially impermeable to floodwaters up to the expected flood height (Tamar, 2010).

Wet flood-proofing measures typically include structural measures, such as properly anchoring structures against flood flows, using flood resistant materials below the expected flood depth, protection of mechanical and utility equipment and use of openings or breakaway walls to allow passage of flood waters without causing major structural damage (Olesya, 2013). Basic wet flood-proofing measures for a residential structure (Saeraj, et al., 2004). A dry flood-proofed structure is made watertight below the expected flood level in order to prevent floodwaters from entering in the first place. Making the structure watertight requires sealing the walls with waterproof coatings, impermeable membranes, or a supplemental layer of masonry or concrete, installing watertight shields on openings and fitting measures to prevent sewer backup (IDB, 2011).

Flood-proofing can be applied in residential and non-residential buildings and the principles of flood-proof design can also be applied to other important infrastructure such as electricity substations and sewage treatment works. Obviously, the decision to choose wet or dry flood-proofing should be influenced by the use of the structure being protected and the compatibility with flood water. One of the main advantages of flood-proofing is that it avoids the need to elevate, demolish or relocate structures and as a result, is often a much more cost effective approach to reducing flood risk (Mathis, 2006).

Flood-proofing measures are also much more affordable than the construction of elaborate flood protection works such as seawalls and dike systems (NMBA, 2004). Flood-proofing is also advantageous because it does not require the additional land that would be needed to offer the same degree of flood protection through seawalls or dikes. Wet flood-proofing measures are beneficial because they allow internal and external hydrostatic pressures (relating to fluids which are not in motion (for example, the maximum still water level caused by extreme events) to equalize during a flood therefore lessening the loads on walls and floors (Janssen, 2011). This means structures are less likely to fail during floods. Although flood-proofing will not allow residents to continue living in their house during flooding, flood-proofing measures will make it much quicker and easier to clean up and repair flood damage (Chagnon, 1996). Flood-proofing can also be undertaken by individuals, rather than requiring funding from central or local government bodies. Even small, inexpensive flood-proofing efforts are likely to result in worthwhile reductions in flood damage. Availability of funds to undertake more expensive flood-proofing measures will no doubt encourage the uptake of flood-proofing however. Disadvantages of the technology Flood-proofing measures require the current risk of flooding to be known and communicated to the public through flood hazard mapping studies and flood warning systems. This will allow flood-proofing measures to be appropriately applied and will allow time for residents to vacate flood-proofed buildings in the event of an emergency. In the case of dry flood-proofing, it will also allow residents to close barriers in a timely fashion. Although the provision of flood hazard maps and flood warnings bring benefits themselves, it is an additional cost that must be borne when implementing flood-proofing measures. Since residents are not able to continue living in flood-proofed houses during flooding, amenities for accommodating evacuated people must also be provided (Chagnon, 1996). These facilities may be required for some period after a flood event, as wet flood-proofing may leave the structure uninhabitable for a small period following flooding. Flood-proofing measures are most effective when applied in areas where flood depth is low. The application of flood-proofing measures does little to minimize damage caused by high velocity flood flow and wave action (Benevolo, 1980). If a flood larger than the design specification occurs, the effect will be as if there was no protection at all (Erickson, 1993). Another disadvantage is that in the case of dry flood-proofing, flood shields are not aesthetically pleasing (Brayant, 1991). Shields for doors and windows are left in place in most circumstances, so that they can be quickly closed when required. However, this means that these measures are permanently on display. Ongoing maintenance of flood-proofing measures is also required to ensure they continue to provide appropriate protection (Olesya, 2013). When wet flood-proofing measures are applied, flood waters still enter the structure. Therefore significant clean up may be required following floods to remove water borne materials such as sediments, sewage or chemicals (Chisholm, 2000). The choices of materials used in these structures will still enable clean up to progress much more quickly than in non-flood-proofed structures.

In the case of dry flood-proofing, if design loads are exceeded, walls may collapse, floors buckle and homes may even float. This has the potential to cause more damage than if the home were just allowed to flood (Gyau, 2000). Financial requirements and costs in the absence of cost information from developing countries, cost estimates for a number of flood-proofing measures in the US are provided. The US is one country which widely applies flood-proofing measures. In the US, the cost of elevating a structure above flood depth is likely to be between US$29 and US$96 per square foot of house footprint (Olesya, 2013). The range in cost is due to the construction and foundation type and the required elevation. Wet flood-proofing measures are likely to include the addition of wall openings for the entry and exit of floodwaters, installing pumps, rearranging or relocating utility systems, moving large appliances and coating surfaces in coverings which make it easier to clean up after flood waters recede. According to Barker (1994), the cost of wet flood-proofing in the US is likely to be between US$2.20 and US$17.00 per square foot of house footprint when considering basement flood-proofing up to a depth of approximately 2.4 m. Dry flood-proofing measures in the US include sealing walls with waterproof coatings, impermeable membranes or supplemental layers of masonry or concrete and equipping doors, windows and other openings below the flood elevation with permanent or removable shields. Installation of backflow valves on sewer lines and drains is also likely to be required (Urdarty, et al., 2006).

Wet flood-proofing is generally less expensive than dry flood-proofing since any action to reduce the number of items that are exposed to flood damage is considered a wet flood-proofing measure (Urdarty, et al., 2006). For example, moving valuable items to an upper story is a wet flood-proofing measure that can be undertaken at negligible cost. The costs of dry flood-proofing a structure will depend on the following factors (Farrelly, 1996). At the community level, flood-proofing costs will depend largely on the number of properties in the flood hazard zone and associated costs such as flood hazard mapping and modeling exercises to determine properties at risk. Flood-proofing measures are very much possible at the community level. At its simplest, wet flood-proofing involves moving valuable objects to higher ground in order to avoid the effects of flooding. Since this can be undertaken at negligible cost, wet flood-proofing is highly achievable on a local level provided sufficient warning time is provided. More advanced flood-proofing measures are not as capital intensive as the construction or realignment of coastal defenses and therefore should also be achievable at the community scale. Implementation of this technology will however, require a proactive planning approach. It may even be possible for individual households to finance basic flood-proofing measures themselves. This may include elevating valuable items and utilities above the expected level of flooding. This will be possible if households are given adequate information on the likely level of flooding. However, more advanced flood-proofing measures are likely to require the assistance of specialists. For example, the construction of houses within the flood zone will require experienced, professional engineers or architects to develop and/or review structure designs to ensure that structures are capable of functioning as designed. Although flood-proofing is achievable at the community level, its effectiveness depends on community uptake and the standard to which measures are implemented. Few benefits will be gained from flood-proofing if the uptake is low or if measures are completed to a low standard. Potential unwillingness to undertake flood-proofing such measures has been highlighted by Thomsen et al. (2010) who found that only 63% of new buildings are in compliance with flood regulations in the US. Due to reluctance to undertake flood-proofing measures on an individual basis, it may be necessary to inspect properties in the hazard zone to ensure that flood-proofing measures have been employed and to an acceptable standard (Urdarty, et al., 2006).

Funding may be provided to local communities in order to increase uptake of flood-proofing projects. This may increase uptake in poorer communities and may help to protect those at risk rather than just those who can afford such measures. A similar outcome may be achieved if flood insurance is regionally important. Reduced premiums for flood-proofed properties will encourage the uptake of flood-proofing. Before communities can go ahead with flood-proofing measures, it will be necessary to undertake some form of flood hazard mapping. This will inform decision-makers on which buildings require flood-proofing and to what depth. It can also support the appropriate design of flood-proofing measures.

Although basic flood-proofing measures can be undertaken at negligible cost, the cost of implementing more advanced flood-proofing may be prohibitive in poorer communities. This may prevent implementation but could be addressed by providing funding opportunities. For more advanced flood-proofing measures, such as anchoring structures and installing breakaway walls, specialist knowledge is likely to be required. This may require the input of experienced architects or engineers. In areas where flood hazard maps do not currently exist, the uptake of flood-proofing measures may be problematic. Non-availability of flood hazard maps will make identification of properties at risk and the minimum specification of flood-proofing measures difficult to define. The main opportunity for the implementation of flood-proofing lies in the capacity to allow development in the flood hazard zone to go ahead albeit, with explicit limitations. Where there is high demand for coastal land, flood-proofing measures present an opportunity to utilize this land. This is in contrast to policies such as building setbacks, which prevent coastal development (Dunham, 1991).

There are common features in Ghana that indicate that local coping strategies are required to reduce the shocks. The combination of cumulative events such as the prolonged dry spell, abnormal torrential rains and the spillage of the Bagre Dam in Burkina Faso all aggravated the humanitarian situation in Northern Ghana. Vulnerable communities are also severely affected because of the timing and magnitude of the flood. The government of Ghana and her development (Urdarty, et al., 2006).

Development partners provided some of the much needed lifesaving assistance to affected populations in the most devastated areas. However, owing to the vulnerability of socio-economically, the floods triggered a rapid deterioration of existing vulnerabilities. In the aftermath of flooding, many of the flooded areas were inaccessible due to breakdown of key infrastructure, including bridges and roads (Urdarty, et al., 2006). Initial assessments by the Ministry of Food and Agriculture (MOFA) estimated that 70,500 hectares of farm lands were affected, resulting in an estimated production loss of about 144,000 metric tones (MTs) of food crops(including maize, sorghum, millet, ground nuts, yam, cassava and rice). This resulted inaccurate food shortage in the affected communities. An estimated 50,000 people in Northern Ghana was expected to remain vulnerable to food insecurity and at risk of malnutrition for at least 15 months beyond the early harvest in October 2008 (Conrad, 1997).

In Ghana, floods are among the most frequent and devastating natural disaster that affects the livelihood of the people. According to Urdarty et al. (2006) government and other stakeholders like Non-Governmental Organizations (NGOs), donor agencies and philanthropic organizations over the years have provided some kind of relief services, rehabilitation and resettlement to flood victims (Conrad, 1997). Flooding in the country mostly occur during the rainy seasons in the months of May, June, July and August. Floods of various magnitudes hit some of the districts and its surroundings in the country.

People have always found ingenious ways to overcome adverse conditions like floods, earthquakes and tsunamis among others, but because of lack of wider dissemination, these initiatives have remained localized to limited areas. Government and developmental organizations the world over, have tried to deal with flood situations in their countries, but their initiatives have been more of settling victims after the occurrence of the said floods (relief oriented) and short period targeted as it is always within a short time frame. As a result, there have been no long-term solutions to the people's problems nor have such initiatives had a positive impact on the people's coping mechanisms and capacities (NMBA, 2004).

Tolon/Kumbungu District in the Northern Region of Ghana is flood prone, during the months of July – September in 1995, 1997, 2004, 2007, 2008, 2009 and 2010; the District was hit by floods. The worst flood in August 2007 resulted in six human deaths, lost of property, with more than 1,300 households rendered homeless. Again, many buildings were submerged and over 3,000 hectares of farmlands destroyed. Additionally, the floods caused outbreak of water-borne diseases including diarrhoea, cholera and malaria particularly, among children. This called for more support from government and other development partners (Afro, 2009).

1.2 Statement of the Problem

The White Volta takes its source up stream in Burkina Faso and flows down through the Upper East, Upper West and Northern Regions of Ghana which are relatively low lands (Ahmed, 2003). Communities along the river basin often experience flooding and their buildings destroyed during the rainy season each year, coupled with perennial rains that magnify the situation. The spillage of the Bagre Dam is an annual practice (Baba, et al., 2012). The inhabitants settling along the White Volta basin are peasant farmers who belong to the low income group and live in Mud houses that easily get destroyed with the slightest drop of rain (Amato, 1995). Afro (2009) identified floods in the north as the most recurrent and costly hazard affecting the three northern regions of Ghana, making a lot of people homeless. Within the past decade, these regions have lost millions of Ghana Cedis as a result of damage to houses and other numerous facilities (Amato, 1995). Out of the 90 events reported by Sheika (2010) continuously for 5 years, 150 residents have been killed through the sudden collapse of houses in flood situations. Considering the fact that majority of the buildings are constructed with mud, the damage to buildings is often severe leading to total collapse. A total of 86,630 people were displaced with an estimated damage cost of GH€992,452.00 in the three northern regions of Ghana (Adelekan, 2010). It is a well-known fact that all the flood events may not have been reported due to the bureaucracy in reporting disaster issues to the appropriate authorities. However, the devastating impact such hazards pose to the economy and the vast majority of the vulnerable population of Ghana cannot be under estimated (Adelekan, 2010).

Afro (2009) viewed the impact of floods in Ghana as an issue of non-availability of flood resistant houses. The major setback is that most developers in flood prone areas are reluctant to employ appropriate measures in constructing their houses citing cost as a major factor. Benevolo (1980) argued that the ignorance of the benefits of resilient design accounts for this trend of events. The low-income inhabitants are left with no other choice than to reconstruct their houses each year. According to Benevelo (1980) the least drop of water from the heavens is likely to cause flood. Afro (2009) warned that rainfall recordings from April – August 2014 for the three northern regions was at least 700mm as against 550mm recorded the same time in 2013. This is extremely on the higher side. The imminent spillage of the Bagre Dam is still very high especially as the rainy season is about to set in (Baba, et al., 2012). In Ghana, flood victims currently depend on government for food and non-food items as pointed out by (Udarty, et al., 2006).

Arguably, well researched and implemented development schemes could minimize if not prevents human suffering and economic loss resulting from the incessant floods experienced by the three Northern Regions. Disaster management is about preparedness, the earlier the issue of annual collapse of buildings is addressed due to floods, the better for the country and its citizenry. There is therefore the need for the development of a framework for mitigating the effects of floods on housing and other physical infrastructure. Most communities affected by floods remain vulnerable to its effects since there has been no considerable change in the rainfall pattern in recent times (Afro, 2009). While much concerted efforts by technocrats or governments to adequately support housing projects for low income flood vulnerable communities and houses is essential, much needs to done by way of research which the findings will provide appropriate measures to mitigating the effects of floods on physical developing including resilient housing schemes. The aforementioned arguments therefore underscore the aim of the present study. Erickson (1993) pointed out this gap in knowledge by citing the need for robust technical guidance by industry consultants for buildings in respect of flood disasters.

1.3 Justification of the Study

The negative effects of floods have brought about living memories on the minds of many Ghanaians who have had their buildings destroyed. This study stems from current devastating floods in the three northern regions. Many flood experts including Afro (2009). Peal (2012) agrees that the quest for coastal land is on the increase in recent years. This current development may be explained by the many modern houses built near water bodies across the country and are mostly exposed to floods. Floods are certainly disastrous and that any opportunity to incorporate certain features that minimizes flood effects on dwelling houses must be exploited. Less research is conducted on the effects of floods in flood prone areas particularly in the three Northern Regions of Ghana, and how flood effects can be reduced if not eliminated through the adoption of appropriate measures (Afro, 2009). Only a few studies have delved into the effects of floods on housing, Analysis of Flood Resistant Foundation, suggested roofs for flood prone areas in the construction industry and Minimizing Flood Effects on walls (Afro, 2009). These solutions are only targeted at particular structural components of the building to the neglect of the entire building. The issue of minimizing flood effects on housing by adopting certain measures still remains unresolved (Blaikie, et al. 2004). Several studies have suggested solutions among others as relocation of building to higher grounds (Adelekan, 2010). Relocation, though, a possible solution but does not address the problem of high demand for fertile land near water bodies for agricultural purposes and the general high demand for land to be used for developmental projects (Benevolo, 1980).

The current research therefore, seeks to discover the contribution of consultants in the Construction Industry to reduce the effects of floods on housing in flood prone vulnerable communities through the adoption of appropriate measures. Furthermore, if the root cause of this problem is not carefully resolved, flood effects will continue to be felt as far as housing in the three Northern Regions of Ghana are concerned. A considerable amount of money and time has been committed to rebuilding of houses annually after flood events but little or no attention is given to ways of minimizing the flood effects on housing in flood prone areas as a long term measure (Adelekan, 2013). The research therefore, is aimed at exploring the role of consultants in the implementation measures to reduce flood effects on housing.

1.4 Aim and Objective of the Study

The aim of the study is to examine the effects of floods on housing in the three northern regions of Ghana and strategies for minimizing the effects. The specific objectives are as follows;

- to identify the principal effects of floods on housing in the three northern regions of Ghana;
- to identify the compelling reasons for the adoption of appropriate measures to minimize the effects of floods on housing in the three northern regions;
- to identify the key barriers to the adoption of appropriate measures to minimize the effects of floods on housing in the three northern regions;
- to determine appropriate measures to be adopted to minimize the effects of floods on housing in the three northern regions of Ghana.

1.5 Research Questions

The following research questions guided the study;

- What are the effects of floods on housing?
- What are the compelling reasons for the adoption of appropriate steps to minimize flood effects on housing?
- What are the key barriers for the adoption of appropriate steps to minimize floods effects on housing?
- What are the appropriate measures to be taken to minimize flood effects on housing?

1.6 Significance of the Study

Potential benefits of a house that can minimize flood effects exist for at least three groups: homeowners, developers and government. Homeowners who live in flood prone areas, such a house will protect the occupants and their property during flood event. The design will require little or no maintenance after flood event thereby saving cost for the occupant.

For estate developers, this concept or model is an attractive new business with great prospects. There is a big potential market to exploit valuable land because many people always want to live near water bodies. For government, a flood resilient house provides another solution in the effort to protect houses against flood effects. Resources that otherwise would have been used to reconstruct damaged houses for victims after floods could be channeled to the provision of developmental facilities. If the Buildings Regulations and National Building Code are to be amended, the findings of the research will serve as a road map for legislative enactment by policy formulators.

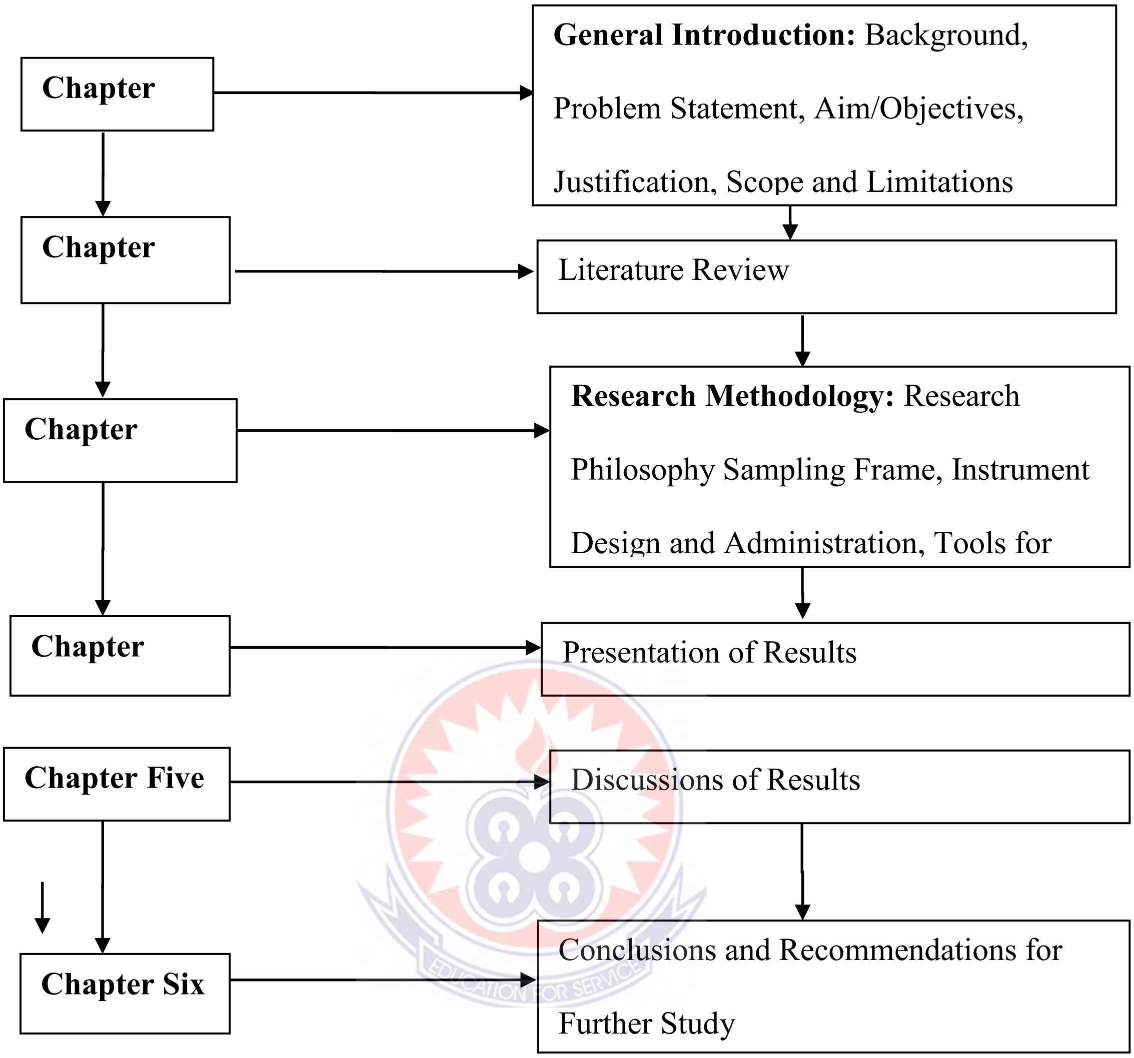
1.7 Limitations of the Study

The study is quantitative and based on the accessible population of Architects, Structural Engineers and Quantity Surveyors. The non-participation of Contractors in the study may not bring out all the facts about the issue under investigation as far as the practical implementation of the designs is concerned. The study also concentrates only on vulnerable communities in the three Northern Regions although there are other equally flood prone communities in Ghana. This procedure therefore decreases the generalization of the findings. The study may therefore not be generalized to all flood prone communities which are prone to the tragic effects of floods on housing (Jabeen, et al., 2010).

1.8 Organization of the Study

The structure of the thesis is organized into six chapters. A General Introduction as Chapter One, Literature Review as Chapter Two, Research Methodology as Chapter Three, Analysis of results as Chapter Four, Presentation of Results, Discussion of Results as Chapter Five and Conclusion and Recommendations for Further Study as Chapter Six. Figure 1.1 below gives the detailed organization of the study.

Figure 1.1: Organization of the Study



CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter presents of a review of relevant literature. The chapter is organized into six main sections including; introduction, effects of floods, the adoption appropriate measures to mitigate the effects of floods, barriers to adoption of appropriate measures to mitigate effects of floods, appropriate measures for mitigating the effects of floods and a summary of the chapter.

2.2 Effects of Flood on Housing

Housing provides the necessary protection against weather. However, this projection is often compromised in events of flood disasters. Floods compromise the functional requirements of the building elements thus endangering life. The sections that follow present a review of literature on the effects of floods on the key elements of buildings.

2.2.1 Effects of Floods on Foundation

The impact of floods on housing is due to several reasons: Flood depth, Flood duration, uplift due to soil saturation and Horizontal force created by flood waves or currents (Livingston, 2000). Direct flood hazard is associated with other types of secondary hazards such as high winds or storms, lightning, slope instability, ground settlement and other factors. Floodwater can submerge buildings and cause various degrees of damage from staining of walls which can lead to structural collapse depending on flood depth, duration and type of building (Adelekan, 2010). The foundation of houses in the three Northern Regions of Ghana usually of sun-dried bricks earthen and sometimes timber posts is embedded directly into the earthen plinth. Extremely vulnerable, it gets damaged even in low intensity flood, thus requiring frequent maintenance (Blaikie, et al., 2004). In moderate to high intensity flood, especially if accompanied by currents, earthen plinths tend to get completely washed off and have to be rebuilt immediately (Blaikie, et al., 2004). Bamboo or timber posts in saturated soil, especially during long duration or recurrent flood, get rotten at the base, thus weakening the entire structure of the buildings to damage by strong wind, differential settlement, sagging of roofing elements and doors, windows and wall elements developing cracks and losing alignment.

Frequent replacement of bamboo posts of „wattle and daub" houses is done regularly in flood-prone areas (Adelkan, 2010). The typical earthen plinth in sun-dried brick houses also behaves similarly. According to IDB (2011) Landcrete brick perimeter plinth in mud In semi-houses, locally known as „atakwame" is better at resisting erosion at the sides of a building, but the infill earth floor can experience settlement due to saturation and in prolonged flood can become muddy, unusable and the mud can escape from below. At the same time, scouring of soil cover of the typically shallow foundation of the perimeter brick wall can result in its instability and settlement (Jabeen, et al., 2010). Opong (2000) agreed that this is relatively durable, but in high intensity flood accompanied by currents, shallow foundations can become unstable due to scouring of soil-cover. Prolonged duration flood can lead to foundation settlement, thereby causing cracks and failures in different parts of the building. Opong (2000) however pointed out that even relatively strong and approved foundations such as solid masonry or concrete walls and use of high hard core filling are not permitted in flood prone areas. Such foundations will also be submerged in intense flood events. However Powell, et al. (2009) disagrees with this school of thought and added that a raised Solid Reinforced foundation with steps at the external side can greatly resist flood. Basements or tanking are not encouraged in flood prone areas since they will be adversely affected by flood waters (Opong, 2000).

2.2.2 Effects of Floods on Walls

Sun- dried brick or mud brick wall typically in „atakpame" houses also often have a lifespan of 2-3 years and bamboo mat 4-5 years Opong (2000). Decay can get accelerated in flood. In flood of high depth and moderate duration, the damage begins in the lower part of walls and hence weakens the walls and eventually results in complete damage. Flood with strong currents can detach wall panels or walling units and wash them away, leading to partial or complete loss, especially if the bricks are laid directly on the sub-grade or connections to posts are weak (Baba et al., 2012). The use of timber framing in place of mud bricks as suggested by Baba et al. (2012) when in contact with water leads to corrosion and gets aggravated in flood. The lower part of walls is particularly vulnerable if the plinth is not sufficiently above flood level or if flood depth is high. Prolonged duration flood can cause damage to lower end of sheet wall panels and timber frame. Flood with strong current can detach and wash away wall panels, especially if not adequately secured to frame (Baba et al., 2012). Earth is used as a walling material in many „atakpame" houses in various designs according to region in the north of Ghana, but not prevalent in all areas. In monolithic construction, flood water can cause serious damage once the base gets affected; the entire structure is liable to collapse, often rapidly. Earthen walls with an internal framework, as in some parts of the regions, are less vulnerable; even if the earth cover is washed away, the building remains standing and can be repaired (Baba et al., 2012).

The fundamental question still remains; how can the structure continue to function without such a damaged wall eventually being replaced (Brahmi, et al., 2004). Brick panels are sometimes relatively durable, but can experience staining, peeling of plaster and weakening of mortar joints at lower ends if immersed in flood of high depth and duration. Cracks may develop if settlement of foundation occurs (Udarty, et al., 2006). Problem areas in most common form of external wall construction in brick veneer with Inadequate ventilation of the wall cavities can lead t0 deterioration of the frame, internal lining and promote mold growth. Silt deposited in the cavity may remain moist, slow the drying process and promote rot of timber frames or corrosion of a steel frame. Silt can also contain sewage or other matter which may be hazardous to health (Jabeen, et al., 2010). Wall frames can fail from high horizontal forces due to water pressure especially as components are weakened by immersion. Timber frames can twist, distort or rot. Wet conditions can initiate corrosion in metal frames and fasteners. External brick cladding can crack or even collapse due to water forces, debris impact or foundation movement. Face fixed brick ties may fail resulting in cracking or collapse of the brickwork. Plasterboard wall linings are weakened and easily damaged Jabeen, et al. (2010) by unbalanced water pressures and by impact from floating objects. Weakened plasterboard can reduce wall bracing capacity. Plasterboard may warp and distort upon drying. Plasterboard linings usually need to be replaced after severe and prolonged flooding. Some forms of sheet wall bracing can lose resistance to nail pull out and be permanently weakened leaving the house prone to damage from water forces or post-flood wind forces. Some insulation materials can lose effectiveness, retain moisture or slow the drying process and promote timber frame decay. Fixtures such as cabinets with sheet backing can inhibit drying out of the wall behind (Jabeen et al., 2010). It is however not clear as to the type of wall construction that resist flood water (Baba, et al., 2012).

Effect of flood on doors and windows varies according to the type of material. Most durable are mild steel (MS) frame and shutters, or glass shutters, although they may experience corrosion if not adequately painted with corrosion-resistant paint. Bamboo or timber frames are vulnerable, especially if timber is not of good quality, not seasoned and treated properly (Urdarty, et al., 2006).

2.2.3 Effects of Floods on Roof

The traditional roofing material is thatch typically in „atakwame" houses; made from grass, rice, wheat or maize straw with usually bamboo and sometimes reed stalk framing. Normally has to be renewed every 2-3 years. This type of roof in flood prone areas results in decay in houses of low height and during flood of very high depth and duration, if thatch comes into contact with flood water. In such conditions, if also accompanied by strong current, thatching materials can get detached and washed away (Brahmi, et al., 2004). Secondary hazard often connected to flood is heavy rainfall, which can cause damage. Strong wind can also blow away thatching materials and damage frame (Brahmi, et al., 2004).

Aluminum Sheet roof, used in „wattle and daub„ houses usually with timber framing, bamboo framing and in some cases without any framing can lead to corrosion when in contact with water and vulnerable to secondary hazard of heavy rainfall accompanying flood. Particularly vulnerable to strong wind – can crumple and get blown off, especially if connections to frame are inadequate. During flood can offer a limited degree of rooftop refuge (Lupala, 2002).

Reinforced Concrete Roof is relatively durable, used in sandcrete block houses, can withstand impact of heavy rainfall and wind (Lupala, 2002). In the opinion of Dynes et al. (1991) concrete roof can withstand flood impact but can get weakened and may even collapse if foundation settles or walls are damaged. However, it offers a high degree of rooftop refuge during flood.

Problem areas according to Lerise, et al. (2005) in domestic construction are roof tiles. They can be dislodged by floodwaters. The pressure of air trapped between the rising water surface and the ceiling could damage the ceiling. Immersion from more severe flooding can cause plasterboard ceilings to collapse or sag permanently (Lerise et al., 2005). According to Kwabena (2000) this augment cannot be sustained since flood water can be conducted safely under the building without immersion to ceiling level.

2.2.4 Effects of Floods on Floors

Timber strip flooring affected by flood waters may distort and cup. Also, timber joists will normally dry out after immersion without any long-term effects. Poorly drained or ventilated sub-floor areas can promote decay or corrosion of floor members. Silt can also be deposited under floors. Foundation soils can be eroded under slabs or footing loss of bearing capacity or they may settle unevenly leading to structural damage to the house (Mathis, et al., 2006).

Other problem areas in the house prone to flood include;

- Some forms of sheet flooring such as particle board can lose strength and even collapse if heavily loaded when wet.

- Electrical supply components (conduits, PowerPoint, light fittings and switchboards) can trap moisture and silt and become unsafe after immersion,
- Absorbent floor coverings such as carpet, linoleum and cork need to be removed to allow the floor to dry out (Lerise, 2005) It is worth nothing that Ceiling types with a confined roof space, e.g. cathedral, can exacerbate roof problems due to difficult access and poor ventilation (Lerise, et al., 2005).

2.3 Adoption of Appropriate Measures to Mitigate the Effects of Floods.

2.3.1 Building Regulations

One major fact is that building regulations exist to ensure that buildings are designed and constructed in accordance with building regulations and associated legislation. The advantage of building regulation is that there is no need to panic after the construction for fear of not meeting design requirements (Adelekan, 2010). The common method of constructing a flood proof house is to elevate the house above the flood level to protect live and property. This is contrary to resilient design where the building is said to be its original position but will be insulated against flood effects (Adelekan, 2010). However, it must be noted that building regulations set national standards for building work. Whether a new a new development, extension or alterations to the building, any measure taken to minimize the effects of floods on buildings must be done in accordance with the building regulations. There is a lot of bureaucracy involved in obtaining building permit. The bureaucratic procedure involved in obtaining building permit however makes the house not only a convenient way of mitigating the effects of floods especially in emergency situations, Tamar (2010). The cost of obtaining a building permit is a serious setback for its acquisition. Tamar (2010) pointed out that vulnerable communities cannot afford to pay for the processing building permit. Apart from the cost element, professionalism is another factor that does not support the obtaining of building permit. There is the need for qualified people to do the put raised pile foundation into practice if accidents are to be avoided in the process. The components of precast concrete piles may be so scarce that they may not be within the rich of vulnerable communities (Kwabena, 2000). When the building permit is obtained, the building inspector does not only supervises the progress of the project, but also helps the building owners to secure components that may not be readily available on the local market. The building permit covers aspects such as construction of the foundation, dam proofing and the general stability of building (Adelekan, 2010). Building permit must be obtained to give some degree of legality to the building.

2.3.2 Climate Change

The devastating effects of floods and the damages often caused or force many buildings to collapse. Homeowners sometimes demolish their buildings in the aftermath of floods because several buildings are often left as mere death traps Kwabena (2000). One of the major causes of these annual floods is change in climatic conditions. Climate change has resulted in loss of sea ice and accelerated sea rise. We now experience more frequent and intense drought, storms and heat waves. The issue of floods has taken a serious dimension over the last decade. It is therefore important that certain appropriate steps are taken minimize the effects of floods on housing (Sahehin, et al., 1980). Several buildings that are cited without taking measures to minimize the effects of floods have had to be demolished immediately to avoid sudden collapse and causing injury to people in the event of floods. The introduction of resilient buildings in flood prone areas is a sure way of ensuring that climate change does not impact negatively on housing (Mud, 2012). Climate change is not only coping with the immediate impact of floods but also about anticipation and planning for future change (Venkateswaran, 1980).

2.3.3 High Demand for Coastal Land

Floods often set in from the beginning of June, July to September each year (Afro, 2009). The vulnerable communities after having studied the trend of floods normally begin the preparation to relocate their houses to higher lands far before they are affected by the catastrophe (Amato, et al., 1995). It is however clear that getting land relocation is the major challenge vulnerable community members‟ face in their efforts to protect themselves and their property from the negative impact of floods. The cost of acquiring land and rebuilding the a new habitable structure is one main reason why most of the inhabitants travel to the urban cities therefore causing overcrowding in the cities which also comes with all forms of social vices (Afro, 2009). Adelekan (2013) suggested the introduction of appropriate measures to avert this yearly hazel of searching for land in the name of relocating to higher grounds. The most important benefit a flood resistant design is for it to continue to exist in times of floods. This saves the cost of relocation and time for other productive ventures (Afro, 2009). The only responsibility on the part of the inhabitants is to convey people and property to available amenities meant for that purpose (Powell, et al., 2009). It is also common knowledge that several people now prefer to build their houses near water bodies as pointed out by Kwabena (2000).

2.3.4 Enforcement of Bylaws

The primary objective of by-laws is to ensure that buildings are not constructed anyhow. Constructing buildings on water ways poses serious challenge to the development of the District Assemblies (Kwabena, 2000). Flood-proofing is to reduce or avoid the impacts of flooding upon structures. This may include elevating structures above the floodplain, employing designs and building materials which make structures more resilient to flood damage and preventing floodwaters from entering structures in the flood zone, amongst other measures. The local authorities are now poised to prosecute any developer who flaws the laws of construction especially in flood prone areas (Opong, 2000). Flood-proofing reduces damage from flooding in three ways; first of all, allowing flood waters to easily enter and exit a structure in order to minimize structural damage. Secondly, the use of flood damage resistant materials and thirdly, elevating important utilities. As a result of this technology, the amount of money the insurance company ought to have paid for a collapsed house would be used to provide social facilities to for the general good of society (Opong, 2000). The ability of the building to be spired of demolition in accordance with the laws of the District Assemblies shows that the building has been properly insolated against floods. It is waste of resources for communities to afford the premium for an insurance policy covering a building project only for it to be demolished for lack of structural integrity. Many of the people in flood prone area belong to the low income group and may not be able to even pay to insure their houses (Olesya, 2013). Flood-proofing can be applied in residential and non-residential buildings and the principles of flood-proof design and cannot be face demolition by the local authority (Olesya, 2013) should be a collaborative between insurance companies and home owners. Insurance companies should be actively involved in educating prospective homeowners on methods of building flood resistant houses. Flood-proofing measures are much more affordable than the construction of elaborate flood protection works such as seawalls and dike systems (Kwabena, 2000). Flood-proofing is also advantageous because it does not.

The advantages of the technology of Flood-proofing measures are that it boosts tourism both internal and external and the building can be used as collateral to secure bank loans (Kwabena, 2000). In the case of dry flood-proofing, it will also allow residents to close barriers in a timely fashion. Although the provision of flood hazard maps and flood warnings bring benefits themselves, it is an additional cost that must be borne when implementing flood-proofing measures. Since residents are not able to continue living in flood-proofed houses during flooding, amenities for accommodating evacuated people must also be provided. These are the very reasons why the local authorities are rigid in enforcing the laws regarding construction of buildings (Olesya, 2013). Building without building document is non-existent in the eyes of the law enforcement task force. Certain facilities may be required for some period after a flood event, as wet flood-proofing may leave the structure uninhabitable for a small period following flooding. Flood-proofing measures are most effective when applied in areas where flood depth is low as required by law (Benevolo, 1980). If a flood larger than the design specification occurs, the effect will be as if there was no protection at all (Erickson, 1993). Another disadvantage is that in the case of dry flood-proofing, flood shields are not aesthetically pleasing (Olesya, 2013). Shields for doors and windows are left in place in most circumstances, so that they can be quickly closed when required. However, this means that these measures are permanently on display. Ongoing maintenance of flood-proofing measures is also required to ensure they continue to provide appropriate protection (Olesya, 2013). When wet flood-proofing measures are applied, flood waters still enter the structure. Therefore significant clean up may be required following floods to remove water borne materials such as sediments, sewage or chemicals (Conrad, 1997). The choices of materials used in these structures will still enable clean up to progress much more quickly than in non-flood-proofed structures.

In the case of dry flood-proofing, if design loads are exceeded, walls may collapse, floors buckle and homes may even float. This has the potential to cause more damage than if the home were just allowed to flood (Gyau, 2000). Financial requirements and costs in the absence of cost information from developing countries, cost estimates for a number of flood-proofing measures in the US are provided. The US is one country which widely applies flood-proofing measures. In the US, the cost of elevating a structure above flood depth is likely to be between US$29 and US$96 per square foot of house footprint (Olesya, 2013). The range in cost is due to the construction and foundation type and the required elevation. Wet flood-proofing measures are likely to include the addition of wall openings for the entry and exit of floodwaters, installing pumps, rearranging or relocating utility systems, moving large appliances and coating surfaces in coverings which make it easier to clean up after flood waters recede. According to Barker (1994), the cost of wet flood-proofing in the US is likely to be between US$2.20 and US$17.00 per square foot of house footprint when considering basement flood-proofing up to a depth of approximately 2.4 m. Dry flood-proofing measures in the US include sealing walls with waterproof coatings, impermeable membranes or supplemental layers of masonry or concrete and equipping doors, windows and other openings below the flood elevation with permanent or removable shields. Installation of backflow valves on sewer lines and drains is also likely to be required (Urdarty, et al., 2006). Wet flood-proofing is generally less expensive than dry flood-proofing since any action to reduce the number of items that are exposed to flood damage is considered a wet flood-proofing measure (Urdarty, et al., 2006). For example, moving valuable items to an upper story is a wet flood-proofing measure that can be undertaken at negligible cost. The costs of dry flood-proofing a structure will depend on the following factors (Urdarty, et al., 2006). At the community level, flood-proofing costs will depend largely on the number of properties in the flood hazard zone and associated costs such as flood hazard mapping and modeling exercises to determine properties at risk. Flood-proofing measures are very much possible at the community level. At its simplest, wet flood-proofing involves moving valuable objects to higher ground in order to avoid the effects of flooding.

Since this can be undertaken at negligible cost, wet flood-proofing is highly achievable on a local level provided sufficient warning time is provided. More advanced flood-proofing measures are not as capital intensive as the construction or realignment of coastal defense and therefore should also be achievable at the community scale. Implementation of this technology will however, require a proactive planning approach. It may even be possible for individual households to finance basic flood-proofing measures themselves. This may include elevating valuable items and utilities above the expected level of flooding. This will be possible if households are given adequate information on the likely level of flooding (Urdarty, et al., 2006). However, more advanced flood-proofing measures are likely to require the assistance of specialists. For example, the construction of houses within the flood zone will require experienced, professional engineers or architects to develop and/or review structure designs to ensure that structures are capable of functioning as designed. Although flood-proofing is achievable at the community level, its effectiveness depends on community uptake and the standard to which measures are implemented. Few benefits will be gained from flood-proofing if the uptake is low or if measures are completed to a low standard. Potential unwillingness to undertake flood-proofing such measures has been highlighted by Brahmi et al. (2004) who found that only 63% of new buildings are in compliance with flood regulations in the US. Due to reluctance to undertake flood-proofing measures on an individual basis, it may be necessary to inspect properties in the hazard zone to ensure that flood-proofing measures have been employed and to an acceptable standard (Urdarty, et al., 2006).

Funding may be provided to local communities in order to increase uptake of flood-proofing projects. This may increase uptake in poorer communities and may help to protect those at risk rather than just those who can afford such measures. A similar outcome may be achieved if flood insurance is regionally important. Reduced premiums for flood-proofed properties will encourage the uptake of flood-proofing. Before communities can go ahead with flood-proofing measures, it will be necessary to undertake some form of flood hazard mapping. This will inform decision-makers on which buildings require flood-proofing and to what depth. It can also support the appropriate design of flood-proofing measures (Urdarty, et al., 2006). Although basic flood-proofing measures can be undertaken at negligible cost, the cost of implementing more advanced flood-proofing may be prohibitive in poorer communities. This may prevent implementation but could be addressed by providing funding opportunities. For more advanced flood-proofing measures, such as anchoring structures and installing breakaway walls, specialist knowledge is likely to be required. This may require the input of experienced architects or engineers. In areas where flood hazard maps do not currently exist, the uptake of flood-proofing measures may be problematic (Udarty, et al., 2006). Non-availability of flood hazard maps will make identification of properties at risk and the minimum specification of flood-proofing measures difficult to define. The main opportunity for the implementation of flood-proofing lies in the capacity to allow development in the flood hazard zone to go ahead albeit, with explicit limitations. Where there is high demand for coastal land, flood-proofing measures present an opportunity to utilize this land. This is in contrast to policies such as building setbacks, which prevent coastal development (Udarty, et al., 2006). The decision to implement a resilient design especially in vulnerable poor communities is quite a difficult one if not impossible (Changnon, 1996). The ability of the consultant to identify the operational skills needed implementation of structural measures in view of lesser known materials. Strategies must also be put in place for the inhabitants to embrace the new design must be given serious consideration (Changnon, 1996). The inhabitants must also be put assured that yearly reconstruction of their dwelling houses will cease with the implementation of resilient design. The beneficiaries must also come to understand that the local building materials available can be harness for the construction of resilient design (Udarty, et al., 2006). Risk management is on the principle that seeks to reduce disaster hazards, decrease the exposure of people to danger and education for general acceptance (Udarity, et al., 2006). Commitment of funds is crucial if the concept of resilient design is to be achieved. Olesya (2013) concluded that social funds should be used purposely to improve the lives of the poor in society. The structural integrity of the structure is another factor to consider as far as resilient design is crucial for its acceptability (Barker, 1994). The type of bond should also be considered. Ericson (1993) suggested that for a reliable resilient design to be designed, a careful study of the climate variability is highly recommended.

The clear difference between a resilient design and an ordinary design is the level of resistance to disturbances (Olesya, 2013). A resilient design should have the ability to remain functional even during flood situation. There must be a system put in place for the resilient structure to comprehend flood control, flood alleviation, and flood abatement (Gyau, 2000) this can be done through water retention, land use change and prevention of erosion (Mud, 2012). The effectiveness of resilience in the construction industry as pointed out by Ericson (1993) is to ensure that the new design does not pose challenges to other inhabitant elsewhere. It should not also pose any danger to the future generation.

There are various resilient design models available in the construction industry. The great challenge however is about the implement is an issue of funding (Dynes, et al., 1994). There is lack of conscious effort to set aside funding opportunity for venerable communities a (Adelekan, 2010). The absence of such a funding provision as pointed out by Adelekan (2010) is a negative set back as far as the implementation of resilient design in vulnerable flood communities in Ghana.

Another serious challenge to the implement of resilient design is lack of the right technical knowledge (Afro, 2009). Several designs are generated and implement by local artisans. These Artisans lack the requisite knowledge and skills results in annual destruction of dwelling houses (Gyau, 2000). The absence of a flood hazard map presents early warning signals on possible flood for the necessary protection to be put in place (Gyau, 2000).

There are several advantages to be derived from resilient design implementation (Kwabena, 1997). First of all, the implementation of resilient design will eliminate the trouble of elevated the structure in times of floods. This, according to Kwabena (2000) will save cost on the part of the client. Secondly, the implementation of resilient design will avoid the need to demolish. Relocating the structure accompanying the cost involved is an advantage on the part of the client (Kwabena 2000). Resilient design is flood proved. This does not only prevent flood water from entering into the building but also maintains the thermal and sound insulation of the building (Beck, et al., 1996). Flood proofing a structure will also ensure that cleaning of the facility is made easier. Flood proof design is normally applied in areas where flood depth is low. Financial requirements on the part of the home owner are minimal since extensive use of local materials is guaranteed (Gyau 2000). The availability of resilient design will encourage government and other stake holders to commit funds for the implementation of resilient design in a prudent manner.

2.4 Barriers to the Adoption of Appropriate Measures

2.4.1 Funding Challenges

The design of buildings is contingent upon the available of funds for the project. In flood prone areas resilient designs are likely to be adopted and the various options are available. The identification of four complementary types of resilience namely: cognitive resilience linked to knowledge and culture. The second category is functional resilience representing the capacity of a technical system to protect itself from major damage while continuing to provide at least the service needed by critical infrastructure. The third model is the correlation relationship between service demand and the capacity of the technical system to respond (Thomsen, et al., 2010). It is a matter of adapting demand to technical system capacity, decreasing demand enables a system to remain in operation and to recover more quickly. However analysis of the internal systems or organizations and government readiness to support vulnerable communities financially as well as the absence of links between technical systems and other regions may also be a set back as far as resilience is concern (Adelekan, 2010). The ability to pay for this design to be implemented can result in a safe and reliable housing for affected communities. Such a programme must first be tested for its utility and potential application by organizations which core mandate is community development network. They must ensure effective monitoring and management of the credit performance. The results can indicate directions for appropriate low-income resilient housing projects (Awour, et al., 2008). Floods are caused by several factors such as torrential rains, dam spillage and illegal settlements among others (Afro, 2009). Several parts of the building have been affected in flood situation including plinth, walls and roof (Gyau, 2000 & Mud, 2012). Many of the buildings are constructed of local artisans who use local material making it difficult to insulate them against floods. Afro, (2009) indicated that to deal with the issue of yearly destruction of houses due to floods the design of such houses should be done by specialist in the construction industry. The concept of resilience as a long term solution to the destruction of houses as a result of floods according to Gyau (2000) cannot be over emphasized. Built environment consultants have a role to play in the design of resilient houses for vulnerable communities (Benovolo, 1980). However, the significance of Built environment consultants‟ contribution in the construction industry leaves much to be desired. Kwabena (2000) noted that certain design features such as the Plinth, walls and roofs are purposefully designed to resist the effects of floods which the local artisan does not appreciate (Kwabena, 2000). There are enabling factors that facilitates the adoption of resilient designs. Sustainability is a key factor that encourages the adoption of resilient designs. Specialist are trained to go into Flood proof houses designed with the mind that current development does not affect future generations or affect vulnerable people leaving elsewhere from meeting their needs (Adelekan, 2010) Climate change also affects the weather pattern and brings about floods (Gyau, 2000). Non-specialist however will not take these dynamics into consideration in the design and implementation of resilient buildings and this surely is not a way to mitigate vulnerable communities against floods (Adelekan, 2010).

The introduction of resilient design alone is not a panacea to the problem of flood impact (Sahehin, et al., 2003). Available statistics suggest that more than 80 percent of flood resistant models have failed as a result of lack of flood hazard map (Adelekan, 2010). Atypical flood hazard map is developed first of all to indicate the severity flood impact on different parts of the affected community. Secondly, a flood hazard map will give early warning signals on the time and magnitude of potential flood for the necessary measures to be taken with regard to closing of shields and evacuation of property upper floors or to available amenities (Adelekan, 2010). Sharma et al. (1980) explained that the absence of these flood hazard maps makes it extremely difficult if not impossible to mitigate negative effects of floods in developing countries. The barriers to the successful adoption of resilient designs include lack of funding, lack of specialist and non-availability of flood map (Adelekan, 2010).

2.5 Appropriate Measures for Mitigating the Effects of Floods

2.5.1 Foundation Types

Pile foundations are required in flood areas and coastal environments so that waves can pass more easily under elevated homes (Brahmi, et al., 2004). Traditional piles are typically constructed of treated timber, steel, or precast concrete and are driven into the ground to a depth required to resist vertical and lateral loads from gravity, wind, and flood forces. Pile foundations use the soil"s resistance to support the elevated home. Critical aspects of a pile foundation include the pile size and spacing, installation method, embedment depth, bracing, and the connection to the elevated home. Piles that are properly sized, spaced, installed, braced and have adequate embedment into the soil (with consideration for erosion and scour effects) will perform properly and allow the home to remain standing and intact following a design flood event (Brahimi, et al., 2004).

Piles can used to make provision for upper floor level, although owners should check the design considerations to understand how the extended piles will withstand lateral movement (Lerise, et al., 2005). Using grade beams provides resistance to rotation also called "fixity" in the top of the embedded piles and improves stiffness of the pile foundation system against lateral loading. When used together, piles and grade beams work together to support the elevated home and transfer vertical and lateral loads imposed on the elevated home and foundation to the ground below (Brayant, 1991). Design and installation of grade beams should include the following concepts: Grade beam design criteria should include resisting lateral flood loads from both hydrodynamic forces and flood-borne debris impacts.

Grade beams are to provide horizontal bracing of piers or piles and should not directly support any vertical load-carrying elements such as floor slabs. They should be designed to be self-supporting between vertical foundation members, such as piles, to account for cases when erosion and scour extend below the grade beam. According to NFIP requirements, grade beams that are structurally connected to slabs are considered to be the lowest horizontal structural member supporting the slab, which is a nonconforming use below Basic Flood Level (BFE). Lupala (2002) and severely increases flood insurance premiums if present. However it is common knowledge that the type of wall and the material used for the walling units remain an outstanding factor to the realization of a flood resistant house.

Foundations supported on micro piles also function similarly to deep pile foundations. Micro piles are defined in the International Building Code (IBC) as 12-inch-diameter (305mm) or less, bored, grouted-in-place piles incorporating steel pipe (casing) and/or steel reinforcement. When used for new construction, traditional driven piles are typically more cost effective than micro piles. However, micro piles may be the only feasible and cost effective retrofitting solution when access is limited, horizontal or vertical clearances are limited, or when strict control of vibrations and settlement is required (Blaikie, et al., 2004).

Micro piles are usually smaller in diameter than traditional piles and can be designed to perform under a wide variety of soil conditions. Micro piles in the opinion of Lupala (2002) can be designed to resist compressive, tensile, or shear structural loads for most situations. The equipment used to install these piles is compact (such as small, front-end loader attachments), and results in less disturbance and vibration to existing homes than traditional pile-driving equipment. Micro piles can be used for underpinning applications, such as halting structural movement, repairing or replacing inadequate foundations, and providing scour and erosion protection, and can transfer loads to deeper, more competent bearing strata (Dacy, et al., 2000).

With a relatively small diameter, micro piles have limited lateral capacity compared to larger traditional piles, and may require grade beams or bracing to resist lateral loads, including flood loads. The bracing must be designed to limit deflections under flood forces when exposed by scour and erosion, or under other conditions of reduced lateral soil support such as areas of soft, weak soils, soils with seismic liquefaction potential, or in areas where subsurface voids are present. A detailed geotechnical investigation must be completed to determine the quality of the bearing soil or rock strata, whether grouting is needed to fill voids, and to select an installation method (i.e., drilling through rock or boulders vs. driving piles through soft material). Helical piles are a type of micro pile with an auger helix on the end of a slender shaft, which is drilled into the ground (Gyau, 2000). A helical pile is defined as a manufactured steel, deep foundation element consisting of a central shaft and one or more helical bearing plates (Awuor, et al. 2008). Each helical bearing plate is formed into a screw thread with a uniform defined pitch. Helical bearing plates attached to the central shaft act as the bearing surface to resist compressive forces from the elevated structure. Increased bearing capacities can be provided by using larger diameter helixes or by attaching more piles to the foundation. As with other micro piles, there is little lateral resistance provided by the helical pile itself, so resistance must be provided by a strong moment-resisting connection to the foundation. Helical piles can be a cost-effective solution to deep/open foundation requirements where access and vertical and horizontal clearances are limited (Awour, et al. 2008).

To successfully elevate a home on an open foundation, site-specific conditions must be identified. Once the site-specific conditions are identified and evaluated, a proper design can then be implemented (Adelekan, 2010). Some of the site-specific factors that must be considered include soil conditions; the required elevation; the flood, wind, and seismic loads the building must be designed to resist; and whether the existing home is structurally sound enough to elevate-in-place. Once all the information according to Benevolo (1980) has been evaluated, the design professional will be able to prepare cost estimates to determine which foundation design The design process for elevating homes on open foundations in the opinion of Benevolo (1980) is as follows;

- Remove existing structure to allow access for pile-driving equipment
- Determine pile depth based on pile load and soil strata
- Determine pile spacing based on pile capacity, building loads, and span capacity of the building and grade beams
- Achieve lateral capacity by increasing the number of piles or by properly connecting batter piles/anchors to the piles and footings with a pile cap
- Design the new access to the building and utility extensions

Contractor qualifications should be specified prior to bidding elevation projects. Qualifications should include prior experience, bonding/insurance, licensure, and familiarity with local construction and soil types. To ensure the foundation is installed properly, micro pile installation should be supervised by an experienced contractor who has recently completed similar projects in similar soils. Geotechnical conditions can vary greatly across one property and an experienced contractor will be able to make site decisions when obstructions, refusal, voids, soft soils, and other unanticipated subsurface conditions are encountered. To be successful, micro piles must be installed with an adequate embedment and must be able to resist the load capacity. Load testing of piles is recommended to verify design calculations and adequacy (Adelekan, 2010). The necessary design steps must be followed for elevating homes. The Contractor installation method is a major factor regardless of the resistance measured during installation or through load testing, the minimum embedment depth specified by the design professional must be satisfied for the pile to perform as designed (Adelekan, 2010).

In a situation when fill is to be deposited near the home, it should be limited to 2 feet, and only under the footprint of the home. This also minimizes the loss of flood storage capacity (IDB, 2011). The fill should slope to natural grade within 2 feet of the foundation. This limited-fill technique has the added advantage of reducing the impact of fill on trees. Foundation fill must be compacted to have adequate bearing capacity and resist erosion; this may be referred to as engineered fill (ITN, 2003). When additional elevation is needed, one of the other elevated foundation methods can be used instead or on top of the minimal fill. Foundation stem walls can be constructed to a reasonable height and the interior filled with compacted soil. The stem wall can consist of reinforced concrete block walls on footings or cast-in-place concrete foundation walls engineered for the soil conditions. The top of the stem wall can be shaped to provide a form for the slab; L-shaped blocks are made for this purpose. Even though the slab cap is elevated, a durable moisture barrier of plastic sheeting is still needed over the soil and should extend over the stem wall before the slab is poured (Adelekan, 2010).

For appearance purposes, the exterior cladding or brick veneer can extend down over the stem wall but should end above finished grade. This type of elevated foundation is more expensive than other options but may provide architectural and market appeal since it can make the home look larger or more majestic. It also avoids potential crawl space problems (moisture, animals, pipe freeze, etc.) and makes it easier to add a safe room to the interior (Adelekan, 2010).

Adelekan (2010) opined that a similar architectural look can be achieved with a framed floor system over a crawl space without the expense of adding and compacting fill within the stem wall foundation. When a raised house is built with an enclosed crawl space (or any enclosure beneath the BFE), it must be designed to allow free entry and exit of floodwater. The interior cannot be finished, and all materials used below base flood elevation must be flood-resistant. The space below BFE can be used only for parking, access and limited storage. For any enclosure below BFE, the required openings (flood vents) on at least two sides totaling 1 square inch of opening for each square foot of enclosed area. The bottom of these openings must be no more than a foot above the outside grade. Flood vents are not required if an engineer or architect certifies that the design will allow for the automatic equalization of flood water forces on exterior walls. This usually involves areas designed to open or break away with water pressure (Adelekan, 2010).

Openings may be fitted with closing vents if those vents conform to the building code for automatic flood venting requirements. A window, door or garage door is not considered a flood opening, but flood openings can be located in areas of slow-moving floodwater, any of these raised foundation types is acceptable. The traditional pier-and-beam foundation with a frame floor system is generally the least-expensive elevated foundation option. Traditional architectural styles in most southern states often include pier-and-beam foundations left open, so this look can offer cultural appeal and community value (Awour, et al., 2008).

The use of fill or stem wall foundations for structural support of buildings is prohibited in coastal floods zones. The code requires homes to be elevated on a pile or column foundation, and an engineer or architect must certify that the foundation and structure are anchored to resist floatation, collapse and lateral movement. A pile/column joint may weaken the foundation and require special attention in design and construction. Using a continuous pile - one that extends seamlessly from below grade all the way to the floor (or roof) - avoids that potential weak foundation (Dacy, et al., 2000).

The space below BFE must be free of obstruction, meaning left open. If the local ordinance allows, this space can be enclosed with non-supporting breakaway walls, open latticework or insect screening designed to collapse under wind and water loads without causing damage to structural supports or the structure (Anderson,1996). Minimum code requirements do not take into account the damage that can be caused when breakaway walls do just that and slam into neighboring buildings. For this reason, it‟s best to avoid the use of breakaway components, even if allowed (Amato, 1995). Homes can be elevated on perimeter foundation walls, or on piles, piers, or columns. If permitted by the community, elevation can also be achieved by placing fill under the structure. If the community permits fill to be placed below the BFE, the fill must be compacted and protected against scour and erosion. It is easiest to place fill before a home is constructed or, for existing homes, when the home is temporarily relocated, the following measures should be observe (Satterthwaite, et al., 2007).

- Basements are not permitted.
- Walls of enclosed areas below elevated homes must have flood openings that allow floodwaters to automatically equalize during an event.
- Enclosed areas below elevated buildings are permitted to be used only for parking, building access, and storage.
- Utilities, including electrical, heating, ventilation, plumbing, air-conditioning equipment (including ductwork) must be elevated above the BFE, or specifically designed to prevent water from entering or accumulating within the components during flooding.
- Flood damage-resistant construction materials must be used below the BFE.
- When the lowest floor is set, and again prior to final inspection, builders must obtain elevation certificates to document compliance.
- Construction of the home and other development must not result in any increase in flood levels within the community during the occurrence of the base flood discharge.

Piers are foundations typically constructed of either reinforced concrete or reinforced masonry columns. Piers are generally placed on footings to support the elevated home. Without footings, piers function as short piles and rarely have sufficient capacity to resist uplift, lateral, and gravity loads. Additionally, when exposed to lateral loads, discrete footings can rotate according to Blaikie, et al. (2004) and therefore, piers supported by discrete footings are not recommended in coastal environments. Piers supported with continuous concrete footings provide much greater resistance to lateral loads because the footings can act as an integrated unit to resist rotation. The integrated footing system must be steel reinforced to resist moment forces that develop at the base of the piers as a result of lateral loads on the foundation and elevated home. Pier foundations are typically shallow due to excavation constraints and are appropriate only where there is limited potential for erosion and scour. To prevent the continuous footing system from being undermined, the foundations must extend below the maximum estimated depth for long- and short-term erosion and localized scour. In some case, existing pier foundations may be retrofitted with grade beams to provide enhanced lateral support (Blaikie, et al., 2004).

2.5.2 Walls

2.5.2.1 Gabion Wall

According to Jabeen, et al. (2010) the failures of walls are usually caused by natural phenomena, especially from flooding. It is apparent that since the past two decades, the incidence of floods has not appreciably changed in many countries. The two leading causes of failures from flooding are scouring (which can also occur without flooding) and debris impact against bridge superstructure. This debris can also reroute flows, resulting in aggravated scouring and/or increased horizontal pressures acting on walls, bridge, piers and abutments (Lupala, 2002).

As stated earlier by Beck et al. (1996) scouring is the result of the erosive action of running water, which excavates and transports material away from the surface of walls. Different types of material scour at different rates and conditions. Thus, loose granular soils would scour more rapidly compared to cohesive soils. In addition, shifting of the stream may aggravate scour by eroding the approach roadway or changing the waterway‟s flow angle. Lateral movement of a waterway is affected by stream geomorphology, diversions, and characteristics of its bed and bank materials. For this purpose, Benevolo (1980) concluded that gabions have long been used as scour arresting devices on bridge abutments and piers. Apart from fortification against flooding, gabion walls are also suited to the following cases poor orientation of bridge piers with respect to water flows. Despite many apparent advantages of gabion walls in protecting walls against aggravated scour, failures can occur if the walls are subjected to high magnitudes of lateral forces. The sudden increase in lateral thrusts tends to cause side-shifting of adjacent gabion units configured in a conventional stack-and-pair arrangement. The end result is usually large-scale lateral movement of the affected abutment surface (Benovelo, 1980).

Conventional wall designs often initially incorporate drainage mechanisms behind the back walls and wing walls of their abutments. The mechanism is usually achieved by depositing free-draining backfill material behind the wall, collecting the seeped-through water and discharging it into an inlet connected to a storm water system. However, clogging of the drainage system can result in accumulated hydrostatic pressure behind the wall over time, subjecting the pier and/or abutment to overstressing, consequently leading to unacceptable lateral movement. The damage is usually more severe is cold countries, owing to repeated freezing and thawing of the accumulated water (Awour, et al., 2008). When gabions are used to fortify walls and piers, the integrity of structural fixity remains the core factor in preserving bridge stability in such hostile environments. In a conventional stack-and-pair configuration of gabion units, resistance to the lateral shifting on individual units rests almost exclusively to the tie wires connecting adjacent units. There is virtually no contribution of the remaining structural components constituting the gabion unit in resisting these aggravated lateral forces. Awour, et al. (2008) indicated that since gabions are essentially gravity structures, which rely on their weight to achieve stability against lateral forces, any increase in gravity function would entail increasing their individual masses. This solution may not only be inefficient from a material perspective, but also pose settlement problems.

To resolve this problem Jabeen et al. (2010) undertook a research to examine the feasibility of using an interlocking configuration of gabion units, instead of the traditional stacked-and-paired system. The system employs a continuum of hexagonal gabions to interlock with one another by virtue of shape and configuration. The new gabion design is functionally similar to the conventional box gabion, but modified conceptually in accordance with the York method used in concrete wall facings. The findings however did not address the issue of foundation and roof design to match with the interlocking configuration of gabion units infill panels. It is a fact that retaining wall composed of an interlocking system of individual gabion units display better overall structural integrity compared to a system of conventional stacked-and-paired gabions units (IDB, 2011).

These questions effectively reflect the principle that form influences function. To this end, the results of individual and cumulative experimentation investigating the hexagonal gabion‟s responses to external load vis-à-vis the traditional design would be examined. The findings intend to promote a new and useful contribution to the field of design and construction of such structures by disseminating the research results to the attention of engineers and offering alternate design solutions (Jabeen, et al., 2010). Gabion walls are cellular structures, i.e., rectangular cages made of zinc-coated steel wire mesh and filled with stone of appropriate size and necessary mechanical characteristics. Individual units are stacked, paired, and tied to each other with zinc-coated wire (or fasteners) to form the continuum. The choice of the materials to be used is fundamental for obtaining a functionally effective structure. In particular, the mesh must satisfy the requirements of high mechanical and corrosive resistance, good deformability and lack of susceptibility to unravel. The conventional gabion possesses some peculiar technical and functional advantages. They are reinforced structures, capable of resisting most types of stress, particularly tension and shear. The mesh not only acts to contain the stone fill but also provides a comprehensive reinforcement throughout to structure. They are deformable structures, which (contrary to popular opinion) does not diminish the structure but increases it by drawing into action all resisting elements as a complex reinforced structure, facilitating load redistribution.

They are permeable structures, capable of collecting and transporting groundwater and therefore, able to attenuate a principal cause of soil instability. The drainage function is further augmented by evaporation generated by the natural circulation on air through the voids in the fill. They are permanent (and therefore durable) structures, with a virtually maintenance-free regime from effects no more severe than the natural aging of any other structure (with the exception of highly corrosive environments). Furthermore, their characteristics over time tend to gravitate toward establishing a natural state of equilibrium. They are easily installed, i.e. that deployment is possible without the aid of special equipment of highly trained personnel. This aspect is notably important in river and marine reclamation, where rapid intervention to retain soil is often necessary and/or when post-deployment modifications are necessary (Adelekan, 2010). Although gabion walls imply resistance to movement, some forms of horizontal and vertical wall yield are still anticipated. This horizontal and vertical movement (i.e. slid and settlement) is essentially a manifestation of the resultant pressures acting behind the wall surface. The resultant pressure, P, is always thought to act upon an inclined plane at a third of the wall‟s height (Adelekan, 2010). Although its computed angle of inclination and height is specific computed figures, it is clear that determination is based on a series of assumptions, depending on which classical theory was subscribed to during analysis. The fact that the total resultant pressure, P, acts along an inclined plane suggests that P may be derived into its horizontal and vertical components. Therefore, different walls would invariably withstand different magnitudes of each force component.

This argument sets the premise that the shape and orientation of distinct gabion designs (i.e., rectangular vs. hexagonal) will likewise result in distinct capabilities to absorb one (or both) of the force components constituting the resultant lateral pressure, P. As a basis for comparison, both types of gabions must conform to similar dimensions, so that shape and orientation remain the determining variables in evaluating various structural properties associated with each gabion type. The research therefore compares the rectangular gabion (also referred to as the box gabion) with the hexagonal gabion to investigate the mechanical responses of either type of structure to external load, both individually and in a cumulative setting (Adelekan, 2010).

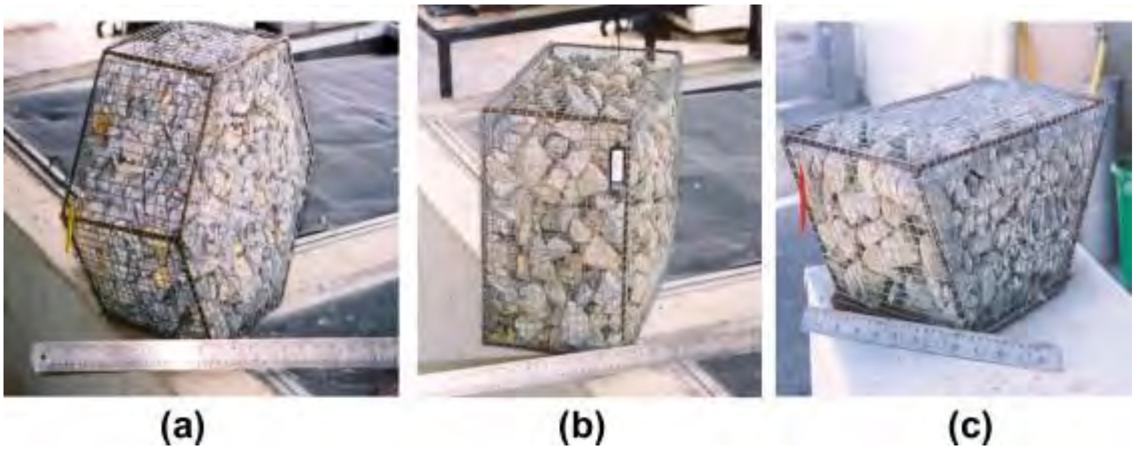


Figure 2.1: Tested Specimens of Gabion Wall Units

(a) Hexagonal, (b) rectangular, and (c) semi rectangular shape

Source; (Adelekan, 2010)

2.5.2.2 Twin Retaining Wall

Two sets of retaining walls composed of each gabion type were constructed for evaluating the mechanical responses of the conventional gabion wall versus the hexagonal wall to external load. The walls were of 1.80 m height and 1.75 m width and spaced 1.80 m from each other. The height-to-base ratio of each wall was purposely designed to be excessive in order to permit large deflections, although overturning moments were not tolerated in the interest of safety. Each wall was built with a stepped front-face and smooth back-face that reduces the wall thickness by 50% at three-fifths of the wall height from its base to the top. The introduction of burnt clay brick wall according to Kombe (2000) is crucial in terms of cost effectiveness instead of twin retaining wall when excessive flood water is to be resisted.

Figure 2.2: Twin Wall Construction

Source; (Adelekan, 2010).

The space between both walls was closed-off with plywood restraining panels to create a boxed area for the subsequent loading stage. The entire "box" was covered with plastic sheeting as an impervious membrane, purposely oversized to accommodate large moments expected of both structures. Several pertinent issues arise from evaluating the behavior of both gabion and twin retaining walls under extreme loading (Adelekan, 2010).

- The gabions‟ abilities to collectively deform under aggravated loads when combined soil-hydrostatic pressures are involved. Reversibility (or irreversibility) of deformation at low stress values was a point of contention.
- The rate in which deformation occurs from changes in displacement under progressive loads. These conditions represent the successive increments in soil lateral thrust occurring at the back of a retaining wall from fluctuations in the back fill‟s water content.
- The nature of the process of deformation in terms of localized mechanical responses when loaded over an indefinite period. Assuming that localized

response is prevalent, it would be necessary to evaluate what factors resulted in the unstable equilibrium.

- Evaluation of the structural characteristics of both walls at the point of terminal failure, i.e., when the structures have been loaded to maximum capacity of particular interest would be if the final load leads to abrupt collapse (or susceptibility to collapse)

The basis for comparing both walls is visual deformation, i.e., changes in horizontal and vertical displacements of an arbitrary point (on the walls" surfaces) vis-à-vis its original position. The assumed plane of deformation is represented along the two-dimensional exterior cross-section of either wall. A standard Cartesian system was adopted to measure the extent of displacement occurring on both walls under the same stress magnitudes. The Cartesian reference grid covers the cross-section of both walls with a matrix of 220 points, based on a specified number of horizontal and vertical gridlines superimposed on each wall. Shifting observed of each point was compared with a permanent vertical line to establish deformation under load. Each point was tagged and measured for horizontal distance from the fixed benchmark to establish relative initial position. For easy identification, standard Roman alphabets were used to represent the horizontal grids and Arabic numerals for the vertical grids.

A digital theodolite was used to determine the horizontal displacements of all principal points as a function of their viewed angular shift. The instrument was used to ascertain all readings from two measuring stations, each placed directly opposite each wall type. The soil load was applied by manually filling the walls" expandable "tank" in successive increments. For obvious reasons, "unsuitable" material was selected to impose higher lateral thrusts against both walls. The imposition of incremental soil load permits progressive assessments pertaining to the mechanical responses of each structure at that particular load level (Peal, 2012).Tachometric measurements of all moving targets under progressively increasing load enabled conversion into horizontal and vertical displacement with respect to the fixed vertical line. From the data generated, it is possible to determine the average values for deformation at various wall heights for each loading stage. On plotting these results, the evolution of the average deflection along the wall as a function of the soil-hydrostatic load is illustrated.

The results of the research conducted by Adelekan (2010) indicate that the hexagonal gabion exhibits better overall structural integrity than the conventional gabion in terms of deformation resistance and susceptibility to collapse. The shear behavior exhibited by each wall illustrates the principal link between unit configuration and overall stability when cellular units are built into a continuum. These assertions undoubtedly present major implications when considering practical application in bridge design, where such mechanical advantages, when magnified, may mean the difference between success or failure in the performance of piers and/or abutments fortified with cellular-based retaining structures against scour for lateral displacement versus load, and that the rate of displacement change for the last three load stages is significantly higher than the initial three.

A possible explanation is that during the initial loading stages, the resultant earth pressure is used to increase structural inertia. Initial sliding on the hexagonal wall experienced is much lower, i.e., only 7.6% for the first three load stages (compared to its maximum deflection) and 10.8% for the last three loading stages. The maximum deflection observed on both walls clearly indicates that the hexagonal-configured wall deforms less and under more controlled outcomes than the rectangular wall. In terms of the vertical lines‟ shifts for the last three load stages, the grid points on the rectangular wall deflect some 1000%, 350%, and 73%, compared to the same moving targets positioned on the hexagonal wall, which deflect about 180%, 17%, and 35%, respectively. This observed erratic behavior of the rectangular-configured gabion wall has tremendous implications in its inherent resistance to deformation, which consequently reflects upon its stability when responding to increasing lateral thrust. This is evident from its profile itself at the region between 0.35H and 0.55H, where the zigzagging pattern clearly indicates shear failure. Despite the polynomial relationship of wall movement versus load from initial to full load, a more linear relationship is evident if movements are strictly assessed above the walls‟ critical 0.33H height, where the resultant earth pressures are believed to act. In the case of both walls, the average gradient values obtained for the first three load stages were −0.135, −0.113, and −0.114 for lines 1, 2, and 3, respectively. The last three load stages, however, produced a marked shift in gradient, i.e., 0.052, 0.050, and 0.051 for the same gridlines. This radical change in gradient sign convention demonstrates the high shear stresses imposed on the rectangular wall at the "shear zone" of 0.35H − 0.55H. The hexagonal wall, on the other hand, registers milder curve gradients of −0.198, −0.248, and −0.263 for lines 4, 5, and 6 (for the first three load stages) and subsequently −0.051 for all Lines for the last three load stages. A consistent sign convention indicates lower shear levels and hence lower susceptibility to shear failure at the same zone (Adelekan, 2010).

The technical focus of the research invariably arises from a social perspective, namely is addressing the alarming trend of scour-induced bridge failures through innovation and improvisation of a common abutment/pier protection device-the gabion wall. By examining the century old pair-and-stack method of using “rock cages” to retain earth vis-à-vis an interlocking alternative comprising a hexagonal design with interlocking properties, the link between shape and structural function has been addressed. The study outcome and subsequent interpretation of findings suggest several pertinent conclusions as follows:

- Comparison of average deflections between both walls suggests that the hexagonal-configured wall deforms under more controlled outcomes compared to its rectangular counterpart. This invariably suggests that lateral deformation exhibited by an interlocked gabion system is more stable than a conventional stacked-and-paired system. This observation undoubtedly presents major implications in the continued utility of conventional gabions with respect to deformation resistance under gradually increasing lateral thrust.
- An examination of wall profiles at the region between 0.35H and 0.55H clearly reveals severe shear-induced deformation of the rectangular wall compared to the hexagonal wall. This observation suggests that the hexagonal wall‟s inherent interlocking mechanisms operating at aggravated loads compensates for the observed excessive strains occurring at the „shear zone‟.
- The deformation induced by the various loading stages is irreversible for both wall systems, which suggests that gabions, regardless of shape or configuration, do not behave as elastic units.

2.5.2.3 Compressed Earth Block Wall

There are a variety of presses for producing compressed earth blocks ranging from manual to motorized ones, but these are mostly uncommon in Bangladesh. Therefore the most suitable method would be to use a simple wooden brick mold operated by hand pressure, which is widely available for brick production. Necessary soil selection and identification should be carried out. If the soil has less than 40% sand extra sand should be added. The soil should be finely crushed, if necessary using a sieve, removing all debris and organic materials from it. At least 5% cement by volume to be added to the processed soil, using a typical 1 cubic foot wooden box. Mixing should be done in dry state and the mix then slightly moistened, taking care not to add too much water (Sheika, 2010). Small batches of mix should be prepared and each batch used up within 15-20 minutes to make blocks using the brick molder. The blocks should be stored in shade or under cover and moistened frequently for curing at least for two weeks. When laying the blocks, mortar of the same mix as used in the block should be used, but using more water. A small amount of lime can be added to prevent shrinkage cracks.

2.5.2.4 Rammed Earth Wall

This is a system of building earthen walls by compacting soil within forms. Typically, wooden forms are used, but steel forms are also useful. Hence, wooden forms are being recommended because they are less expensive, more easily available and easier to use in rural areas. The simplest way to keep the forms in place is to tie them with ropes, but for better control wooden or metal ties can be used. However, the choice of ties depends on the quality required or possible in a certain place and the level of skill. Walls should be built in layers, re-using the forms for each layer, packing and compacting the soil within the forms using a hand-held tamp or rammer, or if that is not available, using strong wooden battens (MBA, 2004). The more one compacts, the stronger the wall becomes, but this has to be done in accordance with availability of suitable soil and affordability. More compaction requires more soil and more labor, so an optimum level of compaction has to be decided by the house builder. According to Blaikie et al (2004) soil for rammed earth construction should be stabilized with cement for water resistance. The processes of soil selection and identification, preparation, mixing, casting and curing discussed in preceding sections should be followed. However, scouring of the soil from the surface of the wall still renders the wall non-resistant to flood effects (Tamar, 2010).

Awour, et al (2008) opined that whenever possible, earthen walls should be built on a brick and concrete foundation and plinth. If brick and concrete proves unaffordable, effort should be made to build a raised cement-stabilized earthen plinth. If the foundation and plinth is not of brick and concrete, monolithic load-bearing earthen walls should not be built. In that case, walls should have an internal structural framework or built as infill non-load bearing walls between posts should build house on raised homestead with slightly sloping ground for drainage.

Basic principles for good ventilation should be followed – exposed roof space, accessible loft space and adequate windows oriented to make use of prevailing wind flow direction. Adequate ventilation is essential for earthen houses, otherwise leads to dampness which can weaken the structure. Protection from Insects and Vermin can also be achieved by Cement-stabilized earthen construction deters insects and rodents from burrowing and building habitats. Termite shield should be used if walls are not load-bearing and do not require connection to the plinth (Adelekan, 2010).

2.5.3 Appropriate Measures to Adopt in Relation to Roofing

Extended roof eaves should be used to protect earthen walls from rain. Rainwater gutters should be used to discharge water away from the house. Added benefit is arsenic-free rainwater collection. Roof should be supported on posts instead of earthen walls. Steel roof structure can be made typically with 1½ inch x 1½ inch x /8inch section. It is advisable to make trusses for better strength, of which a variety of designs are possible (IDB, 2011). However, if that proves too expensive, a simpler structure of rafters, purlins and wall/post plate can be made. The members of the roof structure can be welded to each other, but if welding equipment is not available, they should be designed to be connected by nuts and bolts. Steel angle roof structure should be painted with corrosion resistant paint (Adelekan, 2010).

Completely timber houses are uncommon and timber is mostly used only as framing elements, such as roof structural frame, posts and framing for CI sheet walls. Stilted houses, which are somewhat uncommon in rural areas, often have a floor of timber planks. Good quality timber, such as garjan, although in high demand, is generally expensive and imported from hilly areas and does not grow in the floodplains. Low-income villagers can seldom afford it. In southern regions close to the coast, bamboo is less widely grown and timber is more in use in house construction (Benovolo, 1980). Utilization of local timber should be promoted instead of using timber imported from other areas. For example, in southern areas timber from various types of palm trees, such as betel nut (supari), palmyra (taal) and mature coconut tend to be used, and their production should be supported. Rural housing programs should include a component on promotion of cultivation of trees that can be grown on the homestead (Benevolo, 1980). Chemical treatment of large timber sections requires pressure treatment with expensive and sophisticated equipment. Unless part of an extensive program, use of such treated timber would not be feasible. However, for smaller sections of less thickness (maximum 1½ inch), the dip diffusion method as for bamboo treatment (Benevolo, 1980) If chemical treatment proves difficult, timber should be seasoned properly by the traditional method of completely immersing in water for at least one month. If timber posts are used, they should not be buried into the ground and instead should be supported on concrete stumps. Surface treatment such as painting with creosote or bitumen can serve as waterproofing. Exposure to rain should be avoided by using timber members on the inside surface of walls (Adelekan, 2010).

Although raising house on stilts seems a logical solution for flood-prone areas, it is not very common, possibly due to cultural reasons. There are, however, examples of houses on stilts in some flood-prone regions and also urban informal settlements are sometimes built on stilts on water-logged land which is of low demand. Roadside shops are also quite often stilted and could serve as examples for introduction in houses in flood-prone areas. Typically such houses are raised on bamboo or timber stilts and have a floor made of split bamboo sections or timber planks. Because good quality timber is generally expensive and scarce in many areas, stilted housing is usually prevalent in areas that are relatively better-off economically, or where timber is available locally, especially if the floor is made of timber planks (Awour, et al., 2008). In the face of the numerous advantages of stilted roof, timber tends to yield to decay as a result of wet wrought (Blaikie, et al., 2004).

The use of reinforced concrete (RC) posts as stilts is becoming common in areas with a tradition of stilted housing, substituting the typical timber and bamboo stilts. These have the advantage of being water resistant and hence more durable. Usually bamboo stilts have to be replaced within 2-3 years and although timber stilts can last longer depending on the type of wood used, they are still less durable than RC stilts. Reinforced Concrete Roof is relatively durable, used in sandcrete block houses, can withstand impact of heavy rainfall and wind (Lupala, 2002). In the opinion of Shieka (2010) concrete roof can withstand flood impact but can get weakened and may even collapse if foundation settles or walls are damaged. However, it offers a high degree of rooftop refuge during flood.

2.6 Summary of Literature Review

The impact of floods to housing is due to several reasons: Flood depth, Flood duration, uplift due to soil saturation and Horizontal force created by flood waves or currents (Adelekan, 2010). Direct flood hazard is associated with other types of secondary hazards such as high winds or storms, lightning, slope instability, ground settlement and other factors. Floodwater can submerge buildings and cause various degrees of damage from staining of walls which can lead to structural collapse depending on flood depth, duration and type of building (Adelekan, 2010).

The foundation of houses in the three Northern Regions of Ghana usually of sun-dried bricks earthen and sometimes timber posts is embedded directly into the earthen plinth. Extremely vulnerable, it gets damaged even in low intensity flood, thus requiring frequent maintenance (Blackie, et al., 2004). In moderate to high intensity flood, especially if accompanied by currents, earthen plinths tend to get completely washed off and have to be rebuilt immediately (Blackie, et al., 2004). Bamboo or timber posts in saturated soil, especially during long duration or recurrent flood, get rotten at the base, thus weakening the entire structure of the buildings to damage by strong wind, differential settlement, sagging of roofing elements and doors, windows and wall elements developing cracks and losing alignment.

Sun- dried brick or mud brick wall typically in „atakwame" houses also often have a lifespan of 2-3 years and bamboo mat 4-5 years Opong (2000). Decay can get accelerated in flood. In flood of high depth and moderate duration, the damage begins in the lower part of walls and hence weakens the walls and eventually results in complete damage. Flood with strong currents can detach wall panels or walling units and wash them away, leading to partial or complete loss, especially if the bricks are laid directly on the sub-grade or connections to posts are weak (Baba et al., 2012). The used of timber framing in place of mud bricks as suggested by Baba et al. (2012) when in contact with water leads to corrosion and gets aggravated in flood. The lower part of walls is particularly vulnerable if the plinth is not sufficiently above flood level or if flood depth is high. Prolonged duration flood can cause damage to lower end of sheet wall panels and timber frame. Flood with strong current can detach and wash away wall panels, especially if not adequately secured to frame (Baba et al., 2012). Earth is used as a walling material in „atakwame" houses in various designs according to region in the north of Ghana, but not prevalent in all areas. In monolithic construction, flood water can cause serious damage once the base gets affected; the entire structure is liable to collapse, often rapidly. Earthen walls with an internal framework, as in some parts of the regions, are less vulnerable; even if the earth cover is washed away, the building remains standing and can be repaired (Baba et al., 2012). The fundamental question still remains; how can the structure continue to function without such a damaged wall eventually being replaced? Brick panels are sometimes relatively durable, but can experience staining, peeling of plaster and weakening of mortar joints at lower ends if immersed in flood of high depth and duration. Cracks may develop if settlement of foundation occurs (Udarty, et al., 2006).

Thatch roof typically in „atakpame‟ houses, made from grass, rice, wheat or maize straw with usually bamboo and sometimes reed stalk framing. Normally has to be renewed every 2-3 years. This type of roof in flood prone areas results in decay in houses of low height and during flood of very high depth and duration, if thatch comes into contact with flood water. In such conditions, if also accompanied by strong current, thatching materials can get detached and washed away (Brahmi, et al., 2004). Secondary hazard often connected to flood is heavy rainfall, which can cause damage. Strong wind can also blow away thatching materials and damage frame (Brahmi, et al., 2004). Aluminum Sheet roof, used in wattle and daub houses usually with timber framing, bamboo framing and in some cases without any framing can lead to corrosion when in contact with water and vulnerable to secondary hazard of heavy rainfall accompanying flood. Particularly vulnerable to strong wind – can crumple and get blown off, especially if connections to frame are inadequate. During flood can offer a limited degree of rooftop refuge (Lupala, 2002).

Pile foundations are required in flood areas and coastal environments so that waves can pass more easily under elevated homes (Brahmi, et al., 2004). Traditional piles are typically constructed of treated timber, steel, or precast concrete and are driven into the ground to a depth required to resist vertical and lateral loads from gravity, wind, and flood forces. Pile foundations use the soil"s resistance to support the elevated home. Critical aspects of a pile foundation include the pile size and spacing, installation method, embedment depth, bracing, and the connection to the elevated home. Piles that are properly sized, spaced, installed, braced and have adequate embedment into the soil (with consideration for erosion and scour effects) will perform properly and allow the home to remain standing and intact following a design flood event (Brahmi, et al., 2004).

Piles can used to make provision for upper floor level, although owners should check the design considerations to understand how the extended piles will withstand lateral movement (Lerise, et al., 2005). Using grade beams provides resistance to rotation also called "fixity" in the top of the embedded piles and improves stiffness of the pile foundation system against lateral loading. When used together, piles and grade beams work together to support the elevated home and transfer vertical and lateral loads imposed on the elevated home and foundation to the ground below (NMBA, 2004). Design and installation of grade beams should include the following concepts: Grade beam design criteria should include resisting lateral flood loads from both hydrodynamic forces and flood-borne debris impacts.

According to Jabeen et al. (2010) the failures of walls are usually caused by natural phenomena, especially from flooding. It is apparent that since the past two decades, the incidence of floods has not appreciably changed in many countries. The two leading causes of failures from flooding are scouring (which can also occur without flooding) and debris impact against bridge superstructure. This debris can also reroute flows, resulting in aggravated scouring and/or increased horizontal pressures acting on walls, bridge, piers and abutments (Lupala, 2002).

As stated earlier by Lupala (2002) scouring is the result of the erosive action of running water, which excavates and transports material away from the surface of walls. Different types of material scour at different rates and conditions. Thus, loose granular soils would scour more rapidly compared to cohesive soils. In addition, shifting of the stream may aggravate scour by eroding the approach roadway or changing the waterway"s flow angle. Lateral movement of a waterway is affected by stream geomorphology, diversions, and characteristics of its bed and bank materials. For this purpose, Benevolo (1980) gabions have long been used as scour arresting devices on bridge abutments and piers. Apart from fortification against flooding, gabion walls are also suited to the following cases poor orientation of bridge piers with respect to water flows.

Despite many apparent advantages of gabion walls in protecting walls against aggravated scour, failures can occur if the walls are subjected to high magnitudes of lateral forces. The sudden increase in lateral thrusts tends to cause side-shifting of adjacent gabion units configured in a conventional stack-and-pair arrangement. The end result is usually large-scale lateral movement of the affected abutment surface

(Benovelo, 1980). Conventional wall designs often initially incorporate drainage mechanisms behind the back walls and wing walls of their abutments. The mechanism is usually achieved by depositing free-draining backfill material behind the wall, collecting the seeped-through water and discharging it into an inlet connected to a storm water system. However, clogging of the drainage system can result in accumulated hydrostatic pressure behind the wall over time, subjecting the pier and/or abutment to overstressing, consequently leading to unacceptable lateral movement. The damage is usually more severe is cold countries, owing to repeated freezing and thawing of the accumulated water (Awour, et al., 2008). When gabions are used to fortify walls and piers, the integrity of structural fixity remains the core factor in preserving bridge stability in such hostile environments. In a conventional stack-and-pair configuration of gabion units, resistance to the lateral shifting on individual units rests almost exclusively to the tie wires connecting adjacent units. There is virtually no contribution of the remaining structural components constituting the gabion unit in resisting these aggravated lateral forces. Awuor, et al. (2008) indicated that since gabions are essentially gravity structures, which rely on their weight to achieve stability against lateral forces, any increase in gravity function would entail increasing their individual masses. This solution may not only be inefficient from a material perspective, but also pose settlement problems.

To resolve this problem Jabeen et al. (2010) undertook a research to examine the feasibility of using an interlocking configuration of gabion units, instead of the traditional stacked-and-paired system. The system employs a continuum of hexagonal gabions to interlock with one another by virtue of shape and configuration. The new gabion design is functionally similar to the conventional box gabion, but modified conceptually in accordance with the York method used in concrete wall facings. The findings however did not address the issue of foundation and roof design to match with the interlocking configuration of gabion units infill panels. It is a fact that retaining wall composed of an interlocking system of individual gabion units display better overall structural integrity compared to a system of conventional stacked-and-paired gabions units (IDB, 2011).

Extended roof eaves should be used to protect earthen walls from rain. Rainwater gutters should be used to discharge water away from the house. Added benefit is arsenic-free rainwater collection. Roof should be supported on posts instead of earthen walls. Steel roof structure can be made typically with 1½ inch x 1½ inch x /8inch section. It is advisable to make trusses for better strength, of which a variety of designs are possible (IDB, 2011). However, if that proves too expensive, a simpler structure of rafters, purling and wall/post plate can be made. The members of the roof structure can be welded to each other, but if welding equipment is not available, they should be designed to be connected by nuts and bolts. Steel angle roof structure should be painted with corrosion resistant paint (Adelekan, 2010).

Completely timber houses are uncommon and timber is mostly used only as framing elements, such as roof structural frame, posts and framing for metal sheet walls. Stilted houses, which are somewhat uncommon in rural areas, often have a floor of timber planks. Good quality timber, such as garjan, although in high demand, is generally expensive and imported from hilly areas and does not grow in the floodplains. Low-income villagers can seldom afford it. In southern regions close to the coast, bamboo is less widely grown and timber is more in use in house construction (Benovolo, 1980). Utilization of local timber should be promoted instead of using timber imported from other areas. For example, in southern areas timber from various types of palm trees, such as betel nut (supari), palmyra (taal) and mature coconut tend to be used, and their production should be supported. Rural housing programs should include a component on promotion of cultivation of trees that can be grown on the homestead Benevolo, 1980). Chemical treatment of large timber sections requires pressure treatment with expensive and sophisticated equipment. Unless part of an extensive program, use of such treated timber would not be feasible. However, for smaller sections of less thickness (maximum 1½ inch), the dip diffusion method as for bamboo treatment (Benevolo, 1980) In order to protect an existing building from flooding, elevation of the building is one retrofitting method. The two major types of elevating living spaces above the expected flood level are: lifting up a building on a new or extended foundation; and extending a building upward by elevating the existing floor or adding a new upper story utilizing an existing foundation (Ahmed, 1994) The first method separates the building from its foundation, raises it on a hydraulic jack, and constructs a new or extended foundation below it. The new and extended foundation can be continuous walls, or separate piers, posts, columns or piles and can be exposed to flooding. The second method removes the roof, extends the building walls, and constructs a raised floor. The abandoned lower area can then be used for parking, building access or storage. The height of elevation is determined by the expected flood level, that is, the lowest floor of the living space must be above the flood level, including freeboard. As with a water proofing measure, the foundation of the elevated building must be able to withstand hydrostatic pressure, hydrodynamic pressure, debris impact, and erosion by flooding. Design experts should be consulted for these elevation projects to evaluate whether the existing foundations can support an increased load to the building. If the project site is subject to high winds, earthquakes, or other hazards, such horizontal and vertical forces must be also considered. (Janssen, 2011)

Elevating a basement foundation home on extended foundation walls can be achieved in home elevated by adding a new second story over an abandoned lower floor. Braihmi et al. (2004) conducted an investigation into the hurricane katrina flood event in 2005. The assessment found that the buildings that survived the hurricane event have some elements in common, such as high first floor elevations; a well embedded deep pile foundation, and structurally connected foundation and building frame. The results show that elevation successfully protected the building from flooding which is estimated at the height of the red line. The elevated buildings had water concrete roof that facilitated their survival. However, in the case of three Northern Regions floods, the vulnerable poor inhabitants cannot afford the cost of an elevated foundation and concrete roof at the same time (Baba, et al., 2012).

Moving to the stage where training of professionals is essential to the building industry can help reduce the effects of floods on buildings. Existing flood hazard area is the safest solution among several retrofitting methods; however it is also usually the most expensive method (Lerise, et al., 2005). When a community acquires a flood-prone home from the owner, relocation is often applied, as well as demolition of the building. Relocation includes the following process: lifting up a building from its foundation, placing it on a trailer, transporting it to a new safe area, and setting it onto a new foundation. As with the elevation of a building, a relocated building must be structurally sound enough to withstand all the stresses during the relocation process.

Similar techniques as used for the elevation of buildings are used for lifting and setting a building structure. The moving process requires trailer wheel sets to be placed beneath steel beams supporting the building. The size and weight of a building affects the relocation process and the necessary equipment. A single-story, wooden framed building with a rectangular shape is easier to be relocated than a multi-story, solid masonry one. Given that relocation requires a moving route between the old and new sites, this adds additional consideration because of the route restrictions, such as width of roads, load limits on bridges, and clearance of facilities along the route. If a building is too large to fit on any moving route, they are impediment makes relocation not a better option particularly in vulnerable poor communities (Lupala, 2002)

It may be cut into sections, moved separately, and reassembled at the new site. Taking public roads and changing utility lines requires the necessary permits from local governments or utility companies. The relocated building also needs to meet all zoning ordinances and building codes in the new site (Thomsen, et al., 2010). Due to the fact that relocation is a costly but effective method to prevent recurrence of flood damage, it is often used for preserving historical buildings and monuments (Barker, 1994). Flood proofing structure requires regular inspection and maintenance to ensure appropriate functioning of the flood proofing components during flooding. A maintenance plan describes inspection intervals and repair requirements of the flood proofing components, for example mechanical parts of pumps and generators, flood shields for their watertight function (Nyako, 2013).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents the methodology of the study. The chapter is organized into seven sections compressing an Introduction, Research Design, the Study Population, Sampling Frame, the Sampling Technique, Sample Size, Data Collection and Data Analysis.

3.2 Research Design

There are basically two methods of research design namely; Quantitative approach based on a positivist paradigm and Qualitative approach based on the Constructivist world view (Gyau, 2000). A third design, Sheika (2010) is the combination of both Quantitative and Qualitative termed the Mixed Design. The choice of a particular design depends on the aim of the study and the conviction of the researcher on the various paradigms.

3.2.1 Qualitative Study

Proponents of Qualitative Studies use the Constructivist, Advocacy, Participatory and Knowledge Claims as their philosophical assumptions. It employs strategies of enquiry such as phenomenology, grounded theory, ethnography, case study and narrative.

Gyau (2000) described the term "qualitative research" as a term used as an overarching category, covering a wide range of approaches and methods found among several research disciplines. Qualitative research uses tools such as interview and observation Qualitative research relies on participant meaning, position of the researcher, single concept of phenomenon and brings personal values into the study makes it biased since it sometimes employs no statistical procedure. The findings of this approach cannot therefore be generalized due to the above weaknesses hence, the emergence of quantitative strand (Gyau, 2000).

3.2.2 Quantitative Research

Quantitative is a research strategy that emphasizes measurement and quantification in the collection and analysis of data (Gyau, 2000). It makes use of a deductive approach to the relationship between theory and research, in which the accent is placed on the testing of theories. It has incorporated the practices and norms of natural science model and practices positivism in particular. It entails, also a view of social realism as an external, objective reality. Quantitative research was outlined as a distinctive research strategy. In very broad terms, it was described as entailing the collection of numerical data and as exhibiting a view of relationship between theory and research as deductive, a for a natural science approach (and positivism in particular), and as having an objectivist conception of social reality. Quantitative research should not be taken to mean that quantification of aspects of social life is all that distinguishes it from qualitative research strategy. The very fact that it has a distinctive epistemological and ontological position, suggest that there is a good deal more to it than the mere presence of numbers (Gyau, 2000). Basically, there exist four major preoccupations of quantitative research; measurement, causality, generalization and replication. This concept represents beliefs about what constitute acceptable knowledge. These concepts are the building blocks and represent the point around which social research is conducted (Gyau, 2000).

It is worth adopting because the survey questionnaire is the major reliable data collection instruments extensively used in quantitative research. The survey questionnaire as an instrument administered to the study participants who provide answers to closed ended questions.

3.2.3 Method Adopted for the Study

Quantitative research was preferred for the study as it uses philosophical world view of positivist paradigm. The closed ended survey questions made it possible to test any theoretical aspects, identify variables to study, relates variables in questions, use standards of validity and reliable, observes and measures information quantitatively, uses unbiased approaches and employs statistical procedures. The Survey Questionnaire was used exclusively to gather information from the consultants who are mainly Architects, Quantity surveyors and Structural Engineers on the possibility of the implementation appropriate constructional measures to the built environment in flood prone communities with particular emphases to the Upper East, Upper West and Northern Regions of Ghana. Since this category of professionals is made up of literates, they did not encounter much difficulty in answering closed ended questions.

3.3 Study Population

The selection of the respondents was limited to Architects, Quantity Surveyors and Structural Engineers in the construction industry staying and operating in the three northern regions of Ghana. The choice of this class of professionals was informed based on the fact that they are well established firms duly registered with the Ghana Architectural Council, the Ghana Institute of Quantity Surveyors and the Ghana Engineers Association respectively, thus making it quite easy for the researcher to locate them. The target population (N=260) comprised of Architects, Quantity Surveyors and Structural Engineers located and working in the three regions of the north namely; Upper East, Upper West and Northern Regions of Ghana, who are duly registered with their respective professional bodies in Ghana.

3.3.2 Sampling Technique

Non-probability sampling was adopted due to its advantages over probability sampling as far as this study was concerned. In the case of probability sampling, the decision as to whether a particular element is included in the sample or not, is governed by chance alone. The technique only allows each individual to be chosen randomly by chance. Probability sampling relies on a sampling frame which was nonexistent for the present study. Therefore, purposive sampling which is an example of non-probability sampling technique was used in the selection of the survey respondents namely; Architects, Quantity Surveyors and Structural Engineers.

3.3.3 Sample Size

The sample size for the study was 158 identified built environment consultants namely; Architects, Quantity Surveyors and Structural Engineers staying and working in the three northern regions of Ghana. This sample size was for a population of 260 based on the Sample Size Determination Table by Krejcei and Morgan (1970). Refer to appendix II.

3.3.4 Data Collection

Based on the specific objectives of the research, a questionnaire was developed to obtain an exhaustive collection of data as practicable, from these key players in the Construction Industry. A structured questionnaire was therefore prepared and self-administered to the various respondents. The questionnaires consisted of closed ended questions. The first part of questions related to respondents" profile. This was intended to find out the background and experience of respondents in respect to their level awareness and knowledge on appropriate measures to be adopted for flood prone areas. The second part of questions related to the specific objectives of the study. A 3-point Likert ranking system was used.

3.3.5 Questionnaire

Survey Questionnaire (Appendix II) was the major data collection instrument used to gather data to answer the research questions. The survey questionnaire was organized under two sections: Section A comprises biographical information about the respondents closed ended questions on current design practices in the study area. Section B focuses on the Effects of Floods, Enabling Factors for the Adoption of Appropriate Measures to minimize flood effects on housing in Flood Prone Areas, Barriers to the Adoption of Appropriate Measures in minimizing flood effects and the benefits derived in the adoption of appropriate measures in flood prone areas. The specific objectives of the study were turned to a Likert-type questionnaire. The instrument had a number of features that are described below.

The questionnaire contained 140 items. All of these were of the Likert-scale type. The first section considers the biographical information of the respondents which has to do with their area of specialization and their working experience. Section B of the questionnaire was on scales from „strongly disagree" to „strongly agree" Keeler (2009). All the Likert-type items used a four point scale that has been suggested by (Gyau, 2000). Such a scale encouraged respondents to make forced decisions from several responses. Ordinal values of 4, 3, 2 and 1 were assigned to the different responses of scaling statements. The responses were „Strongly Disagree", „Disagree", „Agree", and „Strongly Agree" and were assigned ordinal values of 4, 3, 2 and 1 respectively concerning items appropriateness of resilient designs and their application to flood prone areas. There were five sub-headings in the questionnaire as highlighted in the literature (Adelekan, 2010).

3.4 Data Collection Procedure

3.4.1 Pilot Study

The main study was preceded by a pilot study in July 2014 using Architects and Quantity Surveyors who are working with the Ghana High Ways Authority. These professionals have their offices in Bolgatanga, in the Upper East Region. In all, six consultants were asked to complete the questionnaire. The main aim of the pilot study was to improve upon the draft questionnaire used in the pilot study. Part One for Architects and Quantity surveyors and Part Two was meant for Structural Engineers. In connection with this, the consultants were given the opportunity to critique the questionnaire, examine it for any ambiguities and relevance of items in relation to the problem under study.

3.4.2 Administration of the Instrument

The questionnaire was administered to cover a period of one month. This was done through personal visits to the destination of each of the Architectural, Quantity Surveying and Structural Engineering firms who participated in the study. The questionnaire was given out and the participants were left alone to complete it. Averagely, it took the researcher a fortnight to retrieve the questionnaires from the respondents.

3.4.3 Validity and Reliability of Instrument

Concerning the validity of the questionnaire, the instrument was shown to the chairman of the Architectural Council of Ghana (ACG), the two Deputy Chairmen, the Acting Director of Ghana Institute of Quantity Surveyors and the Regional Director of Northern Consultants in the Upper East Region for comments.

The following suggestions were made;

- Changing the scales for items 1 – 20 to “Strongly Disagree”, “Disagree”, “Agree” and “Strongly agree”. Originally, they were “Extremely useful”, “useful”, “useless” and “Extremely useless”.
- Simplifying the wording for items 21 and 24.
- Categorizing the items of the pilot questionnaire into three headings (sections).

All these suggestions were accepted and the necessary changes were made in the final instrument. As a result of the pilot study a measure of item consistency was established (the extent the item responses were consistent across constructs) among the consultants. Reliability of the responses was obtained through the co-efficient alpha (crobach‟s). The responses yielded total reliability co-efficient of 0.67. According to Livingston (1985), this alpha value was a fair and clear indication that the instrument was reliable. The Sample Size Determination Chart by Krejcie, et al. (1970) was used to obtain the sample size 60 respondents to participate in the study.

3.4.4 Ethical Considerations

Lupala (2002) identified four major moral principles, autonomy, non-malfeasance, beneficence and justice. Autonomy infers that an individual has the right to freely decide to participate in a research study without knowledge of what is being investigated. In view of this, a permission letter was submitted to the Chief Directors. Participants were thus assured that high ethical standards would be maintained to ensure that no harm is caused to them. They were assured that any information shared would be treated confidentially and privately, and that it would be used for the purpose of the current study. The permission letter stated inter-a-lia that the research was meant to benefit they the participants and the society in general. All participants were treated equally with the respect of human dignity to ensure sure justice. The Ethical Committees of the various professional bodies gave an approval and consent to the researcher before the study was conducted.

3.5 Method of Data Analysis

The statistical methods which were used in analyzing the data were frequencies, descriptive statistics T-Test and Correlation matrix. Regression analysis was also used to present the results of the regression analysis using the statistical program Stated in a variety of functional forms. This was followed by a justification of the functional form that was selected. Following that, the model for multi-co linearity and hetero skedasticity was checked; details of correction for potential problems the results are reported.

First, description of the study population was provided. Second descriptive forming data score (scores) were compiled for knowledge on Resilient Designs (KRD) and each of the Benefits of Resilient Designs (BRD). These included frequency counts, percentages, means and standard deviations and were summarized in various tables. The scores of the KRD in relation to the extent of the attainment of the objectives of the role of consultants were interpreted in accordance with Anderson (1996) criterion of effectiveness of resilient designs. This criterion suggest that scores below 65 percent in knowledge of Resilient Design indicate that consultants are quite familiar with the concepts of resilient designs and that they need to educate homeowners to embrace the concept.

The implementation attitudes of resilient designs of the respondents were determined by interpreting the scores for each of the KRD using Anderson‟s (1996) approach to the interpretation of attitude measure. The approach is based on the estimate of internal consistency, the standard errors of the scale scores is added together and subtracted from the neutral point score. Score falling within the band of scores formed by the neutral point plus or minus two standard errors of measure are interpreted as indicating neutral attitude. Scores to the right and left of the neutral attitude band are interpreted as indicating positive attitude respectively.

The Scheffe method was chosen for the post hoc analysis because of its great stringent comparison test than other procedures and therefore reduces probability differences.

CHAPTER FOUR

PRESENTATION AND ANALYSIS OF RESULTS

4.1 Introduction

The chapter presents the analysis and results of field gathered in order to answer the research questions as well as achieve the research objectives. The chapter organized eight main sections.

4.2 Response Rate

A total of one hundred and fifty eight (158) questionnaires were distributed to construction professionals; Architects, Quantity Surveyors and Structural Engineers in the study regions. Sixty were (60) received and analyzed. Fifty (50) were usable refer to table 4.1. The high usable rate is due to the fact that this group is an elite class. It can be noted that the highest proportion of responding consultants came from the Northern region. The positive response rate can be ascribed to the factors arising from the Northern region. In comparison, responses received from the Upper West Region were relatively lower taking into consideration the responses from Northern and Upper East Regions. Monthly Meetings of the Association were not held, during the period of the research, thus making it difficult for the researcher to locate the respondents personally to collect the questionnaire.

Table 4.1 Response Rate

Region	Profession	Number of Questionnaire Distributed		Number of Questionnaire Returned		Number of Questionnaire Usable		Percentage of Usable Questionnaire
Upper East	Architects	25	50	10	19	8	17	34 %
	Quantity Surveyors	15		5		5		
	Structural Engineers	10		4		4		
Upper West	Architects	25	50	8	16	5	10	20 %
	Quantity Surveyors	15		6		3		
	Structural Engineers	10		2		2		
Northern Region	Architects	30	58	15	25	12	23	46 %
	Quantity Surveyors	20		5		6		
	Structural Engineers	8		5		5		
	Total		**158**		**60**		**50**	**100%**

Source: Survey 2015

4.3 Demographic Information of Respondents

This section of the questionnaire comprised questions seeking basic information and some related issues in order to provide detailed respondent characteristics. The importance of knowing the profile of the respondents is to help have confidence in the reliability of the data generated. Data included job classification of respondents, years of experience in the construction industry, their level of awareness of the destruction of buildings during flood events.

4.3.1 Job Classification of Respondents

From Figure 4.1 below, 18% of the respondents were Structural Engineers. Furthermore, 39% of them were Quantity Surveyors while the remaining 43% were Architects.

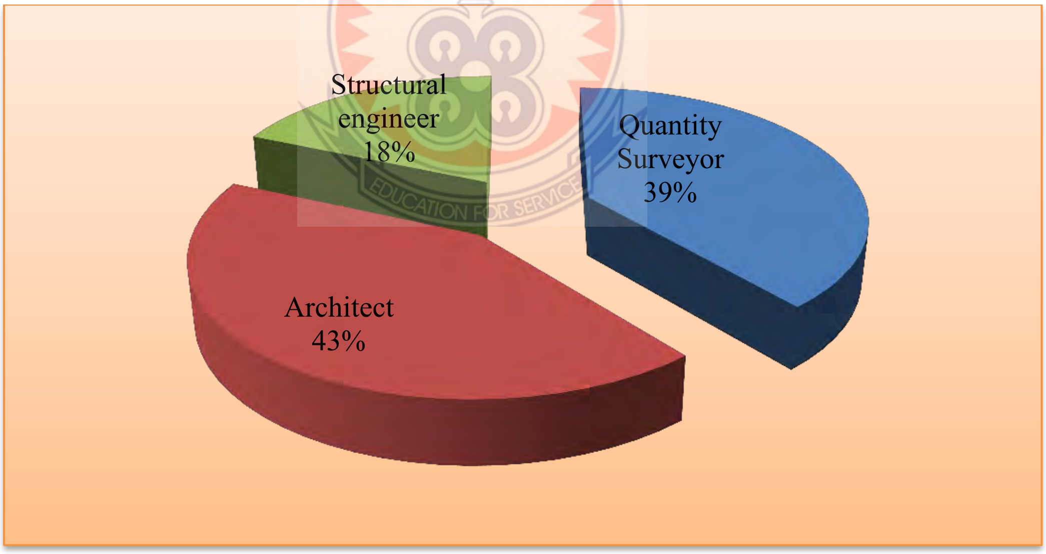


Figure 4.1: Job Classification of Respondents

4.3.2 Experience of Respondents

Figure 4.2 below shows the experience of the respondents. From the bar chart, 55% of the respondents have 5-10 years working experience in the construction industry. The remaining 45% of the respondents have 10-15 experience.

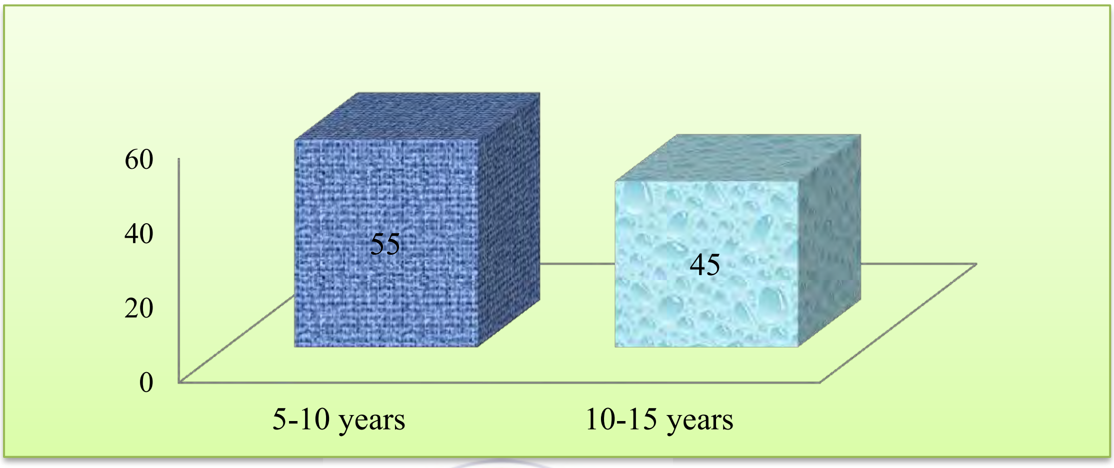


Figure 4.2: Work Experience of Respondents

4.4 Effects of Floods

This section sought to know from the respondents the possible effects of floods on housing in the study area. The effects were identified in three structural components of a typical building namely; foundation, wall and roof. Descriptive statistics was used to rank the responses. Table 4.3 ranks the responses of the respondents. From table 4.3 below, over turn of foundation was ranked1st with a mean of 4.333 and standard deviation of 0.846. Cracks on foundation was ranked 2nd with a mean of 3.8148 and standard deviation of 1.01077. Instability of the foundation was ranked 3rd with a mean of 3.6667 and standard deviation of 1.02791. Collapse of walls was ranked 4th with a mean of 3.6667 and standard deviation of 1.22859, Staining of walls was ranked 5th with a mean value 1.0536. Furthermore, other serious effects of floods include: Hacking of wall surface was ranked 6th with a mean of 3.6111 and standard deviation of 1.0536, *thatch roof leaks 6th, while leakage of concrete roof was ranked*

*7th with a mean value of 3.2222. Dissolution of foundation was ranked 8th with mean value of 1.1296, Weakening of roof was ranked*9th with a mean value 2.9259. Cracks on Concrete Roof was ranked 9th. Exposure of reinforcement was ranked 10th with a mean value 2.9815. Unequal Settlement of foundation was ranked 11th with mean value of 3.0185. Sinking of foundation was ranked 12th, with a mean 8142, bamboo wall decay in flood water was ranked 13th with a mean value of 2.6111, burnt clay bricks gets soaked was ranked 14th with a mean value of 2.9259, reinforcement rods corrode was ranked 15th mean value of 2.8148, solid foundation is washed away was ranked 16th with a mean value of 2.6852, sagging of beams under flood water was ranked 17th while roof tiles leaks was ranked 18th.

Table 4.2 Effects of Floods on Buildings

	Mean	Std. Deviation	Ranking
Over turn of foundation	4.3333	1.84675	1st
Unequal settlement of foundation	3.0185	1.36659	11th
Dissolution of foundation	3.1296	1.63737	8th
Exposure of reinforcement	2.9815	1.33869	10th
Leakage of concrete roof	3.2222	1.86147	7th
Sinking of foundation	2.8148	1.30419	12th
Solid foundation is washed away	2.5000	1.31393	16th
Bamboo wall decay in flood water	2.6111	.97935	13th
Hacking of wall surface	3.2593	.75698	6th
Cracks on concrete roof	2.9259	1.42553	9th
Staining of walls	3.6111	1.05360	5th
Instability of the foundation	3.6667	1.02791	3rd
Collapse of walls	3.6667	1.22859	4th
Burnt clay bricks gets socked	2.6852	1.34338	14th
Cracks on foundation	3.8148	1.01077	2nd
Reinforcement rods corrode	2.6481	1.37577	15th
Concrete roof has no refuge	3.4630	.60541	6th
Roof tiles leaks	3.2037	.40653	18th
Beams sag under flood water	3.2222	.74395	17th

4.5 Enabling Factors for the Adoption of Appropriate Measures

This section sought to know the enabling factors that facilitate the adoption of appropriate measures for flood prone areas to minimize the effects of floods. In other words, a close look at those factors that necessitate built environment consultants to take appropriate steps to reduce the effects of floods on housing. The need to adhere to Building Regulations was ranked 1st with a mean value of 3.3333. On the issue of High Demand for water resources, respondents ranked the factor 2nd with a mean value of 3.8146. The factor Change in Climatic Conditions was ranked 3rd with a mean value of 3.6667. Acquisition of Building Documents was ranked 4th with a mean value of 3.3666, High Demand for Coastal Land was ranked 5th with a mean value of 3.6111. Enforcement of By-Laws was ranked 6th with a mean value of 3.2593. Increased Insurance Claims was ranked 7th with a mean value of 3.4630. Buildings used as collaterals was ranked 8th with a mean value of 3.1296. High Demand for Land for Agricultural Purposes was ranked 9th with a mean value of 2.9259. Involvement of NGOs in the provision of housing was ranked 10th with a mean value of 2.9815. Increased Investor Confidence was ranked 11th with a mean value of 3.0185. Boost tourism was ranked 12th with a mean value of 2.4148. Sustainable Development was ranked 13th with a mean value of 2.6111. Legal Issues was ranked 14th with a mean value of 2.6852. High Cost of Building Materials was ranked 15th with a mean value of 2.6481. Increased in Population was ranked 16th with a mean value of 2.5000. Increased Number of Consultants was ranked 17th with a mean value of 3.2222. Increased Cases of loss of lives through building collapse was ranked 18th with a mean value of 3.2037.

Table 4.3 Enabling Factors for the Adoption of Appropriate Measures

	Mean	Std. Deviation	Ranking
Adherence to Building Regulations	4.3333	1.84675	1st
Increased Investor Confidence	3.0185	1.36659	11th
Buildings as Collaterals	3.1296	1.63737	8th
NGOs involvement in the Built Environment	2.9815	1.33869	10th
Increased in Housing Needs	3.2222	1.86147	7th
Boost Tourism	2.8148	1.30419	12th
Increased population	2.5000	1.31393	16th
Sustainable Development	2.6111	.97935	13th
Enforcement of By-Laws	3.2593	.75698	6th
High Demand of Land forAgric Purposes	2.9259	1.42553	9th
High demand for coastal land	3.6111	1.05360	5th
Change in Climatic conditions	3.6667	1.02791	3rd
Acquisition of building documents	3.6667	1.22859	4th
Legal Issues	2.6852	1.34338	14th
High demand for water resource	3.8148	1.01077	2nd
High Cost of Building Materials	2.6481	1.37577	15th
Increased insurance claims	3.4630	.60541	7th
Increased cases of loss of lives	3.2037	.40653	18th
Increased number of Consultants	3.2222	.74395	17th

4.6 Key Barriers to the Adoption of Appropriate Measures in Flood Prone Areas

The barriers that militate against the adoption of appropriate measures in flood were given to the respondents to be ranked. They included the following in Table 4.4 below; the factors *High Cost of Resilient buildings, Design Challenges, Lack of Standardization of Resilient, Low Involvement of contractor at design stage, lack of adoption of new building Practices* and *low level of professionalism* were ranked to be the most severe barriers with mean values of 3.1852,3.0926, 3.0741, 3.0000, 2.9444 and 2.8889 respectively.

Table 4.4 Barriers to the Implementation of Appropriate Measures

Barriers	Mean	Std. Deviation	Ranking
High cost of resilient buildings	2.4444	1.47516	12th
Design challenges	3.0926	.97649	2nd
Lack of standardization	2.3889	1.12295	13th
Lack of adoption of new building practices	2.7037	1.35465	9th
Low level of professionalism	2.7037	.69035	8th
Time consuming	2.5185	1.23991	11th
Land acquisition challenges	2.7222	1.15606	7th
Lack of supervision	2.5185	.72008	10th
Low level of insuring contracts	2.8889	.69137	6th
The unique nature of each project	2.9444	.23121	5th
Low involvement of contractor at design stage	3.0000	.00000	4th
High levels of risk	3.1852	.61657	1st
Non availability the right materials	3.0741	.42789	3rd

4.7Appropriate Measures to Minimize Effects of Floods on Housing

The effects of floods can be minimized if certain key steps are taken by industry professional. This section sought to let the respondents rank these measures. Descriptive statistics was used to rank the measures. From Table 4.5 below, the need to adopt a Raised Pile Foundation was ranked 1st with a mean of 4.4630 and standard deviation of .50331. The need to design a Deep foundation was ranked 2nd with mean of 4.2593 and standard deviation of .44234. Again, the need to use Clay Roof Tiles for the roof was ranked 3rd with mean of 4.2222 and standard deviation of .74395. Testing of Soil was ranked 4th with mean of 4.1481 and standard deviation of .49172. Adoption of Clay Bricks for the walls was ranked 5th with mean of 4.1296 and standard deviation of .72804. The factor; Clay Stone Wall was ranked 6th with a mean value of 3.9029. The factor, Framed Structure was ranked 7th with a mean value of 3.6296. At least 40mm concrete cover was ranked 8th with a mean value of 3.3519 and Water Resistant Cement was ranked 10th with a mean value of 4.4259.

Table 4.5 Appropriate Measures to Minimize Effects of Floods on Housing

Benefits	Mean	Std. Deviation	Ranking
Use Water Resistant Cement	3.4259	.81500	10th
Stone walling	4.1481	.49172	4th
Clay brick Wall	3.9259	.69640	5th
Raised Pile Foundation	4.4630	.50331	1st
At least 40mm Concrete Cover	3.3519	.91440	8th
Framed Structure	3.6296	.48744	7th
Deep Foundation	4.2593	.44234	2nd
Testing of Soil	4.2222	.74395	3rd
Burnt Clay Roof Tiles	3.7407	.58874	6th
Obtain Building Permit	4.1296	.72804	9th

Further analysis was also carried to determine if there is any link between flood events and effects of floods on housing by testing the null hypothesis below:

Ho: There is no significant difference between flood events and effects on housing.

The hypothesis was tested using T-test. This compared the various effects of flooding in the three Northern Regions of Ghana. The results are shown in Table 4.7 (a), (b) and (c).

Table 4.6 (a): T-Test for Minimizing Effects, Paired Samples Statistics

	Mean	N std deviation	Std. Error Mean
Paired I Agree Minimized	3.0600E2	8 18.46232	6. 52741
Disagree Minimized Effect	25.3750	8 10.08446	3.356540

Source: Field Survey 2015

Table 4.6 (b): Paired Samples Correlation

	N	Correction	Sig
Agree Effect and Disagree Effect	8	-. 811	.015

Source: Field Survey 2015

Table 4.6 (c): Paired Sample Test

	Paired Differences						
Mean	Std Deviation	Std. Error mean	95% Confidence of Difference		T	Df	Sig. (2tailed)
Pair Effects	27.28651	9.64724	Lower	Upper	29.43709	7	.056
			257.81291	303.43709			

Source: **Field Survey 2015**

The null hypothesis is rejected if the p-value is greater or equal to 0.05, else it sis accepted. The interpretation of work indicated that, the overall responses of the respondents were checked and it was found that the p-value is 0.056 which is greater than 0.05 this means that the null hypothesis is rejected and can be concluded that there is significant difference in flood effects and the type of foundation, type of wall roof that a building has in flood prone areas in the three Northern Regions of Ghana.

CHAPTER FIVE

DISCUSSION OF RESULTS

5.1 Introduction

This chapter presents the discussion of results of the study. The chapter is organized into five main sections namely; introduction, the effects of floods, enabling factors for the adoption of appropriate measures to mitigate the effects of floods, barriers to adoption of appropriate measures to mitigate effects of floods and effective strategies/measures to mitigate the effects of floods.

5.2 The Effects of Floods

Over Turn of the Foundation was ranked as the1st factor with a mean value of 4.3333 by the respondents. This corroborates well with available literature that opines that floods in the North washes away the top soil which is usually fertile to lowlands thereby over turning the foundation of buildings since all the communities along the White Volta River usually get flooded each year (Adelekan, 2010). This phenomenon is as a result of the fact that the foundation of such buildings is normally shallow in nature. Considering the fact that the upper surface of the soil often go through over turning, the washing away of the building during the rainy season is eminent.

„Cracks on Foundation" is a major challenge as far as the incidence of flood is concerned. It was ranked 2nd with a mean value of 2.6481. Available literature is uniformly consisting with the research findings in suggesting that Cracks are bound to occur in the foundation when ordinary strip foundations are used in flood prone areas hence gets destroyed in the presence of water. When a foundation is placed on clay soil, expansion and contracting by the soil takes place thereby destroying or causing cracks in the foundation (Lerise, et al., 2005). Cracks occur when a shallow foundation is placed on clayed soil which is a characteristic of flood areas.

The respondents also ranked „Instability of Foundation" 3rd with a mean value of 3.6667. The manner in which this factor is ranked gives a strong indication that the soil moves in flood areas causing the foundation to lack stability (Seraj, et al., 2004). The problem occurs when the foundation is placed at upper surface of the soil which is subject to ground movement.

Collapse of Walls" is one factor that was ranked 4th with a mean value of 3.667 by the respondents. This indication is consistent with literature which revealed that flood water pushes walls therefore making the wall to collapse (Jabeen, et al. 2010). Considering the fact that the walls are commonly masonry such as sandcrete brick or block the walling units themselves absorbs water. Even in cavity wall construction, the wall is often supposed to prevent rain water from penetrating through the outer wall to the inside of the property. But in flood situations when the wall is submerged in water, the space between the two skins is blocked with mud. This defeats the purpose of the wall since any dampness in the outer leaf will eventually affect the inner leaf through the silt. Cavity wall therefore equally collapses during flood events.

The factor, „Staining of Brick or Block Wall" was ranked 5th with a mean value of 3.6111 by the respondents. The indication confirms literature findings that point out that flood water carries several impurities and chemicals thereby have the tendency to stain sandcrete brick or block wall (Lupala, 2002). Staining disfigures the wall and makes it unpleasant to the eye. As much as possible, staining of wall should be avoided because it has the potential to disfigure not only the wall surface but also the plaster and the paint film.

„Hacking of Wall Surface" was a factor was ranked 6th by the respondents with a mean value of 3.4630. This indication corroborates literature evidence that ranked destruction of wall surface, 6th as an effect of floods (Lupala, 2002). One of the major reasons why the surface of the wall is hacked is as a result of driving rains which is a common phenomenon during flood situations. Rendering of walls does not even prevent such an effect in flood events.

„Leakage of Concrete Roof" was ranked 7thby the respondents with a mean value of 3.2593. Available literature concluded that many roofs made of concrete have had to be replaced yearly as a of the floods. Concrete may be strong as compared to other roof coverings but the consistent accommodation of water on the flood roof eventually causes it to leak (Brahmi, et al., 2004).

„Dissolution of foundation" was ranked 8th with a mean value of 3.222 meaning it is not a major effect of flood. This is contrary to the findings made by Brahmi, et al. (2004) that ranked dissolution as 2nd with a mean value of 3.89911. The results of this study though agree that the some type of foundation may dissolve, there are much more stable foundations suitable for flood prone areas (Lerise, et al., 2005). „Cracks on Concrete Roof" was ranked 9th by the respondents. This finding is consistent with available literature that indicates that driving rains destroys the concrete roof (Lerise, et al., 2005).

„Exposure of Reinforcement" as flood wave forces the concrete cover to wear out was ranked 10th with a mean value of 3.0185. This revelation is buttresses available literature that ranked the factor 10thas far as floods is concern. All concrete roofs must have adequate concrete cover to ensure their safety. The absence of adequate concrete cover exposes the reinforcement in the roof due to excessive water. A factor such as this ultimately causes corrosion of the reinforcement bars and can also cause leakage of roof (Adelekan, 2010).

Respondents ranked the factor, „Unequal Settlement" 11th with a mean value of 3.2222. This is contrary to the study conducted by Adelekan (2010) that seeks to suggest that unequal settlement is a major effect of flood on foundations. The low ranking of Unequal Foundation Settlement, indicate that settlement of foundation does not occur by itself but is brought about as a result of citing a shallow foundation in flood prone areas (Afro, 2009).

„Sinking of Foundation" was ranked 12th by the respondents. This revelation confirms literature findings that ranked the factor 13th indicating that when clay soil contracts during the dry season, the foundation is bound to settle (Nyako, 2013). Bamboo Wall Decays was ranked 13thindicating that bamboo, when well treated can be used to construct a durable wall. Burnt Clay Bricks gets Soaked was ranked 14th indicating that this factor cannot be sustained. This is consistent with literature findings that concluded that burnt clay bricks do not absorb water hence, their suitability for flood prone construction (Nyako, 2013). The factor Reinforcement Rods Corrodes was ranked 15th by the respondents which is a clear indication that corrosion of reinforcement rods is not a major effect since it is only when the reinforcement bars are exposed that such an situation can occur. „Solid Foundation is Washed away" was ranked 13th by the respondents. This is evident in literature that suggests that local solid foundations are not permitted in flood areas. Many artisans wrongly introduce solid foundation even on water ways. This has the tendency to block flood water and ultimately causing the building to collapse (Nyako, 2013).

The factor, „Sagging of Beams" was ranked 14th with a mean value of 2.6111 meaning this factor does not in itself is not an effect of flood but comes about due to insufficient concrete cover to the steel reinforcement (Sheika, 2010). When adequate concrete cover is provided to the reinforcement rods, concrete beams are made strong even in flood water.

The factor, „Leakage of Roof Tiles" was ranked 15th with just a mean value of 2.5000 suggesting that it is less likely to be an effect of flood. This is contrary to the research conducted by Adelekan (2010) ranking this factor as high as 2nd and a mean value of 4.2000. „Clay Tiles Easily Get Soaked" was given this ranking by the respondents, which is contrary to available findings that also ranked this factor very high (Tamar, 2010).

5.3 Enabling factors for the Adoption of Appropriate Measures

The respondents generally agreed that there series of enabling factors that compel consultants to take appropriate steps to minimize the effects of floods on housing. The factor, Building Regulations was ranked 1st giving a strong indication that there is the need to adhere to the dictates of the building regulations. This confirms available literature that concluded that it was time built environment consultants operated in the construction industry with due regards to the building regulations (Brahmi, et al., 2004). Strict compliance with the building regulations is key to the design of flood resistant houses.

Respondents also agreed that Change in Climatic Conditions is a factor that necessitates the adoption of appropriate measures to minimize the effects of floods; hence, the factor was ranked 3rd indicating that climate change is a major issue to be considered. This is uniformly consistent with available literature that shows that the depleting of the ozone layer results in long dry spell coupled with sudden destructive floods. The study warns that if appropriate measures are not taken, there will be housing deficit in the country (Jabeen, et al., 2010).

5.4 Barriers to the Adoption of Appropriate Measures to Mitigate Effects of Floods

The factor, „High Level of Risk on the part of Developers" was ranked 1st with a corresponding mean value of 3.1852. This is consistent with literature that portrays resilient design as an uncertainty (Benevelo, 1980). This perhaps is the reason why many developers do not prefer flood resistant design for fear of the structure not bouncing back to its original position after a flood disaster.

The factor, „Design Challenges" was also ranked 2nd with a mean value of 3.0926, showing clearly that consultants face design challenges when it comes to resilience. This interesting revelation is in contrast with the position of Opong (2000) pointing to the fact that industry professionals are up to the task.

The factor „Non-availability of the Right Materials" was ranked by the respondents as 3rd with a mean value of 3.0741. This finding is uniformly consistent with literature that indicated that building materials are often substituted for inferior ones due to their non-availability (Afro, 2009). „Contractors are often „neglected by Consultants" especially at the design stage as pointed out by Afro (2009). The results of the present study give backing to this school of taught as respondents ranked this factor 4th with a mean value of 3.000.

The factor of the „Uniqueness of Each Project" was ranked 5th by the respondents indicating clearly that because each project is unique as indicated by Kwabena (2000), the same principles of construction cannot be applied everywhere without due regard to the soil and other conditions. The factor „Low Level Contracts Insurance" was ranked 6th with a mean value of 2.8889 by the respondents. This revelation is contrary to literature that seeks to suggest that consultants are always ready to ensure their contracts (Benevolo, 1980). „Land Acquisition" according to Afro (2009) is a major challenge as far as the design and construction of resilient design is concern, thus ranking this factor as high as 3rd with a mean value of 3.0002. However the results of this study give a different opinion about this factor as respondents ranked land acquisition difficulty as 7th with a mean value of 2.7222.

The factor, „Low Level of Professionalism" was ranked as low as 8th by the respondents with a mean value of 2.7037 suggesting that industry players have no challenge in executing their projects. This is true with literature as Benevolo (1980) pointed out that all building projects must pass through the right professionals for scrutiny before implementation. The issue of „Lack of Supervision" was ranked 10th with a corresponding mean value of 2.5185, showing supervision is not a barrier to resilient design implementation. This is contrary to available literature that indicated that lack of enough supervision is the cause the reluctance nature of clients to have trust in consultants.

The factor of „Adoption of Challenges" was ranked 9th indicating that it is not true that the construction industry is not ready to adjust to new building techniques. This is against the position of Afro (2009) that gives an indication that the construction industry has not seen major building reforms over the past five decades. „Time Consuming" was ranked the least barrier as 11th with a mean value of 2.5185 by respondents. This is consistent with literature that indicated that resilient buildings do not take more time to construct than normal buildings (Adelekan, 2010). Respondents also indicated that there is lack of funding for resilient design in vulnerable communities. Micro financing opportunities could help these vulnerable inhabitants to acquire affordable housing capable of resisting the effects of floods. It was also revealed that there is the need active involvement of specialist such as consultants and architects. This occasion is a contributive factor for the inability of resilient design to be implemented. There is lack of flood hazard map to serve as warning to inhabitants in the event of flood for them to take refuge.

5.5 Appropriate Measures to Minimize Flood Effects

The factor of „Elevated Foundation" was ranked 1st with a mean value of 4.4630 as a measure to be taken to minimize the effects of floods on buildings. This is uniformly consistent with literature that indicated that when flood water is allowed to pass under the building, such a building is less likely to be affected by the flood. This reduces the risk of damage to the building (Peal, 2012). The factor „Deep Foundation" was ranked 2nd by respondents with a mean value of 4.4630. This is consistent with findings made by Afro (2009) that indicated that deep foundations should be used for flood prone areas. When flood water is blocked, the foundation is most likely to suffer damages. The seasonal collapse of buildings may be as a result of shallow foundations. „Testing of Soil" was ranked 3rd with a mean value of 4.2222. This corroborates available literature that points out that the bearing capacity of the soil should be obtained by carrying out soil investigation for the appropriate foundation to be developed (Baba, et al., 2012). The wrong foundation is likely to be employed if the soil is not tested. „Stone Wall" was ranked 4th by the respondents with a mean value of 4.1481. This is in consonance with literature which stressed on need for the walling material to be impervious to moisture penetration (Afro, 2009). The collapse of walls may be due to dampness of the walling materials. The factor, „Clay Brick Wall" was ranked 5th with a mean value of 4.1296. This is consistent with literature findings that opined that clay brick wall is suitable for the construction of walls in moist condition (Adelekan, 2010). The respondents ranked the factor „Clay Roof Tiles" was ranked 6th with a corresponding mean value of 3.7407. This is contrary to Benevolo (1980) that seeks to suggest that the issue of clay tiles do not mitigate leakage of roof.

The factor, „Framed Structure" was ranked 7th with a mean value of 3.9259. This corroborates available literature that indicated that framed structures are a type of resilient design that has the ability to reduce the effects of floods (Adelekan, 2010). Buildings with framed structures often do not rely on the infill panels for stability but relies on the on the columns and beams. The issue of „At Least 40mm concrete cover was" was ranked 8th signifying that the implementation of the adequate concrete cover does not only reduce fire spread but also prevents the structure from collapsing even under water. This is true with literature that showed that the stability of a building is guaranteed by the structural integrity and the concrete cover. Building Permit was ranked 9th with 2.3333 as a mean value. This is an indication that acquisition of building permit is as important as the executing the project itself. The factor, „Water Resistant Cement was ranked 9th with a mean value of 3.7407 by the respondents. This is true with findings made by Awour, et al (2008) that also ranked the water resistant cement in the 10th position as far as construction in water lodge areas is concerned.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

6.1 Introduction

This chapter presents the findings of the study in relation to the research objectives stated in chapter one. This is followed by a concluding section and one that presents the recommendations of the study.

6.2 Summary of Findings

The findings of the study based on the analysis and discussion of empirical data presented chapters four and five are presented in the subsections that follow. The findings in relation to each research objective are presented as separate subsections.

6.2.1 Fulfillment of the First Objective

The first objective of the study was to identify the key effects of floods on housing especially in vulnerable communities. Farming communities mostly located along river banks which are the worst affected is worth mentioning as far as flood effects in the three northern regions of Ghana are concern. In this regard, the analysis of the effects of floods revealed that floods affect the structural components of buildings. These are the foundation, walls and the roof.

Over turning of the soil causes shallow foundation to tilt and collapse. The foundations are not deep enough to resist the over turning effect of the soil since they are mostly solid foundations. These also block the flow of water and will eventually lead to the collapse of the foundation as a result of cracks. Another area of destruction is the walls. Traditional walling such as „wattle and daub", „sundried brick wall" and „landcrete block walls can collapse during flood event. This is because such materials absorbs water and can easily dissolve in water. Sandcrete block wall is not equally permitted because of its absorption rate.

Roof is a structural component that is normally affected in flood situations. As a result, roof carcass together with the roof covering easily gets destroyed in flood water annually. Concrete roof is not left out as perpetual water lodging on the roof causes the roof collapse.

6.2.2 Fulfillment of Objective Two

The second objective of the study was to identify compelling reasons for the adoption of appropriate measures to minimize the effects of floods on housing. These are the compelling factors that should move or motivate consultants to adopt appropriate measures to minimize the effects of floods on housing. First of all, the need to adhere to building regulations in the construction industry cannot be over emphasized. The building regulations are very clear on issues regarding the type of foundation for a particular soil. Any attempt to introduce a type of foundation which does not match with the particular bearing capacity of the soil is against the building regulations which document serves as guidance to consultants.

Secondly, changes in the use of resources particularly water. The high demand for water resource in recent times is a factor that compels consultants to adopt appropriate measures to reduce flood effects on buildings. The major river in Burkina Faso that flows down wards through the northern part of Ghana is now blocked to form the Bagri Dam, for agricultural purposes. As a result, the dam is often spilled out when it is full to capacity every year. The spilled water automatically runs down stream through the Volta River thereby causing floods in all the communities that have settled along the Volta Basin in the three Northern Regions of Ghana. As the destruction caused by the spillage is an annual affair, and by extension, floods in the three northern regions of Ghana is an annual affair. There is therefore an urgent need to adopt appropriate measures to minimize the effects on housing.

Change in the climatic conditions is another compelling factor for the adoption of appropriate measures to reduce floods effects on housing. The destruction of the ozone layer gives way for long dry spell only to experience a sudden perennial down pour that brings about floods. On the basis of this phenomenon, it is certain that floods are annual disaster as far as the Upper East Region, Upper West Region and Northern Region are concerned. It is therefore imperative for built environment consultants to take immediate steps to minimize the effects of floods on housing.

There are several other reasons why appropriate steps should be taken to minimize flood effects on housing. These include the enforcement of building regulations by Building Inspectors, the formation of task force to insist on the collection of building permit by the local authority before construction begins, high demand for coastal land by prospective clients, enforcement of bylaws by the Local Authorities, increase in insurance claims by victims of flood disasters and awareness of economic losses as a result of floods among others.

6.2.3 Fulfillment of Objective Three

The third objective was to identify the barriers to the adoption of appropriate measures to minimize the effects of floods in the three northern regions of Ghana. The results of the study indicated that adoption of appropriate steps to minimize flood effects is a new concept in the construction industry. Similarly, the evidence of the study has endorsed the position that there is high risk to be confronted with in the implementation of appropriate measures in flood prone areas. There are issues of design challenges regarding professionals since the concept is a fairly new one. The right materials suitable for the construction of the appropriate design may not be readily available in the worse affected areas. Training and retraining of industry professionals on appropriate measures to be taken to minimize the effects of floods on housing is an antidote to solving the problem. There is generally lack of knowledge on the part of some built environment consultants on what exact measures are appropriate to minimize flood effects on housing.

6.2.4 Fulfillment of Objective Four

The fourth objective was to identify appropriate measures to minimize the effects of floods on housing. The study recommended the following measures to be adopted to minimize the effects of floods on housing. First and famous, Raised Piled Foundation must be employed for buildings in flood prone areas. This is due to the numerous advantages associated with a raised pile foundation which included the passage of water flowing freely under the foundation whereas the same space could be used as parking area during the dry season.

Secondly, the study recommended the use of Burnt Clay Bricks as walling units in flood prone areas. They are non-absorbent walling units, as such, they should be used in flood prone areas. Gabion wall which is made of stones in a wire mess is also recommended.

The study equally recommended steep pitch roof to be used in flood prone areas. This will not only throw off rain water from the roof but will also prevent uplift of the roof by wind. The roof covering material should also aid in the stability and durability of the roof. The study therefore recommended that the roof covering material should be interlocking clay roof tiles.

Adoption of appropriate measures to minimize the effects of floods, should as a matter of urgency be made part and parcel of the school curriculum by curriculum experts for Technical and Vocational Training. The study also recommends that contractors should be actively involved in the design stage so as to avoid encountering challenges at the implementing stage.

6.3 Conclusion

Detailed actionable and targeted recommendations are made based on the findings of this study for consideration and implementation by identified stakeholders responsible for minimizing the effects of floods on housing in Ghana.

- Soil test should be carried out to ascertain the nature so that the right foundation can be designed for the said soil.

- Industry payers must ensure that their practices are adhered strictly to the provisions of the building regulations to minimize the effects of floods on housing.
- They must be on going training to build the capacity of industry players to eliminate the issue of risk and design challenges.
- Consultants must also ensure that the raised pile and beam foundation is designed for buildings in flood prone areas.

6.4 Recommendation for Further Research

The focus of this study was on built environment consultants view on appropriate measures to be adopted to minimize the effects of floods on housing in flood prone areas. The views of other stakeholders such as Contractors, who are the implementing agents, were not considered due to time constrains. It is therefore recommended that a further research be conducted to understand the perception of Contractors on the implementation appropriate measures to minimize the effects of floods on housing.

REFERENCES

Adelekan, I. O. (2010). *Vulnerable Poor Coastal Communities in Ghana*, CIB W107 Construction in Developing Economies International Symposium Construction in Developing Economies: New Issues and Challenges January 18th – 20th; 2006 – Santiago, Chile.

Adelekan, I. O. (2013). Vulnerability of poor urban coastal communities to flooding in Lagos, Nigeria‟, *Environment and Urbanization*.

Afro, B. (2009). A conceptual analysis of floods in urban centers; A case study of the

Ahmed, I. (2003). Design and Construction of Housing for Flood-prone Rural Area of Bangladesh.

Ahmed, K. I. (1994). *Up to the Waist in Mud: Earth-Based Architecture in Rural Bangladesh*. Dhaka, University Press Ltd.

Amato, J. & Timmerman, J. (1995). *At the headwaters: the 1993 flood in southwestern America.* Simon & Schuster, New York and the environment. National Wildlife Federation, Washington, DC.

Anderson, B. & Wamsley, S. (editors) (1996). Reflection of the hearts: the Big Applying the benefits of resilient design in decision making" *Information Management and risk measures*, 13(2), 135 – 143. assessment, Studies in water policy & management 5, West view, Boulder.

Awour, C. B., Oridi V. A. & Adwera A. O. (2010). "Web-*enabled project management: an emerging paradigm in construction*", Vol. 12, 341 – 364. Predictive model for evaluating the performance of project managers in MHBPs. Cited in: BEAR. (2006). Construction Sustainability and Innovation/CIB W 89 *International Conference on Building Conclusions and recommendations Education and Research, Hong Kong.*

Awour, C.B., Orindi, V.A. & Adwera, A.O. (2008). Climate change and coastal cities: The case of Mombasa, Kenya‟, *Environment and Urbanization* 20(1), 231–242.http://dx.doi.org/10.1177/0956247808089158.

Baba, A., Musah, Mumuni, P., Abayomi, S. & Jebrel, M.B. (2012). "Factors influencing Resilient Design Within construction clients‟ multi-project environments. *Flood Management*, 11 (2), 113 – 125.

Barker, A. (1994). *Bangladesh*. Oxford, UK: Heinemann Library.

Barry, J.M. (1997). Rising tide the great Mississippi Flood of 1927 and how it changed.

Beck, R. J. & Franke, D.I. (1996). Rehabilitation of victims of natural disasters.

Benevolo, I. (1980). *Security and legal issues in Floods; The role of industry professional*.

Blackie, P., Cannon, T., Davis & Winsner, B., (2004). "Factors influencing Resilient Design Within construction clients‟ multi-project environments" *Engineering, Construction and Architectural Management*, 11 (2), 113 – 125.

Blaikie, P., Cannon, T., Davis, I. & Wisner, B., (2004). *At risk: Natural hazards, Peoples vulnerability and disasters,* (2nd Ed.). Routlede, London.

Brahmi, A. & Poumphone, K. Egar, (2004). *NEEDS: Adoption of a failing Resilience*.

Brayant, E.A. (1991). *Natural Hazards*. Cambridge: Cambridge Univ. Press,.

Changnon, S. A. (1996). The Great flood of 1993, Causes, impacts & responses (ed.) Complicated than just good business in the 9th European conference on information systems Bled, Slovania.

Chisholm, M. P. (2000). *A Study of the Provision of Rural Housing in Bangladesh*. BArchthesis. Newcastle, UK, University of Newcastle.

Conrad, D. (1997). *Higher ground*: Voluntary property buyouts in the nation‟s

Dacy, D. C. & Kunruether, H. (2000). The economics of natural disasters: implications.

Dunham, D.C. (1991). *"Upgraded Bamboo as a Housing Material"*. Unpublished paper. New York: City University of New York.

Dynes, R. R. & Tierney, K. J. (1994). Disasters, collective behavior, & social organization,

Erickson K. (1993). *After the flood the disaster that wouldn't go away, The New federal policy*. Free Press, New York. Floodplains. A common ground solution serving people at risk, taxpayers

Farrelly, D. (1996). *The Book of Bamboo*. London: Thames and Hudson.

Gyau. B. (2000). *The use of Resilience in the construction and Hospitality industry: Critical success factors and strategic relationships in temporary mitigation measures.* Retrieved July 29, 2014 from http://itc.scix.net/data/

Inter-American Development Bank, (2011) *Urban Sustainability in Latin America and the Caribbean,* Inter-American Development Bank, Washington, DC.

International Training Network (ITN) (2003) *Sanitation Strategies and Technologies: Flood-Prone and High Water Table Areas of Bangladesh*. Dhaka, ITN-BUET.

Jabeen, H., Johnson, C. & Allen, A., (2010). Built–in resilience: Learning from grassroots coping strategies for climate change‟, *Environment and Urbanization*.

Janssen, J. J. A. (2011). *Building with Bamboo: A Handbook*. London: Intermediate Technology Publications Ltd.

Kombe, W. J. (2000). *Formal and Informal Land Management in Tanzania: The case of Dar es Salaam City*, Spring Research Series, Number 13, Dortmund, Germany.

Krejcei & Morgan (1972). *Determination table for sample size*.

Kwabena, W. (2000). "Differential introduces extranet creator the first enterprise legal terms of contract in built environment. *Journal of Information Technology in Construction*, VI, 163-174. Minnesota, Minnesota Conservation Corps/Southwest State University Flood

Lerise, F. & Malele, B., (2005). Community initiatives in managing urbanization and risk accumulation processes: Lessons from Dar es Salaam, Tanzania − *Risk accumulation in the development of Msasani Bonde la Mpunga*.

Livingston, S. (2000). *Reliability Coefficient*. Washington DC. American Institute for research.

Lupala, J. M. (2002). *Urban Types in Rapidly Urbanising Cites, Analysis of Formal and Informal settlements in Dar es Salaam, Tanzania*, KTH, Stockholm.

Mathis, M. L. & Nicholson, S. (2006). *An Evaluation of Compliance with the National Flood Insurance Program Part B: Are Minimum Building Requirements Being Met*? Washington DC: American Institutes for research.

Mayo, A. (2001). *Cyclone-Resistant Houses for Developing Countries*. Watford, UK, Building Research Establishment.

Mud, B., (2012). *Guideline 23, A guide for the implementation of buildings with Structural integrity* Canadian Construction Association.

National Mission on Bamboo Applications (NMBA) (2004). *Building with Bamboo: Training Manual*. New Delhi, India, NMBA.

Nyako, J. S. (2013). *Understanding flood Effects on Housing*. Watford, UK, Building Research Establishment.

Olesya, L. (2013), *Sustainable Building Materials.* London Longman.

Opong (2000). "*Flood Mitigation Measures: Architects role in the organization and Recovery Project, Marshall, MN.* Rehabilitation, Oct.-Dec., 62(4):28-33. Republic, Sept. Retrieved July 12, 2014 from http://www.nigeriavillagesquare1. com/Articles/ Retrieved July 20, 2014 from http://www.construction-innovation.com

Pearl, R. G. (2012). *Architectural and Quantity Surveying Professions in South Africa*- Are they suffering from a terminal illness.

Powell, M. & Ringler, R. (2009). Yorklin, DE, and other cities adopt plans to protect buildings in floodplains from water in Kemp, R.L. (ed.). *Cities and Water: A Handbook for Planning*. Jefferson: McFarland and Company.

Salehin, 1M., Khan, 1M.H. & Mannan, 2M.A. **(**2003**)**. *Impact of Socioeconomic Condition and Depth and Duration of Flooding on Housing Damage*: Experience from Flood 1998 in an Urban Area of Bangladesh.

Satterthwaite, D., Huq, S., Pelling, M., Reid, H. & Lankao, P.R., (2007). *Adapting to climate change in urban areas: The possibilities and constraints in low- and middle- income nations*", Discussion Paper Series: Human Settlement Working Paper, London IIED.

Seraj, S. M. & Ahmed, K.I. (2004). *Building Safer Houses in Rural Bangladesh*. Dhaka, BUET.

Sharma, P.C. & Gopalaratnam, V. S. (1980). *Ferrocement Water Tank*. Bangkok, Thailand, IFIC.

Sheika, H. (2010). CITA workshop on Tendering capabilities and systems, Dublin solution for Sustainable Development relationships supporting project resilience, Business Wire, January 26, 1998. Sustainable development. Thompson Canyon flood of July 31, 1976.Drake Club Press, Loveland, CO.

Towards secure and legal Laws in construction. *Journal of Information and Technology in Construction*, XI, 89-102.

Sieke, H. (2010). *Flash Flood Scenario Modeling for Preparedness Planning and Mitigation*: Case Study of Barcelonnette,

Tamar, T. (2010). *Flood risk assessment and mitigation measure for Rioni River*.

Thomsen & Anna (2010). *The role and influence of the Architect in industrialized building.* Second cycle, A2E.Alnarp: SLU, Landscape Management, Design, and Construction.

Udarty, J. & Gundemoni, L. (2006). *Resilient security in construction digging into University of Delaware Press, Newark. vulnerability, & disasters, Routledge*, London. West view V. Press, Boulder.

Venkateswaran, M. E. (1980). *Cost Effective Building Techniques for Houses*.

APPENDIX I

Sample Size Determination Table

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note.—*N* is population size. *S* is sample size.

Source: Krejcie & Morgan, 1970

APPENDIX II

QUESTIONNAIRE

Topic; "MINIMIZING THE EFFECTS OF FLOODS ON HOUSING IN FLOOD PRONE AREAS; THE CONTRIBUTION OF BUILT ENVIROMENT CONSULTANTS"

I am a final year student of the University of Education Winneba- Kumasi (UEW-K) conducting a research on Adoption of Appropriate Measures to Minimizing the Effects of Floods on Housing in Flood Prone Areas in the three northern regions of Ghana, the perspective of consultants.

This is purely for academic purposes and all information will be treated with strict confidentiality. Your response would be highly appreciated for the success of the research. Kindly respond to the questions by ticking the appropriate box for each item.

PART ONE: RESPONDENT PROFILE

1. Which of the following describes your position?

[ ] Quantity Surveyor

[ ] Architect

[ ] Civil engineer

[ ] Other (specify) …………………………...............

2. How many years of experience do you have in the construction industry?

[ ] Less than 5 years

[ ] 5 - 10 years

[ ] 10 – 15 years

[ ] 16 years and above

EFFECTS OF FLOOD ON BUILDINGS

3. Do you believe that concrete roof can be damaged during flood even?

[ ] Yes

[ ] No

[ ] Unsure

4. A clay brick wall is impervious to moisture penetration.

[ ] Not True

[ ] True

[ ] Not sure

The following are causes of floods. Kindly rank in your opinion, the causes of floods using the following Likert scale **[1= Not at all; 2= Less likely; 3=Most likely; 4= likely; 5= Very likely]**. Please tick (√) in the space provided.

Effects of Floods	**1**	**2**	**3**	**4**	**5**
Solid foundation blocks flood water					
Over turn of foundation					
Thatch roof is destroyed					
Landcrete block foundation sinks					
Cracks develop on the foundation					
Unequal settlement of the foundation					
Solid foundation is washed away					
Block wall stains					
Sundried brick foundation dissolves in water					
Stone wall easily gets soaked					
Thatch roof requires frequent maintenance					
Cracks on concrete roof					
Burnt clay bricks gets soaked					
Any other, please state and rank					

Enabling Factors					
The need to adhere to Building Regulations					
Change in Water Resource					
Change in Climatic Conditions					
The Need to Obtain Building Permit					
High Demand for Coastal Land.					

2. CHALLENGES TO BE ADRESSED IN THEIMPLEMENTATION OF APPROPRIATE MEASURES

Kindly rank the following challenges using the following Likert scale **[1= Not severe; 2= Less severe; 3=Moderately severe; 4= Severe; 5= Very severe]**. Please tick (√) in the space provided.

Challenges	**1**	**2**	**3**	**4**	**5**
High level of risk					
Design Challenges					
Non-Availability of the Right Materials					
Low Involvement of Contractors					
Training needs of consultants					
Lack of Contract Insurance					
Land Acquisition Challenges					
Appropriate Measures to Be Adopted					
The use of Raised Piled Foundation					
Testing of Soil Before Commencing Building					
The Use of Stone Wall					
The use of Clay Brick Wall					
The use of Roof Tiles					
The Need to Train Consultants on Appropriate Measures					

Kindly rank the following benefits of Resilient design using the following Likert scale

[1= Not important; 2= Less important; 3=Moderately important; 4= Important; 5= Very important]. Please tick (√) in the space provided.

Measures	**1**	**2**	**3**	**4**	**5**
Land Demarcation					
The Use of Water Resistant Cement					
Awarding contracts to only professionals					
Introduce Lesser Known Materials in Construction					
Punishing professionals who flaws the law					
Educate Home Owners on Flood Disasters					
Building Affordable Housing					
Insuring All Buildings in Flood Prone Areas					
Review the Building Regulations					
Increased Level of Professionalism					
Use Metals to build the Walls					