UNIVERSITY OF EDUCATION, WINNEBA

COLLEGE OF TECHNOLOGY EDUCATION, KUMASI

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JULY, 2015

DECLARATION

STUDENT'S DECLARATION

I, Clifford Kobina Anumbira Ayirzoya declare that this dissertation with the exception of quotations and references contained in published works which have all been identified and acknowledged, is entirely my own original work, and 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 dissertation were supervised in accordance with the guidelines on supervision of dissertation laid down by the University of Education, Winneba.

Supervisor's Name: Dr. Peter P. K. Yalley

Signature: ....

Date: ....

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DEDICATION

This dissertation is dedicated to my children; Jessica, Susana and Jeremiah Ayirzoya. They have been a source of joy to me.

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ABSTRACT

The built environment in any country determines the nature and pace of national development and the citizens' "quality of life". The aim of this study is to find out the causes of building defects in Apowa in the Ahanta West district of Ghana. The researcher went through journals, books and paper presentations of scholars in the field of study as well as the internet in the form of literature review. An observation of the study area was done for a period to justify the need for the study. Questionnaires were administered and interviews were conducted to landlords of the area and other people engaged in the building industry in the district to get facts and to seek their opinion on the subject. Samples of blocks, soil and sand were taken to the Takoradi Polytechnic Laboratory for testing to ascertain the quality of materials used for the building projects in the area. The study found out that, most clients do not go through the due process in putting up their building structures and the appropriate authorities are not able to punish the culprits. Soil is not tested to ascertain its bearing capacity in to design the appropriate foundation. Most sand for blocks and mortar often contain excessive silt. The water table of the area is high; however, the necessary damp proof materials are not used in the buildings. Blocks used for buildings in the area are substandard. It is recommended that the District, Municipal and Metropolitan Assemblies should enforce the law that regulates the putting up of building structures. Clients should: seek professional advice before putting up the building structure; employ competent personnel to build their houses; use quality materials for their building projects.

CHAPTER ONE

Introduction

1.1 Background of the Study

Building is as old as humanity whose product it is; and has evolved through centuries of activities, from dwelling in caves skyscrapers and recently intelligent structures that can smartly respond to stimuli in its environment (Mbamali and Okotie, 2012). A building can be described as envelope which provides protection from the elements of the weather encloses spaces and provides a suitable and conducive environment for activities taking place in it. Although buildings have many functions and uses, one of the most important functions of a building is to provide shelter from the elements of the weather, such as the

The pride of any public level of prosperity, social values, behaviours, sense of confidence and other influences combine to give the community its unique outlook. This is what a good and well conditioned and quality building reflects in a particular social settlement. The built environment in any country determines the nature and pace of national development and the citizens' "quality of life". It has a major influence on the progress towards the attainment of the Millennium Development Goal (MDGs), which is aimed at reducing poverty worldwide. The Bank of Ghana reported a study by Rohe (2002) that people who are satisfied with their homes and neighbourhoods are productive at work (Bank of Ghana, 2007).

The moment a building is constructed, the forces of nature starts acting on it. The general wear and tear erodes its fabric. Regular alterations carried out on the building over the years gradually replace its original components altering its character and weakening its structure.

A building is said to be failing when it starts to develop defects. Some of these defects are cracks, roof leakages, sulphate attacks on concrete floors and walls, and walls falling out of plumb. Olagunju et al (2013) define a building failure as a defect or imperfection, deficiency or fault in a building element or component. Snoonian (2000) asserts that building failures include everything from the dramatic collapses to the nagging persistent problems like; windows that leak, cracks in the walls, malfunctioning roofs and so on. These failures are more common than the crisis collapses that make headlines. The rampant failure of buildings has given birth to a discipline of study in architectural programme called Building Pathology. Building Pathology is defines as the systematic study or treatment of building of building defects, their causes (aestiology), their consequences and their remedies (or therapy) (Douglas and Ransons, 2007).

Most building defects are avoidable; they occur in general, not through lack of basic knowledge but by non-application of it. Any one specific failure needs a detailed examination to decide on the most appropriate repair, for this depend not only upon technical considerations but upon the type of building and its age; upon the related economic consideration.

1.2 The Area Under the Study

The place selected for this study is Apowa. It is located on 4.53N and 1.49W and found in the Ahanta West district of the Western Region of Ghana. Apowa shares a boarder with Takoradi, the commercial capital of the Western Region. Its proximity with Takoradi has brought about a massive increase in infrastructural development in the town in the last fifteen years. The town can boast of a number of warehouses which feed the Takoradi port. A number of companies have sprung up in the town. Some civil servants prefer to stay at

Apowa and commute everyday to work at Sekondi and Takoradi. These factors have brought about a high demand for accommodation in the town.

1.3 Statement of the Problem

Building design and construction are processes which traditionally involve several professionals collaborating for relatively short periods to develop a facility (Mbamali and Okotie, 2012). This collaboration can sometimes bring about misinterpretation and misunderstanding of the building documents used for the execution of the projects. Buildings like all structures are designed to support and withstand certain loads with minimal deformation due to fire or misuse.

The area under study, Apowa, is characterized by rampant cracks and other associated building defects. The situation is more serious at Tuukulu, one of the suburbs of the town, where the GHACEM estate buildings are situated. Two uncompleted buildings collapsed in this area within the last three years. In a period of three years where this study or observation was done, there have been gaps developing between the external walls and backfilling of a number of buildings. A number of houses are seen discoloured or not painted. It is against this background that, it has become necessary to investigate the defects in the walls of buildings and possibly find solutions which will help the Apowa Community and Ghana as a whole.

1.4 Objective of the Study

The aim of the study is to assess the major causes of building defects in the Apowa area and its solutions in Ghana as a whole. The specific objectives of the study are:

I. To conduct site investigations on the site to ascertain the moisture content of the soil, the densities and the composition of the soil at the study area.

II. To conduct a survey on the major type of defects and determine their causes particularly in the superstructure wall.

III. To find out the strategies building professionals have been adopting to prevent defects.

1.5 Research Questions

I. What are the major defects and their causes in buildings in the study area?

II. What measures have building professionals been adopting to prevent defects?

III. Are site investigations conducted before constructions are started?

1.6 Significance of the Study

The researcher has purposely chosen this topic to find out what the causes of building failures in Ghana and more specifically, Apowa in the Ahanta West district of Ghana are. The effects of building failure or collapses are physical damage and psychological trauma, the degree of which is beyond easy prediction (Olagungu et al, 2013).

It has been posited that, collapses historically have helped to lead to a better understanding of structural performance and have contributed much to the art and science of building design and construction (CESA, 1996). This assertion is true in the opinion of researcher because after a building collapse, the 'why' and 'how' have to be looked into. The findings of this work of this work will help people appreciate the causes of building failure in the area under the study.

It is the hope of the researcher that, the findings and recommendation will help to promote good building practices in the country especially, Apowa. The study is built upon existing literature and added some information and knowledge which is by no means an exhaustive work piece to appreciate the problem and contribute to a more stable and durable buildings.

1.7 Limitations

Due to issues such as time and financial constraints, it will be difficult to cover a larger number of participants. The research work may also be confronted with the following problems:

Firstly, some respondents may feel reluctant to give responses that will help in conducting the research. This is so because respondents may think that when they give out the correct responses, it may be used against them. Again, travelling from place to place to collect data for the study involve a lot of money which at times may be difficult to come by.

1.8 Delimitation

This research is focused on the causes of defects in walls. The emphasis is on superstructure walls. The study is confined to Tuukulu, a suburb of Apowa in the Ahanta West in District in the Western Region of Ghana. The area is chosen because of the rampant building defects such as cracks, moisture penetration, and other related building defects which have been observed in the area over period. The scope of the covers the study covers the buildings, the building owners, and the professionals involved in the building industry in the Ahanta West District.

1.9 Organization of the Study

This study will consist of five chapters. The first chapter which is the introduction, talks about the background of the study, statement of the problem, purpose of the study, hypothesis, significance of the study, limitations and delimitation or scope of the study.Chapter two will present the literature review. The literature review talks about what other people (early researchers) have written about the topic of the study. The third chapter which is the methodology will discuss the population of the study, sample and sample selection procedure, data collection instrument and materials and methods that will be used to collect the data. Chapter four will present the results of the study using frequency distribution tables and a graph. The fifth chapter which is the last will talk about the Summary of the findings, Conclusions and Recommendations of the study.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

This chapter is the review of literature of the causes of failure of buildings. It involves a wide range of experiences, both inside and outside the field of work.

The literature is reviewed under the following:

1. The building Structure
2. Building failure
3. The building team
4. Failures attributed to the building team
5. Natural causes of failures
6. Failure in foundations
7. Failure in walls
8. Failure in roofs, and
9. Construction process

2.1 **The building Structure**

A building is a man-made structure with a roof and walls standing more or less permanently in one place. Buildings come in a variety of shapes, sizes and functions and have been adapted throughout history for a wide number of factors from building materials available to weather conditions, land prices, ground conditions, specific uses and aesthetic reasons (Wikipedia 2014). Fadamiro (2002) as citedin Oke (2011) defined a building as an enclosure for space designed for specific use, meant to control local climate, distribute services and evacuate waste. Odulami (2002) is also cited byOke(2011) to define a building as a structure for human activities, which must be safe for the occupants.

Buildings like other structures are designed to support certain loads without deforming excessively. The loads are the weights of people and objects, the weight of rain and snow and the pressure of wind. The building structure is divided into two main parts; the substructure and the superstructure. The substructure refers to the parts of the building structure below the ground level but including the floor bed. Superstructure on the other hand, refers to the part of the structure above the substructure or above the ground level both internally and externally (Chudley and Greeno, 2008).

2.1.1 The Substructure

The foundation, the foundation walls and the floor bed form the substructure. The foundation is the part that lies directly on the soil. The function of any foundation is to safely sustain and transmit to the ground on which it rests the combined dead, imposed and wind loads in such a manner as not to cause any settlement or other movement which would impair the stability or cause damage to any part of the building (Tomlinson, 2001, Chudley and Greeno 2008). The soil which carries the foundation is referred to as the natural foundation. The constructed foundation is distinguished as the artificial foundation (Walton, 1995, Emmit and Gorse, 2008). In this work, the word foundation is referring to the artificial foundation. The foundation walls serve to transmit the load from the superstructure to the foundation.

2.1.2 The Foundation

The functional requirements of a foundation are:

- Strength and stability
- Resistance to ground moisture, and
- Resistance to the passage of heat

There are conditions which affect the foundation. These include:

- The load bearing capacity of the ground
- The depth where you will find suitable load-bearing soil
- The distance from trees, this can affect the stability of the soil
- The level of the water table
- The normal variation in the water table
- The total weight of the building

There are different types of foundations. These include: strip foundation, pad foundation, raft foundation and piled foundation. The type of foundation is chosen depending on the nature of the soil on which the foundation will lie on or the depth of the load-bearing soil and the total load of the building. The subsoil beneath the foundation is compressed and reacts by exerting an upward pressure to resist the foundation loading. If foundation load exceeds maximum passive pressure of the ground (that is, bearing capacity), a downward movement of the foundation could occur. The remedy to this is to increase the plan size of the foundation to reduce the load per unit area or alternatively reduce the loadings being carried by the foundations (Tomlinson, 2001, Chudley and Greeno, 2008).

2.1.2.1 Performance Requirement of a Foundation

Foundation performance standards are not the same for all structures or in all locations. For example, foundation settlements that produce 3mm wide cracks in walls would probably be unacceptable in an expensive house, whereas the same settlement and cracks in a heavy industrial building would probably not even be noticed. The foundation design process can not begin until the design loads have been defined. These are the loads imparted from the superstructure to the foundation. There are four different types of design loads. These are: Normal loads, Shear loads, Movement loads and Torsion. Normal loads are those that act parallel to the foundation axis. Shearloads act perpendicular to the foundation axis. Movement load may be expressed using perpendicular components. Most foundations, especially those that support buildings or bridges are designed primarily to support downward normal loads (Tomlinson, 2001, Coduto, 2001).

A foundation also has to satisfy serviceability requirements. A foundation that satisfies strength requirement will not collapse, but it still may not have adequate performance. It may experience excessive settlement. Serviceability requirements are designed to take care of settlement, heave, tilt, lateral movement and vibration (Emitt and Gorse, 2008).

The vertical downward movement of the foundation is known as settlement. Tomlinson, (2001), stated that, it is unattainable to design a foundation that will not experience settlement. He added that, it is rather defining the amount of settlement that will be tolerable and designing the foundation to accommodate this requirement. Heave refers to the situation where the foundation moves upward instead of downward. The common source of heave is the swelling of expensive soils. Tilt occurs when settlement or heave occurs only on one side of the structure. Failure to satisfy the requirements stated above results in increased maintenance cost, aesthetic problems, diminished usefulness of the structure and other similar effects (Coduto, 2001).

2.1.3 Soil (the natural foundation)

Soil is the general term for the upper layer of the earth's surface that consists of various combinations of particles of disintegrated rock, such as gravels, sand or clay, with some organic remains of decayed vegetation generally close to the surface (Emmit and Gorse, 2008). The top soil which is about 100mm to 300mm deep is sometimes referred to as vegetation topsoil. It is loosely compacted and supports growing plant life. The top soil is unsuitable for foundation because of its poor load bearing capacity. It is normally removed before any engineering project is carried out. The soil below the top soil is referred to as the subsoil (Coduto, 2001).

Liu and Evett (2003) and Emmit and Gorse (2008), classified soil into three broad categories; cohesionless, cohesive and organic soils.Cohesionless soils do not tend to stick together. Examples ofcohesionless are gravels, sand and silt. Cohesion soils are characterized by very small particles size where surface chemicals effects predominate. The particles tend to stick together, the result of water-particles interactions and attractive forces between particles. These soils are sticky and plastic. Clay is an example of cohesive soil. Organic soils are typically spongy, crumbly and compressible.

Soil conditions vary from one location to another; hence, virtually no construction site presents soil condition exactly like any other. A comprehensive knowledge of the soil in a specific location will be important for any project as it will determine the suitable foundation for the project (Liu and Evett, 2003).

2.1.4 **The Superstructure**

The components which make up the superstructure are the walls and roofs. The doors, windows and other fittings which are fixed to the walls are part of the superstructure. The upper floors of storey buildings form the roof for walls below.

2.1.4.1 **Walls**

A wall is a continuous , usually, vertical structure of brick, stone, concrete, timber or metal, thin in proportion to its length and height which encloses and protects a building or serves to divide buildings into compartments or rooms. Walls are defined as external or internal to differentiate functional requirement and load-bearing or non-load bearing to differentiate structural requirements (Barry, 1996, Walton, 1995, and Emmit and Gorse, 2008).

Walls support their own weight and transfer it and the weight of the roof to the foundation. The stability of a wall may be affected by the foundation movement, eccentric loading, lateral forces (wind) and expansion due to changes in temperature and moisture (Emmit and Gorse, 2008, Chudley and Creeno, 2008).

2.1.4.2 **The Roof**

The function of a roof is to:

- Keep out rain and wind
- Provide shade from the sun
- Keep the interior cool
- Retaining heat in cool weather
- Ensure that the structure is properly weighted down

There are basically two types of roofs. These are pitched roof and flat roof**.** Pitched roofs depend for strength on the triangulated form of the roof structure, in which the considerable depth of the roof at mid span gives it strength. A flat roof acts in the same way as a floor, a level platform designed to support loads (Walton, 1995, Barry, 1996, Emmit and Gorse, 2008).

A roof excludes rain through the material with which it is covered. The covering materials include asphalt, tiles or slate, metal sheets and reinforced concrete. The durability of a roof depends largely on the ability of the roof covering to exclude rain and snow. Persistent penetration of water into the roof structure may encourage decay of timber, corrosion of steel or disintegration of concrete.

2.1.5 **Surface Finishes**

Finishes form the interface between building users and hence affect the way in which we interact and perceive our built environment. Colour, or the lack of it, affects our psychology and the atmosphere of our buildings (Emmit and Gorse, 2008). Obande, 1996 puts it that, all walls that are constructed using a wet system require a surface finishes of one type or another. The primary function of a surface finish is to provide a durable, visually attractive and low maintenance surface to floors, walls and ceiling.

2.2 Building Failure

One of the major problems facing the building of industry in Ghana is the rampant failure of buildings, both under construction and in use. This problem has been in existence for sometime now without a solution. Keteke-Atiemo,(2009) affirms this statement and added that the situation has grown worse to the extent that, not a month passes without some news about a failed building. This unfortunately is occurring at a period when modern methods of construction have emerged in the shelter industry.

Salvadori and Levy (1992) as cited by Snoonian (2000) asserts that, "it is the destiny of the man-made environment to vanish. Buildings are born, live and die just as all organisms do. Some, like the pyramids, live for a long time while others still die young". So, whereas human beings have life expectancy, building structures also have an expected period to exist. All structures will be broken or destroyed in the end; just as all people will die in the end. It is the purpose of medicine and engineering to delay this (Feld and Carper, 1995). Building failure, according to Ayininuola and Olalusi (2004), is an unacceptable difference between expected and observed performance of building components. They identified two types of failure in a building, which are cosmetic and structural types. Cosmetic failure occurs when something has been added to, or subtracted from the building, thus, affecting the structural outlook. On the other hand, structural failure affects both the outlook and the structural stability of the building. Snoonian (2000) also puts it that, building failures include everything from the dramatic collapses to the nagging persistent problems of windows that leak, poorly functioning HVAC (Heating, Ventilation and Air Conditioning) systems and malfunctioning roofs. According to Oke (2011), building failure occurs when there is a defect in one or more elements of the building caused by the materials making up the components of such buildings.

To put up a building structure is capital intensive. In Ghana, an average worker will have to save for several years before he or she will achieve the dream of putting up a building structure. So, for one to put up a building for it to collapse or fail within a short time is enough to raise one blood pressure or send one to an early grave.

Any designed artefact is to meet a specific need. If an artefact is not able to meet this need adequately, then it can be said to have failed. One can therefore describe a failed building as a building structure which does not meet its designed purpose adequately. Wardhana and Hadipriono (2003) grouped failure into two conditions, collapse and distress. They defined failure as the incapacity of a constructed facility (in this case a building) or its components to perform as specified in the design and construction requirements.

Table 2.1: Categorization of building failures

Types of failure	**Example**
Aesthetic failure	Crazing or shrinkage cracking of concrete or render. Flaking and peeling of paintwork. Bossing and spalling of render
Functional failure	Misalignment of building components such as doors and windows not operating properly.

	Leaks in elements such as roofs, walls and floors. Sagging of floors.
Failure of material	Chemical attack of rendering, mortar or brick. Fungal attack of timber. Corrosion of metals.
System failure of Components and Elements	Carbonation of concrete, leading to corrosion of reinforcement and subsequent cracking and spalling of concrete members. Debonding and bubbling of membrane from substrate owing to moisture or incompatibility.
Structural Failure	Subsidence (a downward movement of a building caused by below ground factors - such as desiccation of clay soil). Settlement (a downwards movement of a building caused by above ground factors - such as overloading).
Non-structural Failure	Delamination of roof tiles and slates. Cracking and debonding of plaster or rendering. Blistering and peeling of paint coating. Tenting, debonding of roof coverings.
Reversible failure	Jamming of doors and windows as a result of moisture intake by these components - usually in winter; in the summer the wood dries out and the windows and doors become unstuck.
Irreversible failure	Chemical reactions such as sulphate attack on mortar or rendering. Excessive distortion in beam/slab, column owing to structural movement

Source: Douglas and Ranson, (2007), page 8

The term collapse according to them, is used to refer to the situation when the entire or a substantial part of the structure comes down, in which the structure loses the ability to perform its function. Collapse is also subdivided into two categories, total collapse and partial collapse. Total collapse implies that several primary structural members have fallen down, practically eliminating occupancy underneath it. A partial collapse suggests a condition where some of the primary structural members have fallen down-hence, endangering the lives of those inside or nearby the structure.

This implies that with total collapse there will be the need for a full replacement of the building while with partial collapse there may be the need for partial replacement. The term distress as a subset of failure refers to the unserviceability of a structure or its component(s) that may or may not result in a collapse. A distressed building therefore means that, the particular building structure in a particular condition has undergone some deformations without losing it entire structural integration. The term defect is sometimes used interchangeably with failure.

Defect is however distinct from failure. Defect is the deflection in a building causing certain amount of cracking or distortion. However excessive deflection that results in serious damage to partitions, ceilings and floor finishes can be deemed to be a failure (Roddis, 1993). Douglas and Ranson (2007) define defect as a shortfall in performance of a structure occurring at a time in the life of the product, element or building in which it occurs. Building failures have been categorized by Douglas and Ranson (2007) as in Table 2.1.

A defect may trigger a failure. The problem associated with building structures are described according to the severity of the problem. Defects are a less serious followed by failures. A collapsed building is the most severe. In this research work however, distress, defect and collapse are all considered to be subsets of failure.

2.2.1 Causes of Building Failures

Major structure collapses have occurred throughout history. Collapses historically have helped to lead to better understanding of structure performance and have contributed much to the art and science of building design and construction (CESA, 1996). One sometimes wonders why despite out increasing understanding of construction technology and materials, building failures still occur. Douglas and Ranson (2007) opine that, due to the sophisticated nature of modern buildings, so are their systems and facilities. So these advances make the chances of mistakes occurring in the construction industry greater.

The building process may be grouped into three phases: the conception / design phase, construction phase and operation or use phase (Horsely et al 2003). Each phase is very important to the sustenance of the building structure. The client is involved in the conception and the operation or use stage. The client may not be a professional in the building industry but the rest of the personnel involved in the design and the construction phases must be professionals in their respective areas. Anumba (2006) cited by Mbamali and Okotie (2012) puts it that the building design and construction are processes which traditionally involve several professionals collaborating for relatively short periods to develop a facility. So, if there is no proper co-ordinating between these professionals, there can be problem with the building structure concerned.

Several factors have been attributed by a lot of writers as being the cause of building failures. Oke (2011) have it that buildings fail through mainly ignorance, negligence and greed. He explains that, ignorance has to do with when incompetent personnel are in charge of design, construction and inspection. The issue of negligence has to do with specification writing where that of a past project is adopted without cross checking those areas that need improvement, addition or omission. Greed on the part of building construction for example, diversion of building materials, cement in particular, meant for the production on client's site to his own site, the use of sub-standard materials so as to achieve high profit. Four reasons have been attributed for being the cause of building failure by Dimuna (2011). He states that the owners of buildings under construction derail from their approved plans and rely more on imagination and fantasy. The second reason is that the approving authorities are also known to fail to monitor compliance with approved plans. The third reason he gave is that some building owners shun the professionals in order to cut cost. The last reason is that the cost of building materials has led to greedy contractors with eyes on profit, to patronize substandard materials.

Olagunju et al (2013) lists seven causes as being responsible for building failures. These include: (i) Bad design (ii) Faulty construction (iii) Poor quality of materials and construction method (iv) Foundation failure (v) Fire problem (vi) Natural phenomena; and (vii) Inadequate maintenance. A number of writers agree to almost the same factors with few differences. A few have added natural-induced hazards as also being the cause of building failures. Akinpelu (2002), Richards (2002) and Ayedum et al (2012) all cited natural phenomena as also being the cause of building failures. These natural phenomena include earthquakes, volcanic eruptions, flood, fire outbreaks and so on.

2.3 The Building Team

The building team comprises a number of people or group of people who come together to put up a sound structure. The people who form the building team include: (1) the client; (2) the design team; (3) the contractors team; (4) building material supplier; and (5) the regulators (Walton, 1995).The failure of any member or group of people in the building team causes a failure to the building structure, either during construction or after construction. The successful erection of the building and the future satisfaction of the end user depend on all members of the team.

2.3.1 The Client

It is the duty of the client to consult the appropriate personnel who are professionals in their respective areas to put up the building structure. The client will also have to perform a site reconnaissance or visual inspection on the proposed site to ascertain the economic viability of the project (Emitt and Gorse 2005). It will be appropriate if the client visits the site with a surveyor or any of the building professionals for their advice on the suitability of the site for the intended project.

2.3.2 The Design Team

The design team is responsible for the overall layout and appearance of the building. It is made up of high level professionals often led by an architect. Their work is to produce design drawings, working drawings and pictorial drawings based on the available information given by the client and other agencies (Walton, 1996). The structural engineer designs the various structural components which include the foundation, columns, beams, roofs and so on. He should be given the proper information about the soil conditions so that, he can determine and design the appropriate foundation. The responsibility of the design team is also to visit the building project site from time to time to ensure that the contractor is putting up the structure according to the designed drawings.

Failure of the design team to do their work professionally may cause the structure to fail. Some engineers may feel reluctant to leave their air conditioned offices and go to the project site to do their duties. This can contribute to the failure of a structure.

2.3.3 The Contractor's Team

The contractor's team is made up of the main and the sub contractors, supervisors, foremen, artisans, apprentices, labourers and so on. This is the largest group among the various groups in the building team. Most of the members are skilled men and women who are trained in the respective trades. The trades include mason, carpenter, steel benders, painters, electricians and so on. There may also be unskilled labourers among them but whose services are very essential to the project (Oke, 2011). The work of these unskilled labourers includes; digging out the soil, carrying concrete and so on. The leader of this team is the main contractor.

A strong and durable structure depends largely on the contractor's team. The contractor may employ low-skilled tradesmen and women to do the work. The low-skilled tradesmen and women will not demand higher salaries and wages. Some contractors sometimes also patronize poor quality materials of the building project. Patronizing poor quality materials for the project will maximize profit for the contractor. This is also a factor responsible for the failure of buildings.

2.3.4 The Material Suppliers

Material suppliers have clear responsibility during construction. They are to ensure that the materials delivered to the job site are as specified (CESA, 1996). The supply of the various building materials for the execution of the building project must be of the standard materials. The proper storage of these building materials is a key to the strength of the structure as some building materials have standard ways of storing them (Olagunju et al, 2013). Sub-standard materials supplied to contractors by greedy suppliers give rise to sub-standard structures which cannot stand the test of time.

2.3.5 The Regulators

The regulators of the building industry protect the public and the building workers from dangerous and poor quality construction methods. They ensure that all the legal requirements and the good practice guidelines that are to be followed in putting up a building structure are adhered to (Walton, 1995). They are made of the building Inspectors, Town and Country Planning officials and the statutory committee of the District Assemblies in Ghana.

They approve building plans and grant building permits to prospective developers. They also go round to ensure that, on-going projects have the requisite documents. They also ensure that, those who have acquired the documents adhere to their approved plans and the Building Regulation.

2.4 Failures attributed to the building team

2.4.1The Client's contribution to Building Failures

There are some causes of failures in building structures which are attributed to the client. According to Fakere et al (2012), one of the factors responsible for building failures is inadequate preliminary works. Preliminary works is explained to include site investigations and foundation. The owner has a duty of making a reconnaissance with a professional in the building industry to ascertain the suitability of the site to the intended project. The professional may be an architect, engineer or surveyor (Emitt and Gorse, 2005). If the client, who is the financier of the project, fails to do this important function, the structure may fail and funds go waste.

Dimuna (2010), also blame clients for the failure of buildings with the reasons that they shun professionals in order to cut cost. Dr. Stella Arthiabah, the acting Registrar of the Architects Registration Council of Ghana, agreed with this assertion when she was quoted as saying that, most buildings that collapse in the country are due to structural failures, and these structural failures are due to people failing to use professional architect, in order to cut cost (www.ghanaweb.com, 25th May, 2013). When clients decide not to engage the right personnel to plan and design the building, then, they are planning for the failures of their building structures. Some clients also play the role of supervisors of their building projects. The president of the Ghana Institution of Surveyors, Mr. Daniel Kyere, lamented that, "when one takes the trouble to visit the construction site, it is under a mason and being supervised by the owner or the investor who very often may be a lay person to construction let alone a 'high rise' building and always ensuring that there is high cost saving by using minimal reinforcement steel, minimal cement for concrete. Sometimes, they even produce the blocks on the site in order to save cost" (myjoyonline.com, 12th November, 2012).

Building owners also fail to take maintenance of their building structure important. Buildings start to deteriorate from the time they are completed and occupied or in use. The building begins to need maintenance in order to keep them in good condition. This process of gradual deterioration is unavoidable but the speed at which it proceeds can be reduced through the manner in which buildings are maintained. The rate of buildings deterioration depends largely on the nature and manner of maintenance. Poor building maintenance can cause weakening of the building structure which can eventually bring about a failure (Olagunju et al, 2013).

2.4.2 Building Failures attributed to the Contractor

(Dimuna, 2010 and Oke, 2011) blame building failures partly on greedy contractors. They explained that, some contractors divert building materials, especially cement, meant for production of the client's site to his own site. It is added that, some of the contractors use sub-standard materials for the project so as to achieve high profit. The use of sub-standard materials for any project will not make that structure strong or stable.

Some contractors also fail to employ skilled craftsmen to execute the project. Craftsmen are supposed to have a fair knowledge about the various drawings prepared by the architect and engineers. Olayede et al (2010) added that some contractors fail to build according to the plans and specifications of the design. The contractor's failure to adhere to the plans and specifications may be due to incompetence. Adebayo (2000) is cited by Olayede et al (2010), that, the skill, experience and personal ability of the workmen involved in the building construction is of utmost importance in creating value. The quality of the workmen is a measure of the effectiveness and efficiency at all the time during construction while the level of the building maintenance after occupation depends on the performance of the workmen. This can only be relied upon where the building developer or the contractor are capable and willing to appreciate quality and ready to pay for same. The building structure will be at risk if unskilled craftsmen are engaged in the construction of the building and if the building structure is not built according to the designed plans and specifications.

According to Ayedun et al (2012), another cause of building failures is due to the contractor's failure to monitor the craftsmen. This results in poor quality of workmanship. Some contractors fail to play their supervisory role at the construction site but would rather choose to spend all the time in the office or elsewhere and entrusting the supervision entirely in the hands of the foremen. The long absence of the contractor can encourage pilfering or stealing of building materials from the site. The workmen will therefore use sub-standard materials for the job which cannot guarantee the soundness of the built structure.

2.4.3 Building failures attributed to the design team

A good building structure is a reflection of a good design which is the responsibility of the architects and engineers. It has been established that, bad design of the building structure can cause the failure of the building. Olagunju et al (2013), explains that, bad design does not mean poor architectural design, but it involved some other professionals' design input. The architect may contribute to the cause of the building collapse by starting the design without inadequate visibility study; which includes authenticity of the land and nature, soil adequacy, site inventory and analysis. According to Hossain (2009), bad design can come from the errors of computation, reliance on inaccurate data, failure to account for the loads the structure will be expected to carry, erroneous theories and improper choice of materials or misunderstanding the properties of the materials that are to be used to construct the building.

Some designers fail to plan for extra ordinary loads and stress from winds and earthquakes, especially for tall buildings. The designers sometimes make efforts to save initial construction cost. Project cost plays an important role in the designing of buildings. The designers do that by reducing the size of columns, the size of reinforcement bars and foundation. This situation will lead to uncertainty situation in the future where the structure cannot withstand the load and finally fail (Oloyede et al, 2011, Ahzahar et al, 2011).

Some of the professionals also believe that they know everything about buildings. Olanitori (2011) describes these people as 'egg heads professionals'. Ede (2010b), is cited by Ayedun et al (2012), that, one of the causes of building is that, any engineer or professional in the built environment can assume all forms of responsibility in the building process even in the absence of basic skill for such a job. There are different sectors in the building industry, and each sector is responsible for a different group of professionals.

2.4.4 Building Failures attributed to the regulators

Officials of the Building Inspectorate Department of the District Assemblies and the Town and Country Department whose duty is to ensure that, the building code, L.I. 1630, is adhered to, do not live to that expectation. The Building regulation of Ghana, L.I 1630 of 1996, is the regulatory instrument for all the Building Construction Industry in Ghana. A question was asked to an official of the Building Inspectorate Division of the Ahanta West District Assembly by the researcher, as to whether it is their duty to monitor construction sites after granting of the building permit and if it is, whether they do it. The officer replied that, it is in the mandate to inspect construction sites but due to logistics constraints they are not able to go round to do that. The regulatory authorities do not check to ensure that after approving the building plans and granting the building permit, the developer/client and the contractor build the structure according to the approved plans. Some of the developers change the plans of the building during construction after these plans have been approved (Dimuna, 2010). These changes may not be to the knowledge of the engineers. The monitoring of these illegal activities by the developers and contractors by the authorities will avert this looming danger.

Erring professionals not sanctioned for their wrong doings is an encouragement for others to repeat the same things. If the sanctioning authorities are up to the task by punishing anybody who violates the laws of the country, it will help reduce the incidence of building failures. The regulators responsible for approving the building drawings for prospective developers sometimes approve technical deficient drawings. This may be due to ignorance on the part of those who vet and approve the drawings or as a result of outright corruption on their part. Money may at times change hands in the approval of such drawings.

2.5 Natural Causes of Building Failure

Olagunju et al (2013), Oni (2010) and several others all agree that there are also some natural causes of building failures. Earthquakes, volcanic eruption, heavy rainfall could cause a building to collapse. Fakere et al (2012) also state that many buildings failed due to persistent incidence of the weather. The calamities could still cause a building to collapse after all concerned; the client, contractor, others, have taken all precautions. No building is designed to withstand such natural disasters as, earthquakes, floods, thunderstorm, seepage, hurricane, extreme temperature and so on. One or a combination of these forces can manifest in structural failure or settlement.

2.6 Foundation Failures

The foundation of a building structure, being the part buried in the ground is subject to a lot of interactions with the soil environment. A failure or defect in the foundation goes to affect the whole building structure. The most common failure is caused by the movement of expansive and highly plastic soils beneath the foundation footings. This movement can be in the form of shrinkage, which causes settlement or expansion which causes heave.

When dry conditions prevail, soils consistently loose moisture and shrink. When moisture levels are high, soil swells. Regardless of the nature of the movement, it will most likely manifest itself in the form of visible cracks in the foundation walls, exterior brick walls or plaster walls. Another cause of foundation failure is transpiration. Transpiration is the process where trees and large plants absorb the water from the soils beneath. During an active season, roofs extending beneath and around the footings of the house can remove moisture from the soil, causing it to become desiccated. Where an expansive soil exists, this removal of moisture will cause soil shrinkage and settlement.

Poor surface water drainage can also cause problems to the foundation. When gutters, storm water pipes and downpipes overflow or leak, the soil around and under the footing saturate. Once the soil becomes saturated, it then loses its ability to load and the soil can collapse leading to the building element dropping or moving. In some instances, reactive soils can expand also leading to cracking. This then places uplifting loads on the structure which can lead to significant cracking and movement.

2.7 Failure in Walls

2.7.1 Moisture Penetration from the Ground

Rising dampness walls are likely to cause damage to internal plaster and decorations, particularly when hygroscopic ground salts are brought up in solution, as they generally are. The line of dampness due to the complete absence of a DPC is usually fairly continuous and roughly horizontal, and can extend several feet in bad cases. Remedial measures much depend upon the nature of the wall. Old walls of random masonry construction are unlikely to yield to these treatments and these can be nearly impossible to damp-proof.

2.7.2 Rain Penetration

Eaves, canopies, cornices, string course and other forms of overhang have been used traditionally to protect walls from rain and its effect but, lately their use has declined. Flat roofs have become more frequent and, where pitched roofs still prevail, eaves overhang have diminished. The extent to which they remain wet has not been adequately researched. Though overhangs can affect the air stream, particularly in tall buildings, with uncertain effects, it is probably that walls in general are wetter for longer when are absent. The ability of a wall to exclude rain thus depends partly upon such design features but principally upon its topographical and geographical situation. It also depends greatly upon the materials and construction of wall. Generally speaking, rain is likely to penetrate solid brick or block work which is not rendered, usually directly through cracks in the mortar, and between mortars and brick or block.

The risk is increased if the mortar is of poor quality and if the vertical joints of masonry are filled inadequately. Rain penetration shows as damp patches on the internal face of the wall usually within a few hours of rain falling: when the wall dries, a stain is often left. Solid masonry walls are now seldom built and little more need to be stated here, except to warn against possible difficulties if water-repellent solutions are applied to reduce the risk of penetration in existing walls.

2.7.3 Cracking and Spalling Of Masonry through Movement

Load-bearing masonry walls can crack and their surfaces may spall. Lately such defects have been amongst the most numerous, nationally, in recent years, there have been serious building failures. There are reasons for believing that current construction methods and materials may lead to increase in sensitivity to some of the agencies which give rise to these defects. Cracking of masonry is associated with movement and a principal cause is change in moisture content of the units.

2.7.4 Cracking Due to Roof Movement

Cracking of walls caused by the spread of pitched roofs is a common defect with old buildings. It occurs mainly through weakening of the structural members of a roof with time. Another cause, apart from general under-design, which is unlikely today, is the substitution of much heavier roof tiles for those originally specified. As the roof spreads, it moves the top few courses of the wall masonry outwards slightly; horizontal cracks appear in the plaster on the internal wall close to the eaves level and cracking may also be noticeable externally.

2.8 Failure in Roofs

There are numerous possible causes of roof failures. Some of the causes may be minor while others, major. The causes are grouped here into two categories: improper installation or design and the weather.

2.8.1 Improper Installation or Design

Due to human fallibility or negligence of the architect, engineer, or construction workers a list of roof related problems can arise from these root causes. The following is a list of problems that can cause roof failures stemming from improper installation or design: blisters, splitting, roof ponding, open laps, penetration, loose fasteners, Ridging/fish mouthing and flashing. Blisters, which are common to Built-Up Roofs (BUP), are pockets of water vapours that have become trapped in the roof membranes. When the pocket of air and moisture is exposed to intense heat from the sun, it results in an expansion that causes the surrounding roofing plies to push apart, resulting from a blister (Warseck, 2003).

Splitting which also affect BURs, are cracks that appear on the roof or the roof membrane. One reason why splitting occurs at the roof membrane is because of the inability of the roof to sustain a certain load which resulted from poor workmanship and design. Splitting also occurs in a roof because they weren't designed to properly to accommodate for expansion and contraction of roof joints which results from a poorly designed roof (Warseck, 2003).

Roof ponding can afflict low-sloped roofs or flat roofs. Roof ponding is the retention of water in areas of the roof. It is caused by an inadequate roof drainage, poor roof slopes, and sagging roofs. Roof ponding can cause structural settlement, roof leakage and ultimately collapse.

2.8.2 The Weather

Aside human causes, Nature may also cause roof failures. Roofs are constantly being exposed to the weather, which results in the deterioration of the materials used to sustain the roof. The following is a list of weather patterns that can cause roof failure: Snow, Ice

Rain and Wind. Snow and Ice are experienced by the temperate region of the world. Ghana is in the tropics and therefore does not experience the effect of Snow and Ice. Rain and wind cause roof failures in our part of the world. Windstorms, hurricanes with high speed could remove weakened or improperly installed asphalt shingles and metal roofing from residential homes.

2.9 Construction processes

The construction processes of a building structure have an effect on its stability or failure. Concrete is the most important building material and it plays part in all building structures. This is by virtue of its versatility, that is, it ability to be moulded into shapes required for various structural forms (Bhatt et al, 2006).

Concrete is strong in compression but weak in tension. Concrete is usually reinforced to compensate for the tensile strength. Macgregor and Wight (2006) assert that, reinforced concrete is the dominant material in the engineering construction. The constituents of concrete are cement, aggregates (fine and coarse) and water. The characteristics of concrete are influenced by the quality of the materials, grading of the aggregates, proportioning of the materials and the amount of water. For a good concrete to be achieved, the following processes should be passed through well: (1) batching, (2) mixing, (3) Transporting, (4) Placing, (5) compacting and (6) curing.

2.9.1 Aggregates

Aggregates occupy about 70 to 75% of volume of the hardened mass of concrete (Tomlinson, 2001). Cement paste should fill the void in fine aggregates while the fine aggregates and cement paste fill the void in the coarse aggregate. Aggregates are obtained from the soil.

Some aggregates may contain silica which reacts with the alkali in the cement causing the larger aggregates to expand which may lead to the concrete to disintegrate. Excessive amount of sulphate in the aggregates will also cause concrete to disintegrate (Bhatt et al 2006). The presence of chlorides in aggregates especially in marine sands will cause corrosion

CHAPTER THREE

RESEARCH METHODS

3.0 Introduction

This chapter outlines the research methodology used for the study. It describes and justifies the methods and processes that were used in order to collect data that was used to answer the research questions. The chapter is presented under the following sections:

- Research design
- Population
- Sample size
- Data Collection Procedure
- Data Analyses
- Data Collection for Laboratory Experimentation

3.1 Research design

The research design was quantitatively and qualitatively descriptive design. The research instruments used include questionnaire, structured interview and observation. The observation was done to have firsthand information about the prevailing situation and to make a record of the magnitude of the various types of defects in the area.

I used concurrent mixed methods in the study. In concurrent approach, two or more data collection instruments are administered within the same time frame and integrated into the interpretation of the overall results (Creswell, 2003). I used this method for making the observation of the affected buildings and interviewing the residents as well while the distribution of the questionnaire was also going on. This method saves cost and time because the respondents and buildings are in the same environment. Some soil, block and sand samples were also taken from various sites in the study area and tested in a laboratory at the Takoradi Polytechnic.

3.2 Population

The population comprised building owners and buildings in Apowa, engineers/draughts men practicing in the district, masons, foremen and other craftsmen practicing in the building industry in the Ahanta West district of the Western region of Ghana.

3.3 Sample size

The sample size of the study was made of forty respondents who answered the questionnaire. This constituted thirty masons, six foremen and four contractors. Twenty landlords in the study area and two building inspectors of the Building Department of the Ahanta West District were interviewed. Apart from this sample, sixty houses were surveyed to ascertain the various building defects from the study area.

3.4 Data Collection Procedure

Stratified sampling was used to select the buildings to be observed. The affected area was divided into five zones, (Zones 1-5). Twelve buildings were selected from each zone with those worse affected having the priority. Snowball sampling was used. Tools used for data collection was questionnaires given to masons, foremen and other craftsmen , some of who have worked in the area before while some were still engaged in the construction process in the area under study. The snowball method of sampling was also used to interview the draughts men who designed the building plans. Purposive sampling was used to select from the Works Department from the District Assembly for an interview. Interview was also granted to landlords in the study area. A field survey was further conducted to directly observe and record defects in the buildings in order to ascertain the major types of defects in the study area. A tally system was used to record the survey of the defected buildings while specimen of blocks, sand and soil samples of various strata collected from various sites of the study area was subjected to laboratory test at the Takoradi Polytechnic.

3.5 Design of Questionnaire

The questionnaires were organized in three sections. The section A was designed to obtain personal data from the respondents. It comprised two questions. Section B had two questions which sought to find out the extent at which the necessary preparations were done prior execution of the proposed buildings. The section C also required information from building experts strategies adopted to prevent building defects. A total of six (6) questions for this section (refer to Appendix A).

3.6 Data analyses

The data collected was analyzed using the SPSS computer software template for the data collected and the raw data coded unto the template. Also scientific testing of specimen or sample was carried out to obtain data for analyzing. The analysis was done according to the objectives of the research.

3.7 Data Collection for laboratory experimentation

3.7.1 Moisture Content Test

A trial pit was dug from five sites from the affected area and labelled Zones 1, 2, 3, 4, and 5. Samples were taken from these sites at particular strata of the soil was weighed and placed in an oven of temperature 106 C for 24 hours. The dried soil sample was taken after the 24 hours and weighed. The percentage of moisture was calculated and is recorded in chapter 4 in accordance with BS 1289 B1 (1977). The raw data and calculations for the results are in Appendix D.

3.7.2 Compression test on blocks

Samples of blocks which were being used in ongoing construction at the five selected sites under the study were taken and labelled Zones 1, 2, 3, 4 and 5 and sent to the Civil engineering laboratory of the Takoradi Polytechnic for compression test. Each sample was placed between the nozzle plates of the compression testing machine and tested. The compression strength of each sample was recorded and was calculated from the maximum force applied. The result is in the next chapter, Table 4.12.

3.7.3 Field setting test for fine aggregates

This test was used to ascertain the amount of impurities or otherwise in sand. Samples of sand were taken from five different sites under the study which were construction at random and labelled V, W, X, Y and Z. the test conducted by putting one teaspoon of salt into ½ litre of water. The salt solution was then filled into a measuring cylinder up to the mark and sand was poured in until the level of the sand was up to the 100ml. The cylinders with their content were shaken vigorously and placed on a level surface. It was then allowed to settle for about three hours. When the three hours time lapsed, it was observed that, the silt layer settled on top of the sand. The height of the silt was measured and calculated and expressed as a percentage, as indicated in chapter four, figure 1, (refer to appendix D). The silt test was conducted in accordance with BS 1373 (1990).

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Introduction

This chapter records the results of the study conducted. The results are also extensively discussed and thereby establish the main causes of defects in the super structural walls of buildings in Apowa in the Ahanta West District.

A laboratory test was used to test properties of sample soils and sandcrete blocks obtained from five different sites for analysis. A field survey was also undertaken to report on defects in the eighty individual building at the study area. Furthermore, the result from questionnaire and interview made up of seventeen items were analyzed by SPSS (Statistical Package for Social Scientist).

The findings of the research were compared with the existing literature to see how consistent or deviated the current knowledge on causes failures of the super structure of buildings. The discussions based on the causes of defects or failures of building structures as spelt out by Low and Chong (2006), which indicated that, the causes of defects or failure are weather impact, impart from occupants or load and moisture from wet areas.

4.1 Questionnaire

Section A of the questionnaire in appendix A has questions 1 and 2 that seek to find out the calibre and experience of the respondents. Question 1 reads that, what is your schedule of work at the building site? Question 2 on the other hand reads; How long have you been working at construction sites?

4.1.1 Calibre of personnel

Table 4.1 shows a total of 40 construction experts. These personnel comprised masons who make up 75% out of the total, 15% being foremen and 10% being contractors (those who engage in taking contracts for buildings).

Table 4.1 Calibre of personnel on the sites

Site personnel	Frequency		Percentage
Mason	30	75	Foremen
6	15	Contractors	4
10			
Total	**40**		**100**

4.1.2 Site Experience

In finding out the experience of building professionals undertaking the building projects in the area under study, Table 4.2, indicated that 25% of the respondents have work experience from one year up to five years.

Table 4.2 Site experience

Site work experience	Frequency	Percentage	
1-5 years	10	25	
6-10 years	25	62.5	
11-15 years	3	7.5	16
years and above	3	5	

Total	**40**	**100**

Sixty – two and a half percent of them have attained site experience of between six and ten years. Also, 7.5% of them said they have gained a site experience between eleven and fifteen years while 5% of them have experience above sixteen years.

Section B of the questionnaire consist of close ended question tabulated 4.3 and 4.4. They are centred on preliminary works that should be before the start of the actual construction of the building structure.

4.1.3 Testing the site soil

On the question to find out whether site soil was tested before the design or the erection of the building structure. All the respondents who were all field workers said they had no clue whether site investigations were conducted. They were only asked to start work at their respective sites. These responses prompted me to go further to seek answers from the designers of some of the buildings with defects, like cracks, rising moisture and so on in the case study area. A snowball sampling was used to identify draughts men for the interview.

Four architectural draughts men were identified and interviewed. All the participants said they did not conduct any soil test before designing. When further asked on what basis the foundations dimensions were selected, their answer was the have prototype drawings that the use for all foundation of any design they make. What about the reinforcement? I asked. Everything is prototype, they answered. Do you do any structural calculations of your design? No, they answered. They added that, we know the reinforcement for every member of the building structure. Finally, I asked whether any sort of soil investigations are conducted before designing. Their answer was no.

Liu and Evett (2008) stated that, a comprehensive knowledge of the soil in a specific location will be important for any project as it will determine the most suitable foundation for the project. Fakere et al (2012) concluded that all potential building sites should be investigation to determine their suitability for buildings and the nature and extent of preliminary works that would be needed. From these assertions, it can be concluded that, if site investigations are conducted before the construction of the structures, the right type of foundation would be adopted to minimize or eliminate any defects that would occur. In my opinion, some of the defects observed in the study area may be attributed the failure to investigate the site soil before the construction of the buildings. Knowing the nature of the soil will help in planning for a suitable foundation for the building structure.

4.1.4 Removal of Top Soil

On the removal of the top soil before putting structure, the research found out that, 47.5% of the respondents do the site stripping and 52.5% do not do any stripping of the sites. This is shown on table 4.3 below.

Table 4.3 Site clearance

Stripping of top soil	Frequency	Percentage
Stripping of top soil	19	47.5
Non-stripping of top soil	21	52.5

Total	40	100

The top soil which spans between 100mm and 300mm deep has a poor load bearing capacity. It is therefore unsuitable for foundations of buildings and ought to be removed before any engineering project can be carried out on the soil (Coduto, 2001). This result from the research could be evident that, some cracks might be caused by the inability of the soil to bear the building loads as the building structure is put on the vegetable soil which might cause differential settlement in the foundation hence causing tilting and subsequent cracks. If the hardcore is placed on the vegetable matter, it would decay and cause a differential settlement of the floor. This settlement will bring about cracks on the floor. These cracks are sometimes unsightly and even harbour ants other insects.

4.2 Quality of Materials

4.2.1 Test on materials

Question 5 in the section C of Appendix A asked whether the building materials used at the sites are tested to ascertain their suitability before using them. Twenty-four of the respondents answered in the negative, that they do not test the materials, which sixteen of them said that, they do test the materials. This is shown on Table 4.4 below.

Table 4.4 Testing of Materials

Testing of materials	Frequency	Percentage
A test performed	16	40
No test carried out	24	60

Total	**40**	**100**

Fakere et al (2012) stated that, the uses of poor building materials are possible causes of building collapse. A good building construction is enhanced by materials of good quality. Testing of the materials is to ensure their quality and is therefore very important. Using sand with a lot of impurities, using sandcrete blocks with low compressive strength, or concrete with a poor mix design will not make the building structure strong and durable.

At least in the opinion of the researcher, some of the defects in the building structures observed could be attributed to the use of poor quality building materials as it is revealed by the results tabulated above that a lot of people do not test the building materials to ascertain the suitability before using them. Based on this finding, samples of blocks and sand from the study area were selected for testing at the Takoradi Polytechnic.

4.2.2 Prevention of Moisture

The researcher also asked a question to find out the materials adopted for the prevention of moisture in the buildings, (question 6, Appendix A). The result, shown on Table 4.5 indicates that, 25% of the use felt, 67.5% do not apply any damp proof material (d p m) and 2.5% and 5% say they use engineering bricks and polythene respectively.

Table 4.5Prevention of moisture penetration

Material for moisture prevention	Frequency	Percentage

No damp proof	27	67.5
Felt	10	25
Engineering bricks	1	2.5
Polythene	2	5
Total	**40**	**100**

The findings are in agreement with Aqua (2013) which indicated that vertical cracks inside walls could be brought about by changes in temperature, foundation settlement, expansion and contraction of a wall and soil erosion. Omoregie and Atutu (2006) also agreed that, cracks inside walls on the other hand, can be brought about by changes in temperature, foundation settlement, expansion and contraction of a wall, soil erosion and even improper construction.

It could be deducted that, excessive moisture during the rainy season expanding the clayey soil and less moisture during long periods of dry season and severe heat emanating from the external environment causes cracks in the walls due to poor moisture proofing.

4.3 Construction of Foundation

4.3.1 Depth and dimensions of foundations

Question 7 to 9 of the section sought to find out the depth at which foundation trenches are excavated as well as the dimensions of the foundation. All the respondents indicated that, they adopted 450mm depth with 300mm foundation thickness. All of them also used strip foundations with side 750mm. A further probe revealed that they all adopted strip foundation with isolated pad. This confirms the claim of the draughts' men who said that they use prototype design. Hence, irrespective of the site conditions they use 450mm depth.

A building can fail or deform if it is constructed on a faulty foundation (Olagunju et al 2013). Liu and Evett(2008) also write that, foundation must be located properly (both vertical and horizontal orientation) so as not to be adversely affected by outside influence. They added that, outside influence include adjacent structures, water and so on. The type, depth and thickness of foundation, are very critical in ensuring the stability of a building structure. The knowledge of the type or quality of soil a building's foundation will rest on has an influence on the type, depth and thickness of foundation to adopt. A particular foundation may be good for one type of soil but not suitable for another.

It is also said by Liu and Evett (2008) that the weight of soil removed from a foundation trench should be equal to the weight of the building structure to be put on. This therefore means that, the depth of a foundation has a relationship with the type of building structure to be put on it.

As indicated earlier, that they do not test the soil, if the soil is not investigated, the most suitable type, depth and thickness of foundation can be determined well for a building. Knowing the type of soil and its bearing capacity helps to determine the type and dimension of foundation to adopt. It also depends on the type and purpose of the building structure. It can also be concluded that some of the cracks observed are caused by in ability of designers to adopt as suitable type, depth or thickness of foundation.

4.4 Site Supervision

The researcher asked a question on how often building inspectors visit the building sites during construction process, (question 10). It was revealed that 55% of the respondents have not received any visit by a building inspector while 45% said that, building inspectors have visited them at least once during the construction period.

Table 4.6 Site inspection

Visit by Building Inspectors	Frequency	Percentage
No visit	22	55
1 to 3 time	18	45
Total	**40**	**100**

The administration of building regulations includes the code compliance process, which normally consist among others, the on-site inspection to ensure compliance with the contract documents or the general requirements of the building code where contract documents are not specific, (CESA, 1996).It has been affirmed by Olanitori (2011) that, the absence of Town Planning inspection or monitoring of sites contributes to building defects. He adds that, inspection is non-existence in some cases and this means that, buildings are put up without the authority knowing about details of construction.

Dahiru and Okotie (2010) also identify lack of enforcement of building regulation as a significant factor responsible for the problem faced in the building construction sector. From these assertions made, it is therefore important for building inspectors to go round and ensure that these rules and regulations are adhered to hence a lot of avoidable defects are prevalent at most construction sites in the Ahanta West District. To find out the reasons for not inspecting the buildings and to ascertain if any owner of the buildings have obtained permit from the District and the landlords. Twenty of the landlords and two building inspectors were interviewed.

4.5 Interview of Landlords

4.5.1 Building Permit Acquisition

When asked whether the landlords had their buildings plans approved before the start of the construction of their buildings. From Table 4.7, it was noted that only eleven of the respondents, making 55% got their building plans approved before the construction of their buildings started, while, 45% answered that, they did not get their building plans approved.

Table 4.7 Approval of building Plan

Building plan approved	Frequency	Percentage
Approved building plan	11	55
Unapproved	9	45
Total	**20**	**100**

The result from the research has made it clear that, some developers did not seek for approval of their building plans before starting their building structure. This is not surprising that building inspector do not supervise most of the works in the area under study because the inspectors might not be aware of any construction going on. It is mandatory under the Ghana Building code, (Act 462 of 1993), for every prospective developer to get the building plan approved by the respective district assemblies before the building can be started.

The Building Department of the District Assemblies and the Town and Country planning are made of experts in the Building Trade. These experts scrutinize the drawings and structural details and suggest correction if any before approval is given. So failure to obtain a permit means the drawings and structural details are not checked, hence if there is any defect, it will be translated to the construction and hence defects.

4.5.2 Non-acquisition of Building Permit

Another question for the interview was for those who did seek for a permit before starting their buildings. The question was, why did you not go for the approval of your building plan before starting the project?

Table 4.8 Non approval of building plans

Reasons for not seeking approval	Frequency	Percentage
Not aware of procedure	1	11.1
Procedure wastes a lot of time	8	88.9
Total	**9**	**100**

One of the respondents said that, he did not know that, he has to get an approval from an authority before putting up the building while 88.9% said that, they have heard that, the procedure waste a lot of time if one does not know anybody there. They explained that, if they do not start early, they will spend the little money they have got on something else. This is represented on the table 4.8.

It is clear from this result that are people who are still ignorant about the procedure one has to follow when one wants to put up, a building. It could be deducted that the officials responsible are not embarking on any public education in order to sensitize people to appreciate the need to follow the due process in putting up a building structure.

The researcher is also of the opinion that, if there are however bottlenecks in the issuance of the building permit, they should be looked at so that the process is speeded up to encourage people to wait for the approval of their building plans before starting to put up their building structures. This will minimize the defects occurring at the study area.

4.5.3 Defects Experienced by Occupants

The participants were asked about their experience on their floors. 50% of them said they experience moist floor during raining season and 30% of them said they have cracks on their floors. 20% of them however said they do not experience any problem on their floors. This is shown on Table 4.9.

Table 4.9 Condition of floor

Ground floor condition	Frequency	Percentage
Moist floor	10	50
Cracked floor	6	30
No problem on floor	4	20
Total	**20**	**100**

The result presented on Table 4.9 agrees with the result asked in the questionnaire meant for those who practice in the building trade. When draughts men, who design buildings were asked whether they visit the proposed building sites before designing the building plans, all of them answered in the negative. So, if the site is not visited to ascertain the water table level of the site, there will not be any damp proofing prevention measures incorporated in the drawings. Again, some of the respondents said they do not put any damp proof material. It may not be the builders fault because it is the designer who has to say so through the building drawings. The builder could also have advised as a professional if only he is so competent on the job and has observed the site.

4.6 Interview with Building Inspectors

There are only two officials at the Building Department of the Ahanta West District. They have the sole responsibility of visiting building sites to ensure that, clients and other players in the Building industry comply with Act 462 of 1993, the law that regulates the putting up of building structures in Ghana.

4.6.1 Site Inspection

The first question asked was how often they visit building sites to inspect ongoing projects. Their answer was unanimous. They both said when there is the need. In the opinion of the researcher, their visits to building sites are few. The reason is that, only two men visiting building sites all over the district will find it almost impossible to visit all site at the required number of times. Apart from visiting building sites, they also have other duties like issuing permits, attending Statutory Planning Committee Meetings and others. This however confirms the result found on Table 4.6 where 55% said they have not experienced any visit by a Building Inspector.

The second question was to find out whether they encounter buildings built without building permit. The answer was “yes”. The answer goes to agree with the responses given by some landlords on Table 4.7 where 45% of them said they built without approval or building permit.

Another question was on the action taken on those who build without a building permit if detected. They both said that,” the defaulting builders are made to prepare a building plan for approval and necessary fee paid and where possible a penalty”. The researcher made a follow up question as to why defaulters are not punished severely to deter others from committing the same offence. The explanation given was that, there are enough deterrent sanctions for defaulters on the act (Act 462 0f 1993). They are however unable to apply the sanctions to culprits of political interference. One of them explained that, culprits when found out, often gives “powerful figures” to plead. These powerful figures will therefore intervene on their behalf. The department will have no option than to advise the culprits to go and do the right thing, which is, preparing and presenting the necessary documents to obtain the building permit to continue with their construction.

In the opinion of the researcher, the inability of the officials to apply the sanctions prescribed in the law would not help in stopping people from putting up buildings illegally which could have defects.

4.7 Field Survey

This section consists of an observation of various defects. It was recorded in a tally form from sixty building structures in the study area. This was to help the researcher to have firsthand information apart from the information got from the various stakeholders in the building industry. The common defects observed were cracks, moisture penetration, paint discolour, stains, efflorescence and damage by accident, (Appendix D). These defects were observed critically and recorded in a tally form and later put into figures.

4.7.1 External and internal wall defects

A total of 2,091 defects were observed in the external walls in 60 buildings observed. Cracks were the highest external defect observed with a record of 1160, representing 55.5%. Moisture penetration recorded second highest followed by stains with 25.9% and 12.6% respectively.

Table 4.10 External wall defects

Major defects	Frequency	Percentage
Cracks	1160	55.5
Moisture – penetration	542	25.9
Paints discolour	70	3.3
Stains	264	12.6
Damage by accident	10	0.5
Efflorescence	45	2.2
Total	**2091**	**100**

As shown on Table 4.10, the survey also recorded paint discolour for 3.3%. These were spotted at special moisture prone areas. It also recorded 2.2% for efflorescence and only 0.5% caused by accident.

Table 4.11 Internal wall defects

Major Defects	Frequency	Percentage
Cracks	270	49.0
Moisture penetration	125	22.7
Stains	156	28.3
Total	**551**	**100**

The researcher also made an effort to observe internal walls of the sixty buildings. This was however not possible as there was no access to some of the buildings.

Some landlords refused to allow access to their rooms while others were not available to give access to their houses. It was only forty-five buildings that the researcher could get to the rooms to observe their internal walls.

Like the external walls, cracks, moisture penetration and stains were observed. The result is shown on Table 4.11 which shows that, a total of 551 defects were observed. Out of this number 270 representing 49% were cracks, 22.7% being moisture penetration and 28.3% also being stains.

4.7.2 Cracks on walls

It is clear as revealed on Tables 4.10 and 4.11 that, cracks in both external and internal walls in the study are very high that is 55.5% and 49% respectively. This is an evidence to prove that excessive moisture due to poor moisture proofing and severe heat emanating from external environment cause cracks in the walls.

Designers' failure to conduct scientific soil test to ensure the suitability of the soil prior to the execution of building projects coupled with excessive moisture content of the soil in the area as revealed on Table 4.11 might have caused these cracks in the study area.

The findings are in agreement with Aqua (2013) and Omoregie and Atutu (2006) who assert that, vertical cracks inside walls could be brought about by changes in temperature, foundation settlement, expansion and contraction of a wall, soil erosion and improper construction. Atkinson (2003) also reiterated that, cracks in walls may occur due to sudden shift in lower earth whilst shear cracks occur in buildings when there is a large differential settlement foundation due to any of the following causes; Unequal bearing pressure under different parts of the structure, bearing pressure being in excess of safe bearing strength of the soil and low factor of safety in the design of the foundations.

4.7.3 Moisture penetration in walls

As presented on Tables 4.10 and 4.11, 25.9% of defects observed on external walls and 22.7% on internal walls were moisture penetration respectively. This supports the results from the question on the materials adopted to prevent moisture penetration as presented on Table 4.5. The inability of designers to incorporate damp proof materials in their designs is to blame for this defect and this can be attributed to the failure to make preliminary visit to the sites for firsthand information before doing the design as stated by the draughts men.

4.7.4 Stains

The stain found on both external and internal walls as indicated on Tables 4.10 and 4.11 may be due to moisture trapped into the inner fabrics of the buildings, impact from accident and vandalism. Low and Chang (2006) write that, the major causes of wall stains are weather, moisture introduced in the building either by moisture travelling in to the building or being brought into the building by occupants. Ahmad (2004) also reiterated that a stain occurs when there is moisture content in the walls.

4.8 Laboratory Test

A laboratory test was done to ascertain the suitability of the soil on which the buildings are erected, the blocks and sand used for the construction of some buildings. Samples were taken from five different locations in each at the area under the study.

4.8.1 Soil test

Samples of soil from five different holes dug at different locations were taken to a laboratory to test for their moisture content.

Table 4.12 Results on soil test

Soil Sample/Zone	Total depth 0f hole dug (mm)	Depth of Strata (mm)	Moisture Content of Soil (%)

1	**900**		
1A		**250**	**17.05**
1B		**500**	**21.1**
1C		**900**	**22.1**
2	**900**		
2A		**450**	**27.85**
2B		**900**	**30.0**
3	**900**		
3A		**320**	**28.32**
3B		**380**	**30.9**
3C		**900**	**49.6**
4	**900**		
4A		**300**	**17.13**
4B		**600**	**27**
4C		**900**	**37**
5	**900**		
5A		**450**	**26.6**
5B		**900**	**31.4**

The sites labelled Zones 1, 2, 3, 4 and 5. Each hole was dug to a depth of 90 millimetres (mm), and samples taken at different strata. Calculations were made from each sample to get moisture content (MC) of the various strata as shown on Appendix D. From the results obtained from Zone 1, a sample from the depth of 250mm had a moisture content of 17.04% while samples from depths 500mm and 900mm the MC to be 21.1% and 22.1%

respectively. Samples from Zone 2 were taken from depths 450mm and 900mm and the MC got were 27.85% and 30% respectively. From Zone 3, a moisture content of 28.32% was got from the sample from a depth of 320mm, 30.9% from a depth of 380mm and 49.9% from a depth of 900mm.

The moisture content from at Zone 4 at the depths of 300mm, 600mm and 900mm are 17.3%, 27% and 37% respectively. The test on the samples from Zone 5 were taken from depths of 450mm and 900mm and got moisture content of 26% and 31.4% respectively. These results are shown on Table 4.12.

The results obtained from the laboratory test have indicated a high water table which led excessive moisture content of between 17.05% and 49%. In spite of this high moisture content in the soil, 67.5% of the respondents indicated that they do not use any damp proofing method during construction of walls as indicated on Table 4.5. This in no doubt has given rise to uncontrollable moisture saturation in the surface of the walls. The findings was in consistent with Hutton (2006), who reported that the most common source of moisture in the base of walls of buildings is from defective ground and surface drainage. The study therefore indicated that the main causes if moisture penetration in walls are failure to adopt moisture prevention techniques, poor workmanship, poor design, and poor ground surface drainage. This is also in support with Assaf et al (1995) who assert that non-conformance with water proofing specifications results in building defects

4.8.2 Compression strength of blocks

Blocks were also taken from five different sites and labelled, Zone 1, 2, 3, 4 and 5. These tests were done at the laboratory to determine the strength and density of sandcrete blocks used at sites in the study area. This is shown on Table 4.13.

Table 4.13 Mechanical properties of blocks

Site/Zone	Average mass of blocks (kg)	Compressive Strength of blocks (N/mm2)
1	20	0.843
2	20.1	0.942
3	21.6	2.1
4	22.3	1.841
5	22	0.898

The values of the compressive test of block samples from Zone I, 2, and 5 which are 0.843N/mm, 0.942N/mm and 0.898N/mm respectively are lower than the recommended minimum strength of 1.7N/mm, (Okolie and Akagu 1994). So the defects at these sites could partly be attributed to poor quality blocks used for the walls. Even though the blocks of Zones 3 and 4 had a compressive strength higher than the minimum required strength they are still not strong enough for the sites due to the wet nature of the land there. The researcher is of the opinion that, the poor quality of blocks has contributed to the defect of buildings in the area.

4.8.3 Field Setting test for fine aggregates

This test is usually conducted to ascertain the amount of impurities in sand. Samples of sand were taken from five different sites under construction and labeled V, W, X, Y and Z respectively. As shown on the graph, figure 1, in the next page, and raw data in Appendix D, calculations were done to determine the percentage of silt in the sand.

Sample V recorded a sand settlement of 110ml and a silt settlement of 120ml giving 9.1% silt content. Sample W also recorded 117ml and 126ml for sand and silt settlements respectively resulting in 7.7% silt content. The sample obtained from site X provided a silt content of 2.6% from sand and silt settlements of 115ml and 119ml respectively. The sample got from site Y were 7.5% silt content, a sand settlement of 120ml and 129ml of silt settlement. The results obtained sample Z also provided a sand settlement of 115ml and silt settlement of 119ml resulting in 3.5% silt content in the sand.

Seeley (1996) advises that, silt in sand for building works should not be more than 6%. From the laboratory test conducted, and shown on figure 1, three of the samples V, W and Y recorded excessive 7.7% to 9.1% silt content. This also contradicts Amevordzie (1997) who recommends that, sand from buildings should be clean and free from excessive silt and chemical properties.

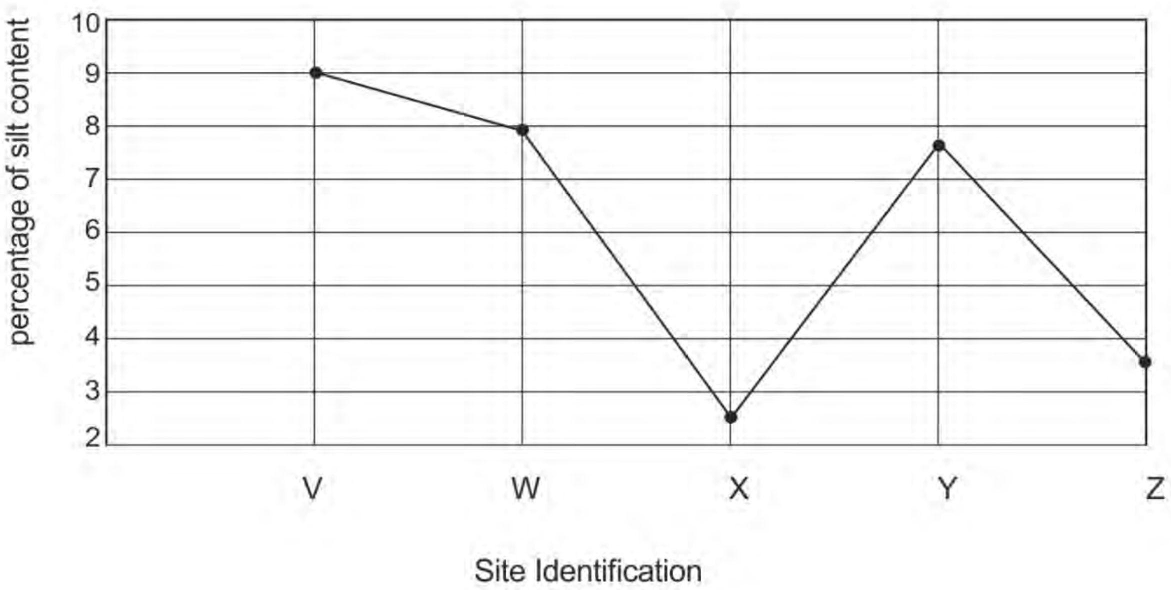

Figure 1: Silt test performed on sand

CHAPTER FIVE

KEY FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter highlight the key findings from the study. The various issues analyzed in the preceding chapters have provided critical insights into the causes of building failures/defects. These insights have informed the recommendations of the study on how building failures/defects can be averted.

5.1 Summary of key findings of the study

The study established that:

Most building designers and contractors do not conduct any site investigation in order to get a comprehensive knowledge of the soil which will give an informed choice for the most suitable foundation to be adopted for the building structure as well as the necessary preparatory works to undertake before starting the structure.

Some of the building projects are started without the prior approval or obtaining building permits from the responsible authorities in the district. Building Inspectors are not able to go round regularly to inspect all ongoing building projects. This has in a way resulted in a lack of compliance of building specification and standards. The building regulations of the country are also disregarded.

Most builders do not adopt any method to prevent excessive moisture penetration in the buildings. The moisture content of a greater part of the study area is high. Engineers do not visit the proposed sites to ascertain their nature before designing the building plans. The engineers therefore do not incorporate damp prevention measures in the design of the buildings.

Majority of sandcrete blocks usedfor the construction of buildings in the study area are substandard. The compressive strengths of most of the blocks tested had a compressive strength below the recommended strength of $1.7N/mm^2$. Most of the sand in the study area contains excessive salt which has an adverse effect on the strength of mortar, blocks and concrete.

The most common defects found at the area under study include; cracks, moisture penetration and stains. These are attributed to poor building practices in the area.

5.2 Conclusion

The findings of this study support the following conclusions:

The right type of foundation was not used in the study area due to the fact that, site investigations were not conducted. This has resulted in the development of cracks in the buildings.

There were cracks, moisture penetration and staining of walls of some of the buildings which might be attributed to the use of poor methods in the construction of the buildings in the study area.

There were inadequate District Assembly approval and development monitoring process of building projects. This has given clients and contractors the chance to use substandard materials and unorthodox methods to build the building structures.

Clients do not seek for bids from contractors in order to select competent ones but rather depend on either friends or relatives to build their building projects.

5.3 Recommendations

The following are recommendations as a way of averting defects in buildings in the study area and the country as a whole:

- The District, Municipal and Metropolitan assemblies should make bye-laws to include engineering site investigations as one of the qualifications for acquiring a building permit.
- The clients should engage experts to carry out site investigation on the proposed building projects in order to avert defects which could cost so much to repair.

- Reconnaissance ought to be conducted by building designers prior to the construction of proposed buildings to ascertain the suitability of the soil for the intended building projects.
- Clients should seek professional advice on site investigation before commencement of the proposed buildings.
- Quality blocks should be used for building in order to prevent cracks.
- Sand containing more than 6% silt should not be used for mortar or moulding blocks.
- Competent builders should be engaged to execute building projects.
- The appropriate building standards and specifications must be adhered to.
- Building Inspectors should make periodic visits to inspect ongoing building projects.
- Damp prevention techniques must be incorporated in all building drawings.

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APPENDIX A

UNIVERSITY OF EDUCATION, WINNEBA

QUESTIONNAIRE FOR CONTRACTORS AND CRAFTMEN

TOPIC: Causes of Building defects

INTRODUCTION

Dear respondent, this research is being carried out in order to enable a study to be conducted on the above topic. Please you are to complete the questionnaire to the bestof your ability by supplying the answer or filling in the tables provided. Be assured that your responses provided will be treated with absolute confidentiality.

PERSONAL DATA - SECTION A

1. What is your schedule of Work at building site?

a) Mason

b) Foreman

c) Contractor

2. How long have you worked at building construction site?

a) 1 to 5 years

b) 6 to 10 years

c) 11 to 15 years

d) 16 years and above

SIGNIFICANCE OF SITE INVESTIGATION - SECTION B

INSTRUCTION: From question 3 - 4, tick Yes or No to show the actions taken before embarking on execution of buildings you have built or supervised.

NO	DESCRIPTION	YES	NO
3	Testing of site soil.		
4	Removing of top soil		

STRATEGIES TO PREVENT BUILDING DEFECTS - SECTION C

5. Do you test the materials used for the building projects?

Yes

No

6. Which of these materials do you use in preventing moisture penetration in walls?

a. Felt

b. Polythene

c. Engineering bricks

d. Others (Please specify)...

7. At what depth is the foundation trench excavated?

a. 0.45m-0.55m

b. 0.60m-0.80m

c. 0.90m-1.0m

d. 1.2m-1.5m

8.What type of foundation do you commonly use for buildings on Sandy areas?

a. Strip foundation without reinforcement

b. Wide strip foundation

c. Deep strip foundation

d. Others (Please specify)...

9. What thickness of foundation concrete do you usually adopt for buildings?

a. 0.10m-1.25m

b. 0.15m-0.2m

c. 0.25m-0.30m

d. Others (Please specify)...

10. How often do you building inspectors visit the building site during construction?

a. No visit

b. 1 to 3 times.

c. 4 to 7 times

d. More than 8 times

APPENDIX B

UNIVERSITY OF EDUCATION, WINNEBA

INTERVIEW FOR LANDLORDS

TOPIC: Investigating the causes of defects in buildings.

INTRODUCTION

Dear respondent, this research is being carried out in order to enable a study to be conducted on the above topic.

Please you are to respond to the following interview questions to the best of your ability. Be assured that your responses provided will be treated with absolute confidentially.

MAJOR BUILDING DEFECTS

1. Was a plan drawn and approved before the construction of your building?

2. Why did you not seek for the approval of the building plan before starting the building?

3. What defects do you experience in your building?

APPENDIX C

UNIVERSITY OF EDUCATION, WINNEBA

INTERVIEW FOR BUILDING INSPECTORS

TOPIC: Investigating the causes of defects in buildings.

INTRODUCTION

Dear respondent, this research is being carried out in order to enable a study to be conducted on the above topic.

Please you are to respond to the following interview questions to the best of your ability. Be assured that your responses provided will be treated with absolute confidentially.

1. How often do you go round to inspect buildings during their construction stage?

....

....

....

2. Do you encounter buildings which have been built without approval or building permit?

....

....

....

3. What actions do you take on buildings built without permit if detected?

....

....

....

APPENDIX D

MAJOR BUILDING DEFECTS

Direct Observation by the researcher:

Inspecting and recording of the various defects in the superstructure walls of buildings.

Number	External Wall Defects	Number of Individual Building (tally)	Total number of defects (frequency)
1	Cracks		
2	Moisture Penetration		
3	Paint Discolour		
4	Stains		
5	Damaged by Accident		
6	Efflorescence		

Stains	Internal Wall Defects	Number of Individual Buildings (tally)	Total number of defects (frequency)
Damaged by Accident	Cracks		
	Moisture Penetration		
9	Stains		
10	Damaged by Accident		
11	Efflorescence		

APPENDIX E

LABORATORY TEST

TOPIC: Causes of building defects

QUESTIONS:

Moisture content of soil

31. What is the common content of the soil at the study area?

Compression and Density ofsandcrete blocks

32. What are the strengths and densities sandcrete blocks for superstructure wall of buildings?

33. What is the quality of the sand used for building works at the study area?

Calculations of moisture content of soil sample obtained from laboratory test results

SITE 1 RESULT

Data

Soil Sample 1A

Soil depth	= 250mm
Weight of Container	= 9.3grams
Weight of container + wet soil	= 117.8g
Mass of dry soil + container	= 102.0g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 117.8g - 102g = 15.8g

Dry Soil = 102.0 - 9.3 = 92.7g

Moisture content = 15.8 × 100 / 92.7g = **17.04%**

Data

Soil Sample 1B

Soil depth	= 500mm
Weight of Container	= 9.4grams
Weight of container + wet soil	= 139.9g
Mass of dry soil + container	= 117.2g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 139.9-117.2g = 22.7g

Dry Soil = 117.2 - 9.4 = 107.8g

Moisture content = 22.7× 100 / 107.8g = **21.1%**

DATA

Soil Sample 1C

Soil depth = 900mm

Weight of Container = 9.4grams

Weight of container + wet soil = 164.78g

Mass of dry soil + container = 136.7g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 164.78g -136.7g = 28.08g

Dry Soil = 136.7 - 9.4 = 127g

Moisture content = 28.08× 100 / 127g = **22.11%**

SITE 2 RESULTS

DATA

Soil Sample 2A

Soil depth	= 450mm
Weight of Container	= 9.6grams
Weight of container + wet soil	= 132.6g
Mass of dry soil + container	= 105.8g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 132.6g -105.8g = 26.8g

Dry Soil =

Moisture content = 26.8× 100 / 96.2g = **27.85%**

DATA

Soil Sample 2B

Soil depth = 900mm

Weight of Container = 9.4grams

Weight of container + wet soil = 123.1g

Mass of dry soil + container = 115.2g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 123.1g -115.2g = 7.9g

Moisture content = 32.52 × 100 / 105.8g = **30%**

SITE 3 RESULTS

DATA

Soil Sample 3A

Soil depth = 320mm

Weight of Container = 9.3grams

Weight of container + wet soil = 120.3g

Mass of dry soil + container = 95.8g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 120.3g -95.8g = 24.5g

MC = 24.5 × 100 / 86.5 =28.32

Moisture content = **28.32%**

DATA

Soil Sample 3B

Soil depth = 380mm

Weight of Container = 9.6grams

Weight of container + wet soil = 133.56g

Mass of dry soil + container = 104.3g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 133.56g - 104.3g = 29.3g

MC =29.3 × 100 / 94.7 = 30.9%

Moisture content =**30.9%**

DATA

Soil Sample 3C

Soil depth	= 900mm
Weight of Container	= 9.4grams
Weight of container + wet soil	= 157g
Mass of dry soil + container	= 108.1g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 157g - 108.1g = 48.9g

MC = 48.9 × 100 / 98.7 = 49.6%

Moisture content = **49.6%**

SITE 4 RESULTS

Soil Sample 4A

Soil depth	= 300mm
Weight of Container	= 9.7grams
Weight of container + wet soil	= 114.3g
Mass of dry soil + container	= 99.0g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 114.3g – 99.0g = 15.3g

MC = 15.3 × 100 / 89.3 = 17.13%

Moisture content = **17.13%**

SITE 5 RESULTS

Soil Sample 5A

Soil depth	= 300mm
Weight of Container	= 9.6grams
Weight of container + wet soil	= 128.9g
Mass of dry soil + container	= 99.0g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 160.1g – 128.9g = 31.7g

MC = 31.7 × 100 / 119 = 26.6%

Moisture content = **26.6%**

Soil Sample 5B

Soil depth	= 900mm
Weight of Container	= 9.7grams
Weight of container + wet soil	= 156.56g
Mass of dry soil + container	= 121.5g

Solution

Wet soil = (container + wet soil) - (container + mass of dry soil)

Wet soil = 156.56g – 121.5g = 35.05g

MC = 35.05 × 100 / 11.8 = 31.4%

Moisture content = **31.4%**

SILT TEST FOR SAND

DATA

Sample V

Sand settlement = 110ml

Silt settlement = 120ml

Solution

Formulae = (silt settlement – sand settlement) × 100/110

$$\text{Silt Content} = \frac{(120-110) \times 100}{110}$$

$$= 10 \times 100/110$$

Silt Content = 9.1%

DATA

Sample W

Sand settlement = 117ml

Silt settlement = 126ml

Solution

Formulae = (silt settlement – sand settlement) × 100/117

$$\text{Silt Content} = \frac{(126-110) \times 100}{117}$$

$$= 9 \times 100/117$$

Silt Content = 7.7%

DATA

Sample X

Sand settlement = 115ml

Silt settlement = 118ml

Solution

Formulae = (silt settlement – sand settlement) × 100/115

$$\text{Silt Content} = \frac{(118-115) \times 100}{115}$$

$$= 3 \times 100/115$$

Silt Content = 2.6%

DATA

Sample Y

Sand settlement = 120ml

Silt settlement = 129ml

Solution

Formulae = (silt settlement – sand settlement) × 100/120

$$\text{Silt Content} = \frac{(129-120) \times 100}{120}$$

$$= 9 \times 100/120$$

Silt Content = 7.5%

DATA

Sample Z

Sand settlement = 115ml

Silt settlement = 119ml

Solution

Formulae = (silt settlement – sand settlement) × 100/115

$$\text{Silt Content} = \frac{(119-115) \times 100}{115}$$

$$= 4 \times 100/115$$

Silt Content = 3.5%