EFFECT OF FAULTY DESIGN AND CONSTRUCTION ON BUILDING MAINTENANCE (CASE STUDY OF AFDIN AND MOTHER CAT CONSTRUCTION COMPANIES IN KADUNA STATE)

By:

Taofik Abdulwahab JIMOH, B.Eng. (ABU) 2010

P13EGME8038

A PROJECT SUBMITTED TO THE SCHOOL OF POSTGRADUATE STUDIES AHMADU BELLO UNIVERSITY, ZARIA IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF A MASTER DEGREE IN MECHANICAL ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING,
FACULTY OF ENGINEERING
AHMADU BELLO UNIVERSITY, ZARIA
NIGERIA

JANUARY, 2016

DECLARATION

I hereby solemnly declare that this project was entirely written and done by me, **TAOFIK ABDULWAHAB JIMOH** with data sourced from appropriate sources, all of which have been properly acknowledged. Every criticism and mistakes are accepted thereof.

JIMOH, Abdulwahab Taofik _____ _____

Signature Date

CERTIFICATION

This project entitled "EFFECT OF FAULTY DESIGN AND CONSTRUCTION ON BUILDING MAINTENANCE (CASE STUDY OF AFDIN AND MOTHER CAT CONSTRUCTION COMPANIES IN KADUNA STATE)", by Taofik Abdulwahab JIMOH, meets the regulations governing the award of Master of Science (M.Sc) degree in Engineering management of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

Dr. D M Kullaa Supervisor	Signature	Date
Dr. M. Dauda Head of Department	Signature	Date
Prof. Kabir Bala Dean, School of Postgraduate Studies	Signature	Date

DEDICATION

This work is dedicated to my loving Parents who made it possible for my accomplishments today.

ACKNOWLEDGEMENT

Words alone can`t express my profound gratitude to almighty Allah (S.W.T), for his guidance and protection over the years and throughout sojourn in this noble institution of ours. It is my sincere prayer that He, in His infinite mercies, will lay the path for us as we embark on a new journey in life. Needless to say I am highly indebted to my supervisor and lecturer Dr D.M kulla who‟s thoughtful, timely and constructive criticisms, corrections and recommendation towards improving the quality of this research work. My special thanks go to all the academic. I wish to register my deep appreciation to all my lecturers in t he Mechanical Engineering Department; Dr. F.O. Anafi, Dr. Dauda, Dr. D.S. Yawas. to mention fewer who have deligently through the years imparted on me the requisite training towards the Mechanical Engineering practice.My special appreciation and deep affection goes to my only wife; Karima Abdulwahab Jimoh and my Friends; Balogun Muyideen, Ahmad Ibrahim, Abubakar Aliyu, Mansur,ibrahim Sulaiman Aliyu, Alabi kola for they are always ready to go extra-mile to bring happiness and joy into my life. We are all one big happy family and proudly portrait the "*Engine boy"* family. Also thanks to all those who had an input in this work this is wishing you Allah‟s blessings and the very best in your endeavour. I must not forget my Ibrahim jimoh, Muyideen jimoh, Rabi Jimoh and Abdul Sadiq Jimoh, I say Jazakumlah Khairan. Finally, I will not forget all those who served out of spotlight, I called them the hidden heroes, and in this endeavor there have been many, to you all I owe my highest gratitude.

ABSTRACT

The study examined the effects of faulty design and construction on the maintenance of building. A survey of randomly selected samples of 20 builders and 15 architects were conducted. Questionnaires were used to collect data from Architects and Builders. The survey included 11 groups of defects and sub defects in each groups. The predominant severity effects of each defects was assessed and ranked based on the severity index as ranked by both the Builders and the Architects. The results shows that 7 defects were rated as most severe, 54 as moderately severe and 6 defects as slightly severe defects. The results also show that increase in maintenance work is the most predominant effects on building maintenance among other factors of defect with an index value of 100.00 as perceived by both the rank of the Architects and that of the builders. The research however includes a hypothesis that Architects and Builders generally agree on the ranking of the severity defects which was tested and proven to be true. The study concluded that there should be a design review before finally approving the design for construction; maintenance expert should not be overlooked in the planning stage of the project and most importantly the employment of professionals for any building projects.

TABLE OF CONTENTS

Contents		Pages
Title page		i
Declaration		ii
Certification		iii
Dedication		iv
Acknowledgment		v
Abstract		vi
Table of Contents		vii
CHAPTER ONE		**1**
1.0	**INTRODUCTION**	**1**
1.1	Background of the Study	1
1.2	Statement of Problem	4
1.3	The Present Work	4
1.4	Aim and Objectives	5
1.5	Scope and Limitation	5
1.6	Significance of the Study	6
CHAPTER TWO		**7**
2.0	**LITERATURE REVIEW**	**7**
2.1	Concept of Building Maintenance	7
2.2	Definition of Building Maintenance	7
2.3	Types of Maintenance	7
2.4	Forms of Maintenance	9
2.5	Importance of building Maintenance	10
2.6	Faulty Design	11
2.7	Faulty Construction	12

Contents **Pages**

2.8 Defects in Civil Design 16

2.8.1 Inadequate provisions for movement 16

2.8.2 Ignoring aggressive environment & weather condition effects 16

2.8.3 Ignoring biological effects 17

2.8.4 Inadequate structural design 17

2.8.5 Ignoring variation in soil conditions 17

2.8.6 Ignoring load impact on structural stability 18

2.8.7 Exceeding allowable deflection 18

2.8.8 Ignoring wind effect on the structure 18

2.8.9 Inadequate concrete cover on the reinforcement 18

2.8.10 Improperly locating conduits and pipe openings at critical structural locations 18

2.9 Architectural Defects in Design 19

2.9.1 Narrow stairs passages & doors 19

2.9.2 Not relating exterior material selection to climatic condition 19

2.9.3 Specifying finishing which needs to be repaired as a whole 19

2.9.4 Not considering the local climatic conditions when designing the exterior shape 19

2.9.5 Inadequate joints between finished faces 20

2.10 Design Defects in Maintenance Practicality and Adequacy 20

2.10.1 Not considering space or exit for maintenance worker, equipment 20

2.10.2 Designing for permanent fixing which should be removable for maintenance 20

Contents **Pages**

2.10.3 Not considering the available maintenance equipment when performing the design 20

2.10.4 Not considering the maintenance requirements in design 21

2.11 Defects Due to Consultant Firm Administration &Staff 21

2.11.1 Lack of Q.A/Q.C program during design 21

2.11.2 Poor technical updating or staff training 21

2.11.3 Hiring unqualified designers 21

2.11.4 Designer field experience 22

2.11.5 Designer technical background 22

2.11.6 Designer ignorance of materials properties 22

2.11.7 Misjudgment of climatic conditions 22

2.11.8 Misjudgment of user's intended use 23

2.12 Defects Due to Construction Drawing 23

2.12.1 Lack of references 23

2.12.2 Conflicting details 23

2.12.3 Lack of details 23

2.13 Defects due to Construction Inspection 24

2.13.1 Lack of inspection 24

2.13.2 Unqualified inspector 24

2.13.3 Proponent negligence of the importance of inspection 24

2.13.4 Weakness of inspection rule implementing corrective actions during job execution 25

2.14 Defects due to Civil Construction 25

Contents **Pages**

2.14.1 Inaccurate measurement 25

2.14.2 Damaged form of work 25

2.14.3 Excavation too close to the building 26

2.14.4 Painting in unsuitable condition or on unsuitable surface 26

2.14.5 Inadequate water proofing and drainage 26

2.14.6 Insufficient reinforcement concrete cover 26

2.14.7 Cold joints 27

2.14.8 Loss in adhesion between materials 27

2.14.9 Early form work removal 27

2.14.10 Poor soil compaction 27

2.14.11 Inadequate curing 27

2.14.12 Lack of communications 28

2.15 Defects due to Contractor Administration 28

2.15.1 Not complying with specification 28

2.15.2 Unable to read drawings 29

2.15.3 Insufficient site supervision 29

2.15.4 Poor communication with the consultant and the owner 29

2.15.5 Unqualified supervision 29

2.15.6 Speedy completion or cheap quality work 30

2.15.7 Unqualified work force 30

2.15.8 Multinational construction experience 30

2.16 Defects due to Construction Materials 30

2.16.1 Different thermal movements in dissimilar materials 31

2.16.2 Selection of material which is unsuitable for existing climatic conditions 31

2.16.3 Use of nondurable material 31

2.16.4 Use of expired material 31

2.16.5 Poor material handling and storage 31

2.17 Defects due to construction equipment 31

2.17.1 Wrong use of equipment 32

2.17.2 Inadequate performance of equipment 32

2.17.3 Lack of required amount of equipment 32

2.18 Defects due to Construction Specification 32

2.18.1 Unclear specification 32

2.18.2 Not defining adequate material types 33

2.18.3 Not specifying the QA/QC construction procedure 33

2.18.4 Not specifying the allowable load limits 33

2.18.5 Specifying inadequate mix design 33

2.19 Effects of Defects on Building Maintenance 34

2.20 Review of Related Past Works 34

2.21 Research Gap 39

CHAPTER THREE 40

3.0 MATERIALS AND METHOD 40

3.1.1 Research Methodology 40

3.2 Population Area of the Study 40

3.3 Method of Data Collection 40

3.4 Data Analysis 40

Contents **Pages**

3.5 Spearman Rank Correlation 41

3.6 Test of Hypothesis 41

CHAPTER FOUR **43**

4.0 RESULTS AND DISSCUSSION **43**

4.1 Presentation of Results 43

4.2 Discussion of Findings 56

CHAPTER FIVE **57**

5.0 CONCLUSION **57**

5.1 Recommendations 58

REFERENCES 59

APPENDIX A 63

LIST OF FIGURES

Figure	Pages
Figure 2.1: Relationship between various forms of maintenance	8

LIST OF TABLES

Tables **pages**

Table 4.1: Response to Questionnaire Administered 43

Table 4.2: Qualification of Respondent 43

Table 4.3: Demography of Respondent 43

Table 4.4: Working Experience 44

Table 4.5: Defects ranked by both Architects and Builders in each defects group 44

Table 4.6: Architect's Rank by Defects Group 47

Table 4.7: Builder's Rank by Defects Group 47

Table 4.8: Architects Defects Ranks 48

Table 4.9: Builder's Defects Rank 51

Table 4.10: Spearman correlation coefficient of the association of the effects of faulty design and construction on building maintenance between the Architects and the Builders 54

Table 4.11: Effects of defects on building maintenance 55

Table 4.12 Spearman correlation coefficient of the association of the effects of defect in building maintenance 56

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background of the Study

'To fail to plan is to plan to fail.'— (Wood, 2003)

The essence of all result-oriented work may be identified in this quotation. In the context of design one can adapt this phrase to, 'if a designer fails to plan well the plan will turn out badly'. In understanding this phrase one can use a law of physics as a metaphor. Newton's third law of force is 'For every action there is a reaction'. For designers this law could be interpreted as 'for every design decision/consideration (action) there is a consequence (reaction)'. As such this research tries to explore the actions of design and the consequence of their actions.

The relationship between design, construction and maintenance is closely related but not easily distinguished. (Maisarah, 2012) explained the vital role of design in the early stage of project management. They stated that a functional design can promote skill; economy, conveniences, and comforts while a non-functional design can impeded activities of all types of detract from quality of care, and raise cost to intolerable levels. A typical saying by Vonnegut: everybody want to build and nobody want to do maintenance. In Nigeria building design are copied from other countries without considering the conditions that lead to such design, hence maintenance experts are seldom included to advice on maintenance efficiency of such design. In a related development (Iyagba, 2005) reveal that there are substantial numbers of people who do not know the meaning of maintenance. The mistakes most designer made is believing that a building that is design with the best aesthetics materials requires little or no maintenance, but such notion or argument are wrong because The

maint enance of a building begins after the construction is completed (Haniff, 2007). (Eizzatul, 2012) observed that the maintainability aspect at the design stage is often ignored and this has contributed to future problems when implementing maintenance work. He further explained that this happens when the aesthetics value has become more important in the design of asset, besides the design factor, site selection, apparatus, tools or facilities to maintain the asset are hard to obtain or very costly. According to (Rozita, 2006) the effectiveness of the building is not dependent on its aesthetic value but on the ability to perform maintenance works on the building in the future. Just like the military slogan that if you fail to plan, and then you are planning to fail. That is, if a building is design and constructed without any plan for maintenance the building is hovering towards failure. According (Norhanizaetal, 2007) if the designer failed to plan well the entire plan would also fail. Every decision made during the building design and construction has its own impact, too often the professionals that constructs and design don't worry whether the building they design and build will work properly, their major concern is just to complete the project and move to the next job while the consequence is left for the client to handle. The effect of faulty building design and construction has become one of the major issues in maintaining building in Nigeria. Nigeria has a population estimated to be around 150 million which has the largest black populace in the world and as such new building are being built daily to accommodate the demands of the teeming population, this has lead to the desperation of every single individual to have a building of his own , the consequence is that an inexperience designer is given a contract to design and same to another to construct in a short period of time which will result in many defects especially during the design and construction stage and this will inevitably result in high maintenance cost. (Abdulmohsen and sadi, 1997) stated that the increase in

maintenance cost is attributed to the failure of the building design. If we compare the production of as cars, for example a car is designed and then built; it is tested exhaustively, fault identified and then rectified. If we relate this to building work, we need to construct a building, test if overtime and then demolish and rebuild, removing all problem in the next design. Faulty construction also accounts for many building failure, if a new copied design has not been specified or built previously(most especially designed copied from abroad) the builder will have no experience of this design and may build it incorrectly resulting in high cost of maintenance with inherent defects. It is therefore sacrosanct for both the designer and the builder to consider the importance of maintenance at the onset of the design because decision made at the planning stage have a large effect on the maintenance of the building and the cost. It is most times worry some that most building expert that suppose to educate the public on the importance of building maintenance will say age building result in high cost of maintenance.

To avoid the implication of design faults on the need for future maintenance, constant research and close observation of existing methods of design and construction practice are needed. In addition, it requires more international forums to address and exchange the issues and experiences seen in different parts of world. In Singapore, an analysis of defects in wet areas of buildings by (Chew, 2005) reported faults in design, the construction phase and material selection. The main sources of defects were the mistakes made at the design stage, construction phase, maintenance practice and in materials selection. The defects that resulted from these failures included tile debonding, mastic failure, the staining of tiles, cracking, water leakage through cracks, water leakage where pipes passed through walls, paint defects, water ponding, spalling of concrete and unevenness of tile surface and poor pointing. This long list of

defects is only those found in the wet areas of buildings which constitute only a small part of the total building. This alarming amount of design faults also creates an opportunity for similar research in other parts of the building as well.

1.2 Statement of Problem

Nigerian is a rich developing country with huge capital resources. It is developing very fast in every area including building construction. Public and private sectors have initiated the need for large and complex construction projects. Meeting the high demand of both parties in a short time, it is expected that many errors and defects have concerned during the design and construction stages which will result later in high maintenance costs and breakdown of structural component. Despite the various strategies being adopted by the government for the maintenance of those facilities, the buildings remain a home for defects that should have been avoided if proper feasibility planning on maintenance has been given cognizance right from the design and construction stage of the project. This has led to unnecessary expenditure from the various authorities in carrying out remedial work to curb the effects. (Brennan, 2000) opined that the main purpose of maintenance of property is essentially to retain it values for investment, aesthetics, safety and durability with a view to ensuring that the property is continually used for habitation and to satisfaction of the owner. It was even observed that majority of the new construction were being built up with defects which later transpire into substantial expenses on maintenance.

1.3 The Present Work

This present research is concerned with the investigation of the effects of faulty design and construction on Building maintenance. Questionnaires were used to collect data from designers and Builders. The predominant severity effects of each defects was assess and rank based on the severity index as ranked by both the Builders and

the designer using SPSS 20. This was used to determine whether there is a correlation between designer and construction professionals.

1.4 Aim and Objectives

The aim of this research is to investigate the effects of faulty design and construction on Building maintenances.

The specific objectives of this research are:

i. To identify the building defects caused by faulty design and construction on building maintenance

ii. To determine the severity index of all defects identified and classify them by severity using SPSS 20.

iii. To determine the severity index for each defect within the group and classify them by severity using SPSS 20.

iv. To assess the effects of the building defects caused by faulty design and construction on maintenance.

v. To test the hypothesis that architects and builders generally agree on the severity ranks of the faulty defects

1.5 Scope and Limitation

The scope of this research is restricted to engineering and architectural buildings and the defect associated with this building was examines at the design and construction stage. Afdin Construction Company and Mother Cat Construction Company was used investigated to illustrate the problem related in this study.

1.6 Significance of the Study

Previous research has shown that the cost of maintaining a building usually involve large amount of expenditure which most times surpass the cost of building structure itself. Therefore, design and construction play a vital role in deciding if defect will transpire later in the building. Hence, by getting it right from the onset of the building can go a long way in minimizing mistakes and error that might occur during construction.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Concept of Building Maintenance

Seeley (1996) stated that it is highly desirable but hardly feasible to produce buildings that are maintenance free, although much can be done at the design stage to reduce the amount of subsequent maintenance work. All elements building deteriorate at a greater or lesser rate dependent on the materials and methods of construction, environmental conditions and the use of the building. Any act of work carried out to prevent or rectify progressive deterioration of structures is said to be a maintenance operation.

2.2 Definition of Building Maintenance

Building maintenance is defined by Seeley (1996) as actions carried out to restore or improve certain parts of a building to an acceptable standard. The BS 3811, defined acceptable standard as "one which sustain the utility and value of the facility. This definition is found to include some degree of improvement over the life of the building as acceptable comfort and amenity standard rise.

2.3 Types of Maintenance

BS 3811 subdivided maintenance into (a) planned and (b) unplanned maintenance as illustrated in figure 1 below:

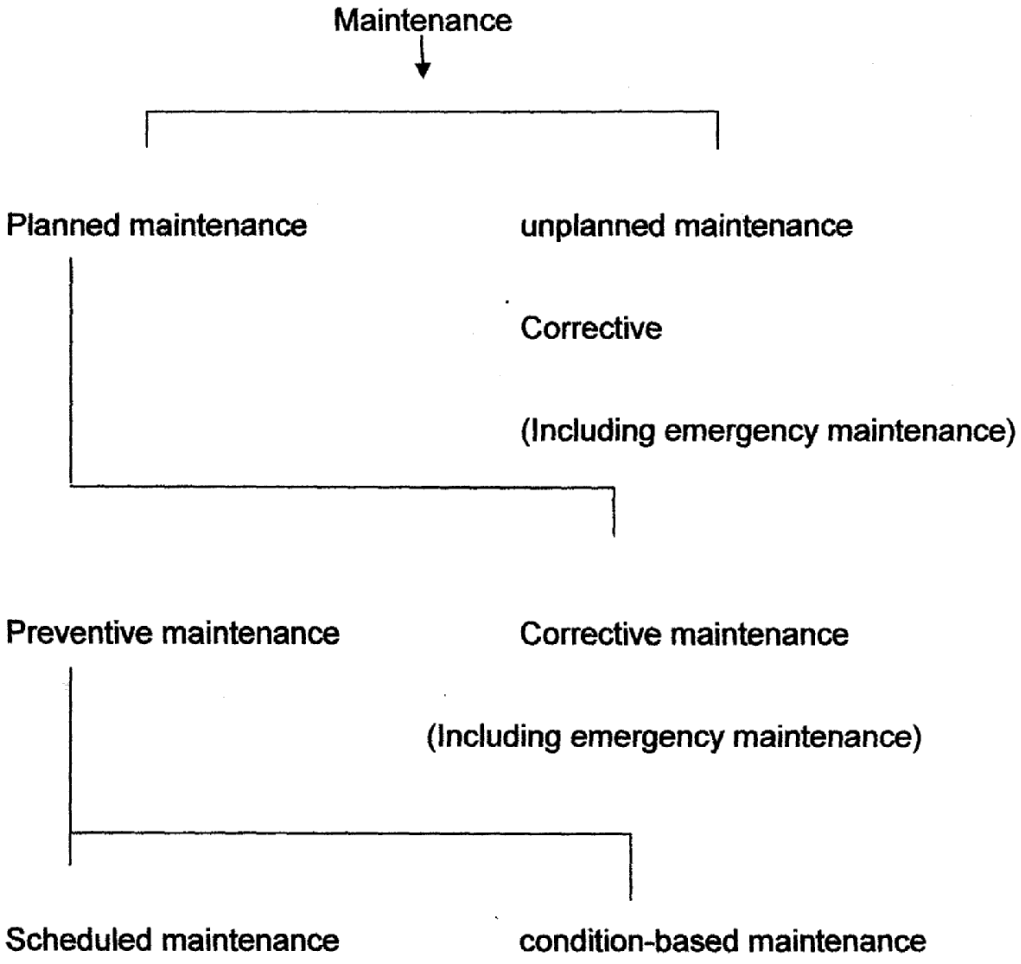


Fig. 1 (Relationship between various forms of maintenance)

(SOURCE: BS 3811: 1984)

a) Planned maintenance

This type of maintenance work is usually organized and carried out with fore though control and records. According to Odama (1999), the planned maintenance is further divided into two namely:

a. Planned Maintenance

i. **Planned preventive maintenance**: This is a process which is directed to the prevention of failure or breakdown of a facility within expected life-span of the facility to ensure its continued function and requirement. This type of

maintenance involves regular inspections, cleaning, testing and routine check from time to time. It does not require building to collapse before it is carried out.

ii. **Planned corrective maintenance**: This is a work that is carried out to restore a building or part of it to an acceptable standard after failure has occurred. In this type of maintenance, the aim is to rectify the damage or worn out equipment to serviceable condition.

b. Unplanned maintenance

i. **Unplanned maintenance:** Unplanned maintenance can be referred to as maintenance work resulting from unforeseen breakdown and damages due to external causes, e.g, blowing of roofs in rainy seasons (Odama 1999). Maintenance in some cases can be categorized as "predictable and unavoidable", predictable maintenance being regular work carried out over a period of time necessary to sustain the performance characteristic of the building as well as change some worn-out materials such as windows e.t.c.

Unavoidable maintenance is that work that is done to correct failure brought about by incorrect design, incorrect installation or use of low quality materials.

2.4 Forms of Maintenance

Seeley (1997) stated that maintenance operation is a system of work carried out to rectify/prevent progressive deterioration of structures. The "action" carried out to improve or to restore certain parts of building includes:

i. **Replacement**: According to Seeley (1996) replacement is Inevitable because service condition cause materials to decay at different rate, much replacement work sterns not so much from physical breakdown of the materials or element as from deterioration of appearance.

ii. **Rectification**: work usually fairly early in the life of the building and arises from shortcoming in design, inherit faults in or in suitability of components damage of goods in transit or installation and in correct assembly. Seeley (1996) also states that rectification work could be reduced by the development and use of performance specification and codes of installation.

iii. **Service**: Seeley (1996) stated that service is essentially a cleaning operation undertaken at regular intervals of varying frequency and is sometimes termed day-to-day maintenance.

2 .5 Importance of Building Maintenance

According to (Abioye, 1995) the importance of maintaining buildings can be summarized as follows:

i. Increase the value of buildings and level of prosperity of such area.

ii. Improve the life-span of the building as well as giving the occupants a sense of belonging and also improves the landlord/occupants relationship thereby making the environment more conducive for living.

iii. Provides employment for the unemployed. Labor is needed for maintenance work and this provides an avenue for learning skills and educating those new in maintenance work and further providing avenue for specialization.

iv. It upholds the standard of comfortable and attractive premises and accommodations.

vi. Sa'ad (1996) also noted that maintenance protect occupant of building from risk poised by dilapidated buildings, serious structural dismay may cause an injury to occupants or passerby

2.6 Faulty Design

Increase of maintenance cost or effort can be attributed to faulty designs. Many of these maintenance problems arise where design is satisfactory in principle but has a low probability of achievement in practice. These are not to be regarded as defects in workmanship but rather as to high an expectation in design. For example, the detail for the placing of the reinforcement in cladding panels may appear to provide the necessary cover on an engineer's drawing but would need a 'watch-making technique[1] to achieve this which would be quite impractical on a building site or even in factory prefabrication (Lee, 2001).

Maintenance problems can also arise where no attention was given at the design stage of a project to the materials and finishes chosen and whether they are capable of withstanding everyday wear and tear. They can also arise from faulty design decisions. Faulty design decisions are the most common faults which may be grouped as follows (Gibson, 2003)

1. Failure to follow well established design criteria in the choice of structural system and selection of materials.

2. Ignorance of the basic physical properties of the materials, e.g. failing to make allowance for the differing thermal and moisture movements of materials used in combination.

3. Use of new materials or innovative forms of construction which have not been properly tested in use. This is often the result of uncritical reliance on manufacturer's literature quoting simulated laboratory tests.

4. Misjudgment of user and climatic conditions under which the material has to perform.

5. Impractical or very difficult to execute design.

6. Poor communication between different members of the design and construction teams.

2.7 Faulty Construction

Another source of maintenance expenditure is construction defects which happen during the construction stage and because of construction contractor performance or material used. Faulty construction is one of the most common causes of early deterioration. Common construction faults include inadequate compaction and failure to position the reinforcement so that it has adequate concrete cover. Under almost any exposure conditions these faults will eventually reduce the service life of the structure as a result of reinforcement rusting after the concrete has become carbonated, (Seeley, 1996).

Another source of fault is the construction method. "The conditions under which construction takes place are often far from ideal, and coupled with an emphasis on speedy completion, can result in careless and skimped work. The Building Research Establishment (BRE) study shows that only a small portion of defects are attributable to faulty materials. It is apparent mat some manufacturers of so-called high technology components have little awareness of the rigours of a building site or the standards of accuracy achievable under such conditions. Thus, whilst the materials may be perfect on leaving the factory they can quite easily be damaged during loading handling, unloading, storing or placing in position. Many such defects can be avoided

by ensuring greater care at all stages in the process, proper training of operatives, and closer supervision. To tackle this problem the construction industry is beginning to introduce the quality assurance techniques developed in other industries such as Quality Assurance (QA) groups and quality control(QC)" (Bre, 2003).

Defects in building design and construction increase and decrease according to the education and the practical and technical experience of the designer and construction contractor Below are defects which are gathered from the literature search and the site interview. They are divided into eleven groups.

A. DEFECTS IN CIVIL DESIGN

i. Inadequate provisions for movement
ii. aggressive environment and weather condition effects
iii. Ignoring biological effects
iv. Inadequate structural design such as foundation
v. Ignoring variation in soil conditions
vi. Ignoring load impact on structure stability
vii. Exceeding allowable deflection
viii. Ignoring wind effects on the structure.
ix. Inadequate concrete cover on the reinforcement
x. improperly locating conduits and pipe openings

B. ARCHITECTURAL DEFECTS IN DESIGN

i. Narrow stairs, passages & doors
ii. Not relating exterior material selection to climatic condition
iii. Specifying finishing which need to be repaired as a whole
iv. Not considering the local climatic condition when designing the exterior shape

v. Inadequate joints between finished faces

C. DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY

i. Not considering space or exit for maintenance worker, equipment

ii. Designing for permanent fixing which should be removable for maintenance

iii. Not considering the available maintenance equipment when performing the design

iv. Not considering the maintenance requirements in design

D. DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION &STAFF

i. Lack of QA/QC program during design.

ii. Poor technical updating or staff training.

iii. Hiring unqualified designers.

iv. Lack of designer field experience.

v. Lack of designer technical background.

vi. designer ignorance of materials properties

vii. Misjudgment of climatic conditions.

viii. Misjudgment of user's intended use.

E. DEFECTS DUE TO CONSTRUCTION DRAWINGS

i. Lack of references.

ii. Conflicting details.

iii. Lack of details.

F. DEFECTS DUE TO CONSTRUCTION INSPECTION

i. Lack of inspection

ii. Unqualified inspector

iii. Proponent (owner) negligence of the importance of inspection

iv. Weakness of inspection rule in implementing corrective actions during job execution

G. DEFECTS DUE TO CIVIL CONSTRUCTION

i. Inaccurate measurement

ii. Damaged form work

iii. Excavation too close to the building

iv. Painting in unsuitable conditions or on unsuitable surface

v. Inadequate water proofing and drainage

vi. Insufficient reinforcement concrete cover

vii. Cold joints

viii. Loss in adhesion between materials

ix. Early from work removal

x. Poor soil compaction

xi. Inadequate curing

xii. Lack of communication

H. DEFECTS DUE TO CONTRACTOR ADMINISTRATION

i. Not complying with specification

ii. Inability to read the drawings

iii. Site supervision

iv. Poor communication with the design firm and the owner

v. Unqualified supervision

vi. Speedy completion or cheap quality work

vii. Unqualified work force

viii. Multinational construction experience

I. DEFECTS DUE TO CONSTRUCTION MATERIALS

i. Different thermal movements in dissimilar material

ii. Selection of material which is unsuitable for the existing climatic conditions

iii. Use of nondurable material

iv. Use of expired materials

v. Poor material handling and storage

J. DEFECTS DUE TO CONSTRUCTION EQUIPMENT

i. Wrong use of equipment

ii. Inadequate performance of equipment

iii. Lack of required amount of equipment

K. DEFECTS DUE TO SPECIFICATION

i. Unclear specification

ii. Not defining adequate material type

iii. Not specifying the QA/QC construction procedure

iv. Not specifying the allowable load limits

v. Specifying inadequate concrete mix design

2.8 Defects in Civil Design

Are defects caused during the early stage of design and particularly in the structural design such as:

2.8.1 Inadequate provisions for movement:

This occurs when the designer ignores the spacing for contraction and expansion movement. Such movement causes cracking of the structure which will result in corrosion of the structural items (beams, columns and slabs) or cracking of the wall or will affect the look of the building (Seely, 1996).

2.8.2 Ignoring aggressive environment & weather condition effects:

In building design, the designer should always select and specify the right material to tolerate the existing weather which will result in less maintenance. Problems result

when the designer is used to certain weather condition and then moves to another place where the weather is different without giving consideration to the weather changes. This problem causes the material to deteriorate in a shorter time and leads to defects in other part of the building, e.g the internal paint when the external paint does not protect the water from seeping through (Seeley, 1996).

2.8.3 Ignoring biological effects:

The designer should always have an idea about the building location and the type of plants and insects existing in that area and if any special treatment is needed against these biological factors to be specified in the design drawings Ignoring biological factors could lead to continuous maintenance which can be avoided during the design and construction stage (lee, 2001).

2.8.4 Inadequate structural design:

This results when the designer under designs the structural elements of the building. This will cause the building to settle: or the building's structural elements to crack and further help initiation of steel bar corrosion or cracking of the walls or wall finishing (Al-Hammed et al., 1997).

2.8.5 Ignoring variation in soil conditions:

Most of the time the soil conditions do not vary in one place but still there are cases where the soil structure varies in one area. Therefore, the designer should always make sure that the soil conditions are similar to the land built next to it. such problem will cause settling which will cause cracking of the structural elements or exterior and interior wall of the building (Al-Hammed et al., 1997).

2.8.6 Ignoring load impact on structural stability

This results when the building is subjected to physical or mechanical action such as elevators, the vibration of central air-conditioning units or wend load in high rise buildings. Such problem will result in continuous surface cracking and cannot be solved until the impact of the movement is isolated(Al-Shiha, 1993).

2.8.7 Exceeding allowable deflection

This happen when the designer exceeds the allowable structural span length or does not evaluate the dead and life load effect correctly.

2.8.8 Ignoring wind effect on the structure

Usually, this happens in a medium size building where it is treated as a two story building. Such factor can cause continuous structural movement which can lead to failure of the structure (Gibson,2003).

2.8.9 Inadequate concrete cover on the reinforcement

Corrodents reach the concrete reinforcement (steel bars) faster if the concrete cover on the steel bars is insufficient .which will result in corrosion of the steel bars and cracking of the concrete element (Al-Hammed et al., 1997).

2.8.10 Improperly locating conduits and pipe openings at critical structural locations

This happens when the designer does not review the layout of the mechanical or electrical designer, where mechanical or electrical designer installs the conduits in a very critical structural area which will result in failure or continuous cracking of the structural element or to the mechanical system of the building, e.g. breakage of the water pipes or sewer leakage (Griffith and Sidwell, 1995).

2.9 Architectural Defects in Design

These are defects caused during the architectural design stage such as:

2.9.1 Narrow stairs passages & doors

Buildings always need minor and preventive maintenance Such maintenance requires some tools (ladder, cleaning equipment, etc.). If the designer does not allow enough clearance to get the tools in and out, these minor problems will get bigger and become major problems (Seely 1996).

2.9.2 Not relating exterior material selection to climatic condition:

The designer should always select the color and type of building's exterior finishing materials to suit the weather and environmental conditions of the building, e.g not painting building with dark color in a dusty area where they require a lot of cleaning or using paints which cannot resist heat and humidity (Al-Hammed et al., 1997).

2.9.3 Specifying finishing which needs to be repaired as a whole

Designers should specify finishing which require minimum maintenance that are always available in the market. If the finishing material is not available, the owner should keep a stock and if no stock is available, the owner may be forced to remove the whole surface. E.g. what happens to wall paper if one area is damage leading to replacement of the total area to maintain the color match. (Al-Shiha, 1993)

2.9.4 Not considering the local climatic conditions when designing the exterior shape

Buildings should be designed in such a way to avoid the collection of moisture, water or dust. Such design will help to reduce the maintenance effort required for continuous cleaning and repairing damages due to, e.g. water collection on building's roofs where moisture collection is always a problem.

2.9.5 Inadequate joints between finished faces

Designers should specify the location of joints in floor slabs, walls, etc. Insufficient joints will cause cracking of the surface or overlapping of tiles or wall cracking due to thermal expansion (Gibson, 2003).

2.10 Design Defects in Maintenance Practicality and Adequacy

This section covers defects caused by improper planning and ignoring the requirements of preventive maintenance during the design stage such as

2.10.1Not considering space or exit for maintenance worker, equipment

Building are designed so that the maintenance workers with their equipment can reach can reach any place in the building to perform maintenance work .ignoring such a factor will increase maintenance cost, effort and obstruct preventive maintenance (Wood, 2003).

2.10.2 Designing for permanent fixing which should be removable for maintenance

Designers should always avoid permanent fixing of elements which need continuous maintenance, e.g. such as lamps, carpets, wash basin separator air filters and external windows.

2.10.3 Not considering the available maintenance equipment when performing the design:

Designer should always design the building according to the available maintenance equipment in the market. The designer should be aware of the equipment available in the market so that he can consider it in his design .such a problem arises during the cleaning of a building's exterior surface or windows or changing lamps in a very high area. Unavailability of the require equipment will increase the maintenance cost and obstruct preventive maintenance(Wood, 2003)..

2.10.4 Not considering the maintenance requirements in design

Designers should always consider the maintenance frequency of the building elements. Areas or elements to be maintained frequently should not be obstructed. And the designer should always consider in his design that the maintenance should be applied smoothly without interruption of the building's operation.

2.11 Defects Due to Consultant Firm Administration &Staff

Some of the defects are attributed to the consultant staff and administration such as

2.11.1 Lack of Q.A/Q.C program during design

Quality consultants usually implement quality assurance/quality control programs on their design to reduce the number of defect and mistakes in the design. The Q.A/Q.C problem request that one group do the design and another group review it to highlight design defects (Bre, 2003)

2.11.2 Poor technical updating or staff training

Consultants should update and expose their staff to the latest construction material and methods in the market. In addition, they should maintain and keep track of the new materials redundant or construction methods and make sure that they perform adequately in the existing building environment.(Gibson,2003)

2.11.3 Hiring unqualified designers

To reduce overhead cost, consultants tend to hire unqualified (inexperienced) designers just because they are cheap and can perform the minimum standards of building design. In this case, the designer will produce poor design and specifications for the owner and contractor to follow (Al-Shiha, 1993).

2.11.4 Designer field experience

Qualified designers should have office and field experience. If the designer has only office experience, he will not experience the faults happening at the construction site during the design implementation (Al-Shiha, 1993).

2.11.5 Designer technical background

Efficient and cost effective building design depend to a great degree on the designer's technical background. The more the designer is exposed to the latest design technology, the better his output is and the less maintenance is required on the building (Al-Shiha, 1993).

2.11.6 Designer ignorance of materials properties

The designer should always study the properties of construction materials before they specify them in their design drawing .A material and proven to be good in one place or country, could be bad in another place because of the change of climatic conditions, poor experience of the construction contractor with this material. This leads to the improper installation or performance of the material.(Hink,1992)

2.11.7 Misjudgment of climatic conditions

Most consultants require from the owner the land details only. They neglect to request more information on the land location to know if it is in a rainy area, where a good drainage system is required, or in a windy area, where some precaution is required. It is very important for the designer to be aware of all the climatic details related to the design to avoid any maintenance problem that could arise from climatic conditions.(Gibson,2003)

2.11.8 Misjudgment of user's intended use

It is very important to know the building owner's intended use and plans, whether the building will be used publicly or privately, so the designer can decide the needed precautions to minimize maintenance cost and efforts. E.g. public buildings need more maintenance precautions than private buildings.

2.12 Defects Due to Construction Drawing

This section will discuss defects due to design faults in the drawings such as:

2.12.1 Lack of references

Building design drawings should always show the cross section and detailed references clearly on the drawings. Lack of references will lead the contractor to construct the building according to his understanding and experience (Al-Shiha, 1993).

2.12.2 Conflicting details

Most of the designs are performed separately for each section, for example civil drawing or mechanical drawings, without consulting other related parties. E.g. when the mechanical engineer makes some changes which will affect the civil work, this action can lead to conflicts which are usually left to the contractor to find and solve.

2.12.3 Lack of details

Most of the building designs lack cross sections, details of structural elements, joints, plumbing, drainage and electrical connections. These are left to the contractor's judgment and experience. As a result, the contractor may perform the job with poor quality and cause many maintenance defects that can be discovered during operation (Al-Shiha, 1993).

2.13 Defects due to Construction Inspection

This section discusses defects due to poor inspection practice, such as:

2.13.1 Lack of inspection

It is well known that when construction inspection increases, quality increases. Therefore, the maintenance needed is reduced. Most of the building owners ignore this or reject it to save in building expenditure. As a result, cheap or unqualified contractors tend to cheat or perform poor workmanship which at the end affects the quality and increases maintenance cost (Gibson, 2003).

2.13.2 Unqualified inspector

Some owners insist on implementing the inspection program. But in some cases it could be that the inspector lacks experience, and the contractor performs the construction as per the inspector's guidance, resulting in poor construction.

2.13.3 Proponent negligence of the importance of inspection

Most of the owners try to save money by selecting poor quality material, and avoiding inspection because of their ignorance of its importance. As a result, the contractor performs the job on his own without inspection .Some owners avoid inspection by performing the inspection themselves where they can improve little in the quality. But sometime they can affect the quality very badly .E.g. most of the owners ask contractors to add water to the concrete mix to make it more workable which will result into a very porous concrete and cause corrosion of steel bars(Al-Shiha, 1993).

2.13.4 Weakness of inspection rule implementing corrective actions during job execution

Some owners insist on having an inspection program, but they make themselves the communication channel between the inspector and the contractor. This causes a lot of delays and any corrective action comes late, after the elements are already constructed with poor quality. In this case, the owner should make a direct communication channel with the assurance that the contractor performs the job as per the contract specification and with the approval of the inspector without the owner's full time involvement (Seely, 1996).

2.14 Defects due to Civil Construction

2.14.1 Inaccurate measurement

Inaccurate measurement occurs where the contractor under measures or over measures the sizes of building elements, the location and the material ratios, for example increasing the gap between door and door frame or window and window frame, which causes water and dust leakage. Another case is where the contractor increases the water content in the concrete mix which causes porous concrete and at the end corrosion of steel bars and cracking of the concrete structure (Gibson, 2003)

2.14.2 Damaged form of work

Damaged form of work affects the quality by producing a honeycomb or porous concrete surface or surface cracks which will allow for moisture penetration and cause corrosion of steel bars. (Al-Shiha, 1993).

2.14.3 Excavation too close to the building

Excavation next to an existing building usually causes soil settlement or vibration to the building's foundation. This action causes continuous wall cracking and requires continuous surface treatment (Lee, 2001)

2.14.4 Painting in unsuitable condition or on unsuitable surface

Painting is considered a continuous maintenance item either for redecoration or renewal purposes .But sometimes it can become a major maintenance item if it is performed improperly, such as painting on a wet surface or a salty surface or painting in humid weather which will result in the peeling of some of the paint and necessitate complete removal of the original paint and cleaning of this surface (Al-Shiha, 1993).

2.14.5 Inadequate water proofing and drainage

Water proofing and drainage are two of the items where contractors lack experience. Most of the time they are performed wrongly or inadequately, especially at the joints, which results in water seepage through the roof ceiling, or block wall. Most building lack proper roof drainage or sewer drainage system (Lee, 2001)

2.14.6 Insufficient reinforcement concrete cover

Most of the standards recommend the increase of concrete cover, for example ACI 301 specifies a concrete cover of 2" on beams and columns and 3" in foundations. Most of the contractors perform the job and ignore the importance of concrete cover and even perform the job with less than drawings requirement of one inch, which expedites the rate of reinforcement corrosion and causes concrete cracking (Cook and Hink, 2003).

2.14.7 Cold joints

Cold joints usually happen between new and old concrete or between new cement plastering or old plastering. Such joints if not treated properly will cause surface cracking and water seepage, e.g. in concrete water tanks or on basement walls.

2.14.8 Loss in adhesion between materials

Loss in adhesion results when the material shell-life has expired e.g. for paints, glue for tiles and PVC fittings, or when the material is used in the wrong place or for the wrong temperature such as using indoor sealants or indoor glue outdoors (Cook and Hink, 2003).

2.14.9 Early form work removal

Most contractors if not all would like to remove the form work as soon as possible and some of them even before the allowable time. This can cause permanent deflection and cracking of the structure. These cracks will cause the moisture to reach the steel and cause continuous corrosion and cracking of the building structural elements (Al-Shiha, 1993).

2.14.10 Poor soil compaction

Most contractors back-fill the soil in one rather than several layers. Therefore, they only compact the top layer. Since, the bottom soil is not compacted, it will settle at a later stage and cause settlement in the building which will cause continuous cracking in the building walls. (Al-Shiha, 1993).

2.14.11 Inadequate curing

Contractors do not spend time and money on concrete curing. It is proven that curing is needed especially in a hot climate to reduce water loss in the concrete, the surface

cracking in the concrete elements. Both defects could be a good source for steel bar corrosion. Even if they cure the concrete, they use salty water which will allow the salt to penetrate the concrete elements and cause corrosion of steel bars or cause loss of adhesion between plastering and the concrete or block surface (Cook and Hink, 2003).

2.14.12 Lack of communications

Most construction industry recruits workers from different nations. Such a problem causes a communication barrier between the construction Engineer, Foreman and the workers who at the end perform the actual job. Site workers will always perform the job as per their understanding. So, if they understand wrong, they will perform it wrong, e.g. use the wrong material or wrong fittings. Such a problem will not be discovered until the building is in use and operation (Wood, 2003).

2.15 Defects due to Contractor Administration

Some of the defects are attributed to the contractor staff and administration such as

2.15.1 Not complying with specification

Contractors tend to do things their own way and few of them follow the construction specification. As a result all the effort spent during the design stage is ignored. Such a problem will increase the maintenance work required during the operation of the building depending on the contractor's experience. If the contractor is well experienced, the maintenance effort need will be less (Al-Shiha, 1993).

2.15.2 Unable to read drawings

The owner should always make sure that the contractor engineer can read the drawings. Most of the design drawings usually are made in Arabic which the construction is sometimes unable to read. And if he can understand the steel and concrete schedules, he may not be able to read the details or the construction specification or references. Again such a problem depends on the construction engineer's experience. The more experienced he is, the fewer the defects will arise during building operation (Chew, 2005).

2.15.3 Insufficient site supervision

Having multinational construction workers who speak different languages and vary in experience requires the site engineer to pay a great attention to his workers and direct them to avoid any problem on time. Insufficient site supervision can cause a lot of problems during the construction stage which will require a lot of maintenance during the building operation.

2.15.4 Poor communication with the consultant and the owner

If the contractor does not communicate with the owner and the designer for consultation or understanding of the specification, he will depend on his experience in performing the job. This can cause a lot of maintenance defects depending on his experience (Al-Shiha, 1993).

2.15.5 Unqualified supervision

The Contractor Engineer is the main controller of the construction quality. A qualified technical and administrative engineer can reduce the maintenance cost and time dramatically. Problems are obvious in buildings built with poor management and unqualified engineers (Wood, 2003).

2.15.6 Speedy completion or cheap quality work

Contractors tend to do the job which needs tools or equipment quickly to reduce rental time. In addition they always tend to select cheap quality material to save money. This problem affects maintenance dramatically. If the contractor selects the right material or performs the job correctly the maintenance required in the future will be reduced. (Nicastro, 1997)

2.15.7 Unqualified work force

Contractor quality is affected by the site engineer and the work force. Both parties have to be well experienced. If the supervision is good but the implementation is poor workmanship, the maintenance defects will increase during the building operation. Therefore, both the construction supervision and construction workers should be qualified.(Nicastro,1997)

2.15.8 Multinational construction experience

One of the items that affect construction quality is the difference in the contractor's workers experience. Workers perform the job according to their past experience. Some of the workers can utilize the available equipment but others cannot. Therefore, having the right tool does not mean the job will be performed properly. Both the right tool and the trained workers should be available to perform the job properly. (Lee, 2001)

2.16 Defects due to Construction Materials

Maintenance defects could be caused by the wrong selection or use of material such as:

2.16.1 Different thermal movements in dissimilar materials

One of the maintenance problems comes from combining materials with different thermal expansion, such as tile glue where the cement thermal expansion is different than the glue. This defect will cause the two materials to separate or dis-bond (Al-Hammed, 1997).

2.16.2 Selection of material which is unsuitable for existing climatic conditions

Using material suitable for cold climatic conditions for hot climate conditions or indoor materials for outdoor conditions, will cause the materials to perform inadequately and required replacement in a short time. (Nicastro,1997)

2.16.3 Use of nondurable material

Cheap or low quality material needs continuous repair and maintenance. Maintenance expenditure and efforts can be reduced by selecting good durable materials.

2.16.4 Use of expired material

Use of expired material at the construction stage will require the owner to replace it at the operation stage, e.g. expired the glue or paints (Hink, 1992).

2.16.5 Poor material handling and storage

Poor handling and storage of material affect the material's quality which will affect the building quality and increase maintenance defects. For example storing building paints outside in the sun will affect paint quality and require replacement in a short time after the building is in operation .(Lee,2001)

2.17 Defects due to construction equipment

In addition equipment can be a source of building defect through;

2.17.1 Wrong use of equipment

Good equipment is the means to perform a good quality job. Therefore, if the equipment is used for the wrong job or misused to perform a job, the quality of construction will be affected, as, for example, when using a wood saw for plastic pipe cutting or a brush instead of a roller for texture paints.(Seely 1996)

2.17.2 Inadequate performance of equipment

Equipment performance affects building quality. If the equipment or tools are performing poorly, the job will be done poorly and accordingly the building maintenance defects will increase.

2.17.3 Lack of required amount of equipment

Having enough equipment will help in performing the job properly. Lack of enough equipment will cause the contractor to perform his work by hand where a special tool is required, as when a level hose is used where a thedolite is needed for leveling roof slab for drainage. As a result, the job will be done poorly and requires continuous maintenance after sometime of operation. (Nicastro,1997)

2.18 Defects due to Construction Specification

In addition to clear construction drawings, the construction specification should be clear also. Maintenance defects can be caused.

2.18.1 Unclear specification

Poor specification will cause the contractor to perform the job to his own standard and interpretation. For an unqualified contract it means poor quality work and more maintenance defects. (Gibson, 2003)

2.18.2 Not defining adequate material types

Weak or inadequate designs specify the materials in general without detailed specifications. Such a problem will allow the contractor to provide the material to meet the general guidelines, where it will not serve the job correctly. For example, if the design specifies only sealant without specifying the type, the contractor will select the cheapest. Another example is when the design specify the strength of concrete as 3,500 psi without specifying the w/c ratio and the allowable dissolved salts in the concrete to prevent steel bar corrosion. As a result, continuous maintenance and replacement of material will be required at the operation stage (Lee, 2001).

2.18.3 Not specifying the QA/QC construction procedure

Most construction specifications do not specify the relationship between the owner, the inspector and the contractor, and how to communicate properly to avoid any defect or solve any problem. In addition it does not specify the responsibility of each party. Therefore, the system becomes loose and many defects can happen during the construction stage without correction (Lee, 2001).

2.18.4 Not specifying the allowable load limits

This can cause the building to be overloaded either with dead or live loads. For example as using a normal activity room for storage or filing cabinets will cause the load to exceed the allowable limits and cause structural cracks or failures. (Gibson, 2003)

2.18.5 Specifying inadequate mix design

Most design the concrete mix to meet the strength requirements and ignore the quality and durability side. The concrete durability is affected highly by the salt content in the sand, water, and aggregate. If the salt content exceeds the allowable limit, the concrete

is contaminated and considered as a corrosion environment. In addition, the w/c ratio should be minimized without affecting the workability of the concrete to increase the impermeability.(Seely,1997)

2.19 Effects of Defects on Building Maintenance

i. Increase in maintenance budget
ii. Increase workforce
iii. Increase in maintenance work
iv. Increase in maintenance quality
v. Difficulties in maintenance planning
vi. Increase maintenance frequency
vii. Maintenance works become obsolete
viii. Lower maintenance quality

2.20 Review of Related Past Works

The building material is widely used in building construction. The building material is an important driver of life cycle of a building and could help prevent maintenance works. High performance building materials provide greater strength, durability and resistance to external elements and can also reduce maintenance costs. In most cases the first building material decisions are generally made during the early stages of the design. Poor material selection is a frequent cause of ineffective maintenance (Ishak et al. 2007).

Graham (1979) stated that, architects and developer has been used new materials and methods which have not been properly test and in adequate research in use. As a result, a vast of problem emerged to future maintenance. These building defects could be reduced by considering the availability of accurate and appropriate material during the design stage.

Dauda et al. (2010) found out that defects within new building are area of non compliance with the building code of practice, older buildings or building out of warranty period may not comply with these standards but must be judged against the standard at the time of construction or refurbishment.

Griffith and Sidwell (1995) refers to inconsiderate designs that affect the building design and influences the construction phase in the form of costly/uneconomic construction which often leads to *incomplete projects* and *improper material selection* by unauthorised personnel. Conceivably the author is directing towards the condition which can cause the design faults that are likely to implicate the cost of future maintenance, for example improper material selection as described previously. Hence, it can be suggested that a designer should judge the realities of their design very closely and try to present a design that is more closely related with the demands of the client and its ultimate user to minimize the undue intervention of other professionals.

Al-Hammad et al. (1997) identified the improper selection of finishing material as being a contributory cause for high maintenance costs in the post-occupational stage of the building. Examples that are quoted included painting buildings with dark colours in a dusty area where they required a lot of cleaning and absorbed heat and also using paints that cannot survive in the climate and humidity to which the building is subjected. The weather and environmental conditions caused deterioration because the design of the façade did not specify suitable types of colour and finish for the building's exterior. The result is a need for more maintenance than should have been the case had proper consideration been given in the design

Seeley (1997) adds that 'cracks in a building normally results from failure or defective construction and are almost invariably unsightly and unacceptable to occupants. If

severe they may result in loss of stability'. Therefore, it can be concluded that cracks in a building are the result of design faults and can cause partial or total collapse.

Assaf et al., (1995) Their study outlines individual and major groups of design and construction defects in large buildings in Saudi Arabia and their relative severity. A survey of a randomly selected sample of 30maintenance contractors and 20 owners from the Eastern Province of Saudi Arabia was undertaken. The survey included 11 major groups of defects and the sub defects in each group. The relative severity effect of each defect on building was assessed and then ranked, based on a severity index by both maintenance contractors and owners. According to owners, 32 defects were rated as "most severe" and 35 defects were rated as "moderately severe." However, according to maintenance contractors 16 defects were rated as "most severe," 49 defects as "moderately severe" and two defects as "slightly severe." It was also found that maintenance contractors and owners generally agree on the ranking of the severity of the defect.

Liska (1988) stated that building maintenance can be carried out at every stage of building life cycle. The maintainability concept could be making the largest contribution to the total life cycle maintenance impact. Furthermore, the maintainability concept can be used to minimize the maintenance problem and building defects. It is important to consider maintainability concept in order to optimize a maintainable building. Although much work has been done already in building maintenance and the efforts improve the maintainability of the building must continue because of the challenges that the building industry is facing.

The design of the building façade can also cause maintenance problems if the designer does not consider the requirements for access if effective maintenance is to be carried

out during the lifetime of the building. For example, the cleaning of a building's exterior surface, windows or changing lamp bulbs in high locations Thus, it can be concluded that building designers are not always aware of the extent of maintenance required for the building's elements and do not make available maintenance equipment to enable these routine tasks to be carried out. This shortcoming of design has implications for future maintenance and the cost of that process.

It is fair to mention that faulty design is not restricted to any one country. But its existence is felt more wherever there is a trend for introducing new materials and technology in construction. It is essential that new techniques and materials should be suitable for the location in which they are used. Therefore, there is a need for newly introduced materials and technology to be tested in different regions and under variety of usage.

A study in England conducted by Olubodun (2000) on housing stock reveals the similar nature of problems in the housing stock under study. The survey revealed that various implicating factors of design faults and construction are present in housing of United Kingdom. These defects are attributed to faults of design, construction, supervision and workmanship. Examples were:

- Rising dampness affecting both exterior and interior surfaces contributing to cladding/plaster decay on external wall surfaces.
- Condensation on floors may increase the relative humidity and temperature variation along with surface deterioration of floor finish. In case of wooden floor, this may cause rot in wood.
- Poor supervision and workmanship has resulted in poor flow in waste pipes and has caused back flow problem in the waste and drainage system.

- Roof and floor failure are also mentioned as being the consequence of inferior workmanship and poor design.

Apart from the direct influence of the design consideration on building maintenance, there are also several other hidden factors that have the tendency or potency to influence the design of building and create the need for extensive maintenance in the building at post-occupational stage. One such factor is the *communication gap*. Communication in design can be explained as the verbal and written discharge of the ideas during design stage or corrective ideas during the construction phase. This involves large numbers of people in the design, construction supervision and management of the building. Three parties are essential to an effective outcome: the designer, contractor/construction manager and owner. A gap will, however, occur if this team does not communicate their needs and expectations to the other.

Masterman (2002) states that poor construction also results from the traditional approach to construction that separates design and construction. The author presents the picture of the ongoing practice in the fields of design and construction where there is a failure to synchronise the design activities and construction phase. But a sound link between design and construction is essential if one is not to follow a path to future faults. Since design is an activity that is to be considered and tailored according to the need of the individuals, it requires close coordination from different parts of the design team. In such circumstances, the contractor and other building trade professionals are not always aware of the requirements of the design or the intention of the designer. Thus, there is a need to develop a working relationship between designer and construction team. Failure of such obligations also causes poor construction and leads to a need for unforeseen post-occupational maintenance or

repair. 'Poor construction' is a broad term and it is associated with a number of faults, for example tile fixing, plastering, formwork, plumbing and flooring. Therefore, it can be concluded that in order to avoid all such construction fault which can cause high future maintenance cost at a later stage, it is necessary to revise the traditional mode of procuring building construction by developing a correlation between designer and construction professionals.

2.21 Research Gap

The way public facilities deteriorate in Nigeria has given room for extra cost to the management of those facilities due to the failure of getting things right when planning the project right from the design and the construction stage. To avoid future negligence among designers and contractors, extensive research work on eliminating the issue of faulty design and construction need to be carried out to improve the design and construction process. The need for maintenance was not given much relevance in the past, in spite of expenses upon expenses incurred doing maintenance after large amount of money has been spent on building a house. Hence, the study aims at identifying the defect caused by faulty design and construction on maintenance and assessing the effect of those defects on maintenance.

CHAPTER THREE

3.0 MATERIALS AND METHOD

3.1 Research Methodology

This research work was carried out using two methods; the first methods involve a literature search and an interview. This stage identifies 67 defects caused by faulty design and construction, and also 8 effects of the defects on building maintenance. In the second method a questionnaire was developed using the defects identified as a parameter and a survey was conducted to assess the effect of these defects on maintenance.

2.9 Population Area of the Study

The population of the respondents consists of 20 Architects and 20 Builders respectively in Afdin and Mother Cat Construction Company of Kaduna state hence 35 questionnaires were returned while 5 questionnaires were not completed.

3.3 Method of Data Collection

Questionnaire was structured and distributed to construction professionals, 40 number questionnaires were distributed to the architects and the builders.

3.4 Data Analysis

The data collected were analyzed using SPSS 20. To measure the data obtained from the respondents, the questionnaire data was analyzed using the severity index formula. The severity index formula is to determine the ranking parameters for each answer to the question and check the weight of each item. For every question there are four (4) parameters that should be used by the respondent as options to answer the questionnaire. The four options given are Does not affects, strongly affects, moderately affects and slightly affects. Each factor has a severity index which can be

calculated as follows. A four scale point was used in solving the question provided. The important index could be obtained for each factor as follows (Assaf et al., 1995)

$$Severityindex(IS) = \frac{\sum(a_i X_i) \times 100\%}{3\sum X_i} \ldots\ldots\ldots\ldots\ldots (3.1)$$

Where a_i = constant expressing the weight given in ith response, i = 1,2,3,4 where a1= 0 is equivalent to Does not affect response, a_2= 1 is equivalent to slightly affects response a_3= 2 is equivalent to moderately affects response,a_4= 3 is equivalent to strongly affects response. While;

X_i = the variable expressing the degree of importance, x_1 = the frequency of does not affects response, X_2 = the frequency of moderately affects response, x_3= the frequency of slightly affects response, x_4= the frequency of strongly affect.

3.5 Spearman Rank Correlation

Spearman rank correlation was used to establish whether there is any form of significant relationships in agreement between the professionals which include Architect and builder.

The following formula will be used to check the degree of agreement

Spearman rank correlation coefficient (Rs) (Maurice, 1994)

$$\rho = \frac{1 - 6\sum d^2}{N(n^2 - 1)} \ldots\ldots\ldots\ldots (3.2)$$

Where d = difference between the ranks given by one party and the ranks given by another party for an individual defects,

N = number of defects or group

3.6 Test of Hypothesis

The research want to test the hypothesis that the architect and the builder generally agreed on the severity ranking of the maintenance defects and effects of the defects on building maintenance. The “t” was used for this study.

The calculated value of t is given by (Maurice, 1994):

$$t = \sqrt{\frac{(n-2) \times r^2}{(1-r)^2}} \ldots\ldots\ldots\ldots (3.3)$$

Where, r = spearman correlation

n = number of observation (number of questions in the study)

CHAPTER FOUR

4.0 RESULTS AND DISSCUSSION

4.1 Presentation of Results

Table 4.1: Response to Questionnaire Administered

Questionnaire	No	Percent
Total administered	40	40
Total returned	35	35
Not returned	5	5
Used for the study	35	35

The results from the table 4.1 show the percentage of the questionnaire administered and the percentage returned and completed

Table 4.2: Qualification of Respondent

Qualifications	Frequency	Percentage
OND	-	-
HND	7	21.82
BSc	10	27.27
MSc	18	50.91
PhD	-	-
Total	35	100.00

Table 4.2 shows that 21.28% are HND holders, 27.27% BSC holders, 50.91% MSC holders. This show that MSC holders are the highest respondents

Table 4.3: Demography of Respondent

Professional	Frequency	Percentage
Architect	15	42.86
Builder	20	57.14
Total	35	100.00

Table 4.3 show that 42.86% are Architects while 57.17% are builders. This show that the builders are the highest respondents

Table 4.4: Working Experience

Working	Frequency	Percentage
1-5 years	8	22.85
6-10 years	12	34.29
Above 10 years	15	42.86
Total	35	100.00

Table 4.4 above show that 22.85% of the respondents have experience between 1-5 years, 34.29% has between 6-10years and 42.86% above 10 years. This shows that the respondents will have enough experience about the research problem.

Table 4.5: Defects ranked by both Architects and Builders in each defects group

S/no	DEFECTS	RANK
A	DEFECTS IN CIVIL DESIGN	
A4	Inadequate structural design such as foundation	1
A2	Ignoring aggressive environment and weather condition	2
A5	Ignoring variation in soil conditions	3
A9	Inadequate concrete cover on the reinforcement	4
A10	Improperly locating conduits and pipe openings at	5
A6	Ignoring load impact on structure stability	6
A7	Exceeding allowable deflection	7
A8	Ignoring wind effects on the structure	8
A1	Inadequate) provisions for movement	9
A3	Ignoring biological effects	10
B	ARCHITECTURAL DEFECTS IN DESIGN	
B2	Not relating exterior material selection to climatic conditions	11
B1	Narrow stairs, passages & doors	12
B5	Inadequate joints between finished faces	13
B4	Not considering the local climatic condition when designing	14
B3	Specifying finishing which need to be repaired as a whole	15
C	DESIGN DEFECTS IN MAINTEANANCE PRACTICALITY	

C1	Not considering space or exit for maintenance workers.	16
C3	Not considering available equipment with performing design	17
C4	Not considering maintenance	18
C2	Designing for permanent fixing which should be removable for maintenance.	19
D	DEFECT DUE TO CONSULTANT FIRM ADMINISTRATION &STAFF	
D3	Hiring unqualified designers	20
D6	Designer ignorance of materials properties	21
D2	Poor technical updating or staff training	22
D4	Designer field experience	23
D5	Designer technical background	24
D7	Misjudgment of climatic conditions	25
D1	Lack of QA/QC program during design	26
D8	Misjudgment of user's intended use	27
E	DEFECTS DUE CONSTRUCTION DRAWINGS	
E3	Lack of details	28
E2	Conflicting details	29
El	Lack of references	30
F	DEFECTS DUE CONSTRUCTION INSPECTION	
F1	Lack of inspection	31
F2	Unqualified inspector	32
F3	Proponents (owner) negligence to the importance of	33
F4	Weakness of inspection rule in implementing corrective	34
G	DEFECTS DUE TO CIVIL CONSTRUCTION	
G5	Inadequate water proofing and drainage	35
G6	Insufficient reinforcement concrete cover	36
G10	Poor soil compaction	37
G1l	Inadequate curing	38
G1	Inaccurate measurement	39
G4	Painting in unsuitable conditions or on unsuitable	40
G3	Excavation tool close to the building	41
G8	Loss in adhesion between materials	42

G12	Lack of communication	43
G2	Damaged formwork	44
G9	Early formwork removal	45
G7	Cold joints	46
H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION	
HI	Not complying with specification	47
H7	Unqualified work force	48
H2	Inability to read the drawings	49
H3	Insufficient site supervision	50
H6	Speedy completion or cheap quality work	51
H5	Unqualified supervision	52
H4	Poor communication with the design firm and the owner	53
H8	Multinational construction experience	54
I	DEFECTS DUE TO CONSTRUCTION MATERIALS	
I2	Selection of material which is unsuitable for existing	55
I3	Use of nondurable material	56
I4	Use of expired material	57
I1	Different thermal movements in dissimilar material	58
I5	Poor material handling & storage	59
J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT	
J1	Wrong use of equipment	60
J2	Inadequate performance of equipment	61
J3	Lack of required amount of equipments	62
K	DEFECTS DUE TO SPECIFICATION	
K5	Specifying inadequate concrete mix design	63
K2	Not defining adequate materials	64
K1	Unclear specification	65
K4	Not specifying the allowable load limits	66
K3	Not specifying the QA/QC construction procedure	67

Table 4.6: Architect's Rank by Defects Group

RANK	GROUP	DEFECTS GROUP	SEVERITY INDEX
1	F	DEFECTS DUE TO CONSTRUCTION INSPECTION	72.22
2	H	DEFECTS DUE TO CONTRACTOR ADMINISTRATION	70.28
3	D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF	69.17
4	E	DEFECTS DUE TO CONSTRUCTION DRAWINGS	67.78
5	C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY	65.28
6	A	DEFECTS IN CIVIL DESIGN	65.22
7	I	DEFECTS DUE TO CONSTRUCTION 'MATERIALS	64.44
8	G	DEFECTS DUE TO CIVIL CONSTRUCTION	64.25
9	K	DEFECTS DUE TO SPECIFICATION	63.56
10	B	ARCHITECTURAL DEFECTS IN DESIGN	57.56
11	J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT	55.19

Table 4.7: Builder's Rank by Defects Group

	GROUP	DEFECTS GROUP	SEVERITY INDEX
1	F	DEFECTS DUE TO CONSTRUCTION INSPECTION	71.01
2	E	DEFECTS DUE TO CONSTRUCTION DRAWINGS	70.00
3	H	DEFECTS DUE TO CONTRACTOR ADMINSTRATION	69.90

4	G	DEFECTS DUE TO CIVIL CONSTRUCTION	69.44
5	D	DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF	69.67
6	I	DEFECTS DUE TO CONSTRUCTION MATERIALS	68.51
7	A	DEFECTS IN CIVIL DESIGN	68.48
8	B	ARCHITECTURAL DEFECTS IN DESIGN	66.97
9	C	DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY	64.90
10	K	DEFECTS DUE TO SPECIFICATION	62.00
11	J	DEFECTS DUE TO CONSTRUCTION EQUIPMENT	68.51

Table 4.8: Architects Defects Ranks

RANK	Q#	DEFECTS FACTOR	MEAN	SEVERITY INDEX
1	D3	Hiring unqualified designers	2.50	83.33
2	A4	Inadequate structural design such as foundation	2.30	76.67
3	D2	Poor technical updating or staff training	2.30	76.67
4	H1	Not complying with specification	2.30	76.67
5	A5	Ignoring variation in soil conditions	2.27	75.56
6	FI	Lack of inspection	2.23	74.44
7	F3	Proponent(owner) negligence of the importance of inspection	2.23	74.44
8	E3	Lack of detail	2.20	73.33
9	H2	Inability to read the drawings	2.20	73.33
10	H3	Insufficient site supervision	2.20	73.33
11	H4	Poor communication with the design firm and the owner	2.20	73.33

12	A9	Inadequate concrete cover on the reinforcement	2.16	72.22
13	F2	Unqualified inspector	2.16	72.22
14	G6	Insufficient reinforcement concrete cover	2.16	72.22
15	H5	Unqualified supervision	2.16	72.22
16	H6	Speedy completion or cheap quality work	2.16	72.22
17	D4	Designer field experience	2.13	71.11
18	D6	Designer ignorance of materials properties	2.13	71.11
19	E2	Conflicting details	2.13	71.11
20	G10	Poor soil compaction	2.13	71.11
21	G5	Inadequate water proofing and drainage	2.13	71.11
22	H7	Unqualified work force	2.13	71.11
23	K5	Specifying inadequate concrete mix design	2.13	71.11
24	B2	Not relating exterior material selection to climatic condition	2.10	70.00
25	I2	Selection of material which is unsuitable for the existing climatic conditions	2.10	70.00
26	I3	Use of nondurable material	2.10	70.00
27	A2	Ignoring aggressive environment	2.07	68.89
28	C1	Not considering space or exit for maintenance worker, equipment	2.07	68.89
29	C3	Not considering the available maintenance equipment when performing the design	2.07	68.89
30	B1	Narrow stairs, passages & doors	2.03	67.78
31	F4	Weakness of inspection rule in implementing corrective actions during job execution	2.03	67.78
32	G11	Inadequate curing	2.03	67.78
33	K2	Not defining adequate materials type	2.00	66.67
34	C4	Not considering the maintenance requirements in design	1.97	65.56

35	D5	Designer technical background	1.97	65.56
36	D7	Misjudgment of climatic condition	1.97	65.56
37	I4	Use of expired material	1.97	65.56
38	K4	Not specifying the allowable load limits	1.97	65.56
39	A6	Ignoring load impact on structure stability	1.93	64.44
40	A7	Exceeding allowable deflection	1.93	64.44
41	G12	Lack of communication	1.93	64.44
42	A10	Improperly locating conduits and pipe openings at critical structural locations	1.90	63.33
43	D1	Lack of QA/QC program during design	1.90	63.33
44	G3	Excavation too close to the building	1.90	63.33
45	G9	Early formwork removal	1.90	63.33
46	G2	Damaged formwork	1.87	62.22
47	G1	Inaccurate measurement	1.83	61.11
43	G4	Painting in unsuitable conditions unsuitable surface	1.83	61.11
49	G8	Loss in adhesion between materials	1.83	61.11
50	K1	Unclear specification	1.83	61.11
51	B5	Inadequate joints between finished faces	1.80	60.00
52	I1	Differential thermal movements in dissimilar material	1.80	60.00
53	E1	Lack of references	1.77	58.89
54	A1	Inadequate provisions for movements	1.73	57.78
55	A8	Ignoring wind effects on the structure	1.73	57.78
56	C2	Designing for permanent fixing which should be removable for maintenance	1.73	57.78
57	D8	Misjudgment of user intended use	1.70	56.67
58	I5	Poor material handling & storage	1.70	56.67
59	B4	Not considering the local climatic conditions when designing the exterior shape	1.67	55.56

60	J1	Wrong use of equipment	1.67	55.56
61	J3	Lack of required number of equipment	1.67	55.56
62	J2	Inadequate performance of equipment	1.63	54.44
63	K3	Not specifying the QA/QC construction procedure	1.60	53.33
64	A2	Cold joints	1.57	52.22
65	A3	Ignoring biological effects	1.53	51.11
66	H8	Multinational construction	1.50	50.00
67	B3	Specifying finishing which are to be repaired as a whole (such as wall paper)	1.03	34.44

Table 4.9: Builder's Defects Rank

RANK	Q#	DEFECTS FACTOR	MEAN	SEVERITY INDEX
1	A4	Inadequate structural design such as foundation	2.38	79.26
2	B2	Not relating exterior material selection to climatic condition	2.34	78.14
3	D3	Hiring unqualified designers	2.33	77.78
4	HI	Not complying with specification	2.29	76.30
5	H7	Unqualified work force	2.28	75.92
6	G5	Inadequate water proofing and drainage	2.27	75.56
7	A2	Ignoring aggressive environment and weather effect	2.26	75.19
8	H2	Inability to read the drawings	2.26	75.19
9	A5	Ignoring variation in soil conditions	2.24	74.81
10	G6	Insufficient reinforcement concrete cover	2.22	74.07
11	I2	Selection of material which is unsuitable for the existing climatic conditions	2.22	74.07
12	A9	Inadequate concrete cover on the reinforcement	2.20	73.33
13	D6	Designer ignorance of materials properties	2.20	73.33

14	F1	Lack of inspection	2.20	73.33
15	H3	Insufficient site supervision	2.20	73.33
16	E2	Conflicting details	2.19	72.96
17	E3	Lack of details	2.17	72.22
18	I3	Use of undurable material	2.17	72.22
19	D2	Poor technical updating or staff training	2.16	71.85
20	B1	Narrow stairs, passages & doors	2.14	71.48
21	F2	Unqualified inspector	2.14	71.48
22	F3	Proponent (owner) negligence of the importance of inspection	2.13	71.11
23	G11	Inadequate curing	2.13	71.11
24	C1	Not considering space or exit for maintenance worker, equipment	2.12	70.74
25	D4	Designer field experience	2.12	70.74
26	G1	Inaccurate measurement	2.11	70.37
27	G8	Loss in adhesion between materials	2.11	70.37
28	H6	Speedy completion or cheap quality work	2.11	70.37
29	G4	Painting in unsuitable conditions	2.10	70.00
30	H5	Unqualified supervision	2.10	70.00
31	G10	Poor soil compaction	2.08	69.26
32	I4	Use of expired material	2.08	69.26
33	G3	Excavation too close to the building	2.07	68.89
34	K2	Not defining adequate material type	2.07	68.89
35	D7	Misjudgment of climatic conditions	2.06	68.52
36	G2	Damaged formwork	2.06	68 52
37	F4	Weakness of inspection rule in implementing corrective actions during job execution	2.04	68.15
38	K5	Specifying inadequate concrete mix design	2.04	68.15
39	G12	Lack of communication	2.03	67.78

40	H4	Poor communication with the design firm and the owner	2.03	67.78
41	B5	Inadequate joints between finished faces	2.02	67.41
42	A10	Improperly locating conduits and pipe openings at critical structural locations	2.00	66.67
43	I1	Different thermal movements in dissimilar material	2.00	66.67
44	A6	Ignoring load impact on structure stability	1.98	65.93
45	D5	Designer technical background	1.97	65.56
46	B4	Not considering the local climatic condition	1.96	65.19
47	C3	Not considering the available maintenance	1.96	65.19
48	D1	Lack of QA/QC program during design	1.94	64.81
49	El	Lack of references	1.94	64.81
50	G9	Early formwork removal	1.94	64.81
51	A3	Ignoring biological effects	1.89	62.96
52	A8	Ignoring wind effects on the structure	1.89	62.96
53	K1	Unclear specification	1.89	62.96
54	G7	Cold joints	1.88	62.59
55	J1	Wrong use of equipment	1.88	62.59
56	A7	Exceeding allowable deflection	1.87	62.22
57	C4	Not considering the maintenance requirements in design	1.87	62.22
58	A1	Inadequate provisions for movement	1.84	61.48
59	C2	Designing for permanent fixing which should be removable for maintenance	1.84	61.48
60	J2	Inadequate performance of equipment	1.83	61.11
61	I5	Poor material handling & storage	1.81	60.37
62	K4	Not specifying the allowable load limits	1.71	57.04
63	D8	Misjudgment of user's intended use	1.68	55.93

64	K3	Not specifying the QA/QC construction	1.59	52.96
65	B3	Specifying finishing which need to be repaired	1.58	52.59
66	J3	Lack of required amount of equipments	1.56	51.85
67	H8	Multinational construction experience	1.51	50.37

Table 4.8 and 4.9 above shows the mean and severity index of the defects caused by faulty design and construction on maintenance of building. According to the Architects the following were rated the most severe defects

- Hiring unqualified designers
- Inadequate structural design such as foundation
- poor technical updating or staff training
- Not complying with specification
- Ignoring variation in soil condition

However, according to builder's the most severe defects acting negatively on buildings are:

- Inadequate structural design such as foundation
- Not relating exterior material selection to climatic condition
- Hiring unqualified designers
- Not complying with specification
- Unqualified work force
- Inadequate water proofing and drainage
- Ignoring aggressive environment and weather condition effect

Table 4.10: Spearman correlation coefficient of the association of the effects of faulty design and construction on building maintenance between the Architects and the Builders

Variable	Rs	Ds	t-cal	t-tab	Decision
Factor	0.83	1	10.92	1.960	Accepted Hi

Where Rs= spearman's rank correlation coefficient, t-cal = t-calculated, t-tab = t tabulated, Ho-null hypothesis.

Referring to table 4.10, the spearman rank correlation coefficient, rho (rs) is 0.83 which indicate a strong positive association between the two professional's perception of the effects of faulty design and construction on building maintenance. At 0.05 level of significant at 95% confident level t-cal is 10.92 and t tab is 1.960 therefore accept alternative hypothesis this is an indication that both the Architect and the Builders agree on the ranking of severity index and have almost the same perception about the defects caused by faulty design and construction on maintenance. This is an indication that both the Architect and the Builders agree on the ranking of severity index and have almost the same perception about the defects caused by faulty design and construction on maintenance.

Table 4.11: Effects of defects on building maintenance

Defects	**Architect**	**Rank**	**Builder**	**Rank**
Increase in maintenance budget	55.6 3	3	93.24	2
Increase workforce	46.67	5	74.36	4
Increase in maintenance work	100.00	1	100.00	1
Increase in maintenance quality	43.33	6	59.05	7
Difficulties in maintenance planning	55.67	3	65.57	5
Increase maintenance frequency	48.33	4	65.57	5
Maintenance works become obsolete	64.00	2	78.09	3
Lower maintenance quality	43.33	6	59.05	6

Table 4.11 above show the effects of defects on building maintenance, the Architects and the Builders both rank increase in maintenance work (100.00) the most predominant effects among other factors.

Table 4.12 Spearman correlation coefficient of the association of the effects of defect in building maintenance

Variable	Rs	Ds	t-cal	t-tab	Decision
Factor	0.99	1	4.27	1.895	Accepted Hi

Referring to table 4.11 the spearman rank correlation coefficient rho (rs) is 0.99 which indicates a strong positive association between the two professionals perception on the effects on the defects on building maintenance. At 0.05 level of significance tcal is 4.27 and t-tab is 1.895 therefore accept alternative hypothesis. This is an indication that both the Architect and Builders agree on the ranking of the defects identified

4.2 Discussion of Findings

From the perception of the Architect's hiring unqualified designers seem to be the most severe defects caused by faulty design while the Builders agreed on inadequate structural design such as foundation the most severe defects caused by faulty design on maintenance. Insufficient concrete covers were both agreed by the Architects and Builders to be the most severe defect caused by faulty construction on maintenance. Speedy completion of work, inexperience workmen and lack of motivation were both agreed to because by contractor administrations and staff by the Architects and Builders. The architects believes misjudgement of climatic condition is most severe defects caused by consultant administration and staff while the Builders rank incomplete implementation as the most severe defects caused by the consultant firm and administration staff.

CHAPTER FIVE

5.0 CONCLUSION

From the findings above the study concludes that the two professionals agreed that out of the total of 67 defects identified. The study shows that seven of these defects are considered 'Most Severe', Fifty four 'Moderately Severe ', six as 'Severe', and zero as 'Non Severe'. The most severe defects which affect building maintenance are:

- Inadequate structural design such as foundation
- Hiring unqualified designers
- Not complying with specification
- Not relating exterior material selection to climatic condition
- Inadequate water proofing and drainage
- Unqualified work force
- Inability to read the drawings

The study concludes that there is a positive association between the perception of the two professionals that is, both the architect and builders have similar idea of the defects caused by faulty design and construction and its effects on maintenance. The results also show that increase in maintenance work is the most predominant effects on building maintenance among other factors of defect with an index value of 100.00 as perceived by both the rank of the Architects and that of the builders. The research however includes a hypothesis that Architects and Builders generally agree on the ranking of the severity defects which was tested and proven to be true. The study concluded that there should be a design review before finally approving the design for construction; maintenance expert should not be overlooked in the planning stage of

the project and most importantly the employment of professionals for any building projects.

5.1 Recommendations

The following recommendations are made in view of the results of the study

1. There should be a design review before finally approving the design for construction

2. Maintenance expert should not be overlooked in the planning stage of the project

3. Selection of contractors should be based on competency and potentials for performance and quality not favourism

4. Registered professional should be employed to handled building projects

REFERENCES

Abdulmohsen Al-hammed and Sadi. (1997). The effects of faulty design on building maintenance. Journal of Quality management, 3:29-39.

Al-Hazmi, Muhammad Hasan, "Causes Of Delay In Large Building Construction Projects ". Master Thesis Submitted To The Faculty Of King Fahd University Of Petroleum And Minerals, Dhahran, Saudi Arabia, June 1987

Al-shiha, M. (1993).The effects of faulty design and construction on maintenance. Saudi Arabic dissertation.

Assaf, Al-hammed, A and Al-shiha M. (1996). The Effect of faulty construction on building maintenance Building Research and information, 23(3), pp.135181

Akinyode B. (1989); "Execution of Rehabilitation/ Maintenance Works" Seminar paper presented at the Nigerian Institution of Architects Conference, Kaduna

Armstorng J.H. (1987) "Maintenance of building Services", Mitchell Publishing Company Ltd

British Standard (BS 1984) " Building maintenance of handbook"3811.

Brennan, B. (2000) Repairs and Maintenance of dwelling. Ireland, Cambridge: Tithloc tile press.

Chew, M.Y.L. (2005) 'Defect analysis in wet areas of buildings', Construction and Building Materials, 19(3), 165–173. | Article | ISI |

Cook, G. and Hinks, A.J. (2003) Appraising Building Defects, Longman Scientific Technical, London, UK.

Dauda dahiru A.D Abdulazeez and MuyiwaAbubakar(2010). An evaluation of the adequacy of the national building code for achieving a sustainable built

environment in Nigeria. Research journal of environment and earth science: 4(10); 850-865

Eizzatul'Ains, Hishamuddinmohdali and suwaibutul Islamiah Abdullah sani (2012). A review of the effect of Building Design on maintenance management. 3rd edition international conference on Business and economic research (3rd ICBER) proceeding. ISSN 9789675705052

Graham, H. (1979). "Operational efficiency and planning in maintenance work', E.J.G. (Ed). *Developments in building maintenance,* Applied Science Publishers, London, pp1-36.

Gresko, J. (2006) '3 Killed in Florida High-Rise Collapse', washingtonpost.com, The Associated Press, Last updated Saturday, 6th May, 2006.

Griffith, A. and Sidwell, A.C. (1995) Constructability in Building & Engineering Projects, Palgrave Macmillan, Basingstoke, UK.

Ghasson, S. (2003) 'A low cost maintenance approach to high rise buildings', Journal of Facilities, 23, 315–322.

Gibson, E.J. (1979) 'Development in Building Maintenance-1', Applied Science Publisher Ltd, London.

Ishak, N., H., Chohan, H., A. and Ramly, A. (2007). "Implications of design deficiency on building maintenance at post-occupational stage." *Journal of Building Appraisal,* Vol.3 No.2, pp 115-124

Itopa M. (2009) "Maintenance of public residential building in Nigeria Unpublished thesis, Department of Quantity Surveying.

Lee Reginald, M. Phil, Frics, "Building Maintenance Management". Collins Third Edition. (2001)

Liska, R. W. (1988). Means facilities maintenance standards. RS Means Company.

Lion, Edgar, "Building Renovation And Recycling", John Wiley And Sons. (1982)

Maisarah Abdulrasak and MasturaJafaar(2012) An assessment of faulty Hospital Design in malaysia.Journal design + Built. Vol5 ISSN: 1985-6881

Masterman, J. (2002) Introduction to Building Procurement Systems, Spon Press, London.

Maurice G. Kendall, Alan Stuart , "The Advanced Theory of Statistics ", Volume 2, Griffin London 3rd Edition. (1994)

Maverick, S.M. (2006) 'Highland Tower Tragedy. Available at http://constructionrisk.blogspot.com/2006/02/highland-tower-tragedy.html, accessed 8th February, 2007.

Me Kaig, Thomas H. "Building Failures Case Studies In Construction And Design". Mcgraw-Hill Book Company. (1962)

Mills, Edward D. Building Maintenance And Preservation – A Guide To Design And Management Butterworths. (1980)

Nicastro, D.H. (1997) Failure Mechanisms in Building Construction, ASCE Press, Reston, VA.

Olubodun, F. (2000) 'A factor approach to the analysis of components' defects in housing stock', Structural Survey, 18(1), 46–58. | Article |

Odama O.T. (1999) "Building Maintenance in public building" Unpublished thesis, Department of Arch., A.B.U Zaria

Olubodun, F. (2000) 'A factor approach to the analysis of components' defects in housing stock', Structural Survey, 18(1), 46–58. | Article |

Ramly, A. (2006) 'A link between design and maintenance', Journal of Building Engineers, 81(5), May.

Ransom, W. H. (1985) Building failures diagnose and avoidance (2n0 edition) Oxford press, UK Pg 165-170

Reginald L. (1988) Building maintenance management (3 edition) oxford printing press, UK pg 39-43.

Reuben Rimaka Omoni kweinka Alarenge Iyagba. (2005). The menace of sick buildings: A challenge to all for its prevention and treatment. An inaugural lecture Delivered at university of Lagos main Auditorium. University of Lagos press. ISSN 11194456

Rozita Arid (2006) Maintenance factors in building design Universitiy of Technology malaysia

Sa'ad T.H (1996) " Relevance of Maintenance in building and infrastructure". Seminar Presented at the Nigerian Institute of Architects Conference, Kaduna.

Seeley I. H, Winfred R. (2005) Building Quantities Explained (5th Edition), Macmillan Press, Great Britain pg 28—30

Seeley I. H. (1976) Building, Maintenance (3d Edition) Macmillan Press, Great Britain pg. 126 – 129

Seeley I. H. (1996) Building Economics, (4th edition) Macmillan Press, Great Britain pg. 326 — 328

Seeley I. H. (1997) Quantity Surveying Practice, (2nd Edition), Macmillan Press. Great Britain pg 261 — 262

Seeley, I.H. (1987) Building Maintenance, Palgrave Macmillan, Basingstoke, UK. World Bank.(1990). World development report. ISBN: 0-8213-1511-0, vol1.

Wood, B. (2003) 'Approaching the care free building', Facilities, 21(3–4), 74–79. | Article |

APPENDIX A

QUESTIONNAIRE

SECTION A

1) Name of organization ----------

2) Indicate profession/rank ----------

3) Nature of activities carried out by your organization

(a) Construction [ ] (b) Construction only [ ]

(c) Maintenance only [ ]

4) Years of experience of your organization

(a) 1-5 yrs [ ] (b) 5-10 yrs[ ] (c) 10-15yrs [ ] (d) above 15yrs

5. Size of your organization with regards to number or workers

(a) 1-50 [ ] (b) 150-100 [ ] (c) 100-150[ ] (d) above 150

SECTION B

To examine the defects associated with buildings maintenance

6) How often do the following defects occur in building maintenance

QN	Defects	Strongly affects	Moderately affects	Slightly affects	Does not affect
A	**DEFECTS IN CIVIL DESIGN**				
1.	Inadequate provisions fir movement	[ ]	[ ]	[ ]	[ ]
2.	Ignoring aggressive environment and weather condition effects	[ ]	[ ]	[ ]	[ ]
3.	Ignoring biological effects	[ ]	[ ]	[ ]	[ ]
4.	Inadequate structural design such as foundation	[ ]	[ ]	[ ]	[ ]

5.	Ignoring variation in soil conditions	[ ]	[ ]	[ ]	[ ]		
6.	Ignoring load impact on structure stability	[ ]	[ ]	[ ]	[ ]		
7.	Exceeding allowable deflection	[ ]	[ ]	[ ]	[ ]		
8.	Ignoring wind effects on the structure	[ ]	[ ]	[ ]	[ ]		
9.	Inadequate concrete cover on the reinforcement	[ ]	[ ]	[ ]	[ ]		
10.	Improperly locating conduits and pipe openings at critical structures	[ ]	[ ]	[ ]	[ ]		
B.	**ARCHITECTURAL DEFECTS IN DESIGN**						
1.	Narrow stairs, passages & doors	[ ]	[ ]	[ ]	[ ]		
2.	Not relating exterior material selection to climatic condition	[ ]	[ ]	[ ]	[ ]		
3.	Specifying finishing which need to be repaired as a whole (such as wall paper)	[ ]	[ ]	[ ]	[ ]		
4.	Not considering the local climatic condition when designing the exterior shape	[ ]	[ ]	[ ]	[ ]		
5.	Inadequate joints between finished faces	[ ]	[ ]	[ ]	[ ]		
C.	**DESIGN DEFECTS IN MAINTENANCE PRACTICALITY AND ADEQUACY**						

1.	Not considering space or exit for maintenance worker, equipment	[ ]	[ ]	[ ]	[ ]
2.	Designing for permanent fixing which should be removable for maintenance	[ ]	[ ]	[ ]	[ ]
3.	Not considering the available maintenance equipment when performing the design	[ ]	[ ]	[ ]	[ ]
4.	Not considering the maintenance	[ ]	[ ]	[ ]	[ ]
D.	**DEFECTS DUE TO CONSULTANT FIRM ADMINISTRATION & STAFF**				
1.	Lack of QA/QC program during design	[ ]	[ ]	[ ]	[ ]
2.	Poor technical updating or staff training	[ ]	[ ]	[ ]	[ ]
3.	Hiring unqualified designers	[ ]	[ ]	[ ]	[ ]
4.	Designers field experience	[ ]	[ ]	[ ]	[ ]
5.	Designer technical background	[ ]	[ ]	[ ]	[ ]
6.	Designer ignorance of materials properties	[ ]	[ ]	[ ]	[ ]
7.	Misjudgment of climatic condition	[ ]	[ ]	[ ]	[ ]
8.	Misjudgment of user’s intended use	[ ]	[ ]	[ ]	[ ]
E.	**DEFECTS DUE TO CONSTRUCTION DRAWINGS**				
1.	Lack of references	[ ]	[ ]	[ ]	[ ]

2.	Conflicting details	[ ]	[ ]	[ ]	[ ]		
3.	Lack of details	[ ]	[ ]	[ ]	[ ]		
F.	**DEFECTS DUE TO CONSTRUCTION INSPECTION**						
1.	Lack of inspection	[ ]	[ ]	[ ]	[ ]		
2.	Unqualified inspector	[ ]	[ ]	[ ]	[ ]		
3.	Proponent (owner) negligence of the importance of inspection	[ ]	[ ]	[ ]	[ ]		
4.	Weakness of inspection rule in implementing corrective actions during job execution	[ ]	[ ]	[ ]	[ ]		
G.	**DEFECTS DUE TO CIVIL CONSTRUCTION**						
1.	Inaccurate measurement	[ ]	[ ]	[ ]	[ ]		
2.	Damaged formwork	[ ]	[ ]	[ ]	[ ]		
3.	Excavation tool close to the building	[ ]	[ ]	[ ]	[ ]		
4.	Painting in unsuitable conditions or on unsuitable surface	[ ]	[ ]	[ ]	[ ]		
5.	Inadequate water proofing and drainage	[ ]	[ ]	[ ]	[ ]		
6.	Insufficient reinforcement concrete cover	[ ]	[ ]	[ ]	[ ]		
7.	Cold joints	[ ]	[ ]	[ ]	[ ]		
8.	Loss in adhesion between materials	[ ]	[ ]	[ ]	[ ]		
9.	Early formwork removal	[ ]	[ ]	[ ]	[ ]		

10.	Poor soil compaction	[ ]	[ ]	[ ]	[ ]		
11.	Inadequate curing	[ ]	[ ]	[ ]	[ ]		
12.	Lack of communication	[ ]	[ ]	[ ]	[ ]		
H.	**DEFECTS DUE TO CONTRACTOR ADMINISTRATION**						
1.	Not complying with specification	[ ]	[ ]	[ ]	[ ]		
2.	Unable to read the drawings	[ ]	[ ]	[ ]	[ ]		
3.	Insufficient site supervision	[ ]	[ ]	[ ]	[ ]		
4.	Poor communication with the design firm and the owner	[ ]	[ ]	[ ]	[ ]		
5.	Unqualified supervision	[ ]	[ ]	[ ]	[ ]		
6.	Speedy completion or cheap quality work	[ ]	[ ]	[ ]	[ ]		
7.	Unqualified work force	[ ]	[ ]	[ ]	[ ]		
8.	Multinational construction experience	[ ]	[ ]	[ ]	[ ]		
I.	**DEFECTS DUE TO CONSTRUCTION MATERIALS**						
1.	Differential thermal movements in dissimilar material	[ ]	[ ]	[ ]	[ ]		
2.	Selection of material which is unsuitable for existing climatic conditions	[ ]	[ ]	[ ]	[ ]		
3.	Use of expired material	[ ]	[ ]	[ ]	[ ]		
4.	Poor material handling & storage	[ ]	[ ]	[ ]	[ ]		
J.	**DEFECTIONS DUE TO CONSTRUCTION**						

	EQUIPMENT				
1.	Wrong use of equipment	[ ]	[ ]	[ ]	[ ]
2.	Inadequate performance of equipment	[ ]	[ ]	[ ]	[ ]
3.	Lack of required number of equipments	[ ]	[ ]	[ ]	[ ]
K.	**DEFECTS DUE TO SPECIFICATION**				
1.	Unclear specification	[ ]	[ ]	[ ]	[ ]
2.	Not defining adequate materials	[ ]	[ ]	[ ]	[ ]
3.	Not specifying the QA/QC construction procedure	[ ]	[ ]	[ ]	[ ]
4.	Not specifying the allowable load limits	[ ]	[ ]	[ ]	[ ]
5.	Specifying inadequate concrete mix design	[ ]	[ ]	[ ]	[ ]

SECTION C

7. What level of damage does the following defect have on building maintenance

How does the following of defects affect building maintenance

QN	Defects	Strongly Affects	Moderately Affects	Slightly Affects	Does not Affects
1	Increase in maintenance budget	[ ]	[ ]	[ ]	[ ]
2	Increase workforce	[ ]	[ ]	[ ]	[ ]

3	Increase in maintenance work	[ ]	[ ]	[ ]	[ ]
4	Increase in maintenance quality	[ ]	[ ]	[ ]	[ ]
5	Difficulties in maintenance planning	[ ]	[ ]	[ ]	[ ]
6	Increase maintenance frequency	[ ]	[ ]	[ ]	[ ]
7	Maintenance works become obsolete	[ ]	[ ]	[ ]	[ ]
8	Lower maintenance quality	[ ]	[ ]	[ ]	[ ]