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JIMMA INSTITUTE OF TECHNOLOGY

FACULTY OF CIVIL AND ENVIRONMENTAL ENGINEERING

CONSTRUCTION ENGINEERING AND MANAGEMENT CHAIR

Assessment of construction defects on multistory commercial buildings in Jimma town

By:

Bisrat Kassahun

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Declaration

This research entitled "**Assessment of construction defects on multistory commercial buildings in Jimma town**" is my original work and has not been presented for a degree in any other university.

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Abstract

A building defect can be defined as a material, component or finish which does not meet its accepted performance criterion. The main objective of this study was to assess the construction defects of multistory commercial buildings in Jimma town.

Data was collected using observational checklist and questionnaire. Currently, there are a total of 64 multistory commercial buildings that are fully operational; from which 18 buildings are taken for the study by using purposive sampling method. Structured questionnaires were developed and distributed to randomly selected consultants, contractors and clients currently engaged on building construction. The questionnaire was utilized by involving 36 respondents from which, 22% (8) clients, 44% (16) contractors and 34% (12) consultants.

According to the observational analysis result, the most common construction defect on commercial buildings, which was observed on 83.3% of the buildings, was plastering crack. The next frequent construction defects were peeling off paint (72.2%), broken/cracked floor tiles (66.7%), defective water supply system (61.1%) and exposed electrical wiring (55.6%). As the causes of the construction defects were assessed by the computed weighted average in the questionnaire analysis, workmanship problem is found to be the first cause of construction defects in multistory commercial buildings. The second and third causes of construction defects were using defective construction material and non-conformance with specifications, respectively.

A questionnaire analysis was also used to investigate the impacts of construction defects on multistory commercial buildings. According to the weighted average of the responses, high maintenance and rework cost is found to be the first impact of construction defects. The second impact of construction defects is the decrement of building functionality. Dissatisfaction of property owners is found to be the third impact of construction defects. According to respondents' weighted average applying an effective quality control mechanism is believed to be the first defect reducing measure. The second defect reducing measure is regular site supervision during construction work. Creating the necessary awareness for low-skilled laborers is the third recommended defect reducing measure.

Since commercial buildings accommodate many people, the safety, serviceability and aesthetics value of the buildings should be monitored by the concerning governmental body, that is, Jimma town construction office.

Keywords: construction defect, multistory building, cause, impact, remedial measure

Abbreviations

DPC Damp Proofing Course

DPM Damp Proofing Material

PVC Poly Vinyl Chloride

UPVC Unplasticized Poly Vinyl Chloride

QC Quality control

mm millimeter

nm nano meter

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CHAPTER ONE

INTRODUCTION

1.1 Background

A building defect can be defined as a material, component or finish which does not meet its accepted performance criterion. Technical knowledge and proficiency and an indulgent of building construction are necessary to accurately recognize the root of building defects and the remedial measures essential to put the defects right (Mydin, 2012).

Defective construction may lead to complete failure of structure. The construction industry all around the world is getting modern, advance and growing day by day with the help of information technology age. Construction defects become a global issue facing by practitioners and researchers around the world. Defects can affect success of construction project significantly. More specifically, it has major impact on construction cost, construction time, productivity, sustainability aspect and on customer satisfaction (Bagdiya & Wadalkar, 2015).

Construction defects are always the key concern of the construction industry. Different constructed facilities generate different types of defects and demands different levels and types of quality depending on the function, system, types and material used. Various systems have been designed to eliminate defects during construction operation (Neha.V.Bagdiya & Wadalkar, 2015).

Construction defects that directly affect the performance of a structure can be the result of defective design or construction; defects that allow moisture intrusion into the structure; and defects that will render the building structurally unsound. In general, examples of these defects are: a design that was not prepared in accordance with the applicable building codes; the failure of the contractor to execute the work in accordance with the plans and specifications; the failure of the contractor to execute the work in accordance with the acceptable standards of workmanship in the construction industry; the improper installation of systems, equipment or materials that are of a lesser quality than required by the plans and specifications (Mr. Jaydeep D. Agola1, 2015).

Problems and failures in buildings can be broadly attributed to either defects or deterioration. Defects arise due to error or omission, that is, breach of contract or negligence by a designer or contractor, but deterioration is a natural process which may be unavoidable, although minimized by care in design and the selection of materials. However, where the rate of deterioration is excessive it may be due to a defect, such as the selection and use of unsuitable materials, or an event, such as a water leak resulting in fungal decay. A defect in such circumstances may be due to a breach of contract or negligence during construction or repair, or it may be a failure by a building owner or tenant to maintain the building adequately or to repair it promptly after accidental or weather damage (Richardson, 2002)

In the entire lifecycle of any building, defective construction can be both a curse and a burden to that building, its users and its neighborhood. Sometimes, designers may not be conscious of the implication of their design decisions and the ability of contractors to meet or fulfill them safely. The client or contractors are sometimes culpable of the procurement of poor building materials. During construction, supervision which helps in resolving certain misinterpretations and unprofessionalism is sometimes needlessly insufficient. The contractors and artisans who bring the designer’s dream to reality are either incompetent, looking for the easiest way out, or in haste in order to create time and clinch other contracts. In the construction stage, these delinquencies affect the cost and time of construction because such works have to be revisited. During use, such buildings are left to the clients to struggle with and maintain (Ojo, 2014).

1.2 Statements of the problem

In the entire lifecycle of any building, defective construction has a negative effect to that building, its users and surroundings. Due to economic reasons, these problems are especially common in developing countries such as Ethiopia. The town of Jimma has different multistory commercial buildings which are constructed within the last decade. All of the buildings are owned by private investors. The researcher noticed that the buildings have different kinds of defects. In the case of this research, multistory building refers to one which has more than one storey. Multistory commercial buildings were a special focus of this research because they are comparatively recent building types and become most popular amongst users. The buildings accommodate considerable number of users daily. As the number of users increase the quality and safety requirement of any building is expected to be high.

Building construction defects have an impact on the safety of the users and occupants, aesthetics of the building, economic status of the owner due to increased maintenance costs and generally fail to give the intended functions effectively. These impacts have their own share on the economy of the country at large. To decrease these impacts there should be mitigating measures based on the level and root cause of each defects. This research was focused on assessing the construction defects and recommend necessary mitigating measures.

1.3 Research Questions

The research questions are as follows:

1. What are the common construction defects that occurred on multistory commercial buildings in Jimma town?
2. What are the possible causes of construction defects that occurred on multistory commercial buildings in Jimma town?
3. What are the impacts of construction defects on multistory commercial buildings of Jimma town?
4. What measures should be taken to minimize construction defects in multistory commercial buildings of Jimma town?

1.4 Objectives

1.4.1 General Objective

The main objective of this study was to assess the construction defects of multistory commercial buildings in Jimma town.

1.4.2 Specific Objectives

The specific objectives of this research were;

1. To identify the common construction defects that occurred on multistory commercial buildings in Jimma town.
2. To study the possible causes of construction defects of on multistory commercial buildings in Jimma town.
3. To study the impacts of the construction defects on multistory commercial buildings of Jimma town
4. To give the necessary remedial measures that minimizes construction defects on multistory commercial buildings of Jimma town.

1.5 Significance of the Study

This research will help the stakeholders of the construction industry, that is, the client, consultant, contractor and government, to know the level of the construction defects in multistory buildings of Jimma town. Knowing the reasons behind it will help to provide the necessary remedial measures in order to reduce similar future problems and keep the users safe and satisfied. The outcomes of the research will also help the government to formulate and modify building codes that are essential for constructing buildings with much lesser defects.

1.6 Scope and limitation of the study

The scope of the research was limited to identifying the common construction defects, assessing the causes, impacts and minimizing measures of the defects on commercial multistory buildings of Jimma town. Commercial multistory building refers to a building which has more than one storey and its purpose is intended for accommodating business activities.

CHAPTER TWO

REVIEW OF RELATED LITERATURES

2.1 Introduction

2.1.1 Defining Defective Construction

Defects are faults that may reduce the durability, usefulness, or strength of a construction work. They are the unacceptable quality of a project which can be identified and remedied. Defective construction works are those which fell short of complying with the specific descriptions or requirements of the contract, especially any drawings or specifications, together with any implied terms and conditions as to its quality, workmanship, durability, aesthetics, performance or design. More importantly, in considering 'defects' as a matter of principle, work may be defective even if it has been carried out with all due skill and care but it fails to satisfy or meet a particular specification. For example, brickwork may be erected correctly but the wrong type or colour of brick could have been used in breach of planning permission (Ojo, 2014).

A construction defect is generally defined as a defect or deficiency in the design, the construction, and/or in the materials or systems used on a project that may not be readily observable and results in a building, structure or component that is not suitable for the purpose intended. Therefore, the term “construction defect” is broader than just defective construction. The term “construction defect” includes both design and construction defects that result in financial harm to the owner (Agola, 2015).

2.1.2 Failures in construction

The construction industry plays an essential role in the economic development of any developing nation and especially in an expanding economy. At least 50% of the investment in various development plans is primarily in construction and the industry is the next employer of labour after agriculture in underdeveloped countries (Ojo, 2014).

There are a number of reasons why building professionals should study the nature and consequences of defects and failures. First, the cost of repairs and corrective maintenance runs into many millions each year. As a result, scarce resources are expended on rectifying many defects that need not have occurred in the first place. Our aim should be to avoid or at least minimize the extent of such building problems. Secondly, the presence and proliferation of faults, particularly within housing, causes needless annoyance or distress to the occupants. Thirdly, the reputation of the industry is being undermined by a seemingly endless stream of incompetent, embarrassing and sometimes dangerous series of failures in construction work. This is reflected in the number of litigation cases against building professionals and contractors (Douglas, 2007).

Every type of building contains defects to some degree. The consequences of some defects may be minor but others are more important and may affect the appearance and usage of the building. However, the cost of rectifying or (worse still) not rectifying building defects could be extensive. In more serious instances, they may pose a hazard to health and safety (Douglas, 2007).

The initial cost of most buildings is high because of the labour-intensive, ad-hoc nature and scale of construction works. As already indicated, it is even more costly and awkward to rectify a failure than it is to prevent it from occurring in the first place. For instance, the installation of movement joints in the external walls of a building is a fairly straightforward operation during its construction. If such joints had been omitted at that stage, installing them at a later date would be troublesome and expensive for both the builder and occupier. Imagine the cost of hiring operatives to carry out this work; materials for the job; the difficulty in obtaining proper access; and the inconvenience and disruption to the occupants (Ransom, 2005).

2.2. Category of Building Defects

Building defects can be divided into two categories, which are (Bakri, 2014):

a) **Structural defect**

Structural defect means any defect in a structural element of a building that is attributable to defective design, defective or faulty workmanship or defective material and sometimes any combination of these. Building structure includes earth retaining walls, columns, beams and flat slabs.

According to the Engineering Encyclopedia, structural defect can be categorized as cracks in foundations (Substructure), cracks in floor or slabs (superstructure), and cracks in walls (superstructure). These defects can be caused by improper soil analysis, inappropriate site selection, and the use of defective materials. Most of the structural problem can be avoided by implying the exact and detail of the design and planning.

Structural defects in a building can occur over time due to deterioration, wear and tear, overloading, and poor maintenance. They must be repaired to maintain the building's structure and to prevent any further failures. Regular inspection is the key to protecting the 'health' of a building's structure. Structural defect that always occurs are steel corrosion, cracks, and deflection.

b) **Non-structural defect**

According to Northern Territory Consolidated Regulation, a non-structural defect in a residential building is described as a defect in a non-structural element of the building as a result of defective residential building work.

According to the Engineering Encyclopedia, non-structural defect includes defect in brick work, dampness in old structures, and defects in plaster works.

2.3 Common Construction Defects

2.3.1 Soil and Foundation Related Problems

Normal foundations comprise concrete strips on which the walls are erected, together with prepared foundations to support any solid floors. It is well recognized that strip foundations must have sufficient width to provide an adequate bearing area to support the imposed load on the ground support concerned; the depth of the foundation strip is important in terms of the ability of the foundations to resist local fluctuations in the bearing capacity of the ground without developing fractures, and the total depth of the foundations is important if it is necessary to excavate sufficiently deeply to provide bearings on better compacted soil or perhaps even rock at a greater depth. The importance of careful preparation of foundations for solid floors is not so widely recognized, as floor loads are much less and the requirements much less severe, but problems commonly arise if the floor slab support is poorly compacted, or support varies on a sloping site between excavated ground at one end and inadequately compacted fill at the other (Richardson, 2002).

Some of the common soil and foundation related problems are described below:

1. Settlement and Subsidence

Settlement is defined as movement in the structure caused by the weight of the building compressing the ground upon which the building stands. All buildings undergo some settlement, and the designer must provide a foundation that will ensure that the settlement is within an acceptable magnitude (Atkinson, 2005).

Settlement is due to normal compaction of the supporting ground as the building loads are imposed on the foundations. Some settlement always occurs during construction, but there is usually some further settlement or creep following completion. Settlement is normal and must be anticipated in design, so that damage due to settlement is an indication of inadequate design in relation to ground conditions or failure to observe the design during construction. General settlement usually occurs on loose ground such as sand or shingle or on readily compressed ground with a high organic and moisture content, such as peat. It is only troublesome because the external walls, the internal walls and solid floors impose different loads and therefore settle to a different extent, the most obvious damage being doming or an increase in height of the floors, although actually it is the walls that are settling around the floors, or settlement of the heavily loaded peripheral walls in relation to the internal partition walls (Richardson, 2002).

Excessive or differential settlement generally results in structural damage to buildings, especially masonry buildings (Atkinson, 2005). For example:

• Foundations built on soft alluvium or peat beds that vary in thickness;

• Foundations built on fill that has poor bearing capacity or has a potential for collapse settlement;

• Foundations built over varied ground conditions.

A special situation arises when buildings are constructed on shrinkable clay soils. Normally clay soils will be moist and in their expanded condition, but abnormal drying may result in shrinkage. Buildings themselves and associated patios, paths, drives and roads all reduce rain penetration into the ground and can result in clay shrinkage damage following construction. For these reasons deeper foundations must always be used on clay soils to provide support below the clay or at a depth within the clay which will not be affected by such moisture content changes (Richardson, 2002).

Subsidence is a downward movement under applied load. It can occur as a wholesale movement whereby the building progressively settles with the soil. This may be small, in the order of millimetres. According to the soil type, it may manifest itself in the first few years following construction, or almost at once (e.g. in granular soil). Clays may react over a long period as they squeeze out the pore water gradually. Minimal subsidence occurring uniformly may produce little in the form of structural problems for the building (Hinks, 2003).

Subsidence occurs when the foundation of a building moves down or up owing to the loss of support of the strata below the foundation or volumetric changes in the strata (Atkinson, 2005). Examples are:

• Wash-out of soils caused by leaking drains;

• Variations in groundwater due to leaking drains or a fluctuating water table;

• softening of clay strata due to water from leaking drains;

• Landslip;

• Mineral extraction, salt brine extraction etc.

• Clay heave or shrinkage due to rehydration of clay soils or frost action, which causes the clays to expand.

Subsidence follows from some unexpected event following construction. Ground water percolation may result in removal of material and loss of support. Water percolation can occur in this way through natural groundwater movement, but usually some event prompts subsidence, such as the diversion of a stream, the overflow of a drainage system, or even a fracture in the rainwater or sewage drains associated with the building itself, although one of the most common causes of subsidence is the fracture of a water main due to frost or traffic damage. Landslip is also another example of subsidence, usually because apparently stable ground has been fluidized through the accumulation of an exceptional amount of rainwater, sometimes causing severe damage to houses and gardens constructed on sloping sites (Richardson, 2002).

2. Trees and buildings

The proximity of trees (or other substantial vegetation) to buildings may cause significant soil shrinkage due to drying. This is a seasonal effect usually, and is most dramatic in clay soils. The root radii of trees vary and can be especially significant for poplar, willow and oak. It is common for tree-related foundation defects to occur within a radius similar to the height of the tree (or less). This may increase to 1.5 times the radius for groups of trees, with mature heights of 20–30 m in ideal conditions for trees such as oak, sycamore, lime and beech trees. This is reduced when grown in heavy clay (Hinks, 2003).

Tree root damage results most obviously from the penetration of tree roots into masonry and beneath foundations, and rupturing due to progressive root growth. Such damage can usually be readily identified by excavation and does not justify special comment, except in relation to safe separation between trees and buildings (Richardson, 2002).

A more serious problem is the presence of trees in conjunction with shrinkable clay. Deciduous trees will remove water from the clay during the summer and the clay will shrink, but the tree will have no demand for water during the winter so that the clay moisture content will increase and it will expand. This seasonal movement can only be avoided by ensuring that buildings are constructed a sufficient distance from established trees, or new trees are planted a sufficient distance from a building. If these requirements cannot be satisfied deeper foundations are necessary to penetrate below the clay, or sufficiently deeply in the clay for moisture content fluctuations to be minimal (Richardson, 2002).

3. Other soil shrinkage and foundation problems

In exceptional and/or prolonged dry periods the soil underneath the building may retain its moisture longer than that surrounding the building. The surrounding soil will shrink and lose its bearing capacity as it dries out; in prolonged drought this effect may extend to the depth of the foundations. The effect on the building is twofold, and manifests itself as cracking. The walls move downwards and outwards and cracks may appear (usually passing through openings) as the walls are placed into tension. Inspection of the surrounding soil will probably indicate separation and cracking in the proximity of the building perimeter (Hinks, 2003).

- **Interaction between soils and buildings**

Under natural conditions, water and air fill the spaces between the soil particles. The properties of soil are influenced greatly by the amounts of water so held, and the volume and strength changes which may occur when this water is reduced or increased. Changes in the behavior of soils influence that of the foundations in contact with them and this affects the behavior of the superimposed building. The building itself, through the loads transmitted via the foundations, compresses the soil and can change its behavior. Interactions between the soil, the foundations and the building are complex and highly dependent upon the forces involved when soils shrink or expand due to loss or gain of moisture (Ransom, 2005).

- **Soil movement**

When the water present between soil particles is removed, the latter will tend to move closer together: conversely, when water is absorbed, they will tend to move apart. Large movement can occur with clays, for these are capable of absorbing and relinquishing large quantities of moisture: drying leads to shrinkage and a gain in strength, and absorption to swelling and a loss in strength. Movement in sands is for the most part negligible, for they have little capacity to hold water. Silts have movement which lies between that of clays and sands. Peat can exhibit very large movement and has little bearing capacity (Ransom, 2005).

Changes in water content of soils may be caused in several ways. The most obvious is that caused when the soil is loaded by the weight of the foundations and the superimposed building. Water is then squeezed out of the soil and the soil particles move closer together. As the ground is compressed or consolidated in this way, the foundations settle, until equilibrium is achieved between the load imposed on the soil and the forces acting between its particles. The more clay there is contained in the soil, the longer does it take for this equilibrium to be achieved. With soils wholly of clay, such settlement may go on for years while, with sands, it is rapid and is substantially finished by the time building is completed. It may be of interest to note that a reduction in loading, such as will be caused by demolition or excavation, can lead to water migrating towards the unloaded soil, causing it to swell—again, appreciable with clays and negligible with sands (Hinks, 2003).

- **Effects of vegetation**

Knowledge that movement can be caused by loss of water through the growth of vegetation and to gain of water by its removal seems to have been overlooked—at least, up until 1976, when the severe drought and hot weather in the UK led to a rash of troubles. Tree roots can extract large quantities of water from soil: a fully grown poplar uses over 50 000 litres in a year. When the soil is of clay, this will lead to a drying shrinkage, the magnitude of which will depend upon the inherent properties of the clay and, of course, on the nature of the tree and its moisture requirements. If tree roots take up moisture from under, or near to, foundations, the latter will subside and such subsidence will almost inevitably be uneven (Ransom, 2005).

- **Effects of foundation movement**

The greatest problems have occurred when shrinkable soils have dried excessively through the removal of moisture by nearby growing vegetation. Such drying is likely to be greatest at the corners of foundations. As the ground falls away, the weight of the building pushes the then suspended parts of the foundations down and the walls in that vicinity crack. Cracking is predominantly diagonal and follows the vertical and horizontal mortar joints in brickwork, unless the mortar is abnormally strong for the bricks used, when cracking may occur through the latter. The cracks are widest at the top corners of the building and decrease as they approach ground level. The appearance of cracks of this pattern at the end of a specially dry summer is a fairly sure sign of desiccation of a shrinkable clay soil. Door and window frames also distort due to the deformation of the walls, leading to their sticking or jamming. In severe cases, service pipes may fracture, walls may bulge and floors may slope noticeably.

The cracks tend to close partly, following periods of prolonged rain, for example, by the end of the following winter (Ransom, 2005).

2.3.2 Concrete problems

The first use for concrete in buildings was in the construction of ground floor slabs, originally unreinforced but now almost always steel reinforced, as it enables a thinner slab and less concrete to be used to achieve the same strength and reliability. Reinforced concrete was subsequently used for the construction of suspended floors, and eventually for beams and posts (Richardson, 2002).

2.3.2.1 Mix design

Concrete mixes were originally specified in volume proportions as concrete was prepared in this way, but batching by weight was found to give much more consistent mixes with more reliable results; concrete is now prepared only in this way, although mortar for jointing and rendering is still usually prepared on site by volume. In recent years it has become less usual for engineers to specify an actual mix, but instead to specify a particular strength designation, the contractor being required to demonstrate using test blocks that their chosen mix will achieve the strength requirements.

These progressive changes in specification method have simplified the situation for design engineers but complicated the situation for contractors. Several problems have developed which can be attributed to this change of emphasis in specification which encourages contractors to adopt a policy of ‘if in doubt add more cement’ to ensure that the concrete meets the specified strength requirements, the various guidance documents emphasizing the importance of an adequate cement content. In fact, excessive cement may lead to high shrinkage; this will either manifest itself as shrinkage of the concrete elements during curing, or as fractures or crazing of the surface of the concrete. The water to cement ratio is also critical, and if the amount of water is excessive it can encourage excessive shrinkage (Ransom, 2005).

2.3.2.2 Aggregate

Concrete consists of aggregate which is bonded together to form a solid material, and the proportion, grading and type of aggregate have a profound influence on the properties of the final concrete product. Aggregate grading is particularly important. Concrete is generally strongest, most stable and least expensive if it uses the largest possible aggregate, but the largest aggregate size must not be more than two-thirds of the smallest space that the concrete is required to fill, the critical dimensions usually being the cover over reinforcement, the minimum space between reinforcement components or the depth of a slab. Ideally aggregate should be continuously graded so that it contains an appropriate proportion of smaller particles to efficiently fill the gaps between larger particles, although in practical terms it is usual to mix large and small aggregate in appropriate proportions to reasonably satisfy this requirement. Small or fine aggregate is itself available in a series of grades which can be further mixed to improve overall aggregate grading, although it is important to avoid the use of excessively fine aggregate, or aggregate containing dust or clay particles. If excessively fine aggregate is present it will be necessary to increase the water content to maintain workability, and the resulting increase in the water to cement ratio will then result in excessive shrinkage (Richardson, 2002).

2.3.2.3 Reinforcement

Although a variety of reinforcements are available, including mineral, glass and carbon fibres, as well as various metal meshes and rods, steel is most widely used and the most serious problems are associated with steel corrosion.

Steel corrosion can only occur in the presence of moisture. The high alkalinity of the cement paste surrounding the steel reinforcement normally inhibits corrosion, but the alkalinity is progressively lost by carbonation and steel corrosion can eventually develop. A reasonable period of freedom from corrosion is normally achieved by specifying a minimum concrete cover over the reinforcement, usually 50mm (2"), although the life that this achieves will depend upon the density of the concrete and the porosity of the aggregate. If cover is inadequate over reinforcement, or even over tie wires, corrosion becomes apparent as unsightly patches of brown staining and brown water runs, but progressive corrosion of reinforcement rods results in expansion and spalling of the concrete surface which is unsightly, as well as being destructive and dangerous. Various methods have been proposed for inhibiting this damage; they usually involve cutting out the spalling concrete to expose fully the corroded reinforcement, removal of the corrosion and treatment of the reinforcement with tar, bitumen or resin coatings in an attempt to prevent further corrosion, followed by patching the spalled concrete, usually with resin repair systems (Richardson, 2002).

Over-stressing, that is, the imposition of loads in excess of the capacity of the structural components can result in structural failures. Collapse is, of course, the ultimate and most serious result, but over-stressing is also evident at earlier stages through the development of distortion and fractures. If a structure is correctly designed and constructed in accordance with the design, over-stressing indicates some other inadequacy, such as the use of an unsuitable material (Atkinson, 2005).

Although a building structure is normally designed to be rigid and inflexible, a considerable amount of movement actually occurs. The main causes of movement are simple expansion and contraction due to changes in temperature or moisture content. They must be repaired to maintain the building’s structure and to prevent any further failures. Such movement is not usually too serious if it affects the entire structure uniformly, but problems can arise through differential movement between parts of the structure differently affected by temperature or moisture content, or parts constructed in different materials which respond in different ways. In a very long structure, shrinkage may cause tensions which result in fractures, and both design and construction should allow for this movement by the provision of vertical movement joints with regular intervals. Internal problems in buildings are usually associated with differential movement due to contrasting properties of adjacent materials. A concrete building will generally shrink as it cures, this shrinkage being fully developed only after perhaps a year or two; installed materials which are too rigid to absorb this shrinkage must be provided with movement joints, the most obvious examples being granite, marble or ceramic tiles on walls and floors. With wood strip or block floors, the wood should be dried or seasoned to the average moisture content that it will achieve in service before it is installed (Richardson, 2002).

Moisture content variations are the usual cause of movement in structural materials, such as concrete, masonry and wood, but only thermal movement is significant with metals. Steel beams and lintels are not often the cause of differential movement problems in masonry, but metals subject to extremes of temperature often cause problems. The main problems in normal service involve hot water and heating pipes, but in a fire initial heating often causes considerable expansion and severe damage to a structure, usually sufficient to prevent repair even if the fire is extinguished at an early stage (Richardson, 2002).

Disregarding wear and tear and the breakdown of inappropriate building materials, structural defects can result from (Atkinson, 2005):

- Excessive foundation settlement or differential settlement;
- Subsidence caused by active mining or the collapse of old mine workings;
- Subsidence as a result of trees drying out clay soils below a foundation;
- Heave on foundations due to re-hydration of clay soils following tree removal;
- Failure to provide for expansion of masonry in long terrace blocks;
- Inadequate design of the foundations and super-structure;
- Bad workmanship

2.3.4 Floors and Floor Finishes

Floors exhibit a range of defects related to their expected performance in use. The main functions of flooring are structural adequacy, including the transfer of all loads (dead and imposed) to the ground or the walls/ foundations without deflecting excessively; to resist water penetration; to control thermal losses; and to provide a safe and stable surface. Special requirements include fire resistance and control of acoustic transmission. Floors can be deficient in any or all of these contexts. Floors may be structurally inadequate because of failures in their bearing at their end supports (or in the case of large spans, possibly at the mid-support also). They may also be defective through excessive span for their sizing, or overloading beyond design specification. Excessive notching, especially in the sensitive middle third of the span, can produce bending as a result of overloading (Hinks, 2003).

2.3.4.1 Hardcore

Hardcore is used to fill small depressions on sites and to adjust the amount of concrete needed in an over-site slab, following removal of topsoil from the site. It is also used on soft and wet sites to provide a good working surface and one which will not affect adversely the over-site concrete during placing. It has, too, some value in reducing moisture uptake from the ground. Hardcore is deemed to satisfy the building regulations when it consists of clean clinker, broken brick or similar inert material free from water-soluble sulphates or other deleterious matter which might cause damage to the concrete. Materials mostly used in practice are concrete rubble, broken bricks and tiles, blast-furnace slag, various shales, pulverised fuel ash, quarry waste, chalk, gravel and crushed rock (Douglas, 2007).

- **Hardcore and sulphate attack**

A particular hazard to concrete floors can arise from the presence of soluble sulphates in hardcore or in the ground water. Solutions of sulphates can attack the set cement in concrete, the severity of attack much depending upon the type of sulphate present and the level of the water table. Broken bricks and tiles may contain soluble sulphates and, moreover, may be contaminated with gypsum plaster. Coal mining waste, too, usually contains soluble sulphates. Burnt colliery waste from old tips tends to have higher soluble sulphate content than unburnt spoil and, when used as hardcore on wet sites, has frequently caused failure of over-site concrete. Other materials used as hardcore which can contain soluble sulphates include spent shales left as residue following the extraction of oil from oil shales, pulverised fuel ash, particularly if mixed with furnace bottom ash, blast-furnace slags derived from iron-making and shales containing pyrites (Ransom, 2005).

- **Hardcore and swelling**

Similar damage can be caused to floors by the swelling of hardcore due to factors other than sulphate formation. Materials likely to swell from these causes are principally slags derived from steel-making, for these may include unhydrated lime or magnesia, some colliery spoils containing clay and refractory bricks used in chimneys and furnaces. These materials therefore should not be used as hardcore (Douglas, 2007).

2.3.4.2 Damp-proofing of floors

Dampness is generally defined as unwanted and excessive water or moisture. The existing of dampness in building is one of the most damaging failures that really must be taken care of. It can cause damage in brickwork by saturating them, decaying and breaking up of mortar joints, rotting in the timber structures, defecting by the corrosion of iron and steel materials and also destroying the equipment in the building. Dampness in walls has been taken in consideration in recent years. If even the level of dampness is low, the value of the building can be highly affected (Bakri, 2014).

Dampness in flooring can produce a range of direct problems in the form of localized rot (dry or wet rot). If unattended, this rot can become extensive, especially where a lack of ventilation due to blockage or omission of air bricks and cross-ventilation occurs. This can cause particular problems where isolated solid floors create zones of dead air in abutting timber flooring. It is important to be able to identify the sources of the damp. Common sources include flooding of underfloor voids via air bricks or breaches in DPMs, DPCs and/or their connections. Direct water penetration may also occur with plumbing or drainage which may have been damaged by another movement related defect (Hinks, 2003).

Rot may extend to sole plates and floor coverings, which with chipboard flooring can be quite destructive. Chipboard can exhibit a range of defects. It must be well supported and fixed, and of the correct (flooring) grade with appropriate perimeter detailing. The consequences of inattention to fixing details can include sagging or buckling or loose, squeaking boards. Floors frequently exhibit secondary defects in buildings suffering other problems. They can be a vital stiffening component in a building, however, and must be considered as an important item during inspection (Hinks, 2003).

Figure 2.1. Rising Dampness (Bakri, 2014)

Dampness also occur when water penetrate through capillaries or cracks between mortar joints, and bricks or blocks before building up trap moisture behind hard renders. Moreover, contribution of dampness is due to the existence of gravity. The other factor such as leaking gutters or down pipes, defective drains, burst plumbing, and condensation due to inadequate ventilation also can be the factors yielding to dampness occurrence. Dampness in building originated from a number of sources such as (Bakri, 2014):

a) **Rain**

Precipitation can be wind driven that it penetrates joints that remain watertight in normal weather condition. The gutter overflow also can collect and be the aspects of dampness against walls.

b) **Condensation**

Humid air condensation on cooler surface or within, or between, building materials also can result to dampness. Air can become humid in several ways, including from the occupants' water vapours.

c) **Construction process**

The construction process too can play its role in this scenario. It is where the process of mixing water to form mixtures that dry out for the construction purpose before the building is functioned, but sometimes by retaining moisture (sealed in by impermeable finishes) that shows and causes problems in the completed building.

d) **Use of the building**

This may include the cleaning of the building, spills, and apparatus leaking.

e) **Moisture in the air**

It is in contrast with condensation. Hygroscopic salts can extract moisture from the air in condition that would not allow that moisture to undergo the process of condensation.

To prevent the rising of moisture from the ground and into the floor finish, it is necessary to provide damp-proofing both in the walls and in solid ground floors. A horizontal DPC in walls is required to be not less than 150mm above ground level. Concrete bases and screeds will allow ground moisture to pass through and it is necessary to provide a damp-proof membrane (DPM) either as a sandwich layer within the thickness of the concrete or upon the surface of the concrete. (In the latter case, the damp-proof layer usually provides the final floor finish, for example pitch mastic or mastic asphalt). These two requirements seem to be generally understood, though not always properly specified and achieved. A crucial need, however, is to link the DPC in the wall with that in the floor by means of a projection of the DPM (Ransom, 2005).

2.3.4.3 Concrete floors

The main problem with concrete floors, apart from sulphate attack, has occurred through failure to remember that concrete shrinks on drying and, in so doing, tends to crack and to exert stress at the interface between it and floor screeds and finishes. There has also been a failure to recognise that concrete does not present a surface which allows ready bonding of superimposed finishes (Douglas, 2007).

- **Screeds**

Most constructional problems have occurred with concrete floor screeds. It may well prove possible, however, to make the surface of a concrete base sufficiently level and smooth to accept the final floor finish without using a screed, and this has much to recommend it. If a screed has to be applied, care is needed to get a good bond between it and the concrete base. If the bond is poor and shrinkage stresses are high, the screed will crack, with a tendency to curl at the edges of the cracks: if the screed is tapped the floor sounds hollow. Finishes applied over the concrete screed, such as tiles and sheet coverings, are also likely to crack and split and, ultimately, lose their adhesion to the screed. There are several factors which enhance the shrinkage and cracking of concrete screeds and weaken its bond to the base concrete. The principal ones are inadequacies in the mix design of the screed and of the base on which it is to be cast; poor texture of the surface of the base concrete; too long an interval between casting the base concrete and the screed; an inadequate curing regime for the screed; too large an area of screed laid in one operation; and too thick a screed (Douglas J., 2007).

Screed requires a high standard of workmanship to produce a durable finish. Excessive trowelling can produce surface crazing. Large areas of screed laid in one operation can cause random cracking due to differential shrinkage. Alternatively, laying screeds in bays can cause the edges to curl. This may show through thin finishes. A rapid curing time for screed can result in considerable shrinkage and a general loss of strength of the screed. Where screed is not laid over a DPM there is a risk of dampness problems. An inadequate bond between the screed and the base concrete is a common failure mode. This may be due to the following (Hinks, 2003).

- Poor mix design of screed. In general, mix proportions of>1:3 cement to aggregate or<1:4.5 may result in differential movement between the screed and the base concrete.
- Excessive water. This may be added to improve the workability of the mix. The high surface area of the small-sized aggregate can tend to reduce workability. Although adding more water will increase shrinkage it may also cause laitance to form on the surface of the screed, causing dusting.
- Too much time between casting base concrete and laying screed and a poor texture of concrete base. These factors are related to the time between casting and laying the screed. The base concrete may not be swept clean of site debris. Where the time between laying concrete and screed to get monolithic construction is>3 hours then the screed and concrete may shrink differentially. Where the screed is laid within 3 hours of the base concrete but exceeds 25 mm thickness or contains aggregate>10 mm then differential shrinkage can occur. Where the screed is laid on mature concrete it may fail if there is inadequate mechanical key, formed by hacking or scarifying, with the concrete base.

- **Terrazzo**

Terrazzo consists of a mix of cement and a decorative aggregate, usually marble, of a minimum size of 3 mm, and this is laid on a concrete screed. The failures that have occurred are of cracking and crazing, and lack of good bond to the screed. The risk of surface crazing is increased by too rapid drying. This has been a common problem caused by failure to cover the terrazzo with sheeting and by too great an absorption of water from the terrazzo mix into the screed. Surface crazing can be caused, also, by too rich a mix but the use of an excessive amount of cement seems hardly likely to be a common problem today (Douglas, 2007).

Terrazzo is normally laid onto screed. It may fail because of bonding in the same ways as described for screed. Cracking is commonly due to poor curing over a short time period. Shrinkage effects may become concentrated and the rapid drying-out of the mix may mean that long-term strength is reduced. Surface crazing may be due to excessive cement content in the terrazzo. Powdering of terrazzo finishes may be due to wet mixes; this can cause laitance and produce permanently weak mixes (Hinks, 2003).

- **PVC tiles**

The moisture from an insufficiently cured screed, a failed DPM or a failed DPC/DPM junction can cause loss of tile adhesion. The moisture, being alkaline, attacks the adhesive used to stick down the tiles. Tiles with adhesive attached may become detached from the concrete, some curling at the edges. The tiles may be stained from failed adhesive or sodium carbonate following evaporation of the moisture. The sodium carbonate can be absorbed into the tile and cause embrittlement and cracking. The adhesive may fail owing to excessive use of general cleaning water. Under dry conditions tiles may lift because of the delay between laying the adhesive and laying tiles. Adhesion can be reduced as the adhesive starts to set. Some adhesives allow the plasticizer from tiles to migrate into the adhesive, softening the adhesive. The floor tiles are then able to move around and joints between them can open (Hinks, 2003).

Of all the elements in and on a building, the floors are subjected to the most wear and tear and maintenance treatment. They are also vulnerable to aggressive agents from below (ground moisture and soil chemicals) as well as chemicals and imposed loadings from above.

As a result, floors, floor finishes and DPMs have to be especially resilient to prevent premature failure (Douglas, 2007).

2.3.5 Masonry problems

Masonry comprises the parts of a building, mainly the walls, which are constructed using blocks of materials set in mortar, and includes stonework, brickwork and block work. Masonry suffers some structural movement due to moisture content and temperature changes, and it may be necessary to incorporate vertical movement joints to accommodate horizontal movement. Where the masonry forms an external weather protection to a structure of a different nature such as a timber, concrete or steel frame, horizontal movement joints may also be necessary to accommodate differential vertical movement (Richardson, 2002).

Masonry deterioration is always associated with excessive moisture contents and design precautions are therefore necessary to minimize moisture absorption. Damp-proof courses must be provided to prevent absorption from the soil by capillarity, as well as copings, eaves and gutter details designed to minimize absorption at wall heads, although such precautions cannot give protection against driving rain (Richardson, 2002).

2.3.5.1 Brickwork and block work

Bricks are commonly manufactured by firing natural clay, although they are also manufactured from aggregate; calcium silicate bricks are manufactured by autoclaving sand or crushed flint with lime, but ordinary concrete mixes are used in some areas. The resistance of these bricks to frost and salt crystallization damage depends, as for natural stone, on their porosity characteristics, macroporosity always being more durable than microporosity.

Clay bricks sometimes exhibit dark specks or brown streaks during weathering which are generally due to coal incorporated into the clay during manufacture. These effects are largely aesthetic, but natural clays also contain salts and shells which can cause more serious structural damage (Richardson, 2002).

Blocks are usually manufactured from various types of concrete. Normal dense blocks use normal concrete mixes based on natural or crushed aggregates, whilst lightweight blocks use either lightweight aggregates such as clinker, expanded clay or foamed slag, or alternatively use a fine powder aggregate coupled with aeration to reduce the density. Compressive strength varies enormously, although generally dense blocks are stronger than lightweight blocks. Thermal and moisture movement precautions in blockwork are the same as for brickwork, and blockwork is basically identical in properties to brickwork constructed from concrete bricks, except that jointing in brickwork tends to be more consistent and reliable than in block work due to the manner of construction. In some areas blockwork is used almost exclusively, but generally finished externally with render. Usually, external walls are constructed using independent blockwork leafs, joined only by normal ties as for brickwork walls, but in some areas hollow concrete blocks are used to construct solid walls, introducing thermal insulation problems, as well as water penetration problems unless great care is taken with the design and execution of the external render (Hinks, 2003).

2.3.5.2 Mortar and render

Joints in brickwork and blockwork, as well as render and screed finishes, usually involve mortar, that is, concrete prepared using only fine aggregate or sand. The strength of a mortar is very important in relation to its use, and mortar designations have now been generally adopted to classify mortars in this way, Lower mortar mix numbers indicate increased strength and improved durability, whilst higher mortar mix numbers indicate increased flexibility and improved ability to accommodate movement due to temperature or moisture changes. Cement and sand mixes are generally more resistant to frost attack during construction than cement/lime/sand mixes, but cement/lime/sand mixes give improved adhesion and are generally more resistant to rain penetration (Richardson, 2002).

2.3.6 Problems Related To Finishing

2.3.6.1 Plaster and Rendering

Plaster and render is mortar coating over the block work. The coating on the inside walls is called plaster, while the coating outside the walls is called render. The render is generally richer in cement than the plaster to be weather resistant (Bakri, 2014).

Most present-day mortars consist of cement and sand—with or without an air-entraining agent—or cement, lime and sand. Mix proportions depend upon the types of brick and block used and their exposure. The effects of shrinkage caused by drying and by carbonation are generally insignificant. Mortars can be affected by frost but their resistance can be increased through the use of an air entraining agent (Ransom, 2005).

Serious disintegration of mortar can occur when soluble sulphates, sometimes present in wet brickwork, react with tricalcium aluminate, present in ordinary Portland cement mortars. A considerable increase in the volume of the mortar can then occur which causes the mortar to split and to become friable. Similar sulpho-aluminate attack can occur when mortar is exposed to condensed water vapour containing sulphates derived from flue gases. This was a particular hazard when slow-combustion fuel appliances were used with unlined chimneys.

Typical external renderings are broadly similar in composition to mortars and have similar properties. Sulphate attack can occur through salts derived from wet brickwork: frost attack is rare. Drying shrinkage can be more of a problem and strong cement/sand mixes can craze and crack, particularly if applied in warm, dry weather (Ransom, 2005).

Plaster can fail where the incorrect plaster has been applied to the background or there is insufficient mechanical key. The browning or undercoat should be matched to the suction and mechanical key provided by the background. The finish coat must then be matched to the undercoat or browning. Within the context of failures in plaster, the failure to match plasters and backgrounds is relatively common. The bulging of large areas of plaster, perhaps with associated cracking, may be caused by a failure of the plaster to adhere to the substrate (Hinks, 2003).

Mostly the defective plaster rendering occurs on the external walls, column and ceiling. Defective rendering are normally caused by biological attacks arising from penetrating rain, evaporation, condensation, air pollution, dehydration and thermal stress. The mould or harmful growth, insect, animals, and traffic vibration also will contribute to the causes of defective plaster rendering. Prior to being decomposed and broken apart, rendering may crack due to either shrinkage or movement in the substrate (Bakri, 2014).

A failure to wet high-suction backgrounds can reduce the bonding between plaster and background and may reduce the strength and durability of the plaster. A plaster finish coat can be applied to certain types of plasterboard. Boards commonly have two surfaces and application of the finish coat to the incorrect side results in inadequate bond and failure.

Because gypsum plaster is very sensitive to dampness, it may fail in locations where the background has high moisture content, e.g. walls above a newly inserted DPC or in defective basements (Hinks, 2003).

Moist plaster can cause corrosion of ferrous metals within it. This is due to the relatively acidic nature compared to cement, of gypsum plaster. Cracking of plaster may be associated with the thermal and moisture movement of the background. They may also be due to structural movement. Differential movement can cause cracking at internal corners where a plasterboard ceiling meets an in-situ plaster wall. In-situ plaster on concrete block walls can fail where the blocks were damp when the plaster was applied. The concrete block work will shrink when drying out and the plaster will expand when drying out, causing the plaster to become detached. Where a cementitious undercoat is applied, this may move with the block work, causing only the finishing coat to become detached. Plasterboard ceilings can crack along the joints of boards, particularly where the joints are not correctly made. Sagging boards may be related to inadequate fixings, particularly a lack of noggins at plasterboard edges (Hinks, 2003).

Renderings may crack, craze and become detached from their background, however, even in the absence of sulphate attack, through differential movements between the background and the rendering. Cement-based renderings shrink as they dry, particularly the strong, dense mixes such as a 1:0.25:3 cement: lime : sand mix. The effect of this shrinkage of renderings on rigid backgrounds is to set up stresses which may be relieved by cracking or by loss of adhesion. The cracks may then allow rainwater to pass through them but prevent its ready evaporation afterwards, which can assist sulphate attack, as already described. Cracking from shrinkage, and in the absence of sulphate attack, is likely to be random and, if tapped, the rendering may sound hollow. Differences in drying shrinkage characteristics between the top coat and the undercoat of renderings can also lead to defects. If the top coat is richer in cement and, thereby, stronger, with a greater drying shrinkage, it can pull away from the undercoat over small or large areas. When the undercoat is considerably weaker, parts of it may come away with the top coat (Douglas, 2007).

2.3.6.2 Paintwork

Defects in paintwork arise from many causes, mostly in combination, but the main culprits are exposure to sunlight (especially so with dark coatings) and rain. Pollution and a range of instabilities of the background can also cause problems. Deficient paintwork may also indicate deeper problems. Paintwork relies heavily on thorough and appropriate maintenance. Deferred maintenance allows the protection to diminish, thus leading to greater damage to the background. The cost of renovatory work also increases, since paintwork in an advanced state of decay is more difficult to prepare and remedy (Hinks, 2003).

Poor paint adhesion occurs if the background is damp during application. Painting in high-humidity conditions will affect the quality of the coat and its eventual durability.

Water-related problems will arise during the life of the coating if condensation occurs behind the paint, or if surface defects allow water to penetrate the surface coating on a large scale.

- **Timber backgrounds and paint defects**

The principal function of external paintwork is to control the entry of water into timber. Wood alters its moisture content to approach equilibrium with the environment and this produces disruptive changes in size. The changes are not the same in all directions: more expansion occurs across the grain than along it.

If timbers are continually changing in moisture content this can give rise to deterioration caused by splitting and distortion. The grain may become obvious and unsightly, too. The extent of moisture-related movement that timber undergoes depends on the particular wood. However, this can be significant enough to cause problems with poor-adhesion paints (Hinks, 2003).

- **Flaking**

'Flaking' occurs with the loss of adhesion between the paint layer and substrate, so that small particles break away. Paints bond less effectively to non-porous surfaces, and some oily hardwoods such as teak are troublesome. Flaking and other bond-related faults occur more easily with such surfaces. All or some of the paint layers may be affected. Flaking is usually an external problem, which tends to arise with hard-drying paint types, or any paint applied to a friable surface. Timber backgrounds can also promote early flaking of paint because of trapped moisture, and this problem is particularly likely at the joints which will experience the greatest movement (Hinks, 2003).

- **Peeling paint**

Peeling usually occurs on building facades, mainly on plastered walls, columns and other areas which are exposed to excessive rain and great dampness. Peeling paint is usually the result of poor surface preparation. The majority of peeling paint problems occurs on surfaces exposed to the rain, sun, and the variation degree of temperature. Walls that have involved can be an unsightly mess in a home or building. It may result in embarrassment and frustration to the homeowner. If paint peels from an interior wall, the reason for the peeling paint is mostly often due to an improper preparation of the surface before painting. Apart from that, the moisture surrounding the wall also seeps in through from the wall to the paint surface. Thus, in order to repair and restore, repainting the wall that had peeling paint on it can be made as to make it attractive again (Bakri, 2014).

‘Peeling’ is a large-scale form of flaking produced by differential movement. It can be caused by the paint layers on their own, as a reaction to other (background) paints or between the paint coating and the substrate. This is distinct from ‘cissing’, where layers ‘roll off the background. Cissing is produced by incomplete wetting of the background, leading to patchy adhesion (Hinks, 2003).

- **Checks and crazing**

Poor-quality paints may develop ‘checking’ in the form of ‘V’ or ‘crows-feet’— shaped cracking. These cracks are very fine and whilst these do not immediately threaten the protective properties of the film, if left unattended will lead to ‘crazing’ (or ‘alligatoring’). Crazing defects arise most frequently with paints based on or containing bitumen. They occur when hard coatings are applied to soft backgrounds. As these dry they shrink and distort the background. Adding excessive driers can produce the same effect. Patterned cracks form in the dried paint but the defect does not always penetrate the film completely. The cracks are raised above the surface producing an alligator skin effect (Hinks, 2003).

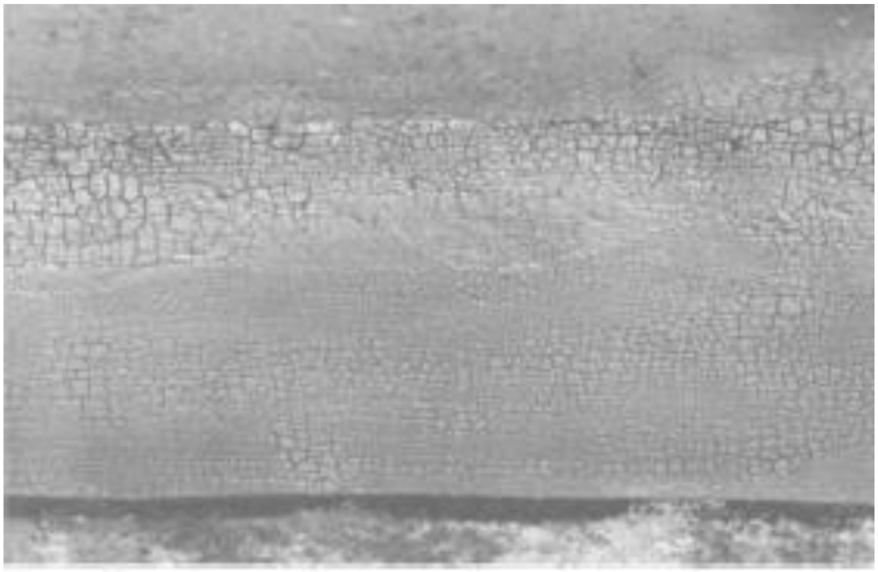

Figure 2.2 'Alligatoring' of a paint film (University of Reading) (Hinks, 2003)

2.3.7 Roof Related Defects

Roofs are among the most difficult parts of a building to survey and unless access to adjacent properties allows a view from above. Modern pitched roofs generally consist of a timber frame covered with an impermeable barrier that is composed of small units such as tiles or slates—though other traditional coverings such as thatch and cedar shingles can also be found in use.

Trussed rafter roofs require careful storage and handling if they are to perform satisfactorily. Poor storage leads to a high moisture content that will not reduce rapidly in poorly ventilated and highly insulated roofs. Older roofs are likely to have been framed in situ and rely on the quality of the workmanship to perform satisfactorily (Hinks, 2003).

- **Clay tiles**

Clay tiles are still made but their expense has led to old tiles being reused. It is, however, essential that badly weathered or defective tiles are rejected. Underfired tiles can delaminate because of frost, but this is difficult to assess (although evidence of satisfactory performance is a good guide). In general the single-lap tiles are suitable for steep pitches of more than 40°.

Where the pitch is shallow, water may enter through the laps, owing to an increased angle of creep (Ransom, 2005).

The fixing of ties to tiling battens using nails can fail because of continual condensation on the underside of the roof covering. The nailing positions are always covered by two other tiles and so replacement of tiles requires support from the tiles (usually lower) next to them. In many cases defects with tiles are difficult to repair without causing further problems.

Reduced ventilation between the tile and the underlay can cause this fault, which in turn can lead to increased susceptibility to frost attack. The problem tends to increase as the pitch reduces. Adequate lapping and support of the underlay felt, particularly at the eaves, is essential to stop water getting in (Hinks, 2003).

- **Concrete tiles**

Many of the points concerning repairs for clay tiles can be applied to concrete tiles too, since although the materials are different, many of the concrete designs were based on clay models.

The high density of concrete tiles can lead to the roof timbers being overstressed where roofs which were previously covered with clay tiles are re-covered with concrete tiles. The risk can be structurally determined, so that any necessary reinforcement of the roof can be established under reduced imposed loads.

Acidic atmospheric pollution will slowly etch cement away from the upper surface of the tile, so that it accumulates in gutters and downpipes (Hinks, 2003).

- **Insulation-related defects**

Insulation in pitched roofs at ceiling level can increase the incidence of condensation, which can be reduced by adequate roof ventilation.

Condensation creates conditions suitable for fungal attack and corrosion of metal fixings and so weakens the roof timbers. Where ventilation has been provided, this can become blocked by insulation or stored items. Masonry carried up to the underside of the roofing felt causes the same effect (Hinks, 2003).

- **Sagging and hogging in pitched roof structures**

The rigidity through triangulation in traditional roofs with purlins and ridge plates meant that a roof in good condition would be self-restraining. Rotting in timber roof frames at connections or bearing points can lead to unbalanced forces being imposed on the supporting walls, as the roof transfers loading and sags. In essence, the well-braced and triangulated structure can revert to a series of two-dimensional unbraced components which are unstable. It is normal for roof frames (and floors) to be structurally supported on the inner leaf of cavity walls, and it would be usual for distortion and cracking to appear in the inner leaf. The eaves area is especially vulnerable because of the low resistance to side forces coupled with unusual self-weight (Hinks, 2003).

- **Problems with roof timbers**

The difficulty in replacing structural timbers is due to the need to relieve loading during the operation. In certain older buildings there may also be a general reluctance to remove or replace parts of visible elements such as roof trusses which may have historic value.

Any localized stiffening of the timber may cause movement stresses, and the change in thermal conductivity and/or vapour permeability could lead to condensation inside the timber at the interface between treated and untreated parts, possibly initiating new decay (Hinks, 2003).

- **Flat Roofs**

Flat roofs fail because they let rain through, construction water is trapped which afterwards drips out, or moisture generated within the building condenses and drips back. Moisture from the last two causes can also assist in the breakdown of the waterproof covering which, in turn, can lead to rain penetration. With some roof decks, the continued presence of moisture has been a contributory cause of structural failure. A major cause of leakage has been an insufficient slope to the roof. A designed fall of 1 in 80 does not result in a finished fall of that gradient. Variations in constructional accuracy, settlement, and thermal and moisture movement, lead to lower finished falls. Local areas of the roof, too, can deviate markedly from the overall falls, particularly around features such as roof drains (Ransom, 2005). Ransom)

Figure 2.3 Ponding on flat roof—a state typical of many flat roofs (W. H. Ransom)

- **Dripping of moisture**

Water used in the construction of concrete decks, and in lightweight concrete screeds used to provide falls and as thermal insulation, can be slow to evaporate. It may be difficult to decide the exact cause of dripping, but that originating from trapped rain or construction water will have no marked seasonal tendency to manifest itself, while that due to condensation is more associated with the winter. If it has been through leakage of the waterproof covering, then it will be associated with rainy periods though not necessarily coincident with the rain. The position at which drips appear can, of course, give some indication of the cause. Thus, defects in parapets, skirtings and verges are likely to result in drips near the junction of the ceiling and external walls. Defects caused by movement at construction joints may well give rise to drips near the junction of ceilings with internal Load bearing walls (Ransom, 2005).

- **Roof coverings**

Pitched roofs are traditionally covered with slates or tiles. Slate rock is formed when successive layers of mud are metamorphosed under heat and pressure to form solid rock, although the layers result in a laminar structure which enables blocks of stone to be cleft into the sheets which are more familiar as roofing slates (Richardson, 2002).

Traditional tiles are manufactured from clay, and their durability depends on their porous properties, particularly pore size distribution; tiles are generally more susceptible to frost damage than bricks because of their greater exposure to rainfall and the higher risk that they will be saturated when freezing occurs. Durability is also related, but to a lesser extent, to the cohesive strength of the baked clay, and in tiles from a single clay source it is normal for well fired darker coloured maroon or mauve tiles to be more durable than underfired pink or orange tiles. Traditional plain tiles have a slightly domed shape which avoids close contact between successive courses, avoiding capillarity between adjacent tiles and allowing them to dry more readily, again improving the durability of the tile roof covering (Richardson, 2002).

2.3.8 Problems Related to Building Services

2.3.8.1 Plumbing and Drainage

The soils through which cold-water supply services pass can vary considerably, from comparatively non-aggressive light sand and chalk to heavy clays containing organic matter suitable for the development of bacteria which can assist corrosion. Some sulphate and chloride-bearing soils can be very aggressive. Ground to a depth of up to 1200 mm is of main interest and here the natural soil may be contaminated, anyway, by a wide variety of builders' rubble. When corrosion or other faults do occur in buried pipework, repair tends to be costly. Protective tapes and wrappings are called for in many areas where galvanized steel is used. Protective tapes are usually recommended to be wrapped spirally around the pipe, with at least a 50% overlap, giving a double layer of tape. Wrapping is a time consuming task, however, and one which requires good supervision if gaps are not to be left which will present an area for concentrated attack. Some tapes, too, can be degraded by bacterial activity and fail unless they, in turn, are protected by an outer, inert plastics tape, also wrapped spirally to give a double thickness (Ransom, 2005).

Metal corrosion in plumbing is most severe with acid soft water which can cause direct corrosion of lead and copper pipes, sometimes resulting in excessive lead or copper content in the water. Lead is the most serious problem and the use of lead supply pipes is now discouraged or forbidden by most water companies. The most severe corrosion problems result from electrochemical action through the use of different metals connected together in a system. If iron and copper pipes are connected, progressive corrosion of the iron will occur, this corrosion often accounting for leaks in supply pipes or where copper pipes are connected through control valves to steel radiators. Corrosion inhibitors can be added to closed circuits such as radiator systems and calorifier circuits in hot water systems and can very effectively reduce corrosion, although some proprietary systems are distinctly more efficient than others. These variations in properties may be associated with the ability of the corrosion prevention chemicals to encourage or prevent development of sulphate reducing and similar bacteria that can develop in these anaerobic closed circuits, despite their high temperatures (Richardson, 2002).

Routine problems with drains are generally associated with obstructions which can often be attributed to unsuitable falls. If the falls are inadequate or vary, foul water drains will be unable to clear solid materials, but if the falls are too steep the solids may become stranded through excessively rapid drainage, again resulting in blockage. Falls are therefore critical, but foul drain runs must also be constructed to avoid sumping through settlement. Blockages usually occur at bends and it is therefore prudent to provide a manhole or rodding eye at every bend to facilitate rodding (Ransom, 2005).

Water and sediment in foul water drains rapidly becomes anaerobic through the high organic content of the sewage, encouraging the development of anaerobic bacteria, such as sulphate reducing bacteria. These bacteria encourage rapid metal corrosion of iron and steel pipes, causing premature failure in sewers with intermittent flows; where there are continuous flows the sewerage is often sufficiently aerobic to avoid these problems. Sulphate reducing bacteria liberate hydrogen sulphide gas into the air space above the sewage and this is absorbed by condensation where it is rapidly converted to sulphate by the action of oxidizing bacteria, causing severe sulphate attack damage to mortar joints, rendered surfaces and concrete. Sulphate resisting cement should always be used in preference to ordinary Portland cement in conjunction with foul drains and sewers.

Unplasticised polyvinyl chloride or uPVC is now extensively used for waste and overflow pipes. One of the features of this material is its high thermal movement which can result in excessive stressing of firmly fixed pipes, as well as noise problems through movement of pipes carrying alternately hot and cold water. Distortion and fracturing of firmly fixed pipe runs can occur, although movement problems are seen most frequently in push fit cistern overflow pipes which are often inadequately supported, simple diurnal and seasonal temperature changes being sufficient to cause severe sagging and disconnection of the joints with serious consequences should the cistern overflow and discharge into the pipe (Richardson, 2002).

2.3.8.2 Electricity Supply

All electric cables give off heat in use and this is usually dissipated without any difficulty. However, cables can get overheated if placed beneath loft insulation, behind insulated dry lining or if placed in a position where the temperature of the surrounding environment is high. The insulation of the cable will then be damaged and there can be a risk of a short-circuit and, possibly, fire. Cable in power circuits is more at risk than cable in lighting circuits for the former is more likely to be loaded near to full capacity. Electric cable should not be covered by thermal insulation nor, ideally, should it be used where ambient temperature regularly exceeds 30°C. It may be worth noting that a cable de-rating factor as low as 0–5 will be needed where cable is insulated on both sides. There can also be an interaction between PVC cables and expanded polystyrene often used for insulation and this can cause degradation of the PVC. The two should be kept apart (Richardson, 2002).

2.4 Causes of Construction Defects

Construction defects may occur due to different reasons. The causes behind their occurrence are summarized below (Chong, 2006):

1) Weather

Weather related defects were caused by: 1) heat and ultraviolet rays from the sun; 2) moisture from the rain; 3) humidity in the air; and 4) wind loads. Sun is the biggest heat source. Heat encourages expansion and when heat source is removed or moisture is introduced to cool materials, contraction occurs. Frequent expansion and contraction increase stress in materials, and with-out a proper defense system, such stress will cause cracks and fracture at the weakest point. The most common defense system against expansion and contraction is the expansion joint. It is an effective system but it often encourages moisture and dirt infiltration. It must be accompanied by a proper moisture and dirt dispelling system to get rid of both moisture and dirt. Weep holes or flushing can be installed near these expansion joints to dispel water and dirt. In areas where installation of weep holes and flushing are impossible, materials that discourage accumulation of moisture and dirt should be used.

2) Moisture from Wet Areas

The presence of moisture in wet areas also triggered several moisture related defects. Capillary action pushes moisture into dry areas. Properly installed and designed waterproofing can prevent moisture from traveling into dry areas. However, there are many poorly installed waterproofing projects that designers had no control over. Installing a moisture stopper between the wet and dry area can help to stop traveling moisture.

Leaking pipes were also very common. Leaks from pipes often caused staining on ceilings and floors. These leaks penetrated the wall and traveled to dry areas. Designers can help control the impact of this workmanship defect by installing a leakage stopping system to stop the leaks from flowing further. A zone that allows water from the leaking pipes to accumulate leaking water can be positioned in such a way to prevent leaks from flowing into dry areas.

3) Impacts from Occupants and Loads

Defects from impacts as of occupants and loads were often due to inadequate design provisions. For example, wall edges were found to chip due to impacts of loads and occupants. Installing metal or rubber protections on edges of walls in locations with high human and load traffic could prevent such defects. In the long run, the cost of edges protection can be significantly lower than the cost of repair to damaged edges.

4) Vandalism and Accidents

Softer building materials often invite vandalism. Wood, gypsum board, softwood ceilings, and noise barriers made of resin were common targets as scratches, cracks, and holes were found in these materials. Most of these defects occurred on wall surfaces. Installing harder materials and designing a zone to distance occupants from these materials can reduce the tendency of vandalism and accidents. Installation protection on the edges can help to reduce the number of such defects.

5) Material Quality Not Up to Expectations

Materials were also found to deteriorate faster than expected. These materials failed before their intended lifespan. Although many were due to poor workmanship, most of these defects could have been prevented with better design detailing, specifications, and using more appropriate materials.

6) Structural and Geotechnical Problems

The impacts of such defects were devastating. Such defect can only be prevented with better geotechnical inputs by conducting more tests and using statistical interpolation of soil tests conducted in other surrounding buildings to estimate soil conditions. Structural and geotechnical problems can only be resolved with better design and tests.

Mydin (2012), also describes the factors which are responsible for deterioration and defects of most buildings. Accordingly, there are six factors that affect building deterioration if no remedial action takes place.

i. Mechanical Agents

These agents impose a physical force on a building. They may be static and permanent such as ground pressure, or static and temporary such as a snow load. Alternatively, the force can be dynamic such as wind or vibration, so the design of the structural item must include mechanical agents, though failures still happen. Besides that, it is sometimes important to remember that non-structural components, particularly plastics, may also be subject to creep and deflection due to self-weight.

ii. Electromagnetic Agents

As far as the durability of building materials is concerned, the most important agent in this group is radiation.

a) Solar radiation

Most published information concerns total solar radiation measured as bright sunshine and total radiation.

b) Ultraviolet radiation

A large proportion of this band of radiation (290 nm-400 nm where a nm is a nanometer or one thousand millionth of a metre) is absorbed by the earth's atmosphere and so has no effect.

c) Infra-red radiation

This band of radiation (700 nm -1000 nm) is absorbed by all forms of matter, causing an increase in temperature such that the surfaces temperature will be greater than the surrounding air temperature. For a given surface texture, the colour of the surface considerably affects the absorptiveness.

iii. Thermal Agents

Temperature is particularly relevant to components that are exposed to an unobstructed sky, for example roofing, cladding and external structural members. The actual temperatures reached can lead to either temporary or even permanent changes in physical or chemical properties, such as embrittlement at low temperature and accelerated oxidation at high temperatures.

iv. Chemical Agents

The chemical agent that is most prevalent is water. It is probably also the agent with greatest influence on the properties of materials, particularly when it is combined with extremes temperature. In many instances the presence of moisture enables physical, chemical or biological reactions to take place (Mydin, 2012).

Moisture, of course, cannot be totally excluded from buildings. It's needed for both the building itself and for the comfort of its occupants. Organic materials such as timber devoid of moisture would be affected by desiccation. This in turn would cause them to shrink, crack and warp. The occupants, too, cannot inhabit a totally dry building (i.e. one in which the relatively humidity is near or at 0%). Excessively dry conditions would make the occupants' nose, eyes and mouth parched and thus uncomfortable, increasing their risk of coughing and suffering from ear, nose and throat problems (Douglas, 2007).

Moisture comes from different sources. Some of them are as follows: (Douglas J., 2007)

a) Water entering during construction

Much water is used during construction for the mixing of mortar, concrete and plaster and for wetting bricks before laying. For brickwork alone, as much as one ton of water may be used in building the average house (Addleson and Rice 1991). Some of this constructional water is immobilized in the hydration of cement and plaster, and some evaporates before occupation of the building.

b) Ground water

Materials in contact with the ground will draw up water by capillary action into their pores and into the structure of which they are a part. It should not be assumed that this will not happen, even on an apparently dry site. Building operations undertaken below ground can, in themselves, change, sometimes detrimentally, the pattern of natural water drainage and also the level of the water table.

c) Moisture from human activities

A great deal of moisture is produced from normal human activities and this can be a major input to help cause condensation (Garratt and Nowak 1991). Just by normal breathing, one person produces at least 0.3 l of moisture in a day. Typical domestic activities can greatly exceed this amount. Clothes washing and drying constitute a major source of moisture input. Drying a normal wash for a family of five can generate as much as 5 litres of moisture, some ten times as much as is likely from the washing phase. To add to the difficulties, the drying of clothes indoors is likely to occur most often when the weather is damp. It is not uncommon, too, for large volumes of water to be left in baths and sinks, for considerable periods of time, to soak crockery and clothes. More than half the daily input of moisture in a typical home is produced in the kitchen.

2.5 Minimizing Building Defects

Given the problems of diversity of participants and techniques used, uniqueness of every building project, outside working conditions, and so on, it is not too difficult to appreciate why failures in construction are more prevalent than those in other industries. Indeed it is the very nature of the building industry itself, which makes it difficult to eliminate such problems entirely. Nevertheless there are a number of measures that would go some way towards minimizing if not avoiding common construction failures (Douglas, 2007)

- An improvement in the "lowest tender" system, without generating excessive inflation of contract prices, should be sought. Cheapest price does not necessarily mean best value for money, particularly in the long term. It is for this reason that some clients use a best value for money approach. This takes into account quality of product as well as lowest whole life cost.
- Increased/improved feedback from builders, research bodies, maintenance engineers/surveyors, and users to designers/specifiers and better feed-forward from designers/specifiers to maintenance managers and users. Increasing the accessibility to information for building professionals, managers and technicians will go a long way to achieving this goal.
- Regular on-the-job training programmes for operatives and site staff.
- Improvements could be made in the quality of graphical and written communications. For example, three-dimensional drawings could be used more and greater use could be made of national specifications. In addition, training could be given to site staff on improving verbal communication skills.
- Better and more available guidance on commissioning buildings and their services and on defects avoidance.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This section presents and describes the approaches and techniques the researcher used to collect data and investigate the research problem. They include the research design, study population, sampling techniques and procedure, data collection methods, and data analysis. The research is intended to gather facts based on research problem initiated mainly from observations and experience of the researcher. Information includes primary and secondary data sources from selected buildings in Jimma town.

3.2 Study Area

The study was conducted at Jimma town, southwestern Ethiopia which is located 335km by road southwest of Addis Ababa. The town is found in an area of average altitude of about 5400 ft. (1780 m) above sea level (https://www.mudco.gov.et, 2008).

3.3 Study Period

This research was conducted from May, 2017 to April, 2018.

3.4 Research Design

The study design employed for this research was cross sectional exploratory method. Exploratory research method is undertaken to gain background information about the general nature of the research problem. In connection to this, quantitative as well as qualitative data types were employed. Having established the basis of the research, necessary data was collected, analyzed, and conclusions and recommendations were made based on the findings. The tools of data collections employed for the research were observational checklist and questionnaires. Hence, in order to achieve the objectives of the research, the research was carried out using the following approaches.

i) **Literature review**: The first is to undertake a literature search on previous related publications in connection with building construction defects. Literature review was carried out throughout the whole research project, this was to compile and discuss information related to the thesis objectives.

ii) **Questionnaire**- questionnaire was developed and distributed to the concerned bodies of building construction, i.e. clients, contractors, consultants.

The questionnaire contains four main sections, as listed below:

- **Section one:** contains a set of question related to the profile of the respondents in relation to organizational profile, personal information and work experience in construction industry.
- **Section two:** contains a set of questions related to causes of construction defects in multistory commercial buildings of Jimma town.
- **Section three:** contains a set of questions related to the impacts of construction defects in buildings.
- **Section four:** contains a set of questions related to the defect reducing measures on commercial buildings.

iii) **Data analysis:** the data gathered from questionnaire and the observational checklist was analyzed on the basis of the objectives of the study.

iv) **Conclusion and recommendations**: from the analysis of the data as well as the literature review, findings are developed and conclusions are formulated respective of the objectives of the study and recommendations are then made from the findings.

3.5 Population

The population under study was commercial buildings in Jimma town. The research specifically focuses on multistory buildings. These populations were used in the case study to assess the common defects of the buildings. The other populations of the study were respondents of the questionnaires such as contractors, consultants, and clients. They participated in responding the questionnaire that covers the causes, impacts and minimizing remedial measures of construction defects.

3.6 Data Collection

Data collection is the accumulation of specific evidence that will enable the researcher to properly analyze the results of all activities by his research design and procedures. The main purpose of data collection is to verify the research hypotheses. In the process of collection of data, primary data and secondary data were used for this study.

The source of the primary data was in the form of observational checklist and questionnaire designed to gather adequate data from building contractors, consultants and clients. The main role of the primary data is to collect information that can be analyzed, and produce conclusion about the construction defects of multistory commercial buildings in Jimma town.

Secondary data used for this study include information from published text such as research journals, books, dictionaries, and internet resources used to compliment the primary data.

3.7 Sampling Techniques and Procedure

As described above data was collected using observational checklist and questionnaire. A checklist which consists of common construction defects was used as a reference during the field observation. Samples were drawn from multistory commercial buildings in Jimma town. Method of sampling was purposive sampling.

A questionnaire survey was used to prompt the attitude of the main parties such as contractors, consultants and clients on the causes, impacts and minimizing measures of construction defects. Structured questionnaires were developed and distributed to randomly selected consultants, contractors and clients currently engaged on building construction. The questionnaire was developed covering different factors carefully designed from literatures conducted in building construction projects. The questionnaire is also carefully designed in light of getting high response rate from participants. Three items were prepared for obtaining information about respondents' organization such as, company type (client, consultant or contractor) and respondents' job position and their work experience.

The alternative answers for the structured questionnaire were developed based on Likert's-scale of five ordinal measures of agreement towards each statement (from 1 to 5).

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree

In Likert scale technique, generally, the level of agreement or disagreement of respondents is measured. The reasons for adopting this simple scale are to provide simplicity for the respondent to answer and make evaluation of collected data easier.

By the time this thesis was done, the multistory commercial buildings found in the town of Jimma begun their operation in the last ten years, according to the information gathered from the town's Investment Bureau. Currently, there are a total of 64 multistory commercial buildings that are fully operational. A purposive sampling is used by taking buildings which have similar features. By using the mentioned sampling technique 18 buildings were selected for assessment. During the assessment, a checklist of common construction defects was prepared and thorough investigation on each building was done accordingly.

3.8 Study variables

i) Independent variable

The independent variables for this research were causes, impacts and remedial measures of construction defects.

ii) Dependent Variable

The dependent variable for this research is construction defect of multistory commercial buildings.

3.9 Data Processing and analysis

The thesis was done by using data collected from observations and distribution of questionnaires. Data was collected using observation by preparing a checklist that contains lists of expected common construction defects based on personal experience and related literatures. The checklist was analyzed by ranking most frequent defects that occurred on the sample buildings.

In the questionnaire analysis, the “Mean Score” or “Average Index” method is adopted to establish the relative importance of different factors. The analysis will rank the factors based on the frequency analysis and mean score/average index. This index was calculated as follows:

$MS = \frac{\sum f * \mu}{N}$ Where: MS – Mean Score

N – Total number of responses concerning each factor

f – Frequency of responses for each score

μ – Weighting given to each factor by respondents (1 to 5)

Weighted Average was calculated by using the following formula;

Weighted Avg. = $w_a x_a + w_b x_b + w_c x_c$

Where; *w*= relative weight (%)

x= mean score

a, b & c represent contractor, consultant and client respectively.

In processing all the design and analysis, identifying literature review of research, and data gathered was evaluated to come up with the research output.

CHAPTER FOUR

DATA ANALYSIS AND DISCUSSION OF RESULTS

4.1 Introduction

This chapter explains about the distribution of the questionnaire, collection of responses and subsequent analysis of the data acquired through the responses of professionals who are working for the client, consultants and contractors and involved in commercial buildings of Jimma town. The chapter also discusses on the results of the case study done on the selected buildings. The principal purpose is to rate the identified variables of construction defects and maintenance practice and then to find out the critical factors that are required to be given due attention in order to give the necessary remedial measures to decrease the construction defects.

4.2 Discussion of Field Observation Results

Field observation was done to identify the most common construction defects that occurred on multistory commercial buildings of Jimma town. The field observation was done by using an observational checklist that contains a list of most common construction defects (see Appendix A). This study took 18 samples of buildings from a total of 64 multistory commercial buildings found in Jimma town. The names of the buildings and owners are kept to be confidential in order to keep privacy ethics of a research and expressed in codes.

From the result of the study, the most common defects observed on the buildings were:

1. Plastering cracks

2. Peeling off paint

3. Broken/cracked floor tiles

4. Defective water supply system

5. Exposed electrical wiring

1. Plastering cracks

The most common construction defect observed on multistory commercial buildings with a frequency of 15 buildings is **plastering cracks**. Plastering is done on finished parts of walls and concrete works. In the case of the observed buildings, the causes of the defects can be generalized to the following factors:

- Workmanship problem: this factor is responsible for defects that arise due to rapid loss of moisture to undercoat, loss of bond between coats, i.e. inadequate key or mineral bond and application of stronger outer coat.
- Using materials of low quality: e.g. swelling of clay materials in unwashed sand.
- Moisture from wet areas such as defective sanitary fixtures.
- Inappropriate paint and finish used.
- Water damage; source of water comes from overflowing tub, leakage in the toilet or shower, seep out of plumbing or roof, storm damage, cracks around a chimney.
- external factors such as vibration from the outside construction, traffic or even sound wave
- Non suitable of renders and plasters; as cement renders has low rate of vapor exchange. For the long time period, the wall contains high level of damp causes the external render to crack and delaminate.

Therefore, the recommended solutions for the defect of plastering cracks would be:

- Applying workmanship standard according to accepted specifications.
- Using materials of specified quality.
- Applying a proper periodic maintenance especially for sanitary fixtures which are responsible for source of moisture.

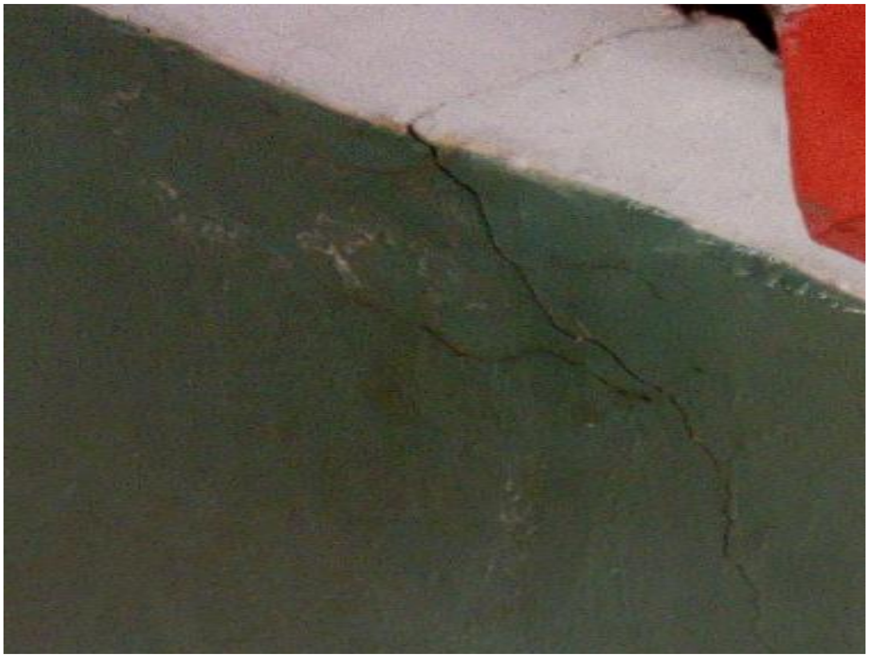

Fig. 4.1 plastering crack (observed on sample building of building P004)

Fig. 4.2 plastering crack (observed on sample building of building P008)

2. Peeling off paint

The second most frequent construction defect on multistory commercial buildings with a frequency of 13 buildings is **peeling off paint.** From the observation, it is noticed that paint peeling mostly occurred on faces of buildings, mainly on plastered walls exposed to rain and extreme dampness. There are also, to some extent, internal parts of the buildings in which paint peeling occurred.

Peeling paint is usually the result of poor surface preparation. The majority of peeling paint problems occurs on surfaces exposed to rain and sun. If paint peels from an interior wall, the reason for the peeling paint is mostly often due to an improper preparation of the surface before painting. Apart from that, the moisture surrounding the wall also seeps in through from the wall to the paint surface. Peeling paint is said to be occurred when the amount of paint film removed is high.

In order to minimize the occurrence of paint peeling, the following measures should be taken:

- Enough time should be given in order for a newly plastered wall to completely dry before painting. If the wall to be painted is not well dried, small-to-large sections of the paint will lift due to poor adhesion and brittleness of the paint.
- When the initial coat of paint is applied on the new plaster, it should be diluted rather than applying directly to the plaster.
- The specified type of paint should be used based on the type of material it is to be applied such as for walls or doors.
- A building should be repainted with some regular intervals in order to keep a building's serviceability and aesthetic value. According to the study, most of the buildings visited have no schedule to be painted on a regular interval.

The following figures show peeling off paint observed from the selected sample buildings.

Figure 4.3 Paint peeling on external façade wall (observed on sample building 004)

Figure 4.4 Paint peeling on internal wall (observed on sample building 009)

3. Broken and cracked floor tiles

The third most common construction defect with a frequency of 12 buildings is **broken and cracked floor tiles**. The common floor tiles observed were terrazo, granite and PVC tiles. Some of the usual causes of defects in floor tiles are:

- excessive exposure to strong sunlight and moisture,
- high occupant load,
- improper layout,
- inappropriate specified material and
- grout failure.

In order to protect safety of floor tiles the following measures should be taken:

- Better structural design to prevent the crack and tiles from delamination (dividing into layers) by shielding the areas from weather and specifying materials that can better resist human and load impacts.
- Give a proper time for curing because cracking is commonly due to poor curing over a short time period. Shrinkage effects may become concentrated and the rapid drying-out of the mix may mean that long-term strength is reduced. Mostly, terrazzo floor tile may fail because of bonding problems.
- In the case of PVC tiles, the moisture from an insufficiently cured screed, a failed damp proofing membrane (DPM) junction can cause loss of tile adhesion. Therefore, using a DPM of specified quality is recommended.

Figure 4.5 Cracked floor tiles (observed at sample building P006)

Figure 4.6 broken floor tiles (observed at sample building P006)

4. Defective Water Supply System

The fourth frequent defect in multistory commercial buildings with a frequency of 11 buildings is **defective water supply system**. In a multistory building the water supply system should have a proper pressure to distribute the water for all floors evenly. But, most of the observed buildings have insufficient water pressure which leads to shortage of water, especially for upper floors. According to the study, the causes for defective water supply system were blockage or leakage of components of the supply system such as pipes and valves, lack of sufficient water pressure system, rusty pipes and dirty supply tanks. The causes of the defect can be generalized to workmanship problem, defective material, and failure to apply the recommended proper water pressure system for the buildings, i.e. non-conformance with specifications.

The problem of defective water supply system can be minimized by:

- Using the right type of material which can give the proper service without failure for the expected period of time.
- Giving the proper maintenance for the defective parts of the water supply system before the defect creates negative impacts to the surrounding and for the building itself. Maintenance should be considered not only after the defects are occurred, but before the defects create hazardous effects.
- Applying the required water supply system sufficient to distribute for all parts of the building. In the town of Jimma, the water is supplied by the concerned governmental body. This body is responsible for providing the necessary service in order to fulfill the requirement of customers at large.

5. Exposed Electrical Wiring

The fifth common construction defect seen on multistory commercial buildings with a frequency of 10 buildings was **exposed electrical wiring**. Electrical power is distributed with copper wires covered with insulators. The wiring is distributed to each floor with different branching. This branching of circuits should be distributed inside the walls and concrete structures to protect unexpected accidents due to exposed branch circuiting.

Cables can get overheated if placed directly beneath a roof of a building, behind insulated dry lining or if placed in a position where the temperature of the surrounding environment is high. The insulation of the cable will then be damaged and there can be a risk of a short-circuit and, possibly, fire. There can also be an interaction between PVC cables and expanded polystyrene often used for insulation and this can cause degradation of the PVC. All the insulating materials used in the manufacture of cables are mechanically week, so requires some form of protection against mechanical injury. Exposed branch circuiting also reduces the aesthetic value of buildings in addition to possible occurrence of accidents.

The problem of exposed branch circuiting is mainly due to poor workmanship. The contractor should give a great care starting from the beginning of the construction work. Each branch circuiting should be distributed inside the concrete structures before pouring of concrete and through the block work wherever necessary. The following figure shows exposed electrical wiring from the observed buildings.

Figure 4.7 exposed electrical wiring (observed on buildings P003 and P010)

Most of the time, especially in the construction works of Jimma town, electrical branch wiring is done at the end of the finishing works by drilling the structures as shown in the next figure. Lack of proper supervision, recklessness from workers, lack of coordination of work between the civil work and the electrical work professionals are the causes for this defective work.

Figure 4.8 Defective electrical wiring due to poor workmanship (observed on building P012)

Observed construction defects of the commercial buildings of Jimma town is summarized below. Each type of defect is mentioned with its respective frequency.

Table 4.1 Observed defects with respective degree of frequency

No	**Type of defect**	**Frequency**	**Percentage**	**Rank**
1	Plastering cracks	15	83.3	1
2	Peeling off paint	13	72.2	2
3	Broken/cracked floor tiles	12	66.7	3
4	Defective water supply system	11	61.1	4
5	Exposed electrical wiring	10	55.6	5
6	Seepage or leakage underside of roof	10	55.6	5
7	Leaking downpipe	8	44.4	12
8	Detachment of plastering	7	38.9	15
9	Defective wastewater drainage system	7	38.9	15
10	Missing handrails on staircases	9	50.0	8
11	Missing corner protection	9	50.0	8
12	Defective skirting	9	50.0	8
13	Broken ceramic wall tiles	7	38.9	16
14	Uneven floor finishes	6	33.3	22
15	Uneven wall plaster	8	44.4	13
16	Broken ceiling	6	33.3	22
17	Water seepage through windows and doors	8	44.4	13
18	Defective door hinges and lock mechanisms	7	38.9	16
19	Broken or leaking sanitary fixtures	10	55.6	5

20	Toilet equipment not securely anchored	9	50.0	8
21	Bathroom sinks not securely fastened or functioning properly	7	38.9	16
22	Ceiling and wall joint separation	7	38.9	16
23	Insecurely fastened, damaged or missing gutter sections	5	27.8	24
24	Loose junction boxes for switches or socket outlets	10	55.6	5
25	Electrical switches or outlets not working	9	50.0	8
26	Salt attack, mold growth, or fungal decay on external wall	4	22.2	26

4.3 Questionnaire Results and Analysis

A questionnaire survey was utilized in this research. There are two fundamental types of questionnaire design: open-ended and close ended. In this research, close ended questions were used to seek the causes, impacts and remedial measures of construction defects that occurred in multistory commercial buildings of Jimma town. There are two types of self-administration procedures for questionnaires:

(1) Self-administration in the presence of the researcher

(2) Self-administered questionnaires without the presence of the researcher.

Self-administered questionnaires with the presence of the researcher were used during this research project.

4.3.1 Respondents Characteristics and Response Rates

There were 36 respondents involved in the questionnaire. Because this questionnaire survey was self-administrated with the presence of the researcher, all the questionnaires were filled out by the respondents. In this study, 22% (8) clients, 44% (16) contractors and 34% (12)

consultants participated in the questionnaire. For the quality of data, all the respondents were professionals who participate in building construction works.

4.3.2 Causes of Construction Defects

The causes of the construction defects were assessed by preparing a questionnaire that contains the common causes of construction defects gathered from different literatures and personal experience. The questionnaire is filled out by contractors, consultants and clients that involve in the construction industry. The analysis was made by computing a mean score for each factor and determining the corresponding rank based on the result. Finally, a weighted average is determined by the average of the mean scores of the clients, contractors and consultants' responses.

According to the computed weighted average, **workmanship problem** is found to be the first cause of construction defects in multistory buildings. Workmanship problem refers to the inability of the worker to perform the required task properly. This problem usually arises from skill gap, carelessness and lack of proper supervision at workplace. The delivery of buildings in accordance with specifications and to the quality desired by the owner is achieved through adequate supervision and implementing proper quality management. This can further be adequately realized by engaging quality, experienced and competent workforce. If the workforce that is directly executing the work lacks competence, the outcome will be buildings requiring constant maintenance. The workforce must be experienced and technically sound in order to realize the project objectives.

The second cause of construction defects in multistory buildings is using **defective construction material**. Defective construction material has a detrimental effect on the serviceability of buildings in general. Lack of supervision at the site is the main reason behind this problem. The use of inferior or sub-standard materials is a key defect that leads to early deterioration of building components or of the whole building during its operation. This usually occurs when specifications are not complied with or when the specifications themselves are erroneously prepared. The quality of materials usually reflects its strength, durability, aesthetics and economy. Lack of supervision at the site also plays its role behind this problem.

The third cause of construction defects according to the survey analysis is **non-conformance with specifications**. Every construction work has its own specifications prepared based on international and national building codes. Failing to abide by this specification leads to defective construction works. Defects arising as a result of non-conformance with specifications of materials, poor workmanship and method of construction result in poor-quality buildings as well as structures requiring frequent maintenance during their life cycle. Such practice undermines the effort spent during the design stage and increases the maintenance effort required to retain the building for usage.

The overall survey analysis result of the causes of construction work is tabulated below.

Table 4.2: Summary of causes of defects from respondents' point of view

Causes of defect	**Overall Analysis**	
	MSi	Rank
Workmanship problem	4.32	1
Defective construction material	4.23	2
Non-conformance with specifications	4.05	3
Lack of coordination of work	3.94	4
Tenant's lack of care	3.77	5
Aging	3.67	6
Design deficiencies	3.29	7
Poor site investigation	2.83	8

The above table clearly shows the potential causes of construction defects of commercial buildings in Jimma town. It is evident that the major causes of the construction defects were found to be workmanship problem, defective construction material and non-conformance with specifications. The other factors which are responsible for the occurrence of construction defects are lack of coordination of work at the site, tenant's lack of care in using the building, aging of the building, cost pressure, design deficiencies, time pressure during the construction work, the effect of weather and poor site investigation before the commencement of the project.

It is well known that in the construction industry, construction defects and failures can occur during the design and construction phases of a project, or after a structure is substantially complete. However, while a design professional is responsible to produce complete, accurate and well-coordinated design and construction documents that are substantially free of defects; and a contractor is required to adhere to the design and construction documents, nothing built is ever perfect nor does the law require a perfect design. Furthermore, all buildings have an expected lifespan and even the structures of the ancient world will erode into sand given enough time. The eventual failure of a structure is an expected result rather than a manifestation of a construction defect.

Even if this paper has focused on commercial buildings, most of the results found are applicable to other types of buildings. Every stakeholder of the building construction industry should play its role by implementing the required preconditions necessary to have a work which has fewer defects.

The following figure shows the causes of the construction defects in chart form. It clearly shows the factors' weighted average based on the response of the questionnaire.

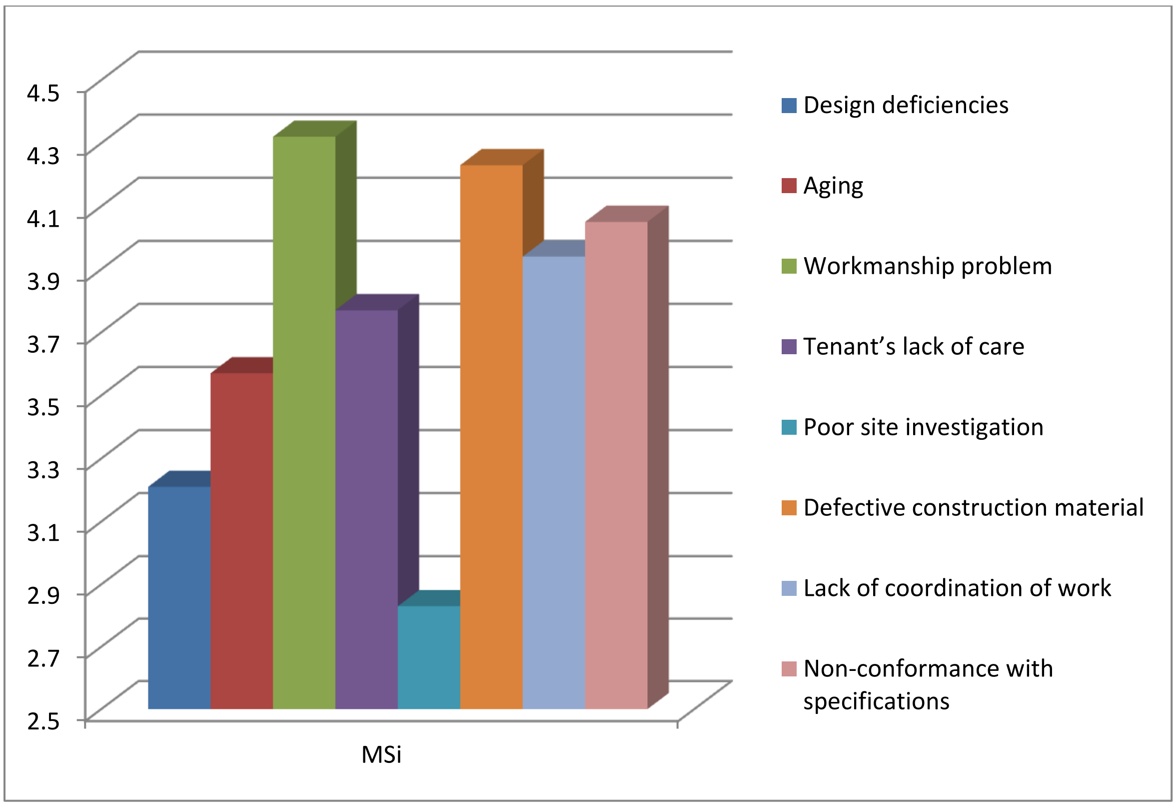

Figure 4.9 the causes of construction defects of commercial buildings from the respondent's point of view

4.3.3 Impacts of construction defects

The impacts of construction defects are assessed by distributing questionnaires for clients, consultants and contractors of buildings. According to the weighted average of the responses, high maintenance and rework cost is found to be the first impact of construction defects with a mean score of 4.35. The defects require maintenance in order to sustain the functionality of the building. As the extent of the defects increase the cost of the maintenance also increases.

The second impact of construction defects is the decrement of building functionality with a mean score of 4.20. Construction defects highly decrease the functionality of buildings. Each defect has a considerable effect on the functionality of the building. Dissatisfaction of property owners is found to be the third impact of construction defects with a mean score of 4.05. The rest of the impacts are tabulated below with their respective mean scores.

Table 4.3: - Impacts of construction defect from respondents' point of view

No	**Impacts of construction defects**	**Weighted average**	
		MSi	Rank
1	High maintenance and rework cost	4.34	1
2	Decrease building functionality	4.21	2
3	Dissatisfaction of property owners and tenants	4.05	3
4	Affect contractor and/or consultant reputation	3.85	4
5	Creates disputes between contracting parties	3.82	5
6	Risk of possible danger on the occupant or user	3.66	6
7	May lead to total failure of structures	3.61	7

The result of the survey analysis of the impacts of construction defects is presented on the chart form below.

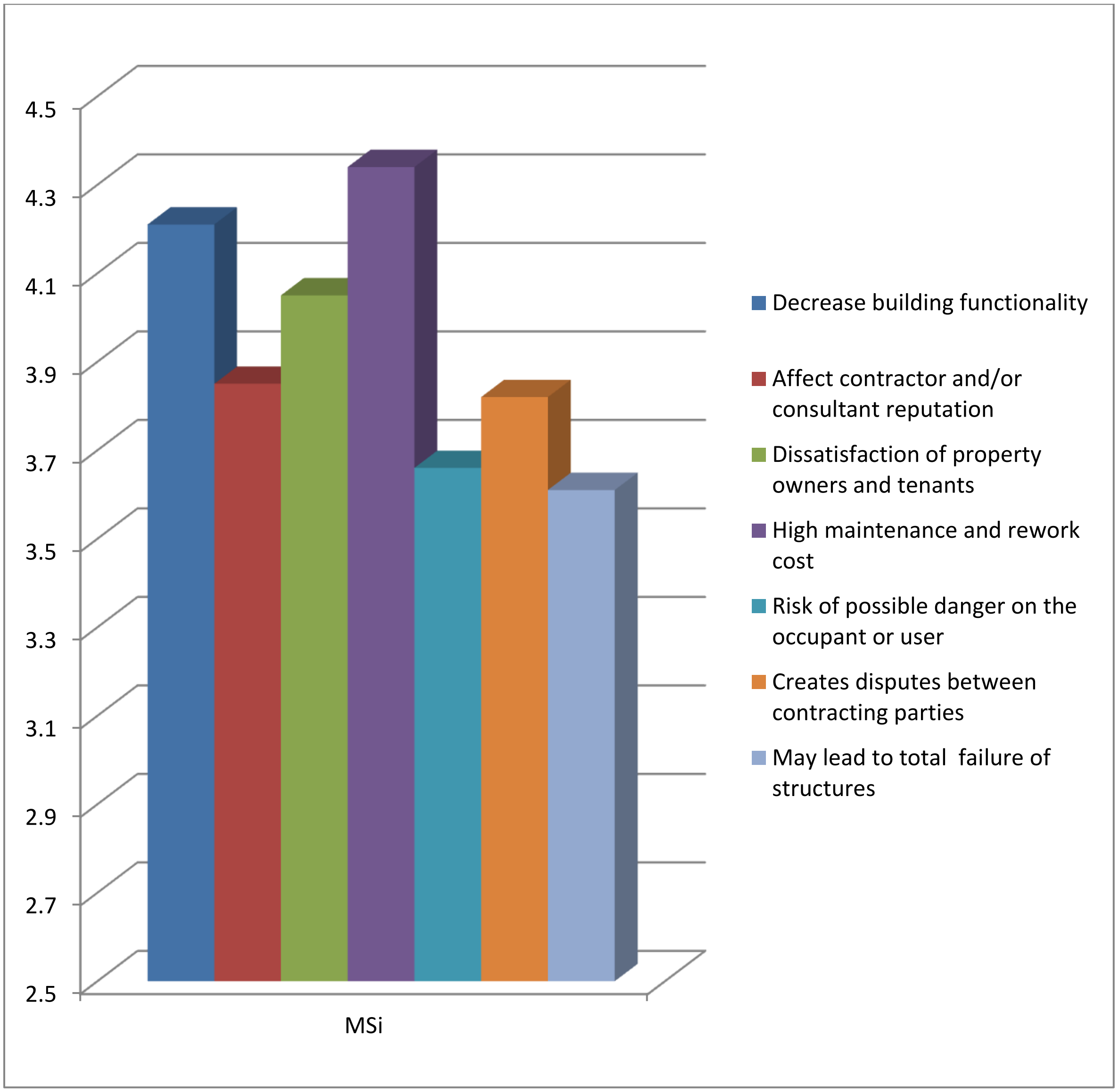

Figure 4.10 Measure of the Impacts of construction defect from respondents' point of view

4.3.4 Measures for Minimizing construction defects

The possible preventive measures used for minimizing the occurrence of construction defects of commercial multistory buildings was analyzed based on the responses made from clients, contractors and consultants. The analysis is made by computing the mean score for each factor and the weighted average of the respondents. The analysis found fifteen factors which are recommended to be the possible measures in order to minimize construction defects.

The table below shows the results of the analysis of the defect minimizing measures based on the respondents' point of view. The mean score for each factor is computed and the overall weighted average from the different respondents is calculated as described in chapter 3. The result of the analysis is presented below.

Table 4.4: - Building defect minimizing measures from respondents point of view

No	**Description**	**Weighted average**	
		Msi	Rank
1	Apply an effective quality control mechanism	4.17	1
2	Regular site supervision during construction work	4.08	2
3	Pre-certification and/or training of low-skilled laborers	4.06	3
4	Proper periodic maintenance	3.88	4
5	Coordinating building systems simultaneously with team works of different disciplines	3.76	5
6	Continuous evaluation of the capacity of consulting and construction firms	3.73	6
7	Taking administrative measures on bodies responsible for more frequent defective construction works	3.70	7
8	Thorough evaluation on the lowest tender system	3.67	8
9	Use experienced and trained workers as much as possible	3.66	9
10	Creating better communication mechanism between contractor, consultant and clients	3.62	10

11	Keeping complete and well-coordinated set of design development documents	3.54	11
12	Avoid accelerated and/or shortened design phase	3.36	12
13	Limit overtime and shift work where possible.	3.34	13
14	Develop the capacity of universities and training institutions related to construction works	3.31	14
15	Peer review when new materials and systems are incorporated into design and construction documents	3.07	15

According to respondents' weighted average **applying an effective quality control mechanism** is believed to be the first defect reducing measure with a mean score of 4.17. A quality control mechanism can be applied by incorporating necessary standards and specifications on contract documents in order to implement defect free construction works. A few common examples of qualities that do not conform to requirements are poor materials, ignorance, providing cheaper/lower quality products, negligence and when financial and speed considerations given more importance than quality.

Effective quality control will eliminate these low-quality conditions and lead to fewer mistakes by ensuring that work is being performed correctly. Since the need for corrective rework is eliminated, there will be a reduced waste of project resources. As a result, lower costs, higher productivity, and increased worker morale will lead to a better competitive position for the company. Lost future revenue and the loss of customer goodwill due to low quality will also be minimized, although costs due to customer dissatisfaction are hard to track. Creating a quality control plan allows one to preplan the means required to obtain the desired quality of work on the jobsite. Low-quality work and the resulting customer dissatisfaction can lead to costly repair work and/or removal from consideration for future construction projects.

The second defect reducing measure is **regular site supervision** during construction work with a mean score of 4.08. Regular site supervision especially helps to avoid construction defects attributed by poor workmanship. Supervision of work is considered to be the most important duty of inspectors. Knowing when to inspect work in-progress is beneficial to the inspector or supervisor. The ability to read and interpret project plans and specifications is an important characteristic since testing and inspection requirements are typically scattered throughout contract specifications. Supervision is usually conducted by personnel of the consultant body, but the contractor's staff or specialized individuals employed by an independent testing laboratory can also perform it. Supervisions must be conducted on a periodic basis to observe and review work conducted by employees of the contractor, subcontractors, vendors, and suppliers.

Pre-certification and/or training of low skilled laborers is the third recommended defect reducing measure with a mean score of 4.06. Since most laborers have limited professional knowledge concerning the construction environment, creating the necessary awareness and preparing on job training would help to avoid construction defects. Low skilled laborers play a considerable role for erroneous workmanship, faulty materials handling, faulty machine handling and insufficient cleaning of the work environment. Building the capacity of these laborers helps to minimize the occurrence of construction defects that arise due to workmanship problem.

CHAPTER FIVE

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The thesis is done by using field observation and questionnaire distribution. The field observation aimed at identifying common construction defects that occurred on the multistory commercial buildings. According to the study, 26 most common defects were identified. Plastering cracks is the most commonly occurred defect with 83.3% of the buildings, peeling off paint is the second frequent defect with 72.2%, and broken/cracked floor tiles is the third frequent defect with occurrence of 66.7% of the buildings.

The causes of the construction defects of the buildings were also investigated. This was analyzed by survey study through distribution of questionnaires to different construction industry professionals such as clients, consultants and contractors. According to the analysis, the first cause of the defects was workmanship problem. This problem usually arises from lack of proper skill, carelessness and absence of proper supervision at workplace. The second cause of the construction defects is found to be using defective construction material. This problem arises due to lack of supervision at the site and failure of the contractor to perform the required material testing prior to using for the construction purpose. The third cause of the construction defect was non-conformance with specifications; since, failing to abide by building construction specifications leads to defective construction works.

The other topic that this research covered was the impacts of the construction defects of multistory commercial buildings. High maintenance and rework cost is found to be the first impact of construction defects. As the defects require maintenance in order to sustain the serviceability of the buildings, the cost of the maintenance increases with the extent of the defects. The second impact of construction defects is the decrement of building functionality. Each defect has a considerable effect on the functionality of the building. Dissatisfaction of property owners and persons who rented parts of the building is found to be the third impact of construction defects.

This research also studied the possible remedial measures that are used to minimize the occurrence of construction defects of multistory commercial buildings. Applying an effective quality control mechanism is believed to be the first defect reducing measure by incorporating necessary standards and specifications on contract documents in order to implement defect free construction works. The second defect reducing measure is found to be regular site supervision during construction work. Regular site supervision especially helps to avoid construction defects attributed by poor workmanship. Creating the necessary awareness for low-skilled laborers is the third recommended defect reducing measure. Since most low-skilled laborers have limited professional knowledge concerning the construction environment, creating the necessary awareness would help to avoid construction defects.

5.2 Recommendation

Even if defect-free construction work is hard to find, especially in developing countries, it is recommended to take measures that reduce their occurrence.

Creating awareness to all parties that involve in the construction work is a key point to reduce construction defects. All the parties have their own share for the occurrence of the defects. Bridging the skill gap between skilled laborers and low skilled laborers enables to reduce defects that arise due to workmanship problem. The other recommended measure that helps to avoid workmanship problem is to make proper site supervision during work time. This helps to make a corrective measure if works are done in contrary to the accepted standards at the early stage. Quality management implementation, by the contractor, of a comprehensive quality control program is critical throughout the construction phase of the project. Experienced and trained workers should be used in order to minimize the occurrence of construction defects. Using the same crew throughout the project is also recommended. Making a pre-certification and/or training of the workers before the commencement of the project is also essential to prevent defective works.

Due to the fact that, using a defective material is found to be one of the causes of construction defects in multistory buildings, the concerned bodies which are responsible for controlling the quality of materials should strictly monitor that the materials are tested and comply with the accepted standards.

Since design deficiency is one of the causes of construction defects; during this phase, architect should implement procedures that will subject the design to extensive review and analysis before it is released for implementation. Proper management of construction documents as well as complete and well-coordinated set of design development documents is necessary. Development of complete, accurate, well-coordinated design and construction documents that contain all of the information necessary for the contractor enhances to construct a building without design defects. Architect and contractor should establish and maintain open lines of communication throughout the project.

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Appendix A: Observational checklist

Table A1. List of observed defects

No	Type of defect
1	Plastering cracks
2	Peeling off paint
3	Broken/cracked floor tiles
4	Defective water supply system
5	Exposed electrical wiring
6	Seepage or leakage underside of roof
7	Leaking downpipe
8	Detachment of plastering
9	Defective wastewater drainage system
10	Missing handrails on staircases
11	Missing corner protection
12	Defective skirting
13	Broken ceramic wall tiles
14	Uneven floor finishes
15	Uneven wall plaster
16	Broken ceiling
17	Water seepage through windows and doors
18	Defective door hinges and lock mechanisms
19	Broken or leaking sanitary fixtures

20	Toilet equipment not securely anchored
21	Bathroom sinks not securely fastened or functioning properly
22	Ceiling and wall joint separation
23	Insecurely fastened, damaged or missing gutter sections
24	Loose junction boxes for switches or socket outlets
25	Electrical switches or outlets not working
26	Salt attack, mold growth, or fungal decay on external wall

Table A2. Observed defects of sample buildings

No.	Observed Building (in code)	Observed Defect (Refer the No on table A1)
1	P001	1,4, 6,10,11,12,15,17,20,21,22, 25
2	P002	2, 3, 4,7,10,12,21,22
3	P003	1,4, 5,6,7,8,11,13,14,15,16,19,20,22,24
4	P004	1, 2,7,14,15,16,18, 20, 25,26
5	P005	2,3, 4, 5,6,7,8,12,15,18, 20,22,23,24,26
6	P006	1,2,3,4,5,6,7,11,13,14, 17,18,21
7	P007	1, 3, 4, 7,8, 17,18, 19,21,22,23,24,25
8	P008	1,2,3, 4, 5,6,10,13,14, 15,16,17,18,20,21,24
9	P009	1,2,3, 4, 5,6,7,12,14,17, 19,20,21,23,25
10	P010	1, 3, 4, 5,6,7,9,11,13,14,20,21,25,26
11	P011	2, 4, 5, 8,11,16,17,19,20,24,25
12	P012	1,2,3, 5,6,8,9,10,11,12,16,17,22,23
13	P013	1,3,8,9,10,11,17, 18,19,24, 25
14	P014	1,2, 3, 9,10,11,12,15,16,17,18,19,20,23,24
15	P015	1, 2,10,13,12,19,22,24,25,26
16	P016	1, 2, 3,5,6,10,11,12,13,15,19, 24
17	P017	1,2,3,9,10,12,13,19,25
18	P018	1,2,4,5,6,8,9,11,12,15,19,22,24,25

Appendix B: Questionnaire

Jimma University

Jimma Institute of Technology

M.sc thesis in Construction Engineering & Management

Dear respondent,

I am conducting a research with a topic "Assessment of construction defects on multistory commercial buildings in Jimma town". Here are list of questionnaires expected to be answered by respondent. Your response to this survey, or any individual question on the survey, is completely voluntary. Your personal information will be confidential and your responses will only be used for the academic research purpose.

Section One: Respondent Profile

1. Which organization are you working currently?

□ Client

□ Contractor

□ Consultant

□Other (specify) :

____

____

______

2. What is your job position in your organization (optional)?

____

____

____

3. Work experience in the construction industry:

a. 1-5 years b. 6-10 years c. 11-15 years d. above 15 years

Section Two: Causes of construction Defects

Lists of causes of construction defects in building construction are mentioned below. From your experience, please tick the appropriate cell by indicating how much you agree to listed causes of construction defects in commercial buildings.

Agreement:

1 - Strongly agree 2 – Agree 3 - Neutral, 4 – Disagree 5 – Strongly disagree

Causes of defect	**Level of Agreement**				
	1	**2**	**3**	**4**	**5**
Design deficiencies					
Aging					
Weather					
Vandalism					
Workmanship problem					
Time pressure					
Cost pressure					
Tenant's lack of care					
Poor site investigation					
Defective construction material					
Lack of coordination of work					
Non-conformance with specifications					
If others, specify					

Section Three: Impacts of construction Defects

Below are lists of expected impacts of construction defects in building construction. From your experience, please tick the appropriate cell by indicating how much you agree to listed impacts in commercial buildings.

Agreement:

1 - Strongly agree 2 – Agree 3 - Neutral, 4 – Disagree 5 – Strongly disagree

Impacts of construction defects	**Level of Agreement**				
	1	**2**	**3**	**4**	**5**
High maintenance and rework cost					
Decrease building functionality					
Dissatisfaction of property owners and tenants					
Affect contractor and/or consultant reputation					
Creates disputes between contracting parties					
Risk of possible danger on the occupant or user					
May lead to total failure of structures					
If other, please specify					

Section Four: **Construction defects minimizing methods**

The following table lists construction defect minimizing methods. Please tick the appropriate cell by indicating how important each method is in minimizing building construction defects on commercial buildings.

Agreement:

1 - Strongly agree 2 – Agree 3 - Neutral, 4 – Disagree 5 – Strongly disagree

Description	**Agreement**				
	1	**2**	**3**	**4**	**5**
Apply an effective quality control mechanism					
Regular site supervision during construction work					
Pre-certification and/or training of the workers					
Proper periodic maintenance					
Coordinating building systems simultaneously with team works of different disciplines					
Continuous evaluation of the capacity of consulting and construction firms					
Taking administrative measures on bodies responsible for more frequent defective construction works					
Thorough evaluation on the lowest tender system					
Use experienced and trained workers as much as possible					
Creating better communication mechanism between contractor, consultant and clients					
Keeping complete and well-coordinated set of design development documents					
Avoid accelerated and/or shortened design phase.					
Limit overtime and shift work where possible.					
Develop the capacity of universities and training institutions related to construction works					

Peer review when new materials and systems are incorporated into design and construction documents					
If other methods, please specify					

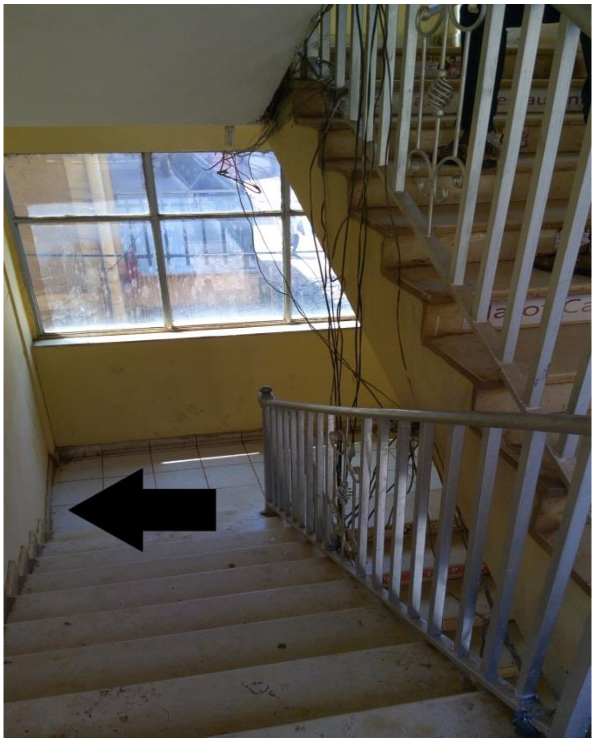
Appendix B: Pictures taken during field observation

Picture 1 Peeling off paint

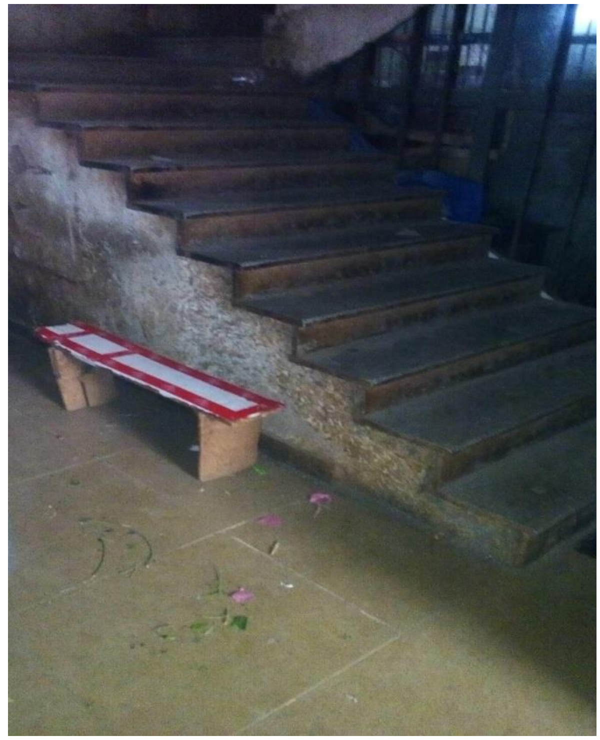
Picture 2 Inadequate height of staircase

Picture 3 Plastering cracks

Picture 4 Defective wastewater drainage system



Picture 5 Missing handrail at one side



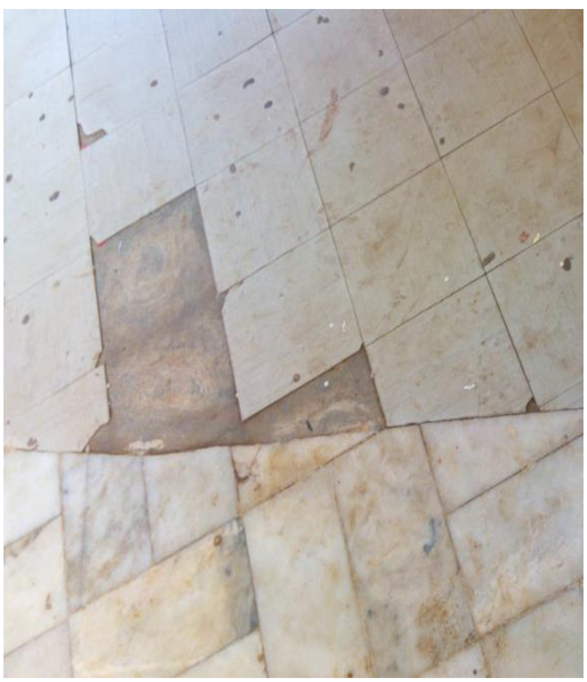
Picture 6 Missing handrail on both sides

Picture 7 Detachment of plastering

Picture 8 Leakage underside of roof cover

Picture 9 Broken ceramic wall tiles

Picture 10 Water seepage through windows



Picture 11 Broken floor tiles

picture 12 Missing skirting