An AHP Damp Penetration Model for Concrete Houses: Green Mountain, Libya

Thesis Submitted for the Degree of

Doctor of Philosophy

at the University of Sheffield Hallam

by

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2018

Abstract

The Green Mountain region of Libya experiences a persistent housing problem with regard to damp, regardless of the quality of the design, materials used, the construction practice and policy. This investigation into the factors influencing the performance of concrete housing to combat penetrating damp identified a broad range of factors: technical, managerial, economic, socio-cultural design and climatic issues. Consideration was given to specific national factors impacting on housing design and construction such as housing policy. The applicability of factors was confirmed by primary data collected from a householder questionnaire and a photographic observation survey of the condition of damp houses. Primary data were combined with secondary data in order to develop a more complete picture of the phenomenon under investigation. The analytical hierarchy process (AHP) technique was applied to construct an evaluation hierarchy of factors affecting the performance of houses in a Albeida city in North Eastern Libya. Factors were weighted and evaluated through interviews of construction professionals and self-build house owners. Results were integrated using the mathematical technique of AHP and a model of the most significant factors proposed. While the technique has been widely applied in various construction disciplines as a multiple criteria decision making technique, this study is the first to apply the technique as an analytical tool for understanding in depth a specific problem of construction and housing rather than for deciding a course of action. The results show that the issue mainly affects middle income and poor householders. Construction and socio-economic design factors are the major causes of the presence of penetrating damp, together with the financial constraints of the owners. Surprisingly, management and climatic factors have less impact on the occurrence of damp. The model was subsequently validated in a sample of houses suffering from penetrating damp in Massa. This indicated that caution should be exercised regarding the application of AHP to the owners' judgments and the transferability of results. Whilst the findings of this research can assist decision makers in similar situations to identify appropriate assessment criteria for the construction of future housing projects, further investigation into the applicability of AHP in comparison with other methods is recommended.

Dedication

I dedicate this thesis to my parents and to Libya in the hope of a prosperous nation in the future.

Acknowledgements

I am most grateful to Allah Almighty for providing me with the patience and making it possible to produce this piece of work. I am also thankful to many people for their help and assistance, both directly and indirectly.

I am indebted to my Director of Study, Dr. Kevin Spence, and supervisor, Prof. Elizabeth Laycock, who provided all the support I needed to complete this study. Through regular supervision meetings, they provided insightful feedback and objective criticism, which gave this study its focus and also helped me to sustain my motivation to the very end - I will forever remain appreciative. Special thanks also go to the research support team (Christy Bannister and Claire Jenkins) at the Development and Society Graduate School, Unit 9 Science Park, City Campus, Sheffield. Special thanks also go to Mr. Simon Rodgers for his IT help and support.

I also acknowledge the help of Omar Al Mukhtar University, particularly the Civil Engineering department, for their assistance and advice. Further, I would like to thank the Ministry of Housing and Utilities, construction companies, jobbing contractors and, above all, the house owners for their cooperation during the field study in the Green Mountain Region of Libya.

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Abbreviations

AHP	Analytical Hierarchy Process
AIJ	Aggregate Individual Judgment
AIP	Aggregate Individual Priority
CDA	Critical discourse analysis
CR	Consistency Ratio
CI	Consistency Index
RI	Random Consistency Index
GAHP	Group of Analytical Hierarchy Process
MCDA	Multi-Criteria Decision-making Methods
MCDM	Multi-Criteria Decision Making
PCM	Pairwise Comparison Matrix
GW	Gross of AHP Weight
GDP	Gross Domestic Product
UK	United Kingdom
USA	United State of America
NMC	National Mining Corporation
UN-Habitat	United Nations Habitat

Chapter One: Introduction

1.1 Introduction and Background

This chapter contextualises and presents the research problem, followed by the research rationale, aim, objectives and questions. It gives an overview of the research process and methodology, after which it indicates the significance of the study. It concludes by presenting the structure of the whole thesis.

1.2 Contextualisation of the Research

‘House’ or ‘home’ is an important concept for individuals and one of the basic human requirements (Graham & Habib, 2005). The house is influenced by cultural, social, environmental and economic aspects (UN-HABITAT, 2006) and people need to conceptualise space to create variance, and how this particular space develops as a consequence of social and material construction (Simonsen, 1996). Another important link is that between home and identity. As various architects have indicated, including Redvall (1987) and Svensson *et al*. (2003), house owners seek identity, privacy and security in their homes. The residential building forms part of people’s identity and is more than a physical structure; it is *"a complicated fabric of symbols dreams, ideals and aspirations*" (Lantz, 1996, p.32, cited in Graham & Habib, 2005, p.146). These are essential for promoting healthy residences, improving living conditions and contributing to physical and psychological comfort (Bonnefoy, 2007).

A house means a building with stability and durability, adequate lighting, ventilation, heating facilities, an accessible location, appropriate space, and adequate privacy and security. Although professionals examine durability, climatic and cultural variables during the planning and design stage, they view the house/home from different angles. In fact, the house/home is identified as a project, construction process, unit of production and/or the marketing of goods (Lawrence, 1987; Lofgren, 1990), while others view it through an empirical investigation or approach (Giddens 1989; Simonsen 1996).

In recent years, concrete has become the most widely used manufactured material throughout the world (Domone & Illston, 2010). Several authors who have studied concrete as a construction material in many cultures and civilisations have drawn attention to the prevalence of concrete as a principal structural material.

It can be utilised in housing, commercial and industrial buildings, airport runways, tunnels, bridges, sewers and other structures. Even in civilisations where steel and timber continue to be the principal structural elements, concrete still plays an important role, particularly during the foundation phase (Domone & Illston, 2010; Ramachandran & Beaudoin, 2001; Rekela, 2004). Concrete is widely used for residential buildings in developing nations (Damtoft, Lukasik, Herfort, Sorrentino & Gartner, 2008). However, one study in informal settlements in Africa highlighted that concrete was not responsive to the needs and environments of developing countries (Wekesa *et al*., 2010). Most developing countries lack enforceable legislation governing the use of high quality materials in construction (Du Plessis, 2002). Additionally, housing affordability is an important issue affecting construction quality throughout Africa (UN-HABITAT, 2011), imposing a significant constraint on the whole construction sector.

Problems due to damp constitute a high percentage of all building defects investigated (Hinks & Cook, 1997). These are generally more severe in residential buildings than in other types of building (Ilozor, Okoroh & Egbu, 2004). Damp can occur in different locations of the house, for instance in external walls, roofs, around windows and in floors. De Haro and Koslowski, (2013) found that despite very many campaigns, we still have damp in houses. In a similar way, medical studies report that patients can carry a disease but it can be some time before symptoms present (American Cancer Association, 2016; National Health Services, 2015). Houses which have particular defects present symptoms some time later. The source of damp can be from indoors or outdoors. Understanding the key sources of moisture is therefore the first step towards controlling the problems of functionality, health, and efficiency (Straube, 2002). "*Good design and construction can minimise the amount of moisture entrapped during construction, entering from the ground and penetrating as rain or snow*" (Douglas & Ransom, 2007, p.153). Given that, is damp caused by defects related to the raw materials, workforce, construction process or the quality of the construction as a whole? To answer this, it is valuable to understand what factors affect the ‘quality’ of concrete buildings in the context of damp problems.

1.2.1 History of Construction Practice in Libya

"The housing stock in many countries in Africa and Asia is grossly deficient both in quantity and quality" (UN-HABITAT, 2011, p.19).

The current construction practice for housing in Libya is the continued and dominant use of a particular construction approach (concrete as a pre-eminent construction material and a single skin wall with a flat roof as a construction design), combined with social and religious design requirements and taking into account the financial constraints of the owners together with the concept of enabling owner-built housing. Based on this line of thinking, it was assumed that those aspects were the most significant factors that influence owners to build an acceptable house for living in terms of its performance.

A number of factors have been identified as affecting building quality (Marshall, Worthing & Health, 2009; Mclean, 2009; Thomas, Palaneeswaran & Kumaraswamy, 2011), although the emphasis varies. Some stressed poor design such as water-to-cement ratio, concrete constituents and poor materials (Forty, 2012; Thomas *et al*., 2011), Others emphasized poor workforce skills and/or construction processes (Addleson, 1992; Bright, Saunders & Fudge, 1990; Hendry, 1998; Neville & Brooks, 1993), lack of and/or poor maintenance (Botsai, Kaneshiro, Cuccia & Pajo, 2010; Lopez, Masters & Bolton, 2011), lack of expert knowledge (Kvande & Robert, 2009; Mclean, 2009) and occupants' lack of awareness of the term 'quality' (Mclean, 2009).

Cultural and religious aspects have a major impact on the planning and size of the housing units. House design reflects the needs of Muslims for privacy, modesty and space for hospitality. The required separation of male and female domains can challenge the owners' budget for the house (Mahmud, 2013). This has led to one floor houses and villas becoming the familiar and customary types of construction in most of the Arab world (Bahammam, 1998). An independent architectural and planning consultant, Lockerbie (2012), who has conducted many research studies on Islamic architecture, asserted that, although the living conditions in the Arab world seem to have changed significantly today, social, cultural and religious factors still play a significant role in daily life and in the planning of housing units.

The current Libyan housing policy of indirect state intervention promotes owner-built housing through regulations, allowing public and private sector investment in housing together with publicly-provided housing projects for poor families (GPCP, 2002). However, substandard houses have appeared because of poor planning, poor-quality construction and/or poor provision of building services (UN-HABITAT, 2011).

Since the discovery of oil, Libya has generally enjoyed a higher GDP than its African neighbours, although fluctuations and revolution in 2010-2014 have resulted in a reduction of more than 50% GDP (World Bank Group, 2015). New and strict policies and regulations are required to sustain construction activity and improve the infrastructure in order to meet future demand.

Libya has experienced a number of changes in the construction industry (Ngab, 2005). Prior to 1960, construction was considered a social and community activity, houses were mostly built from the cheapest available materials with a short life span (Omar, 2003). In the 1960s, there was a great increase in state housing. By 1970, the government had increased spending, allocating almost 20% of the oil revenues to housing (Vandewalle, 1998). In the 1970s, the economic growth following the discovery of oil saw the emergence of open public spaces, state buildings and residential buildings (Awotona, 1999). Concrete residential buildings started to appear with some improvement in construction standards and building materials (Awotona, 1999; General Authority for Information, 2006). Improvements were due to the involvement of international construction companies (e.g. from UK and USA) who adopted higher construction standards than domestic companies who generally constructed a load bearing structure of in-situ cast reinforced concrete columns and floors. The infill wall panels were made from single skin externally and internally rendered concrete block work instead of traditional materials such as limestone and sundried brick. Construction of residential buildings and in particular houses used national building codes (Libyan Specifications Standard No. 253, 294, 470, which were a combination of UK and Egyptian Specifications). However, these may not have taken into considerations of local conditions and/or may poorly enforced (Awotona, 1999).

At the end of the 1970s, the construction industry experienced considerable changes as the private sector was replaced by centralist building programmes under a socialist ideology; private domestic firms were incorporated into the public sector (Amer, 2007). By the mid-1980s, most construction activities had come to a halt due to the political issues faced by the country at that time (Grifa, 2006).

During the various development phases of Libyan housing design and construction, both public and private sectors have participated in provision of adequate facilities and services that suit both the modern life and the financial capabilities of individuals. However, the private sector has been dominant overall in housing production.

In the 1970s, the government established loan funds and housing projects to enable people to build their own houses. Long-term loans at low interest rates, even interest free for poor families, were provided through the Real Estate Fund (Ministry of Housing and Works, 1997). Subsequently, the phenomenon of owner-built housing reappeared, where the house owner manages and controls the building process. A study investigating supervision strategies for residential building construction projects found that owners' tasks consisted of: communication of requirements, instructions and concepts to the local construction firms, acting as supervisors (Krima, Wood, Aouad & Hatush, 2007). In addition, owners monitor, evaluate and make decisions about the works. However, some owners appoint a person experienced in construction to act on their behalf. Levels of poverty experienced historically followed by greatly increased but fluctuating incomes in an environment of persistent uncertainty has resulted in an ever-present awareness of financial constraints. Economic factors have been shown to impact the quality and quantity of the housing strategy and the housing demand and supply (Abdalla, 2007; Omar, 2003 & Ruddock, 2001). For housing strategy in Libya as in many developing countries, there is a gap between aspirational policy statements and their implementation (Omar, 2003).

1.2.2 Climate

The relationship between the appearance of damp and cold conditions has also been highlighted (Bertolini, 2013; Kefei, Chunqiu & Zhaoyuan, 2009; Richardson, 2001). The geography and climatic characteristics of Libya have a direct effect on the housing and urban patterns such house orientation, natural light and ventilation (Almansuri, Curwell & Dowdle, 2007). Libyan engineers and architects tend to consider the north-west as the direction of concern during the design stage in relation to wind and rainfall (Tantosh, 2010). Relevant climatic factors along the Green Mountain coast are winter rain and wind direction. In winter, temperatures can fall below 0°C, and there is a period of rainfall. Most of the rainfall occurs from October to early April, with a peak from December to February during which time the wind direction is predominantly from the north west. Annual rainfall exceeds 500 mm per year (Mahdi, 1998). This kind of weather affects houses which are poorly designed, constructed and/or maintained. It is important to prevent cold temperatures reaching the internal spaces by: orienting the spaces to the best orientation; providing natural protection, using thick walls or cavity walls; double glazing windows; and employing appropriate designs and materials with insulation for the walls, roofs and windows (Almansuri *et al*., 2007; Tantosh, 2010).

This opens up a debate regarding whether climatic factors are the cause of the low standard of housing production in the Green Mountain area of Libya. Culture and social design requirements in house construction, with the owner’s available budget and lack of understanding of the importance of the quality of the house as a structure, may exert influence. Deeper, more insightful research is required. A Middle East study examining the evolution of courtyard houses in Cairo by Salama (2012) concluded that a deeper understanding and interpretation are required regarding the interactive relationship between the house environment and its underlying elements to facilitate future development.

1.2.3 Owner Built Housing

Confusion was found in literature regarding the terms used for owner-built housing. Terms found for houses where the users are involved in their production include self-provided, self-help, self-build, self-provision and owner built (Coit, 1994; Duncan & Row, 1993; Sims, 1990). It is therefore important to define the term ‘owner-built housing’ as the main householder focus in this study. Grindley (1972) defined this as a person who plans and controls the building procedure of his/her own home. Turner (1972) described the owner-builder as a general contractor who controls and manages the design, financing, and construction processes. Consequently, the owner-built housing process involves householders initiating, controlling and managing the design, construction and renovation procedure of their houses. From this, it seems that an owner-builder acts as *"an expert"* (Turner, 1972, p.3), has the ability to manage and utilise resources, hires builders and prioritises his/her own needs. Interestingly, many studies have indicated that owner-builders tend to be more content with their property than other kinds of occupiers, as being able to control the construction processes of their house and adapt their own dwelling has, in many cases, resulted in well-built houses, which bring potential social benefits to householders (Goodchild, 1997; Rowe, 1989).

In the Libyan context, house owners enjoy greater freedom and control over various stages of the decisions within the construction process, including freedom and control regarding the selection of the design of the houses, hiring particular contractors, the selection of building materials, and managing the construction schedule according to their financial circumstances. Libyan house owners play a substantial role in building their own home and shaping their houses' surrounding environment, without any previous knowledge or experience. However, several studies by John Turner (1978, 1979, 1993) found that *"the state should assist owner-builders through regularising tenure, the provision of plots in subdivided residential land, and providing basic and affordable utility and infrastructure services"* (cited in Abdalla, 2007, p.27). Motivation and encouragement for the owner-built housing process should be considered, highlighting the owner-builders' awareness of the proper construction procedure (quality control) in order to obtain the correct standard of housing quality instead of the housing quality that Libya and most developing countries tend to experience (UN-HABITAT, 2011).

1.3 Research Rationale

This is the first investigation into factors causing penetrating damp by using a hierarchy model in the context of the Green Mountain housing problem. Prior to this research, Libyan experts and house owners attributed the penetrating damp to the climate. Importantly, little research had been conducted into building defects in the area. In comparison with other building sectors, the notable and widespread damp in houses in this particular region had been neglected by independent researchers, university researchers and state organisations. In the Green Mountain area, little attention had been given to other factors such as the importance of manufacturing criteria in construction, especially the raw materials and workforce, and the part played by considerations of cost and knowledge effectiveness in socio-economic design. Moreover, the particular role of the owner as the construction supervisor of owner-built housing had not been taken into account. The selected research problem and location offered the possibility of filling a gap in knowledge concerning Libya's national development.

The rationale for selecting concrete residential single and two-storey houses as the unit of investigation was a consequence of several overriding factors which were adopted as the selection criteria. Changes to housing sector policies in Libya have created a situation which implies that each individual has to build his/her own house for their personal use. This in turn has influenced the associated socio-cultural design requirements and financial constraints.

Although housing policy has directly affected house building, there has been a lack of control exercised by the state on the outcome quality standards in the housing sector. This further relates to the construction design which has been adopted for residential buildings and to the prevalent use of concrete, which is the pre-eminent construction material across North Africa and Mediterranean countries. In addition there was little or no understanding or communication between house owners and construction experts regarding either socio-cultural design requirements and constraints, or construction techniques. The combination of these overriding factors highlighted the lack of a sufficiently deep understanding of the problem for a solution to be found.

In addition, as the author’s home city, Albeida offered easier access to relevant data. This was an important consideration given the post-revolutionary turmoil in Libya at the time the research, including the fieldwork, was conducted.

Tables 1.1 and 1.2 show the distribution of buildings according to type and usage respectively, as recorded in the 2006 census in Libya. They illustrate that houses occupy the largest percentage of buildings with regard to completed and under construction projects, and that Libyan citizens have a strong preference for houses.

Table 1.1 Distribution of Buildings According to Type, 2006 Censuses

Type of Building	No. of Buildings	Percentage %
House	631245	63.8
Villa	99271	10.0
Building Block	26241	2.7
Building under Construction	122821	12.7
Others	10980	11.1
Total	989398	100.0

Source. Libya. General authority for information. (2006). *Statistics Book: General Authority for Information and Yearly Bulletin*. Libya.

Table 1.2 Distribution of Buildings According to Usage, 2006

Type of Building	No. of Buildings	Percentage %
Dwelling Only	698374	70.6
Dwelling & Business	39933	4.0
Business Only	67451	6.8
Others	183640	18.6
Total	989398	100.0

Source. Libya. General authority for information. (2006). *Statistics Book: General Authority for Information and Yearly Bulletin*. Libya.

Thus, there are many concrete residential houses in an area where the existence of penetrating damp is widespread and well known, where particular construction practices and housing policy influence the building of homes, and where construction professionals and owner-builders rarely do not communicate or share experiences and knowledge. It is therefore important to find a systematic way of identifying, organising and evaluating the factors that contribute to penetrating damp in the concrete houses in the Green Mountain area in order to ensure that the problem is fully understood.

1.3.1 AHP Technique

It is proposed to organize these broad factors causing penetrating damp into a hierarchy model and to evaluate their relative importance by the application of the AHP technique (Saaty, 2007). It provides a rational, flexible and understandable technique that assists the identification and evaluation of all available factors, criteria and sub-criteria (Saaty & Vargas, 2007). It has been used as an effective decision support tool in diverse settings (Saaty, 2007; 2008). In construction, it has been applied in situations which include: evaluation of advanced construction technology (Skibniewski & Chao, 1992), building assembly selection (Nassar, Thabet & Beliveau, 2003), construction method selection (Pan, 2008), evaluation of intelligent building system (Wong & Li, 2007), and contractor selection criteria (Jaskowski, Biruk & Bucon, 2009). Although the technique has been applied around the world, it has not been widely applied in developing countries, in particular Africa and the Middle East (Vaidya & Kumar, 2006). The AHP technique is also widely adopted in data validation in the fields of construction, maintenance management; housing and urban planning research (Ali, 2011; Amer, 2007; Fapohunda, 2009; Obiajunwa, 2010). Table 1.3 illustrates the proposed evaluation hierarchy for the present study, based on the factors affecting discussed in section 1.2.

Table 1.3 Proposed Hierarchy of Factors

Level 1 Primary Problem	Level 2 Factor	Level 3 Criteria
Poor House Performance against Penetrating Damp	**Construction**	**Manufacturing Criteria**
		Construction Design
	Socio-Economic Design	**Cost & Knowledge Effectiveness**[1]
		Socio-Religious Design Requirements
	Management	**Construction Supervision Criteria**
		Housing Policy
	Climatic	**Rainy Season**
		Wind Direction

Note. Cost & Knowledge Effectiveness is the term used to describe the influence of owner-builders' cost constraints and knowledge of construction.

1.4 Research Aim, Objectives and Questions

1.4.1 Research aim

The aim of this research is to construct and evaluate an analytical hierarchy process (AHP) model of factors causing penetrating damp in domestic concrete houses in the Green Mountain area, North East Libya.

1.4.2 Research objectives

The objectives of this study are:

1. To examine factors causing penetrating damp in concrete buildings
2. To investigate the nature and severity of the damp problem in concrete houses in the Green Mountain, North East Libya
3. To construct an AHP model to evaluate the relative importance of each factor
4. To develop the AHP model to deepen understanding of the damp problem in the Green Mountain, North East Libya
5. To test and validate the AHP model in terms of its effectiveness in a very similar location.

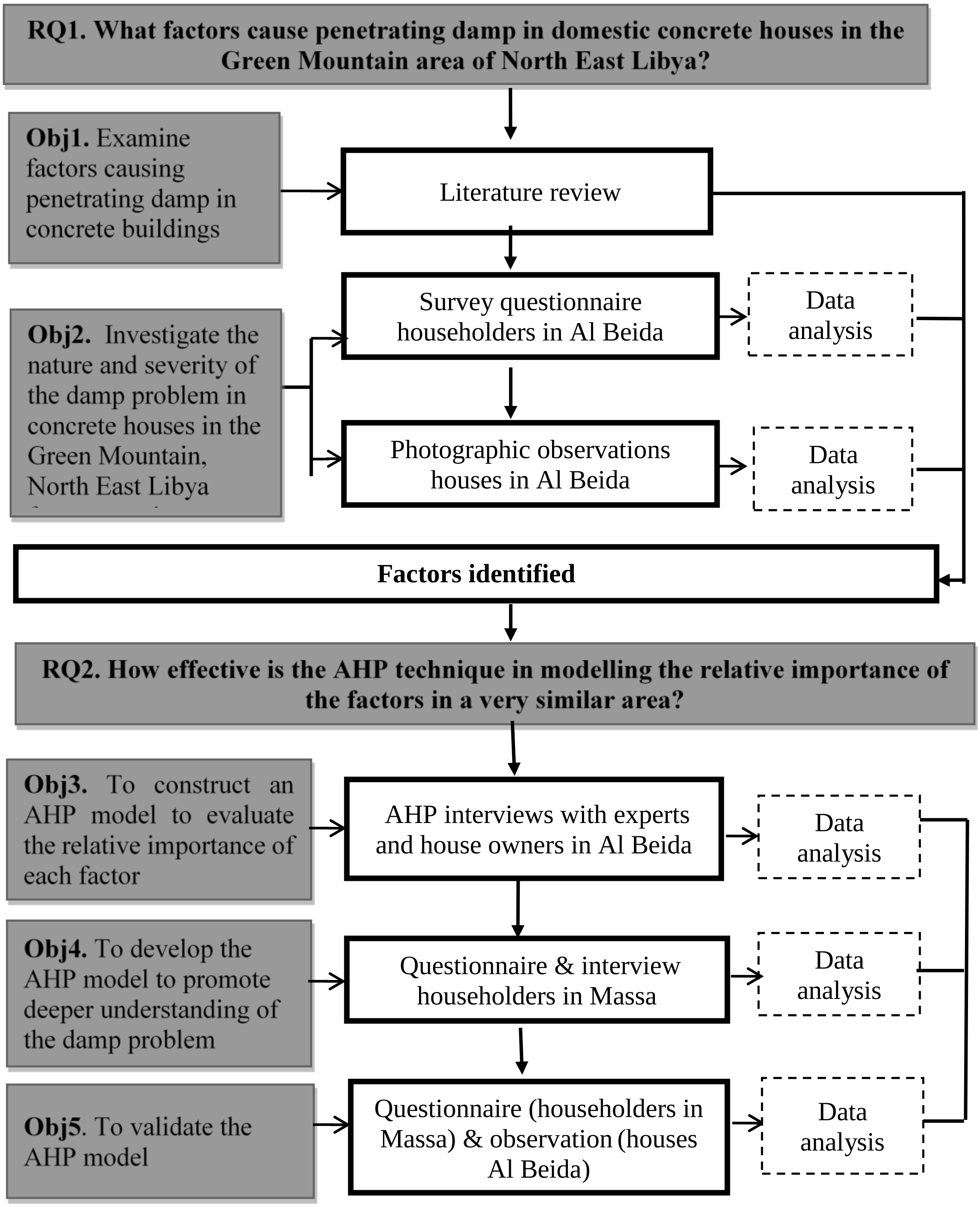
1.4.3 Research questions

The research questions are:

RQ1. What factors cause penetrating damp in domestic concrete houses in the Green Mountain area of North East Libya?
RQ2. How effective is the AHP technique in modelling the relative importance of the factors in a very similar area?

1.5 Overview of the Research Methodology

This research adopts a philosophical stance of critical realism, using both quantitative and qualitative methods as appropriate. Specifically, it employs the AHP technique within a case study strategy involving multiple methods, a questionnaire survey, photographic observation and interviews. The AHP model is developed and the weights are validated. Multiple methods of data analysis are utilised, although the analytical hierarchy process method is the principal method applied to evaluate the most important factors affecting the performance of concrete houses with regard to the damp. An overview of the methodology and the stages used to address the objectives and answer the research questions is shown in Figure 1.1. Full details and justification are set out in Chapter 4 (Research Methodology).



Note. RQ = Research Question, Obj = Research Objective

Figure 1.1 Flowchart of research methods with corresponding questions and objectives

1.6 Significance of the Research

The practical findings will be of use in the future to everyone involved in building concrete houses for use as residences in the Green Mountain area of North East Libya. According to Whitaker (2007), the application of the AHP technique helps to generate debate and alter people's understanding of a situation. This research will offer the first real understanding of the problem of penetrating damp in concrete houses in an area where it has historically been attributed to the climate. Such an understanding will enable better decisions to be made regarding future construction. Use of the technique will also give a voice to owner-builders who have not previously been able to engage in discussion of the causes of penetrating damp in their homes. The knowledge gained will add to Libyan national knowledge about construction in an area which has been neglected in the past. In terms of the theory, understanding of use of AHP technique as an analytical tool, rather than a decision-making tool, will add to knowledge of the range of its applicability.

1.7 Thesis Structure

There are ten chapters, covering the introduction, factors affecting concrete buildings' performance in the context of damp, AHP technique, followed by research methodology, then the research results, model development and AHP validation, discussion and finally the conclusion. Chapter 1 contextualises the research problem, and sets out the research rationale, aims, objectives and questions. Chapter 2 highlights the previously undertaken work and sets out the area profile of the case study (Albeida, Green Mountain region, North Eastern Libya), detailing the region's environment, climate and housing construction history. Chapter 3 explains the AHP technique, including the rationale of use, advantages and limitations and how the technique works. The methodology including the selection of critical realism as a paradigm is described and justified in Chapter 4. Chapters 5 to 7 present the results of the Al Beida questionnaire survey, photographic observations and interviews respectively. The model is developed and validated in Chapter 8. Chapter 9 discusses the research results by linking the research objectives and questions with the literature review with the results of the questionnaire survey, photographic observations and interviews with the validation. The research conclusion with recommendations based on the findings and suggestions for future work are highlighted in Chapter 10. The overall structure is summarised in Figure 1.2.

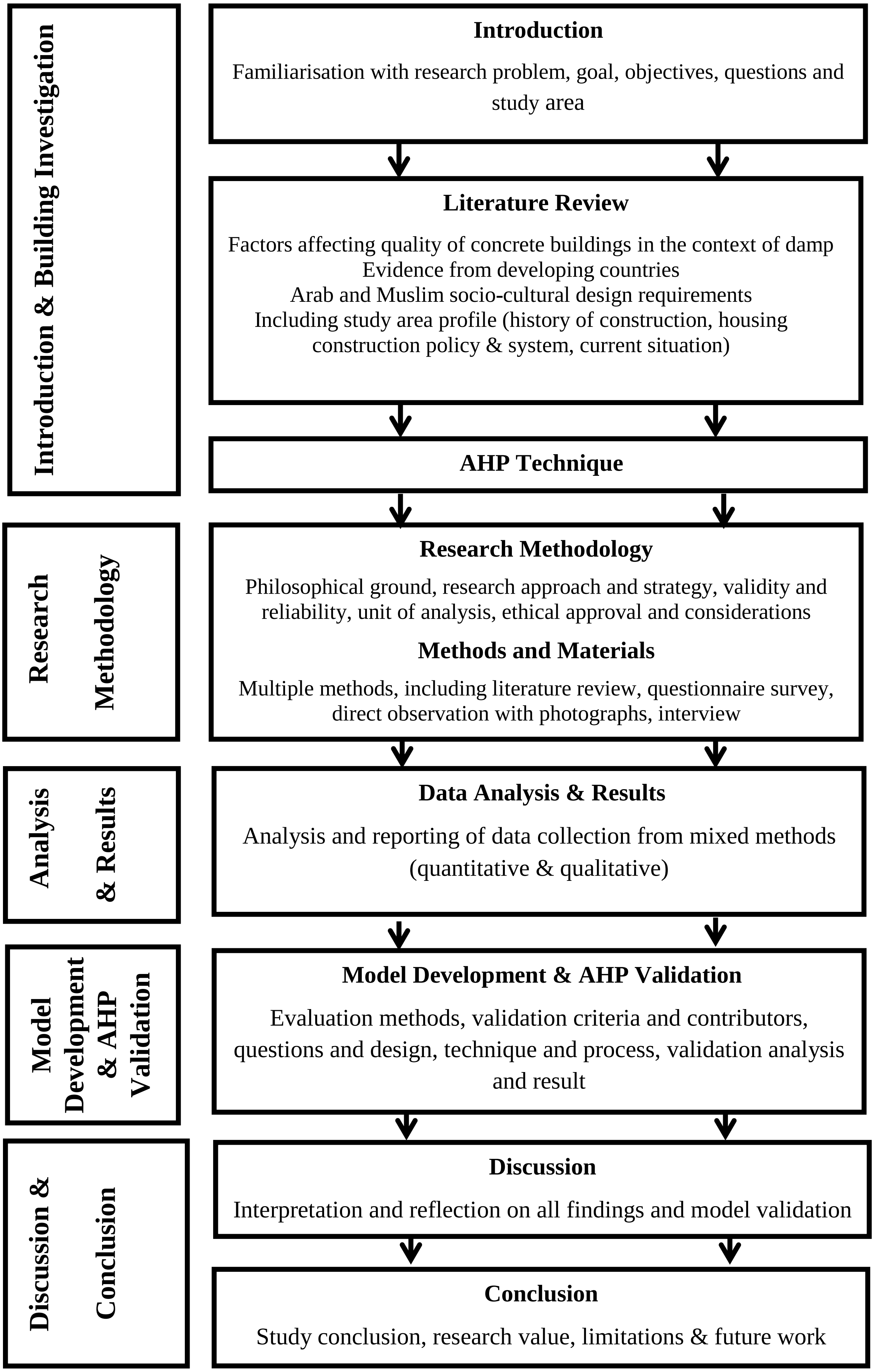


Figure 1.2 Overview of thesis structure

1.8 Summary

This first chapter of the thesis has presented the research problem and the importance of the study, together with why this research focus was selected. The research aim, objectives, and questions were also clarified. Additionally, a brief overview has been presented of the study, the adopted methodology and the thesis structure.

The first step in answering the first research question ('What factors cause penetrating damp in domestic concrete houses in the Green Mountain area of Libya?') is to search within national and international previously undertaken works. The literature review in the next chapter examines the construction, socio-economic design, management and climatic factors.

Chapter Two: Literature Review

2.1 Introduction

In Chapter One, a brief introduction to the research problem was presented in the context of damp in domestic concrete housing in the Green Mountain of Libya. This chapter reviews the relevant literature to identify the contributory factors that cause penetrating damp in concrete buildings. It begins with a discussion of the meaning of 'quality' in concrete constructions and general observations regarding the defects that are typically found in such constructions in the context of dampness. It then explores the factors of construction (under the headings of manufacturing criteria and construction design), socio-economic design (classified into cost and knowledge effectiveness and socio-religious design requirements), management (grouped into construction supervision criteria and housing policy), and climate (rainfall and wind direction).

The term 'quality' is generally understood to mean the ability to satisfy stated requirements or as being appropriate for purpose. Chung (2002) stated that in the field of construction, the word 'quality' means different things to different people. Some understand it as customer satisfaction; some define it as an agreement with a contractual condition, whilst others connect it to prescribed standards. Salama (2007) defined quality as the achievement target of the building's serviceability for which it has been designed and constructed. Consequently, it is a level of standard including plans, specifications, procedure and inspections that satisfies the owner or user of a building.

Forty (2012) declared that, undoubtedly, following the standard design in construction has a great influence on quality, cost and time. Ng *et al*. (2011), who conducted an empirical study in Hong Kong among residents of public housing properties built before and after the implementation of the ISO9000-based quality management system, stated that the defects of a particular building are good indicators of the quality of the construction. Son and Yuen (1993) also pointed out that faulty design, poor workmanship, adverse environmental conditions and poor raw materials can be responsible to varying degrees for the occurrence of building defects. Additionally, Forty (2012) noted that concrete has the potential to last a long time unless it is subjected to poor quality of materials, workmanship and others. Continuous supervision and following quality policy are key factors for obtaining high quality of concrete buildings. Domone and Illston (2010) stated that the knowledge and experience of professionals about concrete is largely based upon empirical studies that investigate the behaviour, design and production of reinforced and pre-stressed concrete.

Interestingly, the link between housing quality and wider social forces and issues has been highlighted in health research. For example, a U.S. study highlighted the relationship between money and housing quality; it found that a failure to improve the gross domestic product and human development index might result in poor housing quality persisting into the second generation and beyond (Evans, 2006). A further study in California about health status, disease, and economic development observed that a lack of access to high-quality materials can contribute to a poor housing environment, ill health and low competence (Quereshi & Mohyuddin, 2006).

It can be seen that there are various factors affect the quality of concrete buildings such as construction, design, management and climatic factors. The following sections highlight each factor in more detail in the context of the research problem. The parameters of this investigation are factors affecting the performance of in-situ concrete buildings in the context of damp problem within the building envelope (roof and exterior walls). The parameters of the literature review are illustrated in Table 2.1, which presents the broad topics and their focus, and Table 2.2, which gives details of how the causes of damp were considered under two levels of subheadings.

Table 2.1 The Research Parameters: Topics and Focus

Topic	Focus
Material	Concrete
Type of Concrete	In-situ concrete
Type of Building	Domestic houses with flat roof
Defect	Penetrating damp
Causes	Construction factor Socio-economic design factor Management factor Climatic factor

Table 2.2 The Research Parameters: Causes of Penetrating Damp

Causes	Subheading	Sub subheading
Construction	Manufacturing Criteria	Raw materials
		Workforce
		Control of in-situ concrete
	Construction Design	Exterior walls
		Roof design
		Exterior finishing
Socio-economic design	Cost & Knowledge Effectiveness	Raw materials selection
		Builders selection
		Exterior finishing selection
		Maintenance
		Delay in construction
	Socio-Religious Design Requirement	Room size
		Interior finishing & decoration
		Hospitality room
		Future requirements
		Social activities
Management Factor	Construction Supervision Criteria	Owners' supervision
		Experts' supervision
	Housing Policy	Changes in housing construction policy
Climatic Factor	Rainy Season	Green Mountain area, Libya
	Wind direction	Green Mountain area, Libya

2.2 Construction Factor

The purpose of the building envelope is to separate the water, air, noise, dust, cold or heat in the external environment from the internal building (Schwartz, 1990). The building envelope can have a great effect on the internal living conditions (Abedi, 2010; Leylian, Amirkhani & Bemanian, 2010). Various factors must be taken into consideration during the design of exterior wall and roof including exterior finishing (Lovell, 2010). Many authors from construction and architectural backgrounds have argued that neither plain nor reinforced concrete is completely impermeable in the face of water vapour, so good workmanship and sufficient cover to reinforcement with well-compacted concrete, particularly in the construction joints, are essential (Deplazes, 2005; Everett, 1994; Neville & Brooks, 1993). According to Shabha (2003), the major issues with concrete are poor quality materials, poor specification of the external envelope and poor casting, resulting in water ingress and the appearance of interior damp. These causes can be categorised as raw materials, workforce production, and control of in-situ concrete, all of which are due to human error or a lack of skills and knowledge among the workforce.

2.2.1 Manufacturing Criteria

Concrete is considered to be the most popular structural material in different parts of the world as reinforced concrete is a demonstrably durable construction material, requiring little maintenance over many decades. However, it is still liable to damage and requires attention (Sharon, 2012). The selection of appropriate raw materials for producing durable concrete is a crucial factor. It has been claimed that one possible way to confirm the durability of concrete is to specify directly its raw materials and/or finished concrete required quality (Chirgwin, 1996). The type and condition of concrete are the key factors for choosing the right materials required for a building and/or its repair (Sharon, 2012). The ingredients, proportions and exposure conditions of concrete can influence its performance positively (Rekela, 2004).

Water may be the cause of shrinkage and cracking, as "*water is the main lubricant in concrete mixes*" (Taylor, 2002, p.236). Both Somerville (2008), who published a book about the management of the deteriorating concrete structures in the UK, and Sommerhoff (2002), who conducted a study in Japan about concrete, asserted that, although concrete cannot be made without water, it can be one of the major factors in reducing concrete durability. Additionally, the selection of aggregates has been considered critical for supporting cement paste, as shrinkage in concrete might be attributable to shrinkable aggregates (Richardson, 2001). Aggregates must be clean and free from constituents that might influence the durability of concrete (Rekela, 2004). Not every type of aggregate is suitable for use in a concrete mix (Bennett, 2007). Aggregate size is also an important factor for preventing concrete from frost damage. Others include the water/cement ratio and the use of air-entraining additives or admixtures (Neville & Brooks, 1993).

According to Somerville (2008), when compared with cement, the characteristics of the aggregates are possibly less important. Unwanted and harmful ingredients may react with cement and affect the strength of hardened concrete in terms of, for example, weather resistance; they can also affect the workability of concrete mixes (Everett, 1994). Moreover, Straube (2002) highlighted that there is a source of moisture within the concrete which plays a significant role during the first few years of a construction's life; however, it is difficult at times to provide the time or environment required for the concrete slab to dry naturally.

In Libya, the local building materials are limited to what is needed for the basic construction of simple units. Insulation materials are unpopular, particularly in residential buildings, despite their long-term financial benefit. This is due to the fact that insulation materials are expensive (Suleiman, 2006) and are therefore not used. Moreover, *"many houses were built without having technical data on the building materials, which made them very unpleasant to occupants during both hot and cold season; technical data such as… moisture effect within the structure"* (Suleiman, 2006, p.548).

Manpower is the key resource for any construction project (Rahman, Memon & AbdKarim, 2012). Various analysts (Bright; Saunders & Fudge, 1990; Hendry, 1998; Hendry, Sinha & Davies, 1997; Schwartz, 1990) have argued that the structure of masonry should survive for hundreds of years if the established standard or code of practice is applied during the design and construction stage, particularly when it is constructed by experienced workers and maintained appropriately. It has been pointed out that a lack of trained workers can result in inherent defects and thin wall dimensions, which could make insulation problematical; also that dampness, water ingress and appearance of internal condensation, can lead to the exacerbation of common defects in concrete building and potentially the total failure of the structure (Mclean, 2009). The correct casting of concrete requires skilled construction workers (Shabha, 2003), while inadequate work can result in many problems. These include cavities caused by poor compaction (Hendriks & Jensen, 1999). Poor workmanship can result in water ingress (Suleiman, 2006). A specific example of the construction method which requires good workmanship, and is of essential significance, is the use of sufficient cover for reinforcement with well-compacted concrete, particularly in the construction joints (Deplazes, 2005; Everett, 1994; Neville & Brooks, 1993).

The workforce in most developing countries has insufficient skills (Uwakweh, 2000). Libya is no exception, and it has relied heavily in the past on foreign workers. Indeed, this is still the case, as there were only some 35,000 Libyans employed in the sector and higher level skills are lacking, as reported in 2014 (Abuhadra & Ajaali, 2014).

Problems such as the insufficient mixing of concrete components and an excessive water/cement ratio in situ have been linked to improper supervision on site (e.g. Rubaratuk, 2013). Understanding building defects makes it necessary to accept that "*unfortunately, many…cast in situ reinforced concrete component of system houses were poorly manufactured, with insufficient depth of cover to the steel, as well as poor quality concrete*" (Marshall *et al*., 2009, p.286). Rekela (2004, p.3) added that *"If the paste is durable, it will be as long-lasting as the aggregate"*. Richardson (2001) stated that shrinkage in concrete might be attributable to the excessive use of water or to shrinkable aggregates. In the context of Libya, the construction sector has no agreed acceptance criteria for concrete (Alazhari & Al Shebani, 2013). This may make the control of in-situ concrete even more important.

2.2.2 Construction Design

In a study in Finland, in which 80% of the houses showed signs of current and previous moisture problems, one major source of faults identified was the design and construction (Nevalainen *et al*., 1998). It has been stressed that a lack of understanding about both the design and construction of the building envelope makes moisture related problems more likely (Kvande & Robert, 2009; Shabha, 2003) and Bertolini *et al*. (2013) asserted that the factors causing deterioration of concrete can originate in the design phase. According to a study in Italy (Alfanoa, Chiancarellab, Cirillob, Fatob & Martellotta, 2006), the selection of a specific type of watertight protection must be based on a careful investigation of its structure and material, exposure conditions, water ingress mechanism and movement and drying, not simply trial and error. Therefore, the design of the building envelope (exterior walls and roofs with their exterior finishing) can be a source of moisture if it has not been designed to a high standard.

The purpose of the external façade is to drain water away from the wall opening, which is designed as a waterproofing barrier for long term performance. In the early 1900s, buildings had relatively massive external walls with several layers of thick absorptive materials which separated the external layer from the internal finishes (Schwartz, 1990). Over time, however, the construction design changed and the external walls became increasingly thin, with lightweight veneers and little separation between the exterior layer and interior finishes (Schwartz, 1990). Although masonry wall construction, such as stone, brick and concrete, has greater resistance to water ingress, it may require plastering or rendering to be watertight (Wekesa *et al*., 2010).

A study related to the subject of the water ingress characteristic of stressed masonry concluded that water ingress usually occurs at a brick or mortar interface, but does not pass through brick units or mortar joints. Ingress at the interface was therefore deemed to have caused the occurrence of a high incidence of water leakage in the exterior walls (Tait, Khalaf & Kermani, 2001). Moreover, moisture can be built in; for example, in concrete blocks, as the water trapped inside the cores during the implementation process, wall compounds, painting, and finishing adhesives can contribute towards building in moisture (Straube, 2002; Allen, 1997).

According to Desjarlais (1995), the roof is an important component of the external envelope because, in the pursuit of controlling rain ingress, the perfection of the building envelope depends on a single layer resisting all inward water diffusion. Roofs made from reinforced concrete slabs contain a great deal of water primarily because the concrete mix contains a considerable amount of water. This might require six or seven years to dry out and for the moisture content to become balanced (Allen, 1997). Therefore, the concrete will release the water over the first few years after the building has been completed.

However, this is not the only possible source of water leakage from the roofs; it has been proposed that water leakage from concrete flat roofs could be due to factors such as rainfall, the construction process and/or interstitial condensation (Addleson, 1992). Specific factors identified by Talib, Ahmad, Sulieman and Boyd (2015) in a study of flat roofs in Malaysian heritage buildings included cracking due to weather, building movement due to the foundations, and leakage from water tanks. Son and Yuen (1993) also highlighted that poor foundation design can cause differential movement within the structure or differential settlement if the loads are too high.

2.3 Construction in Libya

This section outlines the history of construction in Libya and shows the impact over time of the shocks caused by war and the economy on some of the sub-criteria highlighted above in addition to the evolution of construction practices. The overall timeline is presented in Tables 2.2 to 2.5 and is followed by an explanation of the characteristics of the different periods with illustrations of the changes in materials and construction methods and design.

2.3.1 Construction in Libya before 1911

Traditionally, construction skills were transferred from one generation to another and people's values and cultures were reflected in their construction practices, as construction was based on indigenous local building materials and local workmanship. Prior to 1960, many people lived in wooden huts with roofs made from palm leaves or later sheets of zinc, while others lived in tents in the desert areas. As late as 1963, dwellings in Albeida were recorded as being constructed from stone with lime mortar or tents as well as caves, with a further unspecified (Bukamur, 1985). Building materials tended to vary in accordance with the climatic zone, for example: stone with lime mortar and adobe with a thatched roof in Tripoli; caves and stone in mud mortar in Gharian and Yefren in Western Libya; and tents or adobe with thatched roof in Sebha in the southern desert area (Bukamur, 1985). Typical tent and cave dwellings are shown in Figures 2.1 and 2.2.

Figure 2.1 Tents where Libyans lived
Source. Bedouins, (2015). Discover and save creative ideas. *Pinterest.* Retrieved from https://www.pinterest.com/olgazorec/bedouins/

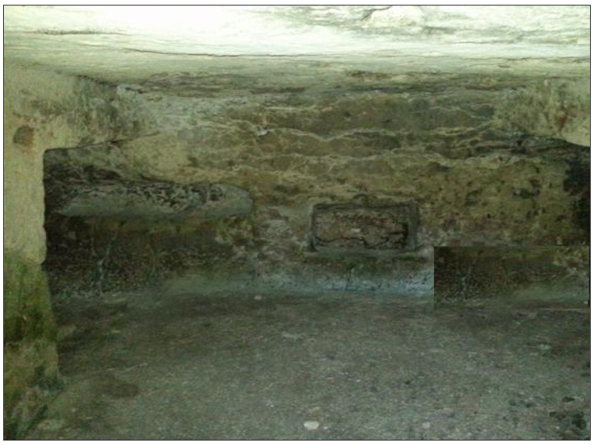


Figure 2.2 Cave dwelling, study area
Source. Author's Photograph, 2014

Local materials were used in construction, such as limestone or sun-dried clay brick for walls; lime or gypsum and clay for mortar; and the bisected and smoothed trunks of palm trees for roofs (Awotona, 1999; Azlitni, 2009). Houses at that time were built without drawings and by agreement between the house owner and builder (Shawesh, 2000). The outer, load-bearing walls were typically constructed of local stone or brick bound with lime, then plastered and whitewashed either inside or outside (Gadi, 1987). Examples of stone and lime dwellings are shown in Figure 2.3.

Figure 2.3 Two domestic houses constructed by limestone or brick in the Green Mountain
Source. Author's Photograph, 2014

The period before 1911 can be summed up as the use of traditional raw materials and construction design as shown in Table 2.3.

Table 2.3 A Summary of History of Construction in Libya before 1911

Dates	Factors, Criteria	Main Events and Characteristics
Before 1911	Raw materials	Stone dwellings, wood huts, tents and caves
	Construction design	Stone with lime mortar (houses), wood with palm tree leaves or zinc sheet roofs (huts)

2.3.2 Construction in Libya 1911-1943: the Italian Period

A major external influence from 1911 until 1943 was the Italian occupation. In the two major cities of Tripoli and Benghazi, the Italian influence on construction was apparent, with the emergence of different architectural forms and principles of planning, such as wide streets and piazzas, with western style shops, offices and housing aimed at meeting the needs of the Italian residents. Major innovations included the use of non-traditional methods and materials, such as reinforced concrete floors and also flats and villas which faced outwards to the street rather than inwards to the courtyard (Amer, 2007). Thus, the Italian influence affected both raw materials and the construction design in addition to the housing construction policy.

2.3.3 Construction in Libya: the 1950s – 1970s

In the last sixty years, Libya has experienced a number of changes in the construction industry (Ngab, 2009). In the early 1950s, when the country emerged from the Italian occupation, funds were limited and construction was considered a social activity (Rghei, 1987). Houses built in the Post-World War II period were mostly built from the cheapest materials with a short life span (Omar, 2003). In 1958, cement was used only in 2% of the buildings in Libya and cement production was 60,000 tons. Thus, the importance and impact of cost effectiveness can be seen, especially in the choice of raw materials.

Following the discovery of oil in 1961, the economic growth in the urban areas encouraged people to move from the traditional agricultural areas to the cities of Tripoli and Benghazi. The first five-year plan (1963-1968) for economic and social development specified the public sector provision of services such as education, health, communication and housing (Omar, 2003). In 1964, Albeida was proposed as the federal capital and a modern master plan was created, as the population was expected to grow from the existing 12,800 to 50,000 inhabitants and potentially to 100,000 in a second phase (Kezeiri, 1983). However, the expansion of the overall national plan, which accompanied the unexpectedly large oil revenue growth, did not specifically include housing, although it aimed to improve the standard of living (Ghanem, 1985). The 1960s were characterised by a great increase in public sector housing, an increased cement manufacturing capacity and some application of planning principles.

Table 2.4 A Summary of the History of Construction in Libya 1911-1964

Dates	Factors, Criteria	Main Events and Characteristics
1911-1943	Raw materials	The Italian influence brought innovations, such as reinforced concrete floors
	Construction design	Flats and villas facing outwards to the street rather than inwards to the courtyard.
	Housing construction policy	Principles of planning introduced. Wide streets, piazzas, western style shops, offices and housing to meet the needs of the Italians.
1950s	Raw materials	Post-war use of the cheapest materials with a short life span. 1958 recorded cement used in 2% of buildings. Cement production was 60,000 tons.
	Cost effectiveness	Limited funds and oil revenues. Construction considered a social activity.
1960s	Raw materials	Outer load-bearing walls usually constructed of local stone or brick, bound with lime, plastered and whitewashed inside or outside.
	Construction design	1963 record of existing Albeida dwellings: 2,415 stone with lime mortar, 3,450 tents, some caves, 2,000 unspecified. Homes built without drawings, and by house owner/ builder agreement.
First 5-year plan 1963-68	Materials	Natural stone, limestone and sun-dried clay brick still in use. Domestic cement manufacturing capacity raised to meet demand
	Housing construction policy	Public sector provision of housing and other services
1964	Construction design	Master plan for Albeida, proposed federal capital

Thereafter, from 1969 until 1980, the oil revenues more than doubled, allowing increased spending in many areas. The five-year plan covering 1969-1974 prioritised industrial and agricultural development in an attempt to reduce the reliance on the income from both oil and foreign countries but, by 1970, the government had set new spending priorities, allocating almost 20% of the oil revenues to housing (Vandewalle, 1998). The construction industry played a significant role in the social and economic development process, although most of the houses in every climatic region of Libya were constructed using the same basic design (Elwefati, 2007). In the 1970s, Libya was the world's leading per capita purchaser of cement, purchasing 6 million tons annually in the 1970s. Cement became the main construction binder in Libya and is now used in more than 97% of Libyan construction activities.

At the end of the 1970s, the construction industry experienced considerable changes as the private sector was replaced by centralist building programmes under a socialist ideology; private domestic firms were incorporated into the public sector (Amer, 2007). The resulting public housing schemes were constructed without taking into account the traditions of the built environment, including vernacular building materials (Omar, 2003).

Developments in construction in Libya from 1970 to 1980 are summarized in Table 2.5.

Table 2.5 A Summary of the History of Construction in Libya 1970-1980

Dates	Factors, Criteria	Main Events and Characteristics
1970s	Raw materials	Hollow cement blocks for walls, cement for mortar, reinforced concrete slabs for roofs.
-Second 5-year plan 1969-74	Housing construction policy	Industrial and agricultural development prioritised to reduce reliance on oil and foreign countries.
		1970 new spending priorities, almost 20% of oil revenues allocated to housing. Role of construction industry increasingly significant in social/economic development.
1969-1980	Cost effectiveness	Greater oil revenues.
	Workforce	International construction companies involved.
	Quality/standards	International companies adopted higher construction standards than domestic companies.
	Materials	Cement became main construction binder.
	Construction design	Same basic design of house requirements used in all climatic regions. Emergence of open public spaces, state buildings and block residential buildings, without systematic overall planning.
	Cost effectiveness	Libya a world leading per capita purchaser of cement (6 million tons a year). Private domestic firms incorporated into the public sector.
	Housing construction policy	Government constructs and allocates housing, and permits the private sector to invest in housing by sale or lease. Loan funds for housing projects from the Real Estate Fund encourage ‘build your own’. Late 1970s’ socialist ideology, centralist programmes replace private sector construction.

2.3.4 Construction in Libya: the 1980s - Present

The introduction of centralist programmes was followed by the departure of skilled foreign construction workers (Grifa, 2006). Combined with a very considerable fall in oil revenues, by the mid-1980s, most construction activities had come to a halt (Grifa, 2006). Additionally, the political issues faced by the country at that time contributed to the severe economic difficulties experienced by the industry during the last two decades.

The period of economic growth following the discovery of oil led to the emergence of open public spaces, state buildings and residential buildings, albeit in the absence of any systematic overall planning (Awotona, 1999). Concrete residential buildings started to emerge, in which there were some improvements in construction standards and building materials (Awotona, 1999) due to the involvement of international construction companies who adopted higher construction standards than the domestic companies and started to use hollow cement blocks for the walls, cement mortar and reinforced concrete slabs for the roofs instead of natural stone, limestone or sun-dried clay brick. Libya responded to this increased demand for cement and other building materials, such as steel-reinforcing bars, by raising the domestic manufacturing capacity to meet the demand, a process managed through the National Mining Corporation (NMC) and the General People's Committee for Industry, Economy and Commerce (Mowafa, 2012).

The 1990s were characterised by a considerable reduction in the workforce before some recovery occurred in the second half of the decade, as the government reduced its direct intervention in housing, instead encouraging private sector and foreign investors (Grifa, 2006; Sheibani & Havard, 2005). The housing shortage increased, although new laws allowed changes in the housing construction policy. These permitted the possession of more than one house or piece of land and gave rights to public and private institutions to build houses for sale, moreover permitting some leasing (Sheibani & Havard, 2005).

From 2000 onwards, cement was used in more than 97% of construction activities. Concrete remains the pre-eminent construction material, while the predominant feature of construction design is a single skin wall with a flat roof. Unfortunately, following the revolution, which had led to the widespread destruction of housing stock and falling oil revenues, combined with falling oil revenues, all government programmes stalled completely in 2014 (Centre for Affordable Housing Finance in Africa, 2015). Housing construction policy therefore continues to have the aim of enabling owner-built housing.

Table 2.6 The History of Construction in Libya 1980-Present

Dates	Factors, Criteria	Main Events and Characteristics
1980s	Workforce	Departure of skilled foreign workers halted most construction activities. A reliance on local companies lacking experience.
	Cost effectiveness	The mid-1980s' fall in oil revenues resulted in limited funds for housing.
1985-1990	Housing construction policy	Government began to assist institutions to invest in the housing sector.
1990s	Workforce	Lower numbers employed as sector activity reduced before some recovery.
	Housing construction policy	Government reduced direct intervention in housing, encouraging private sector and foreign investors. Housing shortage grew. Laws allowed the possession of more than one house or piece of land, gave the right to public and private institutions to build houses for sale. Some leasing permitted.
2000s-present	Raw materials	Cement used in more than 97% of construction activities. Concrete the pre-eminent construction material.
	Construction design	A single skin wall with a flat roof as the construction design.
	Housing construction policy	Destruction of housing stock. All government programmes stalled following the revolution and falling oil revenues. Aim of enabling owner-built housing.

Despite these difficulties, the Ministry of Housing and Utilities (2013) asserted that construction in Libya must re-emerge after the prolonged slowdown. New, strict policies and regulations were required to sustain construction activity and improve the infrastructure in order to meet the future growth in the domestic and export markets. The new vision incorporates diversification in construction materials in order to relieve the industry of its dependency on cement-based materials, which are sometimes unsuitable in terms of location, environmental performance and cost.

2.3.5 The Current Situation

The predominant types of dwellings in Libya are single-storey houses and villas (Libya General Authority for Information, 2006) constructed out of concrete with single skin walls and flat roofs. The walls are constructed using concrete hollow-blocks with two holes (200x200x400mm) joined with mortar, and the flat roof is constructed using a reinforced concrete slab of 150-200mm (Libyan Standard Specifications, 2002). In addition, local building materials are limited to the basic construction of simple units without any insulation. In fact, these materials are unpopular in Libya, particularly for residential buildings, in spite of their long-term financial benefit, as insulation materials are expensive and require skilled labour (Suleiman, 2006).

Construction materials and manpower are the key resources for any construction project (Rahman *et al*., 2012). The functionality, availability and affordability of the construction materials have a major impact on the construction industry. "*In Libya, many houses were built without having technical data on the building materials, which made them very unpleasant to occupants during both hot and cold seasons, technical data such as…moisture effect within the structure*" (Suleiman, 2006, p.548). Additionally, buildings cannot be constructed without labour (Abdalla, 2007). However, the workers in most developing countries tend to lack skills (Uwakweh, 2000). Figure 2.4 shows the current hollow cement blocks which are used in the Green Mountain region.

Figure 2.4 Hollow cement blocks currently used in the Green Mountain area
Sorce. Author's Photograph in 2014

Figure 2.5 shows a house being constructed in the Green Mountain area, with a flat roof and single skin of exterior walls. Image (a) illustrates the front façade of the house. Images (b, d) show the construction method for the walls, which are framed with the load transferred to the columns and also show how the cement blocks are placed uncombined in an internal room. Image (c) shows the construction method for the roof; the nature of the reinforcement network and cement block of the roof. For the roof, layers of concrete paste and layers of bitumen are usually poured to form a waterproof membrane. However, the details of this system play a part in the success or failure of the roof in relation to allowing or preventing water ingress.

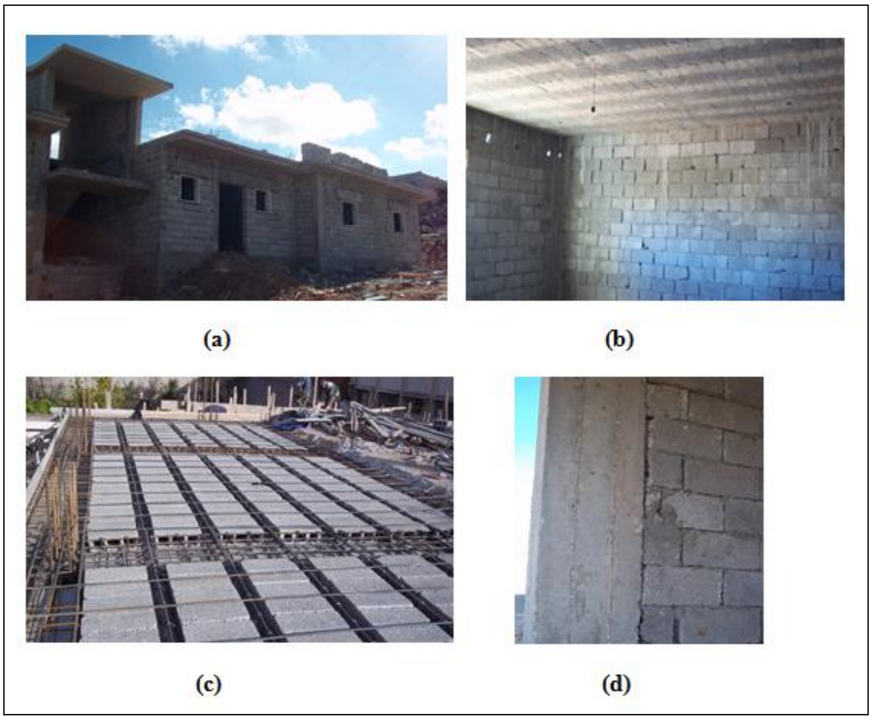


Figure 2.5 The current type of construction design in the Green Mountain area
Source. Author's Photograph in 2014

2.4 Socio-Economic Design Factor

Social unity characterises most of the population of the Arab world. Several different factors underlie this social unity, including religious reasons, social influence, economics, the group of population influence (locality) and historical factors among others (Alvaúdy, 1992; Bahammam, 1998). Germeraad (1993) added political factors and defined regional cultural tradition as a separate factor which could be included in the full list of factors that play a significant role in the shaping of the physical environment. Houses are not limited to a construction unit but denote both a physical and a social domain (Alvaúdy, 1992).

The former consists of a residential unit and the latter consists of the occupants who live in that unit. These two fields overlap and complement each other, and generally there are cause and effect associations between them.

Cultural, religious and economic aspects have a major impact on the planning and size of housing units in the Arab/Muslim world. An independent architectural and planning consultant, Lockerbie (2012), asserted that, although the living conditions in the Arab world seem to have changed greatly today, culture and religion with economic still play a significant role in everyday life, including the planning of housing units. The design of Muslim houses concentrates on Islamic religious teachings that differ from Western culture (Belk & Sobh, 2011). House design reflects the need for privacy, modesty and space for hospitality. The philosophy behind this design is illustrated by the inviolability of the private domain; the family sphere is protected from visual intrusion (Stefano, 2000).

However, socio-cultural design requirements are not simply a question of a nice view and/or design because they are affected by construction quality and financial/economic arrangements. Bahammam (1998) concluded that those socio-cultural and financial factors occur and persist due to the absence of responsibility among those involved in housing design and policy. Germeraad (1993) argued that although several attempts have been made to develop the understanding of Arab-Muslim people's values and behaviour, there is still a lack of value in designs in human settlements. It was declared in 1998 that "*special economic and environmental studies are needed to determine the impact of this phenomenon on the environment and on the national economy*" (Bahammam, 1998, p.569). A study related to Arab management styles, practices and work orientations (Abbas, 1996) highlighted that if Islamic values and culture are identified and understood correctly, they will facilitate organisational change and development. Therefore, a new approach needs to be adopted when designing for the Arab nations. In general, the issue can be considered under the two broad headings of socio-religious design requirements and cost and knowledge effectiveness.

2.4.1 Socio-Religious Design Requirements

Socio-religious requirements have a major impact on Libyan housing design (Almansuri *et al*., 2007). Muslim houses are divided into three spheres: the privacy of the whole house, the privacy between the sexes and, finally, the privacy between family members (Bahammam, 1998). This has resulted in a larger house with large room sizes. In addition, a strong element of hospitality, as a fundamental value of Arab culture, affects housing design (Othman *et al*., 2015). The requirements related to hospitality present

challenges, such as the need for a larger dwelling to provide the space and furniture required. The guest sections, which are used for limited purposes and on fewer occasions, require distinct and cumbersome furnishings; Saudi Arabia is particularly affected in this regard (Bahammam, 1998).

Similar large hospitality rooms are found in traditional Malay houses (Hashim, Abdul Rahim, Rashid & Yahaya, 2006; Hashim & Nasir, 2011). *"Many clients seek to obtain a design with a size which only satisfies the taste of the people whom they know"* (Bahammam, 1998, p.565).

Guest reception rooms in the majority of modest and palatial Arab houses receive the most attention in terms of furniture and decoration (Stefano, 2000). In one Arab country, the interior finishing and decoration were found to be significant factors, even among low income families (Opoku & Abdul-Muhmin, 2010). Similar attention is paid to the interior by residents in South China (Jim and Chen, 2007) in contrast to Western nations, where the residents concentrate on the exterior environment (Luttik, 2000; Tajima, 2003; Tyrvainen & Miettinen, 2000) cited in Opoku and Abdul-Muhmin (2010).

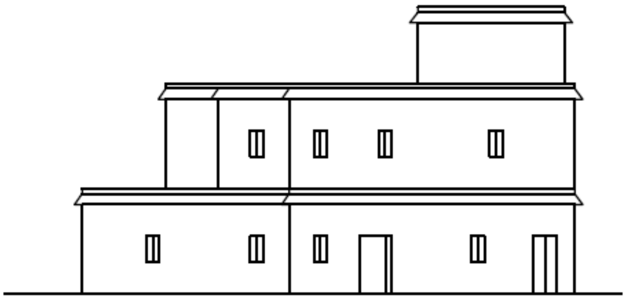
Moreover, the built form is affected by the importance of providing semi-private communal socialization spaces for interior interaction between humans, particularly women (Eben Saleh, 1997; Sobh & Belk, 2011). Even the design of Arab-Muslim cities incorporates the concept of the physical segregation of males and females (Germeraad, 1993). Recognising the problem related to the segregation of living spaces, large room size and defining the reasons for this is a major step towards raising the awareness of housing professionals and owners about the need to produce more efficient residential buildings that are fit for purpose, as well as less expensive to construct, furnish and maintain.

House owners in the Arab world normally build a dwelling to accommodate their family's growing needs (Fadan, 1983). The flexibility to change and expand houses over time can be understood as the family size increases due to marriages or births, requiring horizontal or vertical expansion. Changes in the domestic function of the rooms within the house can also occur in various ways and for various reasons, such as the death of a family member as well as marriages (Stefano, 2000).

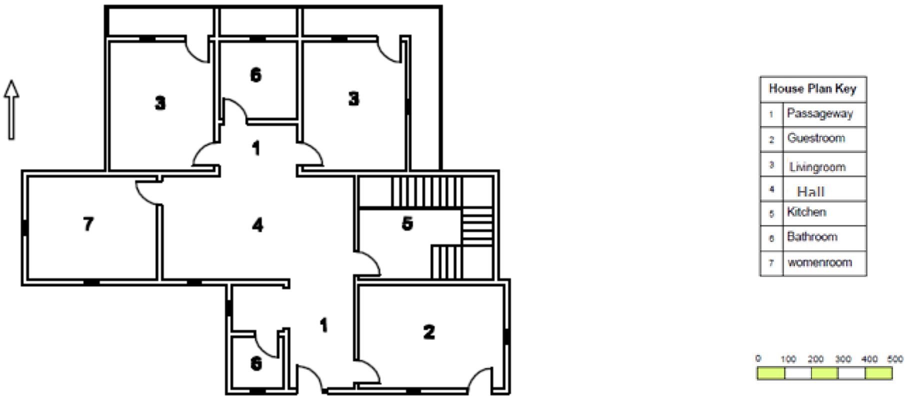
These socio-religious requirements for room size, hospitality space, interior decoration, social activities and future requirements are unavoidably more difficult to meet for low and middle income families, so cost effectiveness is at the front of their mind. The underlying rationale and trend for large rooms has not been investigated since Bahammam (1998).

Architects and designers should consider a multi-function element design in order to arrange spaces more economically (Bahammam, 1998). In many Arab countries, population growth is outstripping the supply of affordable, formal housing; therefore owner-built housing is on the increase, properly planned or otherwise (Verner, 2012). Professionals and owners need to be involved in housing policy, design and life-cycle costs to call for further research into this cultural, social and financial phenomenon which is one of the cofactors causing damp in houses.

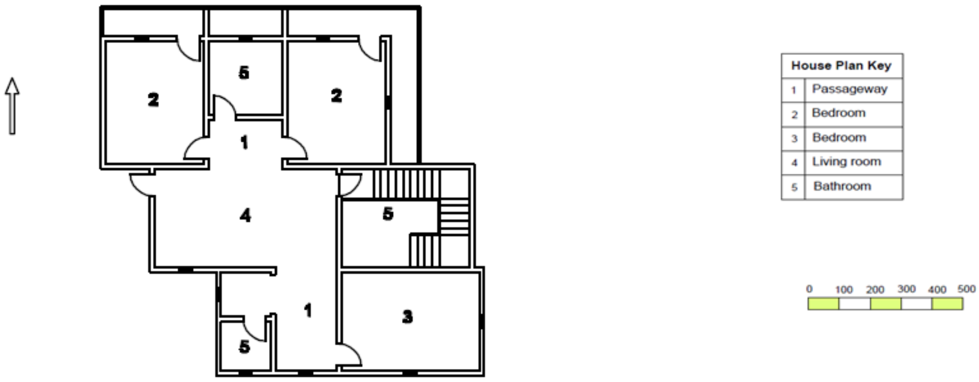
In Libya, the architectural characteristics and styles are integrated with the local culture and environment, combining Islamic values with a climatic approach. House design is influenced by Islamic aspects and social conventions; for example, houses look inwards and have few visible facades. House owners' attention is focused on the interior rather than the exterior, a focus reinforced by conventions such as the existence of large, separate and appropriately decorated rooms for male and female guests, with separate bathrooms for their use (Awotona, 1999). High exterior masonry walls surround the majority of houses (Doxiadis Associates, 1999). The relative unimportance of the exterior is part of the culture shared by the residents of the area; prioritising the interior at the expense of the exterior may cause the problem of damp. Figures 2.6 and 2.7 illustrate the facades and plans of a typical villa and a one-storey house in Libya. Figure 2.6 shows that the sections and relationship between the spaces and rooms at one level of a structure depend on the socio-cultural requirements. A male hospitality section is usually located at the front of the house, followed by the female hospitality section. The last section on the ground floor is the living room and kitchen. The first floor consists of bedrooms and bathrooms, and the space between the rooms is used as a living room for the occupants in the evening. However, if the building has only one storey, as shown in Figure 2.7, the design is similar, with a rear section for bedrooms and bathrooms. Although sometimes there is a separate living room, the occupants might use the hall as a living room. The size of the rooms varies according to their function. For instance, bedrooms are usually 5x4m, bathrooms 2x3m, living rooms 4x4m and male/female hospitality rooms 8x4m, although these may be larger or smaller, depending on the owner's budget.



a. facade

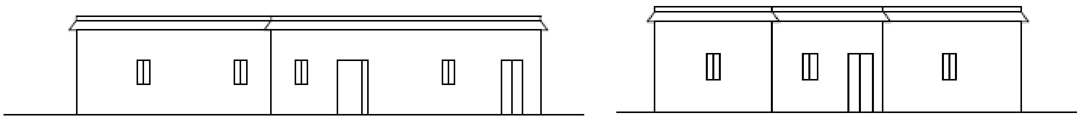


b. Ground floor

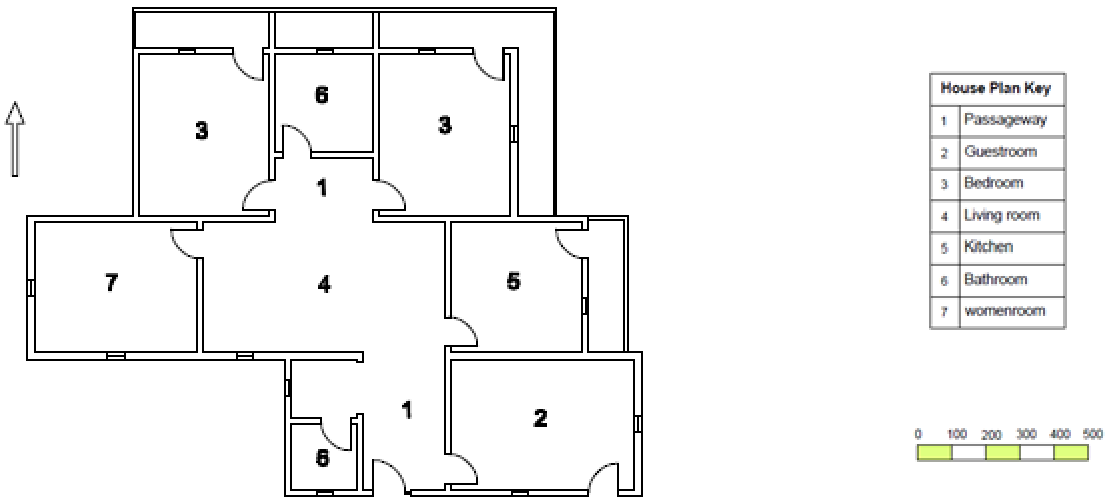


c. First floor

Figure 2.6 Typical villa in Libya



Front Facade of Single Storey House **a Side Façade**



Plan of the House

Figure 2.7 Typical one-storey house in Libya

2.4.2 Cost and Knowledge Effectiveness

The budget available to an owner-builder undoubtedly influences construction, as does their knowledge of construction materials and processes. Constraints on funding certainly affect the selection of raw materials, expenditure on external finishes and choice of builders (Shabha, 2003). Mclean (2009) asserted that defects were not a consequence of an obvious or textbook cause; indeed, they were associated with knowledge of building technology, building pathology, environmental science and surveyors' skill. Judgment makes it possible to identify and diagnose the causes of a particular defect and then propose remedial action. Kvande and Robert (2009) investigated 302 masonry defect assignments over a 20 year period, during which time it was confirmed that moisture related masonry defects were widespread in Norway. Kvande and Robert attributed this to the lack of understanding of both the design and construction of masonry buildings. Mclean (2009) added that the identification of the causes of defects is essential in order to obtain the required level of understanding. This necessarily entails an examination of the owners or occupiers' understanding of the house durability compared with non-standard houses. This is also because the diagnosis might be conducted appropriately but a flawed technical procedure could still be followed.

Minimising defects requires thinking about the future. An evaluation of the approach to the low-cost maintenance and refurbishment of concrete constructions in Birmingham, UK, found that *"No doubt, lack of long-term vision was one of the main contributory causes"* of the building defects (Shabha, 2003, p.320). It is therefore essential to integrate the design, construction and maintenance phases of the building in order to avoid the risk of various types of damage arising. Many defects in concrete residential buildings have been associated with low standards of maintenance (Ng *et al*., 2011) or irregular maintenance (Bertolini *et al*., 2013). Shabha (2003) pointed out that poor and/or lack of maintenance can lead to water ingress and the appearance of interior damp.

Additionally, delays in construction have been attributed to various causes in the Middle East, such as excessively high or low temperatures (Asnaashari, Knight & Hurst, 2009). Postponement in financing the contractor during construction, owner deferments of contractor payments, design changes, incomplete payments during construction, and non-use of specialized construction/contract management instructions have been identified as causing delays elsewhere in the Middle East (Abd El-Razek, Bassioni & Mobarak., 2008). However, little attention has been paid to the consequences of these delays to the building quality itself.

Sources of funds in developing countries include relatives and friends, personal savings and the relatively limited financial institutions, accompanied by varying public sector provision. However, all of these depend to a greater or lesser extent on the state of the economy. The demand in Libya for spacious, multifamily houses is affected by affordability and willingness to pay. A lack of finance also restricts the housing supply, especially among the low-income group (Omar, 2003), and Libya’s economy has experienced severe variability over time due to the oil price fluctuations and economic sanctions (Yahia & Saleh, 2008). Therefore, uncertainty affects the affordability, financial flow and building quality.

2.5 Management Factor

Previous studies have identified economic factors which affect the quality and quantity of the housing strategy and impact on housing demand and supply (Abdalla, 2007; Omar & Ruddock, 2001). Changes to housing strategy require action by the authorities, such as encouraging private sector investment through offering appropriate incentives for investment, and promoting understanding among citizens about the need for, and relevance of, lifestyle-related changes. However, as in many developing countries, a gap exists between the aspirational policy in Libya statements and their implementation (Omar, 2003). Culturally, the house owners in Libya play the role of supervisors, managing and controlling the construction process. Therefore, housing policy and construction supervision criteria are vital and must be examined.

2.5.1 Housing Policy and Construction Supervision Criteria

During the various development phases of housing design and construction in Libya, both the public and private sectors have participated in the provision of facilities and services that aim to suit both the modern lifestyle and financial capabilities of individuals. However, the private sector has been dominant overall in housing production. In the 1970s, the government established loan funds and housing projects to enable people to build their own houses.

Long-term loans at low interest rates (or even interest free for poor families) were provided for citizens through the Real Estate Fund (Ministry of Housing and Works, 1997). Subsequently, the phenomenon of owner-built housing reappeared, where the house owner manages and controls the building process. A study investigating the supervision strategy for residential building construction projects in Libya found that the owners' tasks were: communicating their requirements, instructions and concepts to the local construction firms, which acted as supervisors (Krima *et al.*, 2007). In addition, owners monitor, evaluate and make decisions about the work; they have the right to change any undesirable work, as well as make the final payment and confirm that the construction has been completed. In this way, Libyan house owners play the role of supervisors and decision makers. However, in some cases, owners appoint someone experienced in construction to act on their behalf.

Levels of poverty experienced historically followed by greatly increased but fluctuating incomes in an environment of persistent uncertainty has resulted in an ever-present awareness of financial constraints. Economic factors have been shown to impact the quality and quantity of the housing strategy and the housing demand and supply (Abdalla, 2007; Omar & Ruddock, 2001).

Figure 2.8 depicts the actors and their role in the Libyan construction industry. As can be seen, the operation and process for construction projects are based on the sector and type of construction firm that undertakes the construction work. The organization of the construction industry in Libya is based on the type of construction project; it can be divided into residential projects (e.g. houses, apartments, public housing), non-residential projects (e.g. commercial, educational and clinical buildings) and infrastructure projects (e.g. highways and roads.). Additionally, it can be classified into small or large construction projects; large construction projects such as public buildings or infrastructure projects are undertaken by international or local construction firms whereas small constructions projects include residential building which is undertaken by local construction firms or jobbing contactors. In relation to owner-built housing, the role of the government is to provide permission for the construction, lend money for construction, issue a design approval certificate, and issue a certificate for the construction phases, among others. In practice, the owner-builder's role ranges from purchasing the land to selecting the raw materials and builders, and managing and inspecting the construction process (Abdalla, 2007; Amer, 2007).

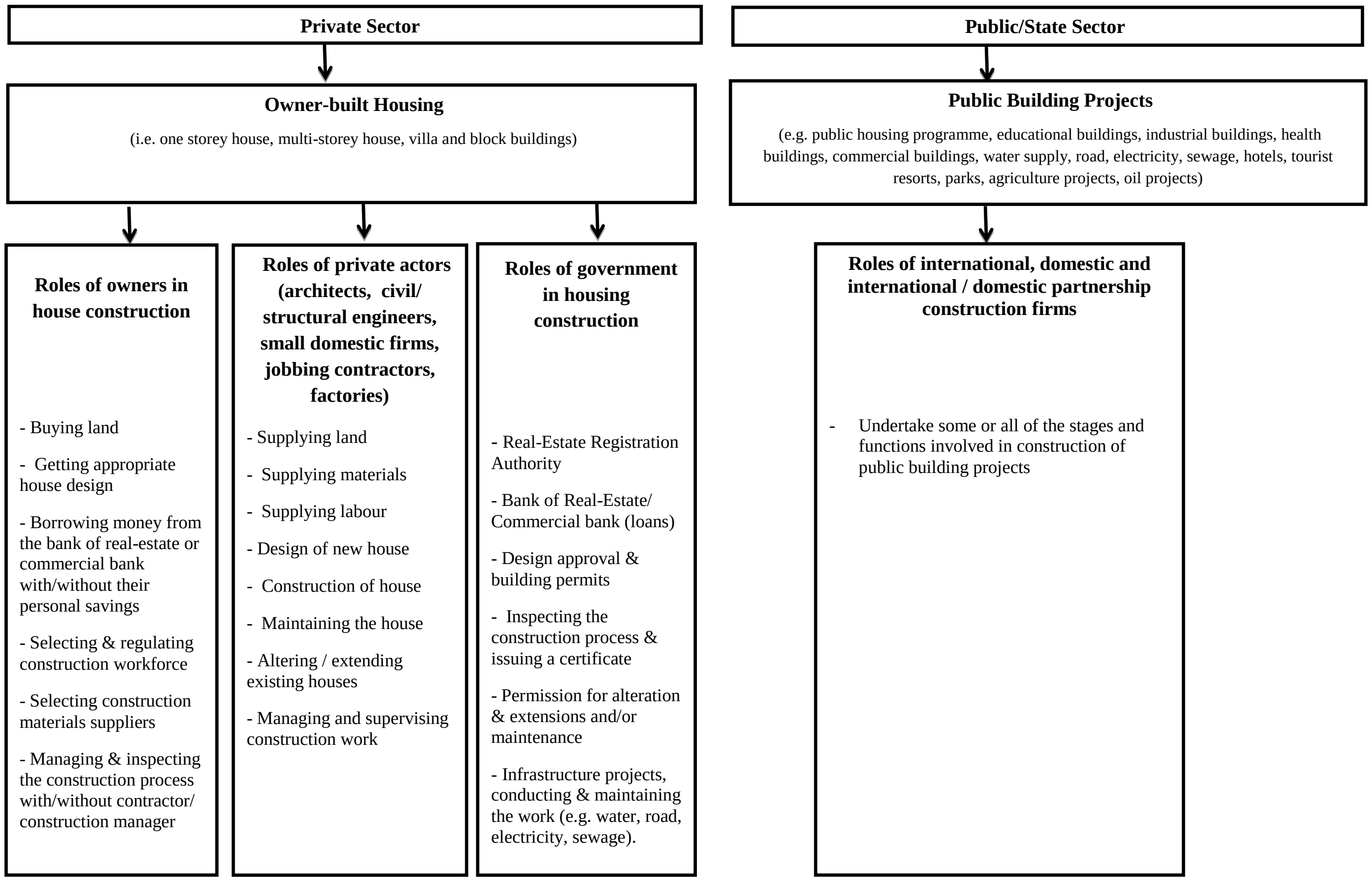


Figure 2.8 Actors and roles in the construction industry in Libya by sector

2.6 Climate Factor

2.6.1 Study Area Location

Libya is a North African country that is situated on the Mediterranean coast. It is noteworthy that Libya has the longest coastline of all African nations, exceeding 1800 km in length. Libya is bordered by six neighbours: Egypt, Sudan, Chad, Niger, Algeria and Tunisia. Owing to its location, Libya has witnessed many civilisations and has become a significant caravan trade link between Africa and Europe. In other words, it has a coastline which has easy communication from land, and also benefits from communication by sea, land and air to other regions of the world, making it the gateway to the African continent (Technical Committee to Study the Water Situation in the Great Jamahiriya, 1999). The total area of Libya is 1,759,540 square kilometres of landmass that supports a population of 6,310,434 people, (including 166,510 non-nationals). Geographically, there are three distinct regions of Libya: Cyrenaica, Tripolitania, and Fezzan. The capital city is Tripoli. The official language is Arabic, although English and Italian are spoken, particularly in relation to trade. Islam is the major religion; in general, the Islamic heritage is deeply rooted in the character of the Libyan people, representing individuals' behaviour in both social and business contexts (Communicaid Group Ltd., 2009).

Although Libya is known as a dry country, it has a region called the Green Mountain (Jebel Al-Akhdar), located in the north-east, on the Mediterranean coast. The region lies northeast of Benghazi and south of Derna and the Mediterranean Sea. It consists of mountains rising to 500 metres and contains a forested area. In contrast to the rest of Libya, Jebel Al-Akhdar receives around 500 millimetres rain annually. The geographic location of Albeida and the Green Mountain area is shown in Figure 2.9.

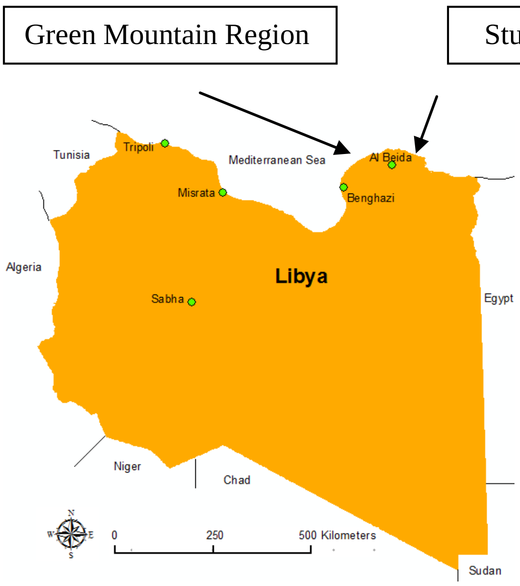


Figure 2.9 Geographic location of the Green Mountain area

Libya has a topographic characteristic of two mountain areas: the western mountain (Jabel Nufusa) in the south of Tripoli, and the Green Mountain (Jabel Al-Akhder) in the northeast of the country. The former has an average width of 20 kilometres and a height between 500 and 960 meters. The region is composed of basalt, limestone,volcanic rock, and gypsum-marl. The study area (Green Mountain Region) is at a height above sea level of between 300 and 830 metres. The land consists of limestone and red soil. Most of the mountain regions are covered with shrubforest, comprising pine, wheat and barley, juniper bushes and others (Grifa, 2006). The high rainfall rate is the major advantage of the Green Mountain Region in addition to the extensively forested areas. Albeida is the capital city of the mountainous region and one of the region's largest cities. Massa, Sousse and Shahat are other famous cities in the region. There are many beauty spots, such as the valley parks and coves in addition to the ancient city of Shahat (Cyrene), which is recognised as a global centre for archaeological and environmental tourism. Indeed, the region is considered one of the most beautiful areas of Libya, although the vegetation and forest decreased from 500000 to 180000 hectares twenty years ago because of uncontrolled construction activities (Ben Amor, 2009).

Libya is considered a small country in terms of its population. The Libyan population was first recorded in 1931 by the Italian colonial government when it was estimated to be about 704,000. A second national Census in 1936 recorded an increase of 144,417 people. Following independence in 1951, the Libyan government undertook another

Census in 1954, which indicated that the population was 1,088,873. After that, censuses were carried out every ten years (Ministry of Planning, 1995), recording a total population increase from 3,063 million to 6,335 million between 1980 and 2010 (Libya General Authority Information, 2010). The Green Mountain region had a population of approximately 208,000 inhabitants in 2010 (Libya General Authority Information, 2010), distributed across the main population centres shown in Figure 2.10.

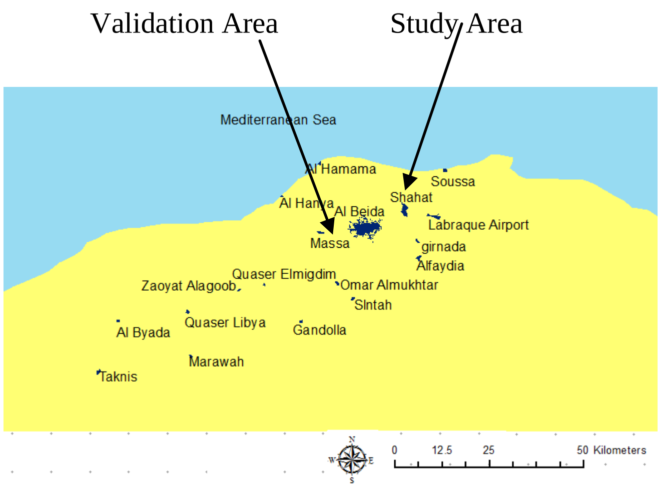


Figure 2.10 Main population centres in the Green Mountain area of North Eastern Libya

It can be seen from Figure 2.10 that the study area where the model was developed, Albeida, is situated only 10 Km from the area where it was validated, Massa.

Table 2.7 and Figure 2.11 show the relative populations of the different regions of Libya in 2010, including the studied area, the Green Mountain or Al-Jabel Al-Akhtar (region 10 in the map depicted in Figure 2.11). They show that most of the population lives in the Mediterranean area (regions 5, 6, 7, 8, 9, 10, 11).

Table 2.7 Population by Area (000s), 2010 Census

No. of Region from Figure 2.11	Region	Year 2010
12	Tubruk	163
11	Derna	167
10	Al-Jabel Al-Akhtar	208
9	Al-Marj	188
8	Benghazi	667
17	Alwaht	30
22	Al-Kofra	46
7	Sit	143
16	Al-Jofra	51
6	Misrata	552
5	Al-Margheb	441

Source. Libya. General authority for information (2010). *Statistics Book: General Authority for Information and Yearly Bulletin*. Libya.

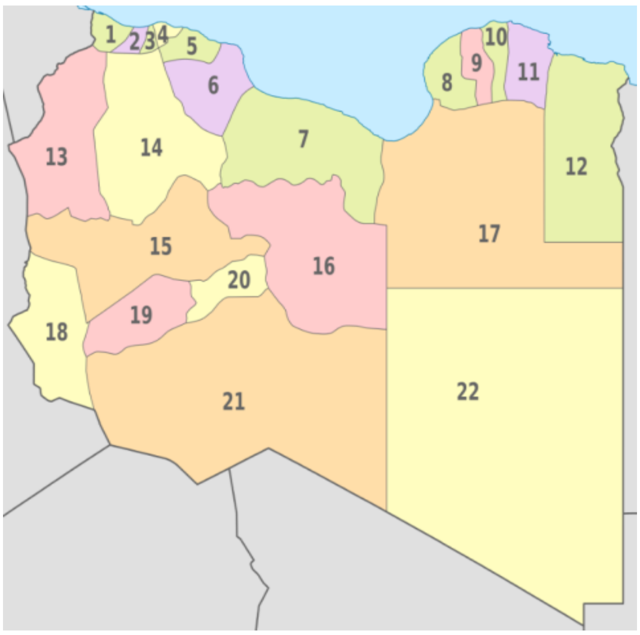


Figure 2.11 Map of regions of Libya
Source. Libya. General authority for information (2010). *Statistics Book: General Authority for Information and Yearly Bulletin*. Libya.

Generally speaking, the area where 80% of the population lives in Libya is characterised by a mild Mediterranean climate and desert. It is warm in summer and mild in winter. In contrast, the desert is characterised by extremely hot summers, particularly during the daytime. In the summer, the temperature is between 40.6° C and 46° C along the Tripolitanian coast and can be even higher in the south. Along the Cyrenaica coast, the summer temperature ranges between 26.7° C and 32° C.

In the winter, the temperature drops below 0°C. Frost and snowfall sometimes occur in the mountains; the rain falls for a short period during the winter season. The mountain areas of northern Libya receive a sufficient amount of average annual rainfall, although the other regions receive less than these areas (Federal Research Division, 2005). Two areas in particular receive a relatively greater amount of rainfall annually. They are the north-eastern region, including the Green Mountain and the Benghazi plain, together with the north-western region, including the Aljafarah plain and the western mountain. The high rainfall rate in the Green Mountain area is due to the influence of the westerly winds, with their known heavy rainfall rates, and also to the mountainous terrain. In general, the rain starts to fall in low quantities in September and then increases until it reaches the highest rate in February, before decreasing again until the end of May.

The Green Mountain area receives over 500 mm of rainfall per year, which is the highest in the country (Mahdi, 1998). Table 2.8 shows the monthly average for relative humidity, the monthly average for rainfall in millimeters and the number of rainy days according to the Met Station (2009) for the studied area. From the Libyan administration's point of view, the station of Shahat on the table includes Albeida station as well. Those two cities (Shahat and Albeida) are considered as a single station, district and location in the census for the entire country. Porter and Yergin (2006) highlighted how Libya changes the names of its municipals, central institutions and local committees from time to time, for national political reasons. Shahat has the largest monthly average percentage for relative humidity and rainfall in millimeters as well as the largest number of rainy days compared with other stations in the country.

Table 2.8 Relative Humidity, Rainfall in Millimeters and Number of Rainy Days in the Green Mountain Region

Monthly Average of the Relative Humidity (%) According to Met Station												
Station	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**August**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Shahat	75	72	70	64	62	56	65	76	76	74	79	70
Monthly Average of Rainfall in Millimeters (%) According to Met Station												
Station	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**August**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Shahat	56.3	182.7	24.7	8.0	33.7	0.0	0.0	0.0	14.4	82.0	25.2	114.1
Number of the Rainy Days According to Met Station												
Station	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**August**	**Sep.**	**Oct.**	**Nov.**	**Dec.**
Shahat	14	19	5	4	3	0	0	0	5	8	7	14

Source. Libya. General authority for information. (2009). *Statistics Book: General Authority for Information and Yearly Bulletin*. Libya.

2.6.2 Climate and Building

The environmental conditions are the most significant source of moisture for concrete construction related to the influential depth of moisture transport in concrete subject to drying-wetting cycles (Kefei *et al*., 2009). A study in the USA highlighted climatic condition as contributing to building defects by changing the physical characteristics of the material, particularly its surface (Lopez *et al*., 2011). Concrete can suffer frost damage, including cracking and spalling, at temperatures below zero (Popescu, Ovararin & Phaobunjong, 2005; Richardson, 2001). Botsai *et al*. (2010) and Lopez, Masters and Bolton (2011) argued that not only the water needs to be addressed in building envelope design but air infiltration is also an important element for the design professional. Schwartz (1990) also reported that, in general, building failures occur due to inadequate accounting for the pressure driven water in the threshold and seal designs.

The main cause of leaks is not the wind striking the surface or the velocity of the water on a building but, rather, the pressure differential itself. Significantly, Botsai *et al*. (2010) clarified that there are many sources of pressure differential; the obvious ones are water head, gravity and wind. However, there are other, less obvious factors, such as insufficient air-conditioning pressure in buildings and negative pressures caused by the kitchen and bath systems. Buildings therefore need to be adapted to the daily and seasonal climatic changes.

In Libya, the geography and climatic characteristics have a direct effect on housing and urban patterns. Some areas are desert while others have a Mediterranean climate, so the heating and cooling requirements differ, as do the orientation of buildings where there are high winds and abundant rainfall common in the North West. Along the Green Mountain coast the relevant climatic factors are winter rain and wind direction (Mahdi, 1998), requiring special attention to be paid to the internal housing spaces, house orientation, natural light and ventilation (Almansuri *et al*., 2007). Adverse weather affects houses which are poorly designed, constructed and/or maintained, and therefore it is important to prevent cold temperatures reaching the internal spaces by: orienting the spaces to the best orientation; providing natural protection, using thick walls or cavity walls; double glazing windows; and employing appropriate designs and materials with insulation for the walls, roofs and windows (Almansuri *et al*., 2007; Tantosh, 2010).

A summary of the factors affecting concrete deterioration as identified in the literature review is presented in Table 2.9, together with a summary of the factors that directly affect the damp in concrete in Table 2.10. In table 2.10, the factors related to design, construction including wetting, drying, and maintenance are grouped together under the heading of knowledge management.

Table 2.9 Summary of Factors Affecting Concrete Deterioration from the Literature Review

Author	Location	Design Factor	Construction Factor	Climatic Factor	Maintenance Factor
Bertolini (2013)	Italy	x	x	x	x
Sharon (2012)	U.S.A	x			
Marshall, Worthing and Health (2009)	U.K		x	x	x
Someville (2008)	U.K	x			
Kefei (2009)	China			x	
Bennett (2007)	U.K	x	x		
Deplazes (2005)	U.S.A		x		
Popescu, Ovararin and Phaobunjong, (2005)	U.S.A	x			x
Rekela (2004)	U.K	x		x	
Shabha (2003)	U.K	x	x		x
Craig (2003)	U.S.A	x	x	x	
Sommerhoff (2002)	Japan	x			
Taylor (2002)	U.K	x			
Richardson (2001)	U.K	x		x	
Hendry (1998)	U.K	x	x		x
Hendry, Sinha and Davies (1997)	U.K	x	x		x
Chirgwin (1996)	U.K		x		
Everett (1994)	U.K		x	x	
Neville & Brooks (1993)	U.K	x	x		x
Son & Yuen (1993)	U.K	x	x	x	x
Addleson (1992)	U.K		x	x	
Lowry (1990)	U.K	x	x		
Bright, Saunders and Fudge (1990)	U.K	x	x		x

Table 2.10 Summary of Factors Affecting the Quality of Concrete Buildings in Relation to Damp from the Literature Review

Author	Location	Knowledge Management (rainfall, design, construction & maintenance phase)	Quality Management	Climatic Factor
Thomas Ng et al (2011)	Hong Kong		x	
Lopez, Masters and Bolton (2011)	U.S.A	x		x
Botsai et al. (2010)	Canada	x		
Mclean (2009)	U.K	x	x	
Kvande & Robert (2009)	Norway	x		
Marshall, Worthing and Health (2009)	U.K		x	x
Shabha (2003)	U.K	x	x	
Craig (2003)	U.S.A	x		
Chung (2002)	U.K	x	x	
Straube (2002)	Canada			x
Richardson (2001)	U.K			x
Nevalainen et al.(1998)	Denmark		x	x
Son & Yuen (1993)	U.K	x	x	
Addleson (1992)	U.K	x		x
Lowry (1990)	U.K	x		
Schwartz (1990)	U.S.A	x		

2.7 Summary

A wide range of factors and issues was identified that influence the performance of concrete houses: construction, socio-economic design, management and climatic issues. These have resulted in the inferior performance of concrete houses with regard to penetrating damp. In other words, the problem can be interpreted in the context of constructing a model of factors which cause damp in concrete houses in the Green Mountain Area of Libya. The examination of these factors has also indicated the involvement of various stakeholders (planners, designers, constructors, maintenance men, decision makers and above all the house owners) in increasing or reducing the possibility of defects related to dampness arising in concrete buildings (Bertolini, 2013; De Haro & Koslowski, 2013; Forty, 2012; Georgiou, 2010; Marshall, Worthing and Health, 2009; Mclean, 2009; Shabha, 2003; Sharon, 2012; Thomas Ng *et al*, 2011).

The literature contains different arguments about the causes of building defects, some of which are classified as due to natural causes and other as due to human causes. It has been argued that the accurate determination of the causes of building failure could reduce or control the incidence of failure in the future (Porteous, 1992, cited in Porteous, 2007). For instance, rain as a source may enter the building and give rise to dampness. This can be considered as a natural cause of building failure which has been caused by human error. Human causes were emphasised by Douglas and Ransom (2007), who noted that many defects in buildings occur as a result of the non-application or misapplication of basic knowledge. This is based on the existence of a sequence of accidents which must occur before it can be stated that a building has failed. Figure 2.12 proposes an overview of the natural and human factors that affect housing construction defects, showing the literature sources on which this overview was based.

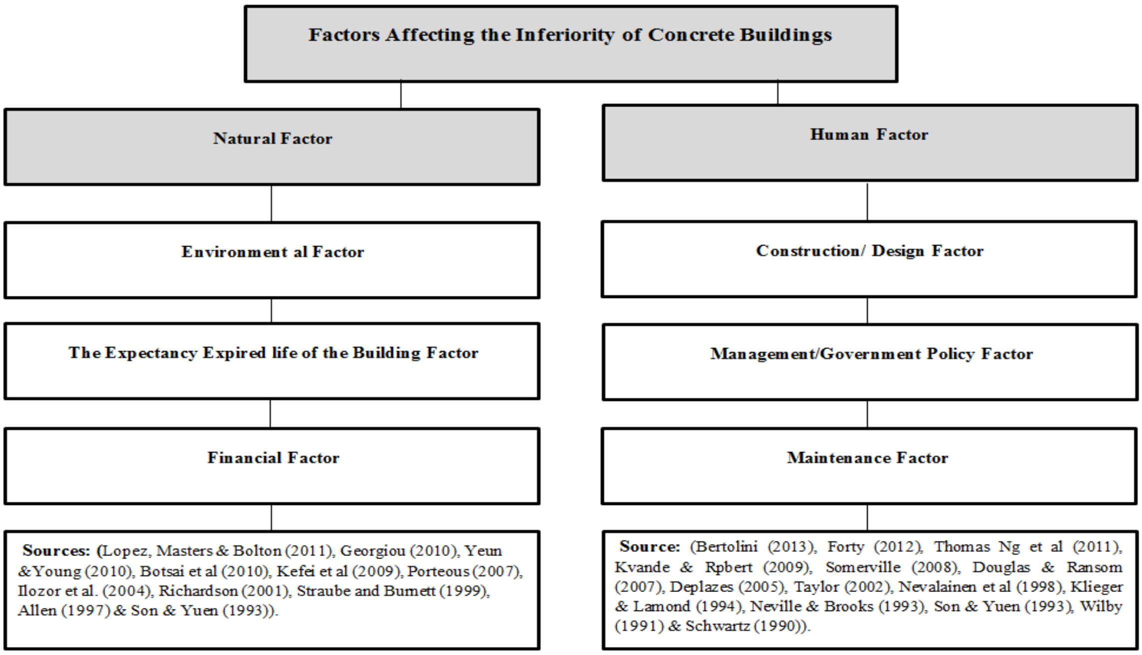


Figure 2.12 Human and natural factors that affect the defects in housing construction from the literature review

The World Health Organisation (2000) forecast that the poor and decaying condition of constructions could threaten the stability of the government in countries that are dedicated to concrete, such as Asian and East European states, where concrete residential buildings are a social unity factor. Research in India and other countries stated that the defects and deterioration of concrete has become a global issue (Bagdiva & Wadalkar, 2015; Yeomans, 2004); many societies from developed and developing countries have faced difficulty in achieving high quality concrete production, despite the various advances in knowledge and techniques. Together with the requirement to improve the gross domestic product (Quereshi & Mohyuddin, 2006), this suggests that an assessment of the relative importance of the factors causing damp in concrete buildings is required to enhance the quality of construction projects from all perspectives: pre-construction, during-construction and after-construction.

A suitable method is therefore required to evaluate the importance of each factor that causes penetrating damp within concrete houses in the Green Mountain area. The Analytical Hierarchy Process Technique was selected to analyse and evaluate those factors. It is a structured tool based on mathematical models for organising and analysing complex decisions (Saaty, 1980) which can deal with the factors identified in the main topic areas of the literature review.

The next chapter explains the application and application and procedures of the technique in more detail.

Chapter Three: AHP Technique

3.1 Introduction

A systematic approach to data analysis and interpretation is important. It condenses an extensive amount of data into smaller analyzable units, on which the integration between the data is built (Bryman, 2007). In this study, the Analytical Hierarchy Process technique provides an applied research method of analysis. It was selected in order to evaluate the most important factors, criteria and sub-criteria that affect domestic houses' performance in the Green Mountain area of Libya in the context of the problem of damp. In general, this technique has been applied in various nations, such as the U.S.A, Asian countries and European countries, among others. However, the technique has not been widely applied in most developing countries, particularly African nations and Middle Eastern counties (Vaidya & Kumar, 2004). Academically, this technique has been applied to various fields as an effective tool to support the multi-criteria decision making process (Saaty, 2007). For instance, it has been applied in carrier selection decisions (Bagchi, 1989), the supplier selection process (Nydick & Hill, 1992), the evaluation of advanced construction technology (Skibniewski &Chao, 1992) and contractor selection criteria (Jaskowski *et al*. 2009). Table 3.1 presents a wider selection of uses of the technique which illustrates its broad applicability.

Table 3.1 Application of AHP in Various Fields

Use of AHP	Sources
Carrier selection decisions	(Bagchi, 1989)
Supplier selection process	(Nydick & Hill, 1992)
Evaluation of advanced construction technology	(Skibniewski & Chao, 1992)
Solution for an airport location problem	(Min, 1994)
Building assembly selection	(Nassar *et al*. 2003)
Contracting model development	(Abudayyeh, Zidan, Yehia & Randolph, 2007)
Equipment selection	(Goldenberg & Shapira, 2007)
Risk assessment for construction joint ventures	(Hsueh, Perng, Yan & Lee, 2007)
Project selection	(Kendrick & Saaty, 2007)
Construction method selection	(Pan, 2008)
Best value bid selection	(Lin, Wang &Yu, 2008)
Evaluation of an intelligent building system	(Wong & Li, 2008)
Contractor selection criteria	(Jaskowski *et al*. 2009)
Land selection criteria for agriculture	(Abushnaf, 2014; Boroushaki & Malczewski, 2008)

In the present study, the technique has been applied to evaluate a collection of factors that affect house performance in the context of the issue of penetrating damp. The study is positioned between the disciplines of construction and architecture and involves a variety of stakeholder views as more usually found in housing studies. Therefore a method which allows subjective decisions to be quantified was needed. This chapter highlights the reasons behind the selection of this particular method, and also presents the advantages and disadvantages of the technique.

3.2 Selection of the AHP Technique

The application of the analytical structured technique contributes to the overall systematic approach of this research, although the research also includes other kinds of investigative tools. The technique is also called the Multi-Criteria Decision-Making Method (MCDM); it includes and integrates the contributors' knowledge and experience at different levels of decision making. This procedure helps decision makers to analyze and evaluate multiple and competing criteria. It is a continuous procedure, which begins with an analysis of the decision background, so that the factors can be built up into different levels and groups (Saaty, 2008; Vogel, 2008).

One reason for choosing the Analytic Hierarchy Process technique was its ability to deal with the multiple, potentially competing factors involved in understanding the research problem by generating weights for the construction, socio-economic design, management and climatic factors influencing the performance of houses in the context of penetrating damp. As Kirkwood (1997) clarified, multi-objective decision analysis with spreadsheets that produces different degrees of significance is vital in evaluation criteria because they are attached to these ranges of variation. Formalising and presenting a systematic approach, which is largely applied as a tool in a decision making process results in an accurate judgment (Abushnaf, 2014; Jaskowski *et al*. 2009; Kendrick & Saaty, 2007; Nassar *et al*., 2003; Pan, 2008; Wong & Li, 2008). Equally important, the technique facilitates understanding of a complex real-life problem by bringing a mathematical approach to the resolution of conflicting subjective judgments (Malczewski, 1999; Saaty, 1980; Voogd, 1983). Ultimately, AHP is used to create an acceptable evaluation among conflicting factors.

Other types of multi-criterion decision-making methods were considered, notably Boolean and Fuzzy logic. The Boolean method is based on the logic of true or false; it qualitatively describes the differences between the classes, although intermediate classes are not considered. The limits are strictly defined on a binary basis (1, 0) which may unduly constrain subjective judgments. Fuzzy logic is a mathematical method designed to denote and manage ambiguity. It is an extension of traditional Boolean logic where the Fuzzy logic set limits are blurred and objective, defined by a number between zero (0) and one (1) (Lodwick, 2007; Malczewski & Rinner 2005; Zadeh, 2008). However, Sicat, Carranza and Nidumolu (2005) criticised these methods by stating that the lack of precision in both the data and the formulation of queries has led to the need for methods that can manage inaccuracy.

There are other types of weighting methods, such as ranking and rating, that have the same function of evaluating particular factors and/or criteria. Considering the derived weight methods, the ranking method is a technique whereby every factor and/or criterion is ranked by the decision makers. It consists of a very simple procedure; either ranking can be applied, for instance straight ranking; the most important = 1, second important = 2 or inverse ranking; the least important = 1, next least important = 2 (Malczewski, 1999; Stillwell, Seaver & Edwards, 1981). However, Voogd (1983) stated that the practical application of this method is limited by the number of criteria. In general, the smaller the number of criteria used, the more appropriate the ranking method. Another method is the rating method in which the decision maker estimates weights based on a predetermined scale. The limitations of the rating method are the lack of a theoretical foundation and the absence of a justification for the weights produced (Kolat, 2004; Malczewski, 1999).

Another derived weights technique is called trade-off. In this method, the decision makers need to compare two alternatives with respect to two criteria at a time and assess which alternative is preferred (Malczewski, 1999). Its limitation is that the decision makers presume to obey the axioms and make judgments (Kirkwood, 1997).

Table 3.2 compares the estimating weights techniques by summarising the main feature of each method. The table provides a simplified assessment of the methods of weight evaluation. The selection of a particular technique depends on its accuracy, degree of understanding by the decision makers, underlying theoretical foundation, ease of use and the availability of computer software.

Table 3.2 Derived Weights Method Comparison

Feature	Method			
	Ranking	**Rating**	**AHP(PCM)**	**Trade-Off**
Number of Judgments	n	n	n(n-1)/2	<n
Response Scale	Ordinal	Interval	Ratio	Interval
Hierarchical	Possible	Possible	Yes	Yes
Underlying Theory	None	None	Statistical/Heuristic	Axiomatic/Deductive
Ease of Use	V. easy	V. easy	Easy	Difficult
Trust Worthiness	Low	Low	High	Medium
Precision	Approximations	Not Precise	Quite Precise	Quit Precise
Software Availability	Spreadsheets	Spreadsheets	Expert Choice	Logical Decision

Source. (Kolat, 2004 & Malczewski, 1999)

3.3 Advantages and Disadvantages of the AHP Technique

The AHP method was developed in 1977 by Thomas Saaty to assist with constructing appropriate decisions for particular problems. It can integrate several data types involved in a particular goal application and its weighting criteria applied to different types of data,as for instance in Abushnaf (2014), Boroushaki and Malczewski (2008), Jaskowski *et al*. (2009) and Saaty (2008). However, like any other analytical approach, the technique has its benefits and limitations, so a high level of understanding of the evaluated context is required.

The technique is a flexible method which can be integrated with other techniques (Vaidya & Kumar, 2004). This technique provides a way of standardising a numeric scale which enables quantitative performance as well as qualitative performance to be measured, in order to solve complex real-life problems (Crowe & Noble, 1998; Saaty, 1980; Wong & Li, 2007). Additionally, the technique tests the consistency of subject experts' judgments through the application of consistency ratio; it has the ability to manage inconsistent judgments and offers a measure of the inconsistency of the judgment of the respondents (Wong & Li, 2007). AHP is a robust and reliable method to capture preference results (Itami, MacLaren & Hirst, 2000).

With respect to Saaty's original scale of 1 to 9 for assessing the relative importance of two items, Saaty and Tran (2007) believed that where individuals felt the difference to be too strong, intermediate values were sufficient to express indecision of opinion.

Several scholars including (Deng, 1999; Erensal, Öncan & Demircan, 2006; Ertuğrul & Karakaşoğlu, 2009; Jaskowski *et al*., 2009; Lakoff, 1977; Prakash, 2003; Vahidnia, Alesheikh, Alimohammadi & Bassiri, 2008; Triantaphyllou & Mann, 1990) claimed that Saaty’s values of 1 to 9 lacked the refinement to capture the uncertainties and subtleties of some individual judgments. Additionally, Erensal *et al*. (2006) argued that the scale used in the technique might not reflect the style of human thinking because decision makers normally feel more confident about providing interval judgments rather than producing single numeric values. Chen *et al*. (2011) added that the opinion and assessment of experts have always involved uncertainty and ambiguity. Consequently, the results may not be adequate for producing weights for criteria in the process of decision making. From a standpoint of qualitative research, Jaskowski *et al*. (2009) stated that it is easier to use verbal description to determine comparative preferences rather than give a specific value on a scale.

3.4 How the AHP Technique Works

Normally, the process yields a hierarchy of criteria which comprises four levels: goal, objectives, attributes and alternatives. However, it does not require all levels to be completed in all cases. The technique is based on three principles: decomposition, comparative judgment and synthesis of priorities (Jaskowski *et al*. 2010). In relation to the principle of decomposition, challenging problems are grasped by analysing them into a hierarchy of criteria; comparative judgment is then used to weight the issues by comparing them at each level of the hierarchy. A group of significances is constructed for each issue at the lowest level of the hierarchy (Boroushaki & Malczewski, 2008). Figure 3.1 shows the AHP matrix.

$$
A = \begin{bmatrix} a_{11} & a_{12} & . & . & .a_{1n} \\ a_{21} & a_{22} & . & . & .a_{2n} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ a_{n1} & a_{n2} & . & . & .a_{nn} \end{bmatrix}.
$$

Figure 3.1 Analytical hierarchy matrix (AHP)
Source. Saaty, T. L. (1980). *The analytic hierarchy process.* New York: McGraw-Hill International.

A complex decision problem is decomposed into simpler issues to form a hierarchy of factors, criteria and sub-criteria. A number of levels are formulated for each issue. The eigenvector is determined from the relative importance matrices. Alternatives are selected with the highest eigenvalue. In the present research, however, alternatives were not introduced because the focus was on correctly understanding a problem rather than seeking a solution to it. Saaty (1980) supported this approach, stating that the hierarchy does not need to be completed; for instance, an alternative does not need to be involved and the technique can be used for analysing problems, preparing assessments and/or making decisions.

Generally, the hierarchy should consist of at least three levels to be useful. The first level represents the goal of the decision-making process, the second level involves the objective or criteria which affect the decision, and the third level contains subdivided criteria which also affect the final decision. Each level of the hierarchy is related to the next higher or lower level (Saaty, 1980). Using the present research as an example, the highest level has the overall aim of evaluating the factors that cause the problem of damp within domestic concrete houses in the Green Mountain of Libya. This is followed by the second level factors, which include four issues: construction, socio-economic design, management and climate. The third level consists of two sub-criteria for each factor. For instance, the construction factor is divided into manufacturing criteria and construction design, and the climatic factor is divided into rain and wind direction.

At the lowest level, the number of sub-criteria of each factor varied according to their identification in the literature review. For instance, there were four sub-criteria within the lowest level of construction design criterion: roof design, exterior walls, water tank location and exterior finishing. In contrast, there was only one sub-criterion in the lowest level of the rainy season criterion, namely rainy season. Table 3.3 illustrates the proposed model of factors affecting the performance of concrete houses in the Green Mountain Region in Libya, based on the factors identified in the literature review.

Table 3.3 Proposed Model of Factors Affecting the Performance of Concrete Houses in the Green Mountain Region of Libya

Level 1	**Level 2**	**Level 3**	**Level 4**
Primary Problem	**Factor**	**Criteria**	**Sub-Criteria**
Model of the Performance of Domestic Concrete Houses against Penetrating Damp	Construction	Manufacturing Criteria	Raw Materials Workforce Control of in-situ Concrete
		Construction Design	Exterior Finishing Roof Design Exterior Walls Water Tank Location
	Socio-Economic Design	Cost & Knowledge Effectiveness	Selection of Raw Materials Selection of Builders Exterior Finishing Maintenance Delay in Construction
		Socio-Religious Design Requirements	Room Size Interior Finishing Hospitality Rooms Future Requirements Social Activities
	Management	Construction Supervision Criteria	Owners' Supervision Experts' Supervision
		Housing Policy	Changes in Housing Construction Policy
	Climatic	Rainy Season Wind Direction	Rainy Season (Nov-May) Northwest Direction

Once the hierarchy has been constructed and defined, the top level is called the ultimate goal of the conclusion. The researcher works down the hierarchy from the general to more specific factors, criteria and sub-criteria until each level, factor and criterion is clear in the sense that it enables the problem to be fully understood. When the decomposition is completed, a fundamental weighting of the factors, criteria and sub-criteria is required. This is performed by using the pairwise comparison method (PCM) for each level of the hierarchy in order to obtain weights for each factor, criterion and sub-criterion. Usually, the comparison starts from the top of the hierarchy and moves down. In general, element (1) is compared against element 2, 3….n, element (2) is compared against element 1, 3, 4….n and so on. This is obtained by the production of an independent assessment of contributors using a scale ranging from 1-9.

In the present research, this was achieved by asking the experts and house owners about their opinions and decisions between pairs of factors, criteria and sub-criteria. This comparison involves three steps: development of a pairwise comparison matrix, assessment of the consistency of judgments by calculation of a consistency ratio, and computation of the weights.

Step 1. Development of a comparison matrix at each level of the hierarchy using a scale ranging from 1 to 9 created by Saaty (1977). Table 3.4 illustrates the Saaty scale. Then, the pairwise comparison matrix is constructed. This process is achieved by asking the experts and house owners to evaluate and compare the hierarchy's elements at each level; house performance factors, criteria and sub-criteria. Each contributor wisely compares and produces a set of ($m=n(n-1)/2$) comparative judgments and provides a numerical value of an importance ratio using the Saaty scale 1, 3, 5,7, 9, 1/3, 1/5, 1/7 and 1/9. However, the scale might be extended to intermediate values, such as 2, 4, 8, 1/2, 1/4 and 1/8 (Saaty, 1980).

Table 3.4 Scales in Pairwise Comparisons

Intensity of Importance	Verbal Judgment of Preference
1	Equally Importance
3	Moderate Importance
5	Strong Importance
7	Extreme Importance
9	Extremely More Important
2, 4, 6, 8	Intermediate Values between Adjacent Scale Values

Source. Saaty, T. L. (1980). *The analytic hierarchy process*. New York: McGraw-Hill International.

These sets of pairwise comparisons are stored in a pairwise comparison matrix (PCM), which is represented in (A) matrix with size (n x n). Each entry in *(*A), as shown in Figure 3.2, is represented by (aij), which indicates the comparison of factor (i) to factor (j), and (aij=1 for i =1, 2… n). Similarly, the comparison of element (j) to element (i) is the reverse of the entry for element (i) compared to element (j). Therefore, (aji = 1/aij for all i, j), and it can be perceived that PCM is a positive 1 reciprocal matrix.

$$\mathrm{A} = \begin{bmatrix} a_{11} & a_{12} & . & . & .a_{1n} \\ a_{21} & a_{22} & . & . & .a_{2n} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ a_{n1} & a_{n2} & . & . & .a_{nn} \end{bmatrix}.$$

Figure 3.2 AHP hierarchy matrix

Source. Saaty, T. L. (1980). *The analytic hierarchy process*. New York: McGraw-Hill International.

In this research, ten pairwise comparison matrixes were constructed. Examples given in Table 3.5 illustrate the way they are constructed by level and incorporate the number of factors (matrix size).

Table 3.5 Pairwise Comparison Matrix Employed by the Study

Pairwise Comparison Matrix (PCM)	Level	Matrix Size
Construction, climatic, management and socio-economic design factors	2	4x4
Manufacturing criteria and construction design criteria	3	2x2
Raw materials, workforce and control of in-situ concrete sub-criteria	4	3x3
Roof design, exterior wall, water tank location and exterior finishing sub-criteria	4	4x4
Raw materials selection, selection of builders, delay in construction, maintenance and exterior finishing selection sub-criteria	4	5x5

Step 2. The estimation of the consistency ratio is the next process in this technique, where an ideal consistency ratio (C.R.) is C.R. ≤ 0.1. A ratio of ≤ 0.1illustrates that the comparison matrix is perfectly consistent and that the comparative weights are valid. The C.R. is constructed for each constructed PCM pairwise comparison matrix at each level of the hierarchy. If the consistency ratio is found to be ≥ 0.1, then the pairwise comparison has to be either re-evaluated or removed (Abushnaf, 2014; Saaty, 1980). Tam, Tong and Chiu (2006, p.181) stated that, "*the reassessment process is impractical and tedious in situation where time is crucial...Reassessment is simply too expensive for sorting out inconsistencies*". In the present research, the unacceptable consistency ratios were simply excluded; re-evaluation was not conducted due to the constraints of the research schedule.

The consistency ratio is calculated using the following steps:

- Sum the elements of each column

$$\sum_{i=1}^{n} a_{ij}$$

- Divide each element by its column sum

$$\grave{a}_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n} a_{ij}}$$

- Calculate the average of elements in each row in order to obtain the weight

$$w = \frac{\sum_{j=1}^{n} a_{ij}}{k}$$

- Determine the input consistency ratio (C.R.)

$$CR = \frac{CI}{RI}$$

Where,

(C.I.) consistency index

(ʎ max) is the maximum Eigenvalue of the pairwise comparison matrix

(n) is the number of elements being compared and

RI is the random index, which depends on the number of elements (n) criteria being compared

$$CI = \frac{\lambda\max - n}{n-1}$$

Table 3.6 Random Consistency Index (RI)

n	1	2	3	4	5	6	7	
RI	0.00	0.00	0.58	0.9	1.12	1.24	1.32	
n	8	9	10	11	12	13	14	15
RI	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.59

Source. Saaty, T. L. (1990). How to make a decision: The analytic hierarchy process. *European Journal of Operational Research, 48,* pp. 9-26.

Step 3. Computation of the weights for each element of the hierarchy is obtained by multiplying the comparative weights matrix for each level in the hierarchy in order to combine the relative importance weights of the factors, criteria and sub-criteria obtained and so produce composite weights.

This can be achieved by means of a sequence of multiplications of matrices of comparative weights at each level of the hierarchy. First, the original comparison matrix is squared, and then the row sums are calculated and normalised for each row in the comparison matrix. This process is continued until the difference between the normalised weights of the repetitions falls below a suggested value (Saaty, 1990; Saaty, 1994; Saaty & Vargas, 1991).

3.5 Group Decision Making

After calculating the weights produced by (K) contributors, a question arises regarding which of the weights should be preferred or is more convincing than the others, particularly where the weights are diverse. To answer this question, it is important to explain how a single representative evaluation can be obtained from diverse evaluators' opinions. Several studies (Elaalem, 2013; Keshavarzi, 2010; Pan, 2008; Prakash, 2003) have applied the technique with only one contributor to determine the weights of particular criteria, which is perceived as too subjective and constitutes a limitation in the generalisation of study findings (Chen *et al.*, 2011; Dinh & Duc, 2012; Thapa & Murayama, 2008). The bias of a single individual should be avoided by involving several evaluators in making the judgments in order to produce a group decision.

Saaty (2008) and other scholars (Dyer & Forman, 1992; Forman & Peniwati, 1998; Ishizaka, 2013; Ishizaka & Labib, 2011; Malczewski, 1999; Ramanathan & Ganesh, 1995) suggested several ways to determine a weighting when working with the judgments of several individuals. They developed two different AHP mathematical techniques for cases where a consensus cannot be obtained within the group decisions. These approaches are Aggregate Individual Priority (AIP) and Aggregate Individual Judgment (AIJ). The former weights geometric or arithmetic means whereas the latter aggregates individual decisions by calculating the geometric mean in order to produce a new pairwise comparison matrix for the group to derive the weight for each factor or criterion, after which the eigenvector (EV) method is applied (Australia Department of Defence Science, 2004; Ramanathan & Ganesh, 1995; Saaty, 1980; Zadnik-Stirn & Groselj, 2010).

The present research included a range of contributors' values which required further work to reduce the agglomeration of multiple experts and house owners' judgments into a value representing the overall weighting. Such an exercise is potentially extremely difficult where opinions might be in conflict, even among a small group. Consequently, the Group Analytic Hierarchy Process was selected to enable a robust result to be reached in deriving the weights for selected factors. This was done by using an Aggregate Individual Judgment (AIJ) method, where a new pairwise comparison matrix is constructed for each group to aggregate the weights of individual judgments by calculating a geometric mean.

Saaty (2008) stated that, when combining the judgments of many individuals in order to obtain a single judgment for a group, reciprocal property plays a significant role. By combining the judgments, the reciprocal of the produced judgments is equal to the combinations of the reciprocals of these decisions. The reciprocal value is used in the transposed positions of the matrix below the diagonal. In this way, every value of Saaty's scale has its reciprocal value for comparison. Jaskowski *et al*. (2009) and Saaty (2008) further highlighted that the geometric mean rather than the arithmetic mean is the only technique for performing that procedure in the classical AHP method, although both can be applied. The geometric mean can combine the contributors' different priorities into a single representative decision using AIJ (Australia Department of Defence Science, 2004; Bahurmoz, 2006; Pan, 2008; Ramanathan & Ganesh, 1995; Saaty, 1980; Zadnik-Stirn & Groselj, 2010). Saaty and Vargas (2007) confirmed that the geometric mean can be applied to the representative weight of the entire group on condition that the dispersion of the group decision is not remarkably large. Cho and Cho (2008), Jaskowski (2010) and Topcu (2004) argued that, although the arithmetic mean method can be applied to the final priority, it cannot be applied to aggregate the pairwise comparison matrix (AIJ).

To illustrate this process, consider a group of four contributors, who completed a PCM by applying AHP, in the Group Analytic Hierarchy Process (GAHP). The four matrices were compiled by calculating the geometric mean of the group comparison matrices involving the four participants; a new comparison matrix was produced containing new elements (numbers) of geometric means by applying the next equation. A consistency ratio then needed to be calculated in order to check the matrix consistency again, which had to be less than 0.1; and then step 3 within the comparison, explained earlier, was applied.

$$\text{Geometric Mean} = (\Pi_{i=1}^{n} a_i)^{1/n}$$

where n is the number of contributors.

In this illustration, four contributors are involved, n = 1, 2, 3, 4

$$A = (a_{ij}) , \qquad n = 1, 2, 3, 4$$

The (4x4) pairwise comparison matrix is generated by the contributors when considering a particular factor, criteria or sub-criteria within the hierarchy.

$$\begin{bmatrix} a_{11} & \cdots & a_{14} \\ \vdots & \ddots & \vdots \\ a_{41} & \cdots & a_{44} \end{bmatrix}$$

Calculating the geometric mean for each entry of A

$$a_{ij} = (a_{ij}^{1} \,.\, a_{ij}^{2} \,.\, a_{ij}^{3} \,.\, a_{ij}^{4}) \qquad i, j = 1, 2, 3, 4$$

The geometric mean maintains the reciprocal nature that is essential for pairwise comparison matrices, that is:

$$a_{ij} = (a_{ij}^{1} \,.\, a_{ij}^{2} \,.\, a_{ij}^{3} \,.\, a_{ij}^{4})^{1/4} = (\frac{1}{a_{ij}^{1}} \cdot \frac{1}{a_{ij}^{2}} \cdot \frac{1}{a_{ij}^{3}} \cdot \frac{1}{a_{ij}^{4}})^{1/4} = \frac{1}{a_{ij}}$$

A= (a_{ij}) is a positive reciprocal matrix. Then, the new representative weight is determined after using the eigenvector method, which was described earlier in the group decision making section.

3.6 Model Development

Hillston (2003, p.102) stated that *"A model is usually developed to analyse a particular problem"*. A model is developed for a specific purpose and its validity specified with respect to that purpose (Sargent, 2009). Model development is a complex process in which the developer, in conjunction with other stakeholders, decides what is important to the chosen problem (Tappenden, 2012).

The purpose of model development is to understand the complexity of the real-world problem that the AHP model is attempting to represent, and the choices available for translating this understanding of complexity into a credible conceptual and mathematical structure.

After the construction and evaluation of the initial AHP model, further development may be required to promote deeper understanding of the nature of the problem. The way in which this was carried out for the problem of damp in concrete houses in the Green Mountain area of Libya is described in Chapter Four (Research Methodology).

3.7 Model Validation

Sargent (2009) stated that model validation is critical in the development of a simulation model. Validation is a task of indicating that the model is a rational demonstration of an actual system (Hillston, 2003). In the AHP technique, evaluators can capture the importance of each factor by making pairwise comparison judgments expressed using the AHP fundamental scale in a matrix which results in a priority vector or in a hierarchical model composed of a number of pairwise comparison matrices. The results are based on subjective judgments while claiming to be normative. Validating the weights given to the subjective judgments made by experts and owner-builders' perceptions is what validation is intended to address (Saaty, 2005).

After the AHP model is developed, it is required to be validated in order to judge how good the model is with respect to the real world situation and how effective the technique is in producing such a model. Observing a number of houses which are subject to penetrating damp and hearing the voice of owner-builders through a questionnaire were the chosen validation tools for this research. These tools are widely adopted as a validation tool particularly in construction, maintenance management; housing and urban planning research (Ali, 2011; Amer, 2007; Fapohunda, 2009; Obiajunwa, 2010). Whilst various statistical methods have also been used to validate AHP, as has comparison of the final weightings with the real-life scenario where possible, *"The AHP is an empirical process more concerned with the success of applications and using information from a decision maker in its simplest and most natural form"* with the use of his/her knowledge and experience (Whitaker, 2007).

Thus, an empirical form of validation was chosen in the present research and achieved by comparing the AHP weights between the houses of Albeida and Massa within the Green Mountain region. Chapter 8 highlights the model validation techniques, process and analysis with interpretation.

3.8 Summary

This chapter has explained how the technique is applied, with reference to the evaluation of the factors that affect the performance of concrete houses in the context of damp in the Green Mountain, Libya. It has highlighted some of the advantages and disadvantages of the technique, offered reasons for its selection and distinguished between the two phases of AHP model development and validation.

The technique is an effective tool for dealing with complex decision making; it assists with the capture of both subjective and objective aspects of a decision (Saaty, 1980), or, as in the present research, the factors involved in a complex problem. This structured and systematic approach can, at least in theory, be applied in any real-life situation and in any fields, using different sets of evaluation criteria and weights. The technique can be also integrated with other methods (Itami *et al*, 2000). This is important when there is insufficient data at the beginning to be able to construct a complete model or when a need for additional data emerges during the modelling process. The next chapter, Chapter Four (Research Methodology) explains in detail and justifies the research methodology as a whole.

Chapter Four: Research Methodology

4.1 Introduction

The further investigation needed to construct and confirm the AHP model meant that additional data were required together with supporting data analysis. In order to investigate the factors causing issues of penetrating damp in domestic houses in the Green Mountain area of Libya, a theoretical framework was required which offered an appropriate way of defining and exploring the topic (Creswell, 2013). Guba (1990) stated that the theoretical frameworks or paradigms which the researcher brings to the research are the basic set of beliefs that guide action. Paradigms act as research frameworks which contain a method of knowledge acquisition (epistemology) as well as methods of data collection and analysis which are consistent with each other. There should be coherence between the researcher's understanding of epistemology and the philosophical approach adopted; this coherence should be seen in the methodology and the methods adopted. In studies which cross disciplines, in this case housing, construction and architecture, it is more important to demonstrate that the researcher’s choices are logical and suit the study than to rigidly follow a traditional paradigm (Then, 1996).

This chapter offers justification and critical examination of the selected research strategy and design, together with the data collection and data analysis methods adopted. It first clarifies the philosophical foundations that underpin this study, the ontology and epistemology. The selection of case study as the research strategy is described, followed by the research design of the methods employed within the case study. For each method, sample selection and procedure are described. There follows a section on data analysis processes for each data collection method. The chapter continues with a discussion of validity and how it was established in this study, concluding with a section on challenges faced and ethical considerations relevant to the study were addressed.

4.2 Philosophical Foundations

The philosophy that underpins the research assists the formulation of the research problem as well as the processes of information gathering, analysis and interpretation.

The philosophy of the study is a means of conveying the assumptions, providing definitions, and discussing how they are illustrated in the study through referring to the literature (Creswell, 2011). Researchers need to take a philosophical stance for their study, as well as decide what kinds of knowledge are being pursued and how knowledge can be adequately and legitimately obtained (Crotty, 1998; Gray, 2009). The choice of philosophical stance is not straightforward, not least because different scholars use different terms. Crotty (1998) distinguished at least five main theoretical perspectives. These do not include pragmatism which is discussed by Gray (2009) among others. Saunders, Lewis and Thornhill (2012), however, identified four: positivism, realism, interpretivism and pragmatism. The confusion of language continues with Crotty (1998) referring to three types of epistemology and Saunders *et al*. (2012) avoiding epistemology and instead identifying three types of approach. Over time, researchers have developed variations of the basic divide between scientific and social research, and between quantitative and qualitative methods. The terms used to describe these variations have become increasingly confused and confusing, for example, pragmatism. Pragmatism is considered a philosophical viewpoint by some researchers (Saunders *et al*., 2012), others argue that pragmatism is associated with practitioners who seek to improve their practice (evidence-based practice), while academic research produced a different kind of knowledge (Tranfield & Starkey, 1998). Another example is when Maxwell and Mittapalli (2010) stated that philosophical realism is a theoretical stance, but then pointed out that there are numerous varieties of realism. The first challenge for a researcher is therefore to select an overview which can guide decisions about the philosophical foundations and how they link to the research design and methods. Several were considered for this study and the version by Fleetwood (2014) was chosen for its clarity. This is shown in Table 4.1.

Table 4.1 Types of Research by Philosophical Foundation

Philosophical foundation	Empirical realist paradigm	Idealist paradigm	Critical realist paradigm
Ontology (belief about nature of truth and knowledge)	Reality is fact-based and absolute	Social construction of multiple realities	Reality includes facts and artefacts as well as differing interpretations of a single reality
Epistemology (how truth and knowledge can be obtained)	Knowledge obtained by testing hypothesis and observation	Knowledge is relative and obtained through discourse	Some knowledge can be absolute, some can be relative. Epistemology should suit the research question.
Methods	Typically mathematical or statistical Experimental designs Identification through case study, questionnaires, structured interviews or questionnaires of hypothesis to be tested	Wide variety of methods e.g., descriptive case study using ethnology, unstructured interviews	Mainly qualitative techniques e.g. explanatory case study

Source. Fleetwood, S. (2014). Bhaskar and Critical realism. In: Adler, P., Du Gay, P., Morgan, G.,& Reed, M. (Eds.), (2014). *Oxford Handbook of Sociology, Social Theory and Organisation Studies: Contemporary Currents*. Oxford: Oxford University Press, pp. 182-219. ISBN 9780199671083 Retrieved from http://eprints.uwe.ac.uk/26526

The differing philosophical stances, or worldviews, can be grouped under three main paradigms as shown in Table 4.1: empirical realist, idealist and critical realist (Fleetwood, 2014). Fleetwood's classification seeks to improve the clarity of thinking about research.

4.2.1 Ontology

Ontology concerns the belief about the nature of truth and knowledge, and the extent to which they are relative or absolute. The empirical realist paradigm encompasses positivism and scientific research, rules and laws, testing hypotheses and predicting outcomes, mainly based on experimental design and mathematical techniques.

Truth is never relative because a hypothesis is either proved or it is not. It assumes that objective truth and meaning can be obtained independently of experience and perception; it is asserted that research can uncover absolute reality based on facts. Several authors (Crotty, 1998; Dash, 2005; Gray, 2009) have stated that, as the social world exists externally to people, it can be measured through observation based on the physical senses.

A contrasting philosophical viewpoint is offered by the idealist paradigm. This assumes that in order to grasp the meaning of the social world, events and situations have to be interpreted, as stated by Schwandt (1994). Researchers who adopt this paradigm assume that meaning is developed and clarified through construction and explanation of what and how sense is embodied socially in language and action. Blaikie (2007) argued that there are major differences between the natural world and the social world. The methods applied in natural sciences research cannot always be applicable in social studies. The researcher cannot be wholly objective and separate from what is being studied because language affects all aspects of research (Knight & Turnbull, 2008). Jacobs, Kemeny and Manzi (2004) asserted that meaning is constructed, not uncovered or discovered, and that truth and meaning do not exist in the external world but are generated through human interaction with this world. Lund (2012) argued that reality cannot be seen separately from individuals' interpretation of that reality; therefore, reality is socially constructed. Research which represents subjective experience and perception can be applicable to all human situations and reality, in the sense of multiple realities, can be obtained from individuals' experiences (Crotty, 1998). Therefore, research findings are built through the researcher’s interpretation and cannot be objective, hence the term interpretivism for the theoretical perspective.

The third paradigm, critical realism, accepts there are different kinds of reality, some of which are factual and external to human perception. It differentiates between realities in terms of: artefacts such as (buildings), material entities (such as climate), ideal (for example, beliefs and ideals), and social (such as house owners, construction companies and the government) (Fleetwood, 2014). It is concerned with understanding causes and providing explanations, but not with predicting outcomes (Fleetwood, 2014). All of these are relevant to this study which seeks explanations for the causes of dampness in a specific context. However, critical realism has been criticised for not giving enough importance to the causal links between regular events (Steele, 2005).

Hammersley (2009) has pointed out that because critical realism seeks to combine knowledge with social change, there is a danger that value judgments can be imposed without appropriate justification for selection of those particular values. Researchers who use critical realism as their preferred ontology therefore need to demonstrate how they have taken into account the empirical scientific evidence related to their projects. They also need to demonstrate how biased value judgments have been avoided. In this classification, there is no place for pragmatism, even though some scholars defend it on the grounds that it advocates the research question as the most important factor in deciding the ontology and epistemology to be chosen (Saunders *et al*., 2012). In fact, a single research question can be answered in different ways, and therefore the choice of philosophical stance will influence the answer.

In relation to social issues, Jacobs, Kemeny and Manzi (2004) stated that social problems may not change, for example poor housing, although the way in which they are defined, understood and interpreted can change as policies for addressing the problem change; therefore, the reality of the problem also changes over time. Consequently, there is a need to take into account both external reality and human perceptions of it in order for researchers to be able to interpret a particular problem in its reality.

Despite the possible philosophical limitations, critical realism has been used in various domains of studies related to housing and the built environment, such as economics, discovering empirical findings, information, communication technology, information system design and housing (Easton, 2010; Jefferies, 2011; Jeppesen, 2005, Njihia; 2008, Carlsson, 2006; Somerville & Bengtsson, 2002). As Dainty (2008) has pointed out, construction management research has relied on a positivist approach while qualitative studies have depended too much on vague interviews, and neither have helped understanding of the social factors involved. Critical realism can help to create a more balanced and logical approach to research that requires both kinds of information. It provides greater rigour than an idealism standpoint and does not reject the existence or importance of material entities and artefacts. Some scholars have asserted that it can provide useful implications for both theoretical development and the research process (Carlsson, 2006; Easton, 2010; Jeppesen, 2005; Njihia, 2008).

In this research, critical realism was adopted as the philosophical foundation, because the causes of penetrating damp identified in the literature contain elements of external reality, such as climate and buildings, but also involve the perspectives of house owners, for example regarding socio-cultural design issues and financial limitations. Moreover, housing policy is part of the external reality for constructors and home owners but is created and changed over time by politicians in response to differing economic and socio-political circumstances. The problem of damp investigated in this study required investigation of physical manifestations and causes as well as stakeholders' perceptions. The area of overlap is shown in Figure 4.1.

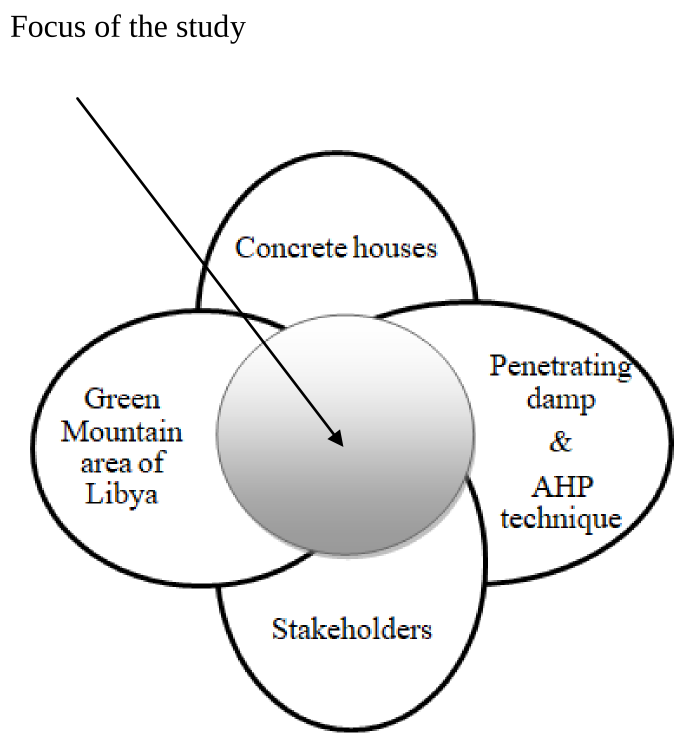


Figure 4.1 The focus of the present study

In Figure 4.1, the philosophical stance or ontology of empirical realism could be applied to the areas of penetrating damp problem and concrete housing construction where there is no overlap with other areas. Idealist ontology would be relevant to the house owners, experts and culture because it highlights the meaning of an existing phenomenon as the critical question for human beings (Merrill, 2011). This study assumes that the reality of the issue of dampness in domestic concrete houses in the Green Mountain area of Libya is interpreted by the stakeholders' perceptions, knowledge and experiences.

At the same time, it exists as a phenomenon relatively independently of their opinions, knowledge and experiences, whether it is perceived or not (Grix, 2004). Thus, critical realism is appropriate.

In terms of the influential theoretical standpoints in studies of housing policy, housing and construction, houses and occupants, among others, Somerville and Bengtsson (2002, p.121) disagreed with 'sociological realism' and 'social constructivism' and *"argued for a form of critical realism that affirms the existence of an extra discursive reality while also questioning the validity of an objectivist sociology of reality"*. Lawson (2006) added that housing, like society itself, is a complex field, underpinned and influenced by the production process, and social, economic and cultural relationships. Therefore, it is valuable to select an approach that has an implication for leading both research and policy in order to obtain a better understanding of the phenomenon concerned and perhaps to improve policy formulation (Lawson, 2006; Somerville & Bengtsson, 2002). With this in mind, Brannen (2005) argued that, in eclectic approaches, the practically relevant part of the research should not be substituted for the theoretically relevant. In other words, learning new research skills is welcome but it should not disregard discipline and the importance of theory.

In terms of paradigms, Kuhn (1970) acknowledged that research communities tended to share a research paradigm and that a paradigm could be changed by accumulation of knowledge and experience. Kuhn also noted that not all disciplines within social science had their own paradigm; this may still be true for research which crosses disciplinary boundaries. In relation to housing research which involves construction design and methods, applying critical realism allows researchers to work with different types of epistemology, methods and data, involving different actors (stakeholders), and offering creative possibilities in order to answer the research questions (Brannen, 2005; Bryman, 2001).

4.2.2 Research Epistemology

Epistemology concerns what knowledge can be considered valid and how it can be obtained, according to the ontology adopted. This affects the types of data collected and the methods employed to collect the data. However, the role of epistemology in built environment research is contested. For example, Knight and Turnbull (2008) have recommended that students should investigate the assumptions involved in epistemology *"without getting completely bogged-down in irresolvable philosophical problems"* (p.64). Traditionally, epistemology has been divided into three categories: objectivism, subjectivism and constructivism (Gul, 2011). Crotty (1998) believed that the epistemology determined the theoretical stance which could be one of several for each of his three categories of epistemology. Some scholars believe that the constructivist perspective offer a means to bridge the gap between objectivism and subjectivism (Cohen, Manion & Morrison, 2000 & Henderson, 2011). Fleetwood (2014) provided a clearer picture; proposing three epistemologies which reflect the ontologies and guide selection of methods (see Table 4.1). According to Fleetwood, if knowledge can involve absolute knowledge, such as the correct way to mix and apply concrete for use in certain climatic conditions, and relative knowledge, such as socio-cultural considerations in house design, then a study with critical realism ontology should adopt epistemology that suits the research question. The question concerning the factors causing penetrating damp requires physical evidence and quantitative information, along with home owners' and experts' opinions of the causes. The AHP technique is a mathematically based decision-making tool which is used to evaluate the relative importance of factors and can take into account subjective as well as objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision making process.

In summary, critical realism has emerged from various strands of research united by their attempts to find an alternative philosophical and theoretical framework to the positivist and interpretivist paradigms which preceded it (Archer *et al*., 2016). The ontology of positivism assumes that there is a single reality and truth determined by facts which can be empirically observed and proved by testing hypotheses, while the ontology of interpretivism assumes that there are multiple realities which are constructed from human interpretation of observations and, experiences. Critical realism asserts that facts and artefacts co-exist with diverse interpretations of a single reality (Fleetwood, 2014). Factors which influence housing performance against damp include climate (a fact), designs of actual buildings (artefacts) and house owners' views and experts' judgments (differing perceptions of the same reality) among others. This research therefore employs the ontological position of critical realism.

In contrast to the hypothesis-testing epistemology of positivism and the epistemology of interpretivism which uses discourse to elicit relative knowledge, critical realism asserts that since knowledge can be both absolute and relative, the epistemology should be appropriate to the particular research question. If both kinds of knowledge are involved, this should be reflected in the use of different epistemologies (Fleetwood, 2014). Facts, artefacts and hypotheses to be used in experimental designs or analysed with statistical or mathematical techniques may be identified through questionnaires, structured interviews or case study. Socially constructed multiple realities are investigated using diverse techniques such as unstructured interviews, ethnology and descriptive case studies. According to Fleetwood (2014), critical realism uses mainly qualitative techniques, such as an explanatory case study. Whilst this follows from the ontological assertion that differing interpretations of a single reality are valid components of truth and knowledge, it does not constrain the use of quantitative techniques within the case study.

This is important because it enables research in housing studies and construction management to take into account human perspectives, as recommended by Dainty (2008) and Moore, Strengers and Maller (2016) respectively, among others. However, critical realism has been criticised for not giving enough importance to the causal links between regular events (Steele, 2005) and for allowing value judgments to be imposed without sufficient justification (Hammersley, 2009). Both criticisms can be overcome by choosing appropriate methods. For example, the present research identified causal factors from a review of existing positivist research and photographic documentation of the phenomenon. The selection of the sample providing value judgments was fully justified and statistical techniques were applied to the emerging judgments in order to handle inconsistencies and derive an overall evaluation weighting.

4.3 Research Strategy

This section justifies the selection of case study as the research strategy within which AHP was applied. A case study is suitable for the present study, which views the situation through the lens of stakeholder perspectives, in accordance with the multi-criteria approach within social sciences research. Crucially, the research strategy adopted needs to answer the specified research questions. The research topic and issues emerging from the literature review make a key contribution to the selection (Remenyi, Williams, Money and Swartz, 1998). In this study, the literature review has identified a range of factors from which exploration and explanation of the damp problem in Albeida can be derived. Research strategy and design therefore also need to be developed in the light of its purpose (Creswell, 2013). Research strategy also involves what Fleetwood (2014) classified as a form of logic: deductive, inductive or abductive. He stated that empirical realism uses deductive logic, while idealism employs inductive logic. Critical realism employs what is termed an abductive logic which moves from observations to producing proposed laws or rules and then applying them to a case. However, this can be seen as a form of inductive logic. Critical realism certainly begins with observations rather than a pre-established truth or assumption, which is how Leedy and Omrod (2005) described inductive research. Attention should be focused on the core concepts, organization or industry and unit of analysis (De Vaus, 2001). There are various strategies available, including experiments, surveys, archival, history and case study (Rowley, 2002; Saunders *et al*., 2012). It should be noted that case study is classified by some scholars as a methodology or method (De Vaus, 2001; Fleetwood, 2014), as both a method and a research strategy (Yin, 1994) and as a research strategy (Rowley, 2002). Creswell (2013) asserted that inquiry strategies are different from methods in research design. In consideration of the similarly diverse terms and definitions regarding methodology, and to avoid confusion between methodology and method, the term research strategy is applied to the case study in the present research.

The present study involves identification of the extent of the problem (what, where, how many and how much), the factors (what, where, how much, how many) and how and why the problem has occurred in a particular geographical and socio-cultural setting, after which the relative importance of the causal factors in that setting is evaluated. Consideration of the climatic factors, the Arab style of building houses, and the involvement of house owners and housing experts in the overall evaluation of factors requires all these to be addressed and any unique aspects of the study to be highlighted. This suggests a case study as the most appropriate research strategy.

However, the term ‘case study’ also presents difficulties since scholarly opinions differ regarding the role of the case study in research. Some scholars have defined case study as both a research strategy and a method (Yin, 1994) which emphasizes the planning and design aspects of research. Others, such as Creswell (2007), stressed the overall approach. The intellectual struggle to classify the case study is further apparent in Yin (1994) who argued that a ‘case’ can be an individual, an event, an entity, or a unit of analysis. De Vaus (2001, p.220) similarly defined a case as the “object” of study which can be a person, a place, or an organisation, among others. Moreover, different authors classify types of case study according to their viewpoint. For instance, Stake (2000) classified the case study into three types: intrinsic (where there is no attempt at generalisation beyond the single case or even to build theory), instrumental (which provides insights into an issue or phenomenon to revise a generalization), and collective case study (whereby a number of cases are studied in order to investigate a general phenomenon). Conversely, Yin (1994), considered that a case study can be exploratory, descriptive, or explanatory. An exploratory case study such as a pilot study is aimed at initial investigation of a research problem, typically seeking to answer ‘what’ questions, and find patterns in the data in order to develop a model or create a theoretical lens for viewing the subject in a fuller study. A descriptive case study seeks to answer more specific ‘what’ questions but should use a theory to guide the collection of data about particular aspects of a research problem (Yin, 1994). An explanatory case study typically seeks to answer ‘how’ or ‘why’ questions and frequently deals with investigating similarities in cause-effect relationships (Stake, 2000). It enables development of the most complete explanation that is possible and may suggest how the explanations could be applicable to other situations (De Vaus, 2001). An exploratory case study was therefore deemed the most appropriate for this research, although there are aspects of explanation regarding the causes of dampness.

The case study parameters are as follows:

1. The environmental component is determined by the climatic factors. The Green Mountain area of North Eastern Libya experiences seasonal highest rainfall in the country.

2. Albeida is the most densely populated conurbation in the Green Mountain area, having more residential buildings than other conurbations within the region. In addition, this city suffers the heaviest rain fall of the whole region (Civil Record Office, 2014 and Libya, General Authority information, 2010).

2. The study is limited to one- and two-storey houses in the five areas of Albeida conurbation. Houses are more affected by dampness than flats and non-residential buildings.

3. The study is further limited to houses built since the 1980s since these represent current construction design and methods, predominantly using concrete.
4. Exploration of socio-cultural factors may be wide-ranging as it has not been previously considered in house building in the study area.

The case can be summarized as penetrating damp in concrete one- and two-storey houses in Albeida city in the Green Mountain region of North Eastern Libya. According to Yin (1994), this would be defined as a single case study which justify of reasons. The first is that a case study focused on a particular phenomenon can develop the factors and issues identified in a literature review. This is useful because in Libya, as in many developing countries, there is no current quality control system for housing construction and so standards of practice are not known. Another major reason is that one house may differ from another in terms of the house type, damp type, damp characteristics and damp location within it. To support the choice of case study, Yin (2009) observes that this strategy is suitable for examining contemporary phenomena from real-life perspectives. *"A case study research is concerned with the complex and particular nature of the case in question"* (Bryman, 2004, p.48). The case study approach can therefore provide answers regarding the occurrence of dampness in concrete houses in the specific geographical area selected. It can also include diverse perspectives on a single situation and employ a variety of techniques. This means that it can include AHP as one of the methods used within a case study, as has previously been shown in studies in housing construction (Pan, Dainty & Gibb, 2012; Wu & Perng, 2017).

Bryman (2004) pointed out that, although case studies have a tendency to be associated with qualitative research, they are frequently employed for both qualitative and quantitative research. The design of case study research varies from one study to another, depending on the investigator’s perspective. Further, Yin (2009) stated that case studies focus on a detailed contextual analysis of a limited number of events or conditions and that their relationships are complex because they generally involve multiple sources of data; they may include multiple cases within a study and produce large amounts of data for analysis. Selection of an appropriate unit of analysis and methods to complete the research design is therefore the next stage.

4.4 Unit of Analysis

The unit of analysis is the cause of penetrating damp, as identified from factors highlighted by the literature review and confirmed and perceived through the eyes and voices of the house owners and experts, as well as the eyes of the researcher. The house owners can provide distinctive responses about the issue of damp because the residents are the most important stakeholders who can reflect on the performance of the houses as the actors living in the properties (Graham & Habib, 2005; Roaf, Fuentes & Thomas, 2003; UN-HABITAT, 2006). A second set of distinctive responses is provided by major actors including house designers, architects, engineers, constructors and maintenance men with knowledge and experience about construction issues (Pan, Dainty & Gibb, 2004; Pan, Gibb & Dainty 2007; Palmer, Jones, Coffey & Blundell, 2003).

This research examines the objective reality about concrete housing defects through construction, socio-economic design, management and climatic factors that cause issues of penetrating damp within domestic concrete houses; it also examines the social reality through human discourse and interaction, and the voices of the actors are involved (Somerville & Bengtsson, 2002). The voices are those of the house owners obtained through a survey questionnaire and the researchers' knowledge, experience and standpoint through direct observation, recorded using photographs of damp houses. The judgments and evaluations made by experts and house owners in interview panels are also involved.

4.5 Methods of Data Collection

Amaratunga, Baldry and Newton (2002), Burns (2000), Sekaran (2010) and Shih (1998) pointed out that the rigour of research can be improved by collecting data from various sources. A large array of data was collected from three different sources to provide an understanding of the whole scenario. This study adopts a quantitative and qualitative form of data collection through using mixed methods, which is compatible with the critical realist ontology and epistemology (Maxwell & Mittapalli, 2010). The questionnaire and direct observation with photographs used in the survey and the AHP technique involve collection of both quantitative and qualitative data. Figure 4.2 gives an overview of the methods used in the detailed research design.

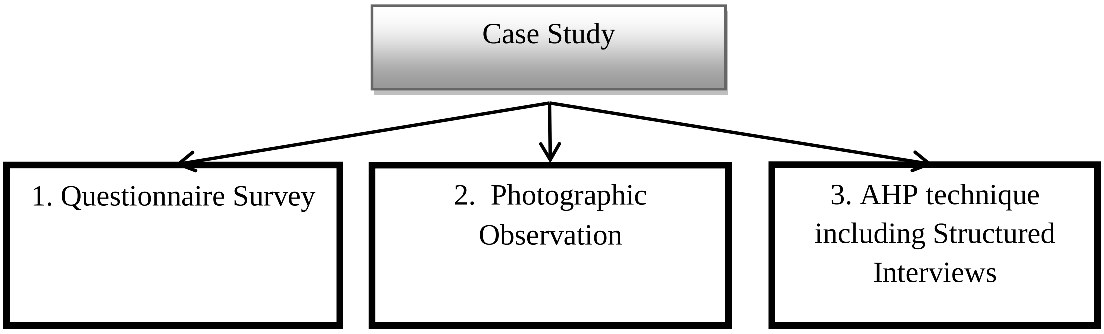


Figure 4.2 Overview of case study methods
Note. The numbers 1-3 2 represent the sequence in which the methods were used.

4.5.1 Questionnaire Survey

This section justifies the selection of the questionnaire survey as a method of data collection, taking into account the criteria for design, distribution and administration. The questionnaire survey collected quantitative data in order to meet the research objectives and answer the first research question: what factors cause penetrating damp in concrete houses in the Green Mountain area, Libya? The questionnaire was designed to fulfill the purpose of the study and to gather applicable and essential primary data. It is adopted in order to hear the occupants' voices. It also provides an opportunity to obtain consent to access defective properties for further investigation, as it asks the occupants at the end of the questionnaire for permission for access to their properties to make observations and take photographs.

A survey questionnaire is a reliable method for data collection owing to the large numbers involved in sampling (Yin, 2003). Another benefit of the questionnaire is that a considerable amount of information can be obtained in a short time. It allows the respondents time to reflect on the questions so that they can provide more accurate information and precise responses. Furthermore, it can be sent to people who are difficult to contact (Yin, 2003). However, Yin (2009) argued that researchers need to be careful when designing a questionnaire; the questionnaire has to be attractive to the participants in order to draw in as many as possible. Yin (2009) also stressed the importance of pretesting the questions before selecting the appropriate ones. In fact, the major benefit of the questionnaire is that a considerable amount of information can be obtained in a short time.

A survey also has disadvantages, as with other techniques. One of these drawbacks is that a poor questionnaire design can attract a small response rate and can also cause misunderstanding on the part of the respondents. A long questionnaire will not motivate the respondents to carry on filling it in (Yin, 2003). However, these drawbacks were taken into account by following advice in Saunders *et al*. (2009) to design individual questions carefully, layout the questionnaire form clearly, explain the purpose of the questionnaire coherently, and use pilot testing so that the response rate can be maximized, and validity and reliability of the research enhanced.

The questionnaire used in the present research was designed to fulfil the purpose of the study and to gather applicable and essential primary data. It was designed with care and attempts were made to make it attractive to the respondents. A series of written questionnaires were tested on a wide range of individuals before selecting the most appropriate ones, as recommended by De Vaus (2002) and Yin (2003). Further, to avoid the questionnaire becoming too lengthy, some questions were tabulated, and the table repeated for each room where damp could occur. Each table was divided into three columns and each column contained questions related to the area affected by damp in that particular room. Images were incorporated to clarify some of the questions and in order to make the questionnaire more attractive to complete (Saunders, Lewis & Thornhill, 2009).

The questionnaire was divided into five parts which together covered qualitative and quantitative data (see full copy in Appendix C). The first part asked about the nature of the problem (damp) and its extent. The second part of the questionnaire asked about the effect of climatic factors on the time of the occurrence of damp. The third part was related to construction factors, including the construction history of the property. This included requesting information from the party who undertook the construction work, supervised the construction process and selected the labour. The fourth part was concerned with the socio-cultural design factor and asked about the owners' social and cultural priorities in designing the house. The final part focused on financial factors; for instance, the construction's funding source, whether there was a delay within the construction procedure, and the reason for and the duration of any delay. The final question explored the occupants' level of awareness of the damp issue.

Although the advantages of online and mail questionnaires are well understood (Babbie, 2013; Reynolds, Woods & Baker, 2006; Rubin & Babbie, 2010), a paper written questionnaire was used. This was more appropriate as the questionnaire could be sent directly to people whom the researcher did not know. This can increase the response rate and gives the participants (occupants) time to reflect on the questionnaire questions (Gillham, 2007, Thomas *et al*., 2005; Yin, 2009). Additionally, there is a possibility that some of those occupants might never or only rarely use the Internet. Also, some people have limited access to the Internet, particularly uneducated and/or older people. The unstable political conditions in Libya at the time meant that web access in the study area could not be guaranteed. Therefore, a paper written questionnaire was selected and circulated to the occupants, despite this technique being more costly and time consuming (Fink, 2013; Fleming & Bowden, 2007).

Kidder (1981, p.132) pointed out that "*every instrument must pass the validity test either formally or informally. Every researcher who has decided on the instrument must judge whether the test measures the construct he or she wishes to study*". Additionally, Bell (1993, p.147) indicated that "*All data gathering instruments should be piloted to test how long it takes recipients to complete them, to check that all questions and instructions are clear and to enable you to remove any items which do not yield usable data*". Therefore, prior to commencing the distribution of the survey questionnaire, it was tested for applicability and ambiguity, using the following procedure. A pilot questionnaire was designed and presented to the director of study and supervisor of this research for their comments. It was distributed to five Libyan Doctoral students at Sheffield Hallam University, who are Libyan householders and also have experience of questionnaire design. Next, the pilot questionnaire was circulated to domestic property residents. Following this, some modifications were made, in terms of question phrasing, the type of question and the addition of further relevant questions. This modified questionnaire was presented to experts at Omar Al Mukhtar University for further modifications before being distributed to the Libyan residents.

This survey questionnaire targeted occupants with varying educational backgrounds, job types and age. Therefore, the design, type of questions, and language of the questionnaire had to be as simple as possible to ensure that every occupant understood the questions.

The survey questionnaire was circulated to Arab occupants and was therefore translated into Arabic by the researcher. Next, it was checked by a language professional, who was competent in both English and Arabic, to ensure that the questions did not lose their original meaning following translation.

A social network snowballing technique was applied for questionnaire distribution during the rainy season. This strategy was a method of contact in a practical sense and was used because participants were hard to obtain during the data collection procedure due to the sensitivity associated with identifying properties with damp issues. Hendricks, Blanken and Adriaans (1992) stated that the snowball technique offers practical advantages for an explorative, qualitative descriptive study. Civil society organisations, such as state institutions, universities and colleges, were used as the distribution and collection points for the questionnaires. Those organisations were situated close to each residential quarter; however, more copies of the questionnaire were distributed in quarters that were more heavily occupied by residents than in the less occupied ones.

Specialists and/or those in positions of authority with relative proximity can provide a route into the required participants (Groger *et al*., 1999), including Libyan housing officers and city council staff. The criteria for distributing the questionnaire were as follows. The city was divided into five areas, as adopted from the Albeida city Civil Record Office: Al Zawea, Western Albeida, Eastern Albeida, The Old Store and Al Gareda area. Figure 4.3 shows the quarters where the questionnaire copies were distributed; for more details in relation to this, see Appendix C.

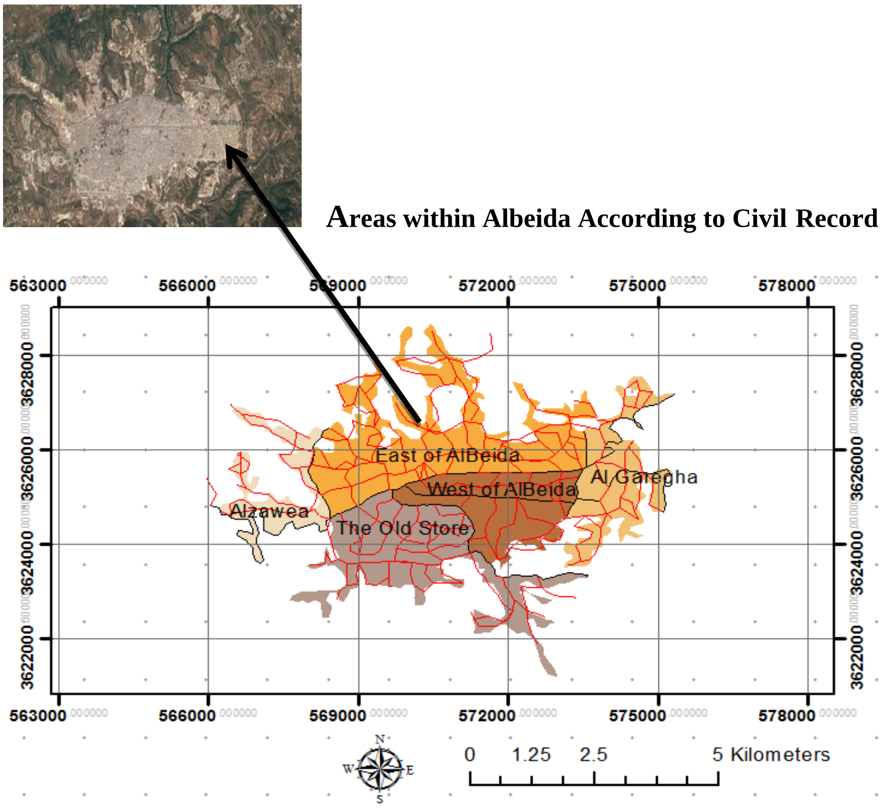


Figure 4.3 Albeida city image 2014, 32°45'54.01"N 21°45'49.92"E elev 622m
Source. Google Earth

Copies of the questionnaire were distributed for one week from the 24th to the 30th of December 2013. The completed questionnaires continued to be returned for a further week from the final date of the distribution. In total, 302 copies were returned, 5 of which were excluded due to a lack of information. Therefore, 297 copies were approved as full returned copies. The deadline for returning the questionnaire was the 19th of February 2014. The response rate was 74%, see Appendix C for more information.

4.5.2 Photographic Observation

This section justifies the use of observation with photographs as a data collection method, the criteria for house visits, the skills of building investigation, the observation and photographs criteria and procedure for recording damp with photography. Observation with photographs is a qualitative method of data collection that was used as a supportive tool to develop the investigation and identify the types and sources of damp.

Non-participant observation is one of the ethnographic methods of gathering data which has been used as an investigation tool to gather opinions and preconceptions on the potential sources of building defects (Henn, Weinstein & Foard, 2006). Observing a particular group of defective houses enhances the research validity and credibility in the context of the factors causing penetrating damp within Libyan concrete houses. Sarantakos (2005) asserted that, when the variability of perceptions increases, the reliability of the study rises also. This method also captures the current construction design that the study area adopts and deepens the understanding of the historical development of construction design in the Green Mountain region of Libya. A review of the historical change was obtained by observing and photographing construction sites and existing residential buildings, as seen in the literature review where it is presented as secondary data.

This data collection technique has been used widely in the construction and architecture fields, particularly for housing defects (Amer, 2007; Forty, 2012; Grifa, 2006; Kvande & Robert, 2009; Nevalainen *et al*., 1998; Somerville 2008). Chouliarki and Fairclough, Graham, Lemke and Wodak (2005) stated that the technology and materials, including the photographs, are used to obtain the necessary data, particularly the social, economic, political and cultural aspects. Belk, Wallendorf and Sherry (1989) reported that *"Photos recorded information on the general site for the researchers, as a device that was shown to remind them of the situation and their behavior, and as an external check…of the field data"* (cited in Basil, 2011, p. 249). Flick *et al*. (2004, p.309) argued that one can use a "*ready-made*" text or other materials to create texts, relations and regularities between signs that could be identified and traced. Notes were taken along with photographs in order to report the type of damp, its location, and its possible direct and indirect causes within properties. With respect to the photographs, this type of practice is considered a reflexive element.

The availability of various critical factors in the literature regarding building defects suggested that a broad range of factors needed to be identified and evaluated. The principal issues related to the presence of penetrating damp in concrete houses were the construction, socio-economic design, management factors and the climate of the study area. The questionnaire asked participants to provide their contact details in order to seek initial consent. When consent was granted, further contact was made in order to explain the purpose of the research and the procedure of the home visit in more detail. During the visit, another consent form was provided to be signed by the householder and investigator. Most of the home visits were conducted in the afternoon, at the householder’s convenience. Each visit took approximately an hour, although some were extended to two hours, and included entry to the property, answering any question, explaining the visit procedure and signing the consent form. Within the case study, twelve houses which met the sample selection criteria for a house visit were observed and photographed. A further three properties underwent visual observation but permission was not granted to photograph them.

4.5.3 AHP Interviews

Interviews were chosen to fulfil the third research objective; to evaluate the construction, socio-economic design, management and climatic factors by applying the the technique of paired comparisons. This section justifies the structured interview as one of the data collection methods. It has a key role in the systematic evaluation of factors causing the damp, formalising and structuring a largely subjective judgment process.

Analytical Hierarchy Process forms the main analytical approach in this research and was dealt with in detail in Chapter 3. However, a brief reminder is necessary here to explain the way in which interviews was used. AHP was developed by Saaty (1980) and helps decision makers to analyse and evaluate multiple and competing objectives as well as multiple alternatives. The technique is based on three principles of decomposition, comparative judgment and synthesis of priorities.

Figure 4.4 illustrates how a complex decision problem is decomposed into simpler issues to form a hierarchy of criteria, sub-criteria and decision alternatives.

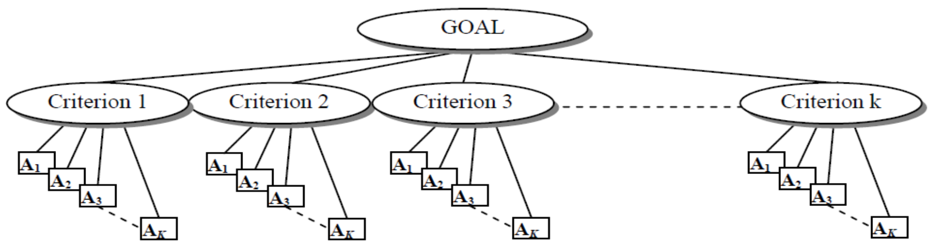


Figure 4.4 Structure of the Analytical Hierarchy Process (AHP)

The full hierarchy does not need to be completed (Saaty, 1980), and decision options do not have to be involved within the structure. The AHP can be used for analysing problems, assessments and decision-making. Once the hierarchy has been constructed, the top level is the ultimate goal of the conclusion. Normally, the hierarchy comprises four levels: goal, objectives, attributes and alternatives. Once the decomposition is complete, a fundamental ranking of the objectives and attributes is required. This is done by using pairwise comparisons for each level of the hierarchy in order to obtain the weighted factor of each objective. This involves three steps: development of a comparison matrix at each level of the hierarchy, computation of weights for each element of the hierarchy, and estimation of the consistency ratio.

Structured interviews were used to evaluate the construction, socio-economic design, management and climatic factors. The final step was to combine the relative importance weights of the factors obtained in the above step in order to produce composite weights. These weightings were achieved through quantitative interviews which use paired comparisons of factors at each of the different levels in order to evaluate experts' different opinions and perceptions about the issue after identifying the most likely causes of damp. Weightings were calculated by means of a sequence of multiplications of the matrices of relative weights at each level of the hierarchy (Figure 4.4). First, the comparison matrix was squared and the row sums were calculated and normalised for each row in the comparison matrix. This process was continued when the difference between the normalised weights of the iterations fell below a prescribed value (Saaty, 1990; Saaty, 1994; Saaty & Vargas 1991). A more detailed discussion has been provided in Chapter 3 (The AHP Technique).

The quantitative interviews also provided a useful follow-up method after analysing the data collected via other methods, such as questionnaire or observation (CDC, 2009). Triangulating the collected interview data with the outcomes of the questionnaire and direct observation with photographs enhanced the level of understanding about the nature and extent of the problem. With respect to the nature of the interview questions, Flick (2009) stated that, within the interview, the evaluators are allowed to use a guideline and follow topical paths in the conversation that may stray from the guide when it seems inappropriate. The purpose of conducting interviews with the experts and house owners was to obtain perspectives and thoughts about the issue of housing performance by evaluating the relative importance of the most significant factors (causes) affecting to domestic concrete housing in the context of penetrating damp. Therefore, guidance was planned and prepared according to Saaty's technique. This allowed grasping the relevant importance of construction, socio-economic design, management, and climatic factors in the context of damp, which were discovered and highlighted using the findings of the questionnaire and follow up observations with photographs. Yin (2009, p.106) stated that the interview is one of the most important sources of case study information, and that, through conducting interviews, one can follow the research line of inquiry and "*ask your actual (conversational) questions in an unbiased manner that also serves the needs of your line of inquiry".*

Although focus group interviews could have been chosen for the data collection, face to face interviews were selected. Focus group interviews are a useful method of data collection, gathering a wide range of opinions within a short time, and allowing the occurrence of unanticipated questions during the discussion session (Berg, 2007; Bouma, 1996; Wholey, Hatry & Newcomer, 2004). However, for the present study it was considered that individual face to face interviews would avoid any potential conflict of interest between evaluators together with any bias that could arise between evaluators in a focus group session. The interviews provided a flexible and free environment to develop ways to communicate with each participant (Patton, 1990; Yin, 2009) and aimed to engage all participants, including the owner-builders whether or not they suffered from damp in their property.

During the third visit to the study area in July/August 2014, interviews with individual members of panels of experts were conducted. A plan was drawn up to include the house owners' judgments concerning the management and socio-economic design factors that affect house performance. The house owners were involved in the activities of the criteria and sub-criteria of those factors (causes) constructed within the hierarchy. With reference to the returned questionnaire, there were particular criteria related to the selection of the house owners. The selection was based on the owners' consent, who are self-builders and who did or did not have damp in their property. Therefore, another interview panel of house owners was involved (Panel 5).

Comparative judgment can be used to evaluate the proposed factors by comparing these parameters at each level of the hierarchy (Abushnaf, 2014; Jaskowski *et al*., 2009; Saaty, 2008). Due to the nature of the proposed hierarchy, involving four independent factors (construction, socio-economic design, management and climatic factors with their criteria and sub criteria), interviewees were assigned to five interview panels. Four panels consisted of the experts and self-builders, while the fifth panel comprised only house owners who are self-builders (the interview panel for the socio-economic design factor). Each panel consisted of a number of experts and/or owners (between 8-12) who have a similar background related to the proposed factors. Therefore, the evaluators provide their opinions and judgments to compare factors that could affect the performance of the house, considering pairs of factors, one pair at a time, and one factor against the other (Jaskowski *et al*., 2009; Saaty, 1980; Wong & Li, 2007).

In total, twenty-five evaluators contributed to the evaluation of factors, selected from face to face interviews with twenty-six construction industry experts in North Eastern Libya and twenty house owners. Evaluations are only accepted in AHP if they are consistent in terms of the overall ranking of factors. Ultimately, thirteen interviews with experts were accepted after the calculation of the consistency ratio (C.R.). The interviewed professional evaluators are architects, engineers, academic researchers and contractors. They occupy key positions at the university, in the housing sector and with local construction firms. Regarding the interviews with house owners, who are self-builders, twelve interviews were accepted after the calculation of the consistency ratio (C.R.).

Saaty (2008, p.83) pointed out that "*we are inclined to believe that all kind of information are useful and the larger the quantity, the better. But that is not true*". Therefore, involving more evaluators does not guarantee a better result. Saaty also added that we need to know the problem, criteria, sub-criteria, stakeholders, group affected and the purpose of the selection in order to make that decision. Further, Wong and Li (2008) stated in their study in Hong Kong that the application of the analytic hierarchy process in the selection of intelligent building systems does not necessarily entail using a large sample size.

Interviews were conducted after the analysis of the survey questionnaire and house visits for photographic observation. This provided an opportunity for the proposed hierarchy to be identified and developed. A schedule for conducting the interviews was prepared. Full consent was obtained from the evaluators through providing and signing a form on the interview date. An introduction to the research purpose and the nature of the question were sent prior to the scheduled date, including a leaflet about how the analytical hierarchy process works and what was required during the interview, stressing the confidentiality and anonymity of the interview data and providing the right to withdraw at any time. This was essential in order to familiarise the evaluators with the nature of the research and the applied technique. Additionally, during the interviews, further explanation was provided regarding the applied AHP technique. All of the interviews took place at the evaluators' workplace. The duration of each interview was 1-2 hours, including the introduction, which included answering questions about the technique and general discussion about the issue.

Panel (1) included ten experts with a construction, engineering and architecture background; it involved construction managers, contractors, civil engineers and academic researchers. This panel weighed the second level of the construction, socio-economic design, management and climatic factors (Second-Level of Pairwise Comparison Matrices of factors, causing issues of dampness in domestic housing in the Green Mountain in Libya; see Appendix D for more information).

Panel (2) involved eight experts with a construction and engineering background. It included contractors, construction managers and academic lecturers. This panel evaluated the third level of the hierarchy; construction factor (Third-Level Pairwise Comparison Matrices for the Construction factor) and the fourth level of the construction design and manufacturing criteria (Fourth-Level Pairwise Comparison Matrices for the Construction Design and Manufacturing Criteria; see Appendix D for more information).

Panel (3) involved nine experts with an architectural background, including construction managers and contractors who had experience of constructing, repairing and maintaining properties. This panel evaluated the third level of the climatic factor (Third-Level Pairwise Comparison Matrices for the Climatic factor; see Appendix D for more information).

Panel (4) comprised three experts and six house owners who are self-builders. This panel assessed the third level of the management and socio-economic design factor (Third-Level Pairwise Comparison Matrices for the Management and Socio-Economic

Design Factor), the fourth level of the construction supervision criterion (Fourth-Level Pairwise Comparison Matrices for the Construction Supervision Criterion Criteria) and the fourth level of the cost and knowledge effectiveness criteria (fourth-Level Pairwise Comparison Matrices for the Cost and Knowledge Effectiveness Criteria). The reason for involving experts and self-builders in this particular panel was that, in relation to the techno-cultural considerations for the Libyan community and housing sector, those factors and criteria and sub-criteria require decision makers who are experts and residents who are self-builders and house owners; see Appendix D for more information.

Panel (5) comprised twelve house owners, all of whom were self-builders. This panel assessed the fourth level of the socio-religious design requirements criteria (Fourth-Level Pairwise Comparison Matrices for the Socio-Religious Design Requirements Criteria; see Appendix D for more information). Table 4.2 summarises the interview panels by type and number of evaluators, together with the level and criteria of the model in which they were involved.

Table 4.2 Interview Panels Including Type and Number of Evaluators

<table>
<tr><td rowspan="4">Panel 1</td><td rowspan="2">Matrix 1</td><td colspan="3">Second level of the model</td></tr>
<tr><td colspan="3">Construction, management, socio-economic design and climatic factor</td></tr>
<tr><td>Type of evaluators</td><td colspan="3">Construction managers, contractors, civil engineers and academic researchers</td></tr>
<tr><td>No. of evaluators</td><td colspan="3">10 Experts</td></tr>
<tr><td rowspan="4">Panel 2</td><td rowspan="2">Matrix 2,3 & 4</td><td>Third level of the construction factor of the model</td><td>Fourth level of the manufacturing criteria of the model</td><td>Fourth level of the construction design of the model</td></tr>
<tr><td>Construction design &manufacturing criteria</td><td>Raw materials, workforce & control of un-situ concrete</td><td>Roof design, exterior walls, exterior finishing & water tank position</td></tr>
<tr><td>Type of evaluators</td><td colspan="3">Contractors, construction managers and academic lecturers</td></tr>
<tr><td>No. of evaluators</td><td colspan="3">8 Experts</td></tr>
<tr><td rowspan="3">Panel 3</td><td>Matrix 5</td><td colspan="3">Third level of the climatic factor of the model
Rainfall & Wind direction</td></tr>
<tr><td>Type of evaluators</td><td colspan="3">Construction managers, architects and contractors</td></tr>
<tr><td>No. of evaluators</td><td colspan="3">9 Experts</td></tr>
<tr><td rowspan="6">Panel 4</td><td rowspan="4">Matrix 6, 7, 8 & 9</td><td>Third level of the management factor of the model</td><td colspan="2">Third level of the socio-economic design factor of the model</td></tr>
<tr><td>Construction supervision criteria factor & housing policy</td><td colspan="2">Socio-religious design requirements & cost and knowledge effectiveness criteria</td></tr>
<tr><td>Fourth level of the construction supervision criteria of the model</td><td colspan="2">Fourth level of the cost & knowledge effectiveness of the model</td></tr>
<tr><td>Owners supervision & experts supervision</td><td colspan="2">Raw materials selection, builders selection, exterior finishing selection, maintenance & delay in construction</td></tr>
<tr><td>Type of evaluators</td><td colspan="3">Decision makers & house owners, who are self builders</td></tr>
<tr><td>No. of evaluators</td><td colspan="3">3 experts & 6 house owners</td></tr>
<tr><td rowspan="4">Panel 5</td><td rowspan="2">Matrix 10</td><td colspan="3">Fourth level of the socio-religious design requirements criteria of the model</td></tr>
<tr><td colspan="3">Room size, interior finishing & decoration, hospitality rooms, future requirement & social activities</td></tr>
<tr><td>Type of evaluators</td><td colspan="3">House owners, who are self builders</td></tr>
<tr><td>No. of evaluators</td><td colspan="3">12 House owners</td></tr>
</table>

Having described and justified the selection of each data collection methods, the following section describes the sample selection for each method.

4.6 Sample Selection

The selection of cases and sample needs to provide a structural representation that suits the aim of the study (Remenyi *et al*., 1998; Stake, 1994). Sample selection can proceed in two stages, selection of a general case followed by within-case sampling (Merriam, 1998), as adopted for this study.

4.6.1 Questionnaire Survey Sample

Krejcie and Morgan (1970) provided a table which can be used or one can apply the following formula in order to obtain the required sample size and the size of the population is needed (see table of determining sample size for a given population in Appendix C).

$$S=x^2 NP (1-P) \div d^2 (N-1) + x^2 P (1-P).$$

Where: S= the required sample size

X^2= the table value of the chi-square for 1 degree of freedom at the desired confidence level (3.841).

N= the population size

P= the population proportion (assumed to be 50, since this would provide the maximum sample size)

d= the degree of accuracy expressed as a proportion (.05)

According to the Civil Record Office (2014), the population of Albeida in 2009 was 99,208 and the number of residential buildings was 11,382 including both existing housing and houses under construction. According to the yearly census of Libya, the Libya General Authority information (2010), that the population of the Green Mountain region in 2010 was 208,000. Following the formula and table of the U.S. National Education Association, the representative sample size for the number of houses was 400.

4.6.2 Photographic Observation Sample

The selection criteria were based on voluntary consent from the occupants of houses that suffer from damp, particularly within the building envelope (exterior walls and ceiling). Attempts were made to exclude houses that have damp kitchens and bathrooms in order to avoid any possibility of having condensation issues. Priority was given to houses built since the 1980s by jobbing contractors and/or local construction firms, and houses owned and built by the householders. Priority was also given to houses where the construction procedure had been supervised by the owner (owner-built houses) and houses that were subject to delays during the construction procedure. Finally, an attempt was made to include houses from as many areas of Albeida as possible. Omar Al Mukhtar University in Libya provided discussion sessions during the first visit to the study area with local professionals on building defects, including the criteria for observing, inspecting and reporting defects within buildings. This was supportive and facilitated the procedure of the direct observation with photographs method of data collection.

4.6.3 AHP Technique Interview Sample

Selection criteria for experts were discussed and confirmed with staff of the civil engineering department of Omar Al Mukhtar University during the second visit to the study area in December 2013/February 2014. A purposive sampling strategy was adopted in order to select the evaluators (see Figure 4.5). This is in an agreement with the views of Creswell and Clark (2007), who stated that purposive sampling can be used where researchers intend to select participants who have experience of the phenomenon or key concept to be explored. Additionally, Flick (2009) pointed out that the purposive sampling technique can be adopted when researchers intend to choose contributors according to preselected criteria. The criteria applied for the selection of experts were the evaluator's reputation, experience and academic background in the study area and ensuring his/her experience with building houses. To support these criteria, Pan (2008), in his study based in Taiwan about selecting a suitable bridge construction method using the AHP approach, stated that knowledge and experience in a subject area are significant when evaluating elements through the analytical approach because experts usually rely on their academic background and practice when making judgments. Selection criteria for house owners were those who were self-builders, whether or not they had dampness in their property, along with their consent and voluntary participation.

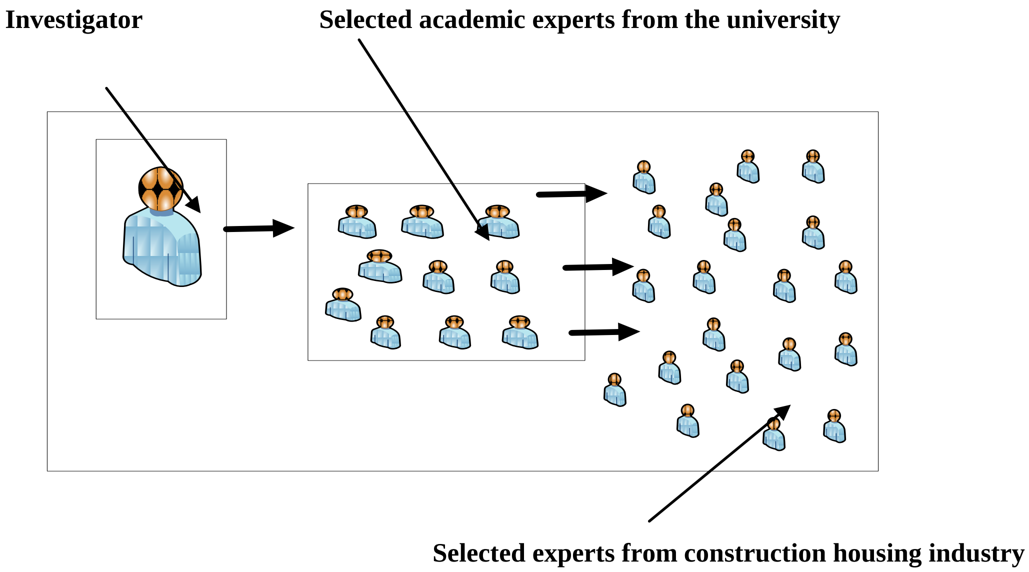


Figure 4.5 Interview sampling technique

All sample selection criteria relating to the within-case methods are summarised in Table 4.3.

Table 4.3 Sample Selection Criteria

No.	Criteria	Questionnaire Survey	Direct Observation Photographs	AHP Structured (Quantitative) Interviews
1	Sample size	400 ✓		
2	Owners of houses affected by damp	✓		
3	Self-builder house owners			20 ✓
4	Construction experts			26 ✓
5	Relevant experience			✓
6	Location of defect (e.g. building envelope)		12 houses ✓ .	
7	Built since 1980s		✓	
8	One- and two-storey houses	✓	✓	
9	Spread of districts	✓	✓	
10	Stage of construction	✓	✓	

4.7 Data Analysis Methods

4.7.1 Questionnaire Analysis

The analysis of the questionnaire was based on the 297 valid responses. Although 400 questionnaires were distributed, 302 questionnaires were returned, of which 5 were excluded from analysis because they were not fully completed and responses were missing. The data were coded and entered into Statistical Package of Social Science software (SPSS, version 21).

The first round of analysis was descriptive in nature (frequencies and percentages) with the purpose of exploring the nature and extent of the damp. At this stage, the results were reported by percentages in tables or graphs. The factors (variables) that had a statistical relationship with the occurrence of damp within the houses were identified through bivariate and multivariate analysis, using Pearson's Chi-square, Cramer's V statistics and Cochran's test. Pearson's Chi-square statistic determines whether two variables are independent; if the chi-square is significant, it shows a trend in the percentages with the percentages for one value of the dependent variable trending one way, and the percentages for another value trending in the opposite direction. Cramer's V statistic takes values from a minimum of 0 to a maximum of 1; the closer the statistic to 1, the stronger the association between the variables. Multivariate analysis was conducted to examine whether there was a significant relationship between two independent variables controlled by another different variable. Cochran's test was applied to measure small sample size and inconsistent data (Field, 2009; Higgins, Thompson, Deeks & Altman, 2003; Pallant, 2010). The results were tabulated and presented graphically with a discussion. This identified the factors (variables) that had a significant statistical relationship with the occurrence of damp within the houses in the study.

4.7.2 Analysis of Photographs

Technical content analysis was used to analyse the photographic data in order to investigate and track the possible sources of the problem and attempt to report its potential causes. Damp was analysed as an indication of underlying issues in the house within the processes of construction and/or maintenance. In addition to confirming the responses that were obtained from the returned questionnaires, it also highlighted the nature of the defect, location, signs, and affected wall orientation, adopted construction design, poor/lack of maintenance, nearby vegetation area, nature of social activities on the roof and, above all, the main and possible contributory causes of damp within domestic houses in the Green Mountain area of North Eastern Libya.

4.7.3 Analysis of Structured Interviews

The AHP technique was applied to analyse a collection of factors that affect house performance in the context of the issue of penetrating damp. The hierarchy builds down from the general to more specific factors, criteria and sub-criteria until a level of phases is grasped. When the decomposition is completed, a fundamental weighting of the factors, criteria and sub-criteria are calculated.

This is performed by using the pairwise comparison method (PCM) for each level of the hierarchy in order to obtain weights for each factor, criterion and sub-criterion. A more detailed discussion about the technique and the analysis was provided in Chapter 3 (AHP Technique).

4.8 Validity and Reliability of Research

Quality criteria for quantitative and qualitative studies are more established than for mixed methods, although the rigour of qualitative research continues to be examined (Byrman *et al*., 2008 & Flick, 2009). Scholars such as Onwuegbuzie and Johnson (2006) consider that mixed methods assumes mixing two paradigms, and that research has to be defended in terms of validity criteria for mixed methods as well as for qualitative and quantitative research. This has led to proposals for new measures of validity, for example, quality and transferability of inference (Tashakkori & Teddlie, 2008) and legitimation (Onwuegbuzie & Johnson, 2011). Bryman (2006, 2008) proposed more generally that studies should use whatever suits the particular study.

In this study, multiple data collection methods are adopted (survey questionnaire, observation with photographs and interviews within the technique). As noted by Gillham (2007, p.99) "*Different methods have different (even if overlapping) strengths and weaknesses. If you use a range of methods you can put together a more complete picture*". The reason why the current research methodology can be termed mixed methods is that the questionnaire and observation collected both quantitative and qualitative data which were analysed quantitatively and qualitatively. Additionally, the technique uses mathematical calculations to derive weights for what are essentially subjective judgments. Thus, the mixing is within two of the three methods. However, there is no mixing of ontologies and the study is conducted within the single paradigm of critical realism.

The quality criteria of quantitative research have traditionally been: generalisability, internal validity, objectivity and reliability (Lincoln & Guba, 1985). Various quality criteria have been proposed for evaluation of qualitative research, such as the overall concept of trustworthiness (Lincoln & Guba, 1985) and more specific criteria, for example transferability instead of generalisability, and dependability instead of the word reliability (Guba & Lincoln, 1994).

One of the suggested methods is triangulation; the involvement of a variety of methods and stakeholders allows valid and reliable results to be obtained and a chain of evidence to be established. This allows explanations to be built and patterns to be constructed (Rowley, 2002). In this research, an initial study was conducted (pilot study) in order to improve the design of the constructed model (see Appendix A or see Laeirj, Spence and Laycock (2013)), after which the model was developed and refined following the data analysis (Riege, 2003) and external validity was confirmed by model validation (presented in Chapter 8). Silverman (2013) pointed out that generalisation can be made possible by combining a quantitative with a qualitative measurement of the population and/or by selecting purposive sampling guided by time and resources; both these requirements were met in the present study. Additionally, the generalisation of the case study can be obtained from an analytical case study (Hammersley, 1992). The model validation process is carried out with different respondents and analysis techniques in order to achieve analytical generalization.

The validity and reliability of this research are therefore considered using a combination of qualitative and quantitative quality criteria, as summarised in Table 4.4

Table 4.4 Research Design Parameters: Quality Criteria

Tests	Definition	Implementation	Phase and method
Construct validity	Measures what claims to measure	Pilot questionnaire and observation Multiple sources of evidence Advice from Libyan civil engineering academics	Before data collection Data collection: literature review, questionnaire and photographic observation
Internal validity	Establish genuine causal relationship (explanatory element)	Explanation building Development of AHP model	Literature review Interviews with experts and house owners (AHP model)
External Validity	Establish domain for generalisation	Validation of AHP model	Data collection: questionnaire, interview in Massa and observation in Albeida AHP model tested in second area (Massa) after data analysis
Reliability	Operations of case study can be repeated	Detailed procedures for case study methods	During designing, gathering data, analysing and judging the results
Credibility	Triangulation	House owners' and experts' voices and the damp houses	Data collection: questionnaire and panel interviews and observation
Dependability	Same case study and methodology would produce very similar results	Model development and AHP repeated in Massa	After data analysis
Transferability	Findings applicable to similar case in different location	Model development & AHP repeated in Massa	After data analysis

Table 4.4 indicates that efforts were made to ensure that quality criteria were addressed within the quantitative and qualitative aspects of the methods used in this study. Patton (2001) stated that validity and reliability are two factors which any qualitative researcher should be concerned about while designing a study, analysing results and judging the quality of the study. Additionally, Davies and Dodd (2002) found that the

term rigour in research appears in reference to the discussion about reliability and validity. If the issues of reliability, validity, trustworthiness, quality and rigour are meant to differentiate ‘good' from 'bad' research, then testing and increasing the reliability, validity, trustworthiness, quality and rigour will be important to the research in any paradigm. To ensure this, data were gathered from various national and international resources from developed and developing countries. Survey questionnaire, photographic observation and interviews were selected as data collection methods. The experts’ and house owners’ perspectives, with the damp houses, were chosen as a unit of analysis. In terms of analysis, various analytical techniques were selected. From a statistical point of view, the reliability of the questionnaire scales was checked (Cronbach’s Alpha was 0.78977. A pilot study was conducted before the data collection commenced. Importantly, the summative validation of the model of the performance of houses against the issue of penetrating damp was carried out through the perceptions of the house owners. A detailed description and discussion of the model development and validation is presented in Chapter 8 (Model Development and AHP Weights Validation).

Model development was conducted by analysing 61 copies of a questionnaire from Massa, another urban location in the Green Mountain area of North-East Libya. Follow up interviews were carried out with 3 house owners to confirm and complete findings regarding house owner perceptions and ratings of dampness. Descriptive analysis (percentage) was applied for the questionnaire and thematic analysis was applied the interviews. These analyses offered a combination of a measure of flexibility, a systematic approach and a means of achieving sufficient depth of analysis and interpretation. This allows the identified main factors within the model to be validated and developed alongside with the same themes that emerged from the interviewees' answers.

Validation of the AHP weights was carried out by analysing 61 copies of a questionnaire from Massa and 12 damp houses from Albeida. Regression analysis and AHP weightings were used to compare and discuss the weights of the construction, socio-economic design, management and climatic factors and how they impact the performance of concrete houses through presenting patterns, constructed meaning and identified and traced signs between Albeida and Massa data.

4.9 Challenges faced

The researcher faced several challenges during each stage of the research journey. For instance, finding sufficient literature relating to Libyan construction, the travel required funding, time management and being a female Muslim investigating building defects. In relation to the literature review, the problem of damp within domestic houses exists in North Eastern Libya and was obvious to almost all of the citizens there. However, there were very limited published and unpublished sources, reports, and documents available from the Libyan government or local construction firms that highlighted the issue. Therefore, the researcher had to depend on other national and some international sources about areas with similar conditions to the study area.

Regarding the field work and data collection, the challenges included the cost of travelling to the study area and printing the written paper questionnaire copies. Time management was the biggest challenge and fear about the completion of the data collection and research as a whole, particularly as three sequential research methods were employed, each involving data analysis and discussion.

In respect of the direct observation with photographs method of data collection, although the researcher has an engineering and construction background through her undergraduate and master's degrees, which reflect her knowledge and experience, she had no previous experience of damp surveying. The researcher faced the challenge of how to set criteria and investigate damps within domestic houses. Therefore, during the research journey, a plan for training and improvement was set out, as stated earlier in the building investigation skills section.

The most significant challenge that the researcher faced was her gender. Libya is a conservative culture, as in other Arab and Muslim countries, and being a female housing construction researcher is uncommon. Therefore, to be a female investigator within the Libyan construction industry was a very challenging task in an Islamic and Arab society, particularly with regard to facilitating communication with the research participants, and transportation during the data collection.

4.10 Ethical Approval and Considerations

The Economic and Social Research Council (ESRC) defined research ethics as "*the moral principles guiding research, from its inception through to completion and publication of results and beyond*" (Stanley and Wise, 2010, p.7). Additionally, Charlesworth (1996), in Davies & Dodd, 2002, p.281) stated that "*ethics are about the issues or potential problems each research situation presents*". Six principles of ethical research are set out, aiming to ensure the integrity and quality of the research. These principles are: integrity, quality, voluntary, confidentiality, anonymity and Independence. Stanley and Wise (2010, p.1) declared that "*Research should be carried out with integrity and quality...participation must be voluntary, confidentiality and as far as possible anonymity of participants must be respected*".

As each project differs with regard to ethical considerations, describing and handling such issues begin with recognition by the researcher opening up the domain for review and examination, and making it visible at all stages during the search process. Confidentiality, the objectivity of the researcher, informed consent, conflict of interests, data storage and the means of withdrawing from the research are addressed. The investigator's aim is to adopt techniques and methods in respect to ethical considerations to ensure that the study is faithful, meaningful and alive with rich information and details.

In this study, consent was obtained from the Faculty of Research Ethics Committee (see Appendix B) before the field work commenced. Due to the sensitivity of the topic, official consent was obtained from the Ministry of Higher Education and Scientific Research of Libya and Albeida Council to conduct the field work without any political or social impact. Additionally, consent was obtained from Omar Al Mukhtar University to form a team which consisted of three individuals along with the researcher to facilitate access to the field data as well as the distribution and collection during the field work period and to improve the efficiency of the time spent in the field. The research assistants were chosen on the basis of their academic background and experience in the field. They were familiar with the study area and had sufficient experience of conducting field work. Prior to and during the field work, several meetings and discussions were held with the assistants in order to clarify the research purpose and discuss any issues and factors that needed to be explored. For more clarification regarding ethical questions, see Appendix B.

A flowchart summarising the research aim, objectives and questions, identified factors causing damp, data collection and analysis methods is presented in Figure 4.6.

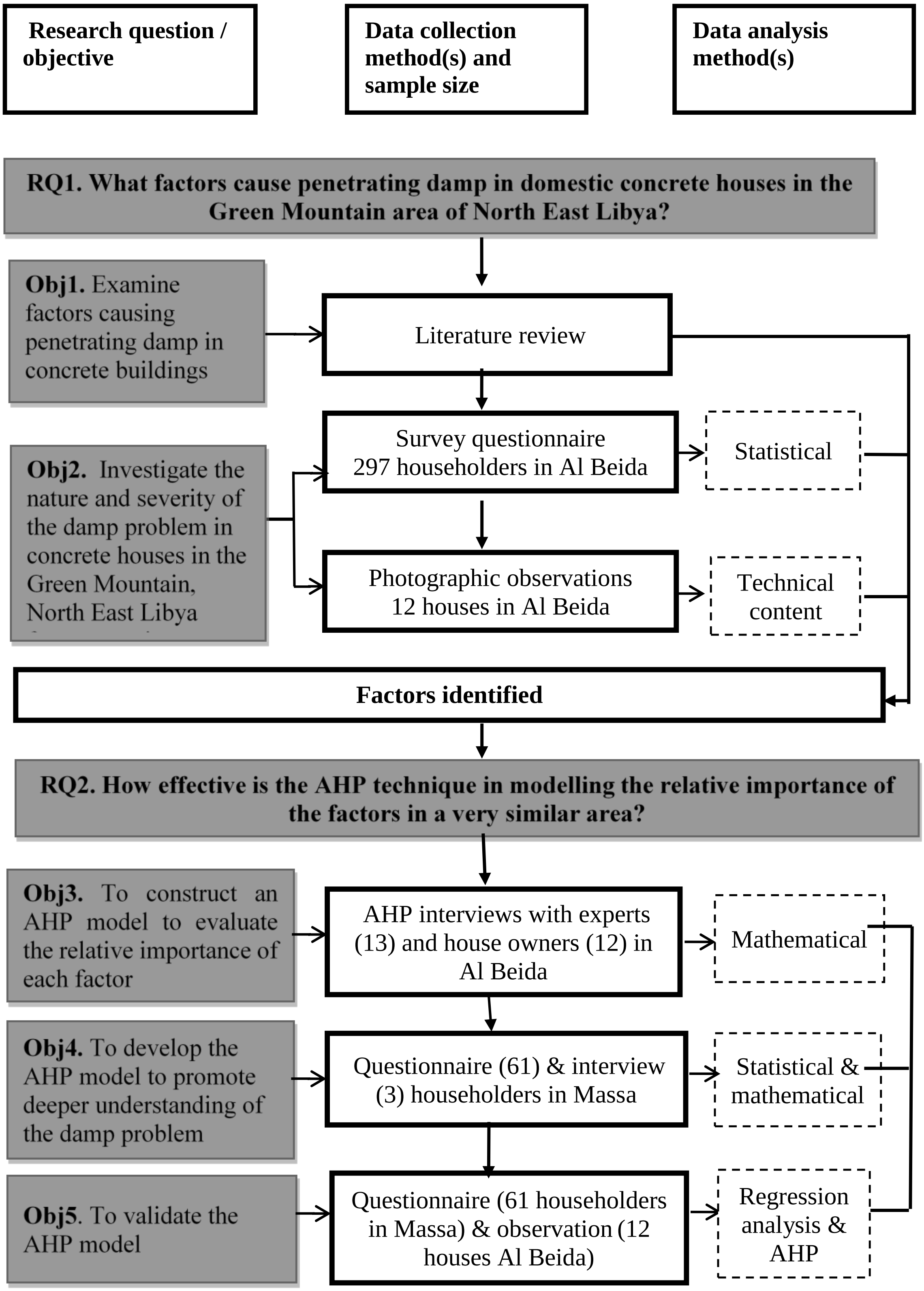


Figure 4.6 Flowchart summary of research methodology

4.11 Summary

In summary, this chapter has described the adoption of a theoretical stance of critical realism which assumes a single reality along with varying perceptions of that reality. The overall research strategy is a case study built around the use of the technique which is both exploratory and explanatory, adopting quantitative and qualitative methods through a survey questionnaire, direct observation with photographs and interviews. Data were collected from house owners, damp houses and experts in addition to the factors identified in the literature review, before being analysed using various techniques. The research validity and reliability have been highlighted, together with the research unit of analysis. Further, the challenges faced during the research journey and the ethical considerations of the adopted methods and materials.

The next four chapters present the findings of the research, beginning with the findings of the first data collection method, the questionnaire directed to house owners in Albeida, in Chapter Five (Survey Questionnaire Result).

Chapter Five: Survey Questionnaire Result

5.1 Introduction

Through a quantitative questionnaire, a large amount of data can be quantified and analysed objectively, then linkages, comparisons and contrasts among the data can be generated (Field, 2010). The purpose of this chapter is to examine the extent to which construction, socio-economic design, management and climatic factors affect domestic concrete houses' performance in the Green Mountain area in Libya. The chapter corresponds to the first research question: what factors do cause dampness within domestic concrete houses in the Green Mountain of Libya? It analyses and surveys the questionnaire data; the first part investigates the nature of the damp according to its type and location, while the second part examines the possible subjective and objective factors (causes) that may contribute to the occurrence of damp within Libyan houses.

The questionnaire results are presented under the headings of the existence of damp and nature of the problem, as well as the possible primary causes/factors. The causes are further categorised as construction, socio-economic design factors, and management and climate factors.

5.2 The Existence of Damp and the Nature of the Problem

The data show that 85% of the occupants reported issues related to damp in their properties. Additionally, the results indicated that houses suffer from damp more than flats. To clarify this further, the Pearson's Chi-square test was performed. Consequently, a relationship was found between the existence of damp and the type of property $X2\ (2, N = 297) = 7.36$, $p = 0.025 < 0.05$.

Table 5.1 Percentage of Types of Property with Damp with Chi Square Test Result

Type of Property	Percentage %	Chi square Test
One Floor House	41%	
Multi-Storey House	33%	$X2\ (2, N = 297) = 7.36$, $p = 0.025 < 0.05$
Flat	26%	

The results also indicated that damp occurred more frequently in newer rather than older houses (Table 5.2).

Table 5.2 Percentage and Cross-Tabulation of the Building Age with the Existence of Damp

Property Age	**Percentage %**	**Frequency Existence of Damp Yes**	**No**
< 10y	34%	79	21
11-20y	23%	58	10
21-30y	19%	49	5
31-40y	13%	33	5
> 40y	13%	33	4
Total		**252**	**45**

In order to investigate the location of the damp within the properties, the respondents were asked to indicate the damp per room and per building component. Figure 5.1 shows that 55% of the damp occurred in multi-rooms although the living/hospitality rooms and bedrooms were the most frequently mentioned types of rooms in the house. However, 10% only of the damp occurred in kitchens and/or bathrooms. Thus, the majority of the damp occurred in living/hospitality rooms and bedrooms (living rooms can refer to male/female hospitality rooms as well). Therefore, the questions arose: why were these types of rooms the most affected? Where did the damp signs occur in these rooms? What was the dominant type of damp?

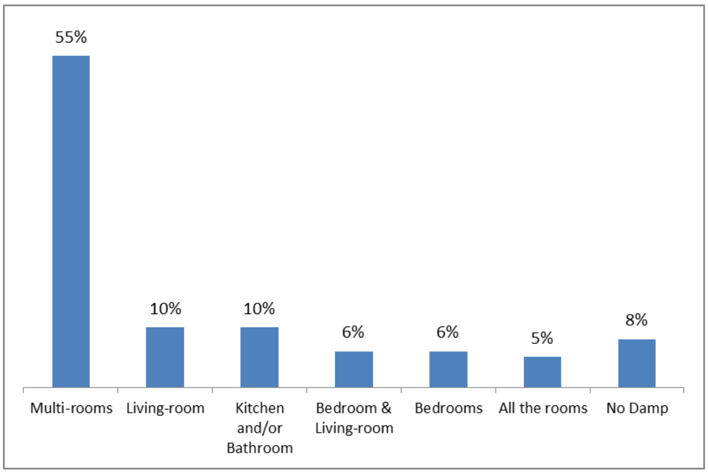


Figure 5.1 Existence of damp by room type

Continuing with the location of the damp, the respondents were also asked to specify the location of the damp per construction component. It was reported that 58% of the properties had damp in the building envelope (ceiling, exterior wall or both ceiling and exterior wall). However, 42% of the properties had damp in the interior walls and the building envelope. Only 6% of the properties had damp in the walls including both the interior and exterior walls.

Table 5.3 Existence of Damp by Construction Component within the Properties

Damp Location by Building Component	Percentage %
Walls & Ceiling	36%
Exterior Wall	22%
Building Envelope	22%
Ceiling	14%
Walls	6%

If the number of properties is ignored here and the number of defective units counted, it was found that 72% of the damp occurs in ceilings and 86% in the exterior walls of houses (Figure 5.2). Since the majority of the damp occurred in the living/hospitality and/or bedrooms, particularly in the building envelope (ceiling and exterior walls), more investigation was carried out on these rooms and these two building components.

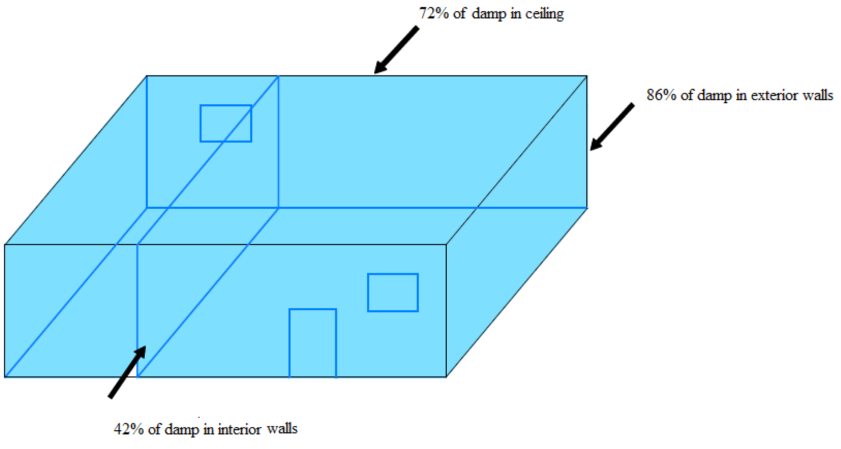


Figure 5.2 Existence of damp by construction component

The respondents were also asked where the damp occurred in the ceilings/exterior walls/interior walls in the defective rooms. Regarding the ceilings, the data illustrated that the middle of the ceiling and damp spread everywhere occupied the highest percentage for all kinds of rooms while the area between the ceiling and the wall occupied the smallest percentage. However, 84% of the occupants reported that damp occurred in the middle of the ceiling in the living/hospitality rooms. Additionally, there were quite similar percentages of damp occurrence spread everywhere in the ceilings of the kitchens, bathrooms and bedrooms (51%, 47% and 42%) respectively. Further, the occupants reported that all rooms had signs of damp, such as patches, stains, peeling and/or blistering in the defective area. The percentages by room type are shown in Table 5.4.

Table 5.4 Damp Location in Ceilings by Room Type

Kind of Room	Middle of the Ceiling	Spread Everywhere	Area between Ceiling and Wall
Living/Hospitality Room	84%	/	3%
Kitchen	37%	51%	20%
Bathroom	43%	47%	25%
Bedroom	25%	42%	25%
Other	4%	20%	3%

In respect to the exterior wall, the data showed that the damp spread everywhere and the upper section of the exterior wall occupied the highest percentage (Table 5.5). Regarding the type of room, again, living/hospitality rooms and bedrooms had the highest percentage (37% and 31%, respectively) although 34% of the damp occurred in the upper section of the kitchen wall. However, a small percentage of damp occurred in the lower section of the exterior walls and around the windows.

Table 5.5 Damp Location in Exterior Walls by Room Type

Kind of Room	Spread Everywhere	Upper Section of Wall	Around the Window	Lower Section of Wall
Living/Hospitality Room	37 %	24%	10 %	4 %
Kitchen	29 %	34%	12 %	1 %
Bedroom	31 %	23 %	11 %	11 %
Bathroom	14 %	16%	2 %	/
Other	21%	11 %	2%	3%

Continuing with the dampness in the exterior wall, our investigation showed that there was no vegetation area near the affected exterior wall on the outside. Additionally, in order to highlight whether there was a relationship between the existence of damp in the exterior walls and the possibility of poor/faulty gutter/rainwater pipes being attached to the walls, the occupants were asked to illustrate this. The results showed that, although some defective rooms had gutter/rainwater pipes attached to them, these are in a good condition. Table 5.6 summarises the main findings for this section.

Table 5.6 A Summary of Main Findings: First Section of Results

Factors Causing Damp within Concrete Houses in the Green Mountain, Libya
1.New houses have more damp than old houses.
2.Houses have more damp than flats.
3.Living/hospitality rooms and bedrooms are the major problem within the house room types.
4.Within the interior of the house, ceiling and exterior wall are the most affected building components within the house.
5.Penetration of damp from external sources occurs internally at high level.

5.3 Possible Primary Causes (Factors)

The results in this section are divided into construction and socio-economic design factors. In respect to the construction design and cost and knowledge effectiveness criteria of the construction and socio-economic design factors, in this section, only the exterior finishing type and selection sub-criteria were examined. The reason for combining certain factors and criteria into one section in this chapter is that those variables are linked within the culture of Libyan housing construction. Additionally, the other three sub-criteria for construction factors (roof design, exterior walls and water tank location) are addressed in the photographic observation analysis Chapter 6.

Here, the data indicated that 85% of the occupants reported that they finished their houses with mortar, cement mortar (the highest percentage) or stucco paint only. Additionally, a significant relationship was found between the existence of damp and the type of exterior finishing of the houses. A Chi-square test and Contingency Coefficient are performed; Chi Square Test: $X2\ (2, N = 297) = 31.67, p = 0.000 < 0.05$. However, the value of the significant relationship was low (Contingency Coefficient= 0.310), see Table 5.7.

Table 5.7 Percentage of Type of Exterior Finishing with the Result of Chi Square Test

Type of Exterior Finishing	Percentage %	Chi square Test
Mortar Cement Finishing	45%	
Stucco Paint Finishing	40%	X2 (2, N = 297) = 31.67,
Tiling/Natural Stone/Brick Finishing	15%	P = 0.000 < 0.05.

Table 5.8 illustrates the key finding. It emerged that it was common to leave the house with only mortar cement or stucco paint, a findings requiring further investigation. This is within the culture of housing construction in Libya, see Table 5.8.

Table 5.8 A Summary of Investigated Construction and Socio-Economic Design Factors

Factor	Criteria	Sub-criteria	Major Issue
Construction	Construction Design	Exterior Finishing	Mortar cement/ stucco paint finishing
Socio-Economic Design	Cost & Knowledge Effectiveness	Exterior Finishing Selection	Mortar cement/ stucco paint finishing

5.3.1 Construction and Management Factors

In this section, the manufacturing criterion for the construction factor and the construction supervision criterion for the management factor are examined. The reason behind examining these two criteria in a single section is due to the nature of the housing construction culture in Libya, where these two criteria are integrated. In respect to the construction supervision criterion, the data showed that there was a moderate similarity with regard to who supervised the construction work. Forty-six percent of house owners supervised the construction work themselves, 41% of whom had no previous experience of construction supervision, while 36% hired an expert to do this. Additionally, a strong significant relationship emerged between the existence of damp and owners who supervised the construction procedure themselves, Chi-Square test $X2$ $(2, N = 297) = 49.803$, $p = 0.000 < 0.05$.

For further investigation, Cochran's test was applied to determine whether there was an association between the existence of damp and who supervised/undertook the construction work. The result showed that most of the defective properties were built by jobbing contractors or local construction firms, supervised by the owners, Cochran's test: $X2$ $(1, N = 242) =11.699$, $p =0.005 < 0.05$. Additionally, Table 5.9 illustrates the construction labour input that the owners contribute. The results showed that raw materials and builder selection, together with supervising the concrete casting stage, occupied the highest percentages respectively that the owners contributed during the construction procedure.

Table 5.9 Percentage of Owners' Criteria Regarding Labour Input Selection

Owners' Criteria of Labour Input Selection	**Percentage %**
Raw Material Selection	23 %
Builders Selection	22 %
Concrete Casting Stage	17 %
Storage of Raw Materials	12 %
Curing Stage	11%
Steel Bar Size Selection	9%
Decision of Forms Removal	6%

Additionally, in relation to the management factor, 67% of the occupants reported they themselves had contributed towards the supervision of the concrete casting stage during the construction procedure and that only 30% of experts supervised this stage. Also, when the Cochran's test was carried out, it appeared that there was a significant relationship between the existence of damp and the supervision criteria for the concrete casting stage, subject to who supervised the construction work, Cochran's Test: X2 (1, N = 172) = 15.94, $p = .000 < 0.05$.

Table 5.10 Cross-Tabulation of the Existence of Damp, Who Supervised the Construction Procedure and Concrete Casting Stage with the Result of Cochran's Test

Existence of Damp	**Who Supervised the Construction Procedure**	**Owner's Supervision Work Concrete Casting Stage**		**Total**
		Yes	**No**	
Yes	House Owner	82	41	123
	An Expert	11	26	37
	Total	**93**	**67**	**160**
No	House Owner	11	/	11
	An Expert	1	/	1
	Total	**12**	/	**12**
Total	House Owner	93	41	134
	An Expert	12	26	38
	Total	**105**	**67**	**172**

Cochran's Test: X2 (1, N = 172) = 15.94, p = .000 < 0.05

5.3.2 Construction and Socio-Economic Design Factors

Other criteria within the construction and socio-economic design factors in the proposed hierarchy were examined, including raw materials, workforce and selection criteria. The results in Table 5.11 showed that most of the house owners did not set any criteria for the raw materials selection, although cost and availability occupied the second highest percentage.

Table 5.11 Percentage of Owners' Criteria Regarding Raw Material Selection

Owners' Criteria for Raw Material Selection	Percentage %
No Set Criteria	37%
Cost & Availability	31%
Quality	23%
Cost, Availability & Quality	9%

To explore further how these criteria were related to the emergence of damp, a significant relationship was found between who supervised the construction work and the builders' selection criteria, subject to the existence of damp, Cochran's test: X2 (1, N = 172) = 32.86, p = .000 < 0.05. Continuing with the builders' selection criteria, the data also showed that 69% of the owners' criteria for builder selection focused on wages, picking anyone from the builders' market and/or their skills, while only 22% of the house owners depended on reputation and skill in their selection. These results are summarised in Table 5.12.

Table 5.12 Cross-Tabulation of the Existence of Damp, Who Supervises the Construction Procedure and the Owner's Criteria for Builders' Selection with the Result of Cochran's Test

Existence of Damp	Who Supervise the Construction Procedure	Owner's Criteria of Builders Selection: Reputation & Anyone Skill	Owner's Criteria of Builders Selection: Wage & & Skill	Total
Yes	House Owner	28	86	114
	An Expert	14	17	31
	Total	**42**	**103**	**145**
No	House Owner	/	11	11
	An Expert	/	9	9
	Total	/	20	20
Total	House Owner	**28**	**97**	**125**
	An Expert	14	26	40
	Total	**42**	**123**	**165**

Cochran's Test: X2 (1, N = 165) = 5.027, *p* = .025 > 0.05

Table 5.13 illustrates the key findings with regard to the construction, socio-economic design and management factors. The main issues were the use of poor raw materials, low quality workmanship and a lack of control of in-situ concrete, together with owners who had no prior experience of construction and were acting in a supervision capacity and selecting the raw materials and builders.

Table 5.13 A Summary of Investigated Construction, Socio-Economic Design and Management Factors

Factor	Criteria	Sub-criteria	Major Issue
Construction	Manufacturing Criteria	Raw Materials	Poor raw materials
		Workforce	Poor workmanship
		Control of In-situ Concrete	Poor control of in-situ concrete
Socio-Economic Design	Cost & Knowledge Effectiveness	Selection of Raw Materials Selection of Builders	Owners with no previous experience in construction work contributed some labour input such as builders and raw materials selection, and concrete casting stage supervision
Management	Construction Supervision Criterion	Owners Supervision	Owners with no previous experience in construction work supervised the house construction procedure.

5.3.3 Socio-Economic Design and Management Factors

In this section, management and socio-economic design factors, including housing policy and cost effectiveness, are investigated. It emerged that most of the defective houses were constructed by jobbing contractors or local construction firms, with only 17% of the properties built by international firms. Additionally, a strong significant relationship was found between the existence of damp and the party who undertook the construction work X2 (2, N = 297) = 55.43, p =0.000 < 0.05. Table 5.14 summarises the findings of this section.

Table 5.14 Percentage of Who Undertook the Construction Work with the Result of Chi- Square Test

Who Undertook the Construction Work	Percentage %	Chi square Test
Jobbing Contractors	57%	
Local Construction Firm	26%	X2 (2, N = 297) =
International Construction Firm	17%	55.43, P =0.000 <
		0.05.

To illustrate further the changes in Libya's housing construction policy, another strong relationship emerged between the type of property and who undertakes the construction work with regard to the existence of damp. The defective properties which were constructed by jobbing contractors and/or local construction firms are both one-storey or extensions developing houses into multi-storey houses (Table 5.15).

Table 5.15 Cross-Tabulation of the Type of Property and Who Undertook the Construction Work with the Existence Of Damp

Existence of Damp	Type of Property	Who Undertaken the Construction Work			Chi square Test
		Local Construction Firm	International Construction Firm	Jobbing Contractor	
Yes	Flat	20	12	26	*X2* (2, *N* = 252) = 14.486, *p* =0.006 < 0.05
	One Floor House	25	10	73	
	Multi-Storey House	23	4	59	
	Total	68	26	158	

For additional elaboration and to explore the financial limitations of the house owners during the construction procedure, it was reported that the owners used bank loans and/or personal savings as a source of construction funds (Table 5.16). However, at times, these two sources were not enough to complete the construction work. A strong relationship was found between the source of the construction funds and delays during the construction regarding the existence of damp, by carrying out the Cochran's test and Contingency Coefficient. It is apparent from the analysis that the majority of the house owners depended on their personal savings to build and complete the construction. Additionally, there was a significant relationship between the source of funds and delays during the construction procedure with regard to the existence of damp X2 (2, N = 244) = 64.67, p =0.000 < 0.05.

Table 5.16 Percentage of Source of Construction Funds with Chi Square Test

Source of Construction Fund	Percentage %	Chi square Test
Both Personal Saving and Bank Loan	36%	**Cochran's Test: X2 (2, N = 244) = 64.67, *p* =0.000 < 0.05**
Personal Saving	29%	
Loan from the Bank	28%	
Others	7%	

Further, in order to investigate whether there was a relationship between the existence of damp and delays during construction, including the winter season, the owners were asked whether they had faced delays during the construction procedure, including the winter season (Table 5.17). Although it was reported that only 30% of the house owners faced delays during the construction process, 25% of the houses were exposed to the wet climatic conditions, and a significant relationship was found between the existence of damp in these houses and delays in their construction, Cochran's test: X2 (1, N = 94) = 13.673, p =0.000 < 0.05 (Table 5.17).

Table 5.17 Delays During the Construction Process, Including Winter Season

Delays during the Construction Process	Percentage %	Delays including Winter Season	Percentage %
Yes	30%	Yes	25%
No	52%	No	7%
N/A	18%	N/A	68%
Cochran's Test: X2 (1, N = 94) = 13.673, *P* =0.000 < 0.05			

Regarding the maintenance sub-criterion, the occupants were asked whether they had carried out any kind of maintenance action against the damp and what was the nature of this. The result shows that no effective maintenance actions had been carried out in relation to the damp.

Figure 5.3 shows that 30% of the occupants reported that no previous maintenance action had been carried out. In a further 30% of the defective properties, the only action taken had been to re-paint the affected area inside the house, and another 26% of the occupants reported that they had plastered over the defective area outside the house and re-painted the entire house inside.

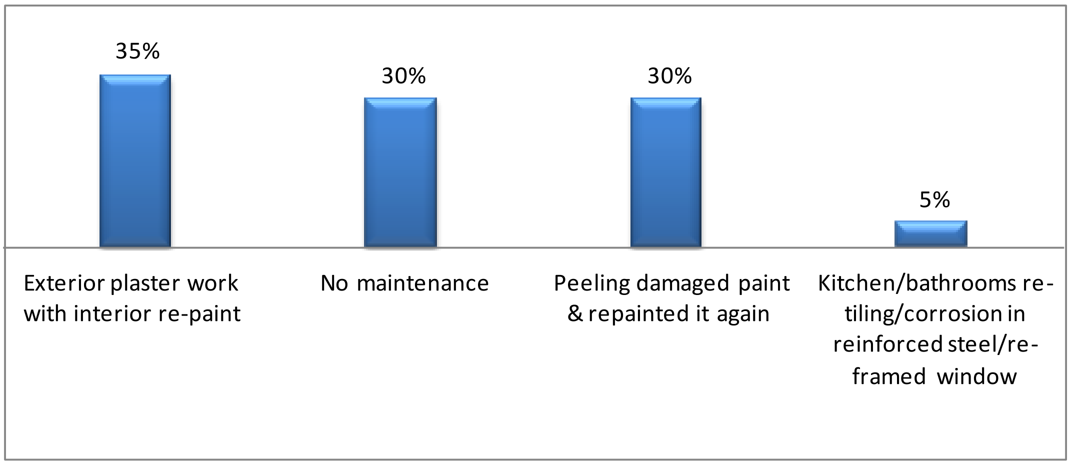


Figure 5.3 Nature of the last maintenance actions

Table 5.18 presents the major findings with regard to the management and socio-economic design factors.

Table 5.18 A Summary of Investigated Management and Socio-Economic Design Factors

Factor	Criteria	Sub-criteria	Major Issue
Management	Housing Policy	Changes in Housing Construction Policy	More defective houses were constructed by jobbing contractors or local construction firms Those construction parties built houses but not flats
Socio-Economic Design	Cost & Knowledge Effectiveness	Delay in Construction	Financial limitation/ delays in bank payment caused the delays
		Maintenance	Poor maintenance was detected

5.3.4 Socio-Economic Design Factor

This section investigates the cost and knowledge effectiveness and socio-religious design requirements criteria of the socio-economic design factor. Those criteria affected houses' performance in North Eastern Libya and were possibly associated with the appearance of damp. This section investigates the financial limitations of the owners with regard to the socio-religious design requirements for house construction. In order to determine the socio-cultural design requirements for Libyan houses, a rating question was asked to identify the most important features that the occupants looked for before/while constructing their houses. The result, presented in Figure 5.4, shows that having a large room size occupied the most important factor (44%) that owners sought before/while constructing their houses. Having high quality interior finishing and decoration and hospitality rooms appeared to be the second and third most significant requirements respectively (at 32% and 27%).

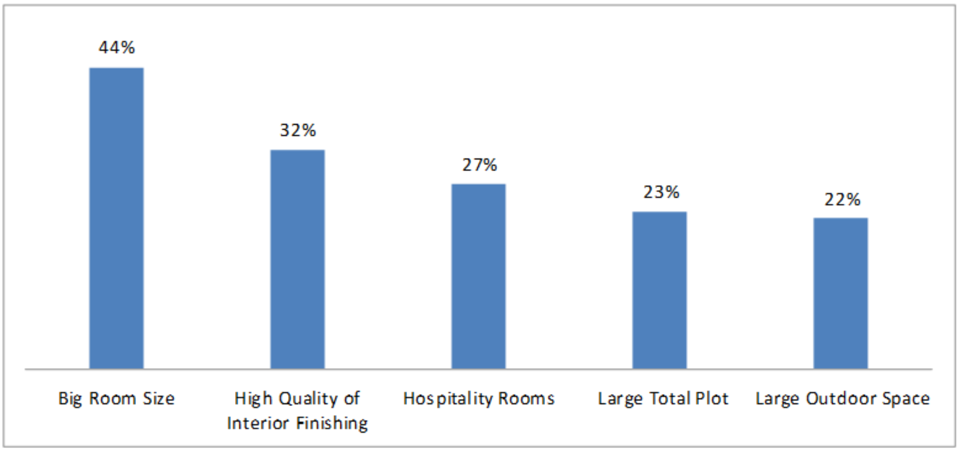


Figure 5.4 Owners' design requirements in house construction

For further investigation, the house owners were also asked whether all of the rooms in the house were currently fully used. It appeared that 57% of the house rooms were not fully used. The previous result gave rise to another question: which types of rooms are not or only rarely used in the house? The result showed that 47% of the occupants reported that the male and female guests' rooms were not fully used and 11% reported that the whole ground floor of the house was not fully used but was used only for hospitality purposes.

Additionally, in order to examine the future requirements of Libyan house owners, the occupants were asked whether they made any kind of amendments/changes within the house after its completion. The results shown in Table 5.19 illustrate that 61% of the house owners did make amendments. Also, the result shows that building another unit in the surrounding setback area occupied the highest percentage (23%) among all kinds of subsequent amendments, 15% of the occupants made changes by constructing another floor, while raising the fence of the house and converting rooms occupied 7% respectively among the other kinds of amendment. Adding rooms, building shops in the setback area and others occupied the smallest percentage. Interestingly, a significant relationship emerged between the existence of damp and the previous modifications (future requirements) to the house (Chi-Square Test: X2 (2, N = 297) = 31.67, $p = 0.000 < 0.05$). However, the value of this significant relationship is low (Contingency Coefficient= 0.318).

Table 5.19 Type of Previous Amendments/Changes within The Houses

Type of Previous Amendments/Changes	Percentage
Building Rooms in Surrounding Setback Area	23%
Adding another Floor	15%
Conversion of Rooms	7%
Raising the Fence	7%
Adding Rooms	5%
Building Shops in Surrounding Setback Area	4%
No amendments/changes	39%

A summary of the key findings regarding the socio-economic design factor is shown in Table 5.20.

Table 5.20 A Summary of Investigated Socio-Economic Design Factor

Factor	Criteria	Sub-criteria	Major Issue
Socio-Economic Design Factor	Cost & Knowledge Effectiveness	Lack of/poor maintenance	Poor and/or lack of maintenance is a major issue in North Eastern Libya
		Mortar finishing	Leaving the house with only mortar finishing
		Big room size	Large rooms
	Socio-Religious Design Requirements	Interior finishing & decoration	High quality of interior finishing and decoration
		Hospitality rooms	Male and female hospitality room

In order to determine the occupants' awareness of the housing construction issue and whether Libyan society intended to make changes to housing construction in the future, the occupants were asked, based on their current experience of living in a self-built house and the defects that occur within the property, to rate their most important desired feature/requirement if they had a chance to re-construct their house. The data show that the construction factor occupied the highest percentage, more than twice as high as any other factor. In fact, the top three requirements that the house owners sought were: a high quality construction process, the type of exterior finishing, the size of the rooms and proper interior design. The relative percentages are shown in Figure 5.5.

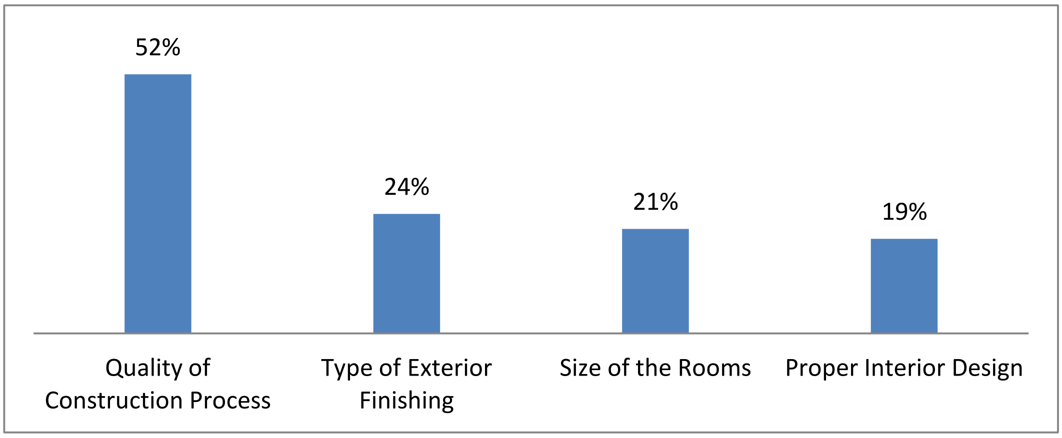


Figure 5.5 What owners would change in relation to house construction

5.3.5 The Climatic Factor

In this section, the climatic factor is investigated. The occupants were asked to specify the time when the damp appeared in the house. As can be seen from Figure 5.6, the damp tends to occur in the houses during the wet season, although 19% of the properties suffer from damp all year around.

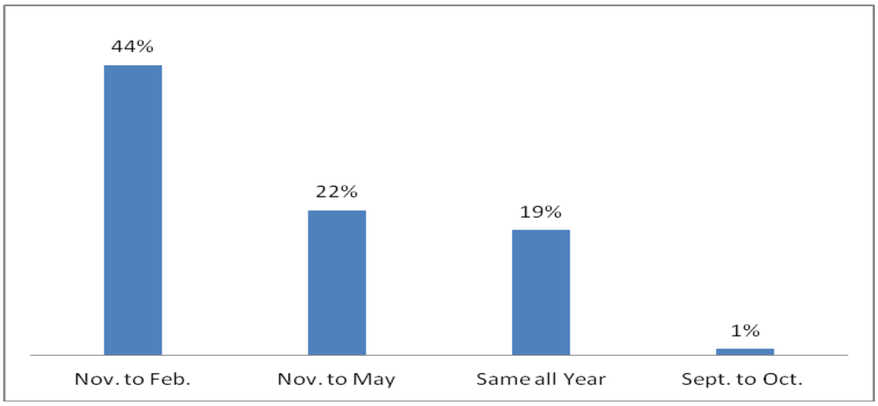


Figure 5.6 Damp occurrence time with the properties

In relation to wind direction with driving rain and defective exterior walls, the data showed that the walls of different types of rooms that faced northwest tended to suffer the most from damp compared with walls that faced other directions. However, it is worth noting that the northwest facing walls of bedrooms (Figure 5.7, Table 21), kitchens (Figure 5.8, Table 22) and living/hospitality rooms suffered the most from damp.

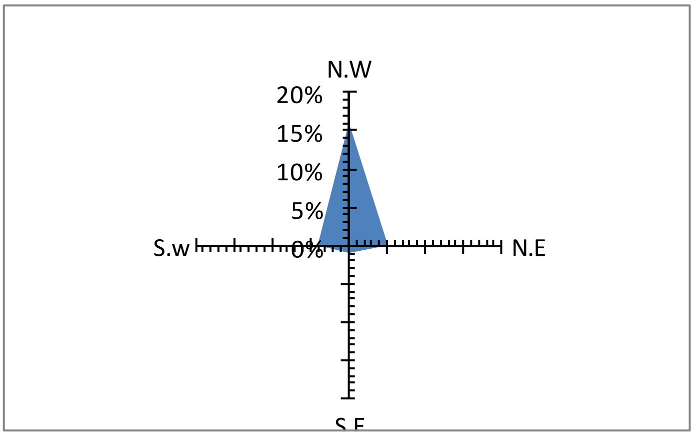


Table 5.21 Percentage of Bedroom

Wall Orientation	Percentage %
N.W	16%
N.E	5%
S.W	4%
S.E	1%

Figure 5.7 Orientation of the affected exterior wall of bedroom

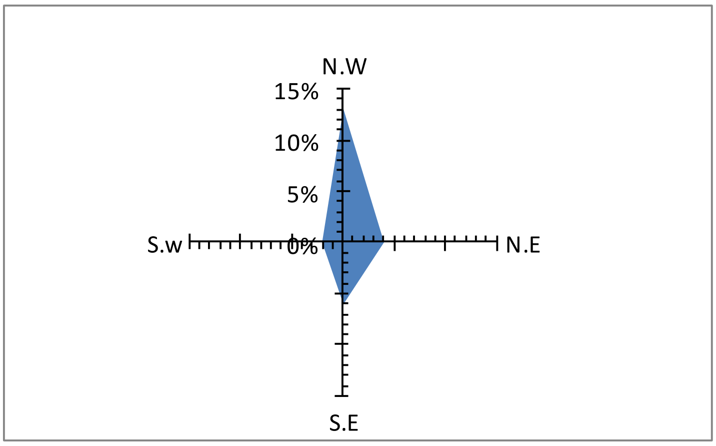
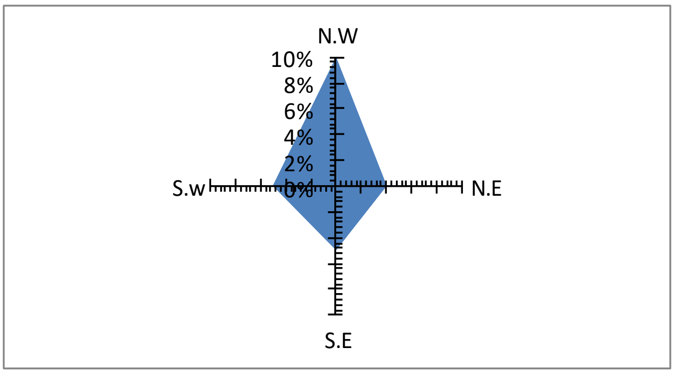


Table 5.22 Percentage of Kitchen

Wall Orientation	Percentage %
N.W	13%
S.E	6%
N.E	4%
S.W	2%

Figure 5.8 Orientation of the affected exterior wall of kitchen

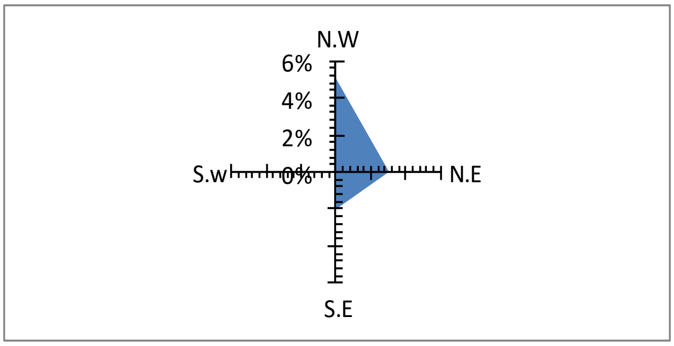
Table 5.23 Percentage of Living/Hospitality Room



Wall Orientation	Percentage %
N.W	10%
S.E	5%
S.W	5%
N.E	4%

Figure 5.9 Orientation of the affected exterior wall of living/hospitality room

Table 5.24 Percentage of Bathroom



Wall Orientation	Percentage %
N.W	5%
N.E	3%
S.E	2%
S.W	/

Figure 5.10 Orientation of the affected exterior wall of bathroom

Table 5.25 illustrates the key finding. It appeared that the wet rainy season and walls that face northwest were the major problems with regard to the climatic factor. Therefore, the issue required further investigation.

Table 5.25 A Summary of Investigated Climatic Factor

Factor	Criteria	Sub-criteria
Climatic	Rainy season	Wet months
	Wind direction	Northwest

5.4 Summary

This chapter has presented the questionnaire results regarding the construction, socio-economic design, management and climatic factors with their criteria and sub-criteria that cause penetrating damp in domestic concrete houses in the Green Mountain of Libya. Results of the house owners’ questionnaire can be summarised as:

- Penetrating damp was reported to be the most dominant type of damp.
- Exterior walls and roofs were the major building components that suffered from damp.
- New houses tended to suffer from damp more than old houses.
- Most damp houses were constructed by jobbing contractors or local construction firms.
- Likelihood of penetrating damp increased when building was supervised by the owners, who had no previous experience of the construction process, and contributed into some labour inputs such as builders and raw materials selection, as well as supervising the concrete casting stage.
- There were signs of owners' financial limitations and lack of knowledge.
- Prioritising houses with big room size, high quality interior finishing and decoration and hospitality rooms were the major socio-cultural and economic design requirements for Libyan houses, which could cause owners to compromise the quality standard of construction.
- Mortar cement render and stucco paint were the most common form of finishing.

- Poor and/or a lack of maintenance of the house were also major issues within the North Eastern Libyan community.
- The wet season and northwest wind direction were the major climatic concerns although northeast and southeast directions are also highlighted.

These results were obtained through the survey questionnaire completed by house owners whose houses suffered from damp. Further investigation was obtained through direct observation with photographs of damp houses, as outlined in Chapter 6.

Chapter Six: Photographic Observation Result

6.1 Introduction

In this chapter, classifications, summaries, photography and tabulations are processed to understand and illustrate the overall scenario of the phenomenon of damp. Twelve concrete houses that suffered from penetrating damp were observed and photographed to explore incidents and factors affecting the performance of concrete houses. The chapter presents analysis and interpretation of those houses, based on technical content analysis. The location and nature of the signs of damp, the construction design, surrounding environment and last maintenance actions were investigated.

6.2 House 1

House 1 was built in 2005. There is a fence around it and other constructions adjacent to the structure on three sides. It is not exposed directly to the driving rain and wind from the north, east or west, since the adjacent constructions are quite close to the house (photograph (a)). The damp appears as small to medium black patches, spreading everywhere at the junctions in the area between the ceiling and walls (photograph (b)). Although the last maintenance action was taken one year previously, the property has suffered from recurrent damp for five years on the living room ceiling; after each maintenance action, the damp recurs during the rainy season and continues to appear until maintenance is carried out. Photograph (c) shows the condition of the roof over the defective ceiling. Water was pooled across the whole roof, even though a good drainage pipe was installed. However, it was only installed on one side of the roof and seems to work only for water that collects on that side, which suggests that the roof slope may be incorrect. Additionally, when the house owner was asked about the water pool, he stated that: "*When water is pumped from a ground water tank into the top tank, we sometimes do not notice whether the tank is full of water or not. Then the water floods onto the roof, as seen, and lasts for a couple of weeks*" (House 1, Owner). He added that carpet washing and cleaning activities tended to be carried out on the roof.

a

South-west façade of the house, year of construction

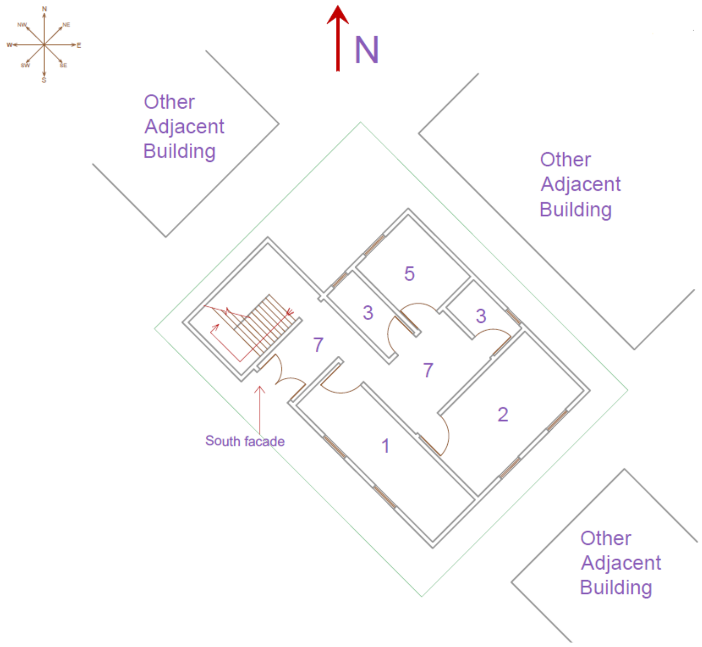
(b)

c

Stains and black patches, indicating damp on the north-western and eastern façade. The damp is in the ceiling and junction of the living room, caused by water pooling on the roof

A pool of water caused by the water tank flooding and/or rainfall during the rainy season

Figure 6.1 Condition survey: house 1, Al Gareda quarter, Albeida, Green Mountain, Libya



Ground floor plan

First floor plan

Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number
e.g. (a,1), (b, 6)	indication for the rooms in the photos and plans

Figure 6.2 Ground floor and first floor plan of house 1, Al Gareda quarter, Albeida, Green Mountain, Libya

The initial dampness investigation was carried out, reflecting on all possible causes. It revealed that the water supply position (water tanks) might be the main reason for the pool of water. Water that pools everywhere indicates the probability of a construction defect with regard to the slope of the roof. At first, this was the only cause considered but the fact that the outside surface of the house had been left with only a cement mortar render due to the owner's financial limitation, and the poorly skilled builders who built the house could be other factors leading to the occurrence of damp, as well as the lack of drainage installed and possibly poor maintenance. While these causes and potential contributory factors could lead to damp in houses, the observed level of damp was low with the likelihood that no further action would be taken and it would worsen over time. Table 6.1 summarises the most significant findings for house 1.

Table 6.1 A Summary of the Finding of House 1

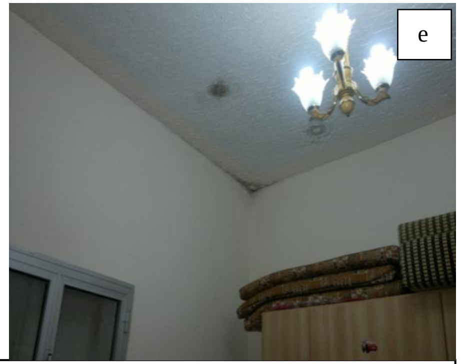
House No.1	
Property Type	Villa
Year of Construction	2005
Condition of Construction	Finished
Damp Location (per room)	Living-room
Defective Construction Component	Ceiling & junction (the area between ceiling and exterior wall)
Type of Exterior Finishing	Rendered cement
Defective Area Direction	N.W. and N.E. side façade
Damp Signs (inside)	Stains and black patches
Damp Signs (outside)	Pool of water
Last Known Maintenance	Repainting the house interior every year
Observed Primary Cause(s)	(1) Construction design defect in the roof slope (2) Construction design under the climate condition (3) Type of exterior finishing (4) Poor maintenance
Potential Contributory Factors	(1) Poorly skilled workforce (2) Water tank location (3) Improper type of exterior finishing (veneer) due to owner's financial limitation: the owner prefers to hide the signs of damp (4) Socio-cultural activity: carpet washing and cleaning on the roof
Observed Level of Dampness	Medium-Low Damp

6.3 House 2

House 2 is a multi-storey house with two levels, built in 2004. There are other constructions adjacent to this structure. In fact, it is joined to the other houses to the northwest and southeast, and is quite close to the other building to the north east direction (photograph (a)). The exterior walls in those directions are not exposed directly to the driving rain and wind since the adjacent constructions are relatively close to the house. The house has suffered from damp since 2007 and was maintained two years previously. The nature of the last maintenance action was peeling the old paint off the affected area from inside and repainting it. Additionally, the exterior finish of the house is only rendered cement. Photographs (b) and (c) show the condition of the roof of the house with extensive water pools. They also show the position of the water tank on the roof. When the house owner was asked whether water might flood from the tank during pumping after it becomes full, he did not provide a clear answer but stated that the water pool lasts for months. Photographs (d) and (e) show the signs of damp on the ceiling and at the junction between two bedrooms within the house. These take the form of black patches and stains, with some areas of peeled paint. Also, photographs (f) and (g) show signs of damp in the living room. Further, there are some leaks in one of the bedrooms (d) and a cracked area in the roof's surface was noticed in Figure 6.3. In relation to social activity, the owner stated that the family usually washed and cleaned the carpet on the roof.

South-west façade of house, year of construction: 2004

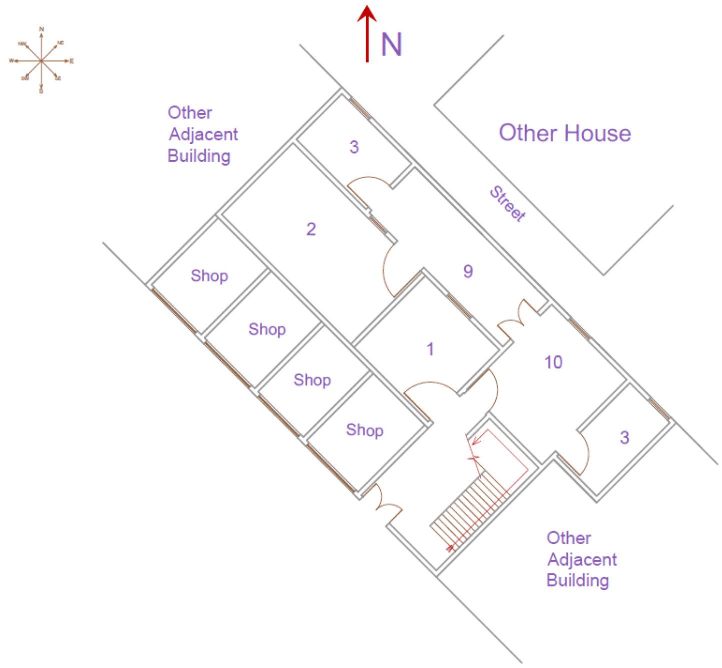
[b, c] Photographs show the roof condition; a water pool caused by the rain during the rainy season and/or the flooding of the water tank

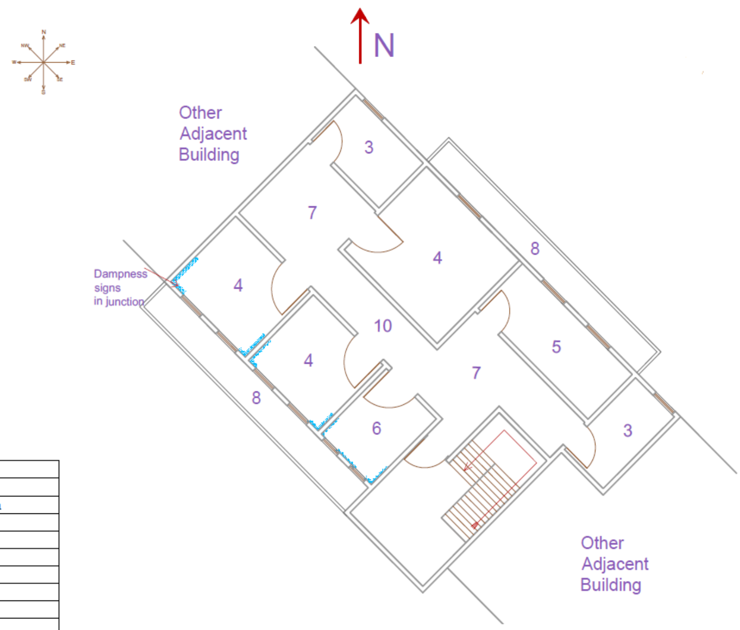


[d, e] Photographs showing signs of damp in two bedrooms in the property, located on the S.W façade. These take the form of black patches and stains, with some areas of peeled paint. They are located at the junctions, the area between the wall and ceiling, and caused by the pool of water on the roof

[f, g] Photographs show signs of damp in the living room junction, which is located on the S.W façade. These take the form of black patches at the junctions, caused by the pool of water on the roof

Figure 6.3 Condition survey: house 2, West Albeida quarter, Albeida, Green Mountain, Libya





Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number
e.g. (a,1), (b, 6)	**indication for the rooms in the photos and plans**

Figure 6.4 Ground floor and first floor plan of house 2, West Albeida quarter, Albeida, Green Mountain, Libya

Rainfall or the possible flooding of the water tank (although not confirmed by the owner) could be factors that contributed to the existence of the pool of water. It could be argued that, if the water pools in the middle of the roof, there may be a construction error with a slope in the flat roof, due to poor workmanship. Also, if the water pools at the edge of the roof, this may be due to a lack of or poor drainage installation, which can be quickly remedied by installing proper drainage. However, surprisingly, drainage was not installed when the house was constructed. Another possible factor was poor maintenance due to the owner's financial constraints, which indirectly contribute to the existence of the damp. The type of exterior finishing (rendered cement) of the house could also contribute to the existence of the damp although it seemed, from comparing the roof condition with the signs of damp on the ceiling, that the building had a high quality finish. Another significant hidden factor was the washing and cleaning activity on the roof which, combined with the poor roof condition, might have caused some water ingress. Table 6.2 summarises the most significant findings for house 2.

Table 6.2 A Summary of the Finding of House 2

House No.2	
Property Type	Multi-Storey House
Year of Construction	2004
Condition of Construction	Finished
Damp Location (per room)	Living-room, Bedrooms
Defective Construction Component	Junction (the area between ceiling and exterior wall)
Type of Exterior Finishing	Rendered cement
Defective Area Direction	In the ceiling, especially on the S.W facade
Damp Signs (inside)	Black patches, stains, peeling paint and leaks
Damp Signs (outside)	Pool of water
Last Known Maintenance	Repainting the house interior
Observed Primary Cause(s)	(1) Construction design defect in the roof slope (2) Construction design under the climate condition (3) Uninstalled drainage (4) Poor maintenance
Potential Contributory Factors	(1) Poorly skilled workforce (2) Water tank location (3) Improper type of exterior finishing due to owner's financial limitation: the owner prefers to hide the signs of damp with (4) Poor maintenance (5) Socio-cultural activity: carpet washing and cleaning on the roof
Observed Level of Dampness	Medium Damp on the Ceiling

6.4 House 3

House 3 is multi-storey and built in 1993. It is exposed to the driving rain and wind since there are no other buildings adjacent to it. The house shows signs of damp on the ceiling of the hospitality and living rooms, and on the exterior walls of the hospitality room and kitchen. The last maintenance action was taken in 2004. The house owner said "*I hired jobbing builders, who re-cast the wall and roof from outside and repainted the interior house"* (House 3, Owner). Photographs (a) and (b) show the south and west facades of the house, photographs (c) and (d) show the roof condition including the water pool, which lasted for a couple of weeks, and photographs (e) and (f) indicate that damp existed on the ceiling of the hospitality and living rooms on the interior and exterior surfaces. In these rooms, damp appeared as stains and blistering, with large areas of peeling paint. There also appeared to be cracks in some areas of the rendered cement of the roof**.** Photograph (g) indicates the presence of damp on the ceiling and exterior wall of the kitchen, appearing as stains and blistering with a large area of peeling paint. Photographs (h) and (i) also illustrate the defective north-western wall, both inside and out. Moreover, in relation to social activity, the owner said that the family usually washed and cleaned the carpet on the roof.

North-eastern façade of the house, year of construction: 1993

South-eastern façade of house

Photographs (c) and (d) show the roof condition; the water pool is caused by the flooding of the water tank and/or the rain rate during the rainy season

Photograph [e] shows signs of damp on the ceiling of the women's hospitality room in the form of stains and blistering, with large areas of peeled paint caused by the pool of water on the roof

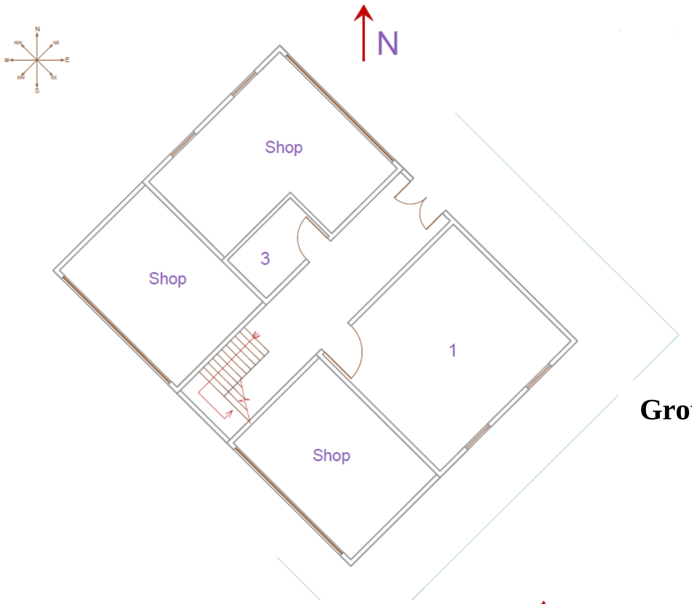
Photograph [f] shows signs of damp on the ceiling of the living room in the form of stains and blistering, with a large area of peeled paint caused by the pool of water on the roof

Photograph [g] shows signs of damp on the kitchen ceiling and wall in the form of stains and blistering, with a large area of peeled paint on the wall and ceiling

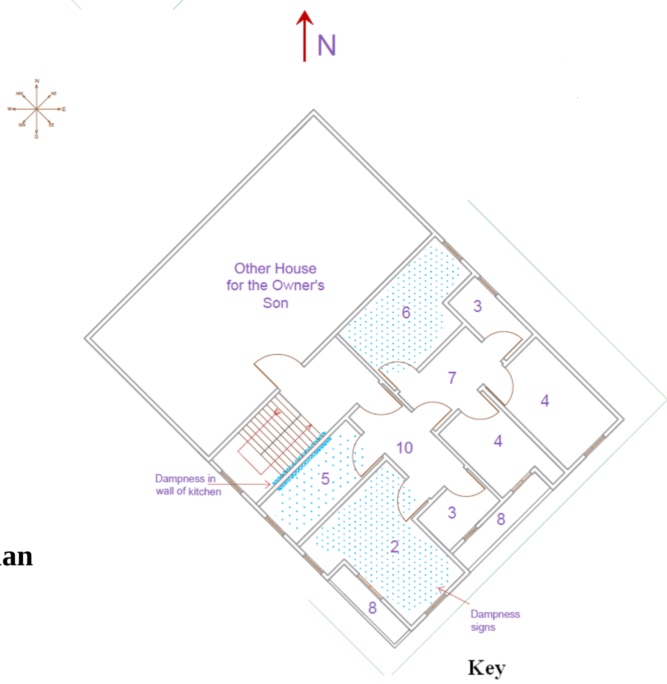
Photograph [h] illustrates the defective north-western exterior surface wall of the kitchen. This wall is located within the stairway

Photograph [i] illustrates the type of ceiling cover on the roof of the stairway

Figure 6.5 Condition survey: house 3, Al Gareda quarter, Albeida, Green Mountain, Libya



Ground floor plan



First floor plan

Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number

Figure 6.6 Ground floor and first floor plan of house 3, Al Gareda quarter, Albeida, Green Mountain, Libya

A possible interpretation of this reported damp is that the location of the pool of water on the roof indicated a poor construction of the form of a slope on the flat roof, which might be caused by unskilled workers as well as the inappropriate covering of the roof of the stairway (photograph (i)). Additionally, there is a high possibility that poor and/or a lack of maintenance (the last maintenance action was taken in 2004) caused by the financial limitations of the owner might have contributed to the continuation of this problem. However, there might also have been a lack of knowledge among experts and/or owners about how to manage this issue, which caused the signs of damp to re-emerge. Further, the wall construction design (single sheet exterior walls) under the Green Mountain climatic condition with the location of the house might be another factor leading to the emergence of damp. Finally, the hidden socio-cultural factor was the carpet washing and cleaning activity on the roof. Table 6.3 summarises the most significant findings for house 3.

Table 6.3 A Summary of the Finding of House 3

House No.3	
Property Type	Multi-Storey House
Year of Construction	1993
Condition of Construction	Finished
Damp Location (per room)	Hospitality Room, Living-room and Kitchen
Defective Construction Component	Ceiling and exterior wall in different rooms
Type of Exterior Finishing	Ceilings: Rendered cement Exterior wall: Stucco paint
Defective Area Direction	N.W. (affected wall)
Damp Signs (inside)	Ceiling: Paint peeling, blistering and leaks Exterior wall: Paint peeling and blistering
Damp Signs (outside)	Ceiling: Water pooling and cracking from the outside Exterior Wall: Cracking from outside
Last Known Maintenance	Ceiling: Re-coating and re-painting the affected area Exterior Wall: Re-coating and re-painting the affected area
Observed Primary Cause(s)	Ceiling: (1) Construction design defect of the slope of the flat roof (2) Construction design under the climate condition (3) Poor finishing materials (4) Poor maintenance Exterior Wall: (1) Construction design under the climate condition (2) Poor maintenance
Potential Contributory Factors	Ceiling: (1) Poorly skilled workforce (2) Water tank location (3) Improper type of exterior finishing materials due to financial limitation (3) Hiding the issue by carrying out poor maintenance (4) Carpet washing and cleaning on the roof Exterior Wall: (1) Wall orientation, facing the wind and driving rain (2) Single sheet exterior wall (3) Poorly skilled maintenance workforce (4) Improper stairway covering materials
Observed Level of Dampness	High Level of Damp on Ceiling and Walls

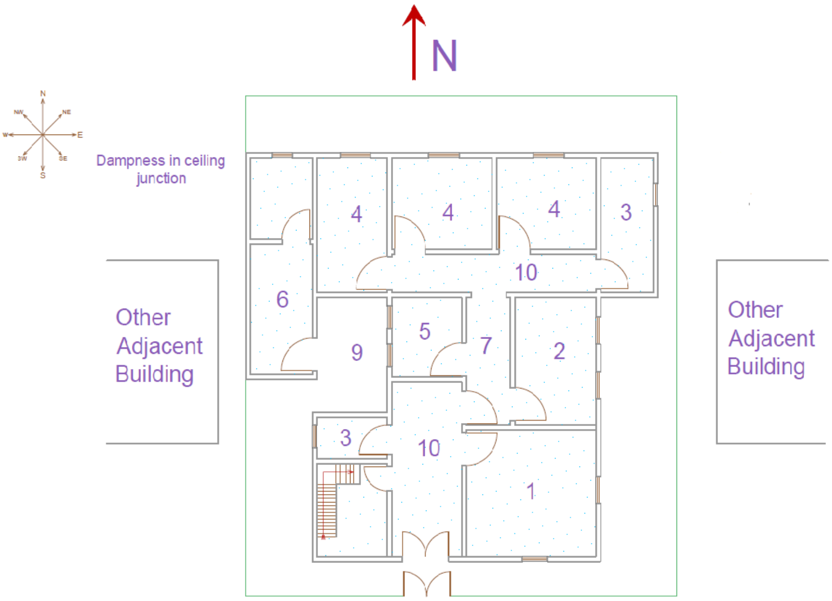
6.5 House 4

As permission could not be obtained to observe and photograph the interior of the house, only the outside of this house was observed and photographed, although the house owner was very helpful in answering enquiries regarding the condition of the defective area inside. It is one-storey house in west Albeida quarter, built in 1993. There are other constructions adjacent to this structure in three directions (north, east and west). It is not exposed directly to the driving rain and wind on those three sides, since the adjacent constructions are quite close to the house. There is a fence around it. In respect to the roof condition, water pools everywhere. Regarding the inside of the house, the owner stated that there were signs of damp only on the ceiling of the entire house, that took the form of a large area of blistering and peeling paint, with black patches on the ceiling and at particular junctions. Also, there were signs of leaks in certain areas, particularly at the junctions. The roof had been maintained several times. The nature of the last maintenance action was removing the old layer of rendered cement from the roof and then recoating it with three layers of bitumen and rendered cement, besides peeling off the damaged damp area of the ceiling and repainting the whole house. However, the damp re-appeared as soon as the rainy season started and the pools of water on the roof lasted for months, the owner said.

Another significant point raised by the owner was the water pumping activity. He described how, when the water was pumped from an underground tank into the top tank located on the roof, the occupants sometimes did not notice that the tank is full, in which case, the water flooded out, as shown in photograph (b). He added that *"We usually wash and clean the carpets of the house on the roof"* (House 4, Owner).

[a] **Photograph of south façade of the house, year of construction: 1993**

[b] **Water pools caused by water tank flooding and/or the rainfall rate during the rainy season**



Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
………………	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number
e.g. (a,1), (b, 6)	indication for the rooms in the photos and plans

Figure 6.7 Condition survey: house 4, West Albeida quarter, Albeida, Green Mountain, Libya with plan of a one-storey house

From this report, it appeared that the inadequate implementation of the construction slope, caused by poorly skilled labour along with the adopted construction design might be the primary cause of the pool of water, which was due to the flooding of the water supply (water tank) as well as the rain rate in the rainy season. Additionally, poor or improper maintenance and carpet washing on the roof could be socio-cultural factors that contributed to the issue. Table 6.4 summarises the most significant finding for house 4.

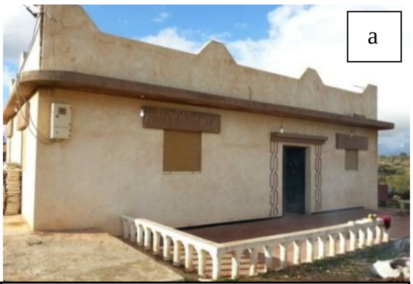
Table 6.4 A Summary of the Finding of House 4

House No.4	
Property Type	Single Storey House
Year of Construction	1993
Condition of Construction	Finished
Damp Location (per room)	The entire house
Defective Construction Component	Ceiling and junction (the area between ceiling and exterior wall)
Type of Exterior Finishing	Rendered cement
Defective Area Direction	All ceilings in all directions
Damp Signs (inside)	Black patches, blistering and leaks
Damp Signs (outside)	Water pooling and cracking from the outside
Last Known Maintenance	Recoating the exterior surface of the roof with rendered cement and bitumen layers. Then repainting the ceiling of the house
Observed Primary Cause(s)	(1) Construction design defect of the slope of the flat roof (2) Construction design under the climate condition (3) Poor maintenance
Potential Contributory Factors	(1) Poorly skilled workforce (2) Water tank location (3) Poorly skilled maintenance workforce (4) Carpet washing and cleaning on the roof
Observed Level of Dampness	Medium to High Damp on the Ceiling

6.6 House 5

House 5 illustrates a one-storey house, built in 2011. There are no other constructions adjacent to this structure in any direction, so it is fully exposed to wind and driving rain. The house developed signs of damp signs a year after it was built. As it is a newly built construction, no previous repair or maintenance work has been carried out. Photographs (a) and (b) show the north and east façades of the house. Photographs (c) and (d) illustrate the damp symptoms in the defective area of the toilet from both the inside and outside. The signs of damp are large blisters, stains and peeling paint across the entire ceiling of the toilet. Additionally, photograph (g) shows the signs of damp on the ceiling of the hospitality room, which take the form of small stains with slightly peeling paint at the junction facing the North West. The owner was asked whether there was any relationship between the pooled water and the flooding of the water tank. He stated that this happened sometimes: "*I forget to turn the pump off when the water tank is full of water*" (House 5, Owner). He added that the pooled water lasted for a couple of weeks.

Moreover, there were further signs of damp on the exterior wall of the bedroom. Photograph (i) shows this wall, which faces northwest. The signs of damp took the form of stains and peeling paint over the whole area, facing the north western façade. This exterior wall had a rainwater pipe installed which is in a good condition. It also had plants near the wall, although the trees were not too close to the wall.



North façades of the house, year of construction: 2011

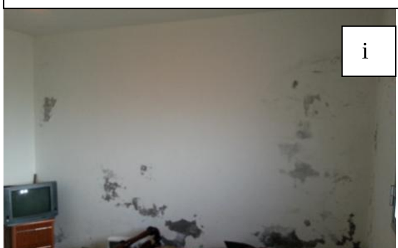
Eastern façades of the house

[c] Signs of damp on the ceiling of a toilet located on the north-eastern side of the house

d] Water pooling above the location of the toilet, caused by water flooding out of the tank and/or rainfall in the rainy season

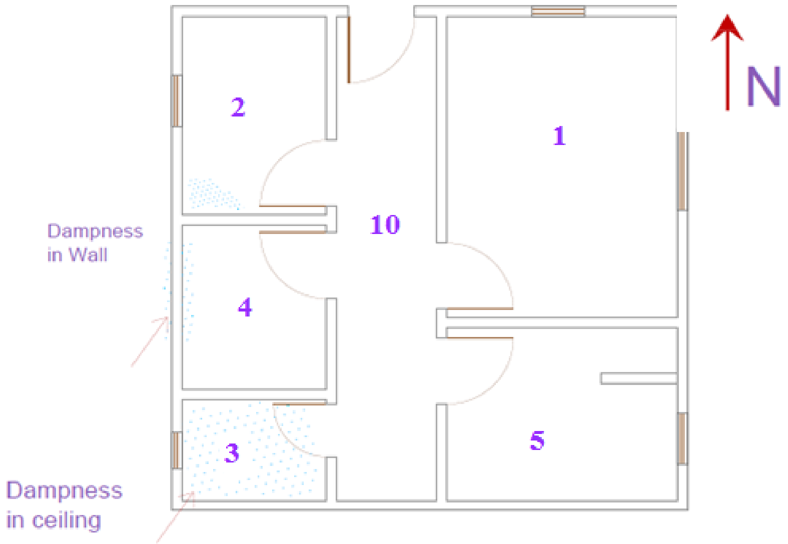
Close up photographs of the signs of damp on the ceiling of the toilet, caused by the water pooling on the roof, in the form of stains and peeling paint

Photograph [g] shows signs of damp on the ceiling of the hospitality room, located on the north eastern side, caused by the water pooling on the roof. Photograph [h] shows signs of damp in the form of stains and peeling paint on the ceiling of the room



Photograph [i] shows signs of damp in the form of stains and peeling paint on the exterior wall of a bedroom, which faces west. Photograph [j] shows the exterior wall of the damp wall shown in photograph [i]. There are vegetation areas near to the damp wall

Figure 6.8 Condition survey: house 5, Al Zawea quarter, Albeida, Green Mountain, Libya



Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number

Figure 6.9 Plan of house 5, Al Zawea quarter, Albeida, Green Mountain, Libya

Regarding the damp on the ceiling, the flooding of the water supply (water tank) could have contributed to the existence of the water pools, as well as the rainfall during the rainy season. However, it can be argued that if the water pools in the middle of the roof, there is construction defect in the form of a slope on the flat roof, caused by a poorly skilled workforce. It appears that water pools were at the edge of the roof, possibly due to a lack of or poor drainage installation; this could be quickly remedied by installing proper drainage. In relation to the damp in the exterior wall, the construction design (single sheet exterior wall) under the climate condition (rainfall with the northwest wind) may have been the cause of this. Table 6.5 summarises the most significant findings for house 5.

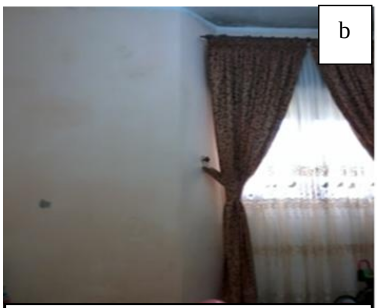
Table 6.5 A Summary of the Finding of House 5

House No.5	
Property Type	Single Storey House
Year of Construction	2011
Condition of Construction	Finished
Damp Location (per room)	Hospitality Room and Toilet (ceiling) Toilet and Bedroom (exterior wall)
Defective Construction Component	Ceiling and exterior wall
Type of Exterior Finishing	Ceilings: Rendered cement Exterior wall: Stucco paint
Defective Area Direction	N.W.
Damp Signs (inside)	Ceiling: Stains, blistering, peeling paint and leaks Exterior wall: Stains and peeling paint
Damp Signs (outside)	Ceiling: Water pooling Exterior Wall: Stains
Last Known Maintenance	None
Observed Primary Cause(s)	Ceiling: (1) Construction design defect of the slope of the flat roof Exterior Wall: (1) Construction design under the climate condition
Potential Contributory Factors	Ceiling: (1) Poorly skilled workforce (2) Water tank location Exterior Wall: (1) Poorly skilled workforce (2) Single sheet exterior wall
Observed Level of Dampness	Low to Medium Damp on Ceiling

6.7 House 6

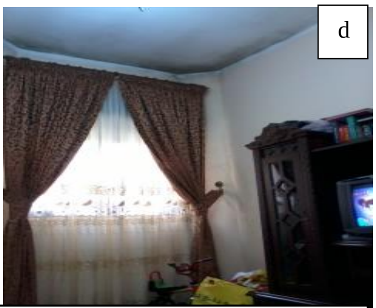
House 6 is a multi-storey house with three levels, built in 2008. Levels two and three are still under construction. There are other constructions adjacent to this structure on three sides (north, east and west). In fact, it is joined to the northeast and southwest, and quite close to the other building to the northwest. Therefore, it is not exposed directly to the driving rain and wind on those three facades since the adjacent constructions are relatively close to it. The house showed signs of damp six months after it was built. It has never been maintained since it was built and the signs of damp remain. Photograph (a) shows the south-eastern façade of the house. Photographs (b), (c), (d) and (e) show the signs of damp and their location from inside and outside the affected living room in the form of several stains that spread everywhere and a slight amount of peeling paint on the exterior wall; they also occur as black patches at the junction in the same room. This exterior wall has no rainwater pipe installed, nor plants close to the wall. It was noticed that the delay in construction work was due to financial constraints. Also, there was a defect in the parapet wall, and an uncovered area between the ceramic tiling and wall cement paste render, probably due to uncompleted or neglected construction work.

Photograph [a] shows the south east façade of house, year of construction: 2008



Photograph [b] illustrates the signs of damp in the living room, which faces south-east, in the form of stains and a small area of peeling paint

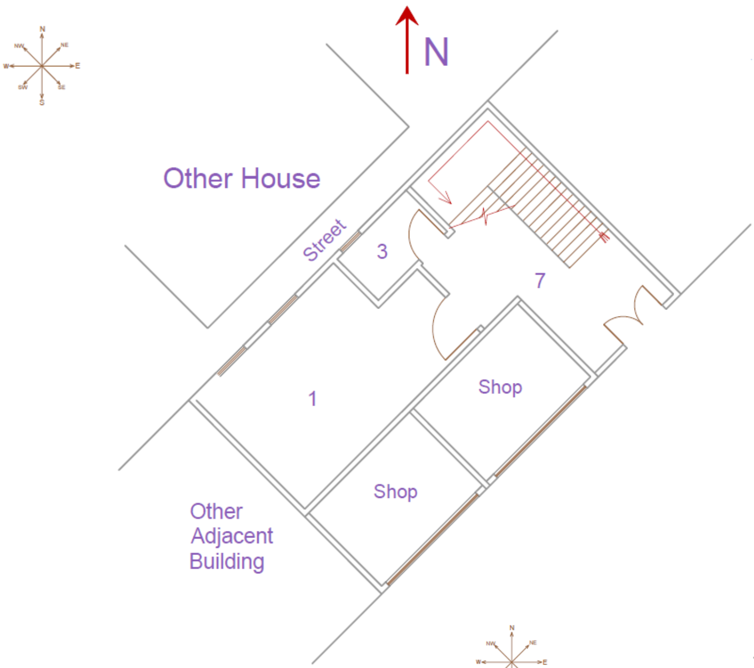
Photograph [c] illustrates the exterior surface of the defective area. The wall has a ceramic tiling finishing from outside

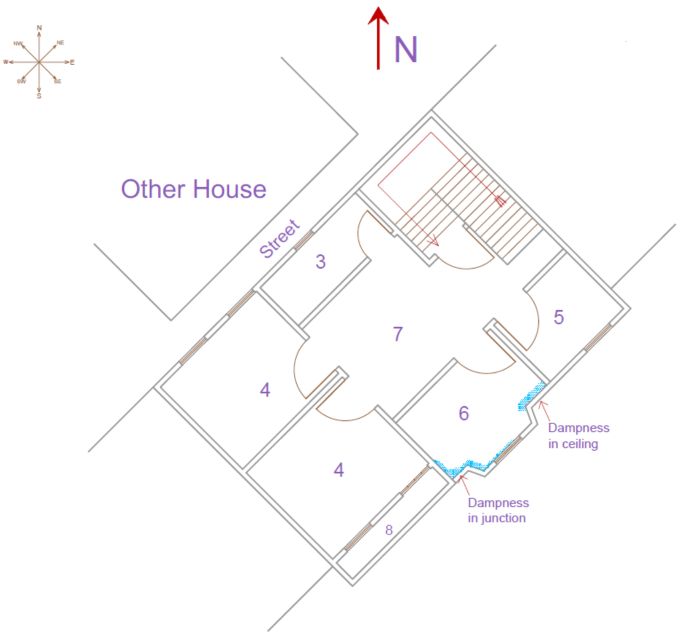


Close up photograph showing the signs of damp on the living room ceiling in the form of stains and black patches at the junction.

Photograph (e) illustrates the defective area on the roof, caused by construction defects of the exterior finishing of the junction (uncovered parapet wall).

Figure 6.10 Condition survey: house 6, Al Gareda quarter, Albeida, Green Mountain, Libya





Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number

Figure 6.11 Ground floor and first floor plan of house 6, Al Gareda quarter, Albeida, Green Mountain, Libya

The damp could be caused by several factors: first, the poorly skilled workforce which led to the defects in the wall and tiling; secondly, the lack of maintenance; and thirdly, the poor ventilation. Further, the lack of knowledge of the owner about the nature and extent of the issue might be other factors that need to be highlighted. Ignoring the damp as well as the construction error within the house and continuing the construction work may indicate a lack of knowledge by the experts or may be a construction-related cultural attitude in Libya. Table 6.6 summarises the most significant findings for house 6.

Table 6.6 A Summary of the Finding of House 6

House No.6	
Property Type	Multi-Storey House
Year of Construction	2008
Condition of Construction	Finished
Damp Location (per room)	Living-room
Defective Construction Component	Exterior wall and junction
Type of Exterior Finishing	Ceilings: Rendered cement Exterior wall: Ceramic tiles
Defective Area Direction	S.E.
Damp Signs (inside)	Ceiling: Black patches Exterior wall: black patches and stains
Damp Signs (outside)	None None
Last Known Maintenance	None
Observed Primary Cause(s)	Ceiling: (1) Construction design defects of the exterior finishing of the wall parapet (2) Lack of maintenance (3) Uncompleted construction, owner's lack of knowledge, social pressure Exterior Wall: (1) Construction design defects of the exterior finishing of the wall (2) Lack of maintenance (3) Poor ventilation
Potential Contributory Factors	Ceiling: (1) Poorly skilled workforce (2) No maintenance (3) Continuing the construction work without solving the issue Exterior Wall: (1) Poorly skilled workforce (2) Single sheet exterior wall (3) Lack of maintenance (4) Very close adjacent constructions in three directions
Observed Level of Dampness	Low Damp on the Ceiling and Wall

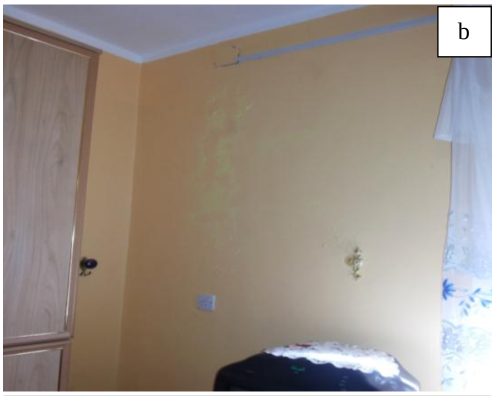
6.8 House 7

House 7 is a villa, built in 2000. There are only two constructions adjacent to this structure, to the east and west. It is not exposed directly to the driving rain and wind on those two facades; since the adjacent constructions are quite close to the house. Photograph (a) shows that there is a fence surounding the house. From the photographs, it appears that the villa has a balcony on every façade except the one facing northwest. The house has damp on the inner surface of the exterior wall that faces northwest, in the bedroom (photograph (b)). The signs of damp take the form of a number of small stains. The owner stated that, "*I was unaware of any damp problem until 2011*" (House 7, Owner). This wall is wet from the exterior surface and there is no rainwater pipe installed on that wall, nor any vegetation nearby, although there is a TV cable installed on the wall (photograph (c)). Addtionally, some parts of the exterior surface of the walls of the house are finished with limestone tiles (photograph (a)), although the affected wall is not. Additionally, the nature of the last repair was merely to repaint the interior surface of the defective room when repainting the whole house from inside. However, signs of damp reappeared as soon as the rainy season started. Moreover, there is no damp on the flat roof of the house. Indeed, the roof's condtion is good, and is finished with concrete floor tiles.

a

Photograph (a) shows the south east façade of the house: year of construction 2000. Some areas of the exterior walls are finished with limestone tiles, and there is a balcony on all facades except for the northwest façade

b

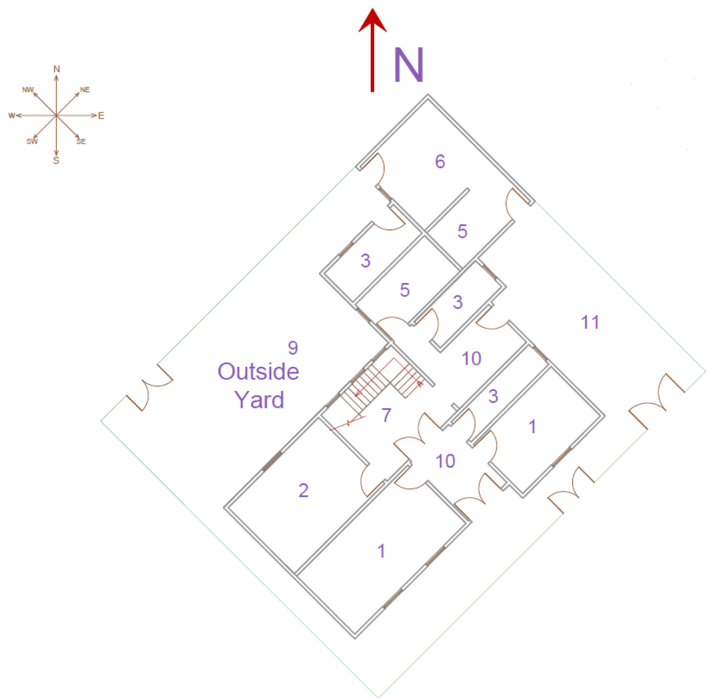


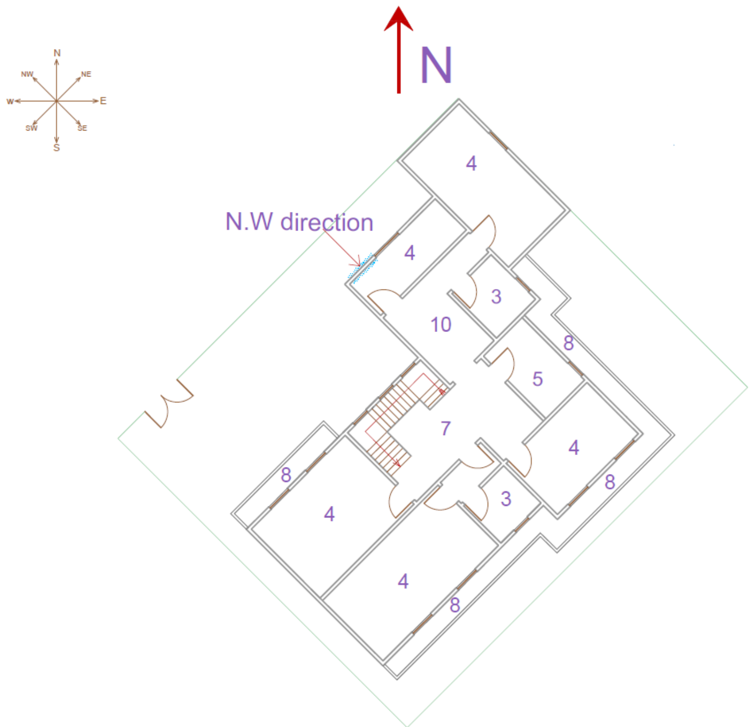
Photograph (b) illustrates the signs of damp on the exterior wall of the bedroom, which faces north-west

c

Photograph (c) illustrates the outside surface of the defective exterior wall, facing the north-west

Figure 6.12 Condition survey: house 7,West Albeida quarter, Albeida, Green Mountain, Libya





Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number

Figure 6.13 Ground floor and first floor plan of house 7,West Albeida quarter, Albeida, Green Mountain, Libya

From these data, it seems possible that this damp was due to the wall orientation, facing the direction that is more problematic in terms of wind and driving rain, as well as the construction design (single sheet exterior wall). There is another possible argument that the TV cable might hold some water against the wall, and the other three facades of the villa have a balcony, while this defective wall does not. Therefore, from this, it appears that the balconies might offer some protection to the exterior wall, although this result has not previously been described in the literature review. Table 6.7 summarises the most significant findings for house 7.

Table 6.7 A Summary of the Finding of House 7

House No.7	
Property Type	Villa
Year of Construction	2000
Condition of Construction	Finished
Damp Location (per room)	Bedroom
Defective Construction Component	Exterior wall
Type of Exterior Finishing	Stucco paint
Defective Area Direction	N.W.
Damp Signs (inside)	Stains
Damp Signs (outside)	Stains
Last Known Maintenance	Repainting the interior of the house
Observed Primary Cause(s)	Construction design under the climate condition
Potential Contributory Factors	(1) Single sheet exterior wall (2) Poorly skilled workforce (3) Poor exterior finishing selection for the wall (4) TV cable pipe (5) Wall orientation (wind and driving rain)
Observed Level of Dampness	Low Damp on the Wall

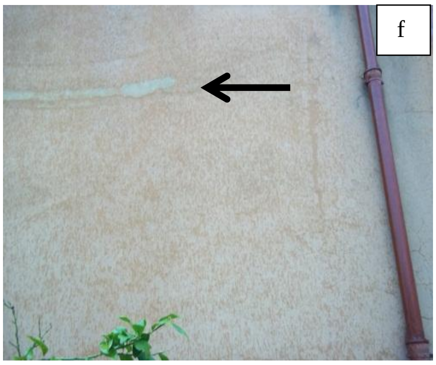
6.9 House 8

Villa 8 was built in 1980. There are other constructions adjacent to this structure on three sides (south, east and west), but it is still exposed to the driving rain and wind on those three facades, since the adjacent constructions are quite a long way away from the house and there is a fence surrounding it. The house is maintained every year; the owner said that, "*I paint the house inside and fill any cracks that have appeared on the exterior surface of the walls or roof*" (House 8, Owner). However, the house suffers from damp on the exterior wall that faces south-east and is near the stairway. Photographs (c), (d), (e) and (f) show the signs of damp inside and outside the defective wall, which take the form of relatively small areas of stains and peeling paint on the interior surface of the wall. The damp appears as soon as the rainy season starts and remains unless maintenance action is conducted. On the exterior surface of the defective wall, there is a horizontal crack that has been filled with cement mortar, but this has crumbled, which may allow water ingress. When asked about it, the owner stated that the crack in the wall appeared a long time ago, three years after the house was built. Addtionally, although this exterior wall has a rainwater pipe on it, it is in a good condtion and the pipe is not close to the defective area. Moreover, there is also a planted area nearby that is not too close to the wall.

Photographs [a] shows north western façade of the house, year of construction: 1980

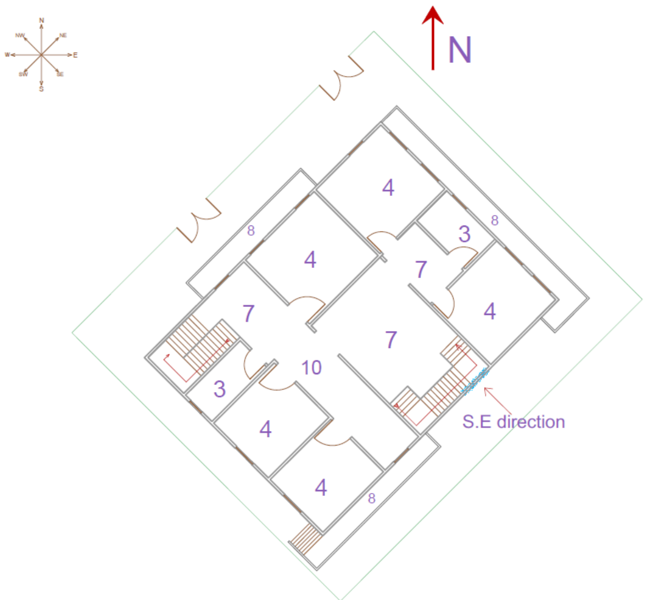
Photographs [b] shows north east façade of the house

Photographs (c) and (d) illustrate the defective wall from inside; the signs of damp on the stairway take the form of stains and peeling paint caused by rainwater ingress due to a crack in the exterior surface of the wall



Photographs (e) and (f) show the defective wall from outside the house, which faces south-east, and the attempt to fill a crack with cement paste in the defective wall which might cause the water ingress

Figure 6.14 Condition survey: house 8, East Albeida quarter, Albeida, Green Mountain, Libya



Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number
e.g. (a,1), (b, 6)	indication for the rooms in the photos and plans

Figure 6.15 Ground floor and first floor plan of house 8, East Albeida quarter, Albeida, Green Mountain, Libya

A possible explanation for this is that the owner’s attempt to block up the crack with cement mortar had proved unsuccessful. This horizontal crack could be an issue, particularly if this wall is a load bearing wall, Therefore, these results need to be interpreted with caution because the house was built in the 1980s, so it is relatively old for a Libyan house built of concrete, even though it has been regularly maintained. It can be said that there was a possibility that the crack in the wall with the constuction design (single skin) under the rainfall season and improper and/or poor maintenance by the workforce could be potential factors affecting the occurrence of the defect. Besides, it was noticed that there were balconies on the walls that faced north, which functioned as water protection, although this was not previously identified in the literature review. Table 6.8 summarises the most significant findings for house 8.

Table 6.8 A Summary of the Finding of House 8

House No.8	
Property Type	Villa
Year of Construction	1980
Condition of Construction	Finished
Damp Location (per room)	Stairway
Defective Construction Component	Exterior wall
Type of Exterior Finishing	Stucco paint
Defective Area Direction	S.E.
Damp Signs (inside)	Stains, peeling paint and blistering
Damp Signs (outside)	Cracking from outside
Last Known Maintenance	Re-painting the interior house and filling any cracks and holes that have appeared
Observed Primary Cause(s)	(1) Construction design defect (2) Lack of maintenance
Potential Contributory Factors	(1) Single sheet of exterior wall (2) Poorly skilled maintenance workforce (3) Poor exterior finishing
Observed Level of Dampness	Medium Damp on the Wall

6.10 House 9

Villa 9 was built in 1984. There are other constructions adjacent to this structure on three sides (south, east and west). It is exposed to the driving rain and wind on those three facades since the adjacent constructions are not very close to the house. There is a fence surrounding the house. There are signs of damp in the building envelope. Photograph (a) shows the north-western facade of the house. Photographs (b) and (c) show the signs of damp from inside and outside the defective area in the hospitality room, which faces the northwest. The damp takes the form of stains with blistering and black patches around the window frame. This wall has no rainwater pipe on it or vegetation area nearby. Although the house was maintained five years ago, it seems that the signs of damp recurred. In fact, the nature of the last maintenance action was to repaint the interior of the house and fill the crack areas with mortar cement from inside and outside. Additionally, although there has been an attempt to repair the water leak around the window frame by applying mortar cement, the water still ingresses and the damp reappears. Cracked and crumbling mortar cement around the window was noticed.

Photographs (d) and (e) also show signs of damp on the ceiling and walls of the kitchen, which take the form of widespread black patches. Outside, water pools on the roof, and there is an indication of green mould growth as a result of this. Photographs (f) and (g) show a defective ceiling in the bedroom from inside and outside the facade. The signs of damp take the form of black patches at the junction. Although there is no indication of leakage, the owner said that, during the rainy season, the ceiling of the room leaks, and also that the water pools on the roof particularly after the rainy season and lasts for a couple of weeks. In addition, the carpets are washed on the roof.

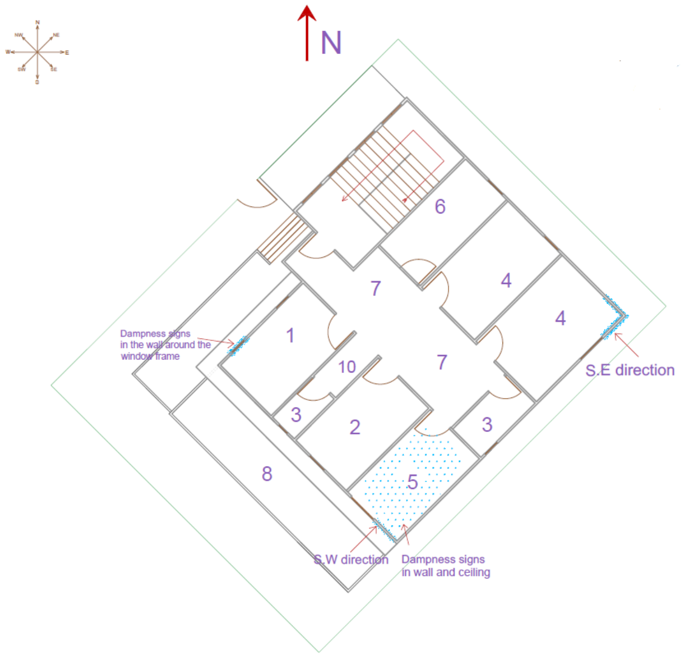
Photograph [a] shows the northwest façade of house, year of construction: 1984

Photographs (b) and (c) show the interior and exterior surface of the defective area in the hospitality room’s exterior wall, which faces northwest. The signs of damp take the form of stains, blistering and black patches around the window frame

Photograph (d) shows signs of damp on the kitchen ceiling and exterior walls. On the wall facing south-east, this takes the form of black patches, caused by water pools and/or rainfall as well as cooking activities with poor ventilation. The roof condition of the affected area is shown in photograph (e)

Photograph [f] shows a defective ceiling and junction in a bedroom. The defective junction faces south-west. The signs of damp take the form of black patches at the junction. The roof condition of the affected area is shown in (g)

Figure 6.16 Condition survey: house 9, East Albeida quarter, Albeida, .Green Mountain Libya



Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number

Figure 6.17 Ground floor and first floor plan of house 9, East Albeida quarter, Albeida, Green Mountain Libya

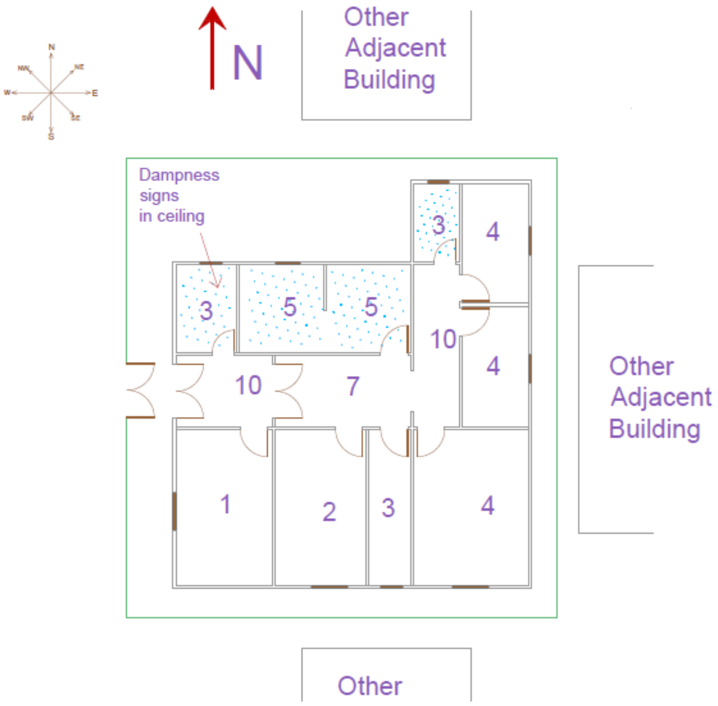
From these data, in relation to the damp on the walls, there is a high possibility that poor maintenance including poor finishing materials with wall direction was the main cause of the damp. In respect to the signs of damp on the ceiling of the kitchen caused by the widespread water pooling, these indicated a defective roof slope as well as inadequate drainage for the roof. The damp in the kitchen could be due to poor ventilation during cooking, causing condensation. In summary, poor maintenance, again due to the financial limitation of the owner, might have contributed to the emergence of damp here. Another hidden factor was the carpet washing and cleaning activity on the roof. Table 6.9 summarises the most significant findings for house 9.

Table 6.9 A Summary of the Finding of House 9

House No.9	
Property Type	Villa
Year of Construction	2000
Condition of Construction	Finished
Damp Location (per room)	Ceiling: Kitchen, bedroom Exterior Wall: Kitchen, hospitality room
Defective Construction Component	Exterior wall, ceiling and junction
Type of Exterior Finishing	Ceiling: Rendered cement Exterior wall: Stucco paint
Defective Area Direction	Hospitality room (Exterior Wall), N.W; Kitchen (Exterior Wall), S.E; Bedroom (Exterior Wall), S.W.
Damp Signs (inside)	Ceiling: black patches and leaks Exterior Wall: Stains with black patches, blistering and leaks
Damp Signs (outside)	Ceiling: Stains and cracking from outside and water pooling everywhere Exterior Wall: Stains
Last Known Maintenance	Ceiling: Recoated the exterior surface of the roof with mortar cement and bitumen layers, then repainted the ceiling of the house Exterior Wall: Re-painted the interior house and filled any cracks or holes
Observed Primary Cause(s)	Exterior Wall: (1) Construction design under the climate condition (2) Type of exterior finishing materials (3) Poor maintenance
Potential Contributory Factors	Ceiling: (1) Poorly skilled workforce (2) Improper type of exterior finishing materials due to financial limitation (3) Hiding the issue by carrying out poor maintenance (4) Carpet washing and cleaning on the roof Exterior Wall: (1) Wall orientation, facing the wind direction and driving rain (2) Single sheet of exterior wall (3) Improper type of exterior finishing materials due to financial limitation (4) Poor maintenance workforce
Observed Level of Dampness	Medium to High Damp on the Ceiling and Wall

6.11 House 10

For this house, permission could only be obtained to perform direct observation, without taking photographs. The observed one-storey house is located in Al Gareda quarter of Albeida city, and was built in 2000. There are other constructions adjacent to this structure on three sides (north, south and west). The house is not exposed directly to the driving rain and wind on those three facades since the adjacent constructions are quite close to the house and there is a fence surrounding it. Damp occurs on the ceilings of the kitchen and bathrooms; it spreads everywhere and takes the form of a large area of blisters, stains and peeling paint. According to the house owner, water pools on the roof above the defective area for several months. Moreover, the water tank is located on the roof. No leaks were observed from the water tank and, when asked about this, the owner denied ever leaving the water pump on after the tank was full. It was noticed that there are cracks in the mortar cement finishing of the roof, and that the building envelope of the house is constructed only with mortar cement render. The owners could not remember the last repair and/or maintenance action, and it does not appear to have been maintained for some considerable time. Figure 6.18 shows the plan of the house.



Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number
e.g. (a,1), (b, 6)	**indication for the rooms in the photos and plans**

Figure 6.18 Condition survey: house 10, Al Gareda quarter, Albeida, Green Mountain, Libya, plan of one-storey house

It is difficult to account for this finding, although condensation may have been a factor due to the location of the signs of damp (in the kitchen and bathroom). Another possible explanation for this outcome may be the poorly constructed, sloping flat roof, on which the water pools and spreads everywhere. Further, there was no sign of proper drainage installation; simply a small hole at the edge of the eastern wall. A lack of maintenance and inappropriate type of exterior finishing materials for the house are other potential factors that could have led to the occurrence of damp. Table 6.10 summarises the most significant findings for house 10.

Table 6.10 A Summary of the Finding of House 10

House No.10	
Property Type	Single storey house
Year of Construction	2000
Condition of Construction	Finished
Damp Location (per room)	Kitchen and toilet
Defective Construction Component	Ceiling
Type of Exterior Finishing	Rendered cement
Defective Area Direction	N.
Damp Signs (inside)	Stains, blistering and leaks
Damp Signs (outside)	Water pooling and cracking from inside
Last Known Maintenance	Not known
Observed Primary Cause(s)	(1) Construction design defect in the roof slope (2) Type of exterior finishing (3) Lack of maintenance
Potential Contributory Factors	(1) Condensation due to occupants' activities (2) Poorly skilled workforce (3) Improper type of exterior finishing materials due to financial limitation (4) Lack of maintenance due to financial limitation
Observed Level of Dampness	High Damp on the Ceiling

6.12 House 11

House 11 is a multi-storey house with two levels that is still under construction. The construction work started in 2014 and was suspended for eight months after it was built, due to the financial constraints of the owner. The construction was exposed to the climate during that time. There are other constructions adjacent to this structure on three sides (north, east and west). However, it is exposed to the driving rain and wind on those three facades, since the adjacent constructions are not very close to the house. As can be observed, the construction suffers from damp even though it has not yet been completed. Photographs (a) and (b) show the south eastern and north eastern façades of the construction, while photographs (c), (d), (e) and (f) show the damp located on the stairway and exterior wall, which faces north east. The signs of damp take the form of large stains on the wall. It was noticed that the cover of the roof of the stairway is incomplete.

Additionally, photographs (g), (h), (i) and (j) illustrate the signs of damp located inside and outside the wall that faces north-west, that take the form of stains in the whole upper part in the bracket area of the window. The affected exterior walls have no rainwater pipe and/or vegetation area nearby. Further, it was observed that, there was a poor selection of raw materials with signs of construction defects. It was obvious from the quality of the mortar cement of the construction that there are cracks in the mortar, as well as the remaining raw materials at the site, without proper storage.

Photograph [a] shows the south eastern façade of house. The house is still under construction

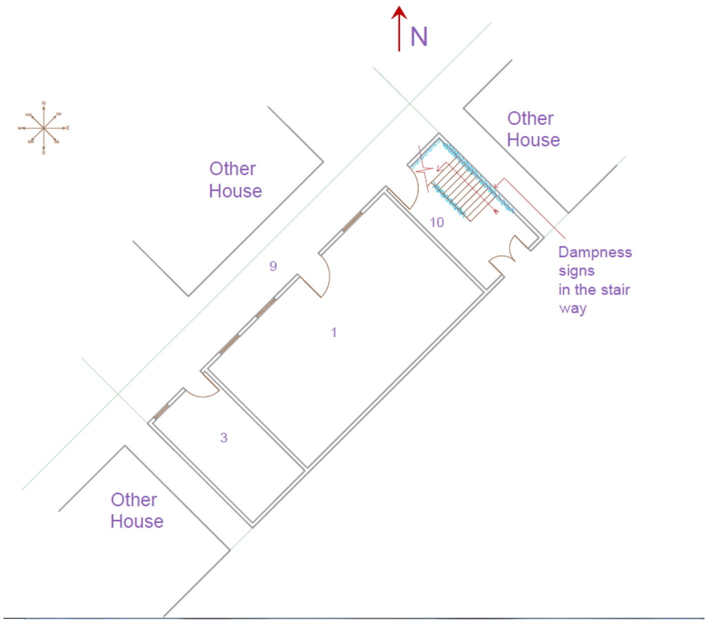
Photograph [b] shows north-eastern side façade. Construction work started in 2014

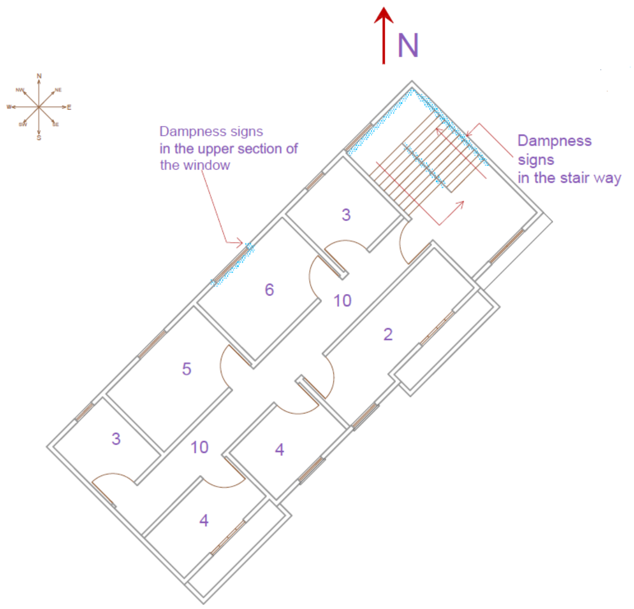
Photographs (c), (d), (e) and (f) show the signs of damp in the stairway's exterior wall, which faces south-east, which take the form of stains spread across the wall and stairs, caused by the uncompleted roof of the stairway

Photographs (g) and (h) show signs of damp in the form of stains on the upper area of the living room window; the exterior wall faces north-west

Photographs (i) and (j) show the defective damp area in photographs (g) and (h) on the exterior surface of the wall

Figure 6.19 Condition survey: house 11, East Albeida quarter, Albeida, Green Mountain, Libya





Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number

Figure 6.20 Ground floor and first floor plan of house 11, East Albeida quarter, Albeida, Green Mountain, Libya

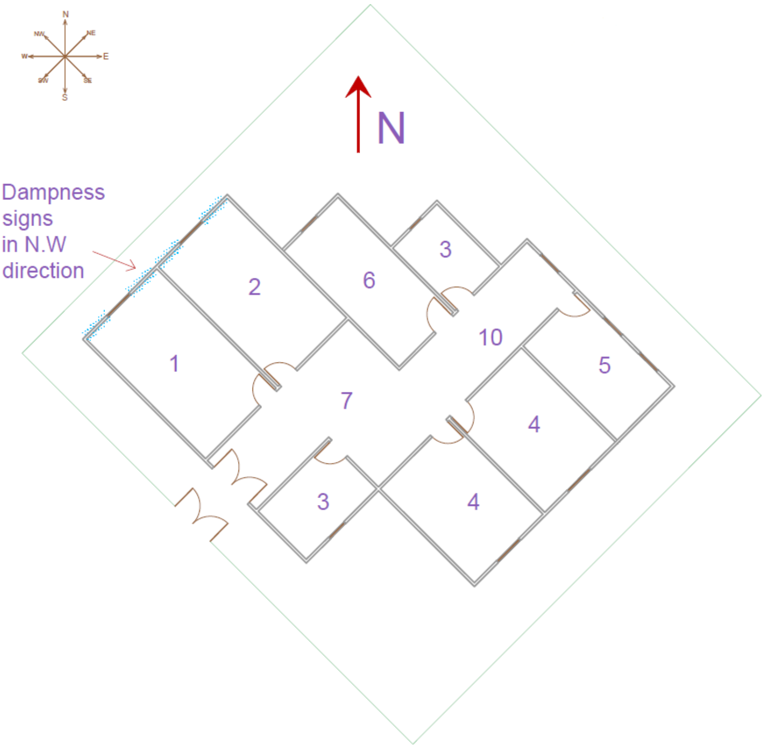
This result may be due to the fact that the construction was exposed to climatic conditions during the delay in the construction work, which was caused by a delayed loan payment as well as the financial limitation of the owner. The overlooked site may be the main reason for the damp, as the neglected, uncovered area (the roof of the stairway) was exposed to the climatic conditions during the construction's suspension. Additionally, the adopted construction design (single sheet exterior wall) is another significant element that might contribute to the occurrence of the defect. Further, the poor selection of raw materials with a poorly skilled workforce could be other factors. Table 6.11 summarises the most significant findings for house 11.

Table 6.11 A Summary of The Finding of House 11

House No.11	
Property Type	Multi-storey house
Year of Construction	2014
Condition of Construction	Under construction
Damp Location (per room)	Stairway and living room
Defective Construction Component	Exterior wall
Type of Exterior Finishing	Rendered cement
Defective Area Direction	Exterior Wall 1 N.E; Exterior Wall 2 N.W.
Damp Signs (inside)	Stains
Damp Signs (outside)	Exterior Wall 1: Stains and cracking from outside Exterior Wall 2: Stains
Last Known Maintenance	None
Observed Primary Cause(s)	(1) Uncompleted construction (2) Delays during the construction (3) Construction design under the climate condition (4) Overlooked site conditions during the suspension of construction
Potential Contributory Factors	(1) Delays during the construction process caused by a delayed loan payment and owner’s financial limitation (2) Single sheet of exterior wall (3) Uncompleted roof of the stairway (4) Poor raw materials selection (5) Poorly skilled workforce
Observed Level of Dampness	Medium to High Damp

6.13 House 12

For this house, permission could only be obtained to conduct direct observation, without photographs. The observed one-floor house is located in Al Gareda quarter of Albeida and is still under construction. The construction work started in 2013 but was postponed for six months after work commenced due to the financial limitation of the owner. There are no other constructions adjacent to this structure in any direction, so it is exposed to the driving rain and wind and there is a fence surounding it. The house suffers from damp on an exterior wall of a hospitality room, facing the north-west direction and takes the form of considerable stains both internally and externally. Figure 6.21 illustrates the plan of the one-storey house.



Key

Symbol	Definition
1	Men Hospitality Room
2	Women Hospitality Room
3	Toilet
4	Bedroom
5	Kitchen
6	Living Room
7	Hall
8	Balcony
9	Yard
10	Corridor
11	Car Garage
12	Storage room
	Window or door for a Balcony
	Fence
....	Dampness Signs
N.W	North Western Direction
S.E	South Eastern Direction
N.E	North Eastern Direction
S.W	South Western Direction
a, b, c, …etc.	Photographic Number
e.g. (a,1), (b, 6)	**indication for the rooms in the photos and plans**

Figure 6.21 Plan of the one-storey house. house 12 Al Gareda quarter , Albeida, Green Mountain, Libya

There is a high possibility that the wall orientation combined with the adopted construction design (single sheet exterior wall) under the rainfall caused the emergence of damp. Additionally, the delayed construction due to the financial limitation of the owner might be another contributory factor to the occurrence of the defect. Other significant factors which were observed were the poor raw materials and poorly skilled workforce, as indicated by the crumbling concrete blocks and cracks in the mortar cement render of the house. Table 6.12 summarises the most significant findings for house 12.

Table 6.12 A Summary of the Finding of House 12

House No.12	
Property Type	Single storey house
Year of Construction	2013
Condition of Construction	Under construction
Damp Location (per room)	Hospitality rooms (male and female)
Defective Construction Component	Exterior Wall
Type of Exterior Finishing	Rendered cement
Defective Area Direction	N.W. façade
Damp Signs (inside)	Stains
Damp Signs (outside)	Stains and cracks
Last Known Maintenance	None
Observed Primary Cause(s)	(1) Construction design defect in the roof slope (2) Type of exterior finishing (3) Lack of maintenance
Potential Contributory Factors	(1) Delay during the construction (2) Construction design under the climate condition (3) Overlooked site conditions during the construction’s suspension (4) Construction defect of the exterior finishing of the wall
Observed Level of Dampness	Medium to High Damp on the Wall

6.14 Summary

This section of the research has analysed the data collected from damp houses by direct observation with photographs. It supports the survey questionnaire results and assists in answering the first research question. Technical content analysis was applied as a data analysis tool to code and interpret the data collected from the twelve identified damp houses. The results were analysed, interpreted and presented in the form of photographs and tables.

In respect of the climatic factor, the results illustrate that houses located on the outskirts of Albeida houses exposed directly to the rain and wind from the north are more likely to show signs of damp, with the adopted construction design of the exterior walls such as (House 5, 11 and 12), compared to houses located in the city centre which are shielded from wind direction and rain (House1, 2, 4 and 6).

The observation with photographs result showed the following in regard to the ceiling condition:

- Eight of the twelve houses had damp in ceilings; those houses had no proper exterior roof finishing, with compressed rendered cement mortar.
- Seven roofs of the twelve houses only had visible cracks; of these, six houses suffered from leaks from the ceiling during the rainy season.
- The observation also showed that seven roofs of the twelve houses had water pools resulting from rain and/or water flooding from the water tank located on the roof.
- It was reported that there was a lack of and/or poor maintenance. Members of five of these eight houses carried out some traditional social activities on the roof, such as carpet washing and cleaning.

Table 6.13 summarises the most significant outcomes.

Table 6.13 A Summary of the Observed and Photographed Ceiling of Damp Houses

House No.	1	2	3	4	5	6	9	10
Exterior finish	B1	B1	B1	B1	B1	B1	B1	B1
Cracks	x	C2	C2	x	x	x	C2	C2
Damage to decorative finish	D1 D2	D1 D2 D4	D3, D4	D1, D3	D2, D3 D4	D1	D1, D2	D2, D3
Water ponding	√	√	√	√	√	x	√	√
Water leaking through ceiling	x	√	√	√	√	x	√	√
Orientation(s) of affected area	NW, NE	SW	All	All	NW	SE	SW, NE	N
Type of repair	F1	F1	F2	F3	F5	F5	F3	F5
Social activity on flat roof (carpet washing & cleaning)	√	√	√	√	x	x	√	x

Note.

B. Type of exterior finish
B1 Grey cement based render
B2 Ceramic/tiles finish
B3 Stucco paint

C. Visible Cracking
C1 Internal cracks
C2 External cracks

D. Damage to decorative finish
D1 Mould patches
D2 Stains
D3 Blistered paint
D4 Peeling paint

F. Type of previous maintenance/repair
F1 Repair of the house interior
F2 Repair and recoating of the affected area
F3 Recoating the roof from outside with cement mortar and bitumen, then re-painting the ceiling of the house (**OR)** Re-painting the interior walls of the house and filling of any cracks and/or holes
F4 Filling any cracks and/or holes with cement mortar
F5 None

With regard to the exterior wall, the results showed the following:

- Eight of the twelve houses had damp in exterior walls. Various types of finishing, includes rendered cement, stucco paint and tiling were used. Stucco paint was the common form of finishing because it was the most socially acceptable and available type of finishing.
- Four walls displayed visible cracks on the outside walls.
- Walls that faced north-west showed more signs of damp than other walls, although walls that faced south-east also seemed to have an issue with damp.
- The majority of the defective walls had a rainwater pipe installed on them and no vegetation nearby.
- It was reported that a lack of and/or poor maintenance was applied with regard to this issue.
- Table 6.14 summarises the most significant outcomes.

Table 6.14 A Summary of the Observed and Photographed Exterior Wall of Damp Houses

House No.	3	5	6	7	8	9	11	12
Exterior finish	B3	B3	B2	B3	B3	B3	B1	B1
Cracks	C2	X	x	x	C2	x	C2	C2
Damage to finish	D3, D4	D2, D4	D1, D2	D2	D3, D4	D1, D2 D3	D2	D2
Rainwater downpipe	x	√	x	x	√	x	x	x
Orientation of wall	NW	NW	SE	NW	SE	NW, NE, SE	NW, NE	NW
Type of repair	F2	F5	F5	F1	F3	F3	F5	F5

Note.

B. Type of exterior finish
B1 Grey cement based render
B2 Ceramic/tiles finish
B3 Stucco paint

C. Visible Cracking
C1 Internal cracks
C2 External cracks

D. Damage to decorative finish
D1 Mould patches
D2 Stains
D3 Blistered paint
D4 Peeling paint

F. Type of previous maintenance/repair
F1 Repair of the house interior
F2 Repair and recoating of the affected area
F3 Recoating the roof from outside with cement mortar and bitumen, then re-painting the ceiling of the house (**OR**) Re-painting the interior walls of the house and filling of any cracks and/or holes
F4 Filling any cracks and/or holes with cement mortar
F5 None

∗Houses 11& 12 inhabited but incomplete construction

The next chapter (Interviews Result) illustrates the application of the technique to generate weights which identify the relative importance of each factor, criteria and sub-criteria.

Chapter Seven: Interviews Result

7.1 Introduction

Applying the AHP technique to the damp problem in concrete houses contributes to the existing knowledge about housing and construction industry. In fact, it can be used to develop assessment criteria during the technical analysis procedure for a particular housing construction project. In this study, the analytical hierarchy process is applied to obtain the weights of the factors affecting the performance of concrete houses in the context of penetrating damp based on experts and house owners' experience, knowledge and perceptions. The technique calculates the weights of the factors, criteria and sub-criteria causing damp within domestic concrete houses with regard to the following: study area characteristics, the Libyan housing construction community attitudes including housing policy and construction design, the attitude of the Libyan house owners as self-builders and, above all, the presence of the available data for the analysis of the multi-criteria decision making technique. In this chapter, the weighting factors of house performance against damp are introduced, including the weighting of the criteria and sub-criteria for each issue. Additionally, it illustrates how the technique can be applied by providing an example at the end of the chapter. Individual interviews were used to obtain the assessments of the factors, criteria and sub-criteria in terms of their relative importance. A summary of the results is presented at the end of the chapter.

7.2 Interview Results

The technique was used to determine the different weights for the factors that cause penetrating damp within domestic houses in Green Mountain of Libya. The contribution of thirteen experts and twelve house owners was used as a basis for assessing the housing performance factors, after calculating the consistency ratio of each pairwise comparison matrix. This set of results from local experts and house owners was accepted as the model for this research, because the obtained consistency ratios (C.R.) were less than or equal to the established acceptable limit of 0.1. This illustrates that the comparison matrix of house performance was perfectly consistent and that the comparative weights are valid for house performance evaluation. In fact, the C.R. was calculated for each hierarchy level or each constructed PCM pairwise comparison matrix.

If the consistency ratio was found to be more than 0.1, then the comparison had to be re-evaluated or eliminated (Abushnaf, 2014; Saaty, 1980). The reason behind the calculation of the consistency ratio for each pairwise comparison matrix was to confirm that the comparisons of the house performance factors were perfectly consistent and that the comparative weights were appropriate, as described earlier in Chapter 3 (AHP technique) in Step 2, after Table 3.5.

Additionally, the set of weights of each level for the pairwise comparison matrix obtained from the local experts and self-builders were addressed and verified by the implementation of a group analytical hierarchy processes (GAHP), which was described earlier in Chapter 3 (AHP technique).

Table 7.1 Weight of Level 1 (Factor) for House Performance Against Damp by Local Experts

Level 1	Local Experts										GAHP
Factors	E.a	E.b	E.c	E.d	E.j	E.e	E.g	E.h	E.i	E.l	AIJ
Management	0.1341	0.1873	0.2480	0.0976	0.1329	0.1261	0.0910	0.1605	0.1556	0.4468	0.1728
Climatic	0.1235	0.1767	0.2402	0.0554	0.2109	0.0894	0.1085	0.0952	0.0733	0.1939	0.1340
Construction	0.5166	0.5210	0.3623	0.3868	0.5750	0.5234	0.3893	0.4065	0.3765	0.2600	0.4584
Socio-Economic Design	0.2257	0.1149	0.1495	0.4602	0.0813	0.2611	0.4112	0.3378	0.3946	0.0993	0.2347
C.R.	0.0238	0.0472	0.0991	0.0954	0.0569	0.0743	0.0764	0.0711	0.0316	0.0538	

Table 7.1 above shows the result of the first level of the pairwise comparison for house performance against damp. From the table, it can be seen that the eigen-values or the weight of the construction factor was higher than the weight of the socio-economic design, management and climatic factors. Although there was a slight difference between the management and climatic factor, the management factor was the third most problematic factor, followed by the climatic factor. In respect to the comparison, although there was disagreement between the experts' weights, the result indicated that only three of the ten experts considered that the socio-economic design factor affected house performance more than the other factors. According to the management factor, only one expert judged it to be the most challenging factor facing house performance, although two further experts weighted the management factor the second most problematic factor, and four experts felt that the management and climatic factors were equally important.

Table 7.2 Weight of Level 2 (Criteria) for the Construction Factor by Local Experts

Level 2	Local Experts								GAHP
Criteria	E.a	E.b	E.c	E.j	E.e	E.f	E.k	E.l	AIJ
Manufacturing Defect	0.6667	0.6667	0.7500	0.7500	0.8333	0.3333	0.5000	0.8750	0.6912
Construction Design	0.3333	0.3333	0.2500	0.2500	0.1667	0.6667	0.5000	0.1250	0.3088
C.R.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

Table 7.2 illustrates the result of the weights for the construction factor (Second Level of the Pairwise Comparison). The weight of the manufacturing criteria was higher than that of the construction design. In respect to the comparison, six experts agreed that the manufacturing criteria were the most significant in terms of affecting house performance of the other two experts, one felt that both criteria were equal and the other reported that the construction design was the most problematic criterion. Although the consistency ratio may not actually reach zero, it could approach zero in particular when the pairwise comparison is between two factors.

Table 7.3 Weight of Level 2 (Criteria) for the Socio-Economic Design Factor by Local Experts and Owners Who Are Self-Builders

Level 2	Local Experts and House Owners							GAHP
Criteria	E.a	E.e	E.f	O.b	O.e	O.f	O.g	AIJ
Cost Effectiveness	0.8750	0.8333	0.6667	0.8571	0.8000	0.8750	0.6667	0.8081
Socio-Religious Design Requirements	0.1250	0.1667	0.3333	0.1429	0.2000	0.1250	0.3333	0.1919
C.R.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

Table 7.3 summarises the result of the second level of the pairwise comparison for the socio-economic design factor. The table illustrates that the weight of the cost effectiveness was very much higher than the socio-religious design requirements. All the participants agreed that cost and knowledge effectiveness was more important in affecting house performance than the socio-religious design requirements.

Table 7.4 Weight of level 2 (criteria) for the management factor by local experts and house owners who are self-builders

Level 2 Criteria	Local Experts E.a	E.e	E.f	O.b	O,e	O.f	O.g	GAHP AIJ
Housing Policy	0.3333	0.5000	0.2500	0.2000	0.3333	0.2500	0.2500	0.2959
Construction Supervision Criterion	0.6667	0.5000	0.7500	0.8000	0.6667	0.7500	0.7500	0.7041
C.R.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

Table 7.4 shows the weight of the management factor (Second Level of the Pairwise Comparison). The eigenvalues of the construction supervision criterion were higher than that of housing policy. Six experts and house owners evaluated the construction supervision criterion as the most important criterion affecting house performance and only one expert felt that both criteria were equally important. In general, in respect to the comparison, it appears that there is a remarkable difference between the weights of the construction supervision criteria and the housing policy.

Table 7.5 Weight of Level 2 (Criteria) for Climatic Factor by Local Experts

Level 2 Criteria	Local Experts E.a	E.b	E.c	E.d	E.e	E.f	E.g	E.h	E.i	GAHP AIJ
Wind Direction	0.3333	0.5000	0.2500	0.3333	0.8333	0.2500	0.2000	0.3333	0.5000	0.3893
Rainy season	0.6667	0.5000	0.7500	0.6667	0.1667	0.7500	0.8000	0.6667	0.5000	0.6107
C.R.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

Table 7.5 displays the result of the second level of the pairwise comparison for the climatic factor (Second Level of the Pairwise Comparison). It can be seen that the weight of the rainy season was significantly higher than the wind direction. In respect to the comparison, six of the nine experts weighted the rain as the more significant criterion affecting house performance. However, two experts agreed that both criteria were equally important and only one expert felt that wind direction was a more problematic criterion than the rainy season in the house performance factors model.

Table 7.6 Weight of level 3 (sub-criteria) manufacturing criteria for the construction factor by local experts

Level 3 Sub-criteria	Local Experts E.a	E.b	E.c	E.j	E.e	E.f	E.k	E.l	GAHP AIJ
Raw Materials	0.5499	0.4126	0.3333	0.3333	0.3874	0.7471	0.3333	0.2922	0.4333
Workforce	0.2402	0.3275	0.3333	0.3333	0.4434	0.1336	0.3333	0.6153	0.3416
Control of In-Situ Concrete	0.2098	0.2599	0.3333	0.3333	0.1692	0.1194	0.3333	0.0925	0.2251
C.R.	0.0192	0.0479	0.0000	0.0000	0.0178	0.0193	0.0000	0.0032	

Table 7.6 displays the result of the third level of the pairwise comparison for the manufacturing criteria (Third Level of the Pairwise Comparison). It can be seen that the raw materials sub-criterion has the highest weight compared with the workforce and the control of in-situ concrete sub-criteria. However, broadly speaking, there was a slight difference between the weight of the raw materials and workforce sub-criterion. With respect to the control of in-situ concrete, there was a disagreement between the experts regarding weighting this sub-criterion. According to the comparison of the local experts, two experts evaluated the control of in-situ concrete as the most important sub-criterion, followed by the workforce and raw materials sub-criteria respectively. Another three experts felt that the three sub-criteria were equally important in affecting house performance.

Table 7.7 Weight of Level 3 (Sub-Criteria) Construction Design for Construction Factor by Local Experts

Level 3 Sub-criteria	Local Experts E.a	E.b	E.c	E.j	E.e	E.f	E.k	E.l	GAHP AIJ
Flat Roof	0.4565	0.2654	0.3539	0.2683	0.1823	0.1261	0.1503	0.2933	0.2617
Exterior Walls	0.1927	0.2654	0.2054	0.2492	0.2717	0.0894	0.2304	0.1375	0.2119
Water Tank Location	0.0801	0.0938	0.0727	0.0793	0.0668	0.5234	0.0563	0.0743	0.1029
Exterior Finishing	0.2707	0.3753	0.3681	0.4031	0.4792	0.2611	0.5630	0.4949	0.4235
C.R.	0.0693	0.0522	0.0994	0.0670	0.0803	0.0743	0.0820	0.0217	

Table 7.7 illustrates the result of the third level of the pairwise comparison for the construction design criteria (Third Level of the Pairwise Comparison). It can be seen from the table that exterior finishing received the highest weight compared to the other three sub-criteria. With respect to the roof design and exterior walls sub-criteria comparison, they occupied the second and third most important sub-criteria respectively; there was a slight agreement between the experts regarding weighting those sub-criteria. Regarding the sub-criterion of water tank location, although it occupied the fourth sub-criterion, only one expert felt that this was the most problematic sub-criteria affecting house performance in relation to the flooding that the tank causes when it is full during the water pumping procedure.

Table 7.8 Weight of Level 3 (Sub-Criteria) Construction Supervision Criterion for the Management Factor by Local Experts and House Owners, Who Are Self-Builders

Level 3	Local Experts and House Owners							GAHP
Sub-criteria	E.a	E.e	E.f	O.b	O.e	O.f	O.g	AIJ
Owners Supervision	0.8000	0.6667	0.7500	0.6667	0.8000	0.7500	0.5000	0.7126
Experts Supervision	0.2000	0.3333	0.2500	0.3333	0.2000	0.2500	0.5000	0.2874
C.R.	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

Table 7.8 displays the result of the third level of the pairwise comparison for the construction supervision criteria (Third Level of the Pairwise Comparison). It can be seen that that owner supervision sub-criterion has the highest weight compared with experts' supervision. In fact, there is a considerable difference between the weights of both sub-criteria. According to the comparison, the experts and house owners felt that the owners' supervision was the most significant sub-criterion although only one house owner felt that both sub-criteria were equally important in affecting house performance.

Table 7.9 Weight of Level 3 (Sub-Criteria) Cost and Knowledge Effectiveness for Socio-Economic Design Factor by Local Experts and House Owners

Level 3	Local Experts and House Owners								GAHP
Sub-criteria	E.a	E.e	E.f	O.b	O.e	O.f	O.j	O.l	AIJ
Raw Materials Selection	0.2963	0.2835	0.3537	0.4268	0.3065	0.3997	0.3060	0.2957	0.3431
Builders' Selection	0.1751	0.3222	0.2439	0.2873	0.1953	0.2339	0.2207	0.2700	0.2432
Delay in Construction	0.1267	0.0955	0.0636	0.0530	0.1244	0.0800	0.0658	0.0772	0.0827
Maintenance	0.1848	0.1355	0.0788	0.0652	0.1869	0.1637	0.1571	0.1678	0.1366
Exterior Finishing Selection	0.2171	0.1633	0.2600	0.1677	0.1869	0.1228	0.2504	0.1893	0.1944
C.R.	0.1008	0.0619	0.0311	0.0950	0.0873	0.1001	0.0362	0.0922	

Table 7.9 illustrates the result of the third level of the pairwise comparison for the cost and knowledge effectiveness criterion (Third Level of the Pairwise Comparison). It can be seen from the table that raw materials selection received the highest weight while delay in construction occupied the lowest position compared to the other three sub-criteria. With respect to builders' selection, although it occupied the second most important sub-criterion, there was a slight disagreement between the evaluators, particularly the experts. Only one expert felt that that selection of builders was the most significant sub-criterion affecting house performance. Additionally, although the exterior coating materials selection sub-criterion occupied the third position, there was disagreement between the participants as to whether it was the second most important sub-criterion in comparison.

Table 7.10 Weight of Level 3 (Sub-Criteria) Socio-Religious Design Requirements for Socio-Economic Design Factor by Self-Builders

Level 3 Sub-criteria	Local Experts and House Owners O.a	O.b	O.c	O.d	O.e	O.f	O.g	O.h	O.i	O.j	O.k	O.l	GAHP AIJ
Interior Finishing & Decoration	0.5264	0.1385	0.3595	0.3213	0.1299	0.1867	0.2012	0.1385	0.2712	0.1935	0.2002	0.2594	0.2519
Hospitality Rooms	0.0370	0.1609	0.3407	0.3234	0.1694	0.3131	0.1410	0.1609	0.2491	0.2927	0.1587	0.2351	0.2147
Room Size	0.2242	0.5397	0.0925	0.0845	0.2560	0.0887	0.4281	0.5397	0.2712	0.2810	0.4255	0.2760	0.2736
Future Requirements	0.1752	0.1019	0.1409	0.2003	0.2485	0.1861	0.1468	0.1019	0.1522	0.1660	0.1409	0.1391	0.1735
Social Activities	0.0372	0.0590	0.0664	0.0705	0.1962	0.2253	0.0828	0.0590	0.0563	0.0667	0.0747	0.0905	0.0863
C.R.	0.0751	0.0799	0.0945	0.0934	0.0779	0.0876	0.0892	0.0799	0.0198	0.0234	0.0930	0.1001	

Table 7.10 illustrates the result of the third level of the pairwise comparison for the socio-religious design requirements (Third Level of the Pairwise Comparison). Generally speaking, there is no obvious difference between the weights of the sub-criteria. Also, there was a measure of disagreement between the occupants in judging the importance of the socio-religious design requirements criterion in affecting house performance. It appears that room size received the highest weight while social activities occupied the lowest sub-criterion compared to the other three sub-criteria. With respect to the interior finishing and decoration, hospitality rooms and future requirements sub-criteria, they occupied the second, third and fourth sub-criteria respectively.

The next section presents an illustrated example from the data (level 4 of the construction factor) in order to clarify the mathematical calculation of the AHP technique.

7.3 An Illustrated Example

To illustrate the process of the AHP technique, a worked example is provided. It presented the level 3 (sub-criteria) manufacturing criteria for the construction factor.

Step 1: Enter the contributor's weight (value) based on Saaty's scale into a pairwise comparision matrix.

Table 7.11 Pairwise comparison matrix and calculation of weight, step (1)

Level 3 (Sub-Criteria)	**Step 1 (entre the contributor's weights into pairwise comparison matrix)**		
Manufacturing Defect	Poor Raw Materials	Insufficient Construction Skills	Lack of Control of the Concrete
Poor Raw Materials	1	2	3
Insufficient Construction Skills	1/2	1	1
Lack of Control of the Concrete	1/3	1	1

Step 2: Sum the input value (sub-criteria) of each column of the matix.

Table 7.12 Comparison matrix and calculation of sum, step (2)

Level 3 (Sub-Criteria)	**Step 2 (sum columns)**		
Manufacturing Defect	Poor Raw Materials	Insufficient Construction Skills	Lack of Control of the Concrete
Poor Raw Materials	1	2	3
Insufficient Construction Skills	1/2	1	1
Lack of Control of the Concrete	1/3	1	1
∑=	1.833333333	4	5

Step 3: Each cell in matrix is divided by the column sum to create a new matrix Table 7.13 (value) of the matrix by its column's sum.

Step 4: Calculate the average of the numbers (value) (sub-criteria) for each row to obtain the average.

Table 7.13 Comparison matrix and calculation of average, step (3,4)

Level 3 (Sub-Criteria)	**Step 3 (element/sum)**			**Step (4)**
Manufacturing Defect	Poor Raw Materials	Insufficient Construction Skills	Lack of Control of the Concrete	**Average**
Poor Raw Materials	0.545455	0.5	0.6	0.548485
Insufficient Construction Skills	0.272727	0.25	0.2	0.240909
Lack of Control of the Concrete	0.181818	0.25	0.2	0.210606
∑=	1	1	1	1

Step 5: the consistency ratio (C.R.) is then determined by calculation the consistency index (C.I.)

$$C.I= (\lambda \max -n)/ (n-1)$$

Calculate (λ max) by using the column sums from Table 8.12 and row average from Table 8.13.

$$\lambda \max= (1.833333333 \times 0.548485) + (4 \times 0.240909) + (5 \times 0.210606)$$

$$\lambda \max= 3.022222222$$

$$C.I= (3.022222222 -3)/ (3-1)$$

$$C.I= 0.011111111$$

Referring to the values on the Table 3.6 (see Chapter 3) of the random consistency index (RI) where n=3, the value of consistency ratio is:

$$C.R. = 0.011111111/ 0.58$$

$$C.R. = 0.019157088$$

Step 6: Given that the C.R =0.019157088< 0.1. The next step is to square the original comparison matrix in steps 1 (multiplying the matrix with itself), which produces the matrix in Table 7.14, and then to calculate the row sums and normalize each row in the comparison matrix.

Table 7.14 Comparison matrix and calculation of weight, step (6)

Level 3 (Sub-Criteria)	Step 6 (Matrix Square 1)			Sum	Weight
Manufacturing Defect	Poor Raw Materials	Insufficient Construction Skills	Lack of Control of the Concrete	Sum of rows	**(Sum/column's sum)**
Poor Raw Materials	3	7	8	18	0.5510
Insufficient Construction Skills	1.333333	3	3.5	7.833333	0.2398
Lack of Control of the Concrete	1.166667	2.666667	3	6.833333	0.2092
∑=				32.66667	1

Step 7: The squaring process is continued until the difference between the normalized weights of the repetitions no longer changes between the iterations.

Table 7.15 Comparison matrix and calculation of weight, step (7)

Level 3 (Sub-Criteria)	Step 3 (Matrix Square 2)			Sum	Weight
Manufacturing Defect	Poor Raw Materials	Insufficient Construction Skills	Lack of Control of the Concrete	Sum of rows	**(Sum/column's sum)**
Poor Raw Materials	27.66667	63.33333	72.5	163.5	0.5499
Insufficient Construction Skills	12.08333	27.66667	31.66667	71.41667	0.2402
Lack of Control of the Concrete	10.55556	24.16667	27.66667	62.38889	0.2098
∑=				297.3056	1

Step 8: The squaring process is continued until the difference between the normalized weights of the repetitions give the same value. From Table 7.16, it can be seen that there are no changes in the weight column.

Table 7.16 Comparison matrix and calculation of weight, step (8)

Level 3 (Sub-Criteria)	Step 8 (Matrix Square 3)			Sum	Weight
Manufacturing Defect	Poor Raw Materials	Insufficient Construction Skills	Lack of Control of the Concrete	Sum of rows	**(Sum/column's sum)**
Poor Raw Materials	2296	5256.528	6017.222	13569.75	0.5499
Insufficient Construction Skills	1002.87	2296	2628.264	5927.134	0.2402
Lack of Control of the Concrete	876.088	2005.741	2296	5177.829	0.2098
∑=				24674.71	1

The illustrated steps are carried out for each contributor involved in the process. For instance, in this example or interview panel, eight experts were involved. The next step is how to calculate a group pairwise comparison matrix (GPCM). This can be obtained by applying an Aggregate Individual Judgment (AIJ) method.

Step 9: Produce one representative pairwise comparison matrix, group pairwise comparison matrix (GPCM), by calculating the geometric mean for each element of the eight expert's matrices (see Appendix D). The technique for calculating GAHP is mathematically obtained. To illustrate this process, consider calculating the geometric mean for a third level group of manufacturing criteria in Table 7.17. The geometric mean for the first level of the matrix a_{11} , a_{12} , a_{13}; the comparison of raw materials to raw materials, raw materials to workforce and raw materials to control of in-situ concrete, where the number of the contributors in this interview panel are eight (k= 1, 2, 3, 4, 5, 6, 7, 8). For more information regarding the contributors' data, see Appendix D.

Raw materials to raw materials of all eight metric are multiplied as follow:

$$a_{11}= (a_{11}^{1} \, . \, a_{11}^{2} \, . \, a_{11}^{3} \, . \, a_{11}^{4} \, . \, a_{11}^{5} . \, a_{11}^{6} . \, a_{11}^{7} . \, a_{11}^{8})^{1/8}$$

These are the input numbers by the eight experts

$$a_{11}= (\frac{1}{1}.\frac{1}{1}.\frac{1}{1}.\frac{1}{1}.\frac{1}{1}.\frac{1}{1}.\frac{1}{1}.\frac{1}{1})^{1/8}$$

$$a_{11}= 1.000000$$

Raw materials to workforce:

$$a_{12} = a_{12}^{1} \, . \, a_{12}^{2} \, . \, a_{12}^{3} \, . \, a_{12}^{4} \, . \, a_{12}^{5} . \, a_{12}^{6} . \, a_{12}^{7} . \, a_{12}^{8})^{1/8}$$

$$a_{12}=(\frac{2}{1}.\frac{1}{1}.\frac{1}{1}.\frac{1}{1}.\frac{1}{1}.\frac{5}{1}.\frac{1}{1}.\frac{1}{2})^{1/8}$$

$$a_{12}= 1.222845$$

Raw materials to control of in-situ concrete:

$$a_{13}= a_{13}^1 \cdot a_{13}^2 \cdot a_{13}^3 \cdot a_{13}^4 \cdot a_{13}^5 \cdot a_{13}^6 \cdot a_{13}^7 \cdot a_{13}^8)^{1/8}$$

$$a_{13}= (\frac{3}{1} \cdot \frac{2}{1} \cdot \frac{1}{1} \cdot \frac{1}{1} \cdot \frac{2}{1} \cdot \frac{7}{1} \cdot \frac{1}{1} \cdot \frac{3}{1})^{1/8}$$

$$a_{13}= 1.996067$$

Table 7.17 shows the previous calculated geometric mean, which are shown in the first raw within the matrix and it shows the geometric mean for each element in the matrix.

Table 7.17 Comparison matrix and calculation of weight, step (9) calculation of the geometric mean of panel responses

Level 3 (Sub-Criteria)	**Step 9 (sum columns)**		
Manufacturing Defect	Poor Raw Materials	Insufficient Construction Skills	Lack of Control of the Concrete
Poor Raw Materials	1	1.222845	1.996067
Insufficient Construction Skills	0.817765	1	1.463111
Lack of Control of the Concrete	0.500985	0.683475	1

Step 10: Square the produced comparison matrix in step 9, and then calculate the row sums and normalize each row in the comparison matrix.

Table 7.18 Comparison matrix and calculation of weight, step (10) after squaring

Level 3 (Sub-Criteria)	**Step 10 (Matrix Square 3)**			**Sum**	**Weight**
Manufacturing Defect	Poor Raw Materials	Insufficient Construction Skills	Lack of Control of the Concrete	Sum of rows	**(Sum/column's sum)**
Poor Raw Materials	3	3.809951	5.781291	12.59124	0.4333
Insufficient Construction Skills	2.368528	3	4.558537	9.927065	0.3416
Lack of Control of the Concrete	1.560893	1.979577	3	6.54047	0.2251
$\sum=$				29.05878	1.0000

Step 11: The squaring process is continued until the difference between the normalized weights of the repetitions fall below a suggested value.

Table 7.19 Comparison matrix and calculation of weight, step (11)

Level 3 (Sub-Criteria)	**Step 11 (Matrix Square 3)**			**Sum**	**Weight**
Manufacturing Defect	Poor Raw Materials	Insufficient Construction Skills	Lack of Control of the Concrete	Sum of rows	**(Sum/column's sum)**
Poor Raw Materials	27.04795	34.30422	52.05555	113.4077	0.4333
Insufficient Construction Skills	21.32656	27.04795	41.04438	89.41888	0.3416
Lack of Control of the Concrete	14.05404	17.82439	27.04795	58.92638	0.2251
∑=				261.753	1.0000

Step 12: The squaring process is continued until the difference between the normalized weights for each sub-criterion no longer changes between the iterations. From Table 7.20, it can be seen that there are no changes with the weight column.

Table 7.20 Comparison matrix and calculation of weight, step (12)

Level 3 (Sub-Criteria)	**Step 12 (Matrix Square 3)**			**Sum**	**Weight**
Manufacturing Defect	Poor Raw Materials	Insufficient Construction Skills	Lack of Control of the Concrete	Sum of rows	**(Sum/column's sum)**
Poor Raw Materials	2194.773	2783.576	4223.987	9202.336	0.4333
Insufficient Construction Skills	1730.519	2194.773	3330.498	7255.79	0.3416
Lack of Control of the Concrete	1140.399	1446.339	2194.773	4781.511	0.2251
∑=				21239.64	1.0000

Thus, the final generated weights for each sub-criterion are:

Raw Materials = 0.4333≈ 43%,

Workforce = 0.3416≈ 34%,

Control of In-situ Concrete = 0.2251 ≈ 23%

Table 7.21 presents the results of the final weights of the factors that affect house performance in the context of the penetrating damp, including the sub-issues related to each factor. Construction and socio-economic design factors were the major factors influencing the presence of damp. Surprisingly, management and climatic factors had less impact. In level 3, cost and knowledge effectiveness, construction supervision and manufacturing criteria were the most challenging criteria that affect the occurrence of the problem. Additionally, the sub-criteria of changes in housing policy and owners' supervision had an impact of the quality of the housing production in Libya.

It is interesting that at lower levels of the hierarchy the weights of cost and knowledge effectiveness, owners' supervision and construction supervision criteria are high but that this is not reflected in the overall weightings. A similar effect is shown for the rain factor. It may be because all these either impact on the choice of raw materials or are related to workforce skills and so are subsumed into the construction factor.

Table 7.21 Weighted analytical hierarchy of causes of damp in concrete domestic houses, Green Mountain, Libya

Level 1 Primary Problem	Level 2 Factor		Level 3 Criteria		Level 4 Sub-Criteria	
AHP Model of Factors affecting the Performance of Concrete Houses against Penetrating Damp 1.00	Construction	0.4584	Manufacturing Criteria	0.6912	Raw Materials	0.4333
					Workforce	0.3416
					Control of in-situ Concrete	0.2251
			Construction Design	0.3088	Exterior Finishing	0.4235
					Roof Design	0.2617
					Exterior Walls	0.2119
					Water Tanks Location	0.1029
	Socio-Economic Design	0.2347	Cost & Knowledge Effectiveness	0.8081	Raw Materials Selection	0.3431
					Builders Selection	0.2432
					Exterior Finish Selection	0.1944
					Maintenance	0.1366
					Delay in Construction	0.0827
			Socio-Religious Design Requirements	0.1919	Room Size	0.2736
					Interior Finishing & Decoration	0.2519
					Hospitality Rooms	0.2147
					Future Requirements	0.1735
					Social Activities	0.0863
	Management	0.1728	Construction Supervision Criteria	0.7041	Owners Supervision	0.7126
					Experts Supervision	0.2874
			Housing Policy	0.2959	Changes in Housing Construction Policy	1.0000
	Climatic	0.1340	Rain	0.6107	Rainy Season	1.0000
			Wind Direction	0.3893	Northwest Direction	1.0000
						Σ W = 1

7.4 Summary

Involving a wide range of factors, such as construction, socio-economic design, management and climatic factors, in one research project was a challenge. However, using the Saaty technique to evaluate these issues related to the performance of concrete houses in the context of damp has enhanced the value of the research and contributed to answering the second research question. Indeed, this chapter has revealed the relative importance of the housing performance factors through the analytical hierarchy process technique; where the participants (experts and house owners) weighted the factors that affected house performance. The local experts and house owners had sufficient experience and knowledge about the issue in the study area. This phase of the research has provided the result of the pairwise comparison for each interview panel, highlighting the most important and unexpected findings. It has also summarised the most significant outcomes.

The main findings of this section were: the evaluation of panel (1), level 1 of house performance factor (First-Level of Pairwise Comparison Matrices) was reasonable. Although there was a slight difference in weight between the factors, construction and socio-economic design factors occupied the first and second most important factors respectively. Regarding Panel (2), Level 2 of the criteria for the construction factor (Second-Level Pairwise Comparison Matrices for the Construction Factor), the quality of the construction materials and concrete production were more important than the adopted construction design. In the Third-Level Pairwise Comparison Matrices for the Construction Design criterion, the assessment indicated that water tank location in the house was the least important sub-criterion within the construction design. The final comparison within panel (2), Level 3 of the manufacturing criteria sub-criteria for the construction factor (Third-Level Pairwise Comparison Matrices for the Manufacturing Criteria Criterion) indicated that there were some similarities in comparison although the lack of control of in-situ concrete production was the least important sub-criterion within the manufacturing criteria.

Additionally, with respect to panel (3), the evaluation of the climatic factor (Second-Level Pairwise Comparison Matrices for the Climatic Factor), in comparison to the rain season with wind direction, showed that the rainy season was more important than wind direction.

In panel (4), the evaluation of the management factor, (Second-Level Pairwise Comparison Matrices for the Management Factor), the result revealed that the construction supervision criterion was noticeably more important than housing policy. In relation to the evaluation of the socio-economic design factor (Second-Level Pairwise Comparison Matrices for the Socio-Economic Design Factor), again, remarkably, cost and knowledge effectiveness occupied the most important criterion in comparison with the socio-religions design requirements within the performance of the house. Moreover, in the evaluation of the construction supervision criterion sub-criteria (Third-Level Pairwise Comparison Matrices for the Construction Supervision Criterion Criteria), the result was significant; there were obvious differences between the comparable sub-criteria. The owners' supervision was the most important sub-criterion in the evaluation of the cost and knowledge effectiveness sub-criteria (Third-Level Pairwise Comparison Matrices for the Cost and Knowledge Effectiveness Criteria), which remarkably indicated that delay during the construction procedure had the least effect among the others.

In relation to panel (5), the evaluation of the socio-religious design requirements criteria (Third-Level Pairwise Comparison Matrices for the Socio-Religious Design Requirements Criteria), the evaluation indicates that social activity such as traditional carpet washing and cleaning on the roof and/or traditional house washing (splashing water) occupied the lowest important sub-criteria within the socio-religious design requirements for the houses.

Whether a combination of methods for a model of factors causing penetrating damp within concrete houses has been obtained; this can be seen in the next chapter (Model Development and Validation), which provides further data to deeply understand the nature of the problem and validated the AHP Weights of the Model.

Chapter Eight: Model Development and Validation

8.1 Introduction

When a model has been developed, it is important to assess its effectiveness. Technically, this can be done by evaluation, which determines whether the whole process leads to an outcome or output which meets the requirements, or by validation, which in addition to determining whether the process meets requirements also has to involve measurement against some verifiable standard. Evaluation is a process that examines a particular programme or data to gauge the level of success. There are two categories of evaluation: formative and summative evaluation (Best, 2012; Rossett & Sheldon, 2001; Then, 1996). In formative evaluation, researchers are able to judge what is right and what is wrong and why during any phase of the research process and make adjustments and improvements to help attain the research aim and objectives are being met. Summative evaluation, meanwhile, is a method for judging the quality of the research at the end of the process; it focuses on the outcome of the research (Best, 2012).

Formative and summative evaluation methods are involved as two complementary techniques that aim to benefit the quality of the research outcomes. Formative evaluation was applied during the research process, particularly during the design of the methods of data collection through applying a pilot study (see Chapter 4 for more information). In this chapter, summative evaluation is implemented in order to obtain a better understanding of the model and to provide points for improvement by validation. Quantitative and qualitative methods are combined in order to develop and validate the model of factors causing penetrating damp in concrete houses in the Green Mountain area in Libya. *"It is important that the developers of quality frameworks do not fall into the trap of substituting intuition and guesswork for evidence-based validation processes*" (Inglis, 2008, p.361). The chapter defines model development and AHP weights validation, including methods, process, analysis and supporting rationale.

8.2 Model Development

8.2.1 Data Collection Methods

Data was collected from another town called Massa within the Green Mountain Region. Massa was selected because it has the same conditions as Albeida in terms of climate, location, construction design and culture. The voice of the house owners was heard again as the first and major stakeholder that affected by the damp problem.

A questionnaire and interviews were chosen as data collection tools. These methods have been applied in previous research as validation methods (Amer, 2007; Forty, 2012; Grifa, 2006 and Somerville, 2008). The questionnaire allows the contributors' time to reflect on the questions, whilst facilitating data collection in a short time (Gillham, 2007; Thomas *et al*. 2011; Yin, 2009). The interview has been applied widely in qualitative research (Patton, 1990; Yin, 2009) and can be the best instrument for obtaining the necessary depth and richness of data (Prescott, 2011). In view of the research schedule, these two methods were the best for obtaining the required data. Figure 8.1 shows the adopted model development methods.

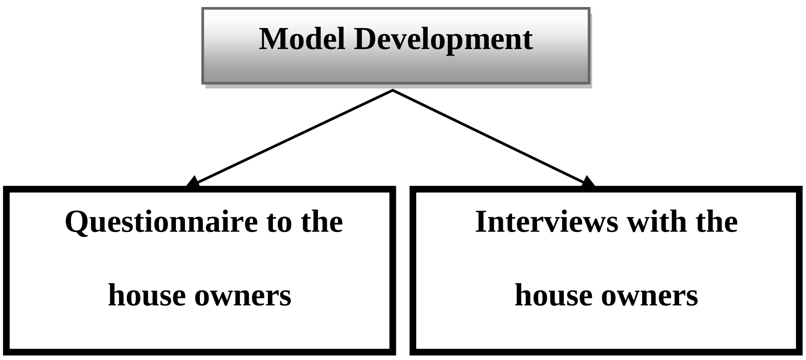


Figure 8.1 The adopted methods for model development

For the questionnaire, the questions were designed to highlight the construction, socio-economic design, management and climatic factors with their criteria and sub-criteria involved within the model. It was planned to ask simple closed questions, because the contributors are residents who come from different backgrounds and have various levels of understanding about the issue (Fink, 2013). However, during the design, care was taken to cover and obtain sufficient data. The questionnaire started by asking if the house showed signs of damp or not, the nature of the last maintenance carried out and the possible consequences of the damp for the house's inhabitants. Then, it was divided into six sections: construction supervision background, construction material, workforce, roof background, exterior wall background and socio-cultural design requirements. Each section included a couple of multi choice questions and/or yes or no questions in relation to the subject area. For more information see Appendix E.

For the interviews, two open questions were asked:

- Why do the Green Mountain houses suffer from damp?
- What can be done to counter this phenomenon?

8.2.2 Sampling Technique

A social network, using the snowballing technique, was adopted to circulate the questionnaire. A hundred and fifty copies of the paper written questions were circulated to house-owners of Massa. Sixty-one copies were returned, giving a response rate of 40%. Each contributor was provided with a copy of the questions with an information sheet about the research aim and objectives, which also outlined their freedom to contribute or not to this procedure as they preferred. They were requested to provide their assessment and opinion on the factors that affect the performance of their houses.

Three copies of the returned questionnaire were selected, because they provided rich data of comments and details, for a qualitative interview with those owners to enhance and strengthen the development of the model of factors causing damp in the Green Mountain area. They were asked to participate in a telephone interview to obtain more in-depth data. A telephone interview was selected because the researcher was outside the study area during that stage of the research.

8.2.3 Analysis Methods

Data are generated to be analysed and to assist the researcher to modify and/or develop the AHP model factors (Landry, Malouin & Oral, 1983). Regarding the questionnaire, the house owners' answers were categorised, coded and analysed statistically. The results were reported by percentages in tables and figures.

For qualitative interview questions, it has been shown that thematic analysis offers a combination of a measure of flexibility, a systematic approach and a means of achieving sufficient depth of analysis and interpretation (Cassell & Symon, 2004; King, 2003).

This allows the identified main factors within the model to be developed and validated alongside with the same themes that emerged from the interviewees' answers. King (2003) stated that categorising and coding the main themes in the data allows the possibility of an a priori selection of the coding frame for further development as the analysis progressed. This thematic analysis relies on the researcher’s knowledge, skills and possible underlying assumptions about the research topic. After the translation and transcription of the answers into an Excel spreadsheet, thematic analysis was applied, including coding the text, based on the main words and key concepts in each answer and conversation. This helps to understand and develop the gathered data. Following the reading, re-reading and looking for themes, a final outline is presented.

8.2.4 Questionnaire Result

Firstly, 90% of the house owners reported that they suffer from damp in their houses and only 10% said that they have no signs of damp in their house. Overall 18% of houses had damp in only the ceiling, 24% of houses had damp only in exterior walls and 48% of houses had damp in both ceiling and exterior walls.

All of the returned copies of the questionnaire reported that the houses were designed with a flat roof, 75% of which suffer from water pooling on the roof. All the houses were designed with a single skin exterior wall. Cement based render and stucco occupied the highest percentage of type of exterior finish, at 49% and 43% respectively. In relation to the manufacturing criteria, it was reported that 70% of the houses were constructed with unwashed sea sand while 87% used un-rusted steel bars. Regarding the control of labour inputs on the site, the results illustrated that the storage of raw materials and concrete placing and compacting occupied the highest percentages respectively (53% and 32%) which were controlled or supervised by the house owners.

In relation to the selection criteria for raw materials and workforce by the house owners, 66% of the house owners contributed to the selection of both raw materials and the

workforce. The main criteria for workforce selection were wage level and then experience, although picking any workers from the builders market also exists within the criteria.

The cost and knowledge effectiveness and socio-cultural design requirements of the owners were examined. In relation to delays in construction, although 46% of the house owners did not face delays during the construction work, 41% reported that the construction work was suspended due to insufficient or delayed loan payments. Additionally, 43% of the house owners reported that they had not carried out any kind of maintenance or had simply peeled off the damaged paint and re-painted it. Thirty-one percent (31%) reported that they had taken only one action, such as exterior plastering work with bitumen layers, interior plastering work, or re-tiling bathrooms and kitchens.

The house owners were also asked whether the design of their house, with the available budget, included large room sizes, rooms for hospitality and/or high quality interior finishing and decoration. All the houses were designed and built with rooms for hospitality and 92% of the occupants concentrated on having high quality interior finishing and decoration rather than spending money on the exterior of the house. Also, 89% of the houses were built with large room sizes.

In respect to the management factor, the result showed that 59% of the houses were constructed by jobbing contractors and 36% were built by local construction firms, with only 5% of the houses constructed by international firms. Moreover, the house owners reported that 63% of the houses were supervised during the construction by both the house owner and an expert, while 37% were supervised by professionally qualified experts or experienced builders. It was noteworthy that 59% of the owners who supervised the construction work had no previous experience of construction and 7% had little experience of it.

Regarding the climatic issue, it was reported that 34% of the houses had damp from November to May, 31% of the residents stated that signs of damp appeared from November to February and 25% reported that they had damp all year around.

Responses indicated that the majority of defective exterior walls face the north-west (53%), followed by the south-east (18%).

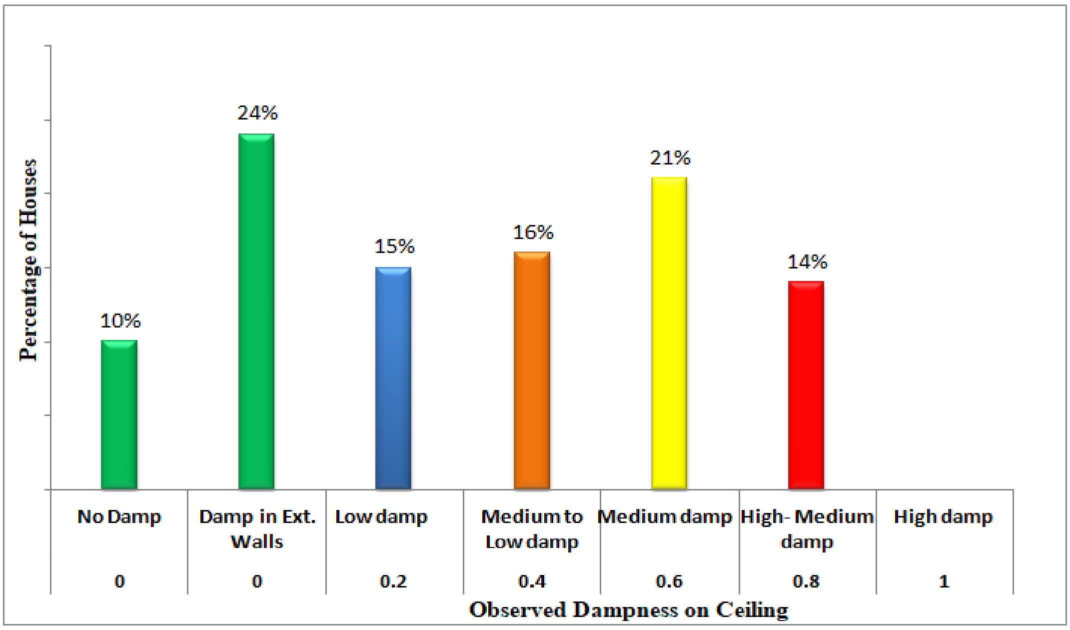
House owners were asked to rank the possible consequences of damp, based on their experience of damp in their house. Table 8.1 shows that 66% of the owners stated that they wasted money every year on maintenance without effective results, followed by damage to the furniture and fabric of the building, at 16% and 11% respectively.

Moreover, cosmetic appearance accounts for 5% of the consequences of damp, followed by adverse impact on the health of the family (2%).

Table 8.1 Possible Consequences of Damp Based on the Owners' Experiences

Consequences of Damp	Percentage
Wasting Money on Property Maintenance	66 %
Damage to Furniture	16 %
Fabric Damage of Building	11 %
Cosmetic Appearance	5 %
Adverse Impact on Health of Family	2 %
Total	100 %

Based on the current house owners' experience of damp, they were also asked to mark the possible level of damp appearing on the ceiling in terms of level of damage. The observed level of dampness which was reported by the house owners highlights the extent of the phenomenon. The result in Figure 8.2 shows that 66% of the houses suffered from damp on the ceiling. Regardless of the percentage of the houses that did and did not have any damp on the exterior walls, at 10% and 24% respectively, there are slight similarities in the level of damp on the ceiling. However, a medium level of damp occupied the highest percentage (21%).

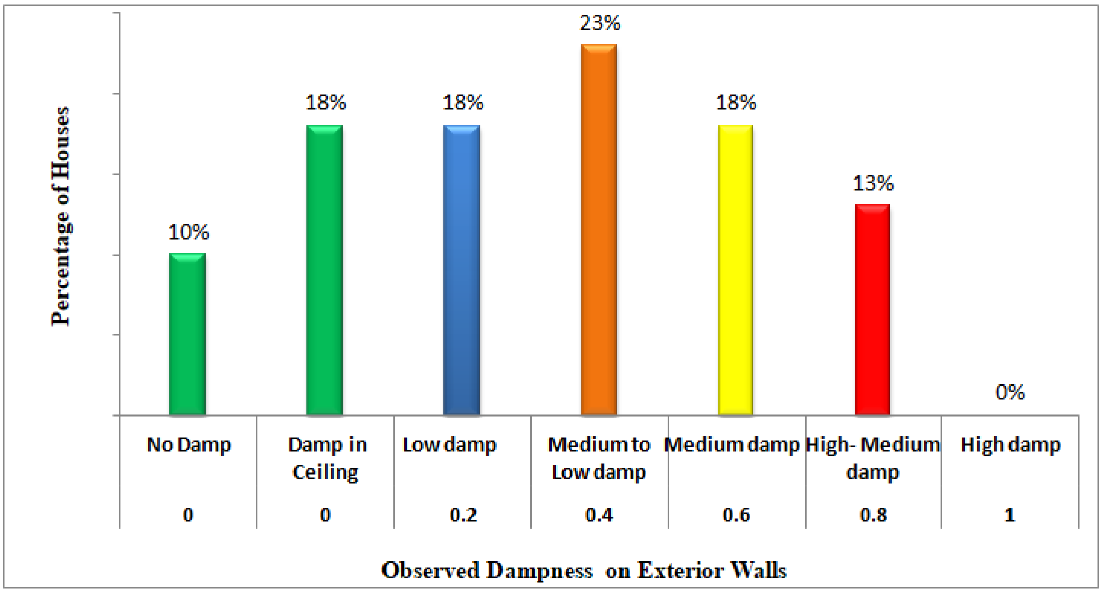


Note.

0	**No Damp**	**No signs of damp within the house**
0.2	**Low damp**	**Slight spots of black patches/stains/peeling paint in the middle or corner of the ceiling without water pooling on the roof**
0.4	**Medium to Low damp**	**Moderate to small area of stains/black patches/peeling paint in the middle or corner of the ceiling with water pooling lasting for a couple of days on the roof**
0.6	**Medium damp**	**Moderate-sized area of stains/black patches/peeling paint in the middle and/or corner of the ceiling with water pooling lasting for more than a week on the roof**
0.8	**High- Medium damp**	**A considrable area of stains/black patches/pelling paint/ blistering in the middle or corners of the roof and/or water leakage**
1	**High damp**	**Large area of black patches/stains/peeling paint, spread everywhere in the ceiling and a cracked area on the roof with water leakage**

Figure 8.2 The observed level of damp on ceiling reported by the house owners of Massa

For the exterior wall, owners were also asked to assess the observed level of damp appearing in terms of the level of damage. The result in Figure 8.3 shows that 72% of the houses suffered from damp in exterior walls. Regardless of the percentage of the houses that did and did not have any damp on the exterior walls, at 10% and 18% respectively, the results showed that 23% of the houses suffered from medium to low signs of damp on the exterior walls and 13% of houses suffered from high to medium signs of damp.



Note.

0	**No Damp**	**No damp signs within the house**
0.2	**Low damp**	**Slight area of black patches or stain in the wall**
0.4	**Medium to Low damp**	**Moderate to small area of stain/black patches/peeling paint or blistered paint in the middle or corner of wall**
0.6	**Medium damp**	**Moderate-sized area of stain/black patches/peelled paint in the middle and/or corrner of wall**
0.8	**High- Medium damp**	**A considrable area of stain/black patches/peeling paint/ blisteed in the middle or corners of the wall and/or wet wall**
1	**High damp**	**Large area of black patches/ stain/ peeling paint/ blistered, spread everywhere in the wall and/or cracks in the exterior surface of the wall with wet wall**

Figure 8.3 The observed level of damp on exterior walls reported by house owners in Massa

8.2.5 Interview Results

The questionnaire result was supported by conducting three interviews with those owners who provided more details and large amounts of information within the returned questionnaire. They were conducted after obtaining official consent from the interviewees. These results not only confirmed and developed the identified factors causing penetration damp within concrete houses in the Green Mountain of Libya, but added several other important themes. For instance, the house owners were asked their opinions about the causes of the damp. Figure 8.4 presents illustrative responses from the interviewees.

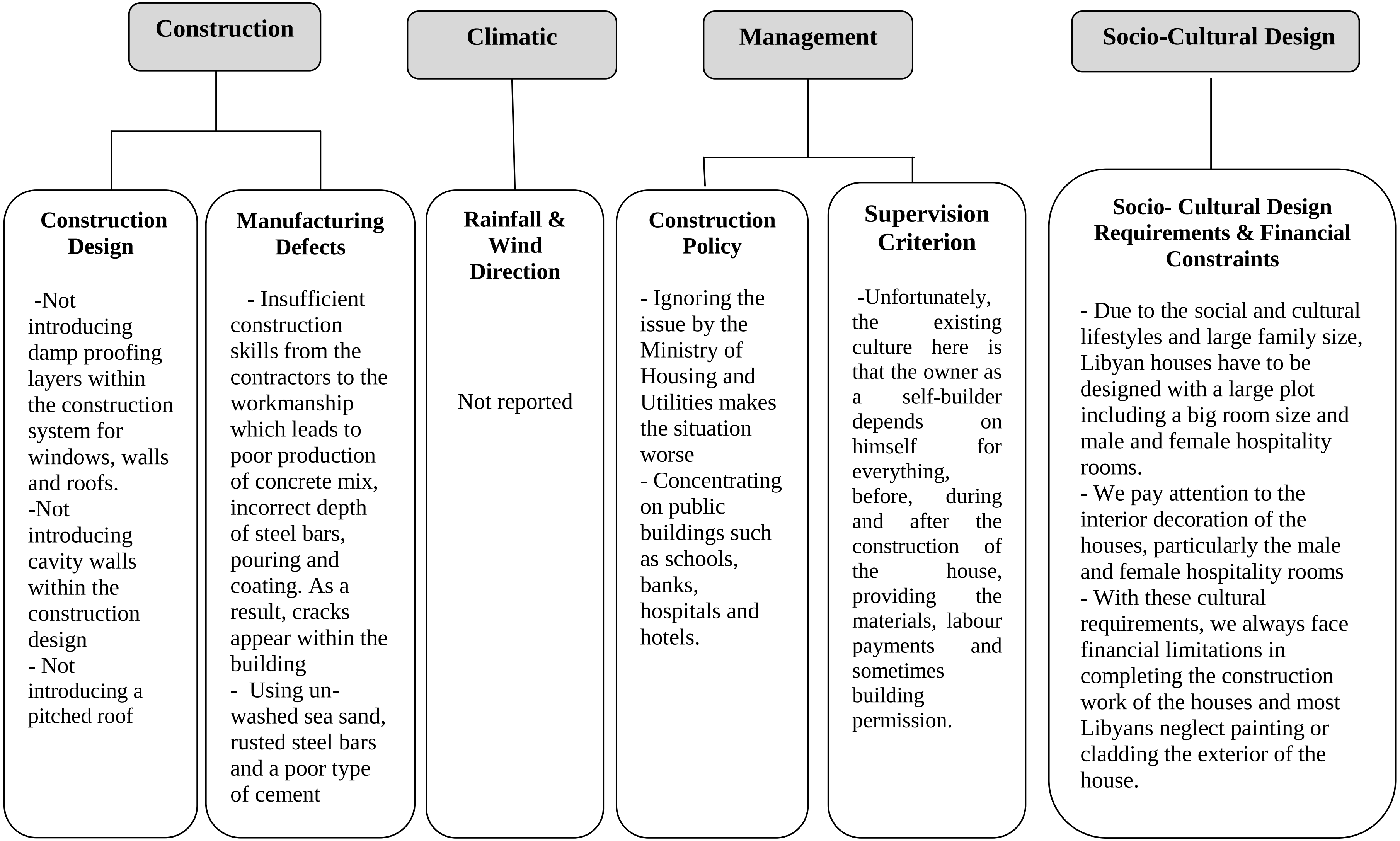


Figure 8.4 Illustrative key messages for each factor from house owners in Massa

The interview results showed that there were construction, socio-cultural design and management barriers in the housing sector in Massa, Libya. However, surprisingly, climatic conditions were reported as one of the least important causes of the occurrence of damp. This verifies the results obtained from the pairwise comparison procedure (see Chapter 7), which found that the climatic factor is the least problematic factor that affects the performance of houses compared with other factors. Additionally, the house owners reported that a lack of knowledge among the experts, such as applying improper design, using poor raw materials, and using unskilled builders, as well as the phenomenon of the owners 'supervision of the construction process which worsens the problem. This also supports the results obtained from the AHP technique that indicated the construction factor is the most significant factor within the hierarchy. Further, they added that the state should introduce effective and practical regulations and building laws for housing to generate robust criteria and standards that accommodate the Muslim and Arab cultural environment and also involve the house owners within a strategy to improve their understanding about the issue, if it still wants to promote the policy of self-building properties.

In relation to room size, hospitality rooms and interior decoration, the interviewees also reported that this is what Libyan society and culture require in their house design, although it exceeds the house owners’ budgets. They highlighted the socio-cultural design requirement under the financial limitations of the owners. Table 8.2 shows some quotations from the interviewees' responses.

Table 8.2 Illustrative Quotes from the Interviews

Theme	Key Answers
Construction	*"Experts do not realize how important the issue is, you cannot find someone who really understands the extent of the dampness problems in houses and they only say it is all about the financial limitations of the owners to buy high quality construction materials, good steel bars and damp proofing products but I say it is all about manufacturing, in relation to construction, the normal type of cement is not the proper choice for building in the Green Mountain of Libya, at least, I mean the type of Portland cement"* **(Interviewee1)**
Socio-Cultural Design	*"Lack of residents' awareness of the issue and how the construction responds to the water helped in expanding the problem. For instance, cleaning the roof, walls of the house by splashing water on them, particularly in bathrooms and kitchens. Also, cleaning the carpets on the roof of the house or house yard."* *"I think the social and cultural requirements in designing the house have become a burden for the house owner as a self-builder, making it impossible for them to provide high quality construction materials or clad the house from outside"* **(Interviewee 1& 2)**
Management	"*There is no support from the state for the construction materials, we as owners and self-builders cannot afford materials of high-quality with the Libyan cultural requirements for house design and construction"* **(Interviewee 3 & 1)**
Climatic	*"The inappropriate construction type in the mountain under the climatic condition helps the emergence of the damp, therefore, different design for each region within the country should be introduced that suit the climate"* **(Interviewee 2)**

Interviewee (1) stated that the manufacturing criteria can be the main cause of the problem, as applying Portland cement Type I in the Green Mountain of Libya was not the right choice. He stated that admixtures for damp proofing should also be added to the cement to resist water ingress. Additionally, interviewee (3) stated that, in relation to the construction design under the climatic condition, another design should be introduced to suit the climatic condition within the region. Interviewees (1) and (3) asserted that the state should subsidise the raw materials in order to enable the owners to afford high quality materials.

In relation to the burden of social and cultural requirements for house design, which the owners cannot afford, interviewees (1) and (2) suggested another theme in relation to socio-cultural design. They stated that there is a lack of occupants' knowledge and awareness about the issue; traditionally, the occupants use water to clean the house, which splashes onto the roof and walls, and contributes, at least indirectly, to the occurrence of damp.

8.2.6 Discussion

Based on the results of this chapter, it was perceived that there are certain factors affecting the performance of the ceiling of concrete houses and other factors affecting the performance of the exterior walls, although there are some shared factors. For example, unwashed sea sand, type of cement and condition of steel bars are, in general, among the causes of damp occurrence (Bennett, 2007; Bertolini, 2013; Popescu *et al*., 2005; Rekela, 2004; Shabha, 2003; Sharon, 2012; Someville, 2008). Additionally, employing unskilled builders or picking any builders from the hiring market is the dominant element in workforce practices (Everett, 1994; Hendry, 1998; Hendry; Neville & Brooks, 1993; Sinha & Davies, 1997; Son & Yuen, 1993). The design of exterior wall and roof, leakage from water tanks on the roof and type of exterior finishing are also highlighted (Allen, 1997; Son &Yuen, 1993; Straube, 2002; Tait *et al*., 2001; Talib *et al*., 2015; Wekesa *et al*., 2010).

In relation to cost and knowledge effectiveness, none or lack of and/or poor of maintenance was also discovered (Botsai *et al*., 2010; Lopez *et al*., 2011; Mclean, 2009). Limited sources of funds, such as delay in loan payment or insufficient loan, caused delays in construction for some houses (Abd El-Razek *et al*., 2008; Omar, 2003).

Further, it was found that socio-religious design requirements restrict the house owner from having a house with a high quality standard. The house owners failed to prioritise quality issues (Mclean, 2009) by focusing on having large room sizes, male/female hospitality rooms and high quality of interior decoration as well as future requirements (Fadan, 1983; Hashim *et al*., 2006, Mahmud, 2013; Sobh & Belk, 2011; Stefano, 2000) and social activities. It seems the culture of the housing construction industry cannot be changed unless strict rules are introduced by decision makers. A long-term programme could be planned for improvement, involving advertisement, leaflets, home visits, conferences, seminars and other initiatives to change the culture of house design and construction as well.

Owners' supervision with/without previous experience is revealed although experts' supervision is also highlighted. Poor supervision results in building defects (Forty, 2012; Georgiou, 2010; Krima *et al*., 2007; Marshall *et al*., 2009). Moreover, jobbing contractors and local construction firms are the main parties who undertook the construction work of the houses although international construction firms are also highlighted (Awotona, 1999; Libya General Authority for Information, 2006).

Although it was not the main concern, rainy season and wind directions are highlighted (Bertolini, 2013; Everett, 1994; Kefei, 2009; Rekela, 2004; Richardson, 2001).

Therefore, it can be stated that model development involved two data collection techniques (questionnaire and interview) and two types of data analysis (statistical and thematic analysis) with hearing the judgments of the house owners of Massa, another town within the Green Mountain Region.

Following the data collection in Massa, a fifth level was added to the model as shown in Tables 8.3 and 8.4. Thus, the model was developed by adding another level. In addition, the model was split into two; one for roof related causes and a second one for causes related to exterior walls (Table 8.3 and Table 8.4 respectively).

Table 8.3 Model of the Factors Affecting the Performance of Houses for Roof in the Green Mountain of Libya

Level 1	Level 2	Level 3	Level 4	Level 5
Primary Cause	**Factor**	**Criteria**	**Sub-Criteria**	**Sub-Sub-Criteria**
AHP Model of Factors causing Penetrating Damp within Concrete Houses : Roof	**Construction**	Manufacturing Criteria	Raw Materials	Unwashed Sea Sand
				Washed Sea Sand
				Desert Sand
				Normal Portland Cement
				Other Type of Cement
				Rusted Steel Bar
				Un-rusted Steel Bar
			Workforce	Builders Hiring Market
				Unskilled & Inexperienced
				Skilled & Experienced
		Construction Design	Type of Exterior Finishing	Cement Mortar
				Others
			Design of Flat Roof	Flat Roof (with slope)
				Flat Roof (faulty slope)
			Water Tanks Location	On Roof
				Other Location
	Socio-Economic Design	Cost & Knowledge Effectiveness	Maintenance	No Maintenance
				Only Repainting
				Interior Plastering
				Exterior & Interior Plastering with Bitumen Layers
			Delay in Construction	Delay in Loan Payment
				Loan is Insufficient
				No Delay
		Socio-Religious Design Requirements	Future Requirements	Building another unit or level
				No
			Social Activities	Washing & Cleaning Carpets on Roof
				No
	Management	Construction Supervision Criteria	Owners Supervision	Owners without Experience
				Owners with Experience
			Experts Supervision	Experienced Builders
				Professional Qualified Expert
		Housing Policy	Changes in Housing Construction Policy	Jobbing Contractors
				Local Construction Firms
				International Construction Firms
	Climatic	Rain	Rainy Season	Nov-Feb
				Nov-May

Table 8.4 Model of the Factors Affecting the Performance of Houses for Exterior Wall in the Green Mountain of Libya

Level 1	Level 2	Level 3	Level 4	Level 5
Primary Cause	**Factor**	**Criteria**	**Sub-Criteria**	**Sub-Sub-Criteria**
AHP Model of Factors causing Penetrating Damp within Concrete Houses : Exterior Wall	**Construction**	Manufacturing Criteria	Raw Materials	Unwashed Sea Sand
				Washed Sea Sand
				Desert Sand
				Normal Portland Cement
				Other Type of Cement
				Rusted Steel Bar
				Un-rusted Steel Bar
			Workforce	Builders Hiring Market
				Unskilled & Inexperienced
				Skilled & Experienced
		Construction Design	Type of Exterior Finishing	Cement Mortar
				Others
			Exterior Walls	Single Sheet of Wall
				Cavity Wall
				Thick Wall
	Socio-Economic Design	Cost & Knowledge Effectiveness	Maintenance	No Maintenance
				Only Repainting
				Interior Plastering
				Exterior & Interior Plastering with Bitumen Layers
			Delay in Construction	Delay in Loan Payment
				Loan is Insufficient
				No Delay
			Future Requirements	Building another unit or level
				No
			Social Activities	Washing & Cleaning Carpets on Roof
				No
	Management	Construction Supervision Criteria	Owners Supervision	Owners without Experience
				Owners with Experience
			Experts Supervision	Experienced Builders
				Professional Qualified Expert
		Housing Policy	Changes in Housing Construction Policy	Jobbing Contractors
				Local Construction Firms
				International Construction Firms
	Climatic	Rain	Rainy Season	Nov-Feb
				Nov-May
		Wind Direction	Northwest	Northwest
				Southeast
				Northeast

It is interesting that the new sub-sub-criteria identified in the fifth level include building another unit or level and the local practice of a builders hiring market. These were added to both models (roof and exterior wall) and highlight the AHP technique's ability to capture specific local elements of a problem or a decision. The addition of international construction firms under housing policy confirms the difference in quality of building that was identified in the history of construction in Libya highlighted in the literature review.

Additionally, the separation of the two models improved the representation of the real world situation by potentially allowing the same elements to have different weightings in each model. These AHP models can assist the stakeholders who are interested in this field to deeply understand the factors that cause penetrating damp within concrete houses. The construction of concrete houses by Libyan companies or jobbing contractors used national building codes, which are a combination of UK and Egyptian Specification. The codes appeared to be poorly enforced, with poor quality control of construction practices, including workforce skills and poor choice of materials (such as sand condition, type of cement and steel bar condition). Inadequate design influenced by socio-economic requirements included faulty slope of roof and single sheet of exterior wall (Awotona, 1999). Changes of housing policy over time (in terms of who undertook the construction work) have contributed to the emergence of the housing quality problem (Allafi, 2011; Nagab, 2008) along with the phenomenon of owners' construction supervision with or without previous experience or knowledge who contribute to the selection of raw materials and builders and supervise the labour inputs (Krima *et al*, 2007).

Additionally, financial capabilities of individuals have played a part in the overall quality standard of housing production. Inadequate financial provision for the overall construction project can impact negatively on the quality of the building envelope due to the client prioritisation of design and build criteria and delays in the construction process (Abd El-Razek *et al*., 2008).

Further development of the model has assisted the assessment criteria to be more accurate in the context of penetrating damp in concrete houses. Deeper analysis which was obtained by the addition of further levels could affect future design and construction of housing projects.

AHP technique is a continuous procedure, which begins with an analysis of a particular problem, so that the problem can be analysed into different levels and groups (Saaty, 2008; Vogel, 2008). Further analysis is always likely to be required before decisions can be made especially when there are conflicting factors of a complex real life problem such as the problem of penetrating damp and concrete housing construction examined here.

8.3 Model Validation

This section compares the AHP weights between the houses of Albeida and Massa for the purposes of validation. It highlights the model validation techniques, process and analysis with interpretation. Validation was carried out to verify the weights of the identified factors, criteria, sub-criteria and sub-sub criteria of the models. *"Validation implies verifying whether any pertinent variable or relationship has been omitted from the formal model"* (Landry *et al*., 1983, p. 213). In relation to research validation, quantitative research measures the degree of frequency of a particular element in a particular situation or problem whereas qualitative research identifies the existence or absence of this particular factor (Then, 1996).

8.3.1 Data Collection Methods

Observation and questionnaire techniques were selected for the weights validation to avoid any bias. A comparison of the AHP weights between the surveyed houses in Albeida, Green Mountain, and a questionnaire directed to the house owners in Massa, Green Mountain, were used to validate the weights of the models. Observing a number of houses which are subject to penetrating damp and hearing the voice of house owners helped to enhance the credibility of the technique validation.

In reviewing previous researchers' validation sections, questionnaires and observations were widely adopted. It has been found that they provide good results, particularly in construction, maintenance management, housing and urban planning research (Ali, 2011; Amer, 2007; Fapohunda, 2009; Obiajunwa, 2010). Figure 8.5 illustrates the validation methods for the AHP weights.

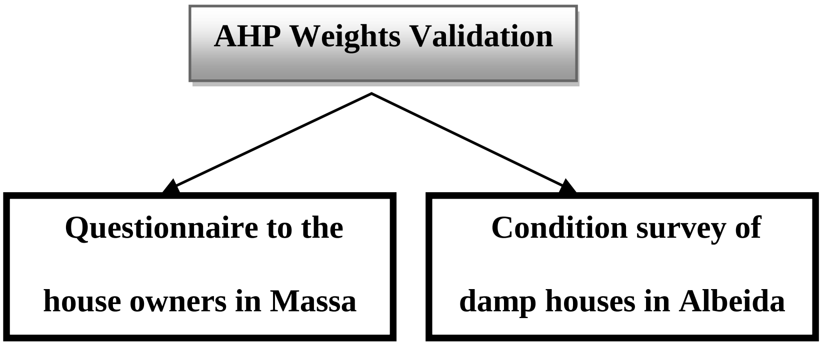


Figure 8.5 Validation methods for the AHP weights

The validation procedure was carried out in November/December 2015. The observed levels of damp in exterior walls and ceiling were the levels reported for each component in each house according to the researcher's knowledge, based on Saaty's scale of values (Saaty, 1980).

Sixty-one copies of the returned house owners' questionnaire in Massa were used in the comparison. The levels of observed damp in exterior walls and ceiling were those reported for each component in each house by the house owners' judgments, again based on the Saaty scale (Saaty, 1980). These criteria were selected for discussion and validation of the weights yielded by the technique.

8.3.2 Analysis Method

Analytical Hierarchy Process technique was applied for the twelve damp houses in Albeida as well as the questionnaire directed to the house owners of Massa. Regarding Albeida data, twelve damp houses were involved to compare and discuss the weights of the construction, socio-economic design, management and climatic factors and how they impact the performance of concrete houses through presenting patterns, constructed meaning and identified and traced signs. A mathematical analysis, AHP technique, was chosen to analyse both the observation data of Albeida and the questionnaire data of Massa. Regarding the observation, the reported damp houses was coded and analysed mathematically through AHP procedure. Regarding the questionnaire, the house owners' answers were categorised, coded and analysed mathematically by the technique in order to reflect on the factors, criteria and sub-criteria.

Since nominal or linguistic terms are not mathematically operable, to cope with such information, the technique was integrated with a single pairwise comparison (Elaalem, 2013; Keshavarzi, 2010; Pan, 2008; Prakash, 2003; Saaty 1980). The pairwise comparison method was applied in order to derive weights based on the experts' judgments, the weight coefficients of the damp factors, criteria and sub criteria (level 2, 3 and 4) were applied using the AHP technique for the observed damp houses in Albeida and the circulated questionnaire in Massa. Each damp factor, criterion and sub-criterion was assigned a particular weight using the Saaty scale, and the mathematical procedure was conducted to produce the weights (Saaty, 1980). See Chapter 3 for more details related to the mathematical calculation.

Then, as the technique is a continuous procedure, which begins with an analysis of the decision background, so that the factors can be built up into different levels and groups (Vogel, 2008), from the data obtained of the observed houses in Albeida and returned questionnaire in Massa, another level was constructed (level5), This confirms the result of the model development section. Each sub-sub criterion (level5) within the model was associated with Saaty scale (Saaty, 1980) in order to break down the issues causing damp within domestic concrete houses in the Green Mountain.

Based on the researcher's knowledge, experience and judgment, the Saaty scale was assigned to the causes of each sub-sub-criterion obtained from the observation data. However, the selection of a particular scale is a critical stage, which might be affected by subjective judgments, such as experts', house owners' or the researcher's knowledge and experience (Abushnaf, 2014; De La Rosa & Van Diepen, 2002). To avoid subjectivity, bias or limitation of the use of the single pairwise comparison, reach rational judgments were reached through consultation and discussion about the assigned scales with five experts from Omar Al Mukhtar University, who had experience and background relevant to the proposed sub-sub criteria. Figures 8.6 to 8.8 show some of the single pairwise comparisons for each sub-sub-criterion. Further details are given in Appendix E.

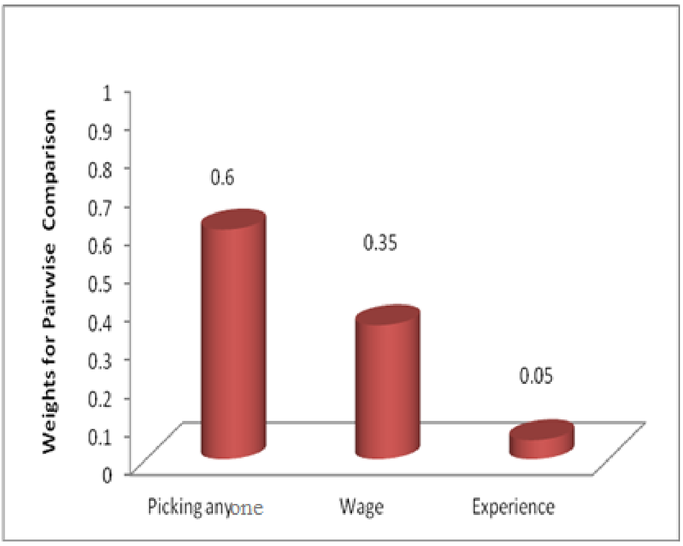


Figure 8.6 Weighting of impact of the selection of builders on likelihood of damp

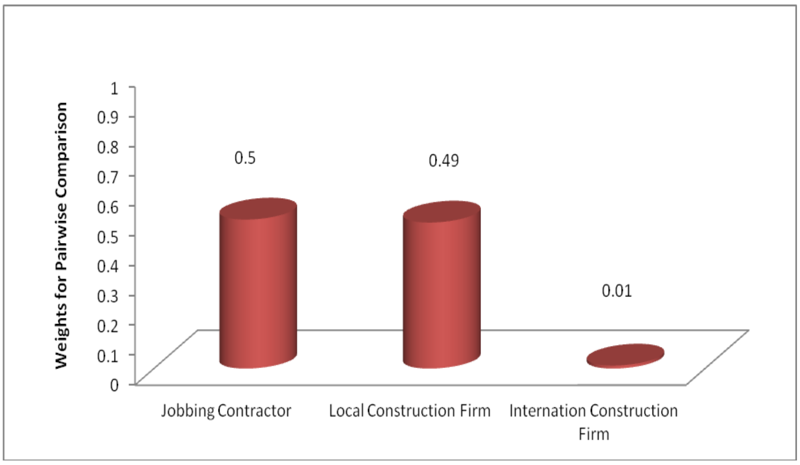


Figure 8.7 Weighting of impact of the party who undertakes the construction work on likelihood of damp

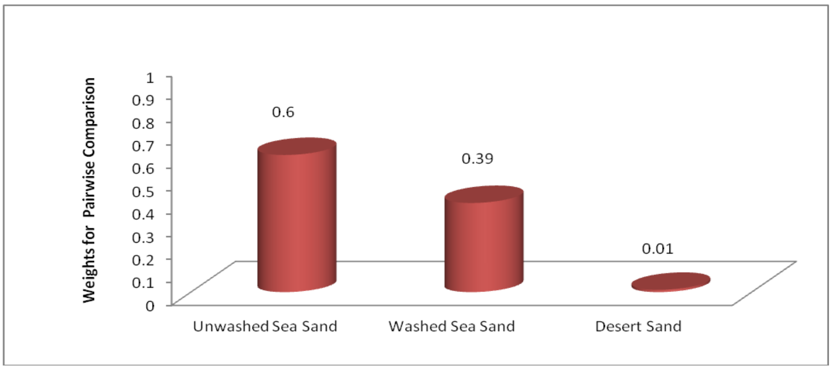


Figure 8.8 Weighting of the impact of the type of sand on likelihood of damp

Continuing with applying the AHP technique, houses that suffer from damp received weights between 0 and 1 ($0< W >1$); the closer the weight's value to 1, the higher the level of damp and vice versa (Burrough & McDonnell, 1998; Joss, Hall, Sidders & Keddy, 2008). Ultimately, every single house was attributed an AHP weight, representing an overall likelihood of damp level based on the most possible recognised causes. Hence, the overall likelihood of AHP in a particular house was expressed as a gross weight (GW) which is the sum of the weights and pairwise comparison of the dampness causes (factors, criteria, sub-criteria and sub-sub-criteria), whether that house suffers from dampness in ceiling, exterior wall or both. The calculation for quantifying the overall indicators of the weight of each house is presented in the following equations.

$$\mathbf{W\,\mathit{i} = (Wa\,)^*\,(Wb\,)^*\ldots\ldots\ldots\ldots\ldots\ldots\ldots{}^*Wn\,^*\,PWC\mathit{i})}$$

Where:

W*i*: the AHP weights with pairwise comparison for every sub-sub- criterion of a particular house, $i = 1, 2, 3\ldots n$ (House number), ($0 < Wi > 1$)

W a, b.............n: the AHP weights obtained from the experts' judgments in Chapter 8 for the factors, criteria and sub-criteria

PWC*i :* the single pairwise comparison weight of the sub-sub- criteria (Level5), ($0 < PWCi > 1$

$$\mathbf{GW} = \sum_{i=1}^{n} wi$$

Where:

GW (Gross of AHP Weight): the sum of the weights and pairwise comparison weight of a particular house.

This mathematical procedure was carried out to produce an overall weighting. The statistical analysis examines the relationship between the damp causes (AHP with pairwise comparison weights) and the observed level of damp which was provided by the researcher in the observed damp houses in Albeida and by the house owners in the questionnaire in Massa.

Table 8.5 presents an applied example of the calculation data of the visited damp house No.9, East Albeida Quarter, Albeida, the Green Mountain, Libya. For further examples regarding the validation data analysis, see Appendix E.

Table 8.5 Calculation of the Overall Weighting for House No.9, East Albeida Quarter, Albeida, the Green Mountain, Libya

Possible Causes of Dampness for House 9	Wa	Wb	Wc	PWC9	Wa*Wb*Wc*PWC9
Workforce	0.4584	0.6912	0.3416	0.7	0.075764235
Control (concrete mixing)	0.4584	0.6912	0.2251	0.4	0.028528821
Control (storage of materials)	0.4584	0.6912	0.2251	0.6	0.042793232
Control (concrete placing & compacting)	0.4584	0.6912	0.2251	0.4	0.028528821
Control (decision of formwork removal)	0.4584	0.6912	0.2251	0.4	0.028528821
Exterior Finishing	0.4584	0.3088	0.4235	0.4	0.023979234
Water Tanks Location	0.4584	0.3088	0.1029	0.7	0.010196129
Roof Design	0.4584	0.3088	0.2617	0.6	0.022226797
Exterior Wall	0.4584	0.3088	0.2119	0.6	0.017997165
Owners Supervision (no exp.)	0.1728	0.7041	0.7126	0.5	0.043350479
Future Requirements	0.2347	0.1919	0.1735	0.7	0.005469978
Changes in Housing Construction Policy	0.1728	0.2959	1	0.5	0.02556576
Raw Materials Selection	0.2347	0.8081	0.3431	0.4	0.026029085
Builders Selection	0.2347	0.8081	0.2432	0.35	0.01614395
Exterior Finishing Selection	0.2347	0.8081	0.1944	0.35	0.012904539
Maintenance	0.2347	0.8081	0.1366	0.01	0.000259077
Social Activities	0.2347	0.1919	0.0863	0.7	0.002720802
Rainy Season	0.134	0.6107	1	0.2	0.01636676
Wind Direction	0.134	0.3893	1	1	0.0521662
GW (Sum)					**0.479519885**

Some common features in the model can be detected: the construction design of the houses (roof design, single skin exterior walls and exterior finishing with the water tank located on the roof) lead to increased AHP weight. The selection of raw materials and builders contribute to the increased weight within the houses. Furthermore, in terms of socio-cultural design, many requirements are affected by cost and knowledge effectiveness; having a large room size, high quality interior finishing and decoration and hospitality rooms might restrict the house owners' selection of good quality raw materials, exterior finishing and skilled workforce. On the other hand, there are causes (variables) that could be expected to be lesser predictors of the occurrence of damp, such as maintenance and/or delay in construction (see Table 8.5 above).

8.3.3 Observation Results, the Damp Index for Albeida

For houses in Albeida, damp level was predicted by examining the relationship between the possible causes of damp (AHP with pairwise comparison weight) and the signs of damp in the twelve observed houses. In this comparison, the observed levels of damp in exterior walls and ceiling were obtained by reporting the level of damp for each component in each house assessed according to the Saaty scale (Saaty, 1980). The results were presented in scatter plots (Figure 8.9, 8.10) of the linear regression for the ceilings and exterior walls separately. The construction, socio-economic design, management and climatic issues affecting the twelve houses were analyzed by calculating the AHP with a pairwise comparison weight of the damp's causes (X axis) and by reporting the observed level of damp using Saaty scale to provide a particular damp level for building component (ceiling and/or exterior wall, (Y axis)).

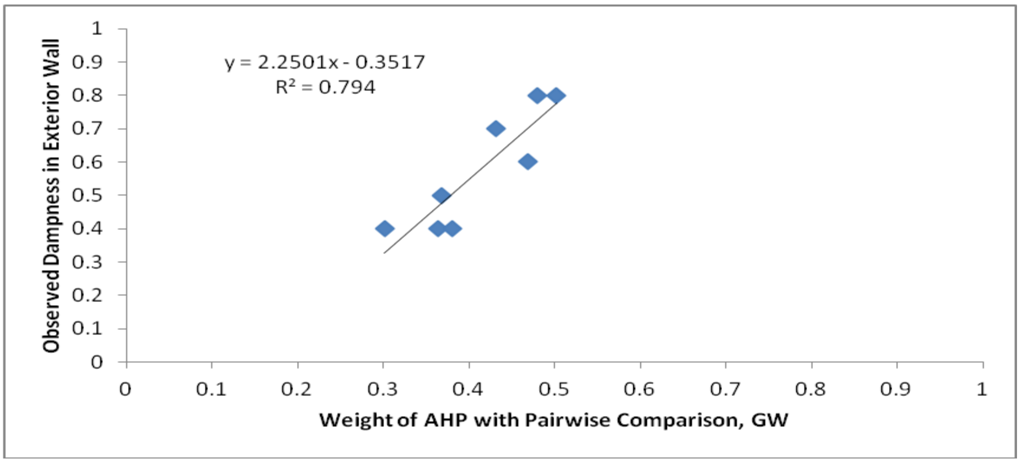


Figure 8.9 The relationship between the overall AHP weighting and the observed level of dampness of the exterior walls, Albeida

Regarding the exterior walls, the results in Figure 8.9 illustrate a high correlation coefficient R^2= 0.794. This indicates that 79.4% of the variation in observed dampness in exterior walls can be explained by the model containing causes of damp. The observed level of damp significantly predicted the causes of damp through weight (b=2.2501, $t_{(8)}$ = 5.141, $P < 0.05$). The observed level of damp (Y axis) ranged from 0.4 to 0.8, while variation in the causes of damp (X axis) was reflected in the range of AHP grades between a minimum of 0.3012 for house 8 and a maximum of 0.5021 for house 3. This variation is due to the nature of the causes of damp for each individual house investigated, as each house differed in terms of its defective building components, construction, socio-economic design and management background as well as its exposure to climatic conditions.

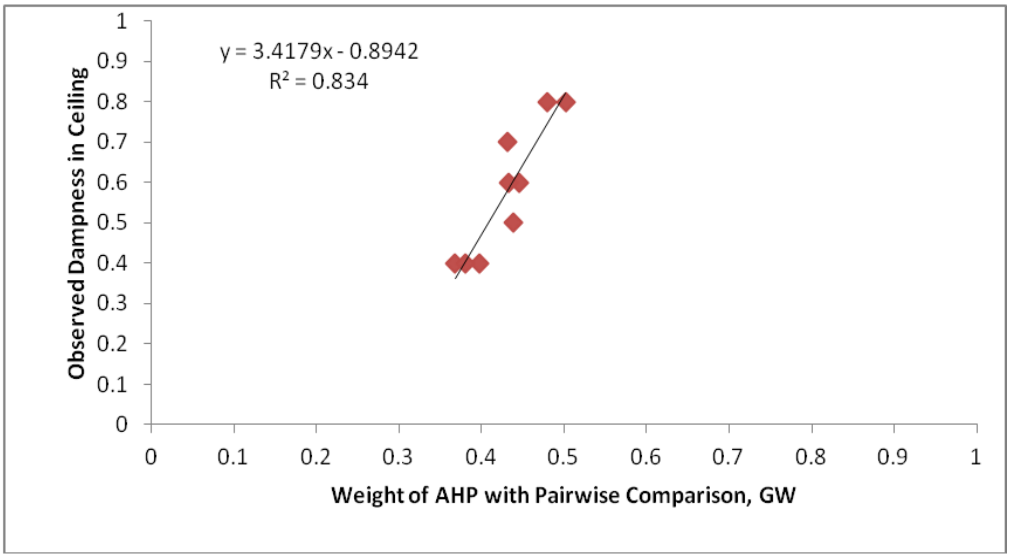


Figure 8.10 The relationship between the overall AHP weighting and the observed level of dampness of the ceiling, Albeida

For the ceiling, the correlation coefficient for linear regression was higher (R^2= 0.834) than for the exterior walls (R^2= 0.794), see Figure 8.10. The data set is good because although it is a small sample there are good agreement between the AHP value and observed damp. The observed level of damp significantly predicted the causes of damp through the weight (b=3.4179, $t_{(9)}$ = 6.2901, P < 0.05). This outcome means the relationship between the damp's causes and effects has been correctly modelled. There is also a range in the weight (Gross of AHP Weight, GW) within the damp houses between a minimum of 0.3677 for house 5 and a maximum of 0.5021 for house 3. Some houses have damp on the ceiling or exterior walls while others have both. Regarding the observed damp (Y axis), it is perceived that the observed level of damp ranged from 0.4 to 0.8. Again, differences are related to the existence of various factors and their differing impact in individual houses. Therefore, particular combinations of factors and their effects vary. This is also what generated the variation in the weight (X axis).

The gradient of the regression line for the ceiling (b=3.4179) is higher than the gradient for exterior walls (b=2.2501); which on average show how many units the observed damp increases when there is a one-unit increase in the weights. It is also tested for significance. If there is no relationship, the gradient of the line would be zero and therefore every cause of damp would be predicted to have an effect of the performance of the house.

8.3.4 Questionnaire Results, the Damp Index for Massa

This mathematical analysis examines the relationship between the cause of damp and the observed level of damp which was evaluated by the owners of Massa. Table 8.6 presents an applied example of the calculation data of visited damp house No. 24 in Massa, the Green Mountain of Libya.

Table 8.6 Calculation of the Overall Weighting for House No. 24 in Massa, the Green Mountain of Libya

Possible Causes of Dampness for House 24	W1	W2	W3	PWC24	W1*W2*W3*PWC24
Raw Materials (sand)	0.4584	0.6912	0.4333	0.6	0.082373644
Raw Materials (steel)	0.4584	0.6912	0.4333	0.4	0.054915763
Control (concrete mixing)	0.4584	0.6912	0.2251	0.4	0.028528821
Control (storage of materials)	0.4584	0.6912	0.2251	0.6	0.042793232
Control (concrete placing & compaction)	0.4584	0.6912	0.2251	0.6	0.042793232
Control (decision of framework removal)	0.4584	0.6912	0.2251	0.6	0.042793232
Workforce	0.4584	0.6912	0.3416	0.7	0.075764235
Exterior Finishing	0.4584	0.3088	0.4235	0.4	0.023979234
Roof Design	0.4584	0.3088	0.2617	0.6	0.022226797
Water Tanks Location	0.4584	0.3088	0.1029	0.7	0.010196129
Raw Materials Selection	0.2347	0.8081	0.3431	0.6	0.039043628
Builders Selection	0.2347	0.8081	0.2432	0.6	0.027675343
Exterior Finishing Selection	0.2347	0.8081	0.1944	0.35	0.012904539
Maintenance	0.2347	0.8081	0.1366	0.01	0.000259077
Delay in Construction	0.2347	0.8081	0.0827	0.45	0.007058237
Owners Supervision (no exp.)	0.1728	0.7041	0.7126	0.5	0.043350479
Experts Supervision (PQE)	0.1728	0.7041	0.2874	0.11	0.003846427
Changes in Housing Construction Policy	0.1728	0.2959	1	0.5	0.02556576
Future Requirements	0.2347	0.1919	0.1735	0.7	0.005469978
Social Activities	0.2347	0.1919	0.0863	0.7	0.002720802
Rainy season	0.134	0.6107	1	0.2	0.01636676
GW(Sum)					**0.610625347**

The relationship between the observed damp on the ceiling/exterior walls and the possible causes of damp (AHP weights) in houses in Massa was examined. The results were presented as scatter plots (Figures 8.11, 8.12) with linear regression for the ceilings and exterior walls separately. The causes of damp or the weights are presented on the X axis and the observed damp which is the house owners' evaluation of the damp in their house is presented on Y axis. As stated earlier, the owners were asked to evaluate the level of signs of damp appearing in terms of the level of damage.

From Figure 8.11, it can be seen that the correlation coefficient for exterior walls is low R^2= 0.3846. This indicates that 38.46% of the variations in the observed damp within the houses are associated with the judgments of the house owners (b=2.1115, $t_{(50)}$ = 4.3850, $P < 0.05$). However, certain conditions can be noticed.

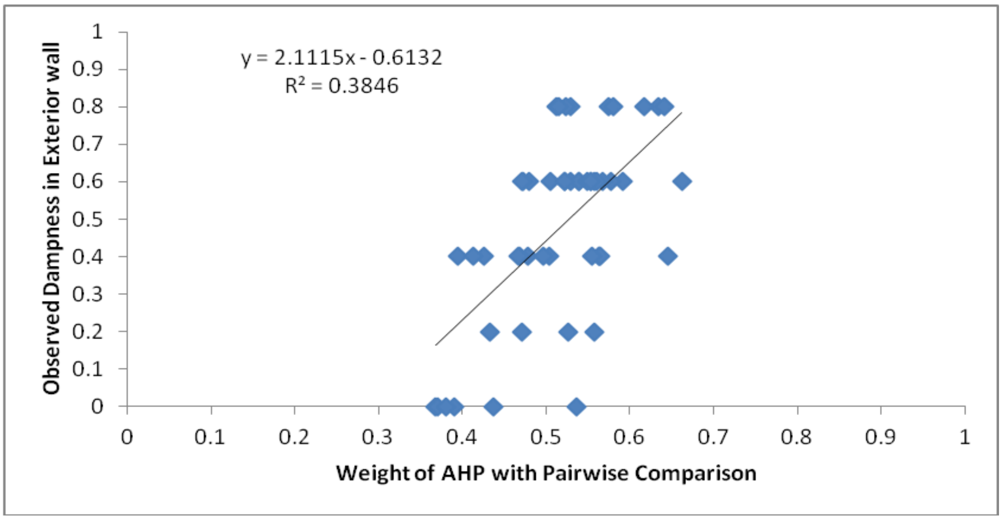


Figure 8.11 The relationship between the overall AHP weighting and the observed level of damp of the exterior wall, Massa

From Figure 8.12, it can be seen that the correlation coefficient for the ceilings is also low R^2= 0.3591 with (b=2.1582, $t_{(46)}$ = 5.0205, $P < 0.05$). The results obtained from the exterior walls R^2= 0.3846 are relatively better than those for the ceiling. However, both Figures (8.11, 8.12) have low correlation coefficients. The gradients and Y intercepts are the same for both and there are several points to either side of the regression line.

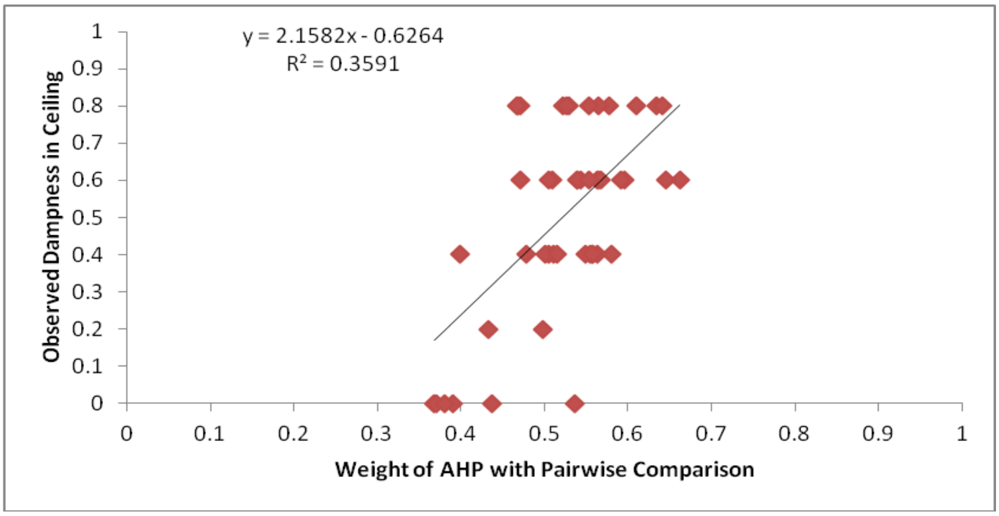


Figure 8.12 The relationship between the overall AHP weighting and the observed level of damp of the ceiling, Massa

These variations in Figures 8.11 and 8.12 highlight the varying level of awareness of the phenomenon among the houses owners. In these figures, some houses have zero observed damp although they have a considerable range of the weight from 0.3684 to 0.5368. A possible explanation for this is that, for the houses that have no signs of damp but have an AHP weight, they may have no damp at the moment but are liable to have it in the near future because the poor construction and management background under the climatic condition with the socio-economic design requirements of the houses may contribute to the presence of damp.

Continuing with the previous point, it seems possible that houses may have no damp signs but they have a high grade of the weight, due to the location of the water tank on the roof, social activity (carpet cleaning and washing on roof) and/or selection of the raw materials' and/or builders which can make the weight of the houses high. Also, the parties who undertook the construction work or owners who supervised the construction work themselves while lacking any previous experience could also contribute to increase the grade of the weight (see Table 8.6).

Additionally, a comparison of the two slopes for the results of ceiling in Albeida and Massa and the results of the exterior walls in Albeida and Massa were calculated. For the exterior walls, results indicated that ($b_{Albeida}$=2.2501, b_{Massa}=2.1115, t = 0.3450, df= 54, $P=0.73142 > 0.05$). There was no significant difference between the two slopes. For the slopes of ceiling results indicated that ($b_{Albeida}$=3.4179, b_{Massa}=2.1582, t=2.09882, df=51, $P=0.0408 < 0.05$). This showed a significant difference between the two slopes although it was small.

8.3.5 Discussion of the Massa Results

These validation results should be interpreted with caution. It can be seen that there are houses with a high level of damp but less weight and vice versa. This inconsistency may be because some houses have the problem but the symptoms are not yet showing, although the AHP result illustrates that those houses have a medium to high risk of suffering from damp.

Furthermore, there are houses with high observed levels of damp but a low grade and vice versa. This inconsistency might be due to the owners' judgments and awareness of the issue; there are some aspects such as a lack of knowledge, embarrassment about having a damp house and/or negligence of the issue itself which could affect the owners' opinions.

It is important to bear in mind that there is a possible bias in these responses which cannot be ignored. For instance, if owners with newly built houses (five years or less) have signs of damp in their properties, even if they are small spots, they consider this a problem while owners with relatively old houses (thirty years or more) do not see damp as an issue in light of the age of the house. Although building age has not been deeply considered in this investigation, its impact on owners’ expectations and judgments cannot be ignored.

Continuing with this theme, another interpretation of these results may be the lack of adequate understanding of the damp sign itself. Some house owners may have seen large signs of black patches of damp on the wall or ceiling which could have been by condensation such as poor ventilation or the owners' activities, which was not investigated in this study. Another reasonable influence on owners’ judgments could be embarrassment; the appearance of damp patches in front of guests could make the owners overestimate the importance of the issue. Alternatively, some owners may have ignored the issue, which could have contributed to the results. Owners with houses that have damp rooms that were not used frequently could distort the results; owners who did not see the damp regularly may not have considered it as an issue. Another important point is that the questionnaire technique could not be helpful in gathering data related to AHP weights.

To conclude this section, although the results are valid, the Massa damp index results are different in comparison with the Albeida damp index results. The gradients for the exterior walls for Albeida and Massa are similar, but the correlation coefficient is worse in Massa. There are three possible explanations for this: it could be argued that, when the technique is applied by the house owners and/or through questionnaire, it needs to be applied with caution, particularly with regard to damp. In support of this view, a health study using the technique in validating the elicited colorectal cancer screening preferences found that the technique is not valid when measuring patients’ preferences through questionnaires; “*it appears not valid for measuring clinical traits like sensitivity, specificity and safety or risk...therefore it must be left, for example, for experts to judge*” (Mulder, 2011, p.26).

The main limitation of the Massa data collection is likely to have been the insufficient training of the participants (house owners) for the assessment of damp. Although the

Saaty technique is a mathematical approach (Malczewski 1999; Saaty, 1980; Voogd 1983), Erensal, Öncan and Demircan (2006) argued that the AHP weights reflect human thinking which might be difficult to present in terms of numeric values. Also, Chen *et al*. (2011) stated that individuals' assessments have always involved uncertainty which may explain this kind of outcome (see Table 8.6 for more clarification). Moreover, the owners' level of knowledge and awareness of the issue is not as high as that of the experts. Additionally, adequate clarification of the level of damp could not be provided within the validation questionnaire. However, the technique in Albeida has yielded considerable results, which were obtained from the face to face interviews with experts and house owners and the observation of damp houses.

However, the technique is likely to be more reliable than other rating methods by applying the consistency test (Eddie, ChengHeng, 2001). Additionally, the technique was applied in mathematics and computer research for a validation purpose by Whitaker (2007), who stated that the benefit of using this technique is in generating debate and changing people's understanding that leads to improvements in the model or judgments.

8.4 Summary

This chapter has explained and defended the development and validation process of the proposed models of the factors causing penetrating damp within concrete houses in the Green Mountain of Libya. However, the insecurity of the country's situation at the time of this data collection limited the researcher's ability to involve more contributors within the interview section. Table 8.3 and Table 8.4 presented the models of the performance of concrete houses in the context of penetrating damp in the Green Mountain of Libya for roof and exterior walls. The validity of the weighted AHP has been demonstrated by the high correlation achieved between calculated weights and scaled observed dampness in ceiling and exterior walls within domestic concrete houses in the Green Mountain of Libya. However, caution needs to be exercised with regard to the owners' judgment, as illustrated by the verification data collected in the town of Massa. The presentation of the model development and validation methods, criteria, analysis, results and discussion can be considered as the summative evaluation of this application of the technique.

The following chapter discusses the overall results obtained after analysis of all the data and the application and validation of the AHP technique.

Chapter Nine: Discussion

9.1 Introduction

This chapter reports and discusses the overall results and the key themes of the research under two headings: causes of penetrating damp and the AHP technique. Discussion of the findings is deepened in the light of theory and previous research findings before conclusions are drawn and recommendations put forward in the concluding chapter

9.2 Causes of Pentrating Damp

From the results of the questionnaire to house owners in Albeida, it was found that penetrating damp was reported to be the most dominant type of damp. Damp was more common in newer than in older houses and the major building components affected were the exterior walls and roofs. were that suffered from damp. Regarding the exterior walls, mortar cement render and stucco paint are the most common form of finishing, The majority of damp houses were built by jobbing contractors or local construction firms and the likelihood of penetrating damp was greater when owners without previous relevant experienced carried out supervision of, and contributed by selection builders or raw materials to, the construction process, including supervision of the concrete casting stage. Poor and/or a lack of maintenance of the house were also major issues which appeared to be associated with the prioritisation given to large room sizes, high quality interior finishing and decoration, in particular of hospitality rooms. This prioritisation probably caused owners to compromise on the quality standard of construction, especially as there were indications that owners not only lack knowledge of construction but also that they experienced financial constraints. Although the rainy season and northwest wind direction were the major concern regarding climate, the northeast and southeast wind directions were also mentioned.

Photographic observations confirmed the nature of the damp and provided further detail regarding its nature. Two-thirds of the houses had damp in the ceilings and lacked proper exterior roof finishing. They had water pools resulting from rain and/or water flooding from the water tank located on the roof Just over half had visible cracks in the roof, all but one suffering from leaks from the ceiling during the rainy season. Family members in five of the twelve houses carried out some traditional social activities on the roof, such as carpet washing and cleaning.

Two-thirds of the houses had damp in the exterior walls. Various types of finishing, including rendered cement, stucco paint and tiling were used, of which stucco paint was the most frequently used because it was the most socially acceptable and available type of finishing. The majority of the defective walls had a rainwater pipe installed on them (without vegetation nearby), walls facing north-west showed more signs of damp than other walls, although some south-easterly facing walls also seemed to have an issue with damp, and four walls had visible cracks on the outside.

Calculation of the weights of the factors at each level of the original AHP model (reported in Chapter 7) showed that construction and socio-economic design factors were the major factors influencing the presence of damp. Perhaps surprisingly, management and climatic factors had less impact. The third level of criteria indicated that cost and knowledge effectiveness, construction supervision and manufacturing criteria influenced the occurrence of the problem. This confirmed that the owners' lack of knowledge when supervising construction, together with financial constraints, increased the likelihood of damp problems and had a negative impact on the quality of housing production in Libya.

Following development of the model with data collected from house owners in Massa, two AHP models were produced, one for the roof and one for the exterior wall, with the addition of a new lowest level of the hierarchy. The raw materials in concrete were broken down into five: unwashed sea sand, washed sea sand, desert sand, normal Portland cement and other type of cement. Steel bars were divided into two (rusted and un-rusted) and added to the new lowest level. Building another unit or level was added to the new lowest level under future requirements, while the practice of recruiting labour from a builders hiring market was added under workforce.

Construction design was separated to identify factors affecting roofs which did not affect exterior walls, such as whether the roof slope was faulty, and vice versa, for example distinguishing between single skin, cavity and thick walls.

These findings are discussed under each of the main factors in the models.

9.2.1 Construction Factor

The construction factor in the present research was decomposed into two criteria: manufacturing criteria and construction design. For manufacturing criteria, the importance of careful specification and selection of the raw materials and ingredients of concrete seen in the research is consistent with the literature (Bennett, 2007; Chirgwin, 1996; Rekela, 2004). Data from Massa specifically mentioned that Portland cement was not suitable for house construction in the Green Mountain area of North East Libya, although it is widely used, which illustrates the absence of technical knowledge of materials identified by Suleiman (2006) and the need for construction standards and adherence to them (Chirgwin, 1996).

The importance of skilled workers, along with knowledgeable and experienced supervision, was identified in both this research and the literature (Rahman, Memon & AbdKarim, 2012). The lack of workers with higher level skills reported by Abuhadra and Ajaali (2014) was evident in the data and can be seen in some of the photographic observations. The need for skilled workers highlighted by Mclean (2009) and Shabha (2003) is made more difficult by the existence and use of a builders' hiring market in the studies area. This was not mentioned in the literature but has a bearing on the construction industry in Libya because its effectiveness relies on the ability of owner-builders to make good judgments when hiring and on the honesty and reliability of the workers they approach or whom they approach.

For construction design, again, the research findings were consistent with the literature. Problems started in the design stage, a possibility highlighted by Bertolini *et al*. (2013), Kvande and Robert (2009) and Shabha (2003) among others. Some roofs were observed and reported to have a faulty slope, some walls were unsuitable for preventing water ingress and choice of exterior finishing did not assist to keep water out of the building envelope. Moreover, roofs constructed with concrete slabs contain water in the concrete mix which can take several years to fully dry (Allen, 1997; Desjarlais, 1995).

9.2.2 Socio-Economic Factor

The principal division of this factor was into the criteria of cost and knowledge effectiveness, and socio-religious design requirements. The criterion of cost and knowledge effectiveness incorporated the sub-criteria of maintenance and delay in construction. Thus, it essentially related to the availability of finance for either completion of construction or repair and upkeep of a completed building. Insufficient money was found to contribute to the persistence of poor housing quality, not only in the Arab world (Alvaúdy, 1992; Omar, 2003) but also in Malaysia (Bahammam, 1998) and the United States of America (Evans, 2006). Bahammam (1998) attributed these difficulties to a lack of responsibility on the part of those involved in housing design and policy. Problems with financing construction have been held responsible for delays to completion of construction in other Middle Eastern countries (Abd El-Razek, Bassioni & Mobarak., 2008). A lack of sufficient finance contributes to low maintenance or irregular maintenance, which are both associated with defects and the appearance of damp in concrete buildings (Bertolini *et al.*, 2013; Ng *et al.*, 2011; Shabha, 2003)

Socio-religious requirements significantly impacted the design of houses in the study area, as indicated by Almansuri *et al*. (2007). Separate living spaces for the sexes (Bahammam, 1998; Eben Saleh, 1997; Sobh & Belk, 2011) and large hospitality rooms with décor and furnishings prioritised at the expense of the building structure (Bahammam, 1998; Hashim, Abdul Rahim, Rashid & Yahaya, 2006; Hashim & Nasir, 2011; Othman *et al*., 2015) were evident. Development of the AHP model incorporated the need for house owners in the Arab world to accommodate the future needs of their family as children married and had children, as identified by Fadan (1983). However, the traditional social activity of washing and cleaning carpets on the roof was identified only in the present research and not in the literature.

9.2.3 Management Factor

There were two main criteria within the management factor, namely construction supervision criteria and housing policy. The research found that penetrating damp and more instance of penetrating damp were more likely to occur when an owner-builder with no previous knowledge or experience undertook much of the supervisory role. The literature identified problems associated with inadequate supervision on site such as the insufficient mixing of concrete components and an excessive water/cement ratio in situ (Rubaratuk, 2013) but the major role played by Libyan owner-builders in supervising the building of their own house was not highlighted. The supervisory role of owner-builders can be traced to the history and development of construction housing policy described in Chapter Two. It is a role that appears to be unique to Libya, at least from the viewpoint of published literature. However, the overall importance of the management factor was less than that of either the construction or the socio-economic design factor.

9.2.4 Climate Factor

The importance of climate, which has been mentioned in number of other studies (e.g. Almansuri *et al*., 2007; Bertolini, 2013; Everett, 1994; Kefei, 2009; Rekela, 2004;

Richardson, 2001; Tantosh, 2010), was not as great as the influence of the other factors, at least according to the data and the judgements of house owners and experts in the present research. However, the rainy season and prevailing northwesterly wind direction do contribute to the widespread persistence of penetrating damp and exacerbate the effects of the other factors.

9.3 AHP technique

The AHP technique offered a systematic method for evaluating subjective statements and judgments which included a mathematical procedure for producing weightings for those statements and judgments as well as employing the geometric mean in a formula for creating an aggregate figure where individual judgments differ to the extent that they be resolved only be argument or omission if a mathematical approach is not used (Malczewski, 1999; Saaty, 1980; Voogd, 1983). Importantly, it is an iterative technique and in an ideal world, with a longer time allowed to complete a PhD, a further iteration would have been applied in this research in order to try to reduce some of the differences between the results for houses in Albeida and those in Massa.

However, it can be said with confidence that up to the point where the PhD research finished, the AHP technique worked well. It did require considerable time to gather all the necessary data due to the lack of prior detailed research in the study area. Despite the fact that AHP has been used in a wide variety of problem situations (see Table 3.1), it may not therefore be suitable when there are short deadlines, when there is a single researcher or small team involved, or when the situation or problem is not large or expensive enough to justify the use of the technique . Nevertheless, the application of a consistency ratio and a technique for presenting conflicting judgments as a single figure may provide a mechanism for resolving particularly entrenched subjective opinions where these form an element of the problem situation, whether that is the analysis of a problem or the decision which follows analysis.

The concerns expressed by Erensal *et al*. (2006), regarding decision makers' greater confidence in making interval judgments than in giving a single numeric value, did not appear in the present research.

The participants appeared to have no difficulties in expressing preferences using the Saaty scale as might have been expected from Deng (1999), Erensal, Öncan and Demircan (2006) and Jaskowski *et al*. (2009) among others.

In fact, the use of the technique enabled this research to take into account human perspectives, as recommended for housing and construction management studies by Dainty (2008) and Moore *et al*. (2016). Identification of the socio-economic factor has potentially opened up a discussion about the design and construction of concrete houses in the Arab and Islamic world. Thus, its value in generating debate and changing people's understanding which can lead to improvements in the model or judgments (Whitaker, 2007) can be seen in this research.

9.4 Summary

This chapter has combined and summarised the key results and findings of the research, comparing them with published literature and identifying several factors contributing to the problem of penetrating damp in concrete houses in North East Libya which have not previously been identified in the literature. In addition, the practical application of the technique, as compared with its theory, has been examined.

The final chapter (Conclusion) reports the extent to which the overall objectives of the research have been achieved and the research questions answered.

Chapter Ten: Conclusion

10.1 Introduction

Following the discussion of key themes in Chapter 9, the thesis concludes with a summary of the main research outcomes. The chapter begins by demonstrating how the research objectives were met, and then presents the study's contributions to knowledge before describing the limitations of the research and setting out recommendations. Finally, possible directions for future research are proposed.

Poor planning, construction and provision of building services has resulted in substandard houses in Libya. Construction practices together with socio-cultural design requirements were the major concerns regarding quality standards of housing, especially when combined with owners' financial constraints. The housing and construction policies promoting owner-built housing also adversely affected housing quality, particularly when the owners had no previous experience in construction. Additionally, the geography and climatic factors along the Green Mountain coast (winter rain and wind direction) had a direct effect on the housing patterns.

10.2 Research Objectives

This section reports the achievement of the research objectives.

Research Objective One: To examine factors causing penetrating damp in concrete buildings. This objective was achieved mainly through the literature review, although the fieldwork in Albeida and Massa revealed additional local factors which were not mentioned in the literature, namely the use of washed or unwashed sea sand, builders' hiring markets, and washing and cleaning carpets on the roof. The interaction of human factors with natural and environmental factors was highlighted, as was the relationship between construction and housing policies, standards or codes, design, materials and workforce skills. A summary of the factors causing penetrating damp is provided in Table 10.1 for ease of reference.

Table 10.1 Factors causing penetrating damp in concrete buildings

Main factor	Sub-factors
Material	Concrete: lack of specification of raw materials (components of cement, type and size of aggregate, additives)
Type of Concrete	In-situ: lack of specification of processes, insufficient mixing, too much water in water-to-cement ratio, impurities in raw materials, drying conditions, insufficient cover for reinforcement with well compacted concrete
Type of Building	Domestic houses with flat roof: design of building envelope, masonry wall may need rendering to prevent water ingress
Causes	Construction factor: lack of or failure to apply standards or code of practice, water trapped in concrete core, concrete roof taking 6-7 years to fully dry, movement in foundations, leaks from water tanks, house design using single skin wall with flat roof Socio-economic design factor: private space, separation of living and hospitality spaces for men and women, additions and changes to the original building over time, financial constraints, little or no maintenance, delays in payment and/or completion Management factor: owner-builders do not always have the necessary skills, housing policy sets the context Climatic factor: in wet and windy areas, pressure differential may be more important than climate

The importance of appropriate specification and selection of raw materials and ingredients concurs with Bennett (2007) and Rekela (2004). Moreover, the importance of technical knowledge of materials (Suleiman, 2006) was underlined by the finding from Massa that Portland cement was unsuitable for house construction in the Green Mountain area of North East Libya, despite its wide usage. The need for adherence to established construction standards (Chirgwin, 1996) is evident.

For the type of building, in the sense of construction design, the importance of avoiding faults in the design stage, such as incorrect roof slope in the present study, by appropriate design was noted by Bertolini et al. (2013) and Kvande and Robert (2009) among others.

A lack of adequate funds, potentially associated with a failure of responsibility at the level of housing design and construction policy, is supported by Omar (2003) and Abd El-Razek *et al.* (2008). Moreover, insufficient finance has been associated with inadequate maintenance and the appearance of damp in concrete buildings (e.g. Bertolini et al., 2013; Ng et al., 2011).

Socio-religious requirements which affect house design were identified by Almansuri *et al.* (2007), including the separation of living spaces (Sobh & Belk, 2011) and hospitality rooms, with the latter furnished at the expense of the building structure (Hashim, Abdul Rahim, Rashid & Yahaya, 2006; Hashim & Nasir, 2011; Othman et al., 2015). Traditional social activities of cleaning carpets on the roof and splashing water on the house to clean it were identified only in the present research.

Whilst poor mixing of concrete had been highlighted by Rubaratuk (2013), the supervisory role undertaken by Libyan owner-builders does not seem to have been recorded previously in published literature. The need for supervisors with appropriate skills, knowledge and experience was highlighted in the literature (Rahman, Memon & AbdKarim, 2012). A lack of skilled workers (Abuhadra & Ajaali, 2014; Mclean, 2009) was exacerbated by the use of a builders' hiring market in the present study.

The relative importance of climate was judged to be lower in the present study than in research by Almansuri *et al.* (2007), Bertolini (2013), Kefei (2009), Rekela (2004) and Tantosh (2010).

Research Objective Two: the second object of this research was to investigate the nature and severity of the damp problem in concrete houses in the Green Mountain, North East Libya. This was achieved through distributing 400 questionnaires to house owners in Albeida and analysing the responses of 297 fully completed questionnaires from a total of 302 returned (response rate 74%). Photographic observations of 12 damp houses in Albeida confirmed the existence of penetrating damp and provided triangulation of data regarding the location and severity of damp reported in questionnaire responses. Penetrating damp was reported to be the most dominant type of damp, with 58% of the properties having damp in the building envelope (ceiling, exterior wall or both ceiling and exterior wall). The findings were largely corroborated during the model development phase (Chapter 8) by fully completed returned questionnaires from 61 house owners in Massa (61 of 150 questionnaires distributed, a response rate of 40%). In total, 85% of house owners in Albeida and 90% of house owners in Massa reported the presence of damp. Overall 48% of houses had damp in both ceiling and exterior walls, 18% of houses had damp in only the ceiling, while 24% of houses had damp only in exterior walls. The modal reported level of damp was medium.

Thus, it can be said that the nature and severity of the damp problem in concrete houses in the Green Mountain, North East Libya, was investigated. In fact, Chapters 5 to 6 elaborate on the detail and causes of the damp. The quality of the Libyan housing production system was found to be low. The owners' financial constraints led to the selection of poor materials, unskilled workers and poor quality control of construction practice. The major socio-cultural and economic design requirements for Libyan houses were prioritising houses with large room sizes, high quality interior finishes, decoration and hospitality rooms. Poor and/or a lack of maintenance of the house were additional contributory causes. The finding is consistent with (Abdalla, 2007; Omar, 2003 and Ruddock, 2001). Construction housing policy and climatic conditions contributed to the problem, but were of less concern when compared to the construction and socio-economic factors.

Research Objective Three: In order to meet the third research objective, the construction of an AHP model to evaluate the importance of each factor, interviews with experts and house owners (including owner-builders) were conducted in Albeida for the purposes of deriving weights for the various factors (see Chapter 7). The factors of construction and socio-economic design were found to have the greatest weights, together with the financial constraints of the owners. Perhaps surprisingly, management and climatic factors had less impact, in terms of their order of importance, on the occurrence of damp.

Research Objective Four: the fourth objective of the study was to develop the model in order to promote deeper understanding of the damp problem in the Green Mountain of Libya. This was achieved through questionnaire and interviews with house owners in a second town in the Green Mountain called Massa (see Chapter 8). Data from these research methods led to the addition of another level of the model (the lowest level).

It was understood that unwashed sea sand, the type of cement and the condition of steel bars were among the specific causes of damp occurrence. The design of exterior wall and roof, leakage from water tanks on roof and type of exterior finishing were also among the concerns. Large room sizes, hospitality rooms and a high quality of interior decoration as well as future requirements were highlighted. Additionally, owners' supervision without previous experience resulted in building defects. Jobbing contractors and local construction firms were the main parties who undertook the construction of the houses.

Also, the model was split into two, one model related to the ceiling and the other related to exterior walls, in which some shared sub-sub criteria reflected the design and construction ideas that were the key parameters in preserving good concrete house quality. It is interesting that the new sub-sub-criteria identified in the fifth level include building another unit or level and the local practice of a builders hiring market. These were added to both models (roof and exterior wall) and highlight the AHP technique's ability to capture specific local elements of a problem or a decision. The addition of international construction firms under housing policy confirms the difference in quality of building that was identified in the history of construction in Libya highlighted in the literature review. Additionally, the separation of the two models improved the representation of the real world situation by enabling different weights ot be given to the same element in the different models.

The final weights of the factors influencing house performance in the context of the penetrating damp, including the sub-issues related to each factor, were construction and socio-economic design (Table 7.21 refers). Although management and climatic factors had lower weights and therefore less impact, in the third level of the model, cost and knowledge effectiveness, construction supervision and manufacturing criteria were seen to affect the occurrence of the problem.

Research Objective Five: The final research objective was to validate the model by examining its effectiveness in a very similar location. A town 10Km distant from the study area which shared the same climatic conditions and culture provided a suitable test. Comparison between the AHP weights calculated for houses in Albeida and Massa (see Chapter 8) showed they were slightly different. Clearly the model would reflect the research problem in Albeida because it was largely constructed on the factors identified

there. It is interesting that the results for Massa were not the same. This could be due to different owners making different judgments, or a lack of understanding and awareness about the problem of damp on the part of the owner, or an inappropriate choice of a questionnaire technique as a data collection tool for generating AHP weights.

Alternatively, the results may simply be less generalizable, for example because different builders are involved even in a town so close to another.

10.3 Research Questions

Meeting the research objectives enabled the research questions to be answered.

1.What factors cause penetrating damp in domestic concrete houses in the Green Mountain area of Libya?

The factors have been summarized in Table 10.1 and were constructed into a hierarchy of weights which indicated their relative importance through the application of the AHP technique. It was found out that construction, socio-economic design, management and climatic factors with their criteria and sub-criteria cause penetrating damp within concrete houses in the Green Mountain Region in Libya

The second research question asked:

2.How effective is the AHP technique in modelling the relative importance of factors in a very similar area?

This is an important question because the technique has been used to develop and propose assessment frameworks in a variety of contexts while validation has typically been carried out by computational methods (i.e. cross-checking the mathematics) or by comparing the weights against the real-life situation from which they were derived. Thus, the answer to the question fills an important gap in the recorded knowledge. The weightings from the technique were successfully applied with the Albeida data, but did not correspond as well with the Massa data. However, the benefits of generating debate and changing people's understanding could apply equally in both areas, leading to improvements in the quality of house construction.

In respect of generalisability and repeatability, unlike quantitative researchers who seek causal determination, prediction, and generalisation of findings, qualitative researchers seek instead illumination, understanding, and extrapolation to similar situations (Hoepfl, 1997).

Although the ability to generalise findings to wider groups and circumstances is one of the most common tests of validity for quantitative research, Patton (2001) stated that generalisability as a criterion for qualitative case studies will depend on the case. In this sense the validity of quantitative research is very specific to the case and the test applied to measure it.

It is proposed here that the process of making and comparing judgments through the technique can encourage the adoption of more appropriate forms of construction in developing countries and that the weights produced in the present research can point to assessment criteria for future housing projects in those countries. Unless or until validation is carried out through individual interviews which offer a better opportunity to explain the comparison technique, which will determine whether the use of a questionnaire was inappropriate for house owners in Massa, it cannot be said with confidence that the AHP weightings can be applied to a very similar situation. However, it can be said that the process can make a positive contribution to addressing the quality of concrete housing construction in similar circumstances.

10.4 Research Contribution to the Knowledge

In answering the research questions, four contributions to knowledge that lead to recommendations for changes in practice; each contribution provided a foundation for guidance and the enhancement of the housing quality programme. The contributions to knowledge are:

Contribution one: a contribution to research methods in housing and construction study. This study has demonstrated how Analytical Hierarchy Process method can be employed as an analytical tool to construct a model of factors causing penetrating damp within concrete houses. The study provided effective assessment criteria to improve the quality standard of housing production. After this study, stakeholders such professionals and house owners are able to adopt the technique within housing and construction programmes.
In fact, the implementation of the study has enabled the evaluators to produce a specific housing and construction information plan for each construction type.

Contribution Two: role of socio-economic factors which have become increasingly taken into account in housing studies yet continue to be neglected in construction research. In fact, it has potentially opened up a discussion about the design and construction of concrete houses in the Arab and Islamic World.

Contribution Three: This study has shown that AHP technique offers a way of gathering, compiling and integrating the knowledge and judgments of different stakeholders while avoiding conflict and disagreement among them. It has deepened the understanding of experts and house owners alike, enabling all their voices to be heard.

Contribution Four: This study also made a national contribution to knowledge. It is the first of its kind to take place in Libya, investigating factors causing penetrating damp in domestic concrete houses. It can contribute to enhancing the level of understanding of the most important factors involved in the issue, by drawing attention to the factors responsible for the existence of damp. Academics in the field of construction, policy decision-makers and construction companies could make use of the study findings to convince developers to provide better structural and environmental elements.

10.5 Research Limitations

The limitations of this study are:

Limitation one: There was a lack of literature resources and references that referred to the same construction materials and methods as those of the study area (flat roof, single sheet of exterior walls and using in-situ concrete). However, the literature review included developed and developing nations, particularly those that adopted the study area's construction materials and method in order to overcome this limitation.

Limitation two: The representative sample size of the observed and photographed houses was limited by the requirement for permission to be granted by owners and by the time constraints of the research schedule for data collection. The same limitation applied to the sample size of each panel of the interviews.
Moreover, the study was conducted during a time of civil unrest, which made it quite dangerous for both the researcher and the participants, therefore, it was considered sensible to minimise unnecessary risks.

Limitation three: Due to the limitation of the time, after the development of the level 5 of the proposed AHP models, a further repetition of weighting calculations should have been conducted. This would have further supported the research findings and potentially enhanced the validity of the models. However, it could be set as future work

Limitation four: Caution should be taken regarding the validity of the models. Although the Analytical Hierarchy Process has not been used yet within concrete housing defects, the questionnaire might not be the right method for obtaining the comparative judgments, or at least the questionnaire has to be tested before collecting the main data.

Limitation five: Generalisation of the findings should be done with great care and caution, although the benefits of generating debate and promote understanding mean that the process may be useful even if the findings are not generalisable.

10.6 Future Work and Recommendations

From this research, lessons can be learned for the current practice of the development of the construction community. The research complements the direction of the construction industry with regard to minimising construction defects or adopting damp surveying programme with a view to remedying defects. The following points are recommended:

1. Presenting the models to the decision makers in Libya.
2. Presenting the models at future national and international conferences and symposia, particularly those in developing nations.
3. Action research related to the defects of residential buildings in the Green Mountain in Libya is needed.
4. Since Saaty's technique is a continuing procedure (Saaty, 1980), re-evaluating the proposed models is recommended and the possible development of a best practice model for the performance of houses in the context of damp is recommended for future investigation.
5. Working on each factor separately through a case study approach would be a valuable research paper.
6. National and/or international statistical comparison research is highly recommended, particularly within Arab societies and/or developing countries.
7. Applying and comparing other mathematical analysis tools is recommended in future research that investigates damp in houses.

8. For the AHP technique, caution needs to be taken with regard to the owners' judgments, as illustrated by the verification data collected at the town of Massa, Green Mountain Region. More advice and information to allow more accurate decisions by house owners is recommended.

10.7 Benefit from this Research

Various stakeholders will benefit from this study: Libyan stakeholders; the Islamic and Arab World where there are similar circumstances; and developing nations that have similar policies and environment; for instance, the same construction policy, environment, culture or social conditions. Indeed, society as a whole can benefit from this study, including the decision makers, designers, architects, construction managers, technicians, constructors and, above all, the occupants/house owners. In fact, the study enhances their understanding of the occurrence of penetrating damp; adoption of the technique could empower communities to make their own contribution to the process of improving their housing conditions. Additionally, from a mathematical point of view, researchers from various subject areas who are going to apply the technique will be interested in reading this research.

Finally, the researcher herself benefited from conducting this study. Prior to this research, it was known that there were climatic, construction and management issues. However, additional contributory factors such as the importance of manufacturing criteria in construction, especially the raw materials and workforce, and the considerations of cost and knowledge effectiveness in socio-economic design requirement were discovered through this research. The researcher has clearly understood what the problem is with the concrete houses in the Green Mountain area. Now she has a comprehensive knowledge to start investigating more deeply, and has provided a foundation of knowledge which will enable others to investigate each factor separately in greater depth. Also, she learned how to apply the AHP technique within construction and housing studies.

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12. Appendix A.

Result of the Pilot Study

Methods

The case study adopted multiple methods following; Snow and Anderson (1991) who maintain that triangulation can involve data, investigators, theories, and even methodologies. The study comprised an exploratory questionnaire sent to the occupants of randomly selected residential buildings and building investigations. Fifty questionnaires were distributed and thirty completed, providing a response rate of 60%. The questionnaire addressed the age of the occupied buildings, damp location in the house in terms of room types and structural elements, the time and duration of the damp occurrence of the year, its effects and any previous attempted remedy or maintenance actions. The final question asked whether damp in the property was considered a problem or not. Additionally, five selected houses, suffering from damp were investigated by visual observation with photographs taken.

Questionnaire Results

Statistical analyses were made in SPSS software for the closed questions. Descriptive analyses with frequency and chi-square tests were used for the major variables. Nvivo Software was used for the open-ended questions. Interestingly, there was no significant association between the occurrence of damp and the age of the building, although damp was more common in houses under 10 years old. Additionally, there was no significant relationship between vegetation growing near to the affected walls and water ingress. Faulty or blocked gutters or rainwater pipes were one cause of water ingress, but not the dominant cause. However, there was a clear relationship between wall orientation (north-west facing) and the occurrence of damp with particular problems occurring after the first two weeks of the annual rainfall. All respondents considered signs of damp in their properties to be a a problem and it has various obvious effects such as the appearance of the domestic interior, impact on the health of the occupants, damage to furniture and structural damage.

Figure A1 shows that some 42% of the damp occurred in the living room and 23% in the bedrooms; kitchens and bathrooms, however, had the smallest percentage of damp occurrence.

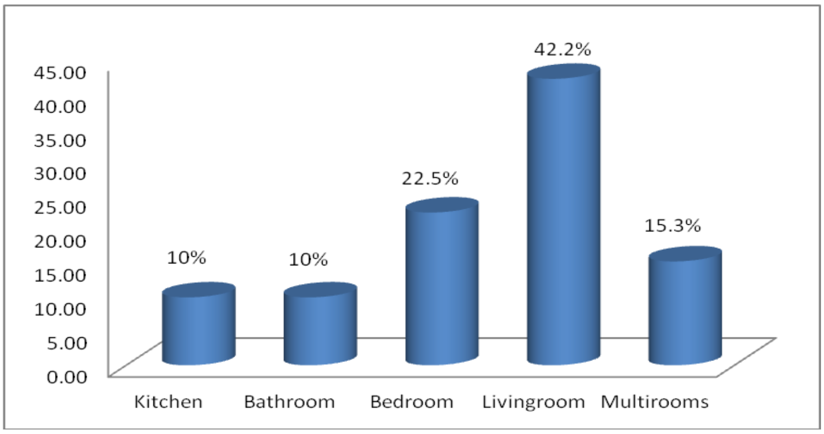


Figure A1. *Percentage of Damp by Room*

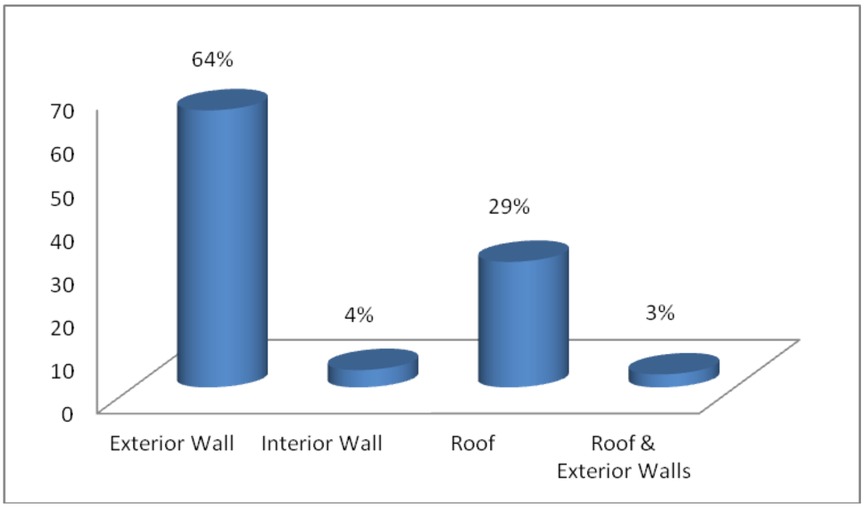


Figure A 2. *Damp Location by Structural Element*

Figure A2 provides further analysis and explanation. It can be seen that building envelopes are the most problematic elements of the construction of residential buildings.

Photographic Observation

Within the case study, five different houses were photographed. Permission was not granted to photograph Case 5, although visual observation was carried out.

Table A1. *Summary of the Most Likely Primary Damp Causes for Ceiling*

House No.	**1**	**2**	**3**	**4**	**5**
Exterior finish	B1	B1	B1	B1	B1
Cracks	x	C2	C2	x	x
Damage to decorative finish	D1, D2	D1, D2 & D4	D3, D4	D1, D3	D2, D3 & D4
Water ponding	√	√	√	√	√
Water leaking through ceiling	x	√	√	√	√
Orientation(s) of affected area	NW, NE	SW	All	All	NW
Type of repair	F1	F1	F2	F3	F
Social activity on flat roof (carpet washing & cleaning)	√	√	√	√	x

Table A2. *Summary of the Most Likely Primary Damp Causes for Exterior Walls*

House No.	**3**	**5**	**6**
Exterior finish	B3	B3	B2
Cracks	C2	X	x
Damage to finish	D3, D4	D2, D4	D1, D2
Rainwater downpipe	x	√	x
Orientation of wall	NW	NW	SE
Type of repair	F2	F4	F4

Note.

B. Type of exterior finish
B1 Grey cement based render
B2 Ceramic/tiles finish
B3 Stucco paint

C. Visible Cracking
C1 Internal cracks
C2 External cracks

D. Damage to decorative finish
D1 Mould patches
D2 Stains
D3 Blistered paint
D4 Peeling paint

F. Type of previous maintenance/repair
F1 Repair of the house interior
F2 Repair and recoating of the affected area
F3 Recoating the roof from outside with cement mortar and bitumen, then re-painting the ceiling of the house (**OR**) Re-painting the interior walls of the house and filling of any cracks and/or holes
F4 None

Summary

All results together reveal a high probability that,

1. Penetrating damp is the dominant damp type in the properties analysed.
2. Two further possible causes are the climatic aspect and the construction system, in particular construction errors. Son and Yuen (1993) recommended that construction sites operate with unequivocal instructions in terms of materials, standards of workmanship and sufficient quality control during the construction process.

3. Observations and photographs highlighted financial and socio-cultural aspects which could be a cause of the damp occurrence;

For more information see (Laeirj *et al*., 2013)

13. Appendix B.

Ethical Considerations

Sheffield Hallam University

Our Ref   AM/SW/26-2013

23 December 2013

Iman A A Laeirj
11 Headford Mews
Sheffield
S3 7XL

INTERNAL

Dear Iman

Request for Ethical Approval of Research Project

Your research project entitled "**Identification and Evaluation of Factors Influencing Damp Occurrence in Residential Buildings in Libya**" has been submitted for ethical review to the Faculty's rapporteurs and I am pleased to confirm that they have approved your project.

I wish you every success with your research project.

Yours sincerely

Professor A Macaskill
Chair
Faculty Research Ethics Committee

Office address :
Business Support Team
Faculty of Development & Society
Sheffield Hallam University
Unit 4, Sheffield Science Park
Howard Street, Sheffield, S1 1WB
Tel: 0114-225 3308
E-mail: DS-ResearchEthics@shu.ac.uk

Confidentiality and Anonymity

Managing issues of confidentiality and anonymity in research is an important agent. The anonymity and confidentiality of participants through the research process must be respected as well as the personal information, concerning research participants, must be kept private (British Sociological Association, 2002). However, in practice, there is various difficulties researchers experience through the research in relation to the issues of confidentiality (Wiles *et al*., 2008). Gregory (2003) stated that qualitative research has been identified as problematic in response to the concern of ensuring confidentiality in the presentation of outcomes. In order to avoid this kind of issues the following points were taken into consideration: this study does not contain sensitive data in relation to the householders' name, age, sex and ethnicity, disability and others. It contains data in connection with the dampness in houses for which it may be considered a sensitive data. Therefore, confidentiality and anonymity were demonstrated in every stage during the research process.

In relation to the survey questionnaire, no personal details were required and no sensitive issues or stressful questions were asked. Each occupant was received an Arabic version of a printed questionnaire and, including an explicit information sheet in the front page, explaining the nature of the study, the study aim, the name of the investigator and the organization who is conducting this study. The house owners were informed in the information sheet that their participation is voluntary, there is no right or wrong answers, they have the full right to not answer any undesirable question and how this data will be used within the project with confidentiality and security statement. It was explicit that the returned questionnaire will be anonymized and secured. Additionally, regarding the confidentiality and anonymity of the observation and Photography, in the consent sheet, it was declared that the photographs will be anonymized and secured. For the interview, in the consent sheet also, it was clarified that their conversation and discussion will be anonymized and protected.

Objectivity of the Researcher

Davies and Dodd (2002) pointed out that displaying a method that is objective in the research process is a crucial element of rigor. Yes, it has by now been well debated that the elimination of subjectivity in research is impossible or a very hard task (Haraway, 1988 and Harding, 1991).

Research challenges many of the principles of so called good and rigorous research, in particular qualitative research (Davies and Dodd, 2002). However, this study remains objective and free of bias and researcher value. No powerful view and/or enduring were enforced in order to ensure validity and true value. Strict application of research methods was devised to overcome the subjectivity within the research process. For instance, the interface between the investigator and participants; distance was kept between the researcher and research objects during the research process as essential in maintaining objectivity. Additionally, in respect with sampling and in response to such concern, particular sampling techniques for selecting research participant was applied to meet the criteria of good research that, its findings could be generalized. Social networks by using snowballing technique were applied for the data gathering system. This strategy is as a method of contact in a practical sense not a method of sampling. This is because the participants under investigation are hard to obtain due to the sensitivity of the topic and identifying properties with damp in them during the data collection procedure with the house owners. Hendricks, Blanken and Adriaans, (1992) stated that snowball technique offers practical advantages for an explorative, qualitative and descriptive study. Moreover, it seems that snowball method has a wider applicability in sociological research. This would be useful in the context of the Libyan society and culture. Moreover, in response to the concern of finding respondents, selection bias, informal research assistants. People in positions of specialist and/or authority relative proximity can provide a route into the required participants (Groger *et al*, 1999) such as Local housing officers, staff of the city council. Large sample was generated for the survey with the householders and involving volunteers, as much as possible, within the interview process. Further, confidentiality was assured and demonstrated over time during the research process for all participants. To conclude this paragraph, a sense of responsibility, accountability and objectivity within the research was taken in to account during the research process even when seemingly disordered.

Informed Consent

Bulger, Heitman and Reiser (2002) stated that informed is a typical guideline to influence researchers to behave ethically at all time. Indeed, it promotes the rights of contributors as independent beings to ensure that the participants are treated with justice, kindness and respect. For this to occur in this study, all participants were fully understood the nature of the study through providing an attached information sheet with the survey questionnaire, house owners consent form to obtain the properties and construction site, Professionals consent forms to conduct the interview panels. However, in practice, this does not always occur. Therefore, in this study, additional care and time was taken when the consent forms were obtained (Lee *et al*., 2001). Participants need to understand and realize the importance of the research and the importance of their voluntary participation in order to avoid any misunderstanding. For the purpose of demographic analysis and geographical location of the study area, all consents were translated and provided into an Arabic version with explicit clarification and justification of the purpose of the academic research for all participants. Having an appropriately interpreted consent form is essential for contributors who do not speak English (Baker, Hayes, and Fortier, 1998). The researcher took the necessary steps to ensure that participants completely understand what is stated in the consent form. Signature was required at the end of each form, including the information sheet of the survey questionnaire. All participants were treated according to the ethical standards set by the Belmont report and Nuremberg code in the context of respect for individuals, be treated as autonomous agents capable of independence, providing voluntary consent without any undue influence (Bulger, Heitman and Reiser, 2002).

Conflict of Interest

A conflict of interest exists "*when legal obligations or widely recognized professional norms are likely to be compromised by a person's other interest"* (Shipp, 1992) quoted from (Lemmens and Freedman, 2002, p.554). Another definition by Orlowski and wateska (1992, p.273) who stated that conflict of interest is *"a discrepancy between the personal interests and the professional responsibilities of a person in a position of trust"*. The declaration of Helsinki stated that experimental processes including human subjects need to be revised by independent committee (World Medical association, 2000). Therefore, Principle of management of conflict of interest was taken into consideration. No personal considerations were compromise, or had the appearance of compromising a researcher's professional judgment in conducting this study. Response to the concern of dealing with or interviewing mangers of construction firms or companies which install damp proof courses, the impartial and unbiased of the researcher were fully and clearly stated. Additionally, this was made clearer to the house owners; no repair application and/or advice were offered or introduced. Further, in the light of officers' interviews and under the heading of bias, it was fully stated that this study is an academic research the phenomenon (issue) cannot be repaired or solved. This is out of the investigator responsibility in the region. In contrary, the research aim is to highlight factors causing dampness occurrence within domestic houses. In this respect, distinction between the research aims and ethics are integral part of the way of research approach, research questions, participants' responds and reflection on the research materials.

Data Storage and Protection

The data collection was processed in accordance with the right of data protection act (DPA). The data obtained was relevant and not excessive in relation to the purpose of the study. Additionally, it was only used for specified and lawful purpose and it was not be used for further processed in any manner unsuited with the study purpose. All data was put into anonymised and secured storage place. For instance, the data was stored in a computer hardware, which requires a password to login; password protection, encryption and facilities were fully used to restrict access on the basis of authority levels for electronic files. Personal password was changed regularly, protected and not divulged to others. The back-up copies were stored separately from other files; USB stick, tape-recorders, camera, photographs, manual documentation were appropriately protected and kept into locked storage when not in use.

Carefulness was taken when taking the personal data off-site and during the journey from Britain to Libya and vice versa. For instance, laptop, data stick, tape-recorder, camera and manual documentation were secured and kept with the investigator during transportation on public transport. The same principle and security procedure was applied to the data storage and protection when the investigator was working at home, for example family, friends or other visitor cannot gain access to the data collected (Williamson, 2012).

Encryption policy was applied to encrypt all data transferred onto portable devices such as laptop, USB sticks in order to avoid any damage or distress to the data and/or researchers. A pre-encrypted USB was used for electronic data storage. Manual data was stored into one of the university store, which are a locked storage and the storage based in one of the unit at the university that, requires an accessible card to get in (Hayes, 2012).

The data will not be kept for longer than it's necessary for the purpose of the study. Disposal will be carried out through official processes. Electronic data will be deleted; photographs and manual documentation will be shredded.

Means of Withdrawing from the Research

All participants were provided with sufficient time to consider whether or not they want to contribute within the research. More importantly, all informed consents were provided the participants with the right to withdraw from the study at any time and stage. Investigator stressed on this by stating that choosing not to participate or leaving the study at any stage will be normally expected and respected from you (adopted from Brockopp and Hastings-Tolsma, 2003). In order to avoid hesitation in expressing that they do not want to continue with a project; the right of withdrawing was reiterated in every stage during and after the data collection, therefore, they had the full right to withdraw from the study at any time. Full contact details of the researcher was provided in order to inform the researcher if any participant decided to withdraw from the study after the data collection will be completed. Additionally, if anyone of the participants showed signs of boredom, discomfort and/or distractions; this was taken as an indication of withdrawing informed consent. Additionally, there was a procedure for making complaints; full contact details of the university and research institution support team were provided in the information sheet of the questionnaire and at the end of each consent form.

Researcher Personal Safety

The field work was conducted in accordance with the SHU lone working policy. A schedule date was set for the data collection. In relation to the interview sessions, all interview sittings were held in public institutions. Further, as the investigator is a female, culturally and religiously, she requires to be accompanied with one of her male relatives such as a husband, brother or father. This relative was not attending the interview session or entre the property (he was waiting outside the interview room or the outside the property) for a confidentiality and anonymity purpose unless one of the participant does not mind (provide his/her consent). Further, a stamped envelope, containing the date, venues, starting time, duration and completion time of the session, was prepared before each interview/house visiting session and kept in a safe place. A member of a family or a close friend was informed that if the investigator could not call him/her at a particular time. This member of a family or a close friend needs to go and open the envelope and make further action. Otherwise, this envelope was destroyed when they returned back from the visit/session.

The Libya's Distinction of Political and Social Context Impact on Confidentiality, Objectivity, Data storage, Anonymity and Informed Consent

Due to the nature of the study, more attention was paid to the management of the ethical procedure through the research process. Official permission was obtained from the researcher's sponsor (Libyan Embassy) in order to collect the data. Additionally, official consent was obtained from the region city council to conduct the fieldwork. Further, it was crystal clear that confidentiality and anonymity was insured through the research procedure. All the collected data was saved and kept in a private place. All participants were protected to not be known or discovered to others or to the authority. All participants including the house owners and professionals could not be harmed. The right of withdrawal was repeated and respected in every stage of the research process. More importantly, there was no collaboration or connection between the house owners and professionals. It was made clearer that this research is an academic program of study.

In response to the concern of partiality of the government approved data sources, yes, this is true as this exists in any country not only in Libya. Government approved sources contain inaccuracy and bias. However, this could be overcome by collecting data from multiple sources. This way of evidence could be validated by the triangulation of data. Other international sources that discussed this area of study in Libya or other similar nation (have the same conditions) was included in the study. More importantly, in respect to the current situation in Libya and what the country has been experienced through since 2011, old sources that are not affected and disturbed was used by the revolution/war.

Data Collection Period

The data collection periods in the Green Mountain Region are divided into two phases; it was for two months and a half (December/February 2013/2014) for conducting survey questionnaire with the occupants and direct observation with photographs for damp houses. The purpose of the visit is to collect data for analysis and inclusion within the theses. This particular time was designed and planned depending on the research schedule and it can be a proper time for recognizing and identifying the dampness sings in the residential buildings (from December to March). Additionally, it is a good time to circulate the survey questionnaire in order to obtain a natural opinion and perception from the householders as the phenomenon is there (in case that the property has already damp or started to suffer from damp because of the rainfall). Sitting a particular date and time for the property visit, to obtain observation and photographs, depended on the house owners" consent and convenience time. The second phase was for another two months for conducting the interview (July/August 2014). The case was not different in relation to the date and time of the interview session. However, plan and design was sit after the completion of the first phase (questionnaire and observation with photograph data collection) in order to sufficient time to construct and develop the hierarchy.

Table A.1 *Conducted Data Collection Period*

From the 22th of December 2013 to 22th of March 2014											
NO	Description of Data Collection Methods	MONTHS	Year 2013	Year 2014							
			Dec.	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**August**
1	Survey Questionnaire										
2	Observation with Photographs										
3	Interview										

14. Appendix C.

Survey Questionnaire

An English Version of the Survey Questionnaire

Sheffield Hallam University

SHARPENS YOUR THINKING

Sheffield Hallam University
Faculty of Development and Society
Natural and Built Environment
PhD in construction Programme

This study focuses on identification and evaluation of factors influencing damp occurrence in concrete residential buildings in Libya. It is a completely an academic study. The investigation is part of my PhD study in Sheffield Hallam University. As an important, but extremely under an academic research area, I would very much appreciate your cooperation in this investigation. The main aim of the study is to identify and evaluate socio-cultural and technical factors that cause the occurrence of damp.

I would very much appreciate your cooperation in the completion of this an exploratory questionnaire. There are no right or wrong answers. Please provide your honest and spontaneous opinion. However, you have the full right to not answer any undesirable question. Additionally, your responses are confidential and secured and you have the full right to withdraw from the study at any stage (before, during and after the data collection period)

As an academic researcher, I am going to be an objective through this study process. No repair application or advice will be offered or introduced by the investigator.The study finding will be used for an academic research only.

Do you agree completing this questionnaire?

☐ **Yes, I agree**

☐ **No I do not agree**

Could you return this questionnaire to the collected place, please?

Iman Laeirj

Sheffield Hallam University

Unit 9 Science Park Soc,

Howard St. S1 1W **Email: Imam.a.laeirj@shu.ac.uk**

Tel: +447405684776 **+21892427623**

Part One: Property address

No. of Questionnaire:……………………………….

Location (city)…………………………………….

Area …………………………………………….

Code:………………………………………………….

Part Two: Technical Factors

Q1. What is the type of your property?

☐ Flat ☐ One-floor house ☐ Multi-store hpuse

Q2. What is the age of your property?

☐ <10y ☐ 11-20y ☐ 21-30y ☐ 31-40y ☐ >40y

Damp Identification

Q3. Do you have any issue with dampness appearance or water getting into your property?

e.g. (Visible mould or damp stains or water leakages on walls, floors and ceiling or detached in ceramic tiles or paint

☐Yes ☐ No

***Note*. If (Yes) please go to the next question, if your answer is (NO) go to question 12 please, however, could you not forget to read the last note in this questionnaire which is in the last paper, please?**

Thank you for your cooperation.

a) There are pictures above to what happens if dampness is present. Do you have any of these in your property? If there is any in your property, tick all that apply and answer the next question please.

☐(a)

☐(b)

☐(c)

<u>Dampens Location and Distribution in the Property</u>

Q4. Where does dampness occur in your property?

☐ Kitchen ☐Bathroom(s) ☐Bedroom(s) ☐ Living room

☐ Others, please specify____

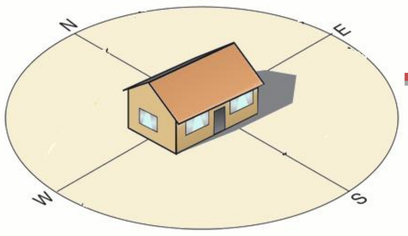
Q5. Where does dampness occur in your room?

Note. (External walls that protects the building from the open air)
(Internal walls are those with no windows)

☐ Ceiling ☐Exterior wall ☐Interior wall ☐ Floor

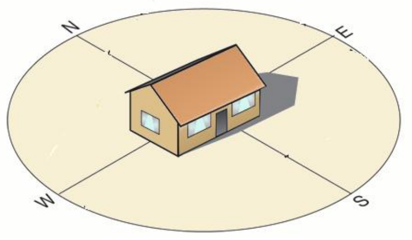
Q6. **Kitchen**

No Damp in the Kitchen (please go to Q6)? Damp in (tick all that apply)?	*Note*. (External walls that protects the building from the open air) (Internal walls are those with no windows) (Dampness signs on the inside of your house)

Celling? Yes	Damp in Internal walls Yes	Damp in External walls Yes
In the middle of the ceiling In the area between ceiling and wall Spread everywhere Don't know/ not sure	in upper section of the wall In the lower section of the wall In the middle of the wall around the door Don't know / not sure	in upper section of the wall In the lower section of the wall around the window Spread everywhere Don't know / not sure
Are there damp patches/stains/ blistering/ peeling paint in the ceiling? Yes No Is there a leak in the roof? Yes No	Does the affected wall share with the bathroom? Yes No	Does the external wall have gutter rainwater pipe from outside? Yes No Does the external wall have vegetation from outside? Yes No
Is the affected ceiling directly over the cooking area? Yes No	Is the affected wall near to the cooking area? Yes No	Is the affected wall near to the cooking area? Yes No
Using the picture below please answer the questions to the right. 		Where is the affected wall located (in terms of Qiblah Direction)? Northeast ward Northwest-ward Southeast-ward (Qiblah Direction) Southwest-ward

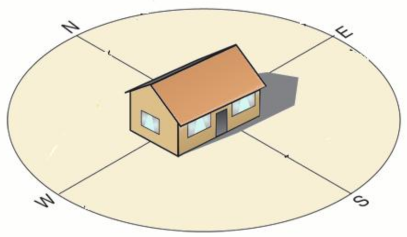
Q7. **Bathroom**

No Damp in the bathroom (please go to Q7)? Damp in (tick all that apply)?	*Note*. (External walls that protects the building from the open air) (Internal walls are those with no windows) (Dampness signs on the inside of your house)

Celling? ☐ Yes	Damp in Internal walls ☐ Yes	Damp in External walls ☐ Yes
☐ In the middle of the ceiling ☐ In the area between ceiling and wall ☐ Spread everywhere ☐ Don't know/ not sure	☐ in upper section of the wall ☐ In the lower section of the wall ☐ In the middle of the wall ☐ around the door ☐ Don't know / not sure	☐ in upper section of the wall ☐ In the lower section of the wall ☐ around the window ☐ Spread everywhere ☐ Don't know / not sure
Are there damp patches/stains/ blistering/ peeling paint in the ceiling? ☐ Yes ☐ No Is there a leak in the roof? ☐ Yes ☐ No	Does the affected wall share with the Kitchen (near to the cooking area)? ☐ Yes ☐ No	Does the external wall have gutter rainwater pipe from outside? ☐ Yes ☐ No Does the external wall have vegetation from outside? ☐ Yes ☐ No
Is the affected ceiling directly over the showering area? ☐ Yes ☐ No	Is the affected wall near to the showering area? ☐ Yes ☐ No	Is the affected wall near to the showering area? ☐ Yes ☐ No
Using the picture below please answer the questions to the right. 		Where is the affected wall located (in terms of Qiblah Direction)? ☐ Northeast ward ☐ Northwest-ward ☐ Southeast-ward (Qiblah Direction) ☐ Southwest-ward

Q8. **Bedrooms**

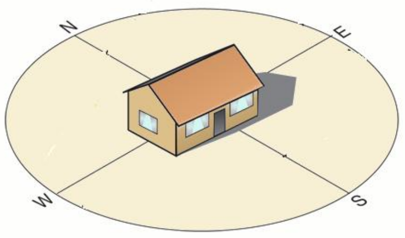
No Damp in the bedroom (please go to Q8)? Damp in (tick all that apply)?	*Note*. (External walls that protects the building from the open air) (Internal walls are those with no windows) (Dampness signs on the inside of your house)

Celling? ☐ Yes	Damp in Internal walls ☐ Yes	Damp in External walls ☐ Yes
☐ In the middle of the ceiling ☐ In the area between ceiling and wall ☐ Spread everywhere ☐ Don't know/ not sure	☐ in upper section of the wall ☐ In the lower section of the wall ☐ In the middle of the wall ☐ around the door ☐ Don't know / not sure	☐ in upper section of the wall ☐ In the lower section of the wall ☐ around the window ☐ Spread everywhere ☐ Don't know / not sure
Are there damp patches/stains/ blistering/ peeling paint in the ceiling? ☐ Yes ☐ No Is there a leak in the roof? ☐ Yes ☐ No	Does the affected wall share with the bathroom (near to the showering area)? ☐ Yes ☐ No	Does the external wall have gutter rainwater pipe from outside? ☐ Yes ☐ No Does the external wall have vegetation from outside? ☐ Yes ☐ No
	Is the affected wall share with the kitchen (near to the cooking area)? ☐ Yes ☐ No	
Using the picture below please answer the questions to the right. 		Where is the affected wall located (in terms of Qiblah Direction)? ☐ Northeast ward ☐ Northwest-ward ☐ Southeast-ward (Qiblah Direction) ☐ Southwest-ward

Q9. **Living room/Hospitality room**

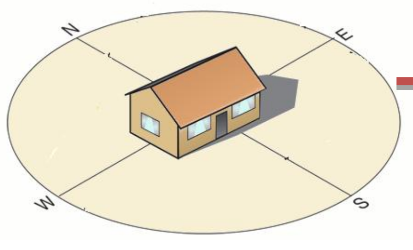
<table>
<tr><td>No Damp in the living room (please go to Q9)?
Damp in (tick all that apply)?</td><td>Note. (External walls that protects the building from the open air)
(Internal walls are those with no windows)
(Dampness signs on the inside of your house)</td></tr>
</table>

<table>
<tr><td>Celling?
☐ Yes</td><td>Damp in Internal walls
☐ Yes</td><td>Damp in External walls
☐ Yes</td></tr>
<tr><td>☐ In the middle of the ceiling
☐ In the area between ceiling and wall
☐ Spread everywhere
☐ Don't know/ not sure</td><td>☐ in upper section of the wall
☐ In the lower section of the wall
☐ In the middle of the wall
☐ around the door
☐ Don't know / not sure</td><td>☐ in upper section of the wall ☐ In the lower section of the wall
☐ around the window
☐ Spread everywhere
☐ Don't know / not sure</td></tr>
<tr><td>Are there damp patches/stains/ blistering/ peeling paint in the ceiling?
☐ Yes
☐ No

Is there a leak in the roof?
☐ Yes
☐ No</td><td>Does the affected wall share with the bathroom (near to the showering area)?
☐ Yes
☐ No</td><td>Does the external wall have gutter rainwater pipe from outside?
☐ Yes
☐ No
Does the external wall have vegetation from outside?
☐ Yes
☐ No</td></tr>
<tr><td></td><td>Is the affected wall share with the kitchen (near to the cooking area)?
☐ Yes
☐ No</td><td></td></tr>
<tr><td>Using the picture below please answer the questions to the right.

</td><td></td><td>Where is the affected wall located (in terms of Qiblah Direction)?
☐ Northeast ward
☐ Northwest-ward
☐ Southeast-ward (Qiblah Direction)
☐ Southwest-ward</td></tr>
</table>

Q10. **Other areas**

Damp in (tick all that applies)?	*Note*. (External walls that protects the building from the open air) (Internal walls are those with no windows) (Dampness signs on the inside of your house)

Celling? ☐ Yes	Damp in Internal walls ☐ Yes	Damp in External walls ☐ Yes
☐ In the middle of the ceiling ☐ In the area between ceiling and wall ☐ Spread everywhere ☐ Don't know/ not sure	☐ in upper section of the wall ☐ In the lower section of the wall ☐ In the middle of the wall ☐ around the door ☐ Don't know / not sure	☐ in upper section of the wall ☐ In the lower section of the wall ☐ around the window ☐ around the door ☐ Spread everywhere ☐ Don't know / not sure
Are there damp patches/stains/ blistering/ peeling paint in the ceiling? ☐ Yes ☐ No Is there a leak in the roof? ☐ Yes ☐ No	Does the affected wall share with the bathroom (near to the showering area)? ☐ Yes ☐ No	Does the external wall have gutter rainwater pipe from outside? ☐ Yes ☐ No Does the external wall have vegetation from outside? ☐ Yes ☐ No
	Is the affected wall share with the kitchen (near to the cooking area)? ☐ Yes ☐ No	I
Using the picture below please answer the questions to the right. 		Where is the affected wall located (in terms of Qiblah Direction)? ☐ Northeast ward ☐ Northwest-ward ☐ Southeast-ward (Qiblah Direction) ☐ Southwest-ward

Pat Three: Climatic Factor

Q11. What time of the year does dampness occur in your property? (You can tick more than one)

☐ from Nov. to Feb. ☐ from Mar. to May

☐ from June to August ☐ from Sep. to Oct.

☐ Same all year around

Part Four: Socio-cultural design Factor

Implementation Details Related to Owner Built Housing

Q12. Who did undertake the construction of your house?

☐ Local construction firm

☐ International construction firm

☐ Informal contractor

☐ Other, please specify
……………………………………………..

Q13. During the construction of your house; did you supervise the construction procedure or hire an expert to supervise the construction procedure?

☐ I supervised the construction procedure

☐ I hired an expert

If an expert, could you specify his/her major, please?

(For instance: contractor, civil engineer , architect or others
……………………………………………..

Q14. If you supervised the construction procedure, did you have any previous skills in construction supervision?

☐ Yes ☐ No

Q15. If you selected the construction materials, could you specify the criteria for the selection, please?

☐ Cost ☐ Availability

☐ Quality ☐ Other, please specify

……………………………………………………

Q16. If you supervised the construction procedure, which of the following labour input did you contribute in? (Tick what apply)

☐ Selection of the raw materials

☐ Selection of the builders

☐ Storage of the raw materials

☐ Concrete casting stage

☐ Steel bar size selection

☐ Compaction and curing process

☐ Decision of forms removal

☐ Others, please specify………………………………………

Q17. If you selected the builders during the construction procedure, what were your criteria in the selection?

☐ Wage

☐ Reputation

☐ Skills

☐ Anyone from the gathering square

☐ Others please specify
……………………

Q18. What type of exterior finishing did your house have?

☐ Tiling finishing

☐ Stucco finishing (cement/water/sand/lime)

☐ Natural stone finishing

☐ Mortar finishing (cement/water sand)

☐ Cladding finishing

☐ Others, please specify……………………

Owners' Requirements in building a house

Q19. What were the most important features that you were looking for while building your house?

(Rate the top three in order, 1= the most important, 2= important, 3= less important)

☐ Large rooms

☐ Large total plot area

☐ High quality interior finishing

☐ Hospitality rooms

☐ Well decorated facades

☐ Large outdoor space

☐ Others, please specify……………………

Q20. Did you make any amendments or changes of your house after the completion?

☐ Yes ☐ No

Q21.If yes, what kind of changes or amendments did you carry out? **(Tick all that apply)**

☐ Adding another floor

☐ Adding rooms

☐ Building rooms in surrounding setbacks

☐ Raising the fence

☐ Building shops in setbacks

☐ Conversion of rooms

☐ Others, please specify……………………

Q22. If your answer was (yes) to the question number (20), would you be willing to make any changes in the future when did you build the house?

☐ Yes ☐ No

Q23. Are all the rooms fully used in the house?

☐ Yes ☐ No

Q24. If your answer was (No) to the question number (23), which rooms are not used or rare used in the house?

☐ A whole floor (hospitality purpose)

☐ Quests rooms

☐ Bedrooms

☐ Others, please specify………………………

Part Five: Cost Effectiveness Factor

Q25. What was/were the sources of construction funds?

☐ Personal and family saving

☐ Building loan from the banking sector

☐ Both loan and personal/family saving

☐ Others, please specify………………………

Q26. If you ticked (Both loan and personal/family saving), could you specify why, please?

……

Q27. During the construction process, did the procedure was delayed?

☐ Yes ☐ No

Q28. If yes, how long did the delayed take?

..............................Months

Q29. If your answer was (yes) to the question number (27), what was the reason for this delay?

………

Q30. If your answer was (yes) to the question number (27), did those months including the winter season?

☐Yes ☐ No

Q31.If you have done any repairing action for the dampness, when was the last date of known repair and what was the type of the repair or maintenance carried out?

Date:…….

(please tick what apply....)

☐ Interior plastering work

☐ Exterior plastering work

☐ Repairing corroded reinforced concrete

☐ Plumbing work

☐ Re-tiling bathrooms and kitchens

☐ Reflating of door and windows

☐ Only interior Painting

☐ Others, please specify……………………

<u>Welling for Change</u>

Q32. Based on your current experience in building your house, what would you concentrate with if you have given another opportunity to build your home again?

Rate the top three in order, 1= the most important, 2= important, 3= less important)

☐ Quality of the construction process

☐ Exterior finishing (protection finishing)

☐ Proper interior design

☐ Interior finishing

☐ Size of the house

☐ House shape and orientation

☐ Others, please specify……………………

***Note*. If you provide us with your consent to visit your property for a data collection purpose, observing and taking photography of damp and non-damp locations, please, provide your contact details in order to contact you for further clarification and discussion**

☐**Yes, I provide my consent**

Contact Details:

..
..
..
..
..

☐ **No, I do not provide my consent**

Thanks for your cooperation

Table for Determining Sample Size from a Given Population

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

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

Table C.2 *Albeida City according to the Population and Number of the Families in 2009*

The Population	99208
Families No.	15694
Residential Buildings No. (including Building under Construction)	11382

Source. (Civil Record Office in Albeida, Libya)

Table C.3 *Libyan Population in 2010 (000)*

Region	2010	2009
Albatnan	163	160
Derna	167	164
Green Mountain	208	204
Almarj	188	185

Source. General authority for information. (2006). *Statistics Book: General Authority for Information and Yearly Bulletin*. Libya.

Table C.4 *Distribution of the Buildings according to the Type in Albeida, the Censuses of 2009 (000)*

Type of Building	No. of Building
House	629
Villa	3606
Building Block	638
Others	381
Building Committed to Housing	4934
Houses Under Construction	1575
Total	11125
Houses have not built yet (Land)	466

Source. Libya. General authority for information. (2006). *Statistics Book: General Authority for Information and Yearly Bulletin*. Libya.

Table C.5 *Criteria of the Questionnaire Distribution and Collection*

Libya (Green Mountain Region), Albeida					
Distributed Location	Alzawea	The Western of Albeida	The Eastern of Albeida	The Old Store	Algareda
No. of the Distributed Copies	50	100	100	100	50
Total	400 copies of the questionnaire were circulated to the occupants of the residential buildings				
No. of the Collected Copies	33	77	79	68	40
Percentage Completed	66%	77%	79%	68%	80%
(Received) Total	302 copies of the questionnaire were returned to the occupants of the residential buildings				
(Accepted) Total & Overall Percentage	297 copies of the questionnaire were accepted 74%				

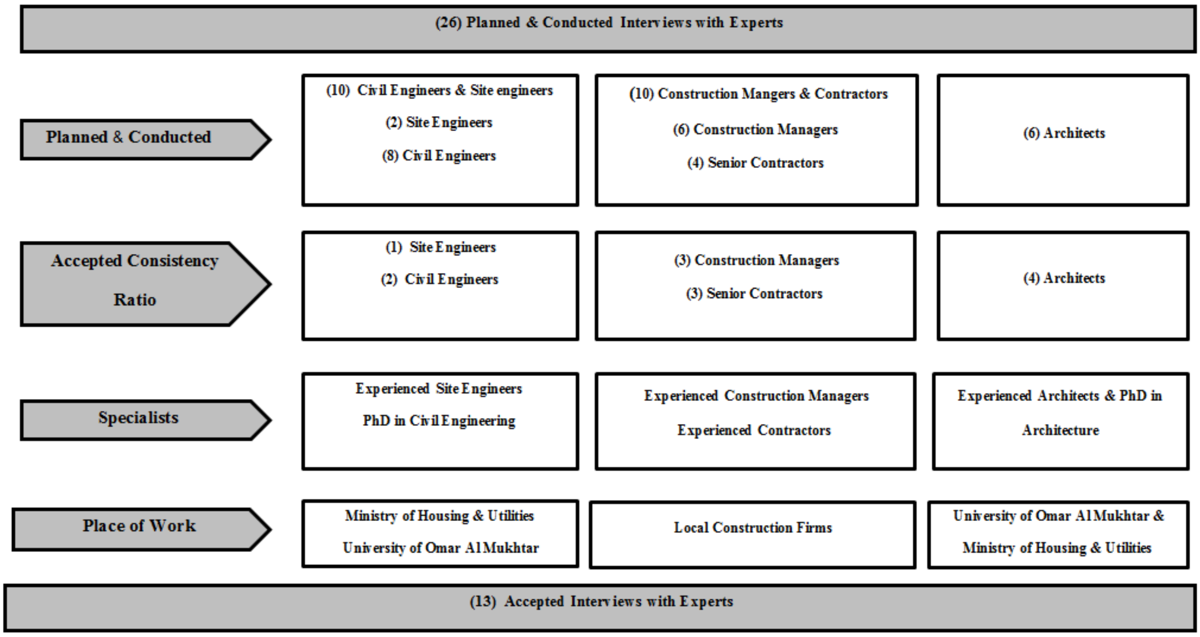
Table C.6 *Variables to be Investigated in the Survey Questionnaire*

Main Issue	Variable (Indicator)	Question (Indicator)
Climatic factor	Rain Rate	Defective Wall orientation Damp occurrence time
	Wind Direction	Wall orientation
Construction Factor	Construction Design	Investigated by (sources of Libyan code construction practice and direct observation with photograph) Type of exterior finishing
	Manufacturing Defects	Criteria of construction materials selection Criteria of builders selection Labour input contribution
Management Factor	Housing Policy	Building age The party who undertake the construction work Type of Construction fund Construction subject to delay (Date and period of delay) Reason for the delay during the construction work
	Construction Supervision Criterion	The party who undertake the supervision work (owners built and supervised houses) Criteria of construction materials selection Criteria of builders selection Labour input contribution
Socio-Economic Design Factor	Cost Effectiveness	Criteria of construction materials selection Criteria of builders selection The date and nature of last previous repair and/or maintenance Type of exterior finishing Construction subject to delay (Date and period of delay) Reason for the delay during the construction work
	Socio-Religious Design Requirements	Owners priorities in building their own houses Changes/amendments made Rooms are not fully used Investigated by (direct observation with photograph)

15. Appendix D.

Direct Observation with Photographs

Figure D.1 Planned and Conducted Interviews with Experts



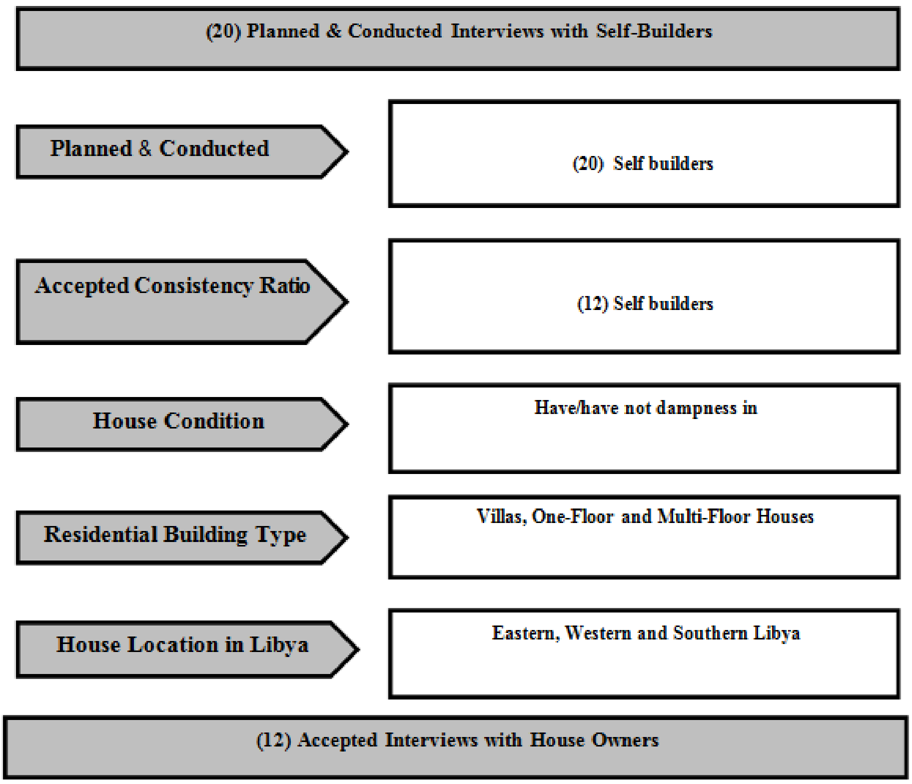


Figure D.2 Planned & Conducted Interviews with Self-builders

Table D.1 *Backgrounds of Experts who Participated in the Interview Panels*

No. of Expert (Interviewee)	Identity Code	Specialization	Current Working Place	Professional
1	E.A	Civil Engineer	Senior Lecturer PhD in Civil Engineering	>20years
2	E.B	Civil Engineer	Senior Lecturer PhD in Civil Engineering	>20years
3	E.C	Site Engineer	Surveying Engineering in the Ministry of Housing and Utilities	>10years
4	E.D	Architect	Senior Lecturer PhD in Urban Design	>15years
5	E.E	Contractor (Civil Engineer)	Job Contractor	>13years
6	E.F	Construction Manager	Manager of Private Construction firm	> 20years
7	E.G	Architect	Project officer in the Department of implementation of Housing Projects	>10years
8	E.H	Architect	Senior Lecturer PhD in Architecture Design	>25years
9	E.I	Architect	Senior Lecturer PhD in Islamic Architecture	>15years
10	E.J	Construction Manager	Manager of Private Construction firm	>15years
11	E.K	Senior Contractor	Job contractor	>25years
12	E.L	Construction Manager	Manager of Private Construction firm	>13years
13	E.M	Contractor	Job Contractor	>15years

Table D.2 *Information on House Owners who Participated in the Interview Panels*

No. of Interview	**Identity Code**	**Who**	**House Condition**
1	O.A	Self-Builder (House Owner)	Houses have/have not dampness issues
2	O.B		
3	O.C		
4	O.D		
5	O E		
6	O F		
7	O G		
8	OH		
9	OI		
10	Oj		
11	OK		
12	OL		

Table D.3 *Backgrounds of Evaluators' Panel of Factors, Causing Dampness Issue in Domestic Housing*

No. of Interview	**Identity Code**	**Specialization**	**Current Working Place**	**Professional**
1	E.A	Civil Engineer	Senior Lecturer PhD in Civil Engineering	>20years
2	E.B	Civil Engineer	Senior Lecturer PhD in Civil Engineering	>20years
3	E.C	Civil Engineer	Surveying Engineering in the Ministry of Housing and Utilities	>10years
4	E.D	Architect	Senior Lecturer PhD in Urban Design	>15years
5	E.J	Civil Engineer	Manager of Private Construction firm	>15years
6	E.E	Contractor (Civil Engineer)	Job Contractor	>13years
7	E.G	Architect	Project officer in the Department of implementation of Housing Projects	>10years
8	E.H	Architect	Senior Lecturer PhD in Architecture Design	>25years
9	E.I	Architect	Senior Lecturer PhD in Islamic Architecture	>15years
10	E.L	Contractor	Manager of Private Construction firm	>13years

Table D.4 *Backgrounds of Evaluators'' Panel for Construction Factor and Construction Design and Manufacturing Criteria*

No. of Interview	Identity Code	Specialization	Current Working Place	Professional
1	E.A	Civil Engineer	Senior Lecturer PhD in Civil Engineering	>20years
2	E.B	Civil Engineer	Senior Lecturer PhD in Civil Engineering	>20years
3	E.C	Civil Engineer	Surveying Engineering in the Ministry of Housing and Utilities	>10years
4	E.J	Civil Engineer	Manager of Private Construction firm	>15years
5	E.E	Contractor (Civil Engineer)	Job Contractor	>13years
6	E.F	Civil Engineer	Manager of Private Construction firm	> 20years
7	E.K	Senior Contractor	Job contractor	>25years
8	E.L	Contractor	Manager of Private Construction firm	>13years

Table D.5 *Backgrounds of Evaluators' Panel for Climate Factor*

No. of Interview	Identity Code	Specialization	Current Working Place	Experience
1	E.A	Civil Engineer	Senior Lecturer PhD in Civil Engineering	>20years
2	E.B	Civil Engineer	Senior Lecturer PhD in Civil Engineering	>20years
3	E.C	Civil Engineer	Surveying Engineering in the Ministry of Housing and Utilities	>10years
4	E.D	Architect	Senior Lecturer PhD in Urban Design	>15years
5	E.E	Contractor (Civil Engineer)	Job Contractor	>13years
6	E.F	Civil Engineer	Manager of a Private Construction firm	> 20years
7	E.G	Architect	Project officer in the Department of implementation of Housing Projects	>10years
8	E.H	Architect	Senior Lecturer PhD in Architecture Design	>25years
9	E.I	Architect	Senior Lecturer PhD in Islamic Architecture	>15years

Table D.6 *Backgrounds of Evaluators' Panel of Management and Socio-Economic Design Factors, Construction Supervision Criterion and Cost & Knowledge Effectiveness Criteria*

No. of Interview	Identity Code	Specialization	Who Supervised the Construction Process	professional
1	E.A	Civil Engineer	Senior Lecturer PhD in Civil Engineering	>20 years
2	E.E	Contractor (Civil Engineer)	Job Contractor	>13years
3	E.F	Civil Engineer	Manager of Private Construction firm	> 20years
4	O.B	House Owner (Self-Builder)	The Owner	/
5	OE	House Owner (Self-Builder)	The Owner	/
6	OF	House Owner (Self-Builder)	The Owner	/
7	OG	House Owner (Self-Builder)	The Owner	/
8	OJ	House Owner (Self-Builder)	The Owner	/
9	OL	House Owner (Self-Builder)	The Owner	/

Table D.7 *Evaluators' Backgrounds of Interview Panel of Socio-Religious Design Requirements Criteria*

No. of Interview	Identity Code	Who Supervised the Construction Process	House Condition
1	O.A	Both (Owner & Expert)	No Damp
2	O.B	The Owner	Have Damp
3	O.C	Both (Owner & Expert)	No Damp
4	O.D	Both (Owner & Expert)	No Damp
5	OE	The Owner	Have Damp
6	OF	The Owner	No Damp
7	OG	The Owner	Have Damp
8	OH	The Owner	No Damp
9	OI	Both (Owner & Expert)	Have Damp
10	OJ	Both (Owner & Expert)	Have Damp
11	OK	The Owner	No Damp
12	OL	The Owner	No Damp

16. Appendix E.

Validation Analysis

Questionnaire for Model Validation

(Direct to the House Owners of Massa)

Q.1. Do you have any issue with dampness on the inside of your house or water getting into your property?

☐ Yes ☐ No

If you have no dampness, move to Q4.1 please

Q.2. When you carry out maintenance action for any damp problem, what is the nature of this maintenance?

☐ No maintenance ☐ Peeling off the damaged paint and repainting it again

☐ Interior plastering work ☐ Exterior plastering work with bitumen layers

☐ Reframing of door and windows ☐ Re-tiling bathrooms and kitchens

Q.3. Based on your current experience with dampness problem inyour house, score the following possible consequences or implications for general living and level of damage in terms of order of importance? **(1 = high damage, 2 = moderate damage, 3= low damage, 4 = very low, 5 = no damage)**

☐ Wasting money on property maintenance ☐ Cosmetic appearance

☐ Fabric damage of builsding ☐ Damage to furniture

☐ Adverse impact on health of family

Construction Supervision Background

Q.4.1. Who undertook the construction work of your house?

☐ Jobbing contractor ☐ Local construction firm ☐ International construction firm

Q.4.2. During the construction of your house; who supervised the construction work? (tick all boxes that apply) ?

☐ You

☐ Professionally qualified expert

☐ Experienced builders

☐ A helpful friend/family member with little or no previous building experience

☐ A family member with some building experience

If your answer was only (Professionally qualified expert and/or Experienced builders) for the previous question, move to Q5 please

Q.4.3. If you supervised the construction work, what amount of experience you have on construction?

☐ Ten years or more of experience ☐ Few years of experience

☐ No experience on construction

Q.4.4. If you supervised the construction procedure, which of the following labour input did you supervise? (Tick what apply)

☐ Storage of the raw materials ☐ Concrete mixture

☐ Concrete placing & compaction ☐ Decision of concrete formwork removal

☐ None

Construction Materials

Q.5. In the Green Mountain region, there are 3 common types of sand available which cost different amounts; which type was used in your house construction?

☐ Unwashed sea sand ☐ Washed sea sand ☐ Transported desert sand

☐ Other; please specify …………………………………………………………………….

☐ Not sure what type

Q.5.1. Did you use normal Portland cement (Type 1) in your house construction for the concrete or mortar?

☐ Yes ☐ No ☐ Not sure what type of cement

Q.5.2. How was the condition of the steel reinforcement when your constructed your house?

☐ Un-rusted steel bar ☐ Rusted steel bar ☐ Not sure

Q.5.3. If you selected the construction materials, could you specify the criteria for the selection, please?

☐ What is available ☐ Cost impact ☐ I did not select the raw materials

Workforce

Q.6. In the Green Mountain region, the available workforce is specified below. Which was used for your house construction?

☐ Unskilled & inexperienced builders ☐ Skilled and experienced builders

☐ I only picked who is avaliable in builders hiring market ☐ I don't know

Q.6.1. If you selected the builders during the construction work, what were your criteria in the selection?

☐ Picking anyone ☐ Wage ☐ Experienced ☐ I did not select the builders

Roof Background

Q.7. What is the design of the roof of your house?

☐ Flat roof ☐ Pitched roof

Q.7.1. During the rainy season or when the water tank floods on roof, does water ponding occur on the roof of your house?

☐Yes ☐ No

Q.7.2. If yes, does the water pond occur?

☐ In the middle of the roof ☐ At the sides ☐ Everywhere

Q.7.3. If water ponds at the sides, is there any water pipe drainage installed on wall?

☐Yes ☐ No

Q.7.4. How long does this pond lasts in days?

……………………………………………………………………………………………….

If you have no dampness in your house or have no dampness signs in the ceiling , move to Q8 please

Q.7.5. Is there ever a leak on the ceiling?

☐Yes ☐ No

Q.7.6. Based on your current experience with the problem of dampness in your house, what is the level of dampness signs appearance in the ceiling of the house?

Mark or score the following possible level of dampness signs appearance from (1-0) in terms of level of damage

	0.00	No damp	No damp signs within the house
	0.20	Low damp	Slight spots of black patches/ stain/ peeling paint in the middle or corner of ceiling without water pond on the roof
	0.40	Medium to Low damp	Moderate to small area of stain/black patches/peeling paint in the middle or corner of ceiling with water pond last for a couple of days on the roof
	0.60	Medium damp	Moderate-sized area of stain/black patches/peeling paint in the middle and/or corner of ceiling with water pond last for more than a week on the roof
	0.80	High- Medium damp	A considrable area of stain/black patches/peelling paint/ blistered in the middle or corners of the roof and/or water leakage
	1.00	High damp	Large area of black patches/ stain/ peeling paint , spead everywhere in the ceiling and cracks area on roof with water leakage

Exterior Wall Background

Q.8. What is the design of the exterior wall of your house?

☐ Single skin of exterior wall ☐ Cavity Wall ☐ Thick wall

Q.8.1. What type of exterior finishing did your house have?

☐ Cement mortar ☐ Stucco paint ☐ others

If you have no dampness signs in your house, move to question 10

(Or) if you have no dampness signs in exterior wall, move to question 9

Q8.2. On the inside of your house, if signs of dampness on an exterior wall, do the signs occur?

☐ In upper section of the wall ☐ In the lower section of the wall
☐ Around the window ☐ Spread everywhere

Q.8.3. If the dampness signs occur in the exterior wall of your house, where is the affected wall located (in terms of Qiblah Direction)?

☐ Northeast wards ☐ Northwest-wards
☐ Southeast-wards (Qiblah Direction) ☐ Southwest-wards

Q.8.4. Based on your current experience with the problem of dampness in your house, what is the level of dampness signs appearance in the interior surface of the exterior wall of the house?

Mark or score the following possible level or of dampness signs appearance from (1-0) in terms of level of damage

	0.00	No damp	No damp signs within the house
	0.20	Low damp	Slight area of black patches or stain in the wall
	0.40	Medium to Low damp	Moderate to small area of stain/black patches/peeling paint or blistered paint in the middle or corner of wall
	0.60	Medium damp	Moderate-sized area of stain/black patches/peelled paint in the middel and/or corrner of wall
	0.80	High- Medium damp	A considrable area of stain/black patches/peeling paint/ blisteed in the middle or corners of the wall and/or wet wall
	1.00	High damp	Large area of black patches/ stain/ peeling paint/ blistered, spead everywhere in the wall and/or cracks in the exterior surface of the wall with wet wall

Q.9. What time of the year does dampness occur in your property?

☐ From Nov. to Feb. ☐ From Mar. to May ☐ From Nov. to May

Q.10. If you faced a delay in the construction work of your house (6 months or more), after work had commenced, what was the reason for that delay?

☐ Delay in loan payments ☐ Loan payments not enough ☐ I have not face delay

Socio-Cultural Design Requirement

Q.11. In the design stage of your house, with your available budget, did you build large rooms sizes?

☐ Yes ☐ No

Q.11.1. In the design stage of your house, with your available budget, did you have high quality of interior finishing and decoration rather than spending money on the exterior surface of the house?

☐ Yes ☐ No

Q11.2. In the design stage of your house, with your available budget, did you build rooms for hospitality? ☐ Yes ☐ No

Q.11.3. Did you make any amendments in your house after the completion?

☐ Yes ☐ No

Q.11.4. If yes, what kind of changes did you carry out? (Tick all that apply)

☐ Adding another floor ☐ Building rooms in surrounding setbacks

☐ Raising the fence ☐ Building shops in setbacks

☐ Conversion of rooms ☐ Others, please specify……………………

Q.12. Do you carry out social activities such as traditional carpet washing on the roof and/or traditional house washing (splashing water on the interior surface of the house such as kitchen, bath, other rooms' wall and floor)?

☐ Yes ☐ No

Many Thanks for your Cooperation

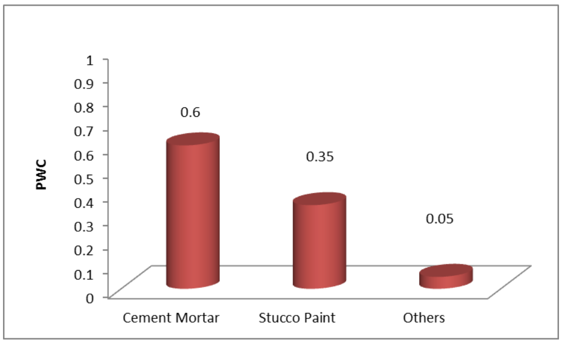


Figure E.1 *Type of Exterior Finishing*

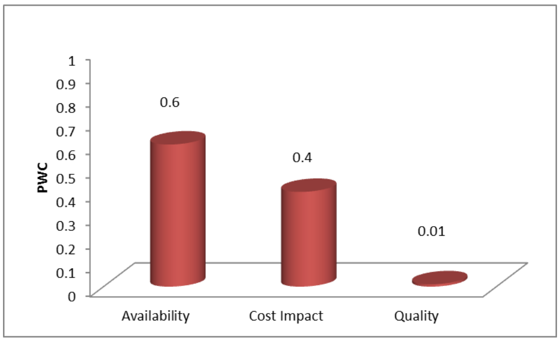


Figure E.2 *Raw Materials Selection*

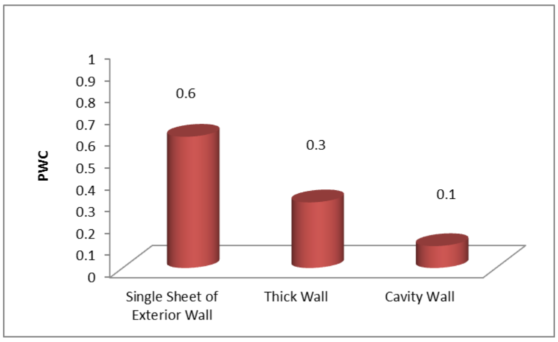


Figure E.3 *Type of Exterior Wall*

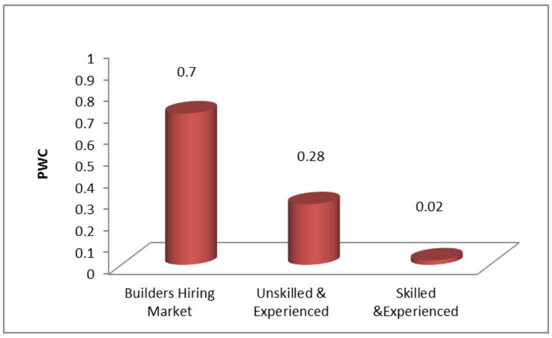


Figure E.4 *Workforce Criteria*

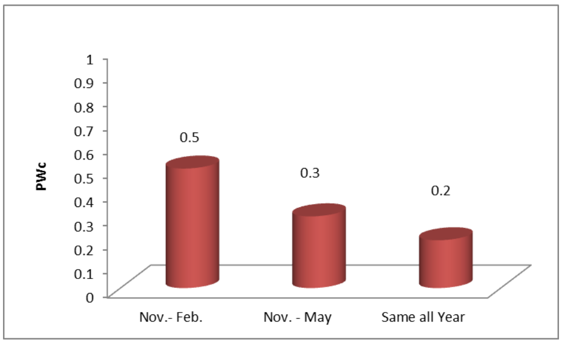


Figure E.5 *Time of Damp Occurrence*

Table E.1 *Illustrated Example of The Calculation of AHP with Pairwise Comparison Weight for House 5 in Albeida*

Possible Causes of Dampness for House 5	Wa	Wb	Wc	PWC5	Wa*Wb*Wc*PWC5
Control (concrete mixing)	0.4584	0.6912	0.2251	0.4	0.028528821
Control (storage of materials)	0.4584	0.6912	0.2251	0.6	0.042793232
Control (C.P.C)	0.4584	0.6912	0.2251	0.6	0.042793232
Control (D.C.F.R)	0.4584	0.6912	0.2251	0.4	0.028528821
Workforce	0.4584	0.6912	0.3416	0.28	0.030305694
Exterior Finishing	0.4584	0.3088	0.4235	0.4	0.023979234
Water Tanks Location	0.4584	0.3088	0.1029	0.7	0.010196129
Roof Design	0.4584	0.3088	0.2617	0.6	0.022226797
Exterior Wall	0.4584	0.3088	0.2119	0.6	0.017997165
Owners Supervision (no experience.)	0.1728	0.7041	1	0.5	0.06083424
Builders Selection	0.2347	0.8081	0.2432	0.05	0.002306279
Exterior Finishing Selelction	0.2347	0.8081	0.1944	0.35	0.012904539
Futrue Requirments	0.2347	0.1919	0.1735	0.3	0.002344276
Rainy Season	0.134	0.6107	1	0.2	0.01636676
Changes in Housing Construction Policy	0.1728	0.2959	1	0.5	0.02556576
GW (Sum)					**0.367670978**

Table E.2 *Illustrated Example of the Calculation of AHP with Pairwise Comparison Weight for House 6 in Albeida*

Possible Causes of Dampness for House 6	Wa	Wb	Wc	PWC6	Wa*Wb*Wc*PWC6
Workforce	0.4584	0.6912	0.3416	0.7	0.075764235
Exterior Finishing	0.4584	0.3088	0.4235	0.4	0.023979234
Control (concrete mixing)	0.4584	0.6912	0.2251	0.4	0.028528821
Control (storage of materials)	0.4584	0.6912	0.2251	0.6	0.042793232
Control (C.P.C)	0.4584	0.6912	0.2251	0.4	0.028528821
Control (D.C.F.R)	0.4584	0.6912	0.2251	0.4	0.028528821
Roof Design	0.4584	0.3088	0.2617	0.6	0.022226797
Exterior Wall	0.4584	0.3088	0.2119	0.6	0.017997165
Builders Selection	0.2347	0.8081	0.2432	0.05	0.002306279
Exterior Finishing Selection	0.2347	0.8081	0.1944	0.05	0.001843506
Owners Supervision (no experience.)	0.1728	0.7041	0.7126	0.5	0.043350479
Future Requirements	0.2347	0.1919	0.1735	0.3	0.002344276
Changes in Housing Construction Policy	0.1728	0.2959	1	0.49	0.025054445
Maintenance	0.2347	0.8081	0.1366	0.5	0.012953851
Rainy Season	0.134	0.6107	1	0.3	0.02455014
GW (Sum)					**0.380750101**