PESHWAZ ABDULLAH ALI

ENERGY REDUCTION THROUGH ARCHITECTURAL DESIGNS : Studying Passive Strategies in Northern Iraq

NEU 2021

ENERGY REDUCTION THROUGH ARCHITECTURAL PASSIVE DESIGNS IN SULAYMANIYAH, NORTHERN IRAQ: BUILDING'S MATERIAL ASSESSMENT

A THESIS SUBMITTED TO THE INSTITUTE GRADUATE STUDIES OF NEAR EAST UNIVERSITY

By
PESHWAZ ABDULLAH ALI

In Partial Fulfillment of the Requirements for the Degree of Master of Science in Architecture

NICOSIA, 2021

ENERGY REDUCTION THROUGH ARCHITECTURAL PASSIVE DESIGNS IN SULAYMANIYAH, NORTHERN IRAQ: BUILDING'S MATERIAL ASSESSMENT

A THESIS SUBMITTED TO THE INSTITUTE GRADUATE STUDIES
OF
NEAR EAST UNIVERSITY

By
PESHWAZ ABDULLAH ALI

In Partial Fulfilment of the Requirements for The Degree of Master of Science
in
Architecture

NICOSIA, 2021

Peshwaz Abdullah Ali: ENERGY REDUCTION THROUGH ARCHITECTURAL DESIGNS: Studying Passive Strategies in Northern Iraq

Approval of Director of Institute of Graduate Studies

Prof. Dr. K. Hüsnü Can Başer

We certify this thesis is satisfactory for the award of the degree of Masters of Science in Architecture

Examining Committee in Charge:

Assoc. Prof. Dr. Buket ASILSOY — Committee Chairman, Department of Landscape, NEU

Assist. Prof. Dr. Tuğşad TÜLBENTÇİ — Supervisor, Department of Architecture, NEU

Assist. Prof. Dr. Çiğdem ÇAĞNAN — Department of Architecture, NEU

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name: Peshwaz Abdullah Ali

Signature:

Date:16/02/2021

ACKNOWLEGMENTS

I would like to express my sincere gratitude to my supervisor Assist.Prof.Dr.Tuğşad TÜLBENTÇİ for the continuous support to my thesis, motivation, and immense knowledge. There guidance helped me through all research and writing of this thesis. I could not have imagined having a better advisors and mentor for my master study. I would like to thank them for encouraging my research. Thanks are due to all the staff and management, Faculty of architecture Department, NEU.

My sincere appreciation also extends to all my family members especially my mother, father, brothers and sisters for their understanding and encourage me all the time until complete this thesis.

I am also indebted to the librarians at Near East University (NEU) for their help in supplying the relevant literatures and lastly, I wish to express my sincere appreciation to all the people that assisted throughout the preparation for this thesis.

To my parents …

ABSTRACT

Maintaining indoor thermal comfort is a key point of building design regardless of external conditions. The largest energy is consuming in the buildings for thermal comfort, in this regard, the consumption of energy is the critical factor in global warming. Achievement of a specific energy reduction program utilizing passive strategies in residential buildings is a successful alternative. The aim of the study is to optimize residential buildings' energy efficiency in Northern Iraq by means of passive strategies and building materials. Northern Iraq and Sulaymaniya have seen a rise in the aggregate use of electricity in the last 15 years. Conservation of the thermal comfort inside the buildings is dependent significantly on electrical power in this area. As a result, the use of electricity has dramatically increased. The ambiguity in understanding the energy-efficient architecture has resulted in high energy consumption in the buildings and a lack of electricity in the study area. The thesis concentrates on the evaluation of energy consumption in most common categories of buildings in the region, which are residential buildings. To achieve the goal for the study, a literature review and theoretical analysis have been approached in order to formulate the initial indicators, for the most effective passive design strategies. Moreover, the most effective tool to evaluate a building's energy efficiency through building materials has been identified. Then, eight case study buildings have been selected in Sulaymaniyah city to be tested and evaluated in terms of energy efficiency. Observation and conventional mathematical calculations have been conducted to reach the results. The study answered the study questions and concluded that there is significant lack in the building potential to perform energy efficiency. The ways to improve energy efficiency have been suggested, and the most effective construction materials, for this reason, have been identified. Several recommendations have been offered at the end of the thesis for improving energy efficiency in the scale of Northern Iraq. Suggestions for future studies have been introduced too.

Keywords: Passive design strategies, thermal mass**,** energy efficiency, building's construction material, U-value, Sulaymaniyah- Northern Iraq

ŐZET

İç mekan termal konforunu korumak, dış koşullardan bağımsız olarak bina tasarımının kilit noktasıdır. Binalarda termal konfor için en büyük enerji tüketiliyor, bu bakımdan enerji tüketimi küresel ısınmada kritik faktördür. Konut binalarında pasif stratejiler kullanan belirli bir enerji azaltma programının başarılması başarılı bir alternatiftir. Çalışmanın amacı, pasif stratejiler ve yapı malzemeleri aracılığıyla Kuzey Irak'taki konut binalarının enerji verimliliğini optimize etmektir. Kuzey Irak ve Süleymaniye, son 15 yılda toplam elektrik kullanımında bir artış gördü. Binaların içindeki termal konforun korunması, bu alandaki elektrik gücüne önemli ölçüde bağlıdır. Sonuç olarak, elektrik kullanımı önemli ölçüde arttı. Enerji verimli mimarinin anlaşılmasındaki belirsizlik, binalarda yüksek enerji tüketimine ve çalışma alanında elektrik eksikliğine neden olmuştur. Tez, bölgedeki en yaygın bina kategorileri olan konut binalarında enerji tüketiminin değerlendirilmesi üzerinde yoğunlaşmaktadır. Çalışmanın amacına ulaşmak için, en etkili pasif tasarım stratejileri için ilk göstergeleri formüle etmek amacıyla bir literatür taraması ve teorik analize yaklaşılmıştır. Dahası, bir binanın enerji verimliliğini inşaat malzemeleri aracılığıyla değerlendirmek için en etkili araç belirlendi. Ardından, enerji verimliliği açısından test edilmek ve değerlendirilmek üzere Süleymaniye şehrinde sekiz vaka çalışması binası seçildi.. Sonuçlara ulaşmak için gözlem ve geleneksel matematiksel hesaplamalar yapılmıştır. Çalışma, çalışma sorularını cevapladı ve enerji verimliliği gerçekleştirmek için bina potansiyelinde önemli bir eksiklik olduğu sonucuna vardı. Enerji verimliliğini artırmanın yolları önerilmiş ve bu nedenle en etkili yapı malzemeleri belirlenmiştir. Tezin sonunda, Kuzey Irak ölçeğinde enerji verimliliğinin artırılmasına yönelik çeşitli öneriler sunulmuştur. Gelecekteki çalışmalar için öneriler de tanıtıldı.

***Anahtar Kelimeler*:** Pasif tasarım stratejileri, termal kütle, enerji verimliliği, binanın yapı malzemesi, U değeri, Süleymaniye - Kuzey Irak.

TABLE OF CONTENTS

CHAPTER 3: METHODOLOGY

CHAPTER 4: RESULTS AND DISCUSSIONS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1

INTRODUCTION

1.1 A Background & Significance of The Study

In view of the substantial energy consumption in the construction industry, buildings play an important part in climate change. Buildings account for 40% of global energy consumption and produce 30% of the atmospheric carbon dioxide emissions (Ozdil, 2010). The main concern in the design of buildings is common throughout the world, which is maintaining indoors thermal comfort independent of the outside environment. Nowadays, the designers are depending on an active system (air conditioning and heating systems) with a high energy consumption to provide thermal comfort. Disadvantages are now apparent when the energy-efficient design became critical for solving environmental problems (Burton, 2012). For traditional buildings worldwide, passive architecture principles are used. These old principles of architecture are used for a long time in different climates for maintaining thermal comfort inside the buildings without using active systems. In hot and dry climate, inhabitants are using the right passive design techniques in buildings to adjust the atmosphere. Such techniques can be tested and applied in newly constructed buildings to reduce energy use in buildings. Free energy sources, including wind and sun, could be created to make buildings comfortable. The use of suitable passive strategies that respond to the specific climate may give buildings a strong ability to decrease energy demand (Saffari et al., 2017). Therefore, the design and implementation of a specific system to reduce energy consumption by passive techniques in almost the entire residential buildings is a good alternative. In ecological, economic and esthetic terms, there are many potentials in the implementation of passive strategies. The human body must be shielded from the outside environment in order to maintain the heat balance in the human body. The building envelope is the protector of an individual body where heat gain and heat loss are controlled (Brager and de Dear, 2001). Hence the study will focus on the envelope elements (external walls, roofs, floors, and windows) of the buildings in terms of construction materials as one of the main architectural elements for reducing energy inside the buildings. For the world in the 21st Century, climate change became a great challenge and this was the concern of UN climate conference, held in Marrakech in November 2016. z This study investigates the possibilities of applying affordable and applicable passive designs in the buildings in northern Iraq. The study focuses on the building materials assessment as one of the important methods to develop buildings energy efficiency even in the existing buildings, because tearing down the existing buildings and replacing them with high performance ones is not affordable or practical.

Sulaymaniyah have been selected, as a region of this study. ‘Sulaymaniyah’ is considered as the cultural city of northern Iraq, and an important economic and industrial center for Iraq (UNHCR, 2004). The population of Sulaymaniyah is estimated in 2013 by 700,000, according to the ‘Ministry of Planning’, (MoDPC, 2005). The city increased in the buildings and construction sectors progressively in the last 15 years. Hence, the demands on the electrical power are increased and the shortage in this power have been increased too. See Figure ‘1.1’.

Figure 1.1: Residential buildings’ construction in Sulaymaniyah- Northern Iraq (Google,2019)

1.2 Statement of Problem

Northern Iraq as part of Iraq has witnessed a cumulative increment in electrical power usage during the past decade, and Sulaymaniyah as part of this region. Buildings in this region are depending heavily on electrical power to maintain thermal comfort inside the buildings.

Recently, contemporary buildings are designed without taking proper account of their form, their orientation and other variables. Therefore, energy consumption increased significantly. The lack of understanding of energy efficiency architecture led to the creation of high-energy buildings and a shortage of electricity supplies in the region of study. This shortage appears clearly in the warmer, and colder seasons, when the demand on power for cooling or heating is high. Furthermore, this increased the demand for electrical power in the region which already was suffering from power shortage. The thesis will focus on the energy efficiency in residential buildings as the most common categories of the buildings in the region.

1.3 The Questions of The Study

The main questions for this thesis are;

1. What are the most effective passive design strategies at the residential buildings in Northern Iraq, in terms of applied strategies to the buildings and their response to climate?

2. How do we reduce energy consumption in Northern Iraq through passive design strategies, within the limits of this study?

3. What are the most effective building materials that can be applied in Northern Iraq for energy efficiency in the buildings?

1.4 Aim and Objectives of The Study

The study aims to improve the energy performance at residential building in Northern Iraq. This is through passive strategies in terms of building material to be applicable to existing buildings and future buildings design. Then objectives of the study:

1. Determination the types of construction materials for the residential buildings in Northern Iraq.

2. Explore the most effective passive strategies for the buildings in northern Iraq.

3. Evaluate the most effective construction material in the region of study in terms of their capacity for maintaining thermal performance, through studying thermo-physical properties of these materials.

1.6 The Methodology

The methodology has used qualitative and quantitative research methods to answer thesis questions and goals. At the beginning of this study, the research questions are allocated. Through the process of methodology, the answer to those questions will be tackled. The following steps will be conducted to reach the research's objectives and aims;

1. Examination of the relevant literature that had done by other researchers to provide an improvement recommendation, as well as the quest for key-related books, journals and reliable web sources in the area.

2. Selecting case study buildings based on the criteria for selecting case studies, to assure covering the majority of the residential building's categories in the region of the study.

3. Field observation and measurement will be addressed, in the process of the quantitative method.

4. Comparative analysis among the results of the case study buildings will be carried out to come out with comprehensive understanding about the existing scenario in the case studies, with the respect of the current study limitation.

The analysis of previous elements based on the positive and negative correlation will, therefore, be applied on the basis of the cause and effect. A case study methodology is therefore used to accomplish this purpose.

1.7 Limitations of The Study

1. Sulaymaniyah as one of the developing cities in Northern Iraq will be the limited region of the study.

2. The study will concentrate on the residential buildings as most prevailed buildings in the region of study.

3. The study will focus on the passive strategies related to the building material of the residential buildings in Sulaymaniyah in Northern Iraq. In this case, such strategy will be more applicable for existing buildings, which have low energy efficiency, and applicable for future building design too.

4. Most climatic responsive passive design techniques will be considered, based on their importance in the literature through previous studies, and the site observations.

1.8 Thesis Outline

Chapter one is demonstrating the outline of this study through identifying the significance of this study. Moreover, the problems, questions, and objectives of this study have been identified in this chapter. the aim of the study is addressed and the methodology outline to achieve the aim has been introduced 'in brief'. The structure of the whole study is showing in this chapter in order to get comprehensive understanding about each chapter in this study.

Chapter two is literature review that includes the introduction the most important keywords in the study like of passive strategies, building materials, and heat transfer coefficient value (U-vale). Moreover, this chapter will discuss many important strategies that are applicable in the study region which is characterized by a hot- arid climate. The most prevailed passive strategies in the region of the study will be identified in order to be applied to check it in several case study buildings in the region of study. Chapter three is the methodology of the thesis. The chapter explains the roadmap of the current study through the methods that approached to reach the goal of the study and answer the study's questions. Moreover, the chapter is introducing the selected case study areas, and their locations and description. Chapter four will shed a light on the results and the way of evaluating construction materials in terms of their thermal capacity (U-value) to control heat gain and heat loss, which is resulting in controlling energy consumptions in the building sector. This is based on the analyzing of the selected case study buildings. The last chapter is chapter five, in this part the conclusions and suggestion for future work will be introduced.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter will try to cover the meaning of passive design strategies and the most effective passive strategies within the limits of this thesis regarding the climate and geographical characteristics. Hence, only those strategies that may be appropriate for this study and can be employed in the case of a semi-arid heat climate will be discussed in this chapter. The most important passive strategies applied in Northern Iraq will be determined in this chapter too. The importance of construction materials and their roles in performing energy efficiency in the buildings will be discussed. The U-value will be introduced and the most recommended U-value for the building construction materials in hot and arid climate will be identified.

2.2 Passive Design Strategies

Passive design can be referred as a way to design buildings to create a comfortable and energy-efficient atmosphere that minimizes mechanical system dependence. Rather than using energy such as natural gas and electricity, passive design strategies are applying natural sources of energy, including natural ventilation, daylight, and solar energy (Baker and Steemers, 2005). Many design strategies are available to achieve a passive design of buildings. The techniques include the selection of building materials, such as construction and finishing materials, orientation, interior design, the volume of the structure, the landscape around the building, and design of building openings. Moreover, managing the sunrays entering into the building, controlling air movement to enter or push out of buildings, and the relationship between building and topography (Baweja, 2008).

Hence, passive design strategies may decrease the building energy consumption by a natural resource so as to provide its users with a comfortable inner environment, which reduces requirements for active heating and cooling, ventilation and lighting.

2.2.1 History of passive design strategies

The passive solar design in buildings represent the pursuit of living in harmony with the environment and nature. The exercise of using passive solar is as aged as architecture. It is exemplifying the buildings ability to maintain the balance for their occupants, environmentally, economically, and socially. By review the past, vernacular and traditional architecture has always guided the professionals to design buildings by using materials in functional way, convenient plan and appropriate structure for acceptable indoor conditions. The relevance between architecture and energy can be returned back to thousands of years ago. Passive solar strategies are not new where, in the ancient Chinese, Greek, and Romans were using passive solar principles in their architectural design, such as orienting the buildings to face the south in the northern hemisphere (Perlin, 2013). The grid streets planned in the Greek cities like '*Priene*', running east- west direction to orient the buildings to southern orientation, in order to reach the sun rays in winter and block it in summer by using '*Portico*'[1] front of the rooms (Vale and Vale, 1996), as seen in Figure '2.1'.

[1] A colonnade or covered ambulatory especially in classical architecture and often at the entrance of a building (Merriam-Webster).

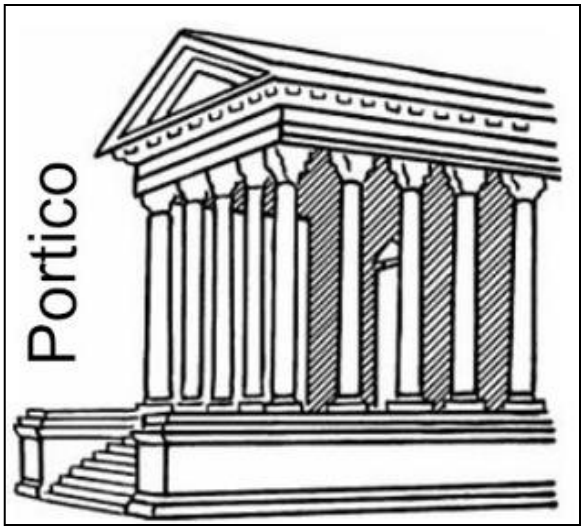


Figure 2.1: Portico (URL1)

The Romans, developed Greek solar architecture through invention of transparent surfaces such as mica and glass, which allow them to penetrate sun radiation inside their buildings and keep it longer, example of these sun spaces is '*Heliocaminus*'[2]. See Figure '2.2'.

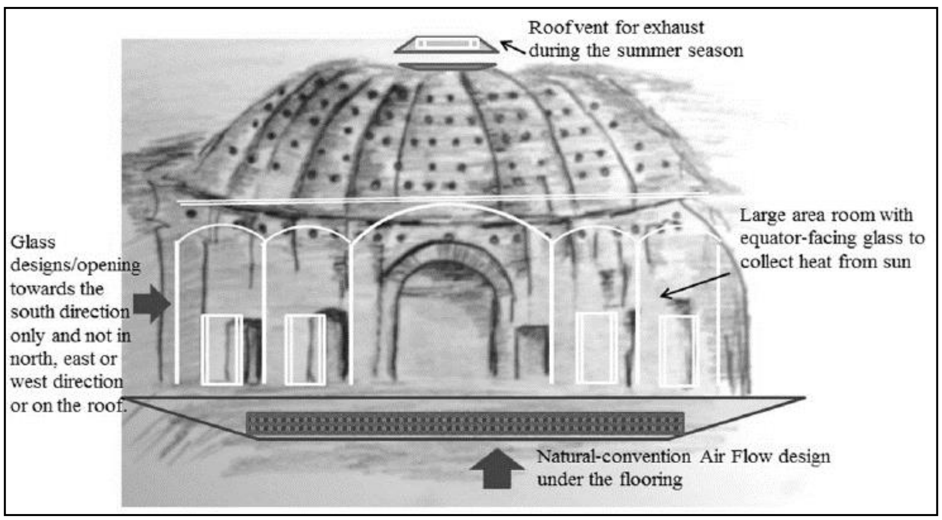


Figure 2.2: Remains of ancient 'Heliocaminus' Baths built in 120 ADS at villa Adriana, near Rome (URL2)

[2] The Greek / Latin term literally means "solar furnace" and refers to a glass-enclosed sunroom designed to become hotter than the outside air temperature, as passive solar strategy for heating.(MEEF Roman Architectural Glossary)

Vernacular and traditional buildings had many passive solar techniques to implement thermal comfort inside the inner spaces (Nahar et al, 2003). Vernacular and traditional architecture have been providing effective solutions for comfort conditions and energy consumption by using local and regional opportunities for the design, coincide with the surrounding environment. Nowadays, solar energy application, gives an opportunity to replace the active heating and cooling systems by consolidate knowledge and methods of traditional building patterns that reconcile solar power with economy and style.

One of the other examples of a developed passive solar architecture is '*Acoma*' (sky city, 1150 A.D.), which is a model for American solar architecture. They took in consideration, shapes, height, and orientation of each buildings to have adequate access to the sun (Butti and Perlin, 1980). The '*Acoma*' houses have been constructed in a climate responsive technique. Thermal mass (thick walls) has been used in the masonry, and facing the buildings southwards to collect sun beams during the day in winters and formed the houses as row houses and adjacent on east and west sides to mitigate the severe impact of sun's radiation in summer on these sides (Knowles, 2003). See Figure '2.3'.

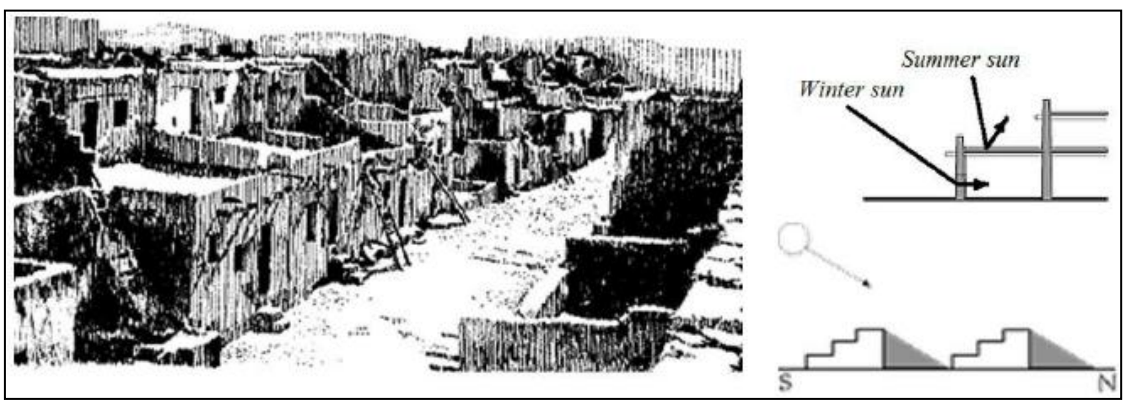


Figure 2.3: Passive Solar Architecture in Acoma (URL3)

Strategies for solar energy were used long back as it was observed. In traditional colonies, orientation was the most significant criterion. The world became dependent on fossil fuels to provide low-cost energy. Later the negative impact on the environment due to excessive use of fossil fuels began to put its effects. Consequently, the world tried to eliminate or reduce the dependence on these fuels by reverting to passive solar energy. In the 20th century the development of passive solar energy led to emerge the sustainable architecture, which was the reaction of the crisis of energy which occurred in the 1940s, and 1970s, of 20th century, and late 2000, (Braham, and Willis, 2013, p.1).

In order to obtain efficient storage, collection and allocation of solar energy in houses, different techniques have been developed. These differences of methods have influenced buildings design as well, they have constituted of solar architecture as a modern possibility for contemporary engineers and architects and with the novel technology. ‘Trombe Walls 'is one of the passive solar strategies and have been used as an early modern app. It was developed by “Frenchman Felix Trombe”, who was the director of the research centre for solar energy at Odelio in France, based on the work of “Edward Morse” in the 1880s. Afterward, this strategy had been employed in architecture by Jacques Michel. (Barber, 2012).

2.2.2 The most significant elements for passive strategies in hot-arid climates

The most important elements for effective passive strategies in hot and arid climates are; building form; thermal mass; building orientation; fenestration; natural ventilation, and shading (Moore, 1993; Givoni, 1969; Rowland and Howe, 1999; Szokolay, 2004; Aynsley, 2007; Lstiburek, 2004; Brawn, and Dekay, 2001). See Figure ‘2.4’.

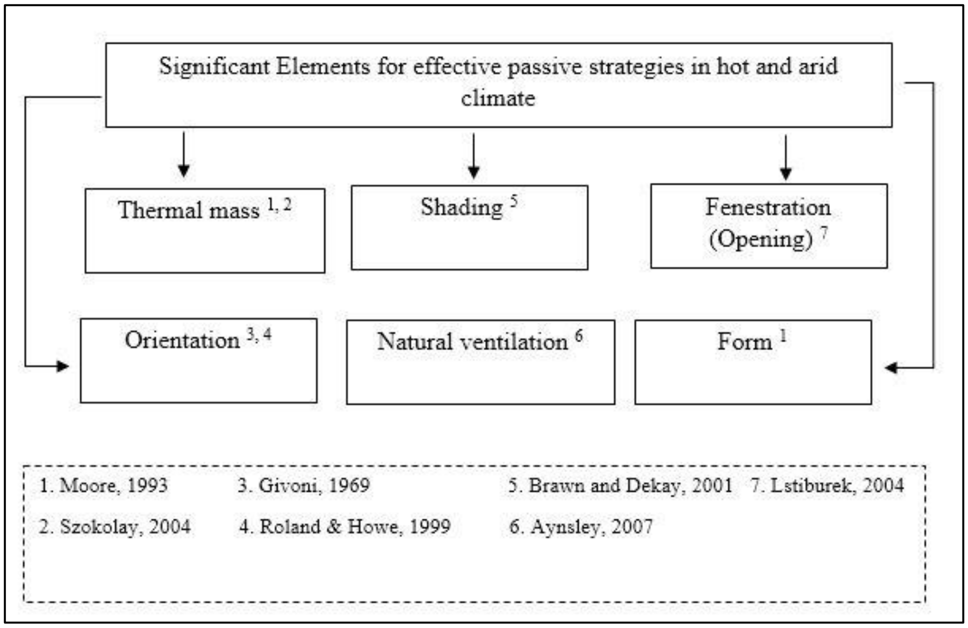


Figure 2.4: The most important elements for effective passive strategies in hot and arid climate (Author,2019)

Each one of these elements operates independently, but they communicate with each other to achieve a comfortable thermal environment and to reduce energy consumption inside the buildings. Shading helps to reduce solar radiation. In a warmer climate and particularly in the summer months, the use of shading becomes more important. In the summer, a suitable shading device, such as overhangs, awnings, and blinds for this purpose, can reduce the cooling energy in the summer (Bahrami, 2008). Shade displays have low costs and are a versatile way to control solar heat gain. They absorb and reflect a large portion of the sun rays (Lstiburek, 2004). The orientation of the building has a major impact on energy consumption. Three important parameters in this issue are; the quantity, orientation and proportion of glazed surfaces. The broad layer of the glass on the south side of a building helps to increase the building's thermal absorption potential in winter. The glazed surface should be fitted with appropriate shading devices to prevent solar heat gain during the summer (Bahrami, 2008). Natural ventilation is a valuable energy conservation tool because it can reduce the dependence on fossil fuel considerably by decrease the relying on electricity and reduce artificial ventilation and air conditioning requirements. Reducing energy consumption for cooling results in reducing emissions of greenhouse gas from the power generating plant. Therefore, before several years, natural airflow started to be used again by architects to achieve two basic building requirements: mitigating pollutant air and humidity elimination, as well as achievement of human thermal comfort (Aynsley, 2007). The construction form in the early stage of design is a very important factor and has a great impact on energy efficiency in the building. (Szuppinger 2011), confirmed that the compact form of a building is stronger than the non-compacted one. In this case, their wall surface volume, an L-shaped house uses greater energy than a cubic building, causing more heat losses from the surfaces. Thermal mass is one of the important elements in achieving energy efficiency. In the next parts, will elaborate more about this strategy (see sub-chapter 2.2.4).

2.2.3 Most effective passive strategies in Northern Iraq

Many new studies in northern Iraq have been analyzed based on the literature review to find the most effective passive strategies in the region. The most effective strategies or techniques to develop thermal performance in the buildings have been reviewed too.

A study by Soran (2019) has done by analyzing traditional buildings in Erbil. The study has addressed that based on the findings and data analyzes, thermo-physical characteristics of building's masonry material, thermal mass, and courtyard are the most effective strategies to minimize cooling/ heating effects of environmental characteristics on the buildings in Erbil.

Furthermore, Amin (2018), has carried out a study in Erbil city at northern Iraq. The study has selected many case studies inside the city of Erbil, and evaluated the achievement of sustainability in these case studies. The study has concluded that the building materials could have a significant role in achieving sustainability, through reducing heat exchange with outer environment. Hence, the study has recommended local building materials such as natural stones, bricks, cement stabilized blocks from laterite soils, etc. for achieving economic and environmental sustainability through improving energy efficiency inside the buildings.

Muhy Al-din and Iranfar (2019), have endeavored to estimate the thermal performance (steady-state) condition of a range of houses skin for the houses in, Northern Iraq. Vernacular, early modern and contemporary buildings were assessed to find the relationship between the architectural style, and the thermal performance through the skin materials. The study is examining the potential of the building skin materials to control heat exchange. The results demonstrated that thermal mass as passive design strategies are one of the most important ways to reduce energy consumption in Northern Iraq and in Iraq in general.

Salih (2018), has implemented a study that conducted in Duhok city in northern Iraq. This study aimed to reduce energy consumption inside the buildings in northern Iraq through architectural design. The study has confirmed that thermal mass, orientation of the buildings, are very effective strategies in the climate of this region. Hence, the study suggested proper thermal properties of the building's material can play a significant role in energy efficiency inside the buildings. The study reminds that architects in northern Iraq should consider these factors.

The study of Rozhbayani (2018) has shown that building materials in Erbil have a good capability for regulating heat gain/ loss in these buildings, both in traditional and vernacular buildings. As a result, an active heating and cooling system would reduce the need for thermal comfort to be maintained all year long in the buildings. The modern houses do not respond to the performance of heating and cooling. The study found the high thermal mass, the evaporative cooling, and the ventilation at night are effective techniques to achieve thermal comfort in the summer. In the winter it is recommended to increase thermal mass and direct solar radiation.

Abdulrahman (2014) researched northern Iraq's traditional buildings and how they can develop energy-efficient buildings through the advancement of architectural design to learn from the region's traditional architecture. It was found that the main reason why a large quantity of energy is used in buildings in Northern Iraq is that buildings are not adequately separated from the exterior environment, due to improper thermal characteristics for the building materials. However, the thermo physical- properties of the windows are weak too. The study has found that energy efficiency of buildings in Erbil can be achieved by increasing the thickness (roofing and walling) through introducing air cavity and wall insulation material and adding roof isolations.

According to the previous studies regarding the most effective strategies in northern Iraq, the studies have concluded that the most effective strategies and techniques are; thermal mass, building orientation, courtyard, evaporative cooling. All the studies have mentioned thermal mass as an effective strategy, which indicates that it is one of the most repetitive strategies. Moreover, this thesis will focus on the passive strategies which are related to the building materials as a limit of this study. Therefore, the study will concentrate on thermal mass as the most effective strategy to reduce energy consumption in buildings.

2.2.4 Thermal mass

Thermal mass will be studied as the most important and repetitive passive strategies to reduce energy consumption in the buildings in the region of the study. Furthermore, this strategy is related directly to the construction materials, which is the concern of this study, as mentioned previously. Hence, the study will elaborate about this strategy.

The building envelope was the main tool for controlling the energy consumption thermal environment and the building was fully adapted to its environment. The building envelope had to be used by the vernacular architects as the basic mediator between the environments of the exterior and interior (Moore, 1993). Thermal mass is a material resistance to temperature change. High thermal mass walls are capable of absorbing and retaining the heat, as seen in figure ‘2.5’. Thermal mass is a substantial passive technique for mitigating the energy loads for heating and cooling in the buildings, particularly in climatic conditions of high diurnal and nocturnal differences in temperature. High thermal mass materials absorb and radiate heat, reducing the rate of the sun heats up space. Without thermal mass, the heat reached into the inner space would simply re-radiate out easily, making the room too warm with sunrays and too cold without it. Thermal mass effects can be harmful in chronically warm or cold climates. This is because all mass surfaces adhere to the average daily temperature; if this is more or less hot, the inhabitants will experience greater discomfort because of unwanted heat gains/losses through the building's envelope. Therefore, buildings are designed for permeable and not thermal mass in warm humid climates such as tropical and equatorial regions. Buildings are usually highly isolated with extremely low thermal mass exposure in very cold and sub polar areas, even when they are used for structural purposes (Koenigsberger, et al., 2010).

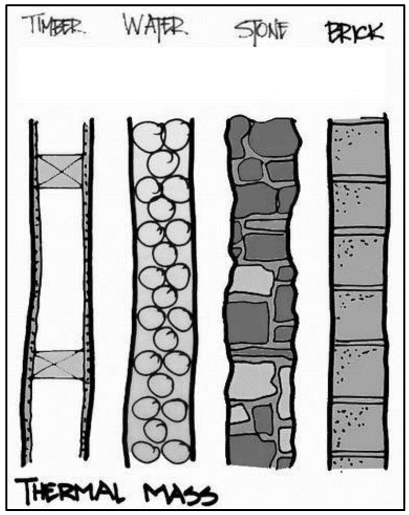


Figure 2.5: Types of thermal mass walls (Rozhbayani, 2018)

2.3 Materials in Architecture

More than one task is performed by most materials. The choice of building materials goes beyond practical requirements as the exterior appearance of the material and the sensory attraction also make a difference in the design development (Ashby and Johnson, 2013). The architect often considers other quality characteristics – resilience, the intensity of compression, etc., as well as aspects connected with the meaning appeal and the experience of the occupant, such as color and visual clarity, when selecting a product. In addition, the designer could also imagine a special environment that the materials would originate from. The group of material options available now to architects and designers made it possible to re-evaluate the conventional material categorization (Malnar and Vodvarka, 2004).

2.3.1 Types of building materials used in construction

Building material is any substance that is applied in the construction process like for use in the building. The most popular type of construction material apply in the construction industry is cement, steel, wood, bricks, aggregates, concrete and soil. The selection of these building materials is according to their economic efficiency. Several existing natural materials have been applied to building construction, including clay, sand, wood and rocks, even twigs and leaves. In addition to natural materials, a number of human manufactured products, more and less are being used. The manufacturing of building materials is a significant industry in several countries and its use is usually divided into specific industries like carpentry, plumbing, roofing, and insulation. The guide discusses habitats and buildings like houses (Khalafalla, and Malyuta, 2013).

2.3.2 Construction materials

Building materials can usually be divided into two artificial and natural sources. Natural materials, like timber or glass, are those which are organic or minimally processed. Artificial materials are manufactured in industrial areas, after various man-made manipulations like plastics and petroleum-based paints, and both of them have their applications. Clay, stone, and fibrous plants are the most common materials, apart from the tents produced by flexible materials like cloth or skins. Individuals in all the world they applied these three materials simultaneously to build houses to be proper for their local weather situation. Totally, in these buildings, stone is applied as primary structural elements, whereas mud acts as a form of concrete and isolation to fill the gap between them. "Wattle and daub" are simple examples which often used as conventional housing in the countries that characterized by tropical climate or summer houses by Indigenous northern individuals. The material of Modern buildings like fabric membranes can be produced by a flexible material, and hold by the technique of air pressure from inside or steel cables (Akkermans, 2010).

2.3.3 Common types of construction materials

The followings are some important types of construction materials which are prevailed in the construction around the world;

I. Mud and Clay

There are various styles of buildings in terms of the quantity of each material in use. Generally, the determining factor is related to soil quality. Larger quantities of clay are generally cob/adobe, whereas low clay soil is normally associated with the cheap construction. The other important components contain almost sand/gravel and straw/grass are Rammed earth is both an old and a modern concept of constructing walls, previously created by hand compressing clay soils among planks, currently, techniques are being used such as mechanical pneumatic compressors. Clay and Soil, in particular, are good thermal masses, and they are very good for constantly maintaining temperatures level. Earth-built houses are usually warm during cold weather and cool in summer. Clay keeps cold or heat, similar to stone emitting it during the time. The earth walls gradually change the temperature, so that a rise of or a lowering the temperature can use more energy than a wood-built house, but heat and coolness remain longer. The building of peoples mostly with impurities and clay, including cob, adobe, and sod, resulted, however, in homes built on a smaller scale over the centuries, both in western and northern Europe and in the rest of the world (Norton, 1997).

II. Rock

There have been rock structures throughout history. It is the oldest accessible durable building material and is generally easily available. There are many rock forms all over the world with different characteristics which for specific uses make them better or worse. Rock is a substance with high density, so it provides much protection too, and its weight and awkwardness are its major drawbacks as a substance. The energy density is also considered a major downside, as the stone is hard to keep warm without the use of heating facilities in large quantities (Akkermans, 2010). The dry-stone walls were built since people placed one stone on the other. Finally, the stones were fixed together in the various shapes by mortar, cement being the most frequent substance. For instance, the granite-tipped uplands in ‘Dartmoor’ National Park in the UK offered early settlers’ sufficient resources. During the Neolithic and early Bronze Age circular cottages were built from brittle granite rocks. In the middle Ages and modern times, granite proceeded to be used. Slate (made up of clay minerals) is also another form of material usually using in the roof in many places around the world. In many big cities, several civilizations largely built of stone, like the Aztec pyramids, the pyramids in Egypt, and the remaining part of an Inca civilization can be seen (Raymond, 1981).

III. Bricks and Concrete Block

A brick consists of a block of kilns-fired substance, generally, clay or shale as well as can be made of a lower quality, mud, etc. Clay bricks are produced by molding (the flexible mud method) or by extruding clay to the appropriate size by wire cutting it into commercial production (the stiff mud procedure).

Back to the 1700s, 1800s, and 1900s, bricks were commonly applied as a building material. In the late 20th century, another form of the block was replacing clay bricks, it was a block of the Cinder, and it is mainly produced by concrete. The Sand Crete Block, which is less expensive than fired clay bricks, is a major cost-effective component in developing countries (Ahmad et al., 2014).

IV. Concrete

Concrete is a composite construction substance produced of a mixture of a composite (aggregate) and a binder like cement. Portland cement concrete, consisting of mineral compounds (usually sand and gravel), Portland concrete and water, is the main usual configuration of concrete. The cement hydrates after combining and finally converts into a stone-like material. This is the material to which the term concrete refers when used in the generic sense. Since concrete has a relatively poor tensile strength, it is typically reinforced with steel rods or bars (called rebar) for any concrete structures of any scale. The strengthened concrete is called reinforced concrete. A vibrator is applied to remove any air bubble that would damage the structure when the fluid concrete mix is pushed into the ironworks. Because of its durability, formability and transport simplicity, concrete was the preferred substance in recent times (Li, 2011, pp: 23-93).

V. Metal

Metal is applied as a building skeleton for larger buildings, including skyscrapers, or use as the outer covering of the building surface. Most types of metals are employed for construction is Steel. It is a metal alloy that has iron as its main part and is the common choice for structural metal construction. It is powerful, flexible and stays for a long time if well-refined or handled. When lifespan is concerned, corrosion is the main enemy of metal. Sometimes their higher cost is compensated by lower density and greater corrosion resistance of aluminum alloys and tin. Brass has been more general in previous years, but currently, it is commonly limited to particular uses or specialty items. Metal production needs a great deal of human labor, especially in the large amounts needed for the construction sectors. Aluminum, copper, and titanium, as well as Gold, silver and copper, are some other metals utilized. For structural reasons, Aluminum is very good metal but it is generally used as decorative because it does not have the hardness of steel. Titanium may be applied for structural reasons but it is more costly than steel. Gold, silver, and copper are employed for decoration, as these materials are costly and lack structural qualities like tensile stability or stiffness (Chen, 2005).

2.4 Building Material and Energy Consumption

The most important building material which has heavy impact on energy consumption in the building is envelope elements materials, exterior walls, roof, floor, and windows. This is because they are the first integrators with outside environment (Basarir et al., 2012). The following part will describe the envelope components and their influence on heat gain/loss in the building.

2.4.1 External walls

External walls are important parts of a building envelope. External walls should be durable, safe, stable, able to resist moisture and have thermal durability and resistance... etc. These are the major functions of the external wall (Van der Merwe, 2011). Building's envelope receives a great amount of solar radiation; a number of factors can influence proper wall building and its thermal conditions such as; heat retention and heat transfer properties of the wall. The external wall's thermal capacity can be increased by adding exterior cladding and the insulating materials (Abdulrahman, 2014). In hot -arid climatic zones, control of the movement of moisture, air, and heat through the building envelope are major objectives for the design and construction of exterior walls (Gilbride et al., 2011). The flow of heating through the building envelope is the most important factor to consider more than any other. Heat is flowing from the warm to the cold and every building component material contributes to the flow of heat at different capacities. Good thermal insulators are the materials with a lower heat transfer capacity. U-value (Heat transfer coefficient value) is a unit to define how well or poorly a component of a building is isolated and described as the rate at which heat is transferred via a building's external envelope. The lower U-value for the building's envelope element is meaning less heat is transferred through the element (Arnold, 2010). In single-story buildings, heat losses are based on 45% of exterior walls and windows. For multi-story exterior walls and windows contribute 70% of the heat loss in the building (Muhy Al-Din et al., 2017). See Figure ‘2.6’.

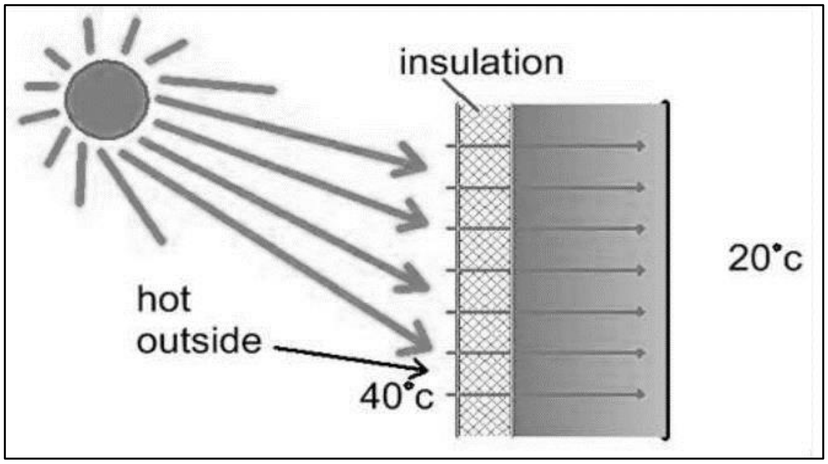


Figure 2.6: The main modes of heat transfer through exterior walls in the building (URL4)

2.4.2 Roofs

The roof is covering the top part of the building, the roof is designed to protect the building from harsh climatic conditions and from low and high temperatures. If the roof structure fails, other building components could be affected. Two styles of roofs are available: flat and tilt roofs. The roof is also is one of the most important elements in controlling heat gain and heat loss, it is responsible for building42% of heat loss (Muhy Al-din, et al., 2017). Hot and moist, internal air passes through the roof structure from the inside of the building when the internal air pressure exceeds the external cold air, at the point of meeting warm air and colder air condensation takes place and the roof becomes damp. The roof with an air conditioning system is at risk with condensation in summer. Thermal insulation material will overcome this defect (Divsalar, 2011). Thermal insulator materials are those with thermal conductivity lower than 0.25 W / m K (Vasiliu, 2008). See Figure ‘2.7’.

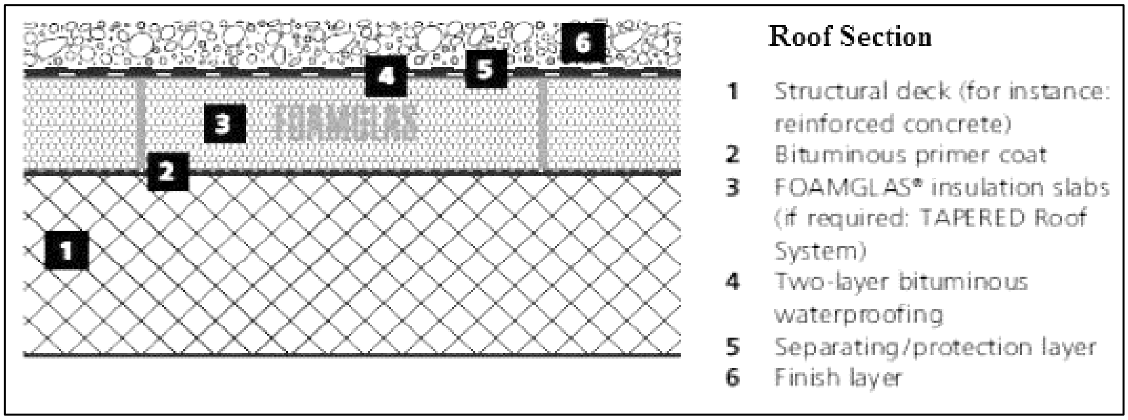


Figure 2.7: Typical section in the reinforced concrete roof with thermal and waterproof insulation layers (Abdulrahman, 2014)

2.4.3 Windows & doors

Window and doors are connecting inside of the building with outside. These structural elements are providing ventilation and sunlight, and they are also decorative elements of the building. Various factors are affecting the energy consumption in a building because of heat gain/ loss through the windows such as window orientation, location, area, shading and window frame, and 'vitrification'. Windows with small U-value are decreasing heat losses in winter but reduces air conditioning load only marginally in the summer in a hot and drying climate. For summertime, windows should have low E-coating to reduce heat losses from solar radiation. According to (Schuwer, et al., 2012), the double low-e-glazing with a U -value of less than 1.3 W / K are ideal windows in a hot and dry climate. The losses of heat and the gain of heat in convection, radiation and conduction from all the window components, measures by U-value. See Figure '2.8'.

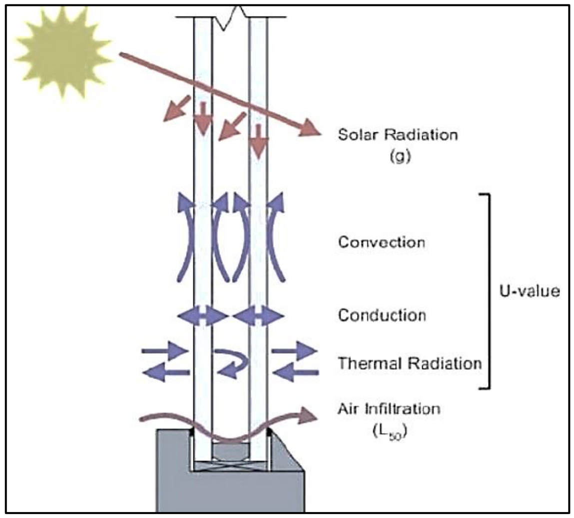


Figure 2.8: The flow of heating energy through a window inside or outside of the building (JRC, 2012)

The lower U-value window loses less energy by heat gain/ loss. Therefore, the study will focus on this measurement indicator to assess the thermo-physical properties for the windows in the region of study. Regarding the exterior doors in the buildings, the ideal U-value should be lower than 1.25 W/m2 K (California energy commission, 2013).

2.4.4 Floors

A floor is one of the most important elements in the buildings. Commonly, in hot and arid climates the floor is constructed with several layers; compacted soil or stone as a bottom layer, plain concrete layer and finishing with tiles or parquet as a floor coating (Abdulrahman, 2014). See Figure ‘2.9’.

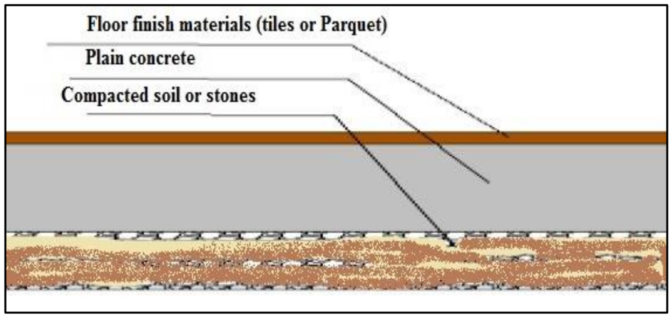


Figure 2.9: Typical section in floor in semi-arid climate houses (Lstiburek, 2014)

The saturated ground around the building due to these plants, which produces indoor mold, is the main problem for floor construction in hot dry climates. Consequently, the wall component may be deteriorated (Lstiburek, 2014). See Figure '2.10'.

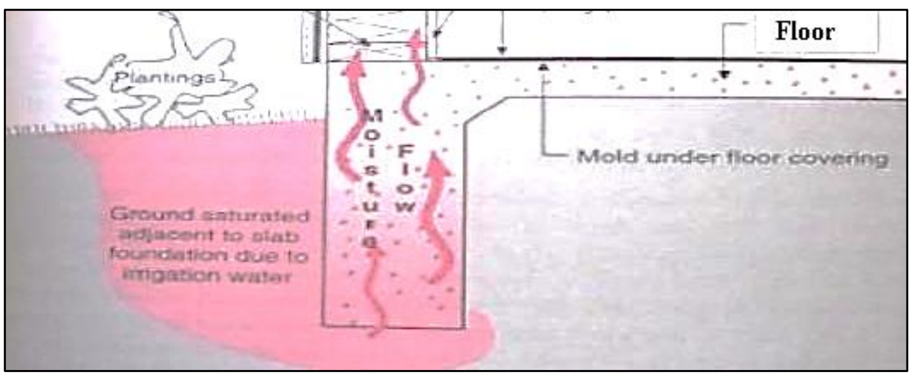


Figure 2.10: Interior mold on the floor due to outside irrigation in hot-arid climates (Lstiburek, 2014)

2.5 Heat Transfer Coefficient Value (U- value)

U-value is defined as the heat level which is transferred inside the buildings through the external envelope. The material insulation capacity decreases by humidity as well as the conductivity of the material is increased by the moisture. U-value can be impacted and its isolating characteristics can be significantly increased and reduced through minor moisture changes (Rozhbayani, 2018). Due to a deficient insulation, leakage of gutter and not proper fixing of the window framework, the humidity could enter the building through the envelope as is a result. Therefore, it is important to maintain the building well to achieve low U-values (Mohammad and Shea, 2013).

To calculate U-value, it is necessary to find the thermal conductivity k (W/m K) for each material in the building element structure as illustrated in the equation (1.1). Then, it is important to obtain the thermal resistance R (m^2K/W) for every material (The Brick Industry Association, 2016) as shown;

$$R = \frac{t}{k} \text{ (m}^2\text{K/W).} \tag{2.1}$$

Where, (t) is the thickness for each single material has used in the building element.

U-value is obtained as the reverse of R-value as demonstrated in equation (2);

$$U = \frac{1}{R} \text{ (W/ m}^2\text{K).} \tag{2.2}$$

And

$$\text{U} = \frac{1}{(\text{Rsi+R1+R2+}\cdots\text{Rx+Rse})} \tag{2.3}$$

Where;

R_{si}. = The inner surface resistance to the thermal transmission (m^2K/W).

R_{se}. = The exterior surface resistance to the thermal transmission (m^2K/W). (Anderson, 2006).

(Rsi. and Rse) in this study will be obtained from BRE-United Kingdom standards.

2.6 Summary

This chapter has highlighted several keywords in this study. Passive strategies have been discussed and the study demonstrated the most important passive strategies. This is through review the literature to discuss the most important elements for passive strategies in hot and arid climate which it is the climate of the study region. Moreover, the previous in this field studies have been conducted to find the most effective passive strategies in northern Iraq based on the repetitive in the researches results. Thus, thermal mass as the most important passive strategy to reduce energy consumption in northern Iraq have been identified and explained. The importance of material in architecture has been discussed. The construction materials role has been discussed as one of the most important dimensions in this thesis. The study has focused on envelope materials as the most important part that is affecting energy consumption through controlling heat gain/loss as the first integrated part with outside environment. The U-value has been introduced and the most ideal U-value in the building's elements has been identified through theoretical analysis and literature review.

CHAPTER 3

METHODOLOGY

This chapter will delineate the methodology and the practical ways to achieve the aims of the thesis. It will explain the main methodology and methods that conducted in this thesis. Furthermore, it will lay out the road map of the thesis and the case study region will be described in this chapter. Moreover, the criteria in selecting case study buildings will be highlighted too.

3.1 The Approaches to The Study

This research applies a quantitative research method in order to address the research question and objectives. The questions of research as set out in chapter one was;

“1. What are the most effective passive design strategies at the residential buildings in Northern Iraq, in terms of applied strategies to the buildings and their response to climate?

2. How, to reduce energy consumption in Northern Iraq through passive design strategies, within the limits of this study?

3. What are the most effective building materials that can be applied in Northern Iraq for energy efficiency in the buildings?”

The nature of this work focused on energy efficiency evaluation in residential buildings at Sulaymaniya city in Northern Iraq, hence, the quantitative method will be approached for this purpose. This study aims to understand the most passive techniques in the dimension of building material development in residential buildings to increase the energy efficiency of existing and future buildings in the city of Sulaymaniyah. Comparative analyses are being carried out for several residential buildings in Sulaymaniyah and the thermo-physical properties for the construction material will be investigated in terms of their effect on energy consumption, for example the external walls, floors, roofs, and window materials. A case study methodology is therefore used to accomplish the research goals and to answer questions of the thesis.

3.1.1 Case study methodology

Several subjects such as the context of case studies analysis; the method of case study analysis and the constraints in selecting case study analysis will be discussed throughout this section. Based on the nature of the collection of data from case studies in the field of current study, the case analysis process viewed a quantitative approach to research. The purpose of reviewing every case study is to gain a full understanding of the case study (Waltz et al., 2010).

3.2.1. Criteria for selecting case study buildings

It is very important to have successful case study selection when the study is related to analyzing energy performance in the buildings, in order to reach successful results and get more realistic answers to the study questions (Muhy Al-Din et al., 2017). Therefore, several residential buildings have been selected inside Sulaymaniyah city in Northern Iraq. The criteria to select these case studies were the following:

- The case study should be residential, and occupied by people.
- The case studies should from different periods and have different construction age.
- The projects should be in the area of Sulaymaniyah city in Northern Iraq.
- Acceptance of the householders to cooperate and allow to get field information.

3.2.2 Field observation

The observation is one of the most common methods used by researchers for collecting data through direct study. This could neutralize personal biases that are created by current events (Kothari, 2004). The need for observation by researchers should spend sufficient time applying different techniques in the study field to obtain clear views of the particular studies variables (Baker, 2006). It was used in residential buildings for the chosen case studies in Sulaymaniyah-Northern Iraq to investigate the materials of the buildings in terms of their thermo-physical properties.

3.2.3 Data collection

In order to validate and enhance the credibility of the research, the real-life case study residential buildings have been selected from ‘Sulaymaniyah’ city in Northern Iraq. The data collection and analysis will be acquired from these case studies as primary data sources. Literature review and theoretical analysis will be the secondary data sources, to gain adequate insight into the key theories and ideas concerning the subject. This is through books, theses, index articles and credible internet sources.

3.3 Research Framework

Ten case studies will be selected for analyzing; all the buildings will be residential with different construction materials of different ages in different places of Sulaymaniyah city. The field observation will be applied to examine the envelope construction materials (roofs, floors, exterior walls, and windows), which have a direct effect on the energy efficiency of the buildings. Thermo-physical properties of these construction materials will be tested through evaluating the heat capacity of each material in each building using U-value as the assessment unit.

A comparison among the construction materials of the elements of the building will be executed in terms of their heat-retaining potential. Then, the study will try to recognize the most effective building materials in the region of the study to develop the energy efficiency in the buildings.

The huge part of the energy in Sulaymaniyah is consumes to preserve thermal comfort inside the buildings. Hence, the most functional construction materials to preserve thermal performance inside the residential buildings will be inspected based on U-value for each material and for the total element. When comparing construction materials' design, then new solutions will be proposed. The goal is to find alternatives that respond to climatic conditions for more energy-efficient buildings in Sulaymaniyah. The methodology roadmap and the main stages of the study will be presented in the following diagram. See Figure ‘3.1’.

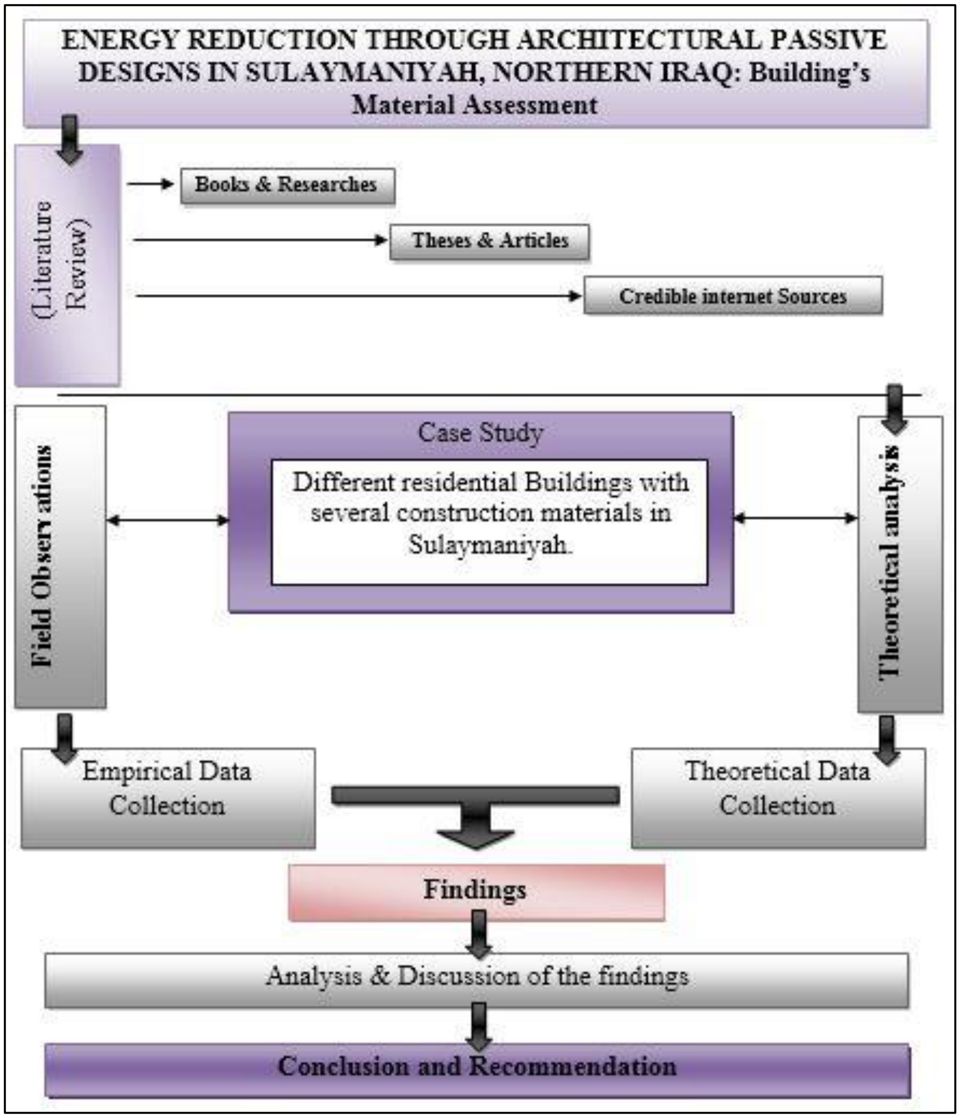


Figure 3.1: The methodology roadmap for the current study (Author,2019)

3.4 Study Area

'Sulaymaniyah' is located in the Northeast of Iraq, in Northern Iraq. 'Sulaymaniyah' borders 'Iran' to the East and have internal borders with capital of Kurdistan Region 'Erbil'. Sharing border with other Iraqi governorates as 'Salah Al-din', 'Diyala' and 'Kirkuk', as seen in figure '3.2'. Sulaymaniyah city established on 14th of November 1784 by the Kurdish prince 'Ibrahim Pasha Baban' who named it by his father 'Suleiman Pasha'.'Sulaymaniyah' was capital of

Baban Emarates from 1784 to 1850 during principality of Baban. ‘Sulaymaniyah’ is considers as the cultural city of northern Iraq and an important economic and industrial center for Iraq (UNHCR, 2004).

Figure 3.2: The location of Slaymaniyah within the Republic of Iraq (URL5)

The geographical coordinate for Sulaymaniyah is 35.55° N, and 45.45° E, and the average height from mean sea level is 890 meters. Sulaymaniyah geographically is dominated by hilly to mountainous territory. It is surrounded by ‘Goizja Range’, ‘Azmar Range’, and ‘Qaiwan Range’ from the north-east. Bordered from the south by ‘Baranan Mountain’ and the ‘Tasluje Hills’ adjacent the city from the west. The climate of the area which the city located is hot - dry summers and very cold winters (Saeed, 2003).

3.4.1 Climatic characteristic

The climate of Sulaymaniyah is classified as BWh according to the Köppen-Geiger system. The average temperatures are 24.6 °C. The precipitation is changing 20 mm between the wettest month and the driest month, as seen in Figure ‘3.3’.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	10.3	12.8	16.8	22.2	28.2	32.6	34.9	34.4	31.1	25.1	17.7	11.9
Min. Temperature (°C)	4.3	6.3	9.9	15	20.4	24	26.1	25.3	22	16.8	10.8	5.7
Max. Temperature (°C)	16.3	19.3	23.8	29.4	36	41.3	43.7	43.5	40.2	33.4	24.7	18.1
Avg. Temperature (°F)	50.5	55.0	62.2	72.0	82.8	90.7	94.8	93.9	88.0	77.2	63.9	53.4
Min. Temperature (°F)	39.7	43.3	49.8	59.0	68.7	75.2	79.0	77.5	71.6	62.2	51.4	42.3
Max. Temperature (°F)	61.3	66.7	74.8	84.9	96.8	106.3	110.7	110.3	104.4	92.1	76.5	64.6
Precipitation / Rainfall (mm)	20	15	14	12	6	0	0	0	0	1	9	19

Figure 3.3: Maximum, average, and minimum temperature, as well as the rainfall in Sulaymaniyah-Northern Iraq (URL6)

Warm season is starting from May, and finishes in end of September, while, the cold season starts in the end of November and finish in the end of February.

3.4.2 Energy consumption in Sulaymaniyah

As demonstrated in Figure (3.4) MEEK's Annual Report in 2014 is indicated that the consumption of electricity for thermal comfort purposes and lighting of residential buildings in Sulaymaniyah amounted to 71 percent of the total national electrical power generated. This shows the value of energy analysis in residential buildings (Radha, 2018).

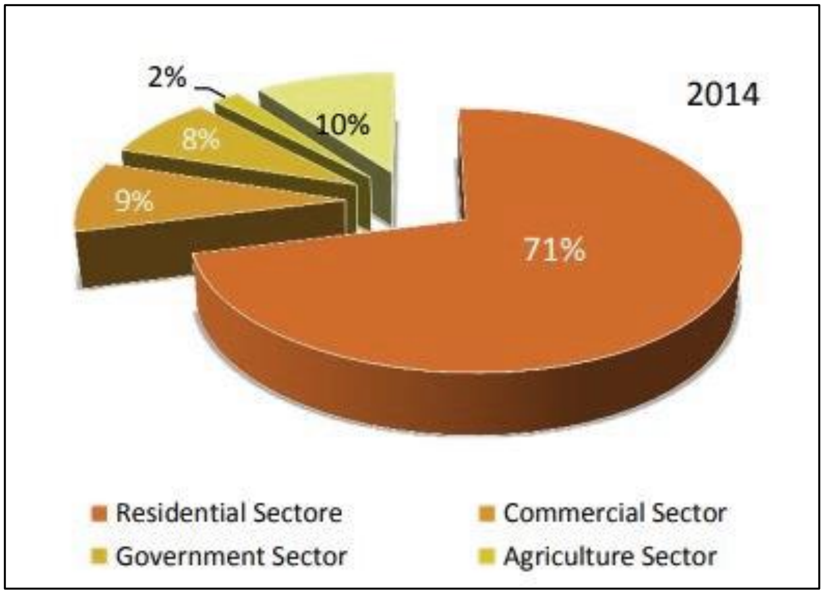


Figure 3.4: Electrical power consumption by sectors in Sulaymaniyah (Radha, 2018)

3.4.3 Selected case studies

Eight residential buildings have been selected to study their envelope construction materials in; Exterior walls, windows, roofs, and floors. The buildings have been chosen from different places in Sulaymaniya city as it is shown below;

3.4.2.1 Case studies in (Sabunkaran district)

The residential buildings in this district are very old and the buildings in the district of '*Sabunkaran*', returns to the beginning of the twentieth century. See Figure '3.5'. The majority of the residential houses in this district are houses with one or two floors. The building material in these buildings are either local stone for as masonry unit for external walls or using burnt brick with thick external walls (*Gunya*). For roofs, the buildings are using burnt bricks with I-beams, covered by bituminous waterproofing layer (*Libad*), and covered by compacted soil, or using trunk of trees, covered with plywood and over that a layer of compacted soil have been laid. Windows are commonly consisted of wooden frame or iron frame, and single transparent or colorful glasses. The floors are finished either with plain concrete or mosaic tiles. Three case study buildings have been selected from this region.

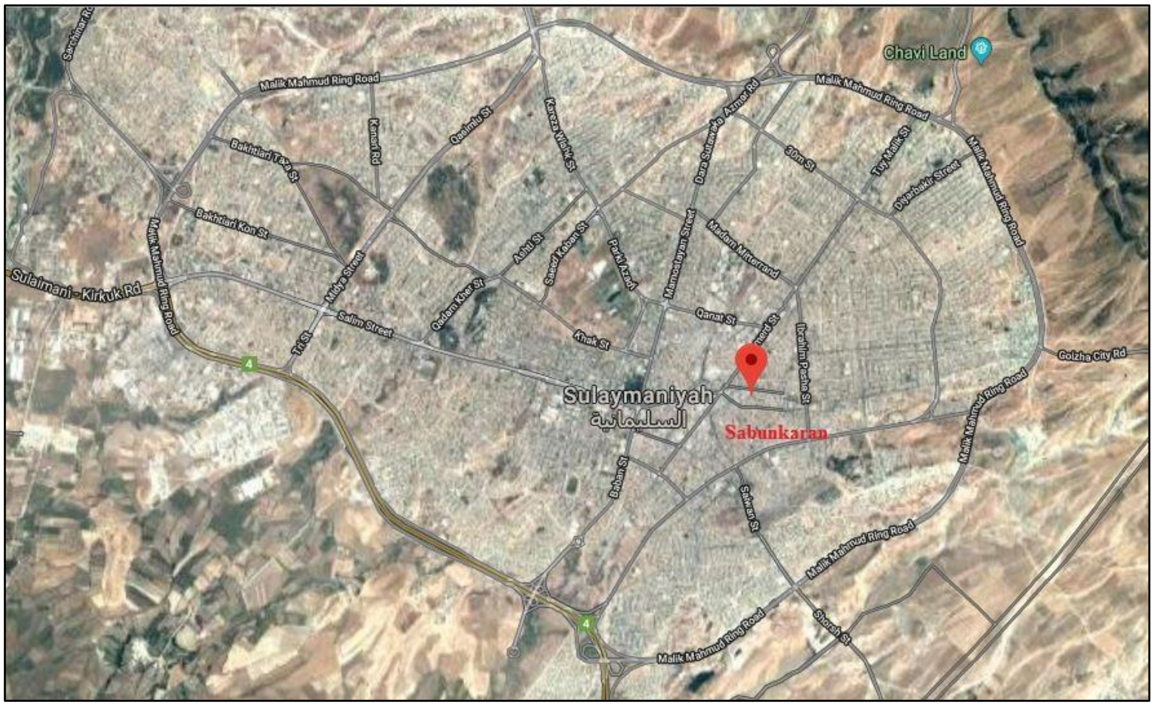


Figure 3.5: Sabunkaran district within Sulaymaniyah city. Retrieved from (Google earth,2019)

Two case study buildings have been selected from this district to be analyzed in terms of envelope material.

a. Case Study 1

The first building is renovated two floor house and it is now a dormitory and built in 1930's by burnt bricks, located in '*Sabunkaran*' at Sulaymaniyah, as seen if Figure '3.6'.

Figure 3.6: First case study Dormitory renovated house in Sabunkaran (Author,2019)

b. Case Study 2

This building is two floor house and located in the '*Sabunkaran*' area, it has been constructed in the end of 40's from the last century. It is occupied by two families. See Figure '3.7'.

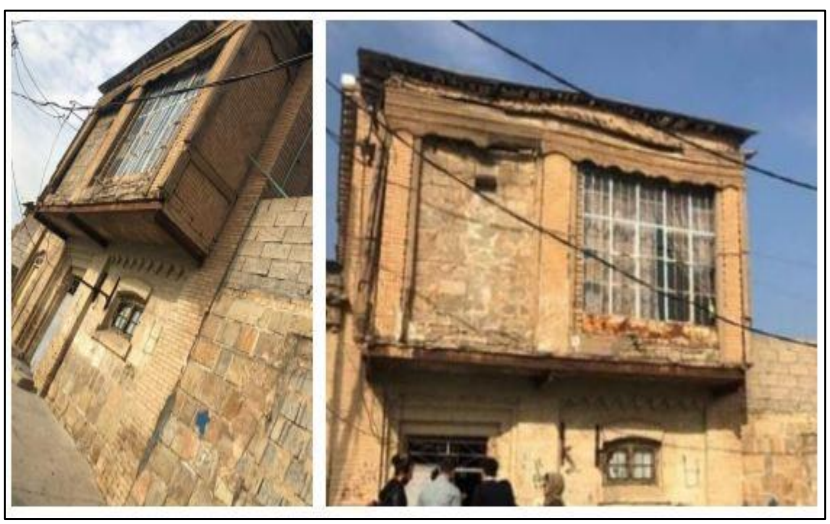


Figure 3.7: Second case study house in Sabunkaran- Sulaymaniyah (Author,2019)

3.4.2.2 Case studies in (Chwarbakh district)

This area is located in Southern part of Sulaymaniyah, and it is residential and commercial district, as seen in figure '3.8'. The residential buildings in this district are built in 70's and 80's of the twentieth century. Building construction materials for the residential buildings in this sector are local stone, concrete blocks, and burnt bricks as masonry units. The slabs are reinforced concrete, either covered with concrete tiles or left without covering materials. The windows are either aluminum frame, or Iron frames, and the glasses are single transparent glasses. The floors commonly are plain concrete covered with mosaic tiles as finish material. One building as a third case study has been selected from this district in the current study, to analyze their construction materials in terms of their capacity for efficiency in energy consumption in the buildings.

Figure 3.8: The location of Chwarbakh district within Sulaymaniyah city (Google earth, 2019)

c. Case Study 3

The residential building is a house with two floors, occupied by one family. The house has been built in 1984. See Figure ‘3.9’.

Figure 3.9: Third case study in Chwarbakh district (Author,2019)

3.4.2.3 Case studies in (Raparin district)

This district is new and developed after 2003. It is near Sulaymaniyah International Airport and located on the western side, in the countryside of the city, as seen in Figure ‘3.10. The residential buildings in this district are houses in general. The building materials are in the majority, concrete blocks as masonry units for the walls. Some cladding like ceramic tiles and other types of decorative stones or materials have been added to the façade of these buildings. The windows are in the majority, PVC with either single glass or double layers transparent glass. The roofs are reinforced concrete with 20-centimeter thickness. The floors are plain concrete covered with ceramic tiles or porcelain (artificial marbles). Two case studies have been selected from this district as shown below.

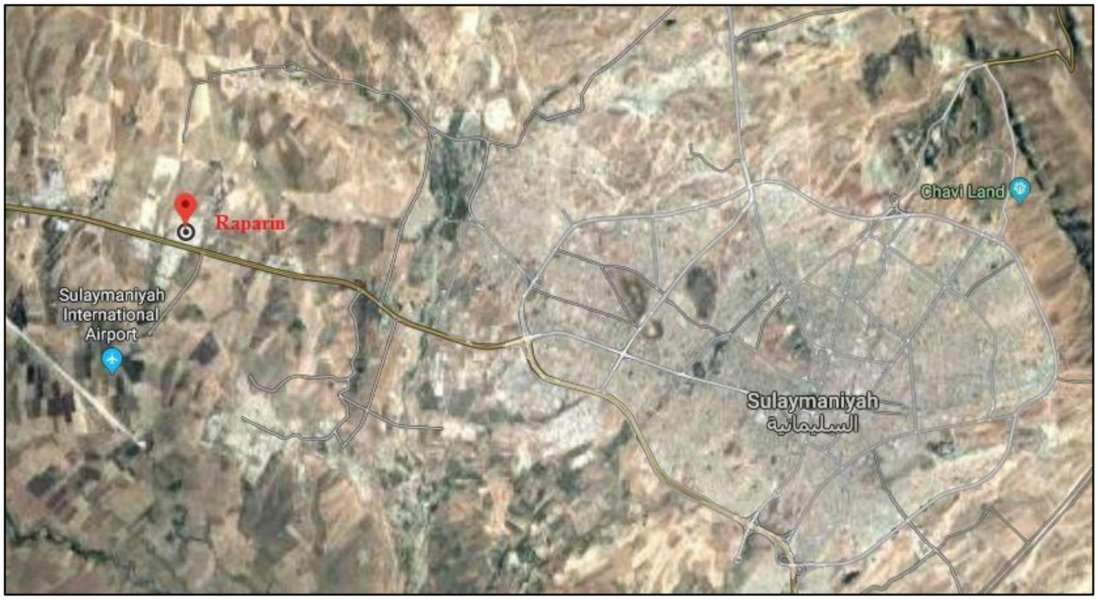


Figure 3.10: The location of 'Raparin' district within Sulaymaniyah city (Google earth, 2019)

d. Case Study 4

This case study is one floor house with total area of 200 m^{2}, the house is constructed in 2009, and occupied by one family which is contains five members. See Figure '3.11.

Figure 3.11: Fourth case study in the district of Raparin, Sulaymaniyah (Author,2019)

e. Case Study 5

This building also, a house with two floors and constructed on an area of 225 m^2. The house has been constructed in 2014, and two families are living in this house. See Figure ‘3.12’.

Figure 3.12: Fifth case study in Raparin district (Author,2019)

3.4.2.4 Case studies in the ideal city (Shari Nmonaiy)

This society is located in the north west of Sulaymaniyah countryside, as seen in Figure ‘3.13’. It is a housing project and it has been completed in 2018. The buildings have been constructed with concrete blocks as masonry unit with adding cladding with decorative materials to the exterior walls, and the roofs are constructed by reinforced concrete. The windows are made by PVC and single glass, while the floors of the buildings are finished by porcelain tiles over one layer of plain concrete. One case study as an example of this community have been taken as a case study.

Figure 3.13: The location of Ideal city community in Sulaymaniyah (Google earth, 2019)

f. Case Study 6

The area of the residential building is 210 m2, and it is one floor. The house has been constructed in 2018. One family with four members are occupying the house. See Figure ‘3.14’.

Figure 3.14: Sixth case study at Ideal city in Sulaymaniyah (Author,2019)

3.4.2.5 Case studies in engineers' hill (Grdi Andaziaran)

The district is located in the west south of the city, as seen in Figure '3.15. The district is constructed throughout 1980's and 1990's, and it has developed after 2003. The majority of the residential buildings are houses with one, two, and three floors. The district is considering one of the good residential sectors. Hence, the good and expensive construction materials have been used in these buildings. Two case study building have been selected to be analyzed in this district.

Figure 3.15: The location of Baranan's district in Sulaymaniyah (Google earth, 2019)

g. Case Study 7

Selected case study has been constructed in 1994, and it is one floor house. The total area of the building is 212 m^2. One family are using this house and the number of the family members are four individuals. See Figure ‘3.16’.

Figure 3.16: Seventh case study building in ‘*Baranan*’ district (Author,2019)

h. Case Study 8

The last case study is in ‘*Baranan*’ district too. The building is house with two floors, and constructed in 2005, and the area of building is 130 m2. Six members of one family are occupying this house. See Figure ‘3.17’.

Figure 3.17: Eighth case study in Baranan district (Author,2019)

Table 3.1: Characteristics materials (ex. walls, roofs, and floors) and construction year For each case studies (Author,2019)

No Case Study	District	Material	Construction year
1	Sabunkaran	Burnt brick, I-beams, plain concrete	1930
2	Sabunkaran	Masonry, trunk of trees, mosaic tiles	1940
3	Chwarbakh	Reinforced concrete, plain concrete, mosaic tiles	1984
4	Raparin	Concrete blocks, ceramic tiles	2009
5	Raparin	Masonry, porcelain	2014
6	Shari Nmonaiy	Concrete blocks, porcelain, plain concrete	2018
7	Baranan	Concrete blocks, wood, concrete, tiles	1994
8	Baranan	Concrete blocks, steel, concrete, plaster	2005

3.5 Summary

The chapter has discussed the methodology of the thesis and the methods which are approaching to reach the goals. The main roadmap of this thesis has been explained with all the methodology and methods that have applied to reach the results and answer the question of the study. A case study as a methodology has been applied in this study. Eight case study buildings from five different places in Sulaymaniyah city. The places have been selected based on their buildings' ages.Different ages of the buildings with different construction materials and methods of construction have been selected in order to assess the characteristics of these materials in whole the city, in terms of their effects on energy consumption in the buildings. The assessment will be carried out based on testing thermo-physical properties of these materials, and this through testing U-value for these materials as explained previously in Chapter Two. For this purpose, the observation will be one of the methods to collect data about case studies. Then, the conventional mathematical methods have been applied to show the results. A comparative analysis will be done to see the differences in the construction materials' thermal capacity in order to evaluate their role in energy consumption in these buildings. This will be illustrated in the next chapter.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Introduction

As explained previously, the most repetitive and effective passive strategy for balancing heat gain/loss in the buildings in northern Iraq is thermal mass, consequently, this strategy will have a significant role in controlling energy consumption in the buildings. This result was built up based on the review of literature and analysis of several recent studies in northern Iraq. Hence, eight case study residential buildings from different districts of Sulaymaniyah have been chosen based on developed criteria to select these case studies, as explained in Chapter Three. The study has focused on residential buildings considering the majority of the energy in the region is consumes by residential building sectors as demonstrated in chapter three.

4.2 Analysis of Case Study Buildings in Terms of Construction Materials

In this part, the construction materials for the envelope's elements for each of the case study buildings (external walls, roofs, windows, and floors) will be analyzed and evaluated in terms of their thermal potential based on the type of each material and the U-value for each element.

4.2.1 External walls

In this part, the types of the external walls' materials will be categorized and the U-value for external walls for each selected case study. The conductivity (W/m^2K) of the materials have been taken from several international standards and sources[3]. The thickness of the materials has been obtained either by direct measurement or through the documentary and plans, sections of the buildings. The thickness of the materials will be by meters. The resistance (R) will be

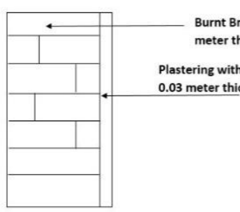
[3] '1. (Anderson, 2006),
2. http://www.zonbak.com/knowledge/passive%20solar%20design/passivesolar11.html, and
3. https://www.cibsejournal.com/cpd/modules/2011-06/'

calculated based on the equation ‘2.1’ and the unit of this parameter is (m^2K/W), while the, and U-value will be obtained based on the equation ‘2.3’, as seen in (section 2.5-Chapter Two).

a. Case Study 1

The exterior walls in this building are constructed by 50 cm thick wall of burnt brick and exposed from outside, whereas, it is covered with white gypsum plastering with 3 cm thickness from inside. See Table 4.1.

Table 4.1: External walls materials with thickness and U-value for the first case study building (Municipality of Sulaymaniyah ,2019)

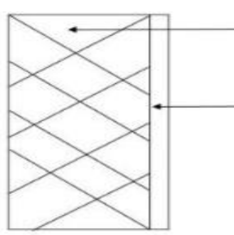
No	**District**	**Section in External walls**	**External wall’s Material**	**k-value**	**Thickness of the Material by meter**	**R-value Resistance See eq ‘2.1’**	**U-Value See eq ‘2.3’**
1	Sabnkaran		Burnt Brick	0.77	0.50	0.65	U value= (1/(Rse +R1+R2+Rsi) = 1.14 W/m^2K
			Plastering by gypsum	0.50	0.03	0.06	

*Rse & Rsi values =0.13, and 0.04, which are taken based on (Anderson, 2006, P.7).

b. Case Study 2

In this case study, the external walls have been constructed with 50 cm thick wall by local stone (Salem), which is available in the mountains of Sulaymaniyah. The walls are exposed from outside and from inside covered by 3 cm of gypsum plastering. See Table ‘4.2’.

Table 4.2: External walls materials with thickness and U-value for the second case study building (Municipality of Sulaymaniyah ,2019)

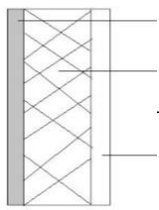
No	District	Section External walls	External wall’s material	k-value	Thickness of the Material by meter	R-value Resistance See eq ‘2.1’	U-Value See eq ‘2.3’
2	Sabnkarar		Local Stone (Salem)[4]	2.15	0.50	0.23	U value= (2.17 W/m^2 K
			Plastering by gypsum	0.50	0.03	0.06	

c. Case Study 3

The external wall of this building is consisting of 3 cm cement plastering from outside, and the masonry unit is natural local stone with 35 cm, and from inside covered with 5 cm gypsum plastering, as seen in Table ‘4.3’.

Table 4.3: The materials of third case study’s external walls materials and U-value evaluation (Municipality of Sulaymaniyah ,2019)

[4] Retrieved from: https://www.naturalstoneinstitute.org/stoneprofessionals/technical-bulletins/rvalue/

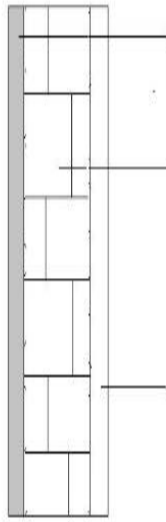
No.	District	Section in External walls	External wall's materials	k-value	Thickness of the Material by meter	R-value Resistance See eq '2.1'	U-Value See eq '2.3'
3	Chwarbakh		Exterior Sand & Cement plastering	0.72	0.03	0.04	U value = 2.13 W/m^2K
			Local Stone (Salem)[5]	2.15	0.35	0.16	
			Plastering by gypsum	0.50	0.05	0.1	

d. Case Study 4

In this building the external walls are contains of 3 cm cement plastering from outside, and the masonry unit is concrete hollow block with 20 cm, and from inside covered with 5 cm gypsum plastering, as seen in Table '4.4'.

Table 4.4: The materials of third case study's external walls materials and U-value evaluation (Municipality of Sulaymaniyah ,2019)

No.	District	Section in External walls	External wall's materials	k-value	Thickness of the Material by meter	R-value. Resistance See eq '2.1'	U-Value See eq '2.3'

4	Raparin		Exterior Sand & Cement plastering	0.72	0.03	0.04	U value = 2.22 W/m^{2}K
			Concrete block[5]	1.44	0.20	0.14	
			Plastering by gypsum	0.50	0.05	0.1	

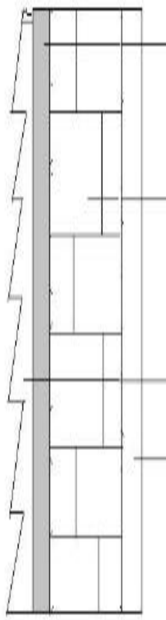
e. Case Study 5

In this building the external walls are covered with wall panel thermo-coal materials with 8 cm thickness, covering the cement plastering layer with 3 cm thickness. The masonry unit is concrete block with 20 cm, and covered from inner face by 5 cm gypsum plastering layer, as seen in Table ‘4.5.

Table 4.5: The materials of third case study’s external walls materials and U-value evaluation (Municipality of Sulaymaniyah ,2019)

No.	District	Section in External walls	External wall’s materials	k-value	Thickness of the Material by meter	R-value. Resistance See eq ‘2.1’	U-Value See eq ‘2.3’

[5] http://aljazeerafactory.com/en/info.aspx?pid=2&i=33

5	Raparin		Wall panel (80mm)	0.50	0.08	0.16	U value = 1.03 W/m^{2}K
			Exterior Sand & Cement plastering	0.72	0.03	0.04	
			Concrete block	1.44	0.20	0.14	
			Plastering by gypsum	0.50	0.05	0.1	

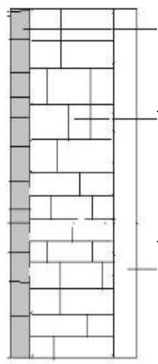
f. Case Study 6

The material of external walls of this case study which is located in the Ideal city, as explained previously, is similar to the fifth case study. Hence, the characteristic of the external walls and the U-value are same the one in case study five. Therefore, the U-value for this external wall is 1.03 W/m^{2}K.

g. Case Study 7

In this building the external walls are covered with limestone cladding of 4 cm thickness, covering the walls that constructed by burnt bricks with 36 cm thickness, and covered from inside by 5 cm gypsum plastering, as seen in Table ‘4.6’.

Table 4.6: The materials of seventh case study's external walls materials and the assessment of the U-value (Municipality of Sulaymaniyah ,2019)

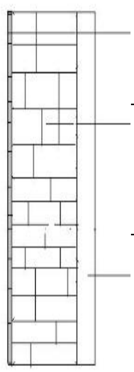
No.	District	Section in External walls	External wall's materials	k-value	Thickness of the Material by meter	R-value Resistance See eq '2.1'	U-Value See eq '2.3'
7	Baranan		Cladding Limestone (high value)[6]	1.26	0.04	0.03	U value = 1.30 W/m^2K
			Burnt Bricks	0.77	0.36	0.47	
			Plastering by gypsum	0.50	0.05	0.1	

h. Case Study 8

The external walls of this case study are covered with ceramic tiles as a cladding with 1.2 cm thickness. The walls are constructed by burnt bricks with 25cm thickness, and covered by 5 cm gypsum plastering from inside, as seen in Table '4.7'.

Table 4.7: The eighth case study external walls' materials with the U-value assessment (Municipality of Sulaymaniyah ,2019)

[6] Holman, (2010).

No.	District	Section in External walls	External wall's materials	k-value	Thickness of the Material by meter	R-value Resistance See eq '2.1'	U-Value See eq '2.3'
8	Baranan		Porcelain tiles[7]	1.48	0.015	0.01	U value = 1.67 W/m^{2}K
			Burnt Bricks	0.77	0.25	0.32	
			Plastering by gypsum	0.50	0.05	0.1	

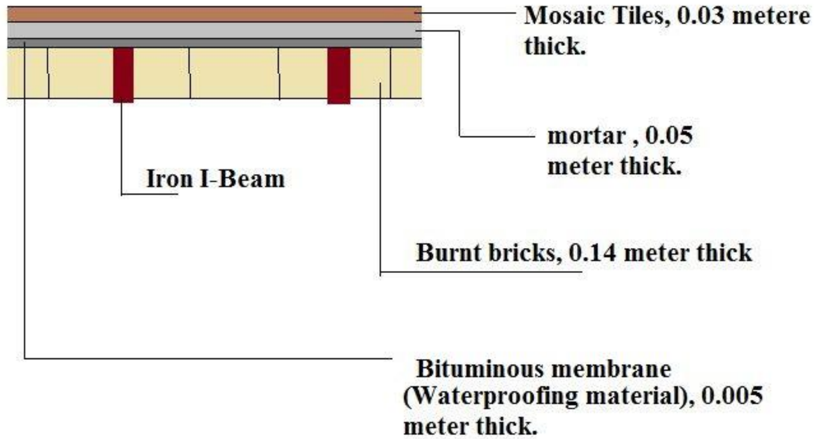
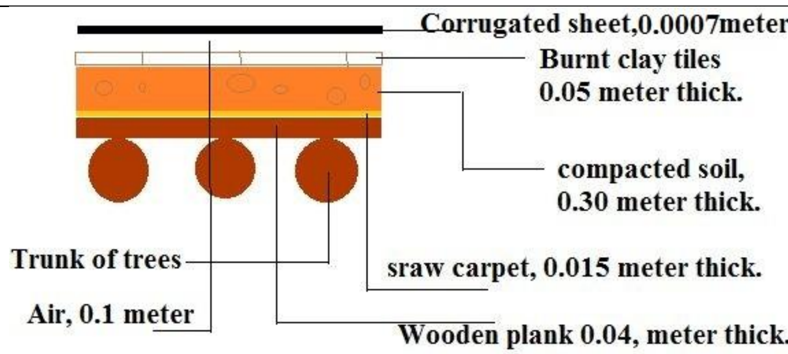
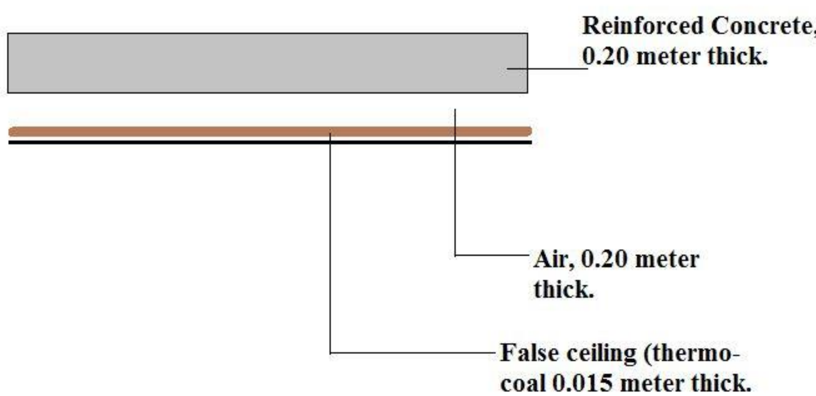
4.2.2 Roofs

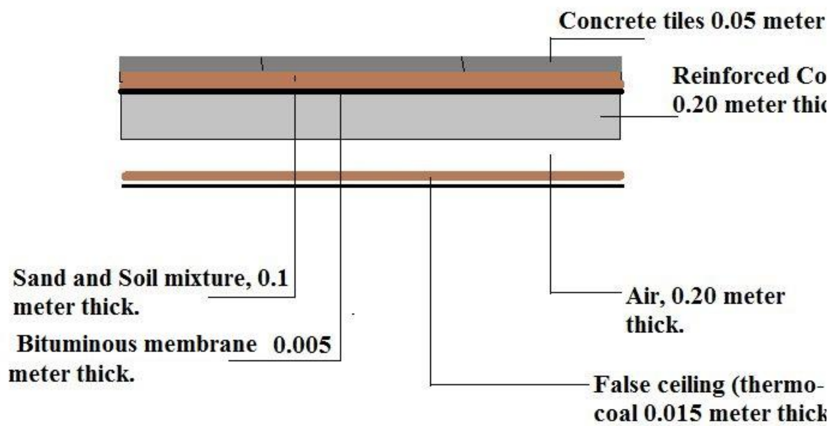
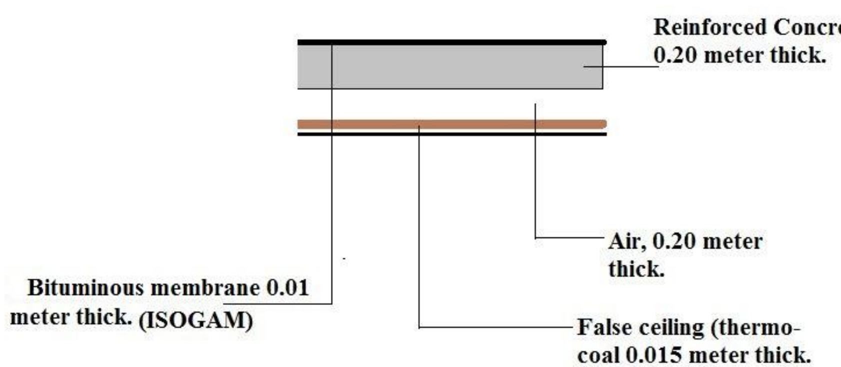
The types of the roofs will be demonstrated in this part based on the observation. Five types of roofs have been found in the case study buildings based on the physical observation and documentary (Plans, sections) analysis. The case studies (3.4 and 7) had the same roof material and construction method, while case studies (5 and 6) had the same materials and construction techniques for roofs. See Table '4.8'.

Table 4.8: Types of roofs in the case study buildings (Municipality of Sulaymaniyah ,2019)

No.	District	Section in Roof

[7] (SP: 41., 1987, p.37)

<table>
<tr><td>1</td><td>Sabunkaran</td><td>
</td></tr>
<tr><td>2</td><td>Sabunkaran</td><td>
</td></tr>
<tr><td>3,4,7</td><td>Chwrbakh,
Raparin,
and Baranan</td><td>
</td></tr>
</table>

5, 6	Raparin, and Ideal City	
8	Baranan	

The same method to calculate U-value in the external walls will be approached in the roofs. See Table ‘4.9’.

Table 4.9: U-value assessment in the different roofs for the case studies (Municipality of Sulaymaniyah ,2019)

No.	District	roof’s materials	k-value	Thickness of the Material by meter	R-value. Resistance See eq ‘2.1’	U-Value See eq ‘3.3’

1	Sabunkaran	Mosaic (Porcelain) tiles	1.48	0.03	0.02	U-value= (1/(Rse+R1+R2+R3+R4+Rsi) = 1.63 W/m^{2}K
		Mortar cement[8]	0.72	0.05	0.07	
		Bituminous membrane[9]	0.2	0.005	0.025	
		Burnt Bricks	0.77	0.14	0.18	
2	Sabunkaran	Corrugated metal sheet 0.7mm [10]	60	0.0007	0	U value = 0.60 W/m^{2}K
		Unventilated Air[11]	0.56	0.1	0.18	
		Burnt bricks tiles	0.77	0.05	0.65	
		Compacted soil[12]	1.48	0.30	0.20	
		Straw Carpet	0.056	0.015	0.26	
		Plywood [13]	0.17	0.04	0.24	
3,4, 7		Reinforced concrete**[14]**	1.58	0.20	0.13	U value = 1.11 W/m^{2}K

[8] (SP: 41. 1987)
[9] Retrieved from, https://www.indexspa.it/indexspacom/TECNOPLAN/pdf/LIGHTERFLEX-EN.pdf
[10] Retrieved from, https://www.steelconstruction.info/images/0/09/SCI_P312.pdf
[11] (EN ISO 6946, 2007, p.5)
[12] (Rajaei and Baladi, 2015)
[13] Retrieved from, http://www.zonbak.com/knowledge/passive%20solar%20design/passivesolar11.html
[14] (SP: 41. 1987)

	Chwarbakh, Raparin and Baranan	Unventilated Air	1.11	0.20	0.18	
		Thermo-col[15]	0.033	0.015	0.45	
5,6	Raparin and Ideal City	Concrete tiles (2300 kg/m3)[16]	1.63	0.05	0.03	U value = 0.98 W/m^2K
		Soil	1.48	0.1	0.07	
		Bituminous membrane	0.2	0.005	0.025	
		Reinforced concrete	1.58	0.2	0.13	
		Unventilated air	1.11	0.2	0.18	
		Thermo-col	0.033	0.015	0.45	
8	Baranan	Bituminous membrane	0.2	0.01	0.05	U value = 1.05 W/m^2K
		Reinforced concrete	1.58	0.2	0.13	
		Unventilated air	0.56	0.2	0.18	
		Thermo-col	0.033	0.015	0.45	

*****Rse & Rsi values= 0.10 and 0.04, which are found based on (Anderson, 2006, P.7)

[15] (Shah and Dake, 2016)
[16] Retrieved from, http://www.virtualmaths.org/activities/topic_data-handling/heatloss/resources/thermal-conductivity-of-building-materials.pdf

4.2.3 Windows

Many types of windows have been observed in the case studies. Single transparent or colored glass, double glass, etc., and the frames of the windows were various; wooden frame, aluminum and metal frame, and Polyvinyl Chloride (PVC) frame. The Table '4.10', demonstrates the types of the windows and the U-value of each one according to international standards[17].

Table 4.10: The categories of the windows and their U-value in the case studies From Municipality of Sulaymaniyah, 2019 (Author,2019)

No.	Windows process types	Glass type	U-Value according to (International Standards)[19]
1,2	Wooden processing frame	Single glass	4.9 W/m^2K
3,7	Aluminum and metal processing	Single glass	5.9 W/m^2K
4,5	PVC Plastic proceeding (with 2 components)	Single glass	5.2 W/m^2K
6,8	PVC Plastic proceeding (with 2 components)	Double glass	3.4 W/m^2K

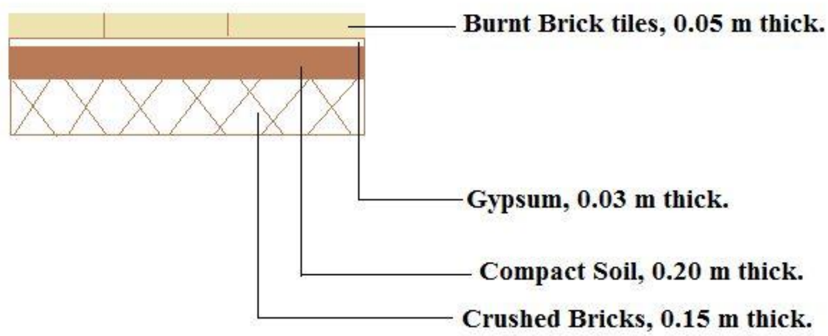
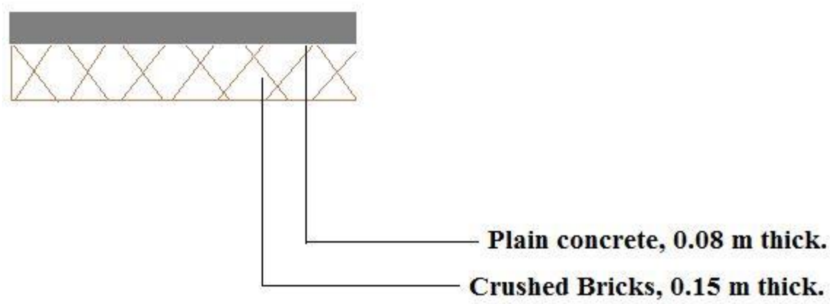
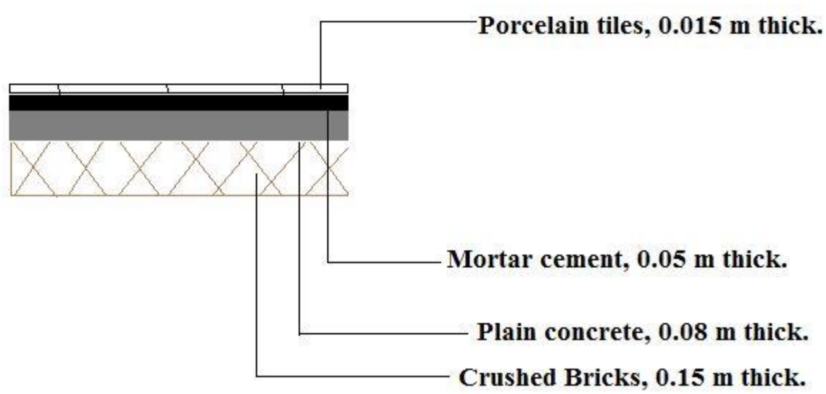
According to Rozhbayani (2018), the required U-value for the windows in hot and dry climates is 2.4 W/m^2K. Hence, based on the previous results, the windows in all the case studies are less than the required U-value.

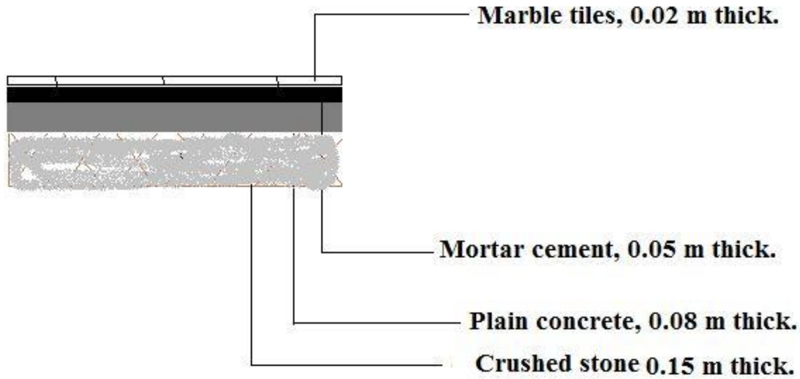
4.2.4 Floors

The floors of the eight-study building have been observed and the results demonstrated that there are different types of the floors in the case study buildings. Four types have been observed and recognized based on the observation and documentary analysis. See Table 4.11.

[17] (Turkish Standards Institute, 2008)

Table 4.11: The categories of floors in the case study buildings (Municipality of Sulaymaniyah ,2019)

No.	District	Section in Floor
1	Sabunkaran	
2, 3	Sabunkaran, and Chwarbakh	
4,6,8	Raparin, Baranan, and Ideal City	

5, 7	Raparin and Baranan	

The U- value as assessment tool for thermo-physical properties of the floor materials have been found, as an indicator to evaluate the potential of these materials to reduce energy consumption in the buildings as explained previously. See Table 4.12.

Table 4.12: Calculation of U-value for case study floors based on their constructed materials (Municipality of Sulaymaniyah ,2019)

No.	District	roof's materials	k- value Conductivity	Thickness of the Material by meter	R-value Resistance See eq '2.1'	U-Value See eq '2.3'
1	Sabunkaran	Burnt Brick tiles	0.77	0.05	0.06	U-value= (1/(Rse+R1+R2+R3+R4+Rsi)) = 1.35 W/m^{2}K
		Gypsum mortar	0.50	0.03	0.06	
		Compacted Soil	1.48	0.20	0.14	
		Crushed Burnt Bricks	0.56	0.15	0.27	

2,3	Sabunkaran, and Chwarbakh	Plain concrete (2300 kg/m3)	1.63	0.08	0.05	U value = 1.89 W/m^{2}K
		Crushed burnt bricks	0.56	0.15	0.27	
4,6,8	Raparin, Baranan, and Ideal City	Porcelain tiles	1.48	0.015	0.01	U value = 1.64 W/m^{2}K
		Mortar cement	0.72	0.05	0.07	
		Plain concrete (2300 Kg/m3)	1.63	0.08	0.05	
		Crushed burnt bricks	0.56	0.15	0.27	
5,7	Raparin, and Baranan	Marble (Granite) tiles[18]	3	0.02	0.01	U value = 1.82 W/m^{2}K
		Mortar cement	0.72	0.05	0.07	
		Plain concrete (2300 Kg/m3)	1.63	0.08	0.05	

[18] Retrieved from, http://www.virtualmaths.org/activities/topic_data-handling/heatloss/resources/thermal-conductivity-of-building-materials.pdf

	Crushed stone (Stone chips)[19]	0.70	0.15	0.21

*Rse & Rsi values= 0.17 and 0.04, and they are taken from (Anderson, 2006, P.7

4.3 Finding and Discussion

According the previous analysis to the case study buildings, which are selected from several district in Sulaymaniyah city, with different ages, the study came out with the following findings;

1. There are many types of external walls in the residential buildings of Sulaymaniyah, and they are changes in materials and the method of construction according to the age and the cost of the buildings. The same can be say regarding roofs, windows and floors.

2. According to the survey of the literature, the international standards the recommended U-value for external walls should be equal or less than 0.8 W/m^2K, and for the floors should be equal or less than 0.6 W/m^2K. The roofs are recommended to be equal or less than 1.5 W/m^2K (Huang, and Deringer 2007). The windows according to the international standards for the study region climate (hot-dry), is recommended to have U-value equals to 2.5 W/m^2K or less than this amount (Turkish standards institute, 2008).

3. The results of U-value for the construction materials in the buildings' elements (external walls, roofs, windows, and floors) were obtained as seen in Table 4.13.

[19] (Turkish Standards Institute, 2008)

Table 4.13: The U-value for building material for (ex. walls, roofs, windows, and floors) in each case studies by Author from (Municipality of Sulaymaniyah ,2019)

No. of Case study	**The building's construction time**	**Wall U-value (W/m^2K)**	**Roof U-value (W/m^2K)**	**Window U-value (W/m^2K)**	**Floor U-value (W/m^2K)**
1	1930's	1.14	1.63	4.9	1.35
2	1940's	2.17	0.60	4.9	1.89
3	1984	2.13	1.11	5.9	1.89
4	2009	2.22	1.11	5.2	1.64
5	2014	1.03	0.98	5.2	1.82
6	2018	1.03	0.98	3.4	1.64
7	1994	1.30	1.11	5.9	1.82
8	2019	1.67	1.05	3.4	1.64

Based on the calculated U-value for the external walls, the results of the construction buildings demonstrated that all the types are not responding to the required thermal potential. The best external walls materials in terms of U-value were case study (e & f). The reason for that is the using of external thermo-col materials as a cladding material. This indicates the potential of this type of material in reducing energy consumption through controlling heat gain/loss through the external walls.

The roofs of all the buildings were found with good thermal capacity and all the roofs were within the recommended U-value for the region which is equal or less than 1.5 W/m2K, as seen in table '2.1' in Chapter Two. For old buildings the layer of compacted soil was effective, and for the contemporary buildings, the false ceiling of thermo-col material had a significant role in keeping thermo-physical properties of the roofs within the requirements. The most effective roofs were in the second case study building. The reason for that is that the roof of the case study (b) is provided with an air layer above the roof due to the covering corrugated sheet to protect the roof from rains and snow, hence, thermal potential for the roof in these buildings was the best among other buildings.

The windows have been demonstrated the same scenario as external walls and roofs, where, all of them were not as per recommended U-value which is 2.5 according to international standards. The results of the case study buildings have demonstrated that the PVC proceeding windows with double layers glass has the best results regarding the heat exchange potential and was 3.4 W/m^2K. This type of window has been found in the case study (f &h). This result is showing that even double layers glass is not enough to reach the required thermal potential in the region of the study which is 2.5 W/m^2K. Hence, double layer glass with low-e coating glass is required to reach the required U-value in windows. In all the case studies, the U-value for the floors were lower than the recommended which is 0.60 W/m^2K. This indicates that all the flooring materials are not responding to the climatic requirements in terms of heat gain and heat loss. Therefore, finding alternative materials or adding addition materials are recommended for this part of the building. As it is remarked from the results of the calculation of U-value (heat transfer coefficient value) that the newly constructed masonry materials like concrete block is not helping the walls to have thermal capacity, for controlling heat gain/loss, as other types like burnt brick. The burnt brick materials demonstrated very good thermal capacity compared with stones and concrete blocks, as seen in case studies (a & g). The study

demonstrates that using the local stone as masonry unit without adding another insulation material is not very much helping to enhance thermal capacity in the buildings, as seen in case studies (b & c).

The study results shows that thermal mass strategy as passive design strategy can be applied in the residential buildings in Sulaymaniyah city through reduce U-value. This is through adding additional materials to the envelope like thermo-col, as seen in case studies (e & f). These additional materials can be applied on the new buildings and existing buildings to improve their thermal performance, and consequently, reduce energy consumption in the buildings. The thermal capacity or U-value for the (external walls, roofs, windows, and floors) of the selected building case studies are demonstrated that the building materials is one of the most effective factors in increasing energy consumption because the majority of the envelope elements (except the roofs) are not responding to outside environmental requirements in terms of controlling heat gain and heat loss, as seen in table '4.13', above.

The heat exchange of buildings can differ depending on the condition of the building. The loss of heat energy for one-floor buildings is 45% through external walls and fenestrations, and 42% through the floors and roofs, while, 13% through air leaks. In the building with more than one floor, the exterior walls and windows are responsible for 70% from heat exchanges, and 13% of the heat s controlling by roofs and the floors, and 17% by air leaks (Basarir, et al., 2012). Therefore, the improper functional control of heat exchange in the building through (external walls, floors, windows) as demonstrated in this study has a significant impact on increasing energy usage in the residential building sector in Sulaymaniyah city.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study has aimed to enhance the energy conservation at residential building sector in northern Iraq. The reason behind this study was to overcome the shortage of energy in Northern Iraq, especially electrical power, which are using heavily by residential buildings to maintain thermal comfort for the occupants. Sulaymaniyah as most industrial city in northern Iraq and Iraq, has been selected as study area. The study has tried to investigate the reduction of energy consumption in the residential sector. This is through determining the most important or effective passive strategies in Northern Iraq. For this reason, the literature has been reviewed and many previous researches in these regards have been analyzed. The results demonstrate that the most used and effective strategy in the climate of the study area (hot-dry) is thermal mass. Hence the study tried to investigate the condition of this strategy in the residential buildings of Sulaymaniyah, based on the assessment of thermal properties of construction materials in external walls, roofs, windows, and floors as the most integrated elements in any building with the outside environment. The assessment of thermal properties has been carried out through determination of U-value for prevailed types of external walls, roofs, windows, and floors. In this regards, eight case study buildings have been selected from different district of Sulaymaniyah to assure the involvement of the majority of these buildings' categories. The criteria of the selection were that all the buildings should be residential buildings and should be in use by people, and all the buildings were within Sulaymaniyah city.

To reach the conclusion in the study, the answer for the study questions should be done, which are;

1. What are the most effective passive design strategies at the residential buildings in northern Iraq, in terms of applied strategies to the buildings and their response to climate?

To answer this question the most related studies in Northern Iraq have been analyzed theoretically, and the most effective passive strategies has been determined. The results demonstrated that thermal mass is the most effective strategy to be applied in the climate of northern Iraq, which is characterized by a hot and dry climate. The importance of this strategy is not only because of its response to the climatic requirements, but, because of its flexible characteristic in applying it in old any new buildings with developing the construction materials' thermo-physical characteristics.

2. How do we reduce energy consumption in Northern Iraq through passive design strategies, within the limits of this study?

According to the literature review and theoretical analysis, the international standards have been recommended some ideal U-values for building elements such as external walls 0.8 W/m^{2}K or less, roofs 1.5 W/m^{2}K or less, windows 2.5 W/m^{2}K, and floors '0.6 W/m^{2}K' or less, as per the limitation of this study. Furthermore, the development of U-value of the building envelope materials is one of the key roles to reduce energy consumption inside the residential buildings. Thus, the site observation with conventional calculation for U-values in whole the envelopes in the case studies have demonstrated a weak thermal capability for the construction materials in the respect with the climatic requirement (except the roofs). The eight case study buildings have shown higher U-value than required in external walls, which are between (1.03 to 2.22 W/m^{2}K), and for the windows between (3.4 to 5.9 W/m^{2}K), while for the floors were between (1.35 to 1.89 W/m^{2}K). Therefore, development thermo-physical properties of buildings envelope elements (external walls, windows, and floors) are highly recommended for these elements. This is through reducing U-value of each of which, by adding insulation materials inside or outside to reach the recommended U-value, as per the international standards for the climate of Northern Iraq.

3. What are the most effective building materials that can be applied in Northern Iraq for energy efficiency in the buildings?

Based on the investigation of construction materials, the study has demonstrated that thermo-col materials when it is used as cladding on the external walls are driving very significant roles in reducing U-value of this element in the building. Moreover, the study has demonstrated that the PVC windows with double layers of glass are good to control the heat gain, but still not proper to control the heat exchange in the region of the study. Therefore, based on the international standards, the PVC windows with double layers of low-e coated glass are required to be applied in the windows at Sulaymaniyah city. Adding thermo-col materials under the floor finishing will increase the capability of thermal control in the floors, and reduce the U-value of the existing floors in the region of the study.

5.2 Recommendations

As per the outcome of the current study, some recommendations are suggested, which are;

1. The process of designing energy-efficient buildings is not the responsibility of one side. The responsibility includes designers, developers, and users. This can be achieved through issuing legislations and specification to manage the role of each side.

2. The awareness of architects and engineers about the specification of construction materials is highly recommended. This is through developing programs to enhance the awareness about these materials and their influence with energy efficiency.

3. The availability of proper materials with suitable price in the construction market is important point. This can be implemented through controlling the imported or produced materials, and apply quality control to each material for better thermal performance in the buildings.

4. Northern Iraq Government is responsible to motivate the issue of power shortage through developing new power generation resources from clean energy such as wind and solar radiation, and monitoring the power expenditure and motivate the price to control the shortage of the power.

5.3 Future Studies

This work has focused only to improve the construction materials of the building. Further studies concerning other methods to reduce energy consumption such as natural ventilation system in the building should be studied. Furthermore, the ability of thermal mass as most important passive strategy has been studied in this thesis, while other strategies like shading, evaporative cooling, courtyards need to be studied too.

REFERENCES

Abdulrahman, I. (2014). *Energy Efficient Buildings in a Hot and Dry Climate*. Master thesis Academy of Economics, Society and Technology. Sweden: Mälardalens Hogskola Eskilstuna Vasteras.

Ahmad, R., Malik, M.I., Jan, M.U., Ahmad, P., Seth, H., Ahmad, J. (2014). Brick Masonry and Hollow Concrete Block Masonry- A Comparative Study. *IJCSER, 1*(1), 14-21.

Akkermans, P. M. (2010). *Late Neolithic Architectural Renewal: The Emergence of Round Houses in the Northern Levant, ca. 6500-6000 BC*. In Diane Bolger & Louise Maguire (eds.). The Development of Pre-State Communities in the Ancient Near East. Oxford: Oxbow Books, 22-28.

Amin, R. (2018). *Sustainable Housing Assessment for Low Income Earners in Northern Iraq*. In Master thesis, Cyprus International University, Nicosia. N. Cyprus.

Anderson, B. (2006). *Conventions for U-value calculations*. UK: BRE.

Ashby, M. F., & Johnson, K. (2013). *Materials and design: the art and science of materials selection in product design*. Butterworth-Heinemann.

Aynsley, R. (2007). Natural Ventilation in Passive Design. The BEDP Environment Design Guide. *Royal Australian Institute of Architects, 2*, 1-11.

Aziz, S.S. (2019). Energy Efficiency Principles in Erbil Traditional Architecture: A Case Study from Erbil-Northern Iraq. Master thesis, Near East University. N. Cyprus.

Baker, N., and Steemers, K. (2005). *Energy and Environment in Architecture : A Technical Design Guide*. UK: Taylor & Francis.

Bahrami, S. (2008). *Energy efficient buildings in warm climates of the Middle East: Experience in Iran and Israel*. Master thesis, Lund University, Lund, Sweden.

Baker, L.M. (Ed.) (2006). Observation: A Complex Research Method. *Library Trends, 55*(1), 171–189.

Barber, S. (2012). History of Passive Solar Energy. *Explorations, 7,* 2-12. Retrieved from: https://uncw.edu/csurf/Explorations/documents/ScottBarber.pdf

Basarir, B., Diri, B. S., and Diri, C. (2012). Energy efficient retrofit methods at the building envelopes of the school buildings. Retrieved from: http://aceee.org/files/proceedings/2015/data/papers/2-207.pdf

Baweja, V. (2008). *A Pre-history of Green Architecture: Otto Koenigsberger and Tropical*. Phd Thesis. Michigan: The University of Michigan.

Brager, G.S. and de Dear, R. (2001). Climate, Comfort & Natural Ventilation: A new adaptive comfort standard for ASHRAE Standard 55. Retrieved from http://web.stanford.edu/group/narratives/classes/08-

Braham, W., and Willis, D. (2013). *Architecture and Energy: Performance and Design*. London, UK: Routledge.

Brawn, G.Z. & Dekay, M. (2001). *Sun, Wind & Light- Architectural Design Strategies. (*2nd edition). United States of America: John Wiley & Sons.

Butti, K. and Perlin, J. (1980). *A Golden Thread: 2500 Years of Solar Architecture and Technology*. New York, USA: Cheshire Books, Palo Alto, Van Nostrand Reinhold Company.

California energy commission. (2013). *Building energy efficiency standards, for residential and non-residential buildings. California energy commission*. Retrieved from: http://www.energy.ca.gov/2012publications/CEC-400-2012-004/CEC-400-2012-004-CMF-REV2.pdf

Chen, W. (2005). *Principles of Structural Design*. Retrieved from: http://nguyen.hong.hai.free.fr/EBOOKS/SCIENCE%20AND%20ENGINEERING/ENGINNEERING-DESIGN/Structural_Engineering_Handbook.pdf

Divsalar, R. (2011). *Building Problems in Hot Climate, Energy Efficient Building Design*. LAP LAMBERT Academic Publishing GmbH & Co.KG.

Gilbride, TL, Hefty, MG, Cole, PC, Adams, K & Noonan, CF. (2011). 40% Whole-House Energy Savings in the Hot-Humid Climate, U.S. Department of Energy, vol. 15. Retrieved from: http://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20768.pdf

EN ISO 6946. (2007). *Building components and building elements* - *Thermal resistance and thermal transmittance -Calculation method.* Retrieved from, https://www.sis.se/api/document/preview/909393/

Givoni, B. (1969). *Man, Climate and Architecture*. London, UK: Elsevier Science Ltd.

Holman, J.P. (2010). *Heat Transfer*. (10th Edition). New York, United States: McGraw-Hill.

Huang, J, and Deringer, J. (2007). *Status of Energy Efficient Building Codes in Asia*. Hong Kong: the Asia Business Council Hong Kong SAR. Retrieved from:

http://csep.efchina.org/report/200962525818511.6156411397687.pdf/07_0710F_10_countries_code_review.pdf

JRC (Joint Research Centre). (2012). *Reference Document on Best Environmental Management Practice in the Building and Construction Sector - Final Report*. EMAS regulation Article 46.1.

Khalafalla, M., and Malyuta, D. (2013). Review of Different Construction and Building Materials Used Before 21st Century in Africa Compared to the Present Situation after 21st Century. Retrieved from: file:///C:/Users/user/Downloads/INVESTIGATION_OF_DIFFERENT_CONSTRUCTION.pdf

Kothari, C.R., 2004. *Research methodology*: Methods and Techniques, second revised edition. New International Publisher. University of Rajasthan, Jaipur (India).

Knowles, R. L. (2003). The Solar Envelope: It's Meaning for Energy and Buildings. *Energy and Buildings, 35*, pp. 15- 25.

Koenigsberger, O.H., Ingersoll, T.G., Mayhew, A., and Szokolay, S.V. (2010). Manual of Tropical Housing and Design: Climatic Design. Hyderabad, India: Universities Press.

Li, Z. (2011). *Advanced concrete technology*. John Wiley & Sons.

Lstiburek, J. (2005). *Understanding Vapor Barriers*, Building Science Corporation. *Building Science Digest, 106*. Retrieved from: file:///C:/Users/Dell/Documents/Downloads/BSD-106_Understanding%20Vapor%20Barriers_2013.pdf

Malnar and Vodvarka (2004). *Sensory Design*. United States: University of Minnesota Press.

Ministry of Planning- Kurdistan Region Government. (2013). Kurdistan Region of Iraq 2020: A Vision for the Future. Retrieved from, http://www.iraq-jccme.jp/pdf/archives/krg_2020_english.pdf

MoPDC/UNDP. (2005). *Iraq Living Conditions Survey*. [Retrieved] from, http://www.iq.undp.org/ILCS/PDF/Tabulation%20Report%20-%20Englilsh.pdf.

Mohammad, S. and Shea, A. (2013). Performance Evaluation of Modern Building Thermal Envelope Designs in the Semi-Arid Continental Climate of Tehran. *Buildings, 3*, 674-688. Doi: 10.3390/buildings3040674

Moore, F. (1993). *Environmental control systems: heating cooling lighting*. New York, United States: McGraw-Hill

Muhy Al-Din, S., Iranfare, M., Surchi, Z. (2017). Building Thermal Comfort Basedon Envelope Development: Criteria for selecting right case study in Kyrenia- North Cyprus. *Energy Procedia (Open Access), 115,* 80-91. doi.org/10.1016/j.egypro.2017.05.009

Muhy, Al-Din, S. and Iranfar, M. (2018, May, 9-10). *The relation between Architectural style and Thermal performance in houses of semi-arid climate: Assessment of Building Envelope thermo-physycal properties.* Presented in 1st Int. Conference on Architecture and Urbanism. Kyrenia, N. Cyprus.

Nahar, N. M., Sharma, P., Purohit, M. M. (2003). Performance of Different Passive Techniques for Cooling of Buildings in Arid Regions. *Building and Environment*, *38*(11), pp. 1345 – 1364.

Norton, J. (1997). Woodless Construction, Unstabilised Earth Brick Vault and Dome Roofing without Formwork. *Lund Centre for Habitat Studies Building Issues Volume 9* (2).

Perlin, J. (2013). *Let It Shine: The 6000-year History of Solar Technology.* Novato, California, USA: New World Library.

Ozdil, O.S. (2010). *Sürdürülebilir Yapılaşma Sorunu ve Çelik* (Sustainable Building Issues and Steel). Retrieved from: http://www.tucsa.org/images/yayinlar/makaleler/Surdurulebilir-Yapilasma-Sorunu-ve-Celik.pdf

Radha, C. A. H. (2018). *Sustainable Renovation of Residential Buildings in Subtropical Climate Zone*. Ph.D. Thesis, University of Pecs, Pecs. Hungary: University of Pecs.

Raymond,R. W. (1981). *Slate, A Glossary of Mining and Metallurgical Terms*. USA: American Institute of Mining Engineers.

Rozhbayani, R. (2018). *An Analysis on Energy Efficiency in Houses Environment: By evaluation of thermal performance in the building, in Erbil, Iraq*. Master thesis, Near East University. N. Cyprus.

Rowland, I. and Howe T. N. (1999). Vitruvius: Ten Books of Architecture. Cambridge, UK: Cambridge University Press.

Saeed, M. A. (2003). *Estimation of Reference Evapotranspiration from Climatic Data in Kurdistan Region-Iraq*, College of Basic Education-Salahaddin University,Erbil, Iraq: Salahaddin University

Saffari, M., de Gracia, A., Ushak, S., & Cabeza, L. F. (2017). Passive cooling of buildings with phase change materials using whole-building energy simulation tools: A review. Renewable and Sustainable Energy Reviews, 80, 1239-1255.

Salih, K. T. (2018). Finding Alternative Methods for Controlling the Power Shortage in Kurdistan through Improving Buildings' Energy Performance. *Academic Journal of Nawroz University (AJNU)*, *7*(4), 124-132.

Schuwer, D, Klostermann, J, Moore, C & Thomas, S. (2012). *The strategic Approach to improving energy efficiency in buildings, new residential buildings, Ultra-Low-Energy Buildings*. Wuppertal Institute for Climate, Environment and Energy. Retrieved from: http://www.bigee.net/media/filer_public/2013/11/29/bigee_txt_0045_bg_strategic_approach_uleb_new_residential.pdf

Shah, S. and Dake, P. (2016). High Insulation Thermal Box. *International Journal of Mechanical Engineering and Technology (IJMET)*, *7*(6), pp.459–473.

SP: 41. (1987). *Handbook on functional Requirement of Buildings other than industrial buildings. Bureau of Indian Standards*. India: Bureau of Indian Standards

Municipality of Sulaymaniah. (2019). *Measurement and Section Details of Roofs, Floors Requirements for Buildings*. Sulaymaniah, Iraq.

Szuppinger, P. (2011). *PRINCIPLES OF ENERGY EFFICIENT PLANNING*, Regional *Environmental Center for Central and Eastern Europe*. Retrieved from: http://www.intense energy.eu/fileadmin/content/broshures/12_PrinciplesEEPlanning.pdf

Szokolay, S. V. (2004). *Introduction to Architectural Science*. Oxford, UK: Architectural Press.
URL1: http://www.eoht.info/page/Zeno+of+Citium

Turkish Standards Institute. (2008). *TS 825: Thermal Insulation Requirements for Buildings*. Ankara, Turkey: TSE.

URL2: https://www.researchgate.net/publication/275655537_Production_of_Utilizable_Energy_from_Renewable_Resources_Mechanism_Machinery_and_Effect_on_Environment/figures?lo=1

URL3: https://www.researchgate.net/publication/281592247_The_Role_of_the_Solar_Light_Quantity_in_the_Architectural_Forming_of_Buildings/figures?lo=1

URL4: https://steelroofing.us/main-modes-heat-transfer/

URL5:https://www.wpmap.org/sulaymaniyah-earthquake-map-map-sulaymaniyah-map-sulaymaniyah-iraq/sulaymaniyah_map/

URL6: https://en.climate-data.org/asia/iraq/babil/sulaymaniyah-939276/

UNHCR. (2004). *Sulaymaniyah Governorate Assessment Report*. Retrieved from, http://www.unhcr.org/459badd426.pdf

Vale, B., and Vale, R. (1996). *Green Architecture: Design for a Sustainable Future*. London, UK: Thames and Hudson Ltd.

Van der Merwe, M. (2011). The importance of external walls in energy efficiency of buildings, Department of quantity surveying and construction management, University of the Free State, Bloemfontein, South Africa. Retrieved from: http://www.icoste.org/wp-content/uploads/2011/08/The-Importance-Of-External-Walls-In-Energy-Efficiency-Of-Buildings.pdf

Vasiliu, S. (2008). *Solution for flat roofs*. Universitatea Tehnic˘a, Gheorghe Asachi" din Iasi. Retrieved from: http://www.ce.tuiasi.ro/~bipcons/Archive/134.pdf

Waltz, C., Strickland, O. L., & Lenz, E. (Eds.). (2010). *Measurement in nursing and health research*. Springer Publishing Company.

APPENDIX A: SIMILARITY

INBOX | NOW VIEWING: NEW PAPERS ▾

Submit File

Online Grading Report | Edit assignment settings | Email non-submitters

AUTHOR	TITLE	SIMILARITY	GRADE	RESPONSE	FILE	PAPER ID	DATE
Peshwaz Abdullah Ali...	ABSTRACT	0%	--	--		1466558511	06-Dec-2020
Peshwaz Abdullah Ali...	ÖZET	0%	--	--		1466557704	06-Dec-2020
Peshwaz Abdullah Ali...	CHAPTER 1	1%	--	--		1466569559	06-Dec-2020
Peshwaz Abdullah Ali...	CHAPTER 5	1%	--	--		1466561932	06-Dec-2020
Peshwaz Abdullah Ali...	CHAPTER 3	2%	--	--		1466560660	06-Dec-2020
Peshwaz Abdullah Ali...	CHAPTER 4	3%	--	--		1466561383	06-Dec-2020
Peshwaz Abdullah Ali...	THESIS	3%	--	--		1466563721	06-Dec-2020
Peshwaz Abdullah Ali...	CHAPTER 2	4%	--	--		1466559945	06-Dec-2020