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AN ENERGY SIMULATION STUDY: REDUCING COOLING ENERGY OF RESIDENTIAL BUILDINGS BASED ON VERNACULAR ARCHITECTURE AND PASSIVE COOLING TECHNIQUES

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES
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BY

Omar Hamad Farag ALGBURI

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THE DEGREE OF DOCTOR OF PHILOSOPHY
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The thesis study titled "AN ENERGY SIMULATION STUDY: REDUCING COOLING ENERGY OF RESIDENTIAL BUILDINGS BASED ON VERNACULAR ARCHITECTURE AND PASSIVE COOLING TECHNIQUES " is submitted by Omar Hamad Farag ALGBURI in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Architecture, Gazi University by the following committee.

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ETHICAL STATEMENT

I hereby declare that in this thesis study I prepared in accordance with thesis writing rules of Gazi University Graduate School of Natural and Applied Sciences;

- All data, information and documents presented in this thesis have been obtained within the scope of academic rules and ethical conduct,
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- No change has been made in the data used,
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Omar Hamad Farag ALGBURI

27/07/2017

AN ENERGY SIMULATION STUDY: REDUCING COOLING ENERGY OF RESIDENTIAL BUILDINGS BASED ON VERNACULAR ARCHITECTURE AND PASSIVE COOLING TECHNIQUES

(Ph.D. Thesis)

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ABSTRACT

In recent years, the economic change experienced in the hot arid climate cities and rapid population growth have developed along with rapid construction, especially the houses which are built to meet the increasing demand for housing. Designing these new residential buildings without respect to the environment, local climate conditions, with fully dependent on mechanical air-conditioning systems lead up to consume an extreme amount of energy. Accordingly, this doctoral thesis mainly aims to propose an application of passive cooling techniques toward enhancing indoor thermal comfort in a single-family house in Erbil city (northern Iraq), to reduce energy consumption. The study also seeks to understand the climatic responsive design solutions in vernacular architecture. To achieve these objectives, this study examines vernacular architecture in the historic core of Erbil, using a descriptive-explorative approach, in two different analysis scales (‘neighborhood’ level and house level). Energy simulation method based on a comparative thermal dynamic performance measured in a typical house modeled by using DesignBuilder program used to investigate the potential of reducing cooling load after applying the proposed passive cooling methods. In this context, different simulation scenarios of the proposed passive applications are each evaluated and analyzed separately, in addition to a combined simulation with all methods. The combined scenario of all proposed passive cooling techniques had the greatest impact, reducing the cooling load significantly from 6997 kW/h to about 4461 kW/h during the peak cooling load in July which is about 67.38% of total cooling load reduction. Lastly, this thesis end with summarizing the key findings of the research which significantly open the way for designing low cooling energy housing in hot arid climate regions.

Science Code : 80103

Key Words : Passive Cooling,Vernacular Building, Energy Simulation, Erbil City

Page Number : 207

Supervisor : Prof. Dr. Figen BEYHAN

ENERJİ SİMÜLASYONU ÇALIŞMASI: GELENEKSEL MİMARLIK VE PASİF SOĞUTMA TEKNİKLERİ DAYANARAK KONUT BİNALARDA SOĞUTMA ENERJİSİ AZALTMAK

(DoktoraTezi)

Omar Hamad Farag ALGBURI

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FEN BİLİMLERİ ENSTİTÜSÜ

Temmuz 2018

ÖZET

Son yıllarda sıcak kuru iklimli kentlerde yaşanan ekonomik değişimi ve hızlı nüfus artışı hızlı yapılaşmayı beraberinde gelişmiştir. Özellikle artan konut ihtiyacını karşılayabilmek amacıyla inşa edilen konutlar ne yazık ki içinde bulunduğu çevreye duyarsız bir şekilde tasarlanmakta ve inşa edilmektedir. Yerel iklim koşulları göz ardı edilerek tasarlanmış olan binalarda ısıl konfor koşullarını sağlayabilmek amacıyla mekanik iklimlendirme sistemlerinin kullanımında hızla artmış, bu durum enerji kaynaklarının tüketimi ile yaşanan sorunları ortaya çıkmıştır. Bu çalışmada soğutma enerjisi yüklerinin fazlasıyla arttığı sıcak kuru iklim bölgelerinde geleneksel mimarlık prensiplerinden gelen teknikler ile günümüz pasif soğutma yöntemleri analiz edilmiş ve yeni gelişen konut binaları için düşük soğutma enerjisi tüketimi odaklı tasarım stratejileri kullanılarak yeni bir yöntem ortaya konulmuştur. Çalışma alanı olarak ise Erbil kenti seçilmiştir. Bu amaçla ilk önce Erbil'deki geleneksel mimarlık yaklaşımı mahalle ve bina ölçeklerinde incelenmiş, pasif soğutma teknikleri araştırılarak iklim bölgesi için uygun yöntemler belirlenmiş, amaca uygun stratejiler oluşturularak tasarlanan model üzerinde DesignBuilder simülasyon programı kullanılarak sınanmıştır. Karşılaştırmalı sonuçlar üzerinden oluşturulan yöntem çerçevesinde elde edilen pasif soğutma stratejileri ile Erbil'deki tipik bir konut projesi yeniden test edilmiş ve sonuçların geçerliliği tartışılmıştır. Sonuç olarak elde edilen verilere göre en yüksek soğutma yükünün gerçekleştiği Temmuz ayında toplam soğutma yükünü 6997 kW/h ile yaklaşık 4461 kW/h arasında önemli ölçüde azaldığı ve 67.38 % oranında düşürüldüğü saptanmıştır. Son olarak, bu tez, sıcak kurak iklim bölgelerinde düşük soğutma enerjisi konutlarının tasarlanmasının önünü açan araştırmanın temel bulgularını özetleyerek sona ermiştir.

Bilim Kodu	:	80103
Anahtar Kelimeler	:	Pasif Soğutma, Vernacular Binası, Enerji Simülasyonu, Erbil Şehri
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SYMBOLS AND ABBREVIATIONS

The symbols and abbreviations used in this study are presented below along with explanations.

Symbols	Explanations
cm	centimeter
m	meter
mm	millimeter

Abbreviations	Explanations
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
DOE	Department of Energy
EPS	Expanded Polyurethane
HCECR	High Commission for Erbil Citadel Revitalization
HVAC	Heating, ventilation, and air conditioning
UNESCO	United Nation Educational, Scientific, and Cultural Organization's
3D	Three Dimensional

1. INTRODUCTION

Research background

Passive cooling strategies are considered as a vital means to maintain indoor thermal comfort of buildings. Nowadays peoples in hot arid climate cities using a mechanical air conditioning systems when the natural outdoor temperature cannot maintain thermal comfort, thus energy demand is increased. In addition, installing an air conditioning unit and operating it will deliver additional energy consumption and costs. According to National Renewable Energy Laboratory, air conditioners use refrigerants made of chlorine compounds that are suspected contributors to the depletion of the ozone layer and global warming (NREL, 2011). The ongoing acceptable trend towards a passive cooling architectural design has turned into an all-inclusive responsibility where passive cooling keeps up a comfortable indoor temperature as an alternative to using a mechanical air conditioning for decreasing cooling energy loads. In hot arid climate cities, a vernacular building design can be used as a motive to understand what were the climatic responsive design solutions that ensured thermal comfort for traditional people without using advanced technologies and electricity. Therefore, this study analyzed the climatic responsiveness design techniques of Erbil vernacular architecture in two different levels (neighbourhood level and house level), to identify passive cooling techniques that can produce comfortable indoor spaces to lowering cooling energy demands. This field study identified these techniques which have led to use building thermal simulation that focused on prevention of heat gains and modulation of heat gains as two main passive cooling strategies. The energy simulation process simulates the proposed passive cooling techniques in this study in different scenarios focusing on indoor thermal performance.

Nowadays, energy depletion, climate change, and global warming are considered as some of the greatest challenges facing the planet. The building construction sector is considered one of the main energy consumers, recording above 40% of entire primary energy consumption worldwide (Cao, Dai, and Liu, 2016). Modern societies depend on the Earth's resources at an increasingly rapid pace to satisfy certain needs and their high-quality living standards. For instance, in hot climate regions, most of the twentieth-century buildings are totally dependent on mechanical systems to provide thermal comfort, making them fully reliant on fossil fuels as energy source. These are the consequences of irrelevant design strategies, which eventually lead to high energy consumption, raising carbon emissions, environmental pollution and decline in air quality. Therefore, decreasing fossil fuel-based energy consumption is of primary concern at the present. Architects, engineers, and city planners have started to search for solutions to reduce energy consumption in buildings.

In contrast to the current situation of modern buildings in terms of energy efficiency and harmony to the local environment, vernacular architecture in hot climate regions are more adaptable and highly appropriate to the surrounding environment. Numerous studies and researches have been carried out so far in the scope of vernacular architecture and it's relation to energy efficiency (Fathy, 1986; Azami, Yasrebi, and Salehipoor, 2005; Anna-Maria, 2009; Dabaieh, 2011). Accordingly these several studies done in different regions along with different time period proved that vernacular architecture techniques are considered energy efficient and sustainable one, although some of them are currently no longer suitable functioning because of changed of living standard in terms of social, economic, cultural and ecological dimension. It is universally believed that vernacular architecture is properly adapted to the topographical characteristics, local environment, and accessible resources in terms of both, urban pattern and building layout.

Many pioneering books in the field of vernacular architecture such as those of Amos Rapoport, Hassan Fathy, Edward Brian, Victor Olgyay, and Paul Oliver with a focus on the link between vernacular architecture and its response to local climate requirements were taken as reference for this study. All these resources introduce the vernacular architecture as a smart architectural solution to live comfortably within their surrounding environment. Unfortunately, many of modern buildings today do not have any connection to their context, local climate, and the user comfort requirement. In this regard, the key challenge is to learn the fundamental architecture design strategies and principles of vernacular architecture. The climatic responsive strategies in vernacular architecture design used as a starting point of this study to realize how the climatic conditions influence the architectural design and how the buildings can be more responsive. However, studying passive cooling design techniques to understand its real value and try to make a valuable contribution to the modern housing design and construction in Erbil city is one of the main objectives in this research. Generally, there are three pathways to limit energy utilization: first is to just lower the request and utilize less energy; second is to be more energy-productive in our energy-based technology and frameworks, and third is to supplant fossil fuels by sustainable power sources to take care of the demand (Charles,2008). The sun is an essential source heating up the building envelope (rooftop, walls, and windows), that's consequently rising indoor temperatures to uncomfortable levels. Therefore, this doctoral study takes the principal first pathway mentioned above as a remarkable approach towards energy-saving in housing buildings. With a particular spotlight on passive cooling to satisfy indoor thermal comfort needs. This study does not intend to cover all passive cooling techniques, but it focused on the two main categories of worldwide accepted passive cooling techniques (prevention of external heat gains and modulation of heat gains) which can be used to enhance thermal comfort in buildings and are presented clearly further in the literature review. As of late, mechanical cooling systems are utilized to control the temperature, moisture substance, dissemination and immaculateness of the air inside a space, so as to accomplish the thermal comforts for the inhabitants. Therefore, to reduce the total dependence on air conditioning systems, development of new technologies and design methods innovations for achieving thermal comfort in buildings by passive cooling techniques is the main focal point of this doctoral research.

Problem of the research

As a result of the USA invasion and occupation of Iraq in 2003, the economic development in northern Iraq has occurred beside the modernization, the growth of population because of inner migration from other parts of Iraq, and housing demands that resulted in considerable mass construction of residential buildings, especially in Erbil city. This rapid urban expansion caused in designing new housing projects without taking an attention to passive cooling design strategies and thermal comfort conditions as have been found in traditional buildings. Most of the architects, engineer, and housing construction companies designing these new houses without respecting to the local climate conditions and environment requirements. These modern housing buildings are usually constructed unsatisfactory in poor methods due to low-quality building standard. A large amount of these houses is built without proper insulation, un-shaded, thin exterior walls, large glazed opening without regarding natural ventilation and daylighting. Therefore, people are using a huge amounts of energy used by air conditioning devices for cooling to ensure the indoor thermal comfort satisfaction. All together with the lack of proper building regulation and codes in Erbil city causing an increase demands of energy loads in the hot summer season. Increased of non-renewable energy resources usage will increase environmental hazards as well. Unfortunately, in Erbil city there are no real steps taken to solve these problems yet. Thus, this research is founded to be a key or step forward to solve this problem and to suggest an architecture solution for the other problems such as:

1. Contemporary architecture design and planning of housing is not meeting the area's social, environmental requirements and is poor in terms of responding to the local climate, leading to the use of extra energy.
2. An increase in using of foreign construction materials has caused great diversity in the houses' design. This inhibits break the continuity between recent and vernacular architecture features and resulted in losing the local architecture identity.
3. New urban expansions and construction projects were designed in Erbil city applied urban planning standards from foreign countries which are unrelated to the cultural heritage and architecture identity of the region. However, no formal standards for housing exist, resulting in the great diversity of planning and designing of housing buildings.

However, when examining exactly the architectural features of the recent housing buildings there are clear differences with the vernacular architecture that demonstrated as a significant example in harmony with the local climate.

Research hypothesis and questions

Designing low cooling energy housing for Erbil city could be achieved through the integration of low energy techniques in vernacular architecture with passive cooling techniques in contemporary architecture. This research mainly seeks to answer the following questions :

1. What can be learned from vernacular architecture in order to propose an application of passive cooling techniques?
2. What were the climatic responsive design solutions that ensured thermal comfort for traditional people without using advanced technologies and electricity?
3. How could the application of passive cooling techniques to future and current housing buildings reduce their cooling energy consumption?

Aim of the research

This thesis research mainly seeks to propose an application of passive cooling techniques into an existing single-family low rise residential building in Erbil city. In addition, this study emphasizes the need to apply vernacular architecture design strategies and principles in modern housing design and construction more consciously. Furthermore, its suggests to benefit from the latest application of vernacular architecture and passive cooling design stratigies by by inventing strategies in harmony with modern lifestyle. Therefore, the author believes that this study opens the pathways in the direction of reducing the huge amounts of cooling energy which utilized toward providing the thermal comfort. While the secondary objectives of this research are as follows:

1. To research vernacular architecture design characteristics in hot-arid climate regions in order to learn a fundamental lessons and defined the most effective method to reduce energy consumption especially cooling energy during summer.
2. To develop an energy simulation model which can aid to evaluate the effect of different proposed passive cooling techniques on cooling loads and energy reduction rate.
3. Presenting instructions for designing low cooling energy residential building based on the outcomes of the thermal dynamic simulation. However, as the passive cooling approaches are endless, it is believed that the present dissertation can help as a positive step for fixing the crisis of cooling energy consumption in the residential buildings, as a consequence, this study findings for Iraq, yet can be considered as a foundation for developing an innovative methods in architecture designing of housing buildings in hot arid climates.

While the tertiary objectives of this research are:

1. Examine the effect of different shading scenarios (windows shading, wall shading, and roof shading) on cooling loads and energy performance.
2. Analysis of the thermal mass performance of different wall construction materials to Find out the best wall materials in terms of thermal conductivity (U-value).
3. Determining the thermal insulation layer position (Inside or outside) in building walls and roof that can aid thermal mass design decisions.
4. Examine four different type of glazing and determine the best one in terms of energy performance.

5. Analyzing the energy performance of each proposed passive cooling scenario using DesignBuilder based on the following:
   - Total energy consumption and savings during the peak cooling load in the summer.
   - The total rate of cooling loads reduction.

Research methodology

In order to achieve the goals of this research study, quailitive literature research approach, filed survey and energy simlution modelling used through three phases as show in Figure 1.1. Thus, the research methodology carried out by three main stages as follows:

First stage (literature review)

Generally, a literature review is based on recent related previous studies, observational methods and qualitative case studies analyses. The first phase of the research methodology consists of a comprehensive review of recently has been done relevant studies. Many books, articles, thesis and academic research has been reviewed in the subjects especially the one which well-connected to climatic responsive design strategies and energy efficiency in hot climate regions. A literature survey was done to create a foundation for the research objectives and questions to help build up the gap of knowledge in the research topic in Erbil city. However, the followin aspects has been reviewed and examined in the first stage of this research:

- Literature survey on passive cooling techniques and its latest applications.
- Literature survey on thermal comfort and climate responsive techniques in vernacular architecture.

Second stage (case study)

After reviewing the recent literature on the subject, the next phase of our research methodology relies on a qualitative field study in Erbil. This field study examines residential architecture in the historic core of Erbil, a registered World Heritage Site, for its use of climate responsive strategies. Using a descriptive-explorative approach, the study seeks to search for ways to adapt the lessons learned from Erbil’s vernacular architecture to the modern city, to reduce mechanical cooling loads. The field study was conducted in the ancient settlement of Erbil citadel in two different analysis scales:

- Urban characteristics

  This analysis investigated the urban fabric in terms of paths and alleyways to check out the width, arrangement, and the access of the paths throughout the citadel. It also investigated the open public and private spaces in order to explore how the neighborhoods are organized as groups of buildings, and how they are compatible with the local environment.
- Housing characteristics

  This analysis investigated individual houses to identify and define the climate responsive design strategies such as housing plans, floors analysis, construction techniques, building material, central courtyard, room's seasonal use, and natural ventilation methods.

However, Erbil city was selected as a field case study for the following reasons:
Firstly, in 2007 UNESCO considered old Erbil city as a World Heritage Site. It is distinguished as a traditional human settlement and reflects the integration with the climate and local setting, and social value. Available documents and drawing helped to understand the vernacular architecture characteristics.
Secondly, Erbil provides an opportunity to study the contrasting examples of adaptability of architecture to climate. It combines two types of housing: the vernacular housing (inside Erbil citadel) and the modern housing. The outcomes from the mentioned above stages are the basis of the thired phase.

Third stage (building energy simulation)

After analysis, the findings of the field study, the third stage contained an energy simulation of a single-family house in modern Erbil city.
Recently, energy simulation or energy modeling method is the most broadly utilized as a part of the request to examine the passive design techniques and evaluate their effect on energy consumption and funds.

However, several kinds of energy simulation software are available nowadays. DesignBuilder as an energy simlution program software chosed in this study according to the research aim and requirements with regard to the software accuracy, availability and its update version. A base case house designed, modelled, evaluated and compared with the proposed energy efficient house model after applying passive cooling techniques. The comparison between the base house model and the proposed model analyzed and discussed. Further explanation about the carried out energy simulation process are mentioned in chapter Five. At last, final result on energy simulation and summary of the entire thesis outcomes and recommendations are presented. Looking through this study as an overall, a clear perception of the energy simulation process is identified which provides different passive cooling scenarios to enhance indoor thermal comfort and reduce energy consumption.

Organization of the dissertation

To accomplish a better understanding of this dissertation aim, hypothesis, methods and the key findings, the study divided into four parts contains six chapters which are as follows:

- Stage 1: This stage consists of chapter 1 and chapter 2.
  This stage mainly focused on highlighting the research background and the motivation behaind this study, (objectives, problem statement, hypothesis and the selected research methodology) together with the literature review focusing on the vernacular architecture of hot arid climate in general and passive cooling techniques in particular.
- Stage 2: This stage consists of chapter 3.
  This stage displayed the first step of the thesis methodology (case study) focusing on analyzing the vernacular architecture of the Erbil city. This is a field study based on a methodology of descriptive-explorative approach aiming at understanding the link between vernacular architecture and climatic-responsive strategies used in the historical site of Erbil citadel. Its end with a brief comparison between vernacular and contemporery architecture in the city in terms of architecture and climatic-responsive strategies.
- Stage 3: This stage consists of chapter 4 and chapter 5.
  This stage displayed the second step of the thesis methodology (energy simulation) focusing on thermal performance analysis of the simulated house by using DesignBuilder after adopting the proposed passive cooling techniques. Chapter four focused on the basic steps of the simulation process by included hourly weather data and description of the simulation modeling. In addition, a brief knowledge about the

building simulation process and an overview of the DesignBuilder Program is provided. Chapter five explains the simulation method and process as well as clarifies the thermal performance simulation result, and also, analyzes the data by comparing the different passive cooling scenarios.

- Stage 3: This stage consists of chapter 6

  The last part included chapter 6 which comprises the key findings of the field study in the vernacular architecture of Erbil city, together with summarising the main conclusions of this dissertation and also presenting the general recommendations for further research.

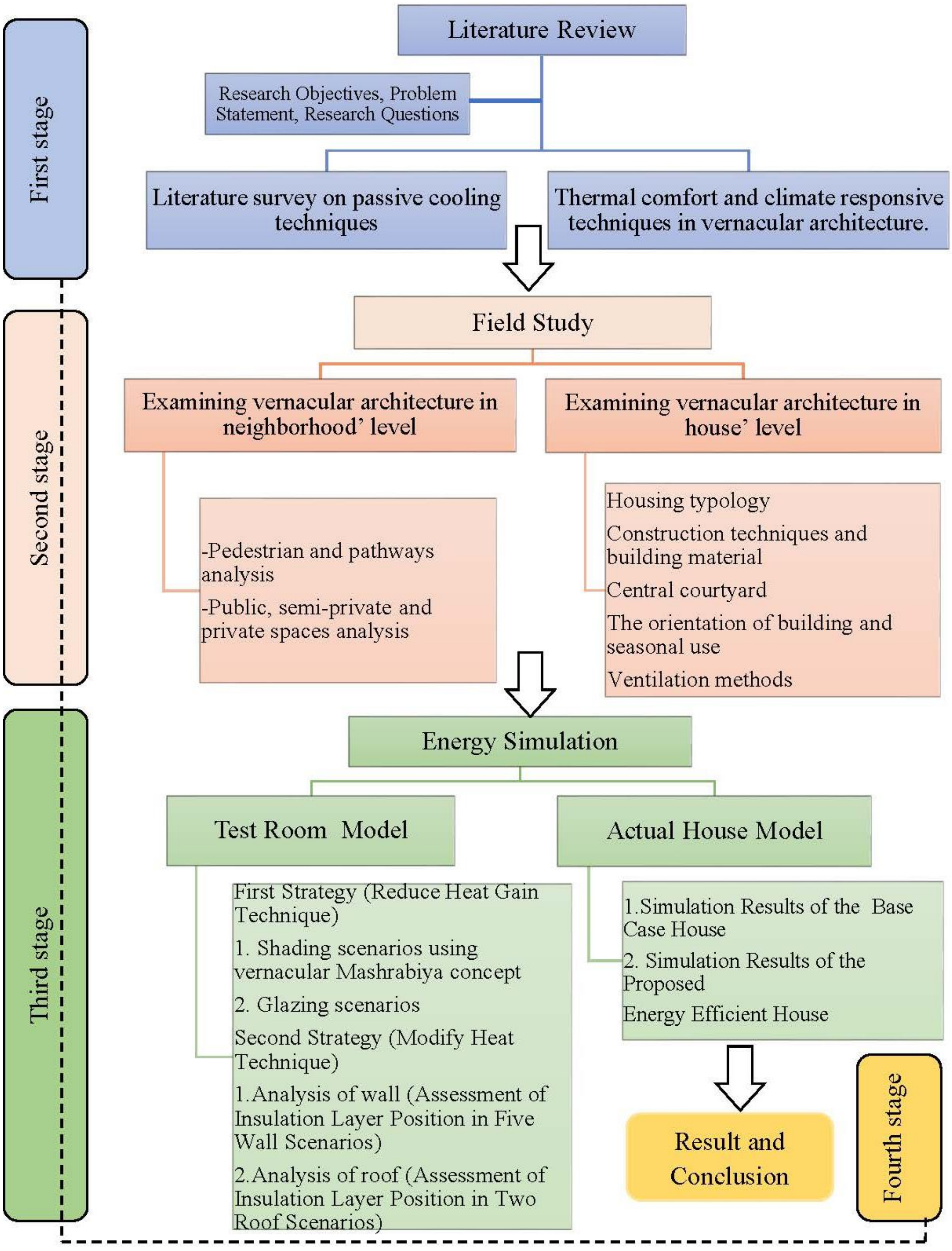


Figure 1.1. Resarch methodology flow chart

2. LITERATURE REVIEW

The literature review helps with setting up an underlying methodology structure for the examination of the simulation analysis. The initial section of the literature review thought about the important investigations of fundamentals of passive cooling and heat transfer mechanism through the building. In addition, it covers recent examinations and considers the recent studies of passive cooling techniques in residential buildings. This gives several investigations of vernacular building focusing on a residential building and the major standards of passive cooling. The second section of the literature review concentrates on the aspects linked to thermal comfort in housing building during summer. Finally, the literature review covered the aspects of passive cooling techniques advancements by examining the most advanced building examples which implemented passive cooling techniques in hot-arid climate.

2.1. Fundamentals of Passive Cooling

For thousands of years there were no air conditioning technologies to provide the required cooling loads to buildings. Especially in hot climates Arabic, Roman and Greek architecture were using their design as the only means of cooling the structures. The use of enough thermal mass to temper the internal conditions together with appropriate shading and urban design, the use of light coloured surfaces as well as ponds or fountains for evaporative cooling are some key design features well known from those early ages. However, after the industrial revolution and the development of technologies, passive cooling has become marginal, especially in the developed countries and has been replaced by HVAC systems. In the last few decades HVAC (Heating Ventilating and Air Conditioning) systems have become widespread all over the developed countries. They are widely used in non-domestic buildings in order to control their internal conditions by providing the adequate amounts of ventilation rates, heating and cooling loads within the buildings. However, they significantly contribute in greenhouse gas emissions. Besides CO_2 emissions that have a great effect on global warming. According to Cook (1989), the term ‘passive’ was selected to define space conditioning methods that are operated essentially by natural phenomena, i.e. without operated mechanical appliances. An oil restriction occurred in the 1970s. Worldwide agreement of the term since then can be seen for example in the organization of Passive and Low Energy Architecture which knew as

PLEA (Yannas & Bowen, 2017). A ‘passive’ design may introduce the application of fan or a pump which conederid as a low-energy devices when it's utilizing might improve the building thermal performance (Givoni, 1994; Balaras, 1996). Bahadori (2010) stated that cooling can be defined simply as it is the removal of heat from the space or from the air provided to space, so as to obtain a lower temperature and acceptable humidity rate than those of the outdoor environment.

Comprehensive sources and useful knowledge on passive cooling whose aims include energy-saving and sustainability can be seen in (Olgyay, 1993; Hyde, 2007; Lauber, 2005), (Roaf, 2013; Bonta and Snyder, 2008; Bauer, Mösle and Schwarz, 2010) and (Cook,1989; Givon, 1994; Kang et al, 2011). In their observations, these books and researchs concentrated on the hot dry climate and Mediterranean climates. All of the above mentioned academic refrences are in agreement that passive cooling methods for buildings can be achieved at three design steps: (1) prevention of external heat gains ; (2) modulation of heat gains; and (3) removing of internal heat from the building by natural ventilation methods, or low energy cooling methods such as radiative cooling, evaporative cooling or earth cooling.

According to Ochoa and Capeluto (2008), passive design, can be defined as a series of architectural design methods employed by the architect to improve the building to react appropriately to climatic conditions with other urban requirements. The passive design framework has obtained incredible significance because of the expansion in high expectations for everyday comforts and energy utilization. As architecture approach, a passive design plans to utilize particular building design standards to limit the energy prerequisites keeping in mind the end goal to accomplish a strange state of thermal comfort (Ralegoankar and Gupta, 2010). There are many parameters, which can influence passive design criteria like, climate condition, thermal comfort, orientation, building opening, building shape, the sort of sunshade, the determination of building materials, vegetation and so forth. Every one of these parameters can be coordinated or utilized independently to accomplish the objective of the passive design idea. Passive strategies can reduce the temperatures in hot climates, which lead to minimizing energy consumption and CO2 emission. The integration between many strategies can achieve a high level of building performance (Ochoa and Capeluto, 2008). Sarswat and Kamal (2015), state that passive cooling systems use non-mechanical methods to maintain a comfortable indoor temperature and are a key factor in mitigating the impact of buildings on the environment.

Keeping up an agreeable environment inside a building in a hot climate depends on decreasing the rate of heat gains into the building and empowering the expulsion of overabundance heat from the building. To keep heat from penetrating into the building or to evacuate once it has entered is the basic rule for achieving cooling in passive cooling ideas (Kamel, 2012). This relies upon two conditions, the accessibility of a heat sink which is at a lower temperature than indoor air, and the advancement of heat exchange towards the sink. However, environmental heat sinks are divided into four types. (see Figure 2.1)

1. Ambient outdoor air (principally heat transfer by convection within building openings)
2. The sky (night) (heat exchange or transfer by radiation phenomenon from the building surfaces such as the roof or another exterior surface of the building)
3. Water (heat exchange by evaporation inside and additionally outside the building envelope)
4. Ground (heat exchange or transfer by conduction through the building envelope) (Al-Obaidi, Ismail and Abdul Rahman, 2014). Passive cooling mehods can diminish the peak cooling load in buildings, this will diminishing the energy utilization of the mechanical air conditioning devices (Kamal, 2012).

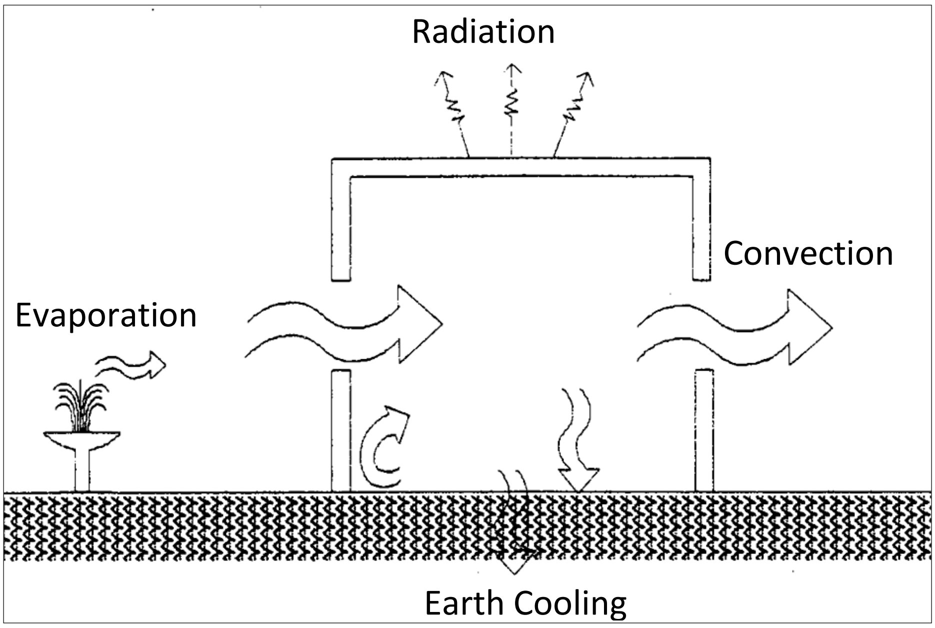


Figure 2.1. Methods of heat exchange to environmental heat sinks (Lechner, 2015)

Each of these environmental heat sinks considered as a cooling source and can be utilised in different ways and systems. For instance, the dismissing or refusing of heat into these environmental heat sinks can be done through the natural means of heat exchange (natural cooling) convection, radiation, conduction and evaporation or through mechanical support using hybrid cooling methods through emplyment of small power pumps or fans (Samuela et al, 2013). As well as, Samuela et al (2013), listed the familiar passive cooling methods into radiant cooling, comfort ventilation, evaporative cooling, nocturnal ventilation cooling, and employing the earth as the passive cooling source. The rapid growth in the population and economy accompanied by depletion of energy resources in Erbil city lead to serious harmful effects on the environment and human life. This construction growth and development coupled with active building constructions ignore the requirement of the environment such as the wind and solar. Accordingly, the strategies and principles of passive solar design have been importantly and urgently required in order to reduce these negative effects on both the humanity and environment. Unforthanitly Iraq and most of developing countries have a big gap between the modern construction practice and passive design principles. Therefore this research is founded to highlight the most suitable architecture solutions driven from passive design strategies and vernacular architecture design methods as step forward to fix this gap. I believe that there should be more attention took from the local government, architecture, engineer, construction firm and real-estate development to clarify and define the current energy consumption problems in order to find suitable architecture solutions before it becomes more difficult and maybe more expensive.

2.2. Passive Cooling Design Strategies

The main design principles of passive approaches require planning the building based on how the designer can take a benefit from natural wind, sunlight in order to determine the behavior of the solar heat gain through the building envelope and especially windows so as to decrease the need for the mechanical air-conditioning and artificial lighting. Moreover, the principal purpose of passive design approaches is to control the thermal comfort during the four season. Therefore, passive design techniques can be obtained by improving the building thermal performance such as designing the building envelope with energy-efficient code and standards, applying external shading patterns, employing natural ventilation, insulation and many other strategies that agree with particular climatic requirements (Lechner, 2015). An investigation research carried by Ruiz and Romero (2011) in Spain, considered typical housing buildings and discovered that utilizing passive approaches can overcome the cooling and heating loads and save 18% of electricity when compared to the real building. The used passive approaches were additional 200 mm insulation on the building façade and 350 mm lintel in window frames. However, Manioglu and Yilmaz (2007) insisted that responsive passive housing architecture design is the only prospect of the sustainable housing in hot arid climate regions when it comes to aspects of the land area, orientation, the distance between building, building envelope and building form. Ralegoankar and Gupta (2010) stated that an exciting reduction in cooling or heating loads and artificial lighting energy waste could be obtained by employing passive design approaches. The two above mentioned studies agreed that practicing passive design methods decreased the amount of thermal discomfort level in the examined buildings. According to Ochoa and Capeluto (2008), the principal design elements in passive design approach in hot humid climates is the smart and effective building envelop, because of its vital role on controls the external solar and wind condition prior come in the building (see Figure 2.2)

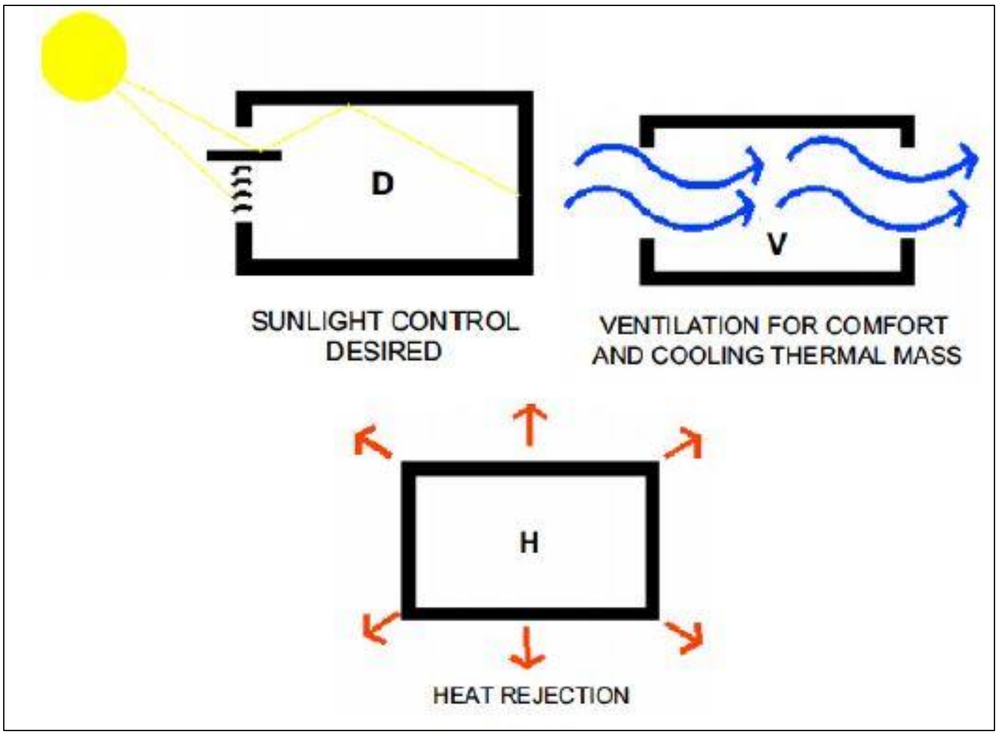


Figure 2.2. Graph shows the main passive cooling methods for hot climate (Ochoa and Capeluto, 2008)

According to Mortada (2016), passive design approaches is a reflection that people are knowledgeable of sustainable buildings and low energy including its value for human beings life and its impact on the built environment. This knowledge guides them to involved passive techniques into the design, further, they combining a few developed technology which help in raising the quality of the built environment as well as the quality of building occupants with minimum energy consumption. Consequently, this help to introduce the idea for low-energy building assessments conception. However, all the above-mentioned research and observations conclude the thermal performance of the building, diminishing the energy waste and reducing CO2 emissions.

The present study attempt to find out the innovative methods for reducing cooling energy consumed by air conditioning systems. As Kamel (2012), stated that passive cooling methods can significantly decrease the peak cooling load in buildings, thus decreasing the period of operation and the size required for the air conditioning devices. However, the most recent two decades has seen a serious energy dilemma in developing nations, particularly among summer season basically because of cooling load necessities of buildings. The energy utilization in buildings is very high and is relied upon to additionally expand in light of enhancing ways of life and expanding populace. Mechanical air conditioning systems utilize has progressively entered the market recently and significantly contributes in the upsurge of greatest energy utilization (Kamel, 2012). A 'passive' solar design includes the utilization of natural means conduction, radiation, or convection without employing any electrical device for cooling or heating to accomplish acceptable indoor thermal conditions (Santamouris and Kolokotsa, 2013). Sustaining satisfactory indoor conditions of a building in a hot-arid climate region depends on decreasing the amount of external heat gains and supporting the elimination of interior heat from the building. Kamal (2012), has examined and prepared a list of several passive cooling methods, which include insulation methods, solar shading methods, forced ventilation methods, evaporative cooling, radiative cooling, desiccant cooling and earth cooling.Geet ha and Velraj (2012), reviews and studied different possible strategies of passive cooling for buildings and presents the utilization example of each strategy. The author also stated that passive cooling methods are intimately combined with the thermal comfort of the inhabitants, and it is probable to obtain this comfort by decreasing the exterior heat gains, heat moderation by thermal mass and transferring the inner heat by natural ventilation.

However, Passive cooling strategies are classified into three categories by Geetha and Velraj (2012). The first category is discussed the architecture design strategies to protect the building from solar heat by solar control and microclimate parameters. Building envelope's insulation, solar shading and surface properties of the building (colour of the surface and texture) are consider the main paremters under the solar control, while the outdoor water surface, landscape design and vegetation are under microclimate control category.

The second category is discussed the heat modulation or amortisation technique. Heat gains ought to be adjusted by the powerful solar control to accomplish a harmony between controlling solar pick up and conceding adequate light, while guaranteeing the design and basic necessities of the building envelope. In addition, an agreeable level of heat load ought to be allowed by modulating the required temperatures for the diverse employment of inner spaces during the design stage (Al-Obaidi, Ismail and Abdul Rahman, 2014). Different parameters are listed under the heat modulation or amortisation technique which aims to heat gain modulated by using night ventilation or thermal mass. The third category of the passive cooling strategies is aim to reduce heat gain or remove internal heat by heat dissipation. According to Al-Obaidi, Ismail and Abdul Rahman (2014), the interior spaces heat in the building could simply be decreased or transferred by heat sinks through air infiltration by natural cooling or hybrid cooling. However as by Geetha and Velraj (2012), passive cooling methods for buildings can be achieved at three design steps: (1) prevention of external heat gains ; (2) modulation of heat gains; and (3) removing of internal heat from the building by natural ventilation methods, or low energy cooling methods such as radiative cooling, evaporative cooling or earth cooling. In the present study, a literature survey has done on the different procedures embraced to accomplish thermal comfort in buildings under the above stated three stages.

Solar heat reduction/prevention

Prevention of heat gains is the initial move towards a change of the thermal comfort conditions in the indoor environment of the building and incorporates each measure that gives minimization of heat gains in it. A building must be adjusted to the atmosphere of the district and its microclimate. It is essential to limit the interior heat increases of a building so as to enhance the viability of passive cooling strategies (Venkiteswaran, Liman and

Alkaff, 2017). The site configuration is impacted by economic contemplations, zoning controls and uniting, all of which can meddle with the design of a building, concerning the episode solar radiation and the accessible wind (Geetha and Velraj, 2012). Vegetation can bring about graceful outside spaces, as well as enhance the microclimate around a building and decrease the cooling load. Solar control is the essential outline measure for heat gain prevention insurance. Solar radiation influences the outer building surfaces in direct, reflected and diffuse forms and enters to the interior by transparent components. For a given surface, solar radiation changes with the orientation and the surface's edge to the level plane. The entry of solar radiation toward an internal space may create problems, for example, raises indoor air temperatures, thermal and visual inconvenience to the inhabitants, damage items and furniture. In this manner, it is of fundamental significance that solar radiation ought to be controlled (Al-Obaidi, Ismail, and Abdul Rahman, 2014). Solar radiation control may be accomplished by the several design techniques such as, form and morphology of the building, solar protection of the building envelope, shading the exterior openings, thermal insulation, and surface properties as the color of the external surface determine the measure of solar radiation received (light colors are associated with the reduced solar heat absorption) (Venkiteswaran, Liman and Alkaff, 2017). Blocking solar radiation from accessing the building and its interior is one of the significant means for evasion of overheating situations in its interior. In spite of solar protection of the building envelope is useful, must significant is shading of the windows. This can be obtained by constructing barriers to the sun bath (shading device) or managing the solar-optical features of the exposed surface (Geetha and Velraj, 2012).

Modulation of heat gains

Modulation of heat gain can be accomplished by the utilization of building materials with high thermal mass or has a high heat storage capacity in the building structure. High thermal mass materials such as concrete block, brick and in general masonry walls perform as storage for both cold and heat as they heat up and cool down moderately gradually (Geetha and Velraj, 2012). Generally, there are two main methods to obtain the thermal mass benefits, either by the application of heavy construction material or by the aid of extra energy-intense phase change material in the building envelope (Al-Sanea and Zedan, 2011).

Remove indoor spaces heat

Much of the time, the prevention and modulation of heat gains can't keep up indoor temperatures at a control level. Further developed cooling system incorporates heat removal to heat sinks, for instance, the surrounding sky, by the natural methods of heat transfer (Al-Sanea and Zedan, 2011). The design and plan layout of a building is a critical factor which impacts the cooling capability of a natural cooling method. Natural cooling indicate to the implementation of natural heat sinks for overabundance heat dispersal from inside spaces, including natural ventilation, ground cooling, evaporative cooling and radiative cooling, and likewise the utilization of a PCM based framework with the expectation of free natural cooling (Al-Obaidi, Ismail, and Abdul Rahman, 2014). However, natural cooling ventilation consists of techniques that use ventilation with mostly natural means to cool buildings; that is natural ventilation, night ventilation and also mixed-mode ventilation.

Natural ventilation uses fresh cool air from outdoors to cool the building. The introduced air that replaces the contaminated indoor air, is heated and then exhausted throughout building openings. The air flow pathway determines the various ventilation methods, as shown in Figure 2.3 cross ventilation, single-sided ventilation, sub-slab distribution ventilation and stack ventilation. (Zarandi, 2013). The author stated that sometimes the cooling capability of natural ventilation could not achieved the thermal comfort at the required level and it relies essentially on the outside air temperature. Therefore, in most cases and especially in non-domestic buildings situated in the urban heat island, where outside temperatures are higher than in the rural areas, natural ventilation cannot cope with the internal heat gains. Therefore, designing a building in a way to allow air flow pass through is one of the most important factors in building ventilated naturally. In this way, mostly and particularly in non-residential buildings located in the urban heat island, where outside temperatures are higher than in the rural zones, natural ventilation can't overcome to the inward heat gains (Dehghan, Esfeh and Manshadi, 2013).

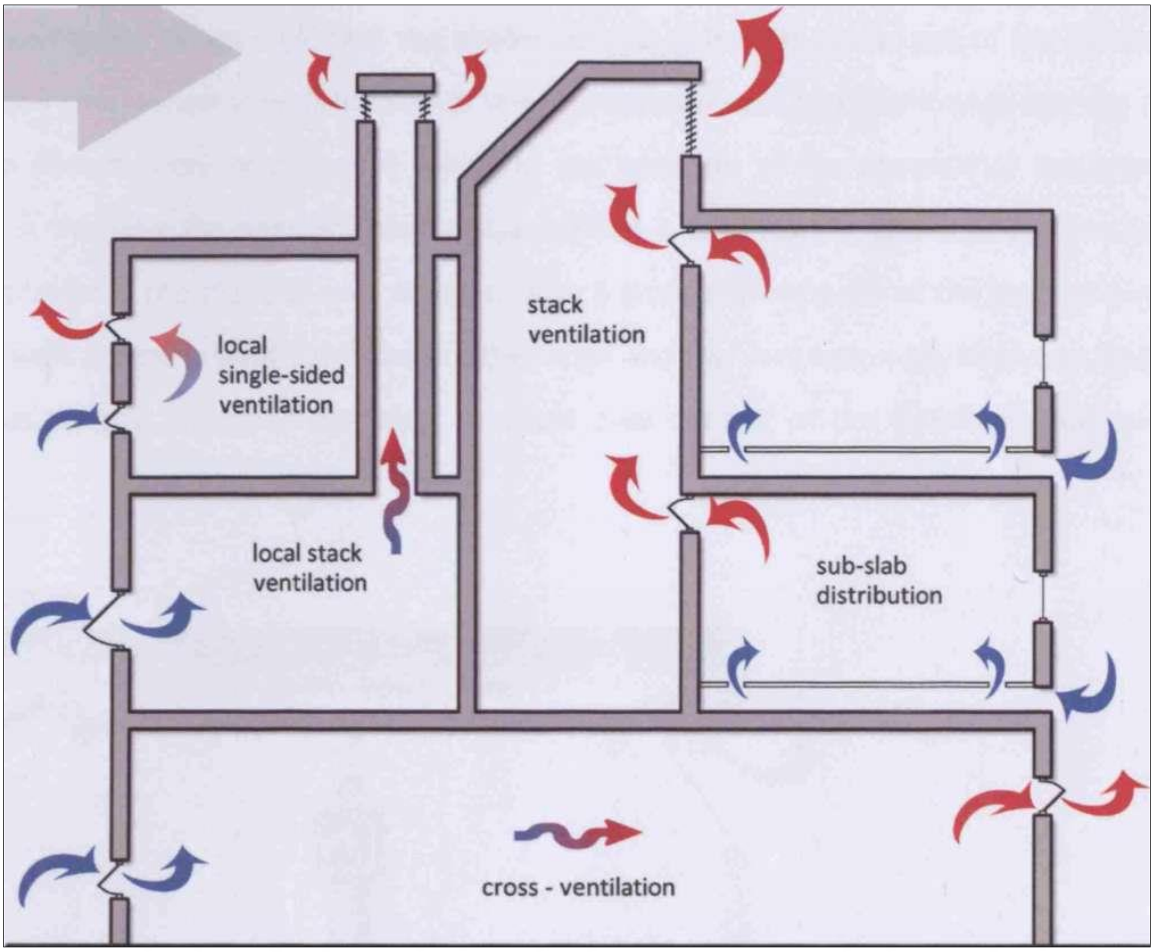


Figure 2.3. Different types of natural ventilation methods for cooling the building (Zarandi, 2013)

2.3. Thermal Comfort

In this section the main issues related to thermal comfort is addressed. The perception of thermal comfort of a person derives from the primary need to keep the temperature of the innermost parts of the body in the range 36-38 °C. To ensure this, it is necessary that the heat produced because of our metabolism and our activity balances the heat released into the environment (Butera, 1998). Comfort sensation derives from the unbalance or balance between the heat produced and the heat lost. Therefore, when we are cold, it is a warning that we lose more heat than we produce, and our body is cooling down; when we are hot, we produce more than we lose, ad our body is warming up. The human body not only produces heat, but also mechanical work, when walking, running, cycling, climbing, sawing, hammering, etc (Carlucci, 2013). The total energy produced is called metabolic rate. Thus the energy balance of our body can be written as:

M = W + Q where:

M = Metabolic rate,

W = Mechanical work,

Q = Heat loss, the metabolic rate is expressed in met or in W per square meter of body surface area (1 met = 58.1 W/m2) (Butera, 1998).

A seated person produces 1 met. As the average man has a surface of 1.8 m2, an average seated person will produce slightly more than 100 W (Bessoudo, 2008). The higher is the activity level, the higher the metabolic rate. Human body exchanges heat with the environment through: (1) Convection, which depends on skin temperature, air temperature and its speed.(2) Radiative heat exchanges, which depend on the temperature of the skin and on the temperatures of the surfaces enclosing the space. (3)Transpiration (which can turn into sweating) and respiration, which result into the evaporation of water, with consequent removal of heat from the skin or lungs; it depends on the relative humidity of the air. (4) Conduction; it takes place if a part of the body is in contact with a solid object; it depends on the temperature of the skin and of the object as well as on the thermo-physical characteristics of it (Butera, 1998). Thus, the heat loss (Q) is given by:

Q = C + R + E + H, where:

C = heat loss/gain by convection

R = heat loss/gain by radiation

E = heat loss by evaporation;

H = heat loss/gain by conduction (Butera, 1998).

Of course, the heat exchanges between the body's surface and the environment depend also on the clothing we wear, as clothing acts as a thermal insulation (Bessoudo, 2008). Thus, clothing is measured by its thermal resistance and is expressed in the unit clo (1 clo = 0.155 m2K/W). The value clo = 1 corresponds to the typical winter clothing, the lowest value is clo = 0 (naked person), the value clo = 0.5 corresponds to the typical summer clothing. In summary, the body heat balance, hence the thermal comfort, depends on six factors, of which two personal and four environmental. The personal factors are: activity and clothing. The environmental factors are: air temperature, air relative humidity air relative velocity, means radiant temperature (Butera, 1998). With radiant heat the apparent size of each radiating surface must be taken into account, not only its temperature. The apparent size is measured with the so-called view factor.

The mean radiant temperature

The mean radiant temperature is defined as the uniform temperature of an imaginary enclosure in which the radiant heat transfer from the human body is equal to the radiant heat transfer in the actual non-uniform enclosure (Butera, 1998). It is important to note that the mean radiant temperature is function of the position at which it is measured (Carlucci, 2013). This is a particularly critical aspect of thermal comfort to consider in rooms with large glazed surfaces. The only environmental parameters affecting our heat balance, thus our comfort, are air temperature and mean radiant temperature (Bessoudo, 2008).

The operative temperature

The operative temperature defined as the mean between air and mean radiant temperature: if the room is air conditioned and air temperature is 26 °C, the operative temperature in the two cases is respectively 27.5 and 26.5 (Carlucci, 2013). It is evident that the person close to the glazed surface feels hotter than the other, even if the air temperature is the same. A general index, more general than the operative temperature, as it is valid for any value of environmental and personal factors, is the PMV (Predicted Mean Vote), according to the standard ISO 7730. The PMV model derives from thermal comfort surveys carried out on a large group of people exposed to the same environment (Bessoudo, 2008). The survey was about their thermal sensation on a seven-point scale from cold (-3) to hot (+3). From these surveys, empirical equations were derived, capable to predict the thermal sensation in terms of Predicted Mean Vote, PMV. In order to predict the number of people likely to feel uncomfortable in an environment, another index was introduced, the PPD (Predicted Percentage of Dissatisfied), which provides a quantitative prediction of the number of thermally dissatisfied people (Kontes, Giannakis, Horn, Steiger and Rovas, 2017). Because of individual differences, it is impossible to obtain a thermal environment satisfying everyone. Even with PMV zero, there is always a 5% dissatisfied. In non air conditioned buildings, the principles of adaptive comfort can be applied, which takes into account not only the purely physiological factors but also include psychological and behavioral factors. The issue of adaptive comfort is addressed in the ANSI/ASHRAE Standard 55-2004 (see Figure 2.4) (Kontes, Giannakis, Horn, Steiger and Rovas, 2017). The standard applies the principles of the adaptive comfort in spaces without air conditioning, or when the system is turned off, and where the thermal conditions of the space are regulated primarily by the occupants through freely opening and closing windows (Carlucci, 2013). In this conditions, the values of operative temperature for which the environment is perceived as reasonably comfortable depends on the mean monthly outdoor air temperature. Acceptable comfort conditions are met when indoor operative temperatures are within the limits indicated in the Figure 2.4. There are two sets of operative temperature limits, one for 80% acceptability and one for 90% acceptability. The 80% acceptability limits are for typical applications. The 90% limits may be used when a higher standard of thermal comfort is desired (Butera, 2017). The graph tells us that in non air conditioned spaces comfort is achieved with temperatures higher than in air conditioned spaces. Concluding, thermal comfort is the main driver of energy consumption in buildings; the more uncomfortable is the space, the more energy is necessary to make it comfortable. For this reason the knowledge of thermal comfort principles is crucial for designing energy efficient buildings (Carlucci, 2013).

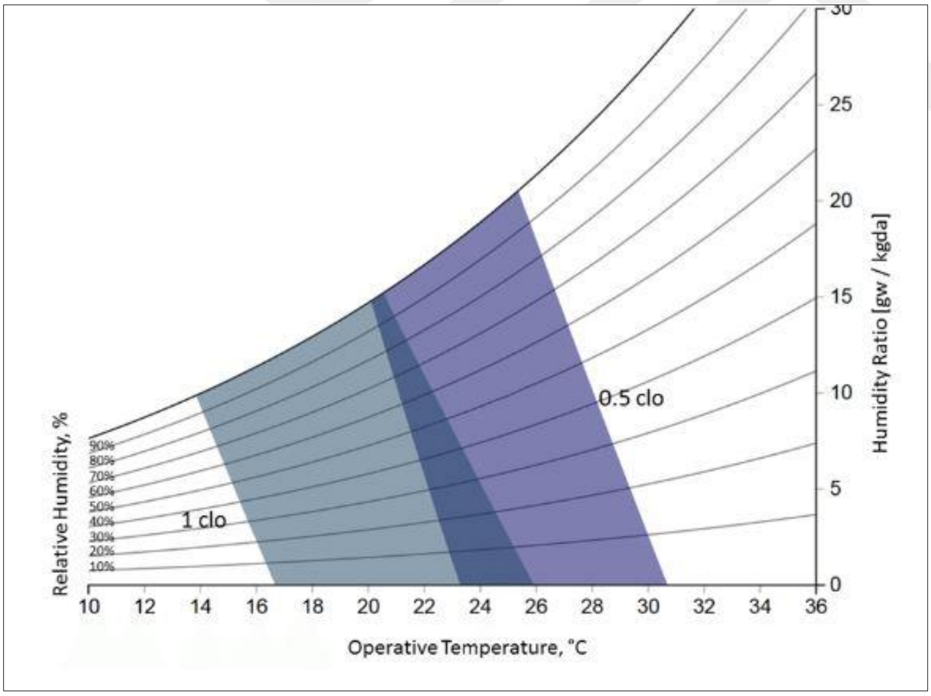


Figure 2.4. Acceptable domain of operative temperature and humidity rate based on ASHRAE Standard 55. (Kontes, Giannakis, Horn, Steiger and Rovas, 2017)

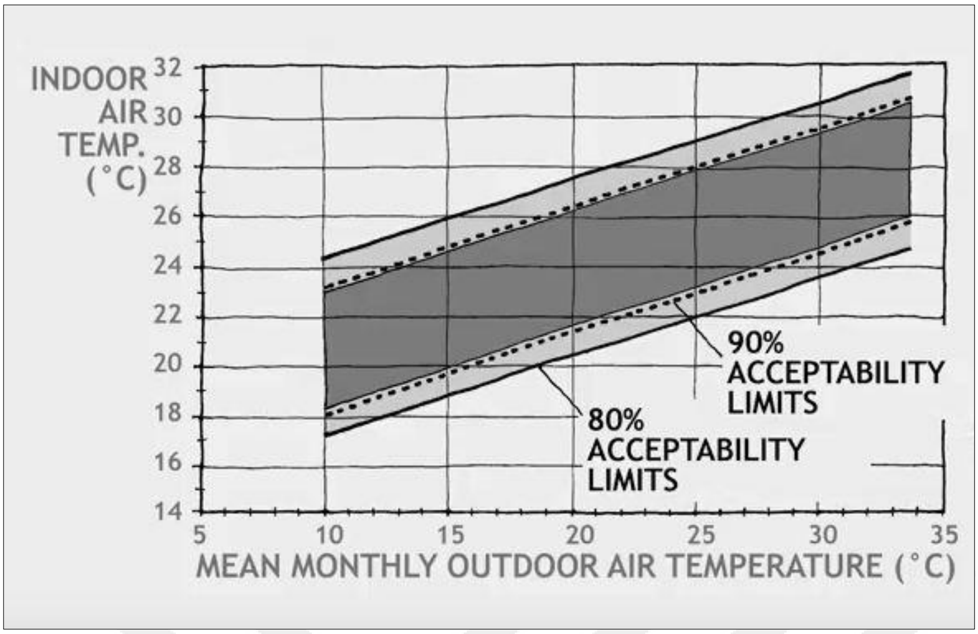


Figure 2.5. The values of operative temperature and thermal comfort in air-conditioned space (Butera, 2017)

In summary, observations made by many researchers (Rijal, 2014; Sekhar and Goh, 2011; Attia and Carlucci, 2015) concentrating on hot arid climate indicate that the subject of thermal comfort standards in modern buildings, designs becomes less questionable since the residents used mechanical air conditioning as a ventilation mode to achieve their thermal comfort. However, most of these modern building envelope has a poor resistance to the local climate and still unimproved with the basic standards of low heating and cooling design requirements. Therefore, the above-mentioned authors state that thermal comfort requirements in an air conditioning building could be enhanced by using passive cooling approaches and enhancing natural ventilation air movement rates when the outdoor air temperature is low enough to remove interior spaces heat from the building especially during a night in the summer season (Sekhar and Goh, 2011).

2.4. Vernacular Architecture

The pioneer's books in the filed research of vernacular architecture like Amos Rapoport, Hassan Fathy and Paul Oliver are examined and studied in details. The encyclopedia documents by the pioneer of vernacular architecture (Encyclopedia of Vernacular Architecture of the world) which consider as a global architectural research is conederd as a worthy and great source.It was done in the last 3 decades present over approximately

2500 pages in 3 volumes. Many great books are reviewed during this research study through focusing on the link between vernacular architecture and its response to local climate requirements.Among those books (architecture without architects) by bernard rudofsky define the architectural history and art as a universal phenomenon.He introduces the architecture as continuing activity done by people spontaneously by present the basic and simple architecture solutions for the inhabitants to live comfortably with their surrounding environment. He recognized the beauty of the vernacular architecture throughout its primitive environmental friendly features such as low-energy techniques to provide for the human thermal comfort, other approaches that are totally integrated to the building form, building orientation, and building materials that are obtained from local resources. Vernacular is strongly tied to cultural and social traditions. It responds to ambient environmental conditions, and it is, in a way, a naturally evolving process. It comprises all buildings, not just dwellings and relates to environmental contexts and available resources. It is built to meet specific needs, while accommodating the values, economies, and ways of life of the cultures that produce them (Oliver, 1998). Vernacular architecture is adapted to specific social and cultural contexts. The built spaces are not arbitrary; they are the expression of a reality slowly elaborated during centuries, executed with local techniques and means, expressing precise functions and satisfying social, cultural and economic needs. Vernacular buildings are the response to the climate and express the relationship between culture, nature, material, and climate. Each community over the years develops a prototype that responds to local needs and carries it forward through generations . The vernacular constructions express the physical form of values that the tribal, peasant and popular cultures have coded in the different types of dwellings (Oliver, 1998). Vernacular architecture buildings can be described as building constructed in unpretentious construction techniques, fully combined to local climate conditions, using locally available building materials, responding to local social and traditions conditions of the region.

Amos Rapoport (1969) presents vernacular architecture as a society custom that is a (direct and unself-cognizant) interpretation into the physical type of a culture, its need, and qualities and also the wants, and interests of the general population. From the earliest starting point, Houses have been guided by the climate of the area. Vernacular arrangements demonstrate an assortment of designs identified with the conditions that encompass it, reacting to the nature, culture, representative translations and meaning of comfort around there (Rapoport, 1969). In addition, vernacular architecture is a human build that outcomes from the interrelations between natural, monetary, material, and social components (Asquith and Vellinga, 2006). Through history, numerous vernacular techniques and materials formed by the neighborhood culture, climate and land area were utilized far and wide. Moreover, a significant number of these techniques and materials have been used in different areas with various climatic conditions and social foundations. For instance, adobe construction (mud or clay) has been utilized as the principle construction material for thousands of years for the construction of buildings in most occupied districts everywhere throughout the world (Asquith and Vellinga, 2006). In addition, a few cases of present-day buildings worked from adobe construction can be found in numerous nations that have different climatic conditions. Also, numerous vernacular techniques like courtyards and wind towers (catchers) were connected in present-day buildings for passive designs (Asquith and Vellinga, 2006). However, there are some vernacular techniques that have been developed for hot desert climates to seek cooling and daylighting. Asquith and Vellinga, (2006) determines these techniques as courtyards, wind towers, badgers, domes, air vents, planting, cooling towers, roof ponds, water walls, solar chimneys, induction vents and mashrabiya (Asquith and Vellinga, 2006). Because of the specification of the vernacular architectural buildings such as constructions techniques of thermal mass walls and local building materials, therefore, it considered as a low energy building.

2.4.1. Low energy strategies of vernacular architecture

Currently, energy conservation has been an interesting area of academic research. There are many reasons behind the increase of energy demands such as the rapid growth in economic, population increase, new needed network of transportation, advanced technologies devices and new high-quality standard of life.Consequently, these mentioned factors could influence human life and environment which leads to caused non-renewable energy depletion. Architecture, engineering, construction development companies, and academic researchers start to search about low energy technique which can decrease the problems of non-renewable energy consumption. One of the important techniques of low energy building design is to look out for our traditional building which acts as an environment-friendly and provided human comfort in many aspects such as the environment, social and economic requirements. In order to reduce the negative influence on the environment and humanity low energy building design needed to investigate and applied in modern built environment instantly. Most of the academic research and experimental research has been done by investigating the link between vernacular architecture and low energy techniques and most of this research concluded with the same results. They conclude that the vernacular architecture in many different climate regions is an ecological system because of the self-adaptive to the local environment and its harmony with nature. In the 21st century rises a unique landmark of architecture trends interest: recuperation of old shrewdness exemplified in vernacular architecture designs, which needn't facilities or technology or innovation to appreciate comfortable indoor temperatures, and consequently, they were sustainable. "One of the advantages of vernacular architecture is that it can guarantee a steady and agreeable indoor condition against harsh climatic conditions (El-Shorbagy, 2016).

Low Energy Building, Zero Energy Building, and energy-efficient building are nowadays very general terms you face in many thesis literatures and academic research articles. All those well-known titles have the same purposes which are minimizing the consumption of non-renewable energy sources in the building. Diminishing building energy utilization in new building construction or remodel can be refined through various means, including energy effectiveness retrofits, lessened cooling and heating loads and energy protection programs (Naboni and Edwards, 2014). Decreased energy utilization makes it less complex and more affordable to meet the building's energy needs with sustainable wellsprings of energy (Toguyeni et al, 2012). These concepts, in general, aim to meet the requirements of the occupants and reduce the energy consumption as well as limit the impact of energy use on the environment. To make a distinction between them some definitions can be presented (Radhi, 2008).

Energy-efficient buildings: those buildings strive towards the lowest possible energy requirements with the reasonable utilisation of resources through the use of efficiency measures. (Futcher et al., 2017).

Low energy buildings: those buildings use less energy than typical buildings by utilising low energy standards and technologies such as high level of insulation, energy efficient windows and low level of air-infiltration to lower heating and cooling energy. They may also use passive solar building design techniques and active solar technologies. (Futcher et al., 2017).

Zero energy buildings: the concept of zero energy buildings has been a progressive evolution from low energy buildings. Zero energy buildings (ZEB) are any residential or commercial buildings with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies (Toguyeni et al, 2012).

The concept of ZEB can be dealt with from a variety of views, depending on the project goals and the values of the building designer and owner. For instances, owners typically care about energy costs, so, it can be seen as zero cost energy buildings. Governments are concerned with national energy figures, and are typically interested in source energy, and therefore, it possible to say zero source energy buildings (Radhi, 2008). A building designer may be interested in site energy use for energy code requirements (zero site energy buildings), while those who are concerned about pollution from power plants and the burning of fossil fuels may be interested in reducing emissions (zero emissions energy buildings) . The view we deal with the ZEB can have a significant impact on the design and characteristics of zero energy buildings (Toguyeni et al, 2012).

2.4.2. Passive cooling in vernacular architecture

Passive cooling in vernacular buildings is a piece of the traditional technologies inside neighborhood natural environments to improve indoor atmosphere comfort. Albeit some of them are right now never again suitably working due to changed social and environmental circumstances, they are likewise underestimated and unused in new architecture developments (Foruzanmehr and Nicol, 2014). Furthermore, in Iraq where the experience of vernacular structures are not considered so as to help update the advancement procedure in modern residential territories, However, the passive cooling strategy can accomplish its ideal execution and potential advantage with a particular design framework. In such manner, the key test is to learn basic lessons and standards of vernacular design and to discover methods for coordinating those standards into advancement projects to design new settlements or to redesign existing ones (Santamouris and Kolokotsa, 2013).

Recently, research adopted scientific methods to analyses the effectiveness of traditional techniques. In this regard, qualitative studies were devoted to assess the aspects of passive cooling strategies, while the quantitative approach involved in-depth studies to evaluate the real performance of thermal environment under climate factors through field measurement. Taylor et al. (2009) applied qualitative studies to vernacular architecture in hot-dry climate of Oman. The study outcome illustrated that vernacular architecture of the region both culturally and climatically provides appropriate solutions for creating comfortable environments utilizing only natural and renewable forms of energy. Regarding the benefit of using the application of qualitative and quantitative studies, Foruzanmehr and Nicol, (2014) study naturally ventilated building in the city of Yazd, Iran where the climate is hot and dry. The studies pointed out the acceptability and applicability of traditional Iranian architectural technologies in a modern context as well as their effectiveness in reducing energy consumption and CO2 emission.

However in quantitative study, Meir and Roaf (2005) investigated different building technologies and materials, morphologies under different arid conditions typical of the Middle Eastern and Mediterranean climatic regions to provide resilient buildings for the 21st Century. The investigations carried out a number of methods and techniques, including monitoring, modelling, and numerical analysis. Interestingly, vernacular prototypes were built with high thermal mass, with very limited fenestration area, usually unglazed. These properties make them very inert in relation to ambient daily fluctuations. Therefore, the results presented that an extreme inertia is counter-productive due to the inability of such structures to take advantage of solar gains in winter and of night cooling by cross ventilation in summer, primarily, but only, due to their limited fenestration size. However, the construction technology adapted to the environmental constraints proved to be uncomfortably hot in summer and uncomfortably cold in winter, for most of the hours of the day. On the other hand, the thermal performance of such buildings proved to be better in highland and mountain regions rather than the lowlands and more humid coastal plains.

2.4.3. Climate responsiveness in vernacular architecture

Maria (2009) has completed an assessment of a sustainable Greek vernacular settlement and its scene which manages structural typology and building material science. Her examination was done on Sernikaki, a Greek vernacular settlement that can be envisioned as a living life form is the result of hundreds of years of enhancement of material utilize, construction procedures and climate contemplations. Her examination along these lines assesses particular vernacular staying composes and their reaction to climate, in light of inactive plan rules that could be adjusted to current compositional practice in the region, so as to upgrade the connection between site, building and climate. Dabaieh (2011) has made a hypothetical and practical investigation of Balat town in Egypt in her master thesis. To comprehend the significance of protection of desert vernacular architecture as a motivating quality for contemporary desert architecture, she discovered that vernacular architecture was dependably a result of a characteristic cycle of sustainable building convention. Individuals acquire the conventional method for working from their precursors and the information was exchanged and created from age to age along the years. Residents react to their encompassing condition and climate through experimentation in a way fulfilling their necessities and yearnings. This regular cycle is going to vanish because of the way that occupants are leaving their houses to break down or they destroy them to construct present day solid concrete houses.

Shokouhian and Soflaee (2011) have made a broad investigation into the natural cooling frameworks in the sustainable vernacular architecture of Iran which focuses on the aftereffects of sustainability caused by natural cooling frameworks in Iranian conventional architecture of hot-dry districts. They guarantee the learning of building biology centers around its ability to incorporate environmental and climatic parameters into a plan and in this way improves space characteristics, for example, agreeableness. Assist they clarify that there are different natural cooling frameworks in the vernacular architecture of Iran such as Hozkhaneh, Khishkhan, and Badger or wind catcher. The wind tower is a building component in the conventional architecture seen in hot dry and hot muggy climates. It makes accessible auditable natural ventilation which is known as a vital rule for preserving vitality. Conventional building systems are typically very much adjusted to the climate and we can utilize them with new innovation. By this examination, they reason that as indicated by a few elements it is conceivable to address Iranian conventional architecture. Iranian vernacular architecture delicates impact of climatic powers on framing of livable spaces and it clarifies climate was seen as an environmental constructional subject. It is certain significance utilization of sustainable and inexhaustible wellspring of vitality, for example, wind structure and type of building.

Manioglu and Yilmaz (2007) have made an exploration on energy proficient outline procedures in the hot dry zone of Turkey. Climate majorly affects the execution of the building and its energy utilization. Their examination depends on an understudy workshop, which has been done for a hot dry territory of Turkey. Further, the examination first means to demonstrate the likenesses and the distinctions of the traditional housing standards from the climate responsive outline perspective. Furthermore, it plans to advance the essential standards and their important changes in use that can be utilized as a part of the sustainable housing outlines without bounds. Moreover, plan systems in Mardin a town arranged in the hot-dry region of the south-eastern piece of Turkey, were inspected and present day and traditional houses were assessed regarding outline criteria, for example, choice of the zone, the separation between structures, building orientation, building envelope and building construction. Accordingly the examination brought about, an uncomplicated thermal assessment and comparison of a selected traditional house with a contemporary one which has been given by utilizing just information got from the estimations and this assessment has been done by means of the two estimations and surveys which are done for 100 houses.

Number of architecture element nowadays are also inspired by building traditions, since many experance people contributed that the local traditional forms have certified to be energy saving and "sustainable" pointed by local sources, topography, and environment
Khoshsima et al (2011) have made an investigation to examine the gaining's from the past by taking a contextual analysis of the traditional architecture of southern shores of Caspian Sea area in Iran. The examination asserts that climate has an essential part in the outline of structures. Today we are confronting some environmental issues, for example, a dangerous atmospheric devation, Ozone layer exhaustion and a deficiency of non-renewable energy sources which make it important to consider the impacts of climate on the building plan. Traditional architecture has dependably been a decent case of climatic outline and speaks to the strategies which our precursors have found to enhance their living conditions. Also, traditional architecture can be a wellspring of motivation in the contemporary building configuration to gain from it and endeavor to adjust present day structures with the natural condition quite far. Consequently this examination reasons that the traditional architecture of southern shores of Caspian Sea area in Iran is investigated to discover the part of climate in the development of the buildings.

Muhaisen (2006) has completed a basic examination on shading simulation of the courtyard frame in various climatic districts the investigation shows a displaying study did into the impact of rectangular courtyard extents on the shading and introduction conditions delivered on the interior envelope of the shape in four distinct areas. These areas are Cairo, Rome, Kuala Lumpur, and Stockholm. The investigation features the impact of the climatic conditions on the proposed courtyard proportions and statures to accomplish a sensible yearly execution in the inspected areas. Additionally, it illuminates the variety in the courtyard day by day shading and introduction exhibitions because of changing the area latitude and thusly the sun's situation in the sky. Further, the examination recommends rules and general guidelines for proficient courtyard plan in the thought about climatic areas. Besides, it expresses the reaches inside which the parameters of the frame can be changed with least deviation from the ideal execution.

The investigation finishes up with the outcomes demonstrating that the shading states of the courtyard inner envelope are altogether subject to the frame's extents, area latitude and accessible climatic conditions. In addition, an exploration in thermal conduct of brick work walls in Istanbul has done by Tavil (2004). This examination depends on thermal execution investigation and assessment of brick work divider setups as for thermal comfort and energy protection with the software DOE- 2. The investigation contains the correlation of the yearly heating and cooling loads of the masonry wall options of the example building. Also, the outside and inside surface temperatures of the wall options are processed for evaluating dynamic temperature impacts on their thermal conduct both in heating and cooling seasons under the climatic conditions in Istanbul having a temperate damp atmosphere.

2.4.4. Mashrabiya as a vernacular cooling techniques

Vernacular architecture throughout the world is interestingly widespread with pioneer design methods reflected in traditional dwellings utilizing it to keep safe from the harsh weather conditions affecting them (Fathy, Shearer and Sultan, 1995). A great number of the vernacular architecture methods and techniques are nowadays rediscovered and implemented into the modern context of architecture. This work is focused on the traditional shading elements known as Mashrabiya. Mashrabiya is a flat box used as a shading element in the vernacular architecture of hot climate zones such as Iraq, Syria, and

Egypt. It is a valuable vernacular technique due to several functions offered by it. For instance, due to the lattice openings on its surfaces, passage of outdoor air and natural light occurs through these openings, which helps to reduce the indoor high temperature as well as controlling the natural light at the same time. Another very important function which was essential in the past is privacy. The architect Hassan Fathy in his book, Natural Energy, and Vernacular Architecture explains how several models of Mashrabiya were developed to satisfy a set of functions (Fathy, Shearer and Sultan, 1995). The concept of using this element in the energy modeling of this work is to provide shading. Shading is one of the most effective and essential steps to provide natural cooling by preventing overheating generated by solar radiation. It is strongly believed that the starting point for reducing overheating, and as a result reducing energy demands for cooling in hot climate zones is by shading the building.

The last decades have witnessed considerable changes on architectural context and style. For instance, applying sustainability principles in housing building design in Arab cities is considered one of the new architectural trends in the region (Abdelsalam and Rihan, 2013). An obvious and great example of implementing the vernacular architecture principles in the region is the Masdar City in UAE, where vernacular architecture elements are used as a passive cooling technique and it is considered the first energy sustainable city in Middle East (Ibrahim, 2016).

2.4.5. Thermal insulation and energy saving potentials

Great amounts of energy are consumed by air conditioning units due to un-insulated buildings envelop which allows heat transmission through it. Therefore, preventing heat transmission through building envelope by adding a thermal insulation layer is considered among the most effective energy saving methods. Many scholars have studied the issue of energy conservation and thermal insulation of the building envelope (Macias et al, 2009; Ozel, 2014; Zhang et al, 2017). All of them have come to the fact that, building envelope components are one of the most effective design variables for energy conservation. Considerable studies have been undertaken for evaluation of energy behavior depending on wall and roof thermal insulation position. A study was carried out by Ozel (2014) in Turkey to investigate the optimum location of the insulation material in three wall sections. Depending on the characteristics of the heat storage capability (time lag and the decrement factor) in the building structure element, the author concludes that the worst insulation was observed when there was a minimum time lag and maximum decrement factor, while the best insulation was on the opposite case (Macias et al, 2009). Another work by Zhang et al. (2017), tested the air-conditioning operating system behavior of buildings to assess the influence of the insulation layer applied on the external wall on energy consumption. The results of that study showed that the air-conditioning intermittent operation "on-off" control can get the great energy-saving rate . Al-Sanea and Zedan (2011) investigated the influence of thermal insulation layer’s position and thickness on 8 different wall sections with on-off operation behavior of air conditioning. The study recommended placing thermal insulation layer on the inner face of the wall if the AC operation system is switched on and off intermittently.

Additionally, Al-Sanea, (2002) investigated and compared the thermal performance of six roof structures typically used in the construction of Suadi Arabia’s buildings. The results demonstrated that adding a thermal insulation layer to the inside layer of the roof section offers little advantage on the heat-transfer load as compared to un-insulated roof case . Friess et al (2012) examined the influence of thermal bridging on six wall structures composition effects on the building's energy consumption by using DesignBuilder hourly simulation modeling in a single-family house in Dubai. Their simulations showed that designing with appropriate external wall insulation could save up to 30% energy . Numerous other researchers have studied vernacular architecture and its link with thermal comfort, passive solar design, low energy techniques and energy efficient features (Al-Sanea and Zedan, 2011; Fang et al, 2014; Al-Sanea, 2002; Bojićand Yik, 2005). However, as this work aims to reduce cooling energy consumption in residential buildings located in a hot climate zone, it is important to limit the amount of heat transportation through the building envelope. In Iraq, the flat roof is considered as the most exposed building envelope component to the impact of solar radiation, therefore it is the most challenging envelope components to protect from solar heating.

3. RESEARCH FIELD STUDY: ERBIL CITY/IRAQ

The architectural analysis of historical sites, in its environmental and physical aspects, is the method chosen to describe the elements and parts of vernacular architectural heritages. Archaeological site analysis is the necessary starting investigation tool to defining the characteristic of Erbil vernacular architecture in its historical context.

This chapter discussed the vernacular architecture through architectural heritage and architectural elements of the traditional housing building of Erbil city. Research in vernacular Architecture in Erbil city definitely requires an accurate and deep study of the building and urban fabric of Erbil citadel which is considered the center of the historical and cultural of Erbil city. Also this chapter gives an overview of the Erbil citadel houses and strategies of vernacular architecture used in traditional houses by clarify the features of the architecture elements and its precise interaction with the environmental circumstances such as natural ventilation and natural light.

3.1. Necessity of Passive Cooling Design in Erbil City

Modern societies depend on the Earth’s resources at an increasingly rapid pace to satisfy certain needs and their high-quality living standards. With the present global climate change and related environmental pollution by carbon outflows, the utilization of energy from petroleum derivatives turns into a primary concern. Building developer, engineers, and researcher start to search for solutions to reduce energy consumption in buildings whereas building in hot climate regions consume a huge amount of electric power for cooling the buildings. To simply lower the demand and use less energy for cooling many researchers supposed passive cooling methods as a fundamental approach towards energy-saving in buildings located in hot climate zones. The sun is an essential source warming down the building envelope which assimilates warm from daylight through the rooftop, walls and windows, therefore rising indoor temperatures to awkward levels. However, supplying air conditioning units can bring some thermal comfort. Although, introducing air conditioning unit and working it will convey extra expenses of costly bills. Additionally, regular air conditioners utilize refrigerants made of chlorine intensifies that are suspected givers to the exhaustion of the ozone layer and global warming. The current winning architecture trend towards a passive building configuration has turn into an all inclusive commitment where passive cooling keeps up an agreeable indoor temperature as a contrasting option to utilizing mechanical systems for diminishing energy loads. In hot dry climate of Erbil, a vernacular building configuration can be utilized as a beginning stage to acknowledge how the environmental burdens and climatic dangers impact the design components of the house and how the buildings can be positively responsive. However, in Erbil building regulators did not consider the climatic plan issue as conditions ought to take after as well as there is an absence of information between the specialist, planners, contractual workers and inhabitants to enhance indoor thermal performance. Thus, current architecture of individuals in Erbil has endured from building arrangements proposed by architects for whom the possibility of securing the environment is not a preference. Therefore, the key goal of this research is to consider the impact of climate on the building components and to distinguish passive cooling methodologies that can create agreeable indoor spaces to upgrade individuals' expectations for thermal comforts. In summery, the cooling energy demand of buildings increases significantly due to the unexpected rise in global temperatures that arise from the climate change, the growing internal heat loads in buildings and the inappropriateness of the building construction. This can be done by replacing air conditioning systems with alternative means. Passive cooling techniques adopted in buildings have become a major challenge nowadays as they comprise energy saving, pollution free and cost efficient solutions. These techniques consist of strategies integrated into building design that minimise the use of mechanical cooling of buildings while at the same time they maximise the potential use of passive measures; that is the use of natural sources such as sun, wind or earth to cool the buildings. Thus, overheating of buildings particularly during summer period can be avoided effectively. It is imperative that during the design stage of the building the most significant steps are achieved while adopting passive cooling techniques.

3.2. Analysis of Current Architecture in Erbil

In recent decades, Erbil has seen real interests in its foundation and in addition a large development in its business activities. Erbil is thought to be the financially most grounded and most organized city in Iraq, where the airport and the recently developed organizational structures and facilities existed. Moreover, the political and continues conflicts in the rest of Iraq have moved the trade locally and internationally to the north of Iraq zone, especially Erbil. Therefore, it becomes the most secure and safe city for residency and looking for an occupation in Iraq. In March 2008, the International Organization for Migration evaluated that 2.7 million Iraqis had been dislodged inside Iraq among the previous decade, and a large portion of these individuals moved to Erbil city in the north. This normally brings about urban expansion and increased the population. Contemporary architecture in Erbil city is described by a wide range of structural styles that are stranger or opposed to the locale. Local Architecture schools are affected by Western architecture. Qualities of the locale's climate, vernacular architecture, and social viewpoints have been overlooked by building developers and engineers. Contemporary architecture is not meeting the zone's social, ecological, basic people needs. For instance, the natural execution of contemporary architecture in Erbil is poor regarding reacting to the zone's environment, prompting the utilization of additional energy. Contemporary architecture has developed rapidly in light of the fact that vernacular architecture is seen to be old and undesirable. One evidence of this issue is the replacement of traditional brick with solid concrete blocks. Local architecture losses its identity, in light of the fact that they take components from various Western architectural styles. Along these lines, the contemporary architecture in Erbil has turned out to be conflicting with its heritage. Weak new building materials, for example, the solid concrete blocks that are considered not quite the same as locally utilized materials have overflowed the Erbil building materials market. As specified above, concrete has ended up being a standout amongst the most predominant materials in contemporary buildings, since it is exceedingly tough, simple to produce, and the pieces are bigger than brick, which quickens the development procedure. It is likewise regularly maintenance free. Concrete is gainful when utilized for building foundations and ground surface. However, it is adverse to energy proficiency when utilized as a part of roofs and walls, since they are presented to climatic components. The shortcomings in contemporary Erbil architecture mentioned above have caused disappointment with the present buildings. These shortcomings promoted the author to start this study, which focuses on enhancing the contemporary architectural shortcomings with passive cooling techniques and climate responsive vernacular methods.

3.2.1. Location, geographical, and climate of Erbil

<u>Location</u>

Erbil is a historical city, it is one of the earliest continuously occupied towns in the world, which is accepted to have been in existence for 7,000 years (HCECR, 2009). It is one of the largest cities in Iraq. Erbil has always been a central meeting point for different civilizations throughout history. Erbil is existing in the north of Mesopotamia used to be a trade centre and still is. it is considered the commercial center of Iraq and among the significant trade centers in the region.

Geography

Erbil is located in an almost plain area (a rich topography ranged from mountains in the north, plains in the south and plateaus in the middle) (see Figure 3.2) and has an average elevation of 426 meters above sea level (Aziz 2003). It lies between the latitude-longitude coordinates(36°11'33.25"N, 44°0'38.23"E) (Fadhil, 2011).

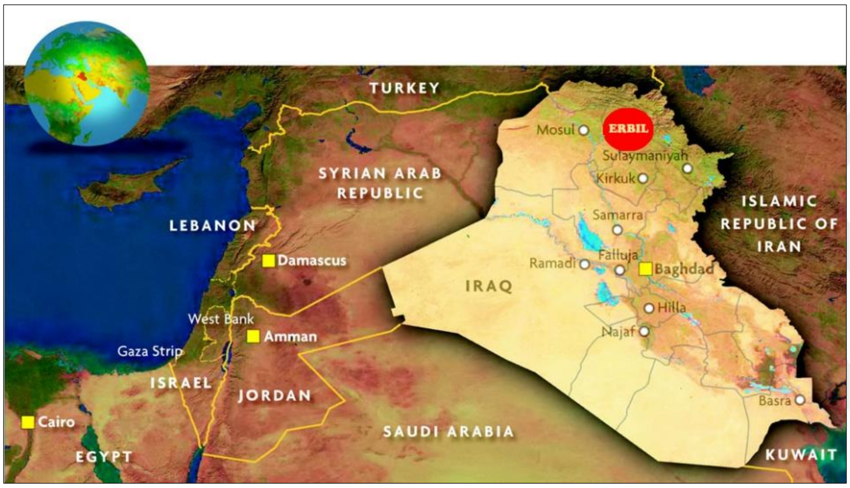


Figure 3.1. Iraq map showing the location of Erbil city in the norten part (Fadhil, 2011)

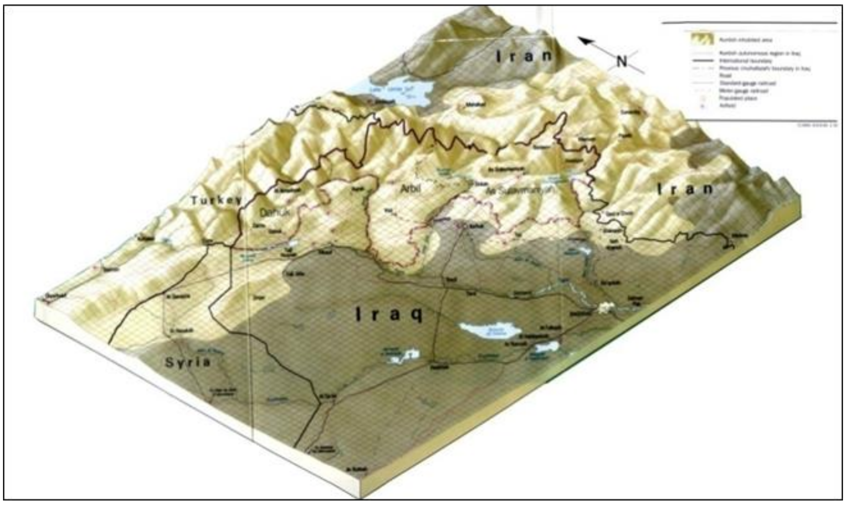


Figure 3.2. Physical geography of northern region of Iraq

Climate

The climate of Erbil city is described by extreme circumstances, including great temperature variations between night and day as well as between summer and winter. Summer is dry and hot, the temperature reaches about 45º in the daytime of July and August as the hottest months, while at night in the same months it comes down reaches less than 18° C (Aziz, 2003). Winter described as cold and wet, In December and January the coldest months the temperatures drop to below zero as can be seen in Figure 3. Autumn and Spring are short comparing with to winter and summer. The winters are rainy too, rains fall amongst November and April with a yearly normal precipitation of around 360 mm in the plateaus levels of the Erbil, the precipitation normal increments bit by bit toward the northern piece of the district and a normal precipitation in the mountains achieves in excess of 1100 mm with overwhelming snowfall (Aziz 2003). In northern mountainous regions, the low temperatures and snow stay until August (Fadhil, 2011). Hot Summer and cold Winter seasons last longer than gentle temperatures of Spring and Autumn. North breezes that blow from the north give help from the warmth in the peak of summer while south-eastern breezes blow amid the late-spring and winter months (Fadhil, 2011).

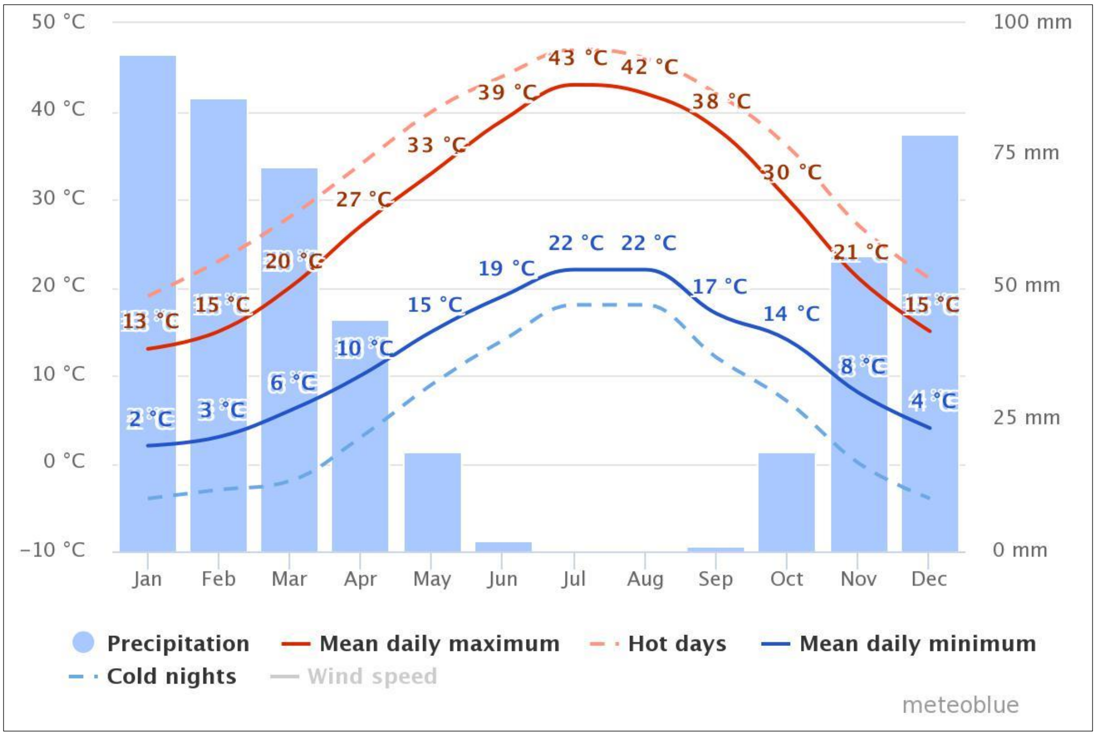


Figure 3.3. Climate graph showing the temperature average and precipitation of annual record (www.meteoblue.com)

MONTH	AVERAGE MAXIMUM TEMPERATURE (° C)	AVERAGE MINIMUM TEMPERATURE (° C)	AVERAGE SUN HOURS PER DAY	AVERAGE NUMBER OF DAYS PRECIPITATION PER MONTH	AVERAGE PRECIPITATION PER MONTH
January	12	2	5	14	💧💧💧
February	15	3	6	11	💧💧
March	19	7	7	10	💧
April	25	11	8	10	💧
May	32	21	14	1	
June	39	21	14	1	
July	43	25	14	1	
August	42	24	13	1	
September	38	19	11	1	
October	29	14	8	5	💧
November	21	8	6	7	💧💧
December	14	4	5	10	💧💧💧

Figure 3.4. Climate graph showing the difference between the driest and wettest months

3.2.2. Recent architecture studies in Erbil city

Firstly, the present study sought to improve the performance of the Residential Building to achieve occupant thermal comfort reducing cooling load during the summer season. The study used a field research study investigating the vernacular houses in Erbil city in step forward to extract the most effective passive cooling techniques to be used in modern context. On the other hand, the study focused on thermal dynamics simulation methodology to evaluate the proposed passive cooling techniques when implementing it in modern residential buildings. However, this section showing the recent architecture studies in Erbil City to find out whether there is a gap of knowledge or not in the topic of the present thesis.

Nooraddin (2012) in his research paper "architectural identity in an era of change" make an effort to achieve understanding about architectural heritage of Erbil city and other Iraqi cities as a great amount of neglected people cultures. This paper depends on contextual investigation and perceptions utilized an inductive strategy in searching for the advancement of the entire architectural identity circumstance of the two urban communities Baghdad and Erbil. The author comes to the following conclusion: Misusing local architectural identity can have negative consequences on the local society, culture, economy, and environment. Further, he states that even local architects attempts to obtain contemporary local Iraqi architectural identity had failed because they used only one cultural heritage as a reference for their designs and neglected the fact that Iraq is composed of many cultures. Chwas, (2014) discusses the subject of the urban morphology of Erbil city as an example of the traditional and fast-growing city. She addresses the urban morphology of Erbil city in different times since 1920. Through presents the transformation of the urban form of the city through the outline of local legislation which is assumed to follow procedures that satisfy a number of circumstances such as economic, political, social, environmental, cultural, climate, and technological advancement. An illustrative and interpretative approach is received as an intention to give a comprehension of how and why this procedure of progress has happened. The author inferred that the urban type of Erbil city has seen both sensational changes and moves in various periods. These progressions primarily corresponded to enactment factor in parallel to social, financial, and politic determinants more than four resulting periods.

Husein and Mahmood, (2015) studied the social factors that could be enhancing public interaction and communication in one of the gated residential communities in Erbil city. This paper investigated the spatial arrangement and form of a traditional neighborhood in Erbil city focusing on traditional Arab district and compares it with a designed modern one which known as Ashti city neighborhood. The result of comparing both communities showed that the model of planning in the traditional neighborhood supports more social communication among the residents of the same alley in comparison with the alleys of the modern neighborhood. In addition, open public spaces and green zones created in the modern neighborhood to allow social communication is kind of separated or eliminated from the low-cost housing group. Further, the state of being enclosed, especially in Erbil as a religious community is a lot higher for the traditional neighborhood alleys than in the modern neighborhood alleys.

Finally, the traditional neibouhood alleys allow more control of the area that gives the sense of security and safety and results in more confidence as it is also more relevant to human scale. The above mentioned previous studies showing that the energy efficiency in residential building, thermal comfort of building users in the hot summer of Erbil city have been neglected yet it is important in terms of many aspects such as environmental, social and economic aspects. Therefore the gap of knowledge in energy efficiency building motivated the author of this thesis to present this work in a step forward to fix this gap of knowledge and provide guidelines for local architecture in order to design low energy housing buildings in Erbil city.

3.2.3. Analysis of modern housing projects

The rapid increase in population due to the inner immigration of Iraqi people with the recent urban expansion, many new residential projects, housing complexes and apartment buildings are built and under construction. Designing these houses buildings without respect to the environment and local climate conditions creates many problems such as increased of non-renewable energy consumption which linked directly to worldly known global warming and climate change problems due to the increase of carbon footprint. Thus,the motive behind this doctoral research is to find a an architecture solution to achieve human thermal comfort and to reduce their dependence on non-renewable energy resources. Business, political, industry, trade and social developments in the north of Iraq region turned to a brand-new transformation affecting the quality of life in this region especially Erbil city.

There are several reasons for the increase in the population in Erbil in recent years, which caused the rapid urban growth and horizontal expansion of the city. One of the most important reasons that led to the increase in the population in northern Iraq and especially the province of Erbil is the people migration, whether from inside Iraq or from other neighboring countries such as Syria. Recently, the North of Iraq region has been presented to the extensive quantities of families coming to Erbil, searching for security. In addition, due to the economic growth people from the mid and south of Iraq comes to Erbil looking for jobs and investment. However, since 2003, Erbil has witnessed an industrial and economic improvement process that aims to encourage foreign investments to come and invest in Erbil.

Consequently, a great migration of local people from rural areas to urban centers has increased significantly looking for jobs and more advanced quality of life standards. For instance, in 1978, Erbil was placed to approximately 545,000 people; while; now it exceeds 1.7 millions of inhabitants (Abtar, 2014). Furthermore, Nooraddin (2012), state that the recent development and the prosperity that Erbil city, in particular, is experiencing, has led to high demand for better quality housing building from the growing local population and many families migrating from the other parts of Iraq. The total housing need in Erbil in the next five years is approximately 28,500 units plus 7000 units per year to accommodate the growing population. Whereas, the current supply of housing is around 4,000 units per year. It is obvious that the gap between supply and demand is very wide and requires immediate attention.

As economic improvement and prosperity of Erbil in general and after the local board of finance began to assign land for investment, a great number of residential projects started to construct. This development of construction activities heavily include large residential developments especially high standard residential gated communities for rich people as can be seen in Figure 3.5, and on the other hand, a poor quality standard residential projects for low-income people as can be seen in Figure 3.6. Both types of the mentioned house are suffering from improper design methods and poor quality construction technique.

Figure 3.5. High quality modern mix project (residential and business offices) known as empire world project

Figure 3.6. Poor quality residential project usually built for low income people

This new housing construction, which develops completely independent of the local culture, construction systems and local materials in Erbil, ignoring the local potential and the requirements of the community, has begun to bring increasing environmental problems with each passing day. Water pollution, air pollution, noise and micro-climate change have begun to be experienced in Erbil with this rapid urban growth. Due to the dense build-up, the concrete surfaces formed in the building shells, a large area of exposed asphalt streets and urban areas behave like thermal masses, so it is very important to create heat islands in the city which has high temperatures especially in summer and to increase the cooling load by changing the micro-climate negatively. In addition to the environmental dimensions, the problems caused by intensive housing construction that negatively affect other social and cultural dimensions. However, the major negative effects of modern housing projects in Erbil can be summarized as follows:

1. Local architecture identity loss : contemporary architecture in Erbil city is characterized by many different architectural styles that are a stranger to the region. Local architectural schools are influenced by Western architecture. see Figure 3.7.
2. Characteristics of the region’s climate, vernacular architecture, and social aspects have been ignored by builders.
3. Mostly, the decisions are taken in the design and construction of these houses based on the gain objective.

4. Contemporary Housing is poor in terms of responding to the area's climate, leading to the use of extra energy.
5. The modern houses in Erbil city mostly constructed from concrete blocks materials and reinforced concrete. Houses are built generally from thin un-insulated walls and reinforced concrete roofs.
6. The houses buildings are mainly dependent on air conditions systems to provide the thermal comfort level and that consume extreme amounts of cooling and heating energy.

Figure 3.7. Imported western architecture style housing projects in Erbil city, the houses have gabled roofs and do not have private fenced yards

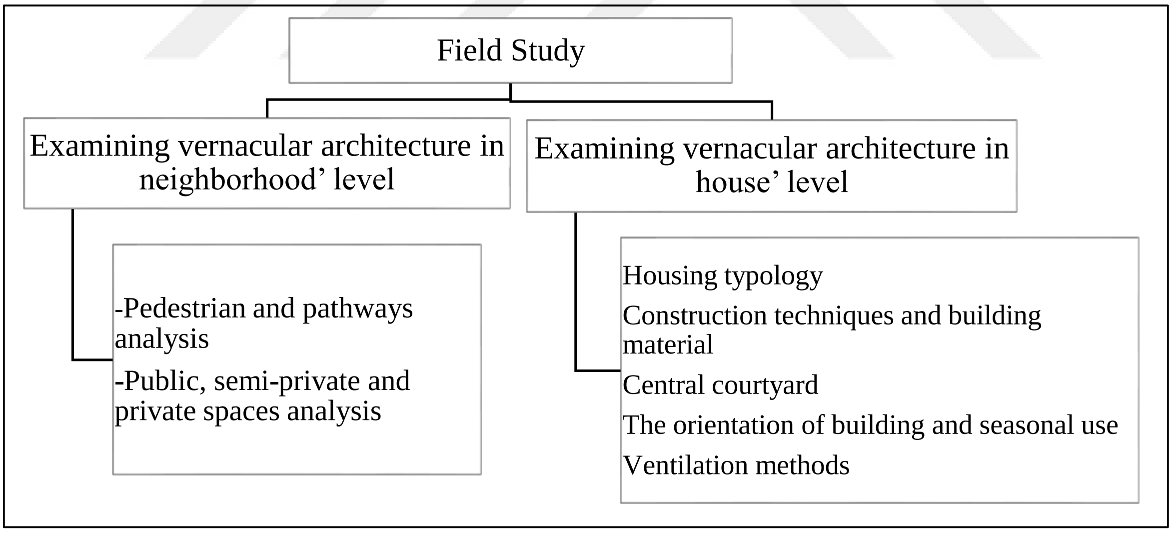
3.3. Vernacular Architecture Analysis: Erbil Citadel Case Study

The Erbil citadel in northern Iraq was chosen for several reasons. First, the citadel contains a original urban town, meaning the streets and alleys were built according to the natural features of the land. Also, the citadel contains both individual courtyard style houses and public buildings like mosques, cemeteries, and a public bath. Second, documentation and data have been made available for the citadel due to its outstanding historical value and the Erbil Citadel Revitalization project which originated by UNESCO in 2007 in partnership with the High Commission for Erbil Citadel Revitalization (HCECR). Types of data used in the analysis of vernacular architecture of the Erbil citadel include floor plans, cross-sections, elevations, photos, maps, site plans which came from the HCECR.

Analysis Method

1. The first step of analysis investigated the urban fabric in terms of streets and alleyways to check out the width, arrangement, and the access of the streets throughout the citadel. As well as analyses investigated the open public spaces and private spaces to explore how the neighborhoods are organized as a group of building.
2. The second step of analyses investigated the individual houses to identify and define a climatic responsive design strategies of vernacular houses in Erbil such as open courtyards, orientation of building and seasonal use, natural ventilation, construction method and building materials.

Table 3.1. Analysis method of the Erbil citadel in two differnt scale urban fabric and housing unite analysis



Case Study Overview: Erbil Citadel

Erbil Citadel is one of the world's most established consistently occupied urban destinations with unbroken occupation going back around 6000 years and through hundreds of years it was considered as a remarkable station on the antiquated "trade road" (Al-Jameel, Al-Yaqoobi ve Sulaiman, 2015). The Citadel takes up a zone of 10.2 hectares on a circular formed earthen hill of around 32 meters tallness over the city level, along these lines it turns into a notable milestone and is viewed as the Crown of Erbil. The Citadel settlement which comprises of traditional courtyard houses and some of the public buildings which are connected to each other through narrow alleyways surrounded with contiguous houses that generate its fortified look perimeter wall (Al-Jameel, Al-Yaqoobi ve Sulaiman, 2015).

Figure 3.8. Erbil citadel 1992, view from the air

The present name of "Erbil" is derived from the Assyrian word "Arba-Illu" meaning "Four Gods"(Al-Jameel, Al-Yaqoobi ve Sulaiman, 2015).

Figure 3.9. The old erbil known as al-Muzaffari (1638)

There was no change or any significant extent in the urban form and structure of Erbil citadel until the 18th Century. It was not changed until the arrival of the British occupation in Erbil in 1918 and later the foundation of the state of Iraq in 1921 that some measure of urban modernization started to take place. In 1913 the first modern vehicular road was opened in the lower town (Ibrahim, Mushatat and Abdelmonem, 2015).

Figure 3.10. Modern otomobil presencein Erbil city, in 1950 (Ibrahim, Mushatat and Abdelmonem, 2015)

Modern vehicular roads started to be cut through the lower town but the citadel town remained totally pedestrian until the 1950s (see Figure 3.10) . The citadel is located at the center of the Erbil city and is situated on an earthen mound made up of layers of past ruins (Ibrahim, Mushatat and Abdelmonem, 2015). It is visible to the rest of the city because it rises about 32 meters above it. The citadel was probably raised on an earthen mound for defense reasons. It has an elliptical form, with a long diameter of about 430 meters and a short diameter of 340 meters; its slope is around 45 degrees (Al-Jameel, Al-Yaqoobi and Sulaiman, 2015).

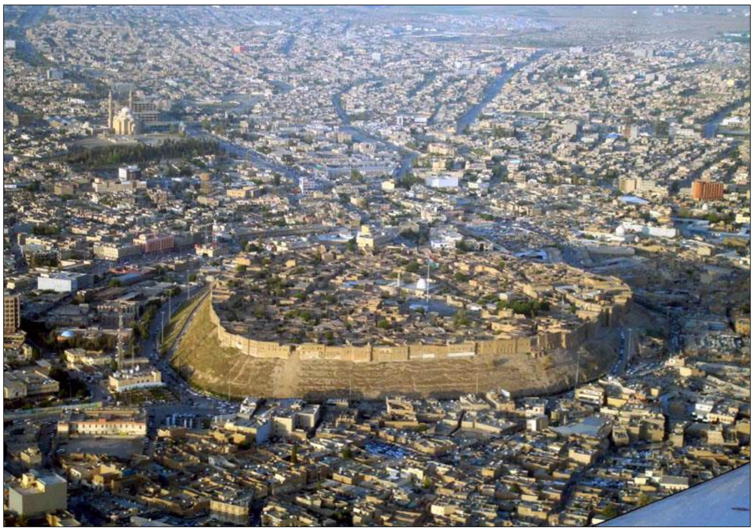


Figure 3.11. The citadel of Erbil and its surroundings town (Aloomary, 2014)

The citadel, which is about 102,000 square meters , consists of three district containing approximately 506 traditional courtyard houses (small house, large house, one-story house and two-story house) and few public facilities, such as public bath, mosques, seven historic graves, and two gates (Aloomary, 2014) . The three quarters, are the Saray neighborhood which consists of the eastern side of the citadel, including the southern gate and some large houses; the second quarter is known as Takya neighborhood, which located in the central and northern part of the citadel; and the last one is Topkhana neighborhood, which makes up the western side of the citadel (Aloomary, 2014). The main gate entrance is located on the south side of the citadel. The street network spreads from there till the residential dwellings . Narrow alleyways spread from the center major streets, which start at the southern gate (Bornberg, Arif and Jaimes, 2014). The first houses were built on the southeastern part of the citadel. They were made of fired brick and mud with wooden roofs. The houses consisted of one or two stories, and some of the houses had basements (Bornberg, Arif and Jaimes, 2014). The public bath, or hammam, dates back to 1775 and is considered to be the oldest structure in the citadel. Some houses were built in 1893, while there is evidence that others were built in 1903 (Aloomary, 2014). There are about 500 vacant houses in the citadel: 30 houses are large, about 120 houses are medium-sized, and the remaining 350 houses are the small houses formerly occupied by low income families. Most of the courtyard houses are formed in irregular geometric shapes, because the room arrangement was the decision of the usta, master mason (Aloomary, 2014).

The exterior walls of houses contained small openings located on the upper part of the wall to restricting visual access facing the outside to allow natural ventilation. The majore and the large opening windows in a house looked inside toward the courtyard. The ground floor rooms were accessed through steps rising from the courtyard. The distance between the two level floors was used for providing natural lighting and ventilating to the basements from the courtyard (Bornberg, Arif and Jaimes, 2014). The ground floor ceiling height was around 4 to 4.5 meters, Several materials such as wood, marble and baked bricks were used for building columns (Aloomary, 2014). The underground rooms were half buried spaces because of that it named semi-basements. Basement ceilings were vaulted, rising about 2.5 meters. The underground rooms was used as a storage. The main family service spaces, such as kitchens, bathrooms, and toilets, were usually located on the corner of the open courtyard (Bornberg, Arif and Jaimes, 2014). Erbil Citadel joined the United Nation Educational, Scientific, and Cultural Organization's (UNESCO) world legacy list in June 2014, and is one of the world's most established constantly possessed human settlements. From the primary many years of the twentieth century, it has seen constant crumbling because of vast number of impacting factors which have abandoned it weakened and out of date (Al-Jameel, Al-Yaqoobi and Sulaiman, 2015). With a specific end goal to preserve and upgrade this one of a kind notable Citadel, a revitalization venture was started. The "Protection and Rehabilitation Master Plan" was proposed as a noteworthy basic leadership apparatus for the High Commission for Erbil Citadel Revitalization (HCECR). The Master Plan embraces versatile re-use as the center methodology for a socially determined revitalization (Al-Jameel, Al-Yaqoobi and Sulaiman, 2015).

Figure 3.12. Conservation and rehabilitation project of erbil citadel by HECER ,2007

However, Erbil city has witnessed a significant development recently because of increased population and economy growth which lead to the rapid growth of urban. The final state of the city's growth process and master plan, which is rapidly growing around the citadel and its surroundings, is noted below in Figure 3.13.

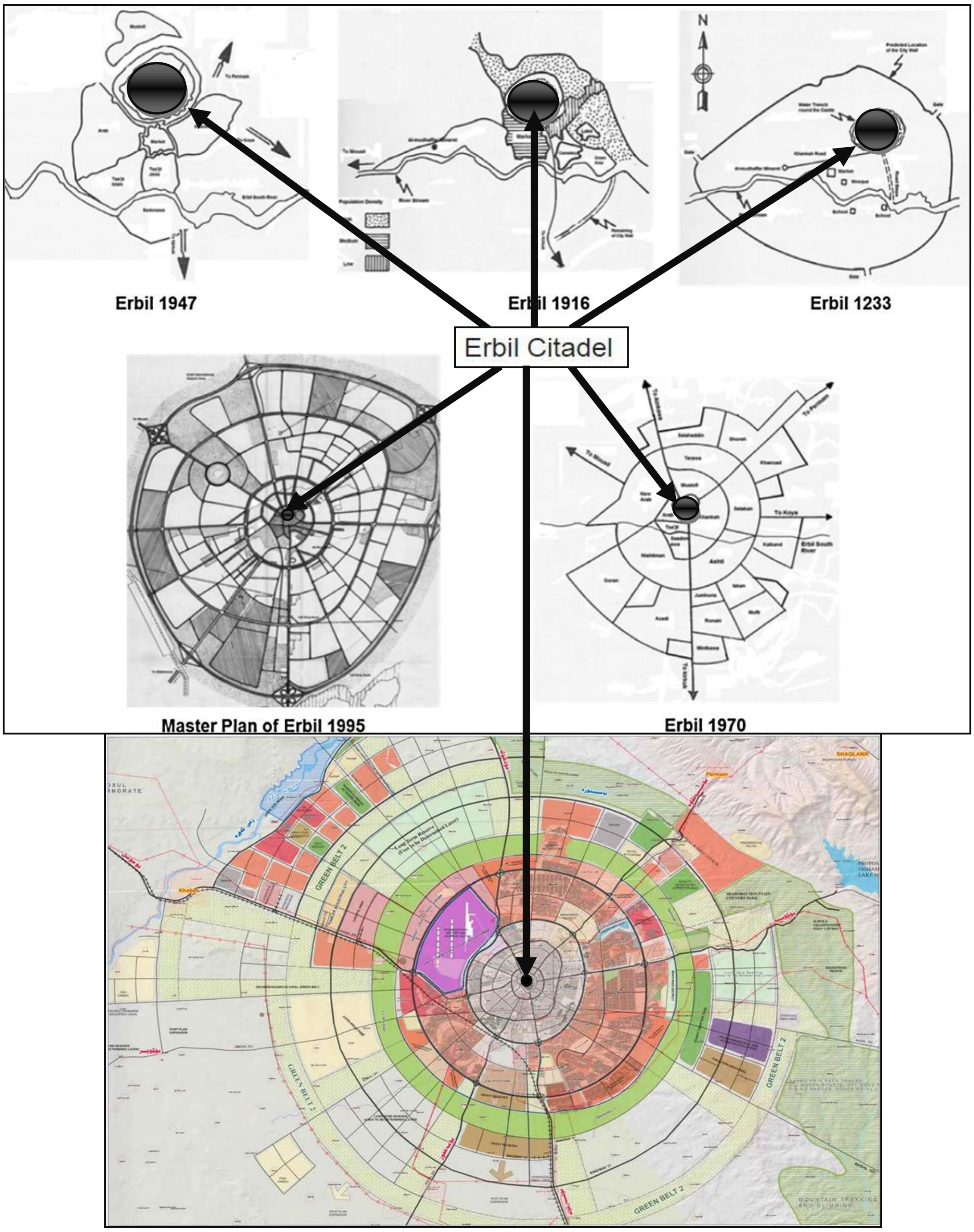


Figure 3.13. Master plan development of Erbil city (Dar-Al handasah, 2012)

3.2.1. Vernacular urban analysis

Historically, the citadel was divided into three traditional quarters; Saray**:** Occupied the Eastern side of the citadel, so-called because it included the administrative governmental offices, It was largely occupied by the rich and notables families and government officials houses (HCECR, 2014). Takya**:** Occupied the central and northern part of the citadel and so-called because it contained several takyas (buildings utilized for religious rituals). Topkhana**:** Occupied the western side and inhabited largely by craftsmen and farming families. Its name suggests that it contained cannon to defend the town against attackers (see Figure 3.14) (Ibrahim, Mushatat and Abdelmonem, 2015).

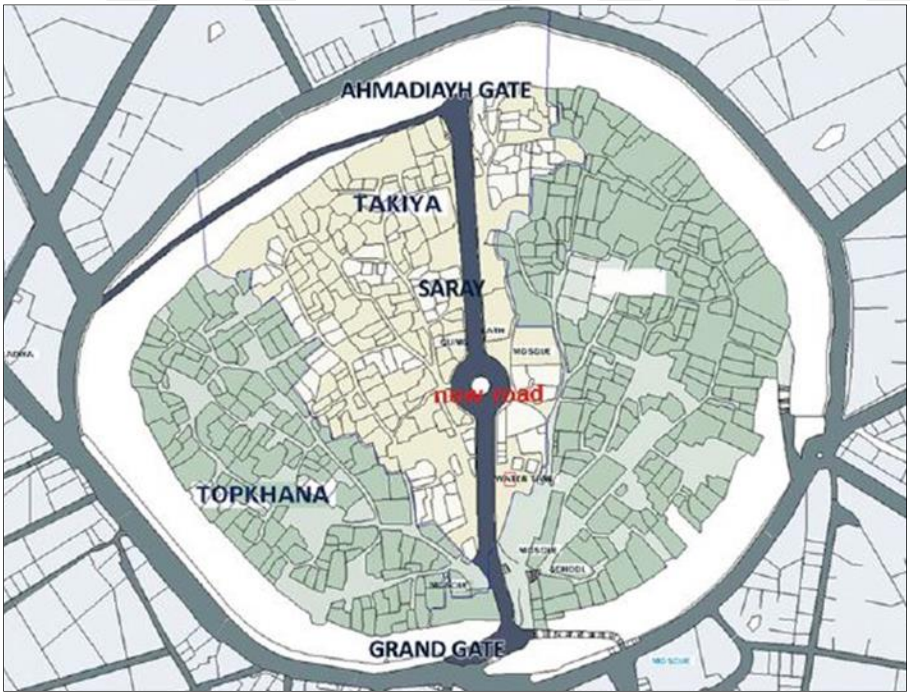


Figure 3.14. Erbil citadel three traditional quarters; Saray, Takya and Topkhana (Erbil Citadel Revitalization Project, 2014)

The perimeter wall of the citadel is considered one of the most impressive features which gives the citadel its fortified look and dominates the modern city of Erbil, the wall is a continuous ring of houses of various ages. These houses provided dramatic views of the town below and beyond (Ibrahim, Mushatat and Abdelmonem, 2015).

Figure 3.15. The perimeter wall of the Erbil citadel

Pedestrian and pathways analysis

The urban plan of the citadel in Figure 3.16 shows different widths of the alleys and pathways throughout the citadel. They are color-coded to easily differentiate according to their widths and separate between major and secondary ones. It also explores the organic form of the pathways and alleys since they follow the topography of the citadel. The southern gate is the main gate of the citadel because most of the main pathways begin from it and branch out into the other districts. The major pathways are approximately 6 to 18 meters wide. All main roads are linked to the main gate on one side, and to the narrower road on the other. The transportation and movements inside the citadel are carried out by animals such as camels and horses. This method of transportation does not require wide roads thus, the zigzagged and narrow paths are in perfect harmony with it. The semi-private spaces are linked to the narrower roads which are between 2 to 6 meters wide. These roads are limited to be used only by the people living in that group of houses in that particular zone. In addition, there are different alleys less than 2 meters wide surrounded by a small group of houses. As a result, there is a clear gradation of the space privacy in the urban layout of the citadel. These narrow pathways are considered to have a great environmental impact on the citadel's settlement. They are shaded by one or two- story houses from both sides during summer, making the air cooler during the hot season (Figure 3.17). Such shadowing also helps to reduce the intensity of light coming directly from the sun. Moreover, due to the zigzagged shape of the narrow paths and alleys, the wind direction always changes. In addition to the environmental benefits, another important aspect of these zigzagged pathways is the great privacy offered to the residents of the citadel.

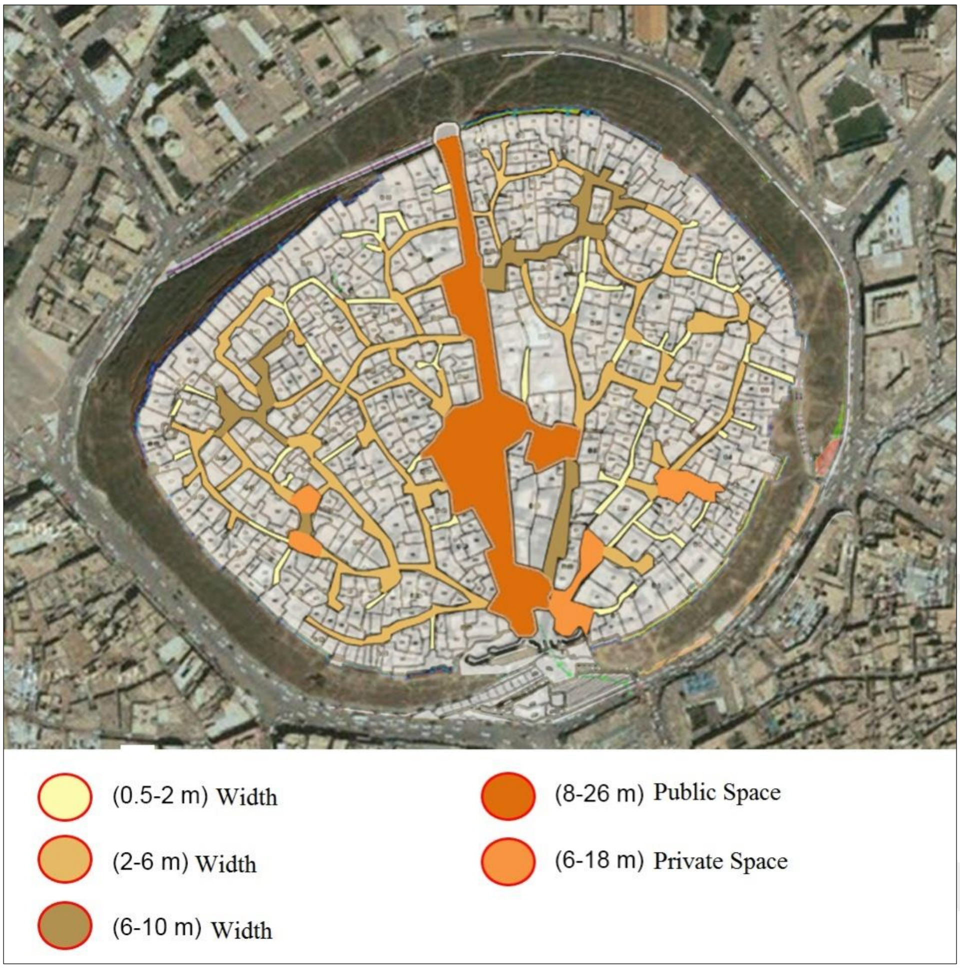
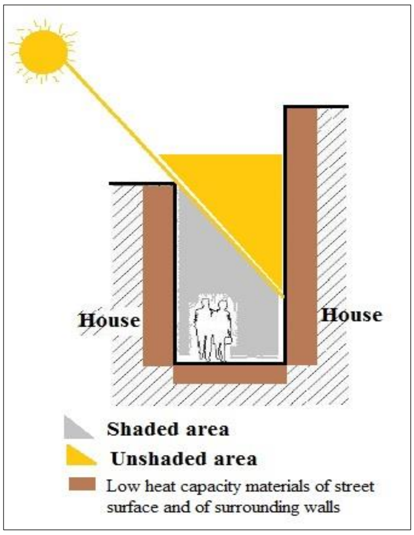


Figure 3.16. The urban plan of the Citadel shows the location and width of the streets, the public area, and the private area., details by author



(a)

(b)

Figure 3.17. (a) Shaded pathways with low heat capacity of surrounding surfaces, (b) real view

Public, semi-private and private spaces analysis

The second step of the investigation after the analyzing of the streets and alleys finished is carried out inside a selected area at the western side of the citadel to identify the public spaces, semi-private spaces and private spaces, to understand the citadel neighborhood arrangements. Figure 3.18 shows the selected part in the westward side of the citadel.

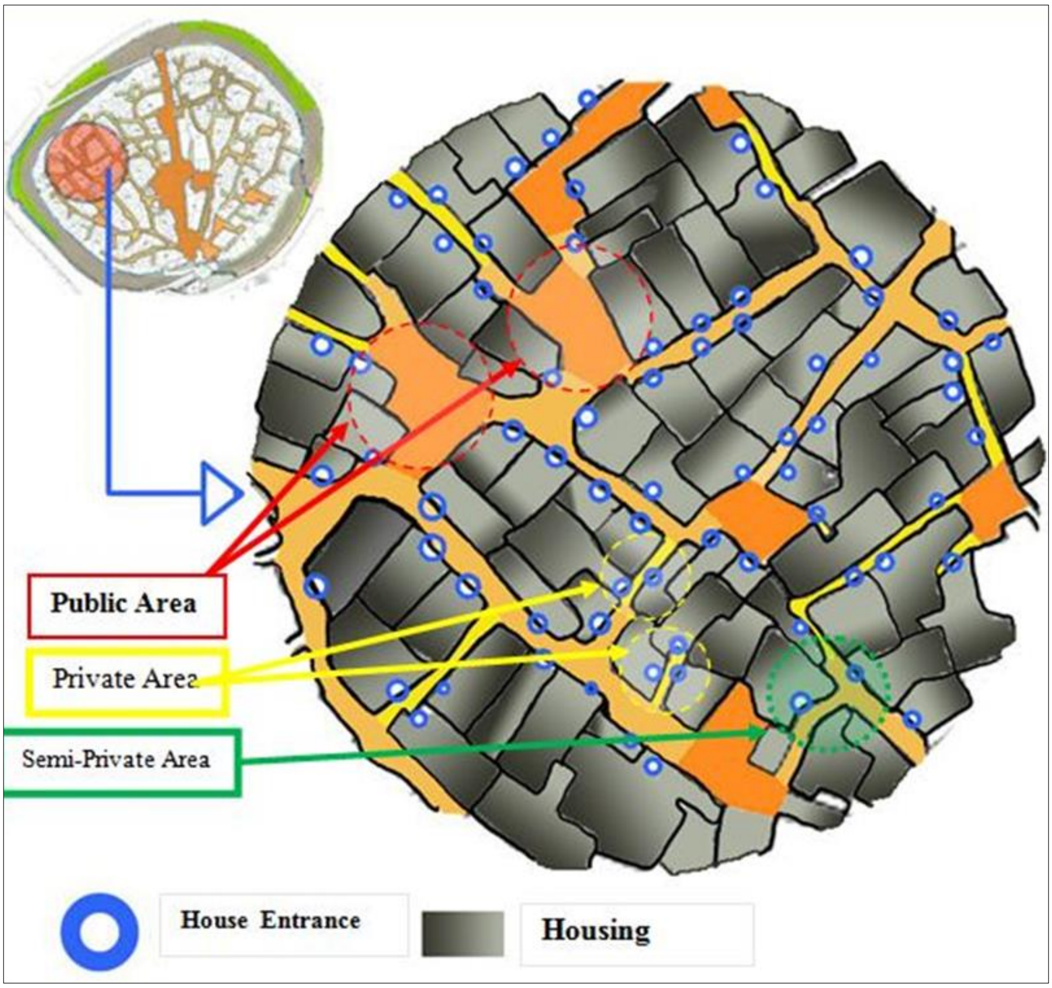


Figure 3.18. The western side of the citadel showing selected area for analyzing the public spaces, semi-private spaces, house entrances, and neighborhood arrangements, details by author

There is different size of open spaces which located in different areas. Corners and open spaces usually are created by a group of houses assembling or because of the zigzagged shape of the paths and the organic shape of the houses, which are used as semi-private spaces as shown in Figure 3.18. According to the analysis the houses entrance have different location which can be explain in the following three groups:

1. First Group: House entrances open toward the public areas.
2. Second Group: House entrance open toward the semi-private areas.
3. Third Group: House entrances open toward the private areas.

The following step is analysis the plan layout of the selected houses to clarify the level of connection between the house entrance and outdoor space (alleys and street). The analysis showed that there are different type of connection some are direct and others are indirect. The following analysis focused on the issue of the connection between the indoor and outdoor spaces to investigate the privacy, security and social interaction among the neighbors.

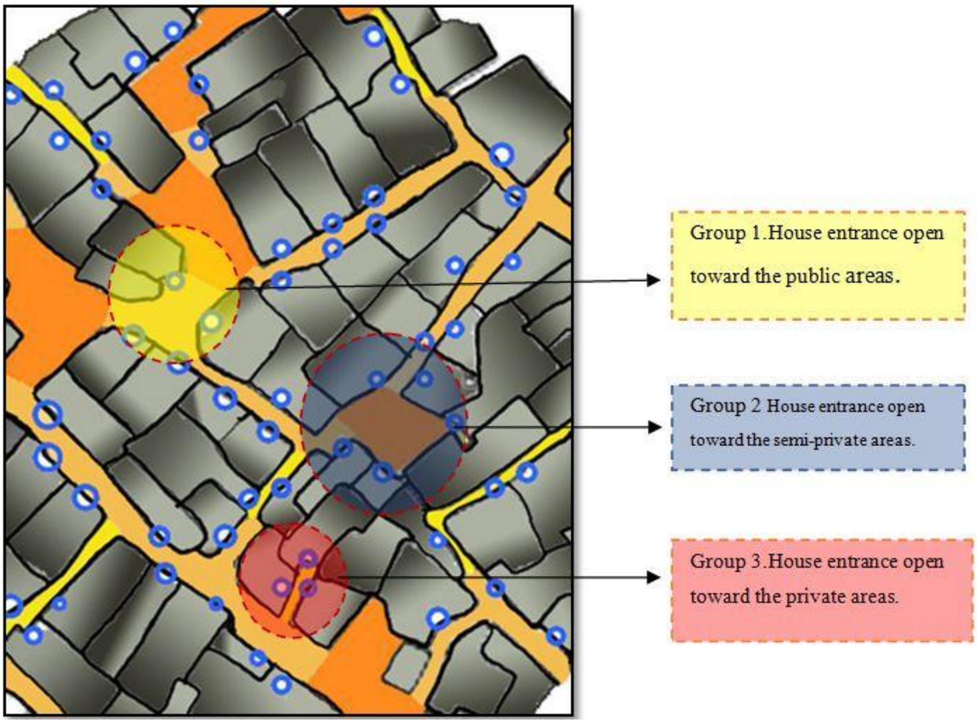


Figure 3.19. Three different location of house entrance, details by author

The following Figure 3.19 showed the indirect entrance shape which its characters can be summarized as

1. Limits visibility connection from the outdoor toward the house indoor space.
2. This type of connection protecting the family's privacy which is favorable factor socially , and it also helps block the speed of the wind which is favorable factor environmentally.

3. On the southern side of the house, there is no shared wall; instead, windows have outdoor city views. Other room windows have looked towards the courtyard.
4. The house's boundary, which is shaded yellow, shows the shared walls from three side between this house and the neighbors', this improve thermal insulation which is favorable factor environmentally.

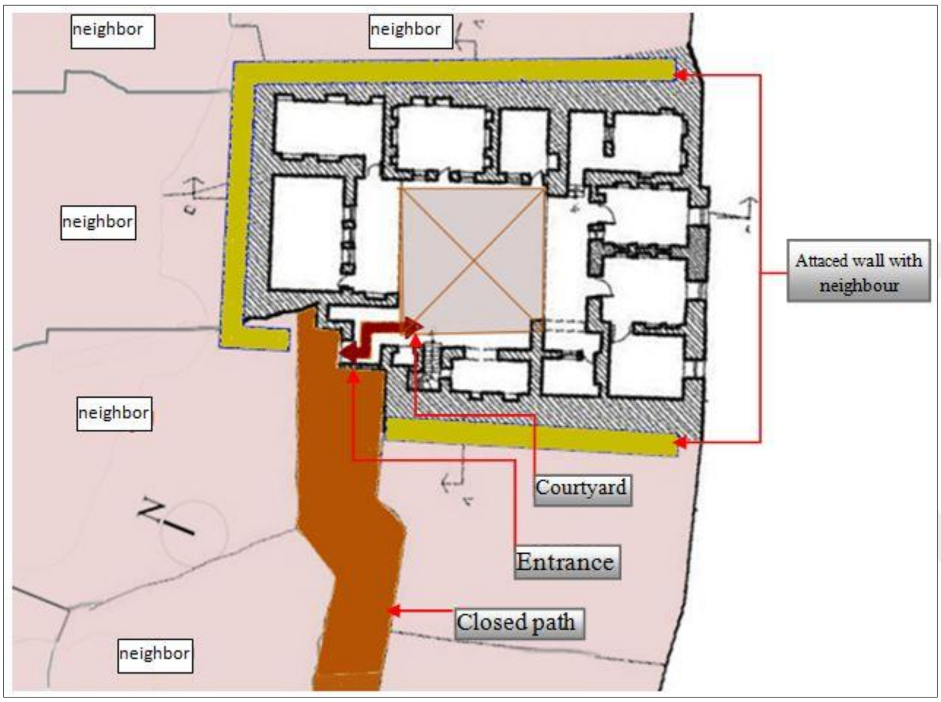


Figure 3.20. House plan showing the entrance's shape and ground floor house plan, details by author

The second selected vernacular house in Figure 3.20 differs from the first one,

1. The entrance leads directly into the house without prevent visual access from the outdoor space.
2. This type of connection does not work to protect the family's privacy which is considered as unfavorable factor socially
3. Guest room (green shaded) located in the entrance lobby of the house
4. Placing the guests in the isolated area (giriş lobisinde) provides privacy for the family.
5. The direct entrance does not helps block the speed of the wind which is unfavorable factor environmentally
6. The house's boundary, which is shaded yellow, shows the shared walls from three side between this house and the neighbors', this improve thermal insulation which is favorable factor environmentally.

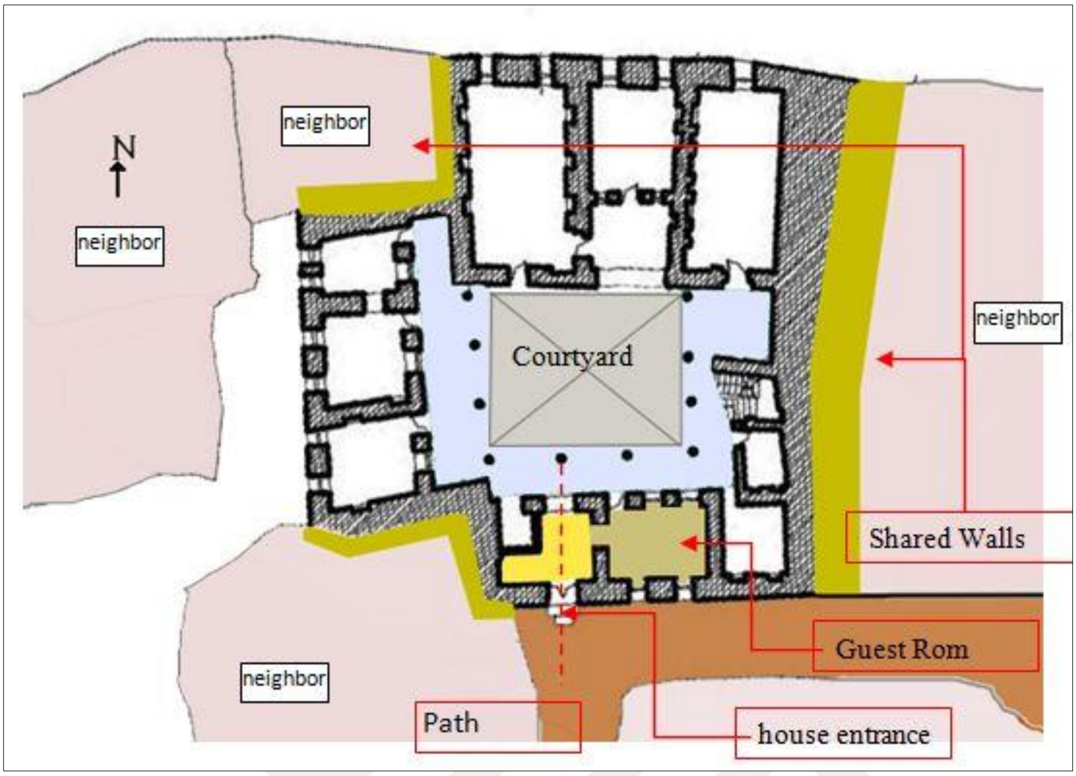


Figure 3.21. This house plan shows a direct entrance, adjacent guest area, details by author

As a result different type of entrances were used in the vernacular architecture houses of Erbil citadel due to the exaggerated isolation of guests and family inherent in the lifestyle at that time. The indirect entrance is the best strategy used in the vernacular architecture of Erbil citadel houses, because it is an efficient way to prevent visibility toward the family inner areas as well as it is an efficient way to block wind and dust. It can be clearly notice that the guest area is generally one room positioned at the reception front part of the house adjacent to the entrance. So, this placement is ideal, because it gives privacy to the family which is considered as favorable factor socially at that time. The second step of analysis (Open Public Spaces and Semi-Private Spaces Analysis) we can summarized the result as Public open spaces: They provide places for social gatherings in the level of small groups of houses and the neighborhood as well. The landscape areas, trees and plants in open spaces provide necessary shade in a hot, arid climate. However, house entrances should not open directly toward the public spaces to provide the residents' more privacy.

Semi-private spaces: They provide private areas for limited group of houses outside. These spaces help create the streets' zigzagged forms.

Private spaces: The grouping that forms the private space for 2-4 house is the better space as the privacy and security factors, because it gives limited access into the neighborhood, as well as maintains of the space will be under responsibility of the household. It also enhances the cultural practice of families living close by, sharing the same entrance space.

The urban layout of the Erbil citadel are comparable to other ancient towns in Iraq which are characterized by their narrow paths and organic urban fabric and open courtyard houses that resulted due to several circumstances, such as environmental, social, cultural and religious issues. All paths and alleyways start from the main south gate of the citadel which was the only gate at that time. The results of the analysis have shown that repetition, hierarchy, proportion and directionality are the vital principles in the layout of the old urban fabric of the citadel. However, the key point was in the directionality of paths which was towards the main gate of the citadel and not towards the main street or towards the public buildings such as the mosque like other ancient Islamic cities (Kirkuk, Mosul). This key point has an important influence on the part of the urban fabric form and neighborhood spaces distribution. In addition, the location of the public building such as the mosque and the bath was in the main central street (see Figure 3.21) which is the wider one start from the main south gate crossing to the other side.

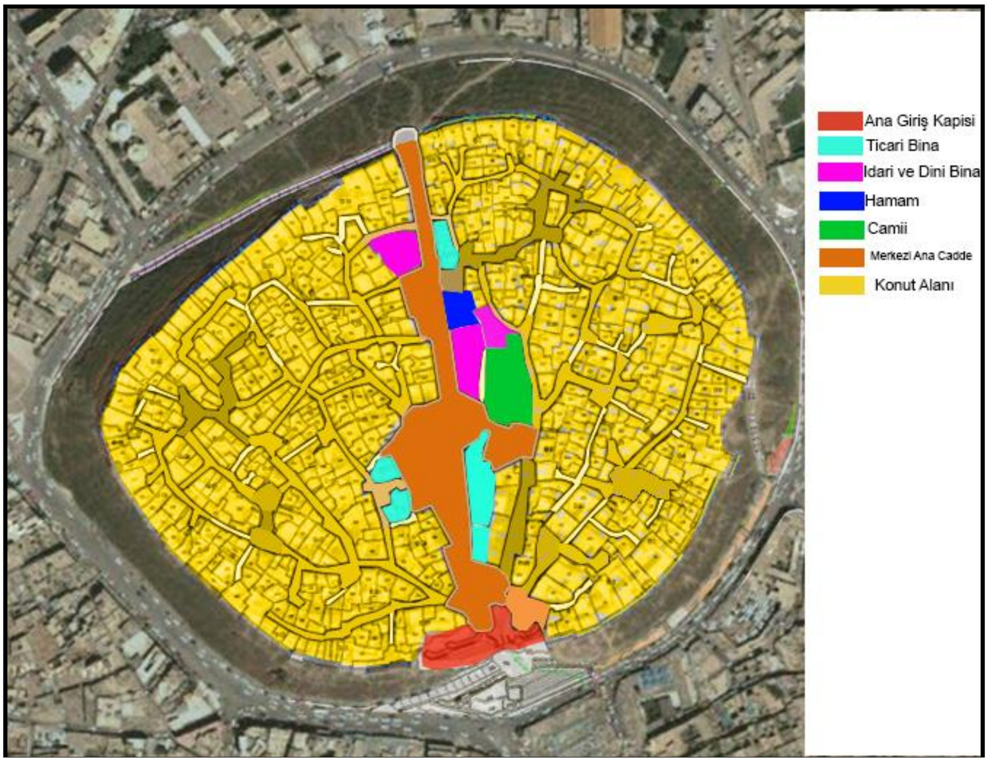


Figure 3.22. Erbil citadel land use map, details by author

The traditional urban neighborhood had a compact and mixed use pattern, as well as the different part of the open outdoor spaces (public, privte and semi-private), are well-connected through a network of pedestrian paths. The mix of these characteristics made the traditional urban fabric fruitful in accomplishing needs, for example, privacy, accommodations needs, security, social relations, and foremost responsive to local environment conditions.

3.2.2. Vernacular housing analysis

Housing plans and floors analysis

The following step of the analysis focuses on vernacular architecture individual house using the drawing plans, section, elevation and the architecture element details documents with permission from high commission of Erbil citadel revitalization. The selected traditional houses are analyzed under five categories; type of plan, construction techniques and building material, ventilation methods , building materials, and architectural elements.

Generally, the plans of the houses in Erbil citadel is limited with restrictions in the form of land. If the interface is broadly the courtyard placed with the long axis in the middle (if rectangular) perpendicular to the alley (see Figure 3.22). The plan is divided in such a case into two versions, the corridors are placed with several rooms on one of the sides another variation is to copy the plan to two houses are alike (twins), but with a single entry, which in turn is divided into two parts (UNESCO, 2013). Some plans of the houses take the form of the character L. Majority of the houses contains two floors only. Basement beneath the courtyard is located at a distance (1 to 1.5) meters and can be accessed on a five steps away or little more from the yard (UNESCO, 2013). The lower floors usually have vaulted ceilings based on the thick brick sidewalks (see Figure 3.18). Usually, ceilings on about 2.5-3 meters high and room windows are facing the open courtyard (see Figure 3.23).Some rooms cannot access them only by the central distance or central room, but the rooms in general can be accessed directly through “Tarma” (UNESCO, 2013).

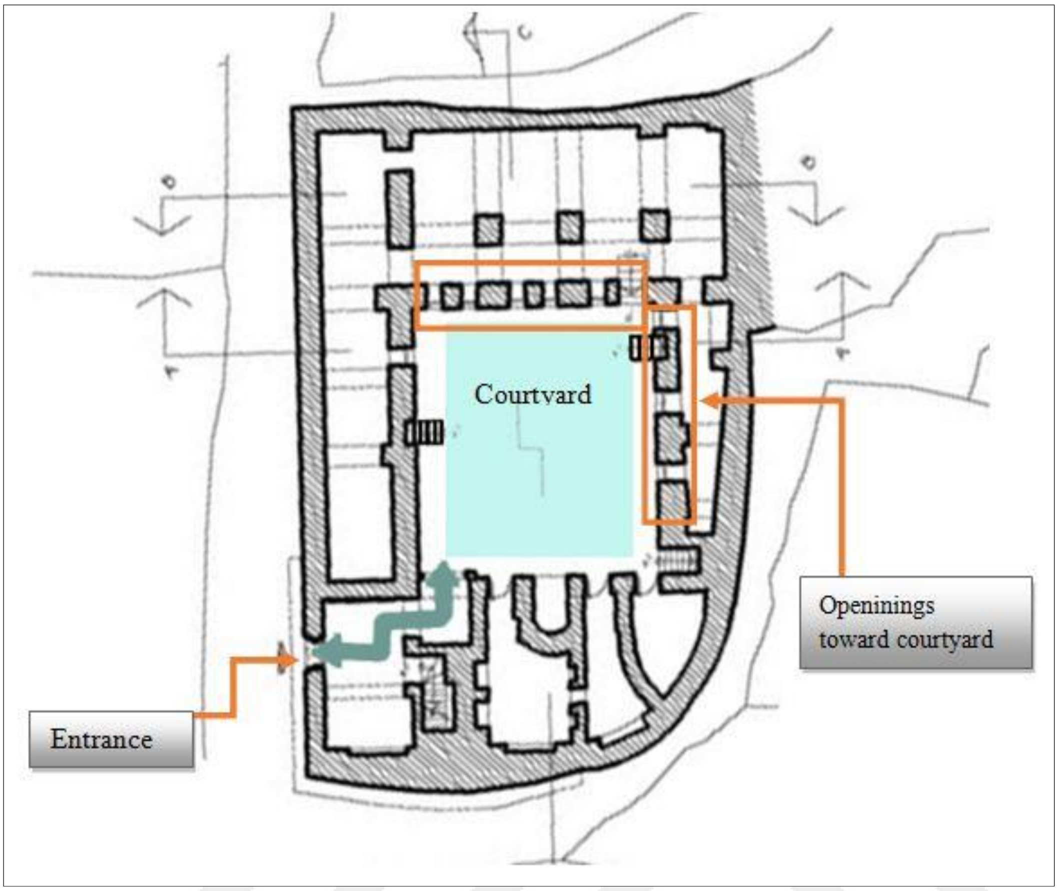


Figure 3.23. Selected house drawing by HECER in Erbil citadel (Fattah Chalabi house), ground floor plan, details by author

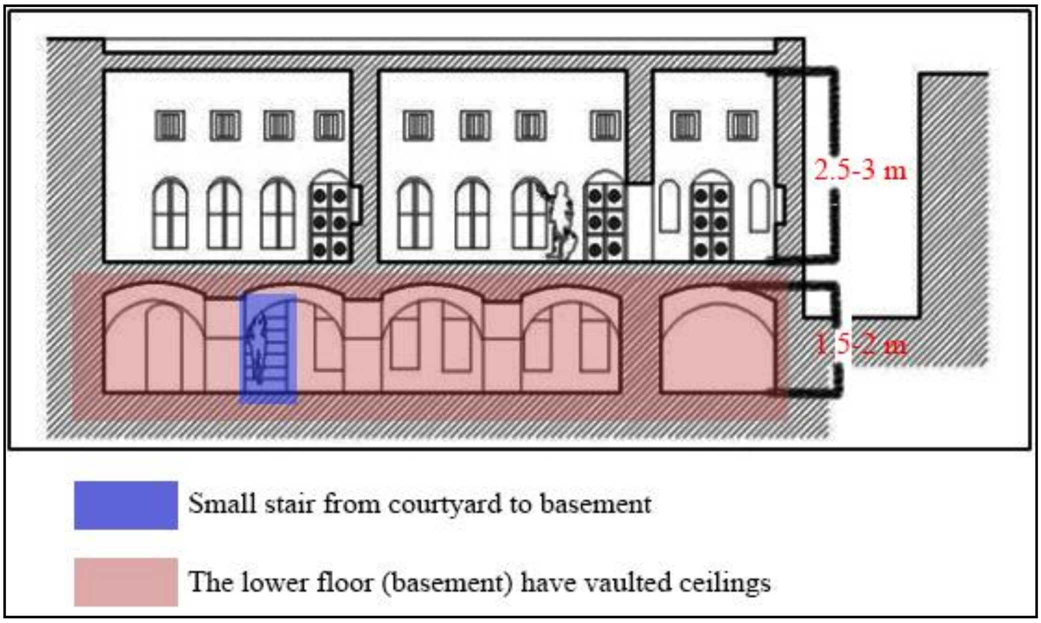


Figure 3.24. Selected house in Erbil citadel ,Sections B-B, details by author

Mostly, houses had a constructed patio or terrace with columns or with arches (Arcade) facing the open courtyard and serve as an in-between space to above level rooms. The terrace is reached straight by some steps from the open courtyard. The main family rooms of the house are located following the arcade or colonnade, which is located on both or one side of the courtyard. These main rooms, which are directly reached from the terrace, are generally outlined with their linear axis vertical to the terrace. These rooms took their natural ventilation and daylight by windows overlooking the terrace. In the situation of border houses, they further had openings overlooking the city below (UNESCO, 2013).

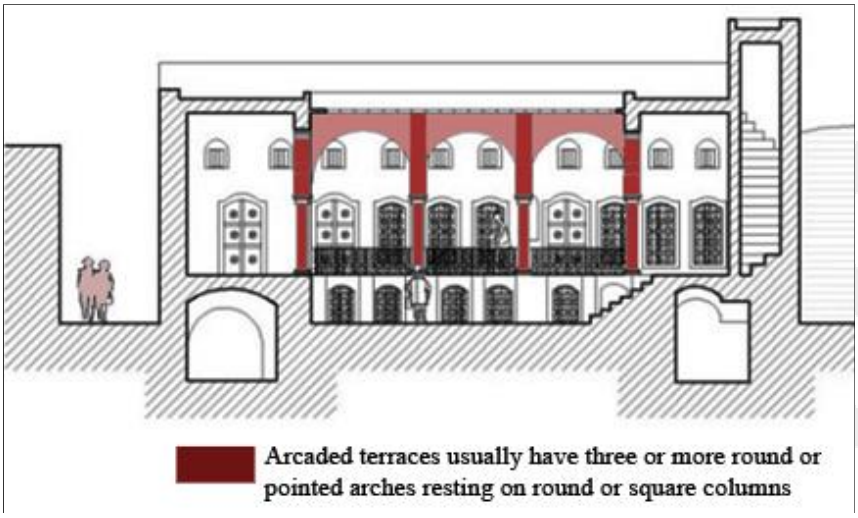


Figure 3.25. Selected house drawing by HECER in Erbil citadel, sections A-A, details by author

As a result of the analysis, courtyards were usually planned to be geometric in shape- either square or rectangle. This differs clearly with the state of the land area which was almost continually irregular with no proper angles. This implies that the builder, often the chief worker "Usta" himself, determined the spatial arrangement of the house plan after initial determining the form, area, and position of the courtyard. Still, in quite small areas it remained not possible to obtain a regular form for the courtyard (HECER ,2014). For instance, if the land had a small and narrow facade of a building and was deep in length then the builder would reasonably pick out for a deep rectangular courtyard adjacent its axis. If, otherwise, the land was square in overall shape he would choose to start with a square courtyard. However, utmost lands were irregular proportional layouts were not possible to shape a regular shape of houses. (UNESCO, 2013).

This also meant that the entrance to the house had to be on one side of the frontage and rarely in the middle. Ideally, the entrance was usually a "broken" arrangement to provide added privacy (HECER ,2014). In terms of the house floors arrangement, the large and small-sized houses were constructed in two levels to great as possible the floor area. The lower floor level was ordinarily halfly underground and an above floor which is slightly constructed above the lower floor as can be seen in Figure 3.25. Therefore, the above floor is recognized as the main floor where all the main rooms such as the guest reception are located. In contrast, the lower floor is used for siesta sleeping and storage.

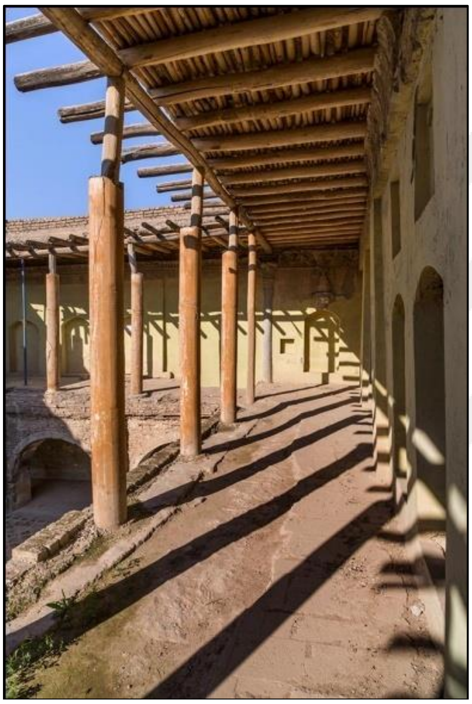


Figure 3.26. Photo showing the first floor including patio or terrace with wooden columns facing the open courtyard

Familly service rooms or places like, stores, bathrooms, and kitchens were usually located on one corner of the open courtyard and directly reached from it. Wall used as shelves therefore they enlarge wall thickness in services rooms when it possible. (see Figure 3.26) (HECER , 2014).

Figure 3.27. Familly service rooms with thick wall in the corner of courtyard

The lower floor is more often than not around 1 to 1.5 meters underneath yard level and is gotten to straightforwardly from the patio by around 5 or so steps. Semi-basements dependably have vaulted rooftops laying on thick block wharfs (HECER ,2014). Roofs are normally about 2.5 meters high and light and air are acquired from a few windows confronting the courtyard. The upper floor is gotten to straightforwardly from the courtyard by maybe a couple stairs. Therefore in the upper floor, the height of the roof is between 4 to 4.5 meters(HECER ,2014). This floor, being the principle one, is normally given a great deal of consideration and improvement by adornment, painting, and roof framing. The arcade, which was normally made out of at least three arches, is built with stone sections and stone arches (HECER ,2014). The terrace or sometimes called Tarma, was usually constructed with wooden columns that end in elaborate muqarnased capitals as can be seen in Figure 3.25. Some houses have a colonnaded tarma on three sides of the courtyard (HECER ,2014).

The Erbil citadel houses shows some similarity to houses in other ancient cities such as Mosul city which had a slightly raised upper floor, an arcade or Tarma, and a basement. Still, Erbil citadel houses built without the famous Iwan space while it is ideal for the Mosul vernacular house. Some details, such as marble cladding of walls, the round marble arches, and several windows and doors details, were apparently built by stonemasons from Mosul city (HECER,2014) .

Figure 3.28. Courtyard and first floor facing the round stone arches in Erbil citadel house

Construction techniques and building material

In this section, analysis investigates the construction methods and building materials used in the vernacular architecture of Erbil citadel. Bricks were used in as construction materials of almost all the structures in the buildings, although a small portion of the houses used mud bricks. The basic building material of the citadel was brick and not stone because of the abundance of mud bricks material naturally (HECER ,2014). This attractive yellow brick employed for almost everything- vaulted, floors, walls,columns, arches, and ornament or decoration items. Basically, bricks came in two types- one for building load-bearing walls and the other for paving floors and other surfaces. Structural bricks came in several sizes but commonly they were about 20 x 10 x 5 centimeters. Paving bricks, on the other hand, were about 28 x 28 x 5 centimeters. (HECER ,2014).

Figure 3.29. Brick as the basic building material for of the citadel

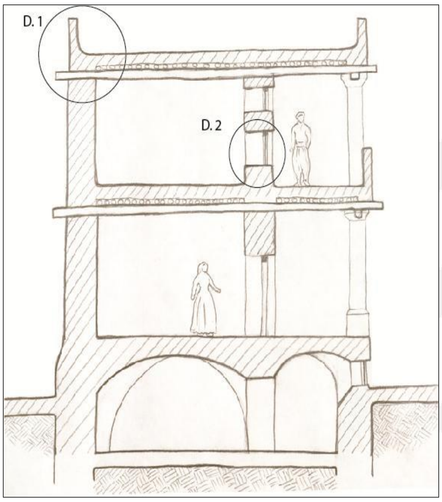


Figure 3.30. Cross-section of a typical vernacular house that uses wooden beams as construction technique for the ceiling (Abdulkareem, 2012)

Figure 3.30 shows the detail (D-1), the wooden beam has a long circular form that holds on the two facing walls, with the smaller span between them. These wooden beams are purposely formed with a width greater than the span between the two facing room walls, which makes the wooden beams to extend out from the outside walls. This technique provides the roof more resistance. The distance between the long wooden beams is random; it differs within two and three feet. Whereas the small beams are installed vertically to and above the large wooden beams. On top of these small wooden beams, pieces of twisted palm-leaf mat hold on. This palm-leaf mat layer is folded very strong to prevent the roof materials standing on it to fall down through. The last ceiling layer is the roofing, which is formed with materials such as broken bricks, mud, or diminutive stones and mortar (Abdulkareem, 2012).

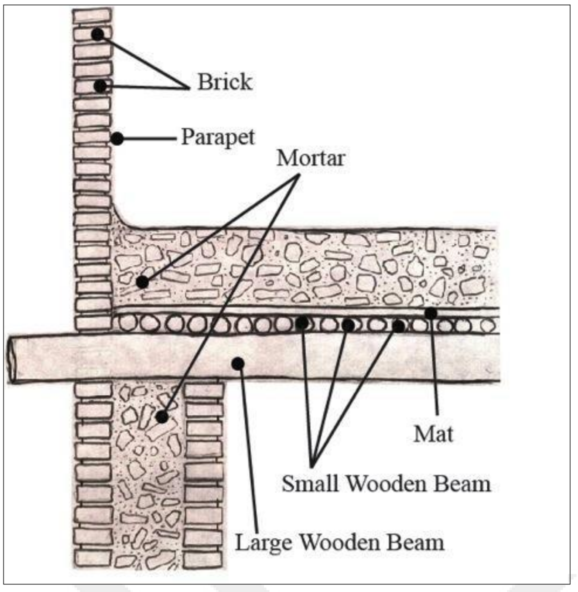


Figure 3.31. Detail (D-1), Section of a wooden timber ceiling construction technique using large and small beams, a burlap mat, and rubble (Abdulkareem, 2012)

The second detail (D-2), in Figure 3.31 shows the technique of installing wooden beams on top of the windows , standing on both sides of the opening. Then, the wall layers of brick are rested on top of these beams.

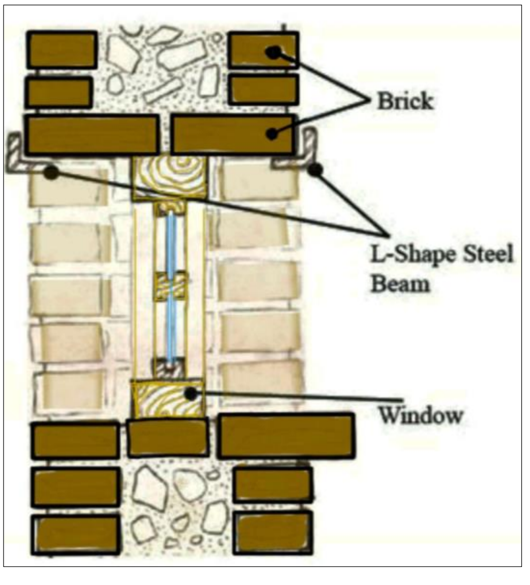


Figure 3.32. Detail (D-2). Opening construction technique using wooden beams, which are placed on top of the opening. Bricks are then laid on top of the beams (not to scale), (Abdulkareem, 2012)

Figure 3.33. Exterior small opening in the upper part of the wall

The foundation of the houses were constructed in a wider area to support the wall that rests on it. Some foundation gradually moves down, which transfers the weight of the building into the ground, obtaining it more steady (see Figure 3.33). The main construction materials of building foundation were stone or baked brick while stone considered more water-resistant and stronger than brick (HCECR,2014). However, some houses were built directly on the land without any kind of foundation, especially for those low-income people.

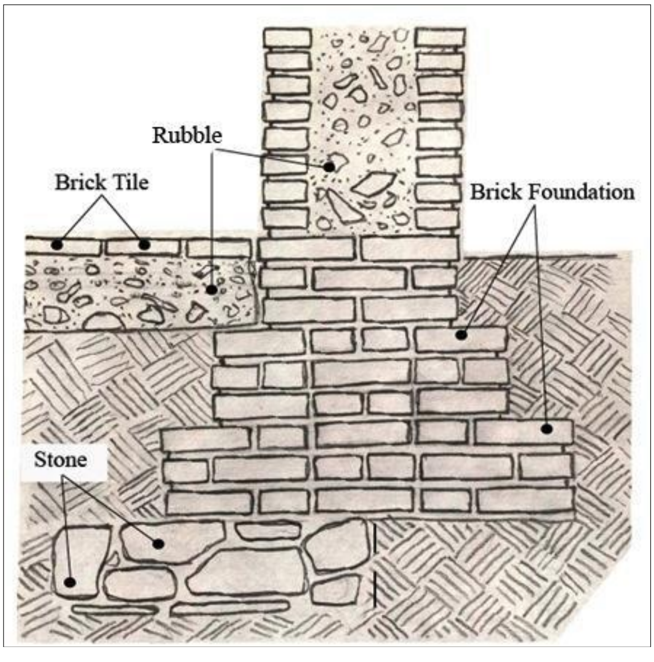


Figure 3.34. Detials of a traditional house’s foundation in Erbil Ciadel (not to scale) (Abdulkareem, 2012)

However, during the 1930s, new houses and other public buildings began to be constructed inside the citadel, as well as the lower city, in a different and new style regarding a significant difference from the tradition. This new style also involved an important structural change in roofing techniques that employed steel section (HCECR,2014). This new construction techniques enabled for much longer spans, strength, and caused the removing of classic arches and brick vaults in housing and other buildings. Other modifications included the using of large outside windows with glass introduced from elsewhere abroad, new paving tiles, doors, and plaster decorations. However, the interior open courtyard remained to be practiced until it was totally discarded in the 1950s (HCECR,2014). As a result, the earth have regularly been the most common building construction material in almost all hot-arid climate regions. Much of vernacular houses in hot climate areas used the earth as the major source of construction materials because of it is a realistic and viable option. Earth materials (rock, stone, mud, sand, and gravel) founded in many different structures and compositions and can be changed and transformed to use in construction in several ways (Morgan, 2008). As well as, earth building materials in vernacular building used as an interior and exterior decorative materials for plastering and painting walls and other building elements. The benefits of the earth materials described by Morgan (2008) in his book (Earth architecture from ancient to modern). The author claims that substance of the land surface or earth vernacular materials in hot climates obtained a high degree of adaptation to climate, environment and human needs. The earth materials that make houses:

1. Thermally benefits: cool in summer warm in winter
2. Well protected against the sand storms and undesirable wind
3. Its capability of absorbing extreme humidity,
4. Its capability of fire resistant (Morgan, 2008).

The benefits of the earth materials described also by Hassan Fathy in his book (Building without Borders). The author mentioned that traditional earthen material remains the interior spaces cool during a summer day and release heat during the night. According to Hassan Fathy’s experience in traditional architecture of hot climate especially in Egypt, modern building materials are in opposition to traditional one. He argued that concrete holds unbearable high temperatures in hot climate.

Central courtyard

The central courtyard is an essential feature of the traditional Arab house , which represented mostly in all traditional Arab houses, specifically in hot arid regions. In the traditional Arab houses, the courtyard served usually as an open to sky space usually located in the center of the house (El Shorbagy, 2016). This open courtyard has several purposes, not only to obtain separation and privacy, which is a demand social factor in Arab society but further to improve the thermal comfort by introducing natural ventilation inside a house (El Shorbagy, 2016). To understand the reason behind inventing the courtyard in traditional housing the architecture Fathy states that the relatively cooling system utilized in a courtyard house can afford the foundation for understanding building adjustments that can create air movement by convection. In hot arid climate, air temperature decreases significantly after sunset because of re-radiation phenomenon to the evening sky (Fathy, 1986).To improve occupants thermal comfort, this phenomenon has been utilized in the building design of traditional buildings by engaging the courtyard space (Fathy, 1986).

Courtyards space in traditional houses are effective building space that presents different function (Foazi, 2006). They give a particular spatial significance to the inside of the house as well as giving a small garden inside the house. Most important of every one of functions, these courtyards control the climate inside the house(Foazi, 2006). The main climatic preferred standpoint of these courtyards is the way that they permit light and air into the house. This light infiltrates every one of the rooms, since they are altogether organized around this chamber . The second climatic preferred standpoint is the ventilation and passive cooling. The introduction of the rooms towards the courtyard makes great cross ventilation amid the warm weather (Foazi, 2006). The open courtyard can help to cool the entire house spaces, where fresh air trapped in the yard works on cooling the building room next to it. Either in the daytime they're ,the house members, do not feel by great warmly because of the shade provided by the building itself. Since the cold air mass is heavier than warm air mass, so it is not only cools the building blocks, but penetrates into neighboring rooms and working on cooling them too (Haas, Stulz, Baumgartne and Sigg, 1993). Warm air is accompanied by cold air in the yard during the day and because of the shade provided by the building itself, the wall facing the courtyard be protected from the heat through the day, nonetheless usually patios not be too large. This principle works well in climates where the difference between the temperature between day and night is very large, and for the continuity of this principle should be packing the walls in front of the yard or make it huge and also avoid large openings that can be contained in the yard (Haas, Stulz, Baumgartne and Sigg, 1993). Buildings do not provide enough breeze that helps to get rid of cold stored inside the building because there are other factors that may be affected in the cold, the most important is the volume of the courtyard and the amount of cold stored in adjacent rooms. Factors that prevent air movement are alleys and narrow streets, such as those in Erbil citadel (Oliver, 1998).

Although winter conditions in hot-arid climate regions would statement an elongated house design. The early, traditional solution - specially for flat land - is a compact, inward-looking building with an interior courtyard space. This minimizes the solar radiation effect on the outside walls and provides a cool area inside the building. The traditional solution also meets other requirements such as privacy, safety and lifestyle (Foazi, 2006).

In the typical Arab courtyard house, the covered terraces, usually take a space around the courtyard and the covered terrace on the first floor support to reduce the heat gained from the direct sun throughout the day by provide shaded areas (Haas, Stulz, Baumgartne and Sigg, 1993). In general, the correct ratio between the width and height of the courtyard should always allow for sufficient shading, specially when the summer sun is almost directly overhead. If the courtyard is provided with water fountain and plants, it would serve as a fresh air source and changes the microclimate inside the house respectively (Haas, Stulz, Baumgartne and Sigg, 1993). According to the field research study all the large,medium and small-sized houses in Erbil Citadel were used open courtyard. However, the one or two storied courtyard building type can always fulfill functional and urban planning requirements at their time. See Figure 3.34 shows an example of open courtyard house in Erbil citadel.

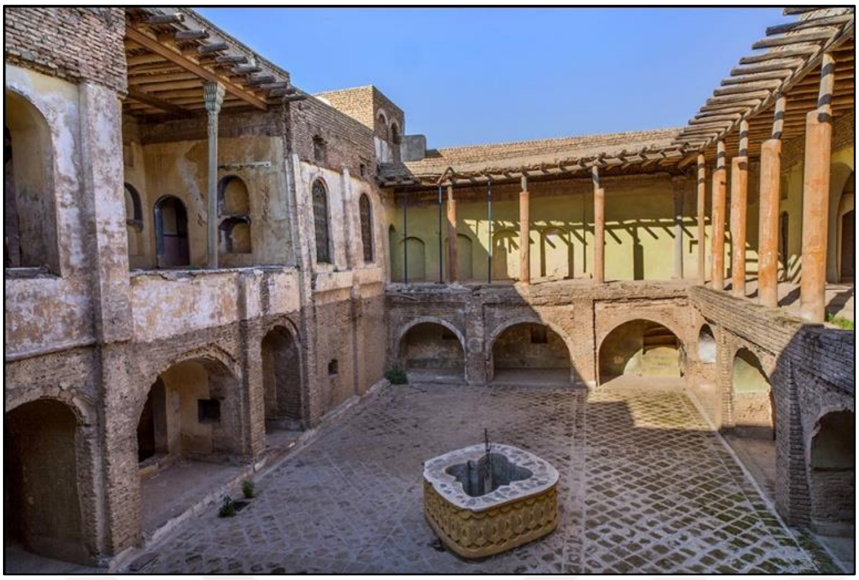


Figure 3.35. Sheikh Jamil Afandi house with the large courtyard surrounded from three sides by an arched portico supporting a roofed passage

The courtyard in traditional house acts as a temperature controller and as an open space within a building, a courtyard is a considered an essential design element in most of the vernacular buildings (public and private) originally used in the Middle Eastern and hot climate regions. Due to its function, everyday activities like; cooking, eating, relaxing, and working the courtyard considered as one of the most significant spaces in the traditional Erbil house. Further, Due to the role of the courtyard in enhance environment requirement of the building it is consider as one of the important passive design strategies for indoor thermal comfort and manage the climatic conditions.

<u>Orientation of building and seasonal use</u>

According to the climatic conditions and space functions in the different seasons, the traditional families choose how to spend their time. During hot summer’s days, almost the underground spaces and the space in the shadow (underground space known as Serdab), are being used for running away from this heat. These underground spaces have cooler more pleasant temperature rather than their upper counterparts (Foazi, 2006). Generally the vernacular Middle East buildings are oriented to make the interior and exterior living spaces appropriate during summer and winter session (Fathy, 1986). According to Fathy (1986) there are tow major factors that affect room orientation and arrangement in a traditional courtyard house. In summer, the West and East sides of the house receive more light and heat because the sun shines at a low angle in the morning and afternoon which made the East- and West-side windows difficult to shade . Therefore, usually, rooms on these sides contain the fewest and smallest openings. In winter, the northern rooms of the traditional courtyard house, which are exposed to longer periods of sunlight became more heat, for that reason usually used for dining and living facilities. Rooms and service faclities usually located in western and eastern side due to its function which need short time periods in compare with other living function (Almssad et al. 2007). However, Traditional people in Erbil and other cities in Iraq have used the roof space for sleeping due to the lower temperature at summer nights. They also spent most of their daytime inside the underground spaces (Serdab) escaping from the hot sun. Modern buildings, unfortunately, neglected such type of spaces which naturally and passively provide thermal comfort for occupants.

Ventilation methods

Ventilation and fresh air is a major part of protect the microclimate in a courtyard house. There are several strategies which are employed to keep cool air flowing throughout the traditional courtyard houses in middle east region such as wind tower, windcatcher, badgir and mashrabiya. According to the field research study, wind tower as a method of ventilation is not available in traditional house of Erbil citadel as other Middle East ancient cities and heritage sites. The traditional houses of Erbil citadel used cross-ventilation system to naturally ventilate and provide fresh air from courtyard space toward rooms next to it. The following Figure shows different types of windows size and location to enhance cross-ventilation strategy which considered as the main ventilation methods presented in Erbil citadel houses.

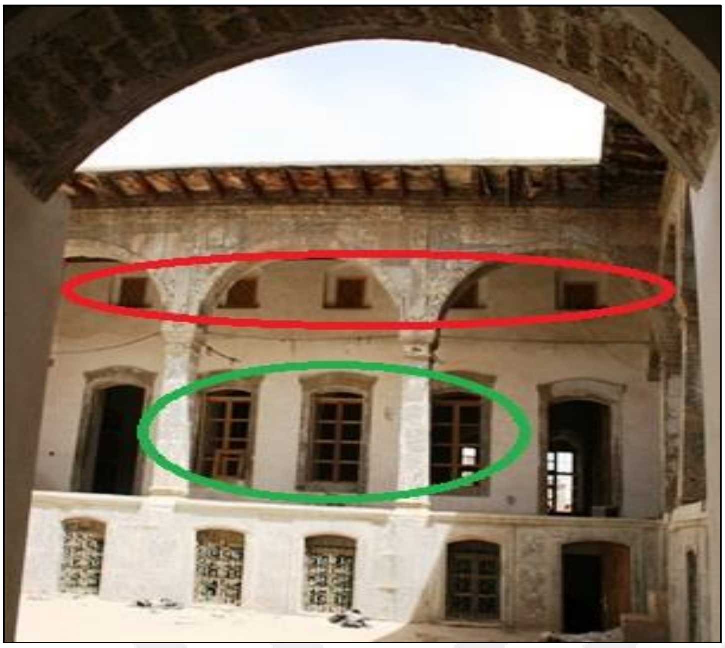


Figure 3.36. The cross ventilation methods, the cross ventilation opening located in the upper level marked in red color and the lower opening of an inner wall marked in green color

The red shaded areas are small ventilation openings located high on the walls whiel the green shaded areas are low-level ventilation openings. This approach of openings improved the cross-ventilation inside the house spaces during summer by ejecting the hot air by the upper-level openings and getting fresher air from the low-level openings as shown in Figure 3.36. Traditional buildings in hot climate regions had applied number s of architecture element to allow cool air inter in interior spaces to provied thermal comfortable living conditions for building occupants. Among these architecture elements or design techniques are the wind tower or wind catcher, Mashrabiya and wall gap ventilation method. This thesis research focused to discuss about the most major elements which were used extensively in vernacular architecture of hot arid climate regions and can play import role in terms of a architecture passive cooling to control indoor climate in modern building design. Therfore the following section introducing the ventilation methods and elements which employed in hot arid climate cities.

3.4. Ventilation Methods in Hot Arid Climate Region

In hot-arid climate regions, ancient people had been adopted themselves with the condition of the outdoor environment. The heat of indoor air temperature during a hot summer day is normally high due to many reasons such as:

1. Building surfaces (walls, roofs) absorbed solar radiation
2. Solar heat enters inside the building throw windows.
3. Heat reflected from the surrounding building surfaces and pathways (Dehghan, Esfeh and Manshadi, 2013).

The builder of traditional buildings had relied on natural passive strategies to increase the indoor thermal comfort (Dehghan, Esfeh and Manshadi, 2013). For instance, houses are traditionally constructed in positioned or occurring closely together or group of building attached to each other by combined walls. Buildings come into a cluster or close group reduces their overall exposed surface area, as result of that reducing the solar-heat gain. Another feature of the vernacular building in hot climate regions to reduce the absorbed heat from solar radiation is using domed roofs and vaulted. Traditional buildings in hot regions had applied number s of architecture element to provide cooling in internal spaces and thermal comfortable living conditions for building occupants. Among these architecture elements or design techniques are the wind tower or wind catcher and Mashrabiya (a wooden box built up in the second story wall for the purpose of ventilation).

3.4.1. Wind tower

Returning to the history, a wind catcher was embeddings as an architectural component, which gives regular ventilation. There is trusted that it is a conventional Persian architectural component, which was utilized for a long time, yet there is prove that the possibility of the wind-catcher goes back to the early Pharaonic periods (El-Shorbagy, 2016). Other popular and effective illustrations can likewise be found in the traditional engineering of the Middle East, Pakistan, and India, which display the effect of the customary Persian design on these locales (El-Shorbagy, 2016). As indicated by El-Shorbagy (2016), there are a wide range of kinds of wind towers, whose structures and capacities depend on the climatic states of their locales. The most well-known ones are the unidirectional (malqaf, windcatcher), and the multi-directional (Badgir, windscoop).

Malqaf (Windcatcher)

In the twelfth century time frame, an adjustment in the style of the house design format occurred that included the covering of the courtyard, and the presentation of the (qa'ah) which is a shut rooftop space as the primary guest room in the house (El-Shorbagy, 2016). With the courtyard, another arrangement of ventilation was developed to accomplish thermal comfort inside the qa'ah space which was called malqaf (a breeze catcher), which is a shaft extending high over the building with an opening confronting the overall wind. It traps the cold air and directs it down into the inside of the house (El-Shorbagy, 2016). The contemporary architect Hassan Fathy in his book, Natural Energy and Vernacular Architecture, explains the reason upon inventing this architecture element in hot aird climate regions .Fathy (1986) claims that in hot arid region, the main function of the ordinary windows is: light, ventilation, and view. So there is a difficulty in merge the three functions in the same time. For example on one hand, If windows are used to provide for air circulation indoors, they must be very small, which reduces room lighting. However, increasing the size to permit sufficient daylighting and an outdoor view lets in hot air conditions as well as strong aggressive glare. Thus, it is needful to satisfy the mentioned functions of the ordinary windows separately. To be content with the need for natural ventilation alone, the malqaf or wind-catch was invented. (Fathy ,1986). The malqaf thus deal with the requirement of normal windows to guarantee natural ventilation and air movement throughout the building (Fathy ,1986). The author states that, this natural ventilation element is further helpful in diminishing the dust and sand which usually common in the winds of hot climate regions.

Figure 3.37. Wind catchers in Iran -Yazd City.

The system in Malqaf or Windcatcher principally rely on the air flow generated by the pressure differential, even though convection creates the stack effect likewise (Calautit, Hughes, and Sofotasiou, 2016). Wind tower or windcatcher is among one of the most worthy elements of vernacular architecture in the hot arid climate regions such as Dubai, Cairo, Yazd cities which considered an efficent method of the vernacular ventilation passive system. Wind tower also works as a dominant feature in the sky line of the ancient city panorama.

a) b) c)

Figure 3.38. A traditional Malqaf windcatcher outside view (a) Malqaf windcatcher inside view (b) airflow through a building with Malqaf (c), (Calautit, Hughes, and Sofotasiou, 2016)

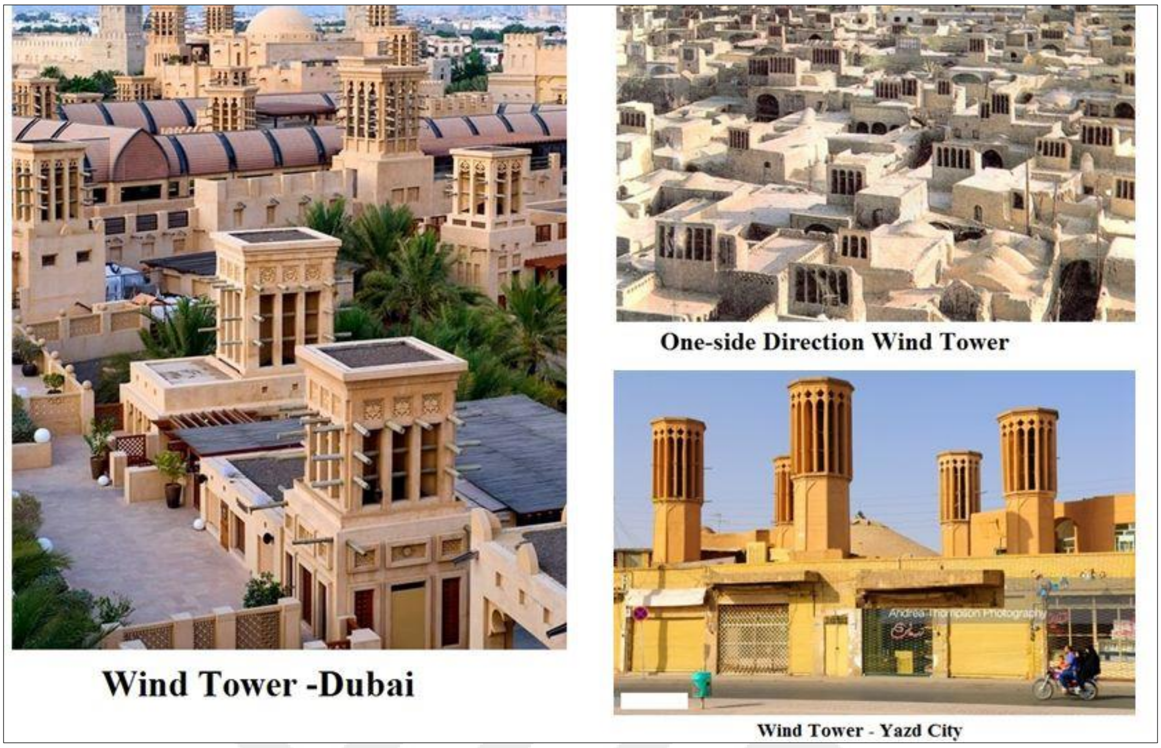


Figure 3.39. Wind tower applied in different hot climate cities (El-Shorbagy, 2016)

Malqaf is regarded as a bidirectional windcatcher which is mounted on the top of Arab's covered court yard . Malqaf is normally combined with another architectural element known as Salasabil which is a wavy marble plate that is linked to a source of water.(Saadatian, Haw, Sopian, and Sulaiman, 2012).

Badgir (windscoop)

A wind scoop (badgir in persian) is a traditional Persian architectural device used for many centuries to create natural ventilation in buildings. There are different architectural forms of windcatcher applied in different vernacular architecture of hot climate region cities with diverse efficiency. The city of Yazd in Iran is an important example of Iranian vernacular architecture whose architecture elements such as a windcatchers , well adapted to regions dry and hot climate (Pour, 2012). According to the research and analysis study done by Pour (2012) these wind towers in Yad city serve three fundamental functions: to ventilate basements, to provide convective cooling and to cool the interior mass of the house. There are less than 500 wind towers located above the roof of historic buildings of Yazd, witnessing the modern mechanical and electrical ventilations on the roof of many other structures (Pour, 2012). These wind towers are well equipped with openings facing to catch favorable wind, slightest movement of air and direct it downward into underground spaces. This model had became a part of the identity of the city in coping with natural forces for many centuries (Pour, 2012).

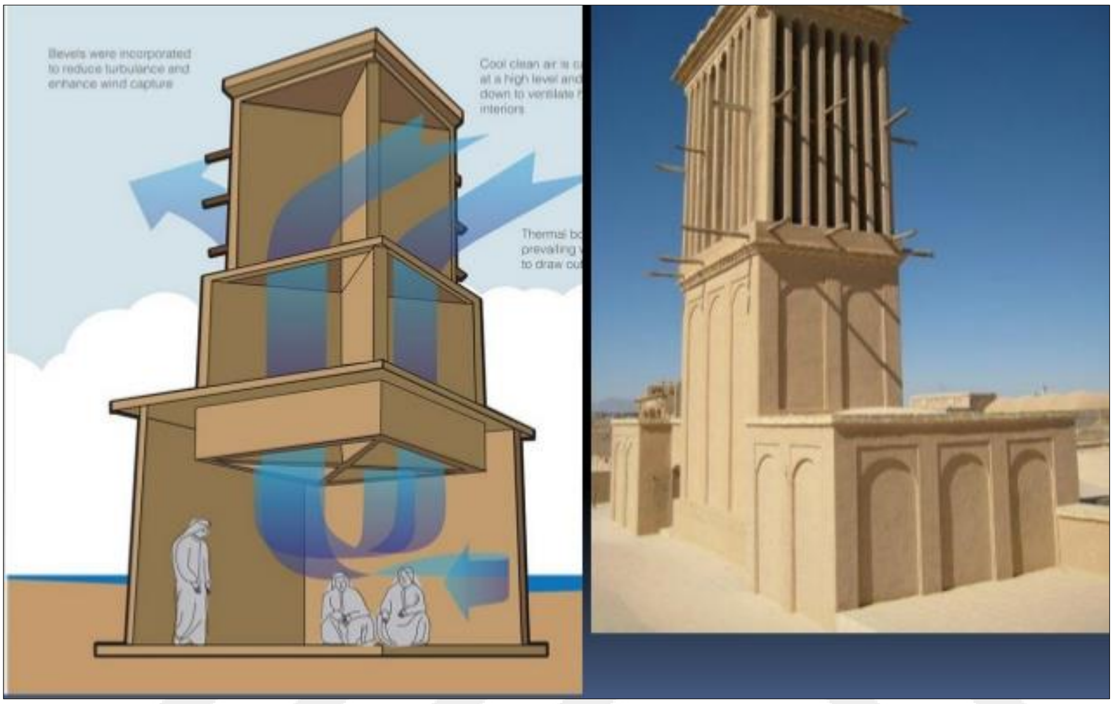
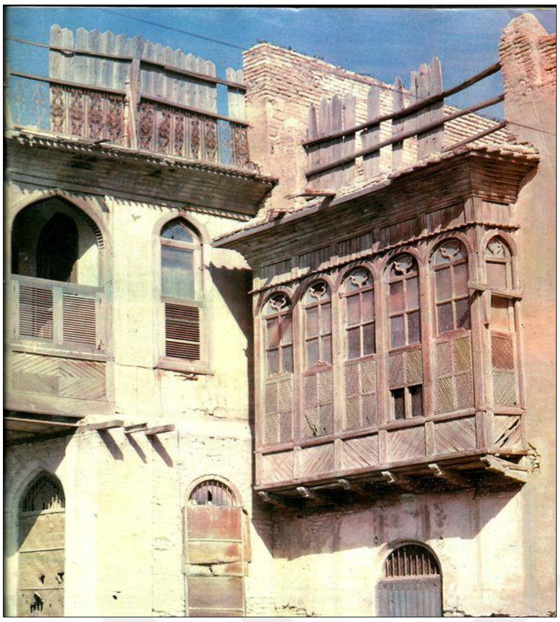
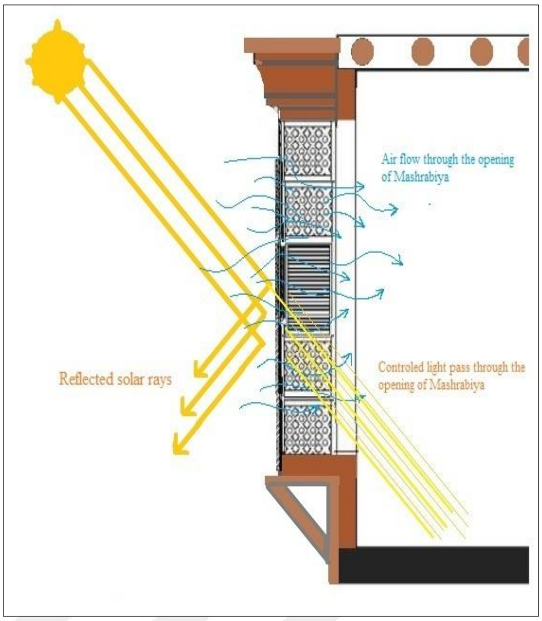


Figure 3.40. Badgir (windscoop) in vernacular Arab architecture at Dubai city

3.4.2. Mashrabiy

The name Mashrabiya is obtained from the Arabic word "drink" and basically indicated to place for drinking and resting. This place is a cantilevered space with mesh openings. Traditional people placed water pots in front of this mesh to be cooled by the evaporation effect as outdoor air passed within the mesh holes. Mashrabiya is on of the traditional Arabic architecture element which is window enclosed with wooden lattice work located in second floor (Fathy, 1986). Figure 3.36. shows such a Mashrabiya that of traditional house in Baghdad city.





a) b)

Figure 3.41. (a) Mashrabiya of traditional house (b) Details drawing by author

According to Fathy (1986), the traditional architecture element mashrabiya has five functions. Different patterns have been developed to satisfy a variety of conditions that require emphasis on one or more of these functions. These functions involve:

- Controlling the passage of light,
- Controlling the air flow,
- Reducing the temperature of the air current,
- Increasing the humidity of the air current, and
- Ensuring privacy.

Therefore, Mashrabiya element is designed to accomplish number or all of these functions (Fathy, 1986). The author also recognizes that the Mashrabiya, which thought to exist in Egypt since the 14th century, is not only a traditional method of cooling water, but also an architectural element that provided both shade and privacy. The contemporary architect Hassan Fathy in his book, Natural Energy and Vernacular Architecture, explains how the several models of mashrabiya were generated to provide a mixture of requirements or purposes (Fathy, 1986).

Figure 3.42. Mashrabiya in traditional house of old Cairo/Egypt (Mohamed, 2015)

mashrabiya element was experienced in different hot climate zones such as the Middle East and Northern Africa, south of Turkey and Spain, Western and Southern Asia especially India, and it is trusted that the concept behind this structure was employed as a climate control component. As mentioned by Mohamed (2015), the main function for Mashrabiya is providing privacy. It preserves the isolation of the house resident while they sit to watch the outdoor life without being identified from outside. Since the shape of it is mesh wooden, air can smoothly move into the interior space without breaking the resident privacy (Mohamed, 2015). It also produced shade from the extremely hot of the summer sun while allowing the cool air to flow. In addition to the functional use of the mashrabiya, Mohamed (2015) further explains those religious and social purposes of constructing it as a place for women to peek through while remaining hidden, a place where they can watch the life of the street or the life of the courtyard without being seen. As Feeney (2009) in his artical "*The magic of The Mashrabiyas*." notes that the utility of the Mashrabiya was not limited to the private homes. Rather it was used into mosques and other semi-public buildings. In that case, Mashrabiya was used on a much larger scale, but still served the same purpose of conditioning the atmosphere for occupants or worshipers. The description of the Mashrabiya as vernacular architecture element seems to introduce its use as a flat wood box installed in the wall of the upper level story for the purpose of ventilation. To conclude, this vernacular architecture element analysis of mashrabiya, seem to be directly related with the functions or purposes for which the mashrabiya was found; as a place to cool the water jars, lookout the surroundings life, provide home privacy, and to control climate conditions in the dwelling. As Feeney (2009) notes, making use of traditional architecture forms and materials is a successful method of conserving energy and optimizing material resources, which is in fact what the mashrabiya screen has offered its homes, as well as public places, for centuries. The use of the element was successful in terms of function and climate regulation, but also played a role in terms of the social, cultural, and aesthetic presentation. For centuries, the mashrabiya served both cultural and environmental purposes (Mohamed, 2015)."Mashrabiya" as a method of ventilation is rare in used in traditional house of Erbil citadel as other Middle East ancient cities and heritage sites.

3.5. The Latest Application Of Vernacular Architecture Techniques Toward Energy Efficiency

Masdar City, Abu Dhabi

Masdar City was initiated in 2006 as one of the most sustainable cities in the World. It is being constructed 17 km away from the center of Abu Dhabi and targeted to a 2016 completion date. Designed by the famous architect Norman Foster, Masdar city is wanted to be the principal city where carbon emissions are zero, squander is changed over to energy, desalinated water creation lessened by 75%, and 80% of water will be reused and controlled by 100% renewable energy (Haggag and Elmasry, 2011). The city includes Masdar Institute of Technology, laboratories and research facilities, commercial spaces for energy-related companies, and a science museum. Masdar, as an auto-free city, connected to the focal point of Abu Dhabi by another mass travel railroad. Electric buses and personal rapid clean-energy vehicles are provided as inner city transport system, while a light railway is proposed to link the city with the metropolitan area. Most private vehicles are to be kept in parking lots located at the edge of the city. The city is designed to be self-sustaining; therefore, the surrounding land outside the city will contain photovoltaic and wind farms, research fields and plantations, desalination plant, water treatment plant, a recycling centre, and visitors' parking (Abdelsalam and Rihan, 2013). According to Abdelsalam and Rihan (2013), the remarkable design idea of Masdar City depended on customary vernacular arranging belief systems, described by thin shaded back roads, wind-towers, and courtyards concept. See Figure 3.38. According to Abdelsalam and Rihan (2013), Masder city was designed in an ecological and resource-efficient manner. The road grid design is situated on a southeast-northwest hub to get the cooling breezes, give shading, and lessen thermal loads on building façades. The combination of the applied green design techniques won't just diminish energy utilization and natural effect, yet additionally lessen running expenses, make more charming spaces, and enhance tenants' wellbeing. To bring down the greenhouse gas emissions, an assortment of renewable energies are considered inside the city created (Ibrahim, 2016).

Figure 3.43. Wind-tower and courtyard of Masder city (Haggag and Elmasry, 2011)

According to Ibrahim (2016), the point of Masdar is to demonstrate that an expensive standard of living is likewise possible with clean energy and, moreover, to transform Abu-Dhabi into an antecedent of renewable energy. We can summarize the application of passive cooling strategies in Masdar City as follows:

1. Intelligent shading devices are utilized to lessen heat gain on building façades, while expanding regular light. (See Figure 3.44).

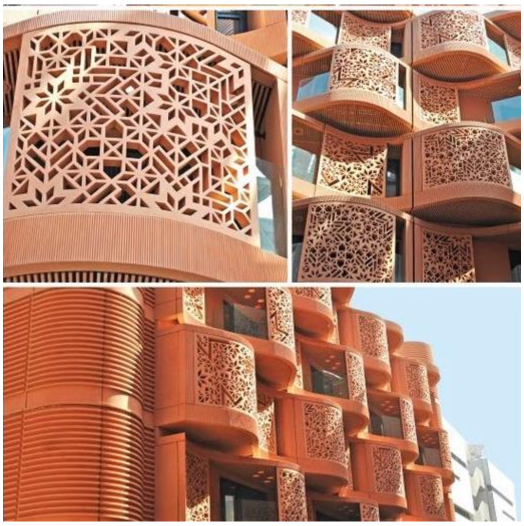


Figure 3.44. Shading devices in housing building facade of Masdar city (Ibrahim, 2016)

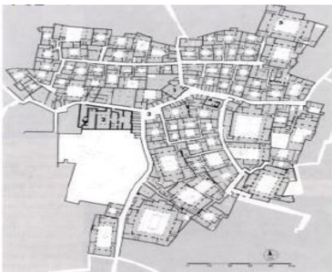
2. Person on foot walkways are shaded with retractable canopies which can be opened during the evening to get the cooling breezes .(See Figure 3.45)

Figure 3.45. Shaded pedestrian walkways in Masdar city (Haggag and Elmasry, 2011)

3. Newly designed wind-towers are situated in the fundamental piazzas to gather cooler upper breezes and direct them down to the public spaces and patios. (See Figure 3.43).

Masdar neighborhood architectural features proposed from the design concept stage to receive the conventional approach at this level contributing to fit with the harsh atmosphere of the city (Ibrahim, 2016). As a result the following Table 3.2 showing the application of vernacular architecture techniques in both Neighbourhood and building unite level.

Table 3.2. Application of vernacular architecture feartures in Masdar city in both neighbourhood and building levels.

	Traditional Neighbourhood Features	Traditional Neighbourhood Illustration	Masdar City Neighbourhood Illustration
Neighbourhood Level:	1. Low rise building, high density , mixed use, walkable distances		Applied all the features  successfully
	2.Appropriate street widths and orientation to mitigate local microclimate conditions		Applied all the features successfully 
Building Level	1.Traditional mashrabbya provided, natural ventilation, ensures privacy, acoustic separation, daylight.		Applied all the features successfully 

University of Qatar

The conventional use of windcatchers has been these days reinterpreted from multiple points of view utilizing both natural and mechanical supported ventilation, the famous Egyptian architect Hassan Fathy utilized it broadly in his structures, yet without a doubt, outstanding amongst other practice is the Qatar University Campus planned by the

Egyptian planner and architect Kamal EL Kafrawi (with the coordinated effort of Ove Arup company) and began used in 1985(Saadatian, Haw, Sopian, and Sulaiman, 2012). The wind-tower, or truly known as windcatchers, can be found as a vernacular architecture component in the greater part of the advanced Islamic world region with some of local changes, its utilization has been steady through the ages yet in the western Gulf region it nearly vanished because of the quick urban development and modernization of the urban areas, in Bahrain, for instance, just a single antiquated badgir remains(Saadatian, Haw, Sopian, and Sulaiman, 2012). (see Figure 4.45)

In this pioneering campus project, the utilization of windcatchers is orderly and represents in the entire building of the university. In light of an octagonal and square arrangement geometry, the low ascent solid modules the undertakings makes expansive utilization of natural light and natural ventilation through the many Windtowers and the Mashrabiya to shield the schoolroom from sunshine whiel allow the air flow. The accumulation of the modules compare classroom modules, lobbies and rest spaces enhanced with vegetation and always ventilated through the rooftop.

Figure 3.46. The University of Qatar in Doha using vernacular windcatcher (Saadatian, Haw, Sopian, and Sulaiman, 2012)

Figure 3.47. External view of classrooms in Qatar University Campus showing Mashrabiyas and windcatchers model (Saadatian, Haw, Sopian, and Sulaiman, 2012)

Visitor Center at Zion National Park, US

There has been an increasing realization of the application of natural ventilation and passive cooling system in western countries, specifically the wind-catcher (El Shorbagy, 2016). Experimental studies have been conducted to explore the performance of windcatcher, which depends greatly on the wind direction and wind speed. The results verify that natural air movement inside the building improves the air quality and reduces the interior temperatures. The concept of windcatcher brought the concentration of western architects, who renewed the old Arab windcatcher as a form and purpose and applied it in their modern wooden buildings without the addition of any modern mechanical devices as shown in the Visitor Centre at Zion National Park, US see (Figure 4.47). This visitor center exemplifies a successful model of the reception of energy-sparing advancements, for example, the windcatcher, which yields a huge, quantifiable energy investment funds in the building rooftop.(El Shorbagy, 2016)

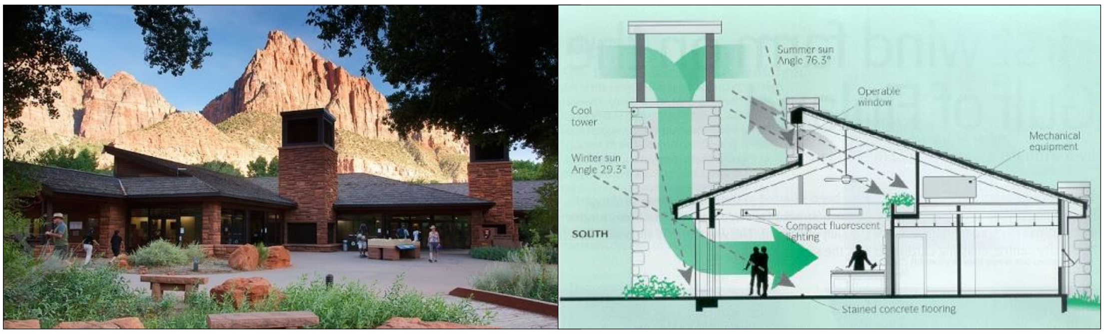


Figure 4.48. Modern example of using windcatcher in the Visitor Center at Zion National Park, US (El Shorbagy, 2016)

As a conclusion, throughout the history,there are various vernacular architecture design elements in diffrent climate region condition have been used in different part of world for thermal comfort both in neighbourhood level and building level as well. According to Sarswat and Kamal (2015), these vernacular architecture design elements such as orientation of building, thermal mass, water body, open courtyard, various kind of shading devices, vegetation, lattice screen, domes, wind towers and air vent mostly perform multiple functions. For instance, water body located usually in the center of the courtyard behaves like aesthetical feature in the building as well as a source of natural cooling. Open courtyard functions like a source of ventilation as well as a part of integrated indoor-outdoor living area, shading devices provides shade but also capable to change direction of wind at micro level. Lattice screen provides ventilation as well as privacy from outside and so on (Sarswat and Kamal, 2015). Domes stores hot air since it is the high mass in the structure, and additionally carries on as a ventilation source if the vent is given. With this, it causes thermal comfort on account of self-shadow delivered by the dome on itself. With all these features it is an important architectural as well as structural element. All these design elements was used extensively in hot climate traditional buildings of different regions for the purpose of thermal comfort and ventilation. Vernacular architecture is the natural product of society’s customs and requirements, and has evolved from the public's perception of its needs (Baper and Hassan, 2010). It is considered self-building; non-professional buildings are built by families and tribal members (Mortada, 2016). It evolves over time and is influenced by a range of factors that determine the context of construction and configuration of shapes, which are: climate, religion, community, socio-economic considerations, culture, environment, local materials, and construction techniques. The vernacular architecture of the Middle East and North Africa is especially well-suited to protect its inhabitants from the weather conditions found in a hot, arid climate (Mortada, 2016). Climate has an important impact on vernacular architectural forms (Sibley,2006). For instance, the ratio of window area to wall area changes according to the region's temperature (Sibley, 2006). In a tropical climate, the sizes of the windows are smaller to avoid the sun's heat. Buildings are designed with natural ventilation; cavities and wooden partitions help the flow of air inside the building. The roof type varies with the amount of rainfall. In low rainfall areas, the roof is flat, while high gables are located in areas with high amounts of rain and snow (Sibley, 2006). The internal microclimate is different inside the house itself, depending on the room's location. Vernacular architecture in a hot, arid region is characterized by building thick walls and a few small windows to insulate structures from the heat of summer. In the coastal areas, stone coral reefs were used due to lack of building materials. These stones have pores that help thermal insulation (Sibley 2006). Because the Middle East is classified as a hot, arid region, its vernacular architecture focuses on maintaining a comfortable climate in the home year-round. This is achieved principally through the courtyard house. Courtyard style house has existed for thousands of years in areas extending from Morocco to China . Courtyard houses were used by the Sumerians and Egyptians and even later in Greece and Rome (Bekleyen and Dalkiliç, 2011). The courtyard evolved from ancient cosmological beliefs that the world consists of earth and sky with wind connecting them (Bekleyen and Dalkiliç, 2011).

The courtyard, considered to be the most active space in Islamic architecture, is located in the middle of the house and separates between reception rooms and family rooms (Foazi, 2006). Usually, the courtyard contains a fountain and attractive places to sit. In general, the courtyard house in Iraq is a multi-story building, while in the Arab Peninsula region, especially Kuwait, the houses are single-story buildings (Foazi, 2006). In the northern part of Iraq, traditional houses are built with baked brick, which allows the building of multiple stories. In places with an uneven topography, the outside walls are higher than the outside walls of houses in flat areas; the tall walls provide privacy for the family (Foazi, 2006).

Families living in houses with side or front courtyards differed in that they did not utilize the courtyard as a main living area . The third type did not have a courtyard; they only had a ventilation shaft or light well for the service areas of the house (Sibley, 2006).

In the Middle East, the climate features hot, dry summers and cold winters. Residents use northern rooms of the house in summer during the day because they receive the largest amount of sunlight, and they use corner rooms with few openings at night because they lose less heat. In the winter, the southern rooms are used. The western side of the house, with its exposure to direct light and heat, is avoided during the summer (Sibley 2006). Another important factor to make the microclimate suitable is the availability of plants, trees, and fountains in the courtyard (Foazi, 2006). For the purpose of reducing the temperature inside courtyard buildings, other techniques are also used, such as windows that open toward the courtyard, which weakens the impact of direct sunlight on the rooms . The exterior walls contain few windows and vent holes are situated high in the wall (Foazi, 2006).

Arched porticos located between the open courtyard and the rooms protect the rooms from the direct sunlight and at the same time allow the entry of wind and light (Sibley 2006). The inward orientation of the courtyard restricts the outside noise and intrusion while providing a natural environment to the house by opening the courtyard to sky, sunlight, and desirable wind (Sibley, 2006). In addition, grouping buildings close together gives the narrow footpaths between them a shaded area so that the atmosphere is comfortable in the alleyways and streets. The ends of alleyways head in the direction of the prevailing winds (Foazi, 2006).

Courtyard houses, which are common in regions with hot and dry climates, demonstrate strict localism and attempts to create private space for introversion. Such conform to the climate, but are also a reflection of culture. The privacy measures that influence the design of the houses are representative of particular cultural norms (Bekleyen and Dalkiliç, 2011)

Table 3.3. Brief analysis and environmental evaluation of vernacular architecture characteristics in Erbil/Iraq

Evaluation Criteria	Vernacular Design Strategies	Illustration	Environmental Evaluation
Settlement Characteristics	1. Settlement in harmony with topography 2. Organic form of the paths and alleys because they follow the topography of the citadel 3. High density of the building context 4. Different house entrance showing different types of neighborhood groupings and open spaces. 5.Clear Hierarchy of spaces (public,semi-private and private space)		1. The great ecological performance of shaded zigzag and narrow paths results to provide thermal comfort and cold air during hot summer days. 2. Due to the arrangement of the main and long paths in parallel to north-south direction radiation solar do not heat up the dwellings as if directed towards the East-West. 3. Using animals (horse or Camel) for transportation does not harm the environment. 4. The wind direction always changes becuase of zigzagged shape of the alleys which reduce the speeds of the wind.
Planning Layout Characteristics	1.Generally, all of the houses have a courtyard 2.House rooms located acorrdıng to climate response and seasonal use 3. During the hot summer days, underground basement level was used.		1. The courtyard in traditional house acts as a temperature controller introduced larger areas of indoor passive zones. 2. The courtyard is the source of natural lighting and ventilation, and makes the house climatically responsive by bringing nature to the ınterior resulted in facilitating energy efficiency. 3. Basement located under the yard and called “Sardab”, it is a traditional solution to escape from the extreme heat during the summer days. According to its location underground, it keeps the cool temperature because hot sun rays cannot reach it.

Table 3.3. (continued) Brief analysis and environmental evaluation of vernacular architecture characteristics in Erbil/Iraq

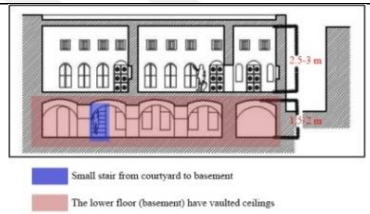
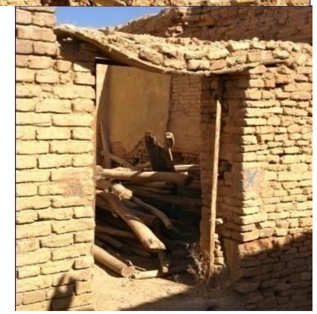
Evaluation Criteria	Vernacular Design Strategies	Illustration	Environmental Evaluation
Form Characteristics	1. Some houses consist of two floors and all houses had a flat roof. 2. Irregular shape of houses with no angles 3. Enclosed building mass (compact form , inward looking)		1. The inward orientation of the rooms towards the courtyard creates good cross natural ventilation. 2. Compact form of housıng less exposure to the direct solar radiation which help to reduce heat gain during summer and heat loss during winter
Building Envelope Characteristics	1. Exterior windows are few in number and small in size 2. Thick external walls (60_1.50 cm)		1. positioning and size of window play a significant role in allowing the required amount of daylight and fresh air which provide users comfort 2. The great thickness of the house walls and their materials construction is the principal basis for their great thermic protecting feature thus facilitating the thermal comfort of the house users. 3. As the analysis shows some houses walls are plastered with mud mortar mixed with broken pieces of stone tiles, ensuring further strength to the structures of these walls

Table 3.3. (continued) Brief analysis and environmental evaluation of vernacular architecture characteristics in Erbil/Iraq

Evaluation Criteria	Vernacular Design Strategies	Illustration	Environmental Evaluation
Construction Material Characteristics	1. Locally available construction materials like mud brick, stone and wood are used	  	1.Utilization of local community construction applicability which significantly enhances the building harmony with its surrounding environment conditions 2. Use of accessible local materials which are from the same climatic zone, fit consummately into the local climate conditions. 3. These accessible local materials have natural favorable circumstances contrasting nowadays counterfeit non-local materials, for example, the great decrease in energy associated with material assembling and transportation, low ecological effect amid their formulation. 4. The construction strategies and the building materials which are eco-accommodating, locally accessible and require the least energy for creation and use, furthermore play a remarkable role in giving an agreeable thermal condition in the inside independent of the outside temperature. 5. They are naturally handled to pick up the required level of quality, durability, and strength. The heat capacity and basic characteristics of these materials guaranteed energy proficiency of the buildings.

Focused on the environmental behavior evaluation, this analysis investigates how the traditional urban form and vernacular housing design characteristics can affect the low energy building aspects and criteria. After completing the analysis of vernacular architecture features in terms of urban planning scale and architecture building scale in Erbil city and other hot climate regions, it is important to give a comparative analysis to modern era architectural design. Comparative analysis of vernacular architecture and modern architecture patterns supporting to discover and enhance the knowledge of the research topic more. Therefore the purpose of the comparison analysis is as follows:

1- To identify the failures and successes aspects linked to environmental behavior and local climate responsive features.

2- Extract passive cooling techniques from vernacular architecture of both urban fabric and building unite, and finally

3- An attempt to apply these passive cooling techniques as an architecture solutions into modern housing building to achieve more environmentally friendly communities and reduce the need for the non renewable energy to provide human comfort.

Table 3.4. Comprition between contemporary architecture and vernacular architecture charaterstics in both urban and building scale

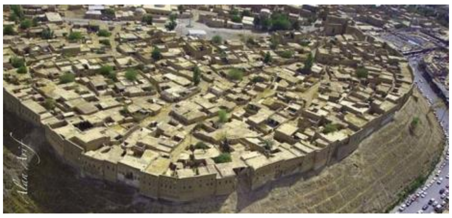
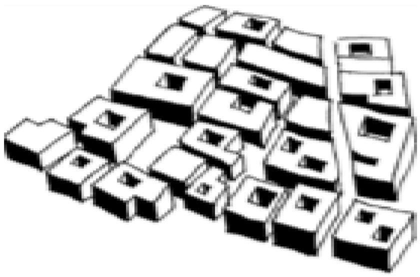
Urban Form		Illustration
Vernacular Architecture	1. Compact urban form 2. Harmony with topography 3. Bazar is the main commercial axis of the city 4. Outdoor spaces sheltered from harsh weather conditions (Solar heat, sandstorms) 5. Hierarchy principles (Public, semi private and private) 6. Neighborhoods spatial segregation based on ethnicity and religion	 

Table 3.4. (continued) Comprition between contemporary architecture and vernacular architecture charaterstics in both urban and building scale

	Urban Form	Illustration
Current Architecture	1. The main changes in urban form is street systems according to the need of automobile 2. Street side shops 3. Outdoor spaces does not sheltered from harsh weather conditions. Street exposed to direct solar heat resulting in rising urban air temperature. 4. Weak of hierarchy principles (Public, semi private and private) 5. New neighborhoods were segregated according to economic status.	
	Paths and Walkways	Illustration
Vernacular Architecture	1. Organic form of the paths and alleys 2. Narrow roads, various angles of winding roads, shaded walkways 3. Using animals (horse or Camel) for transportation 4. High density of the building context. 5. Building are very close to each other 6. Priority of traditional path is given to human needs. 7. Quite suitable for human scale	
Current Architecture	1.Grid pattern 2.Wide and straight roads 3.Car is the main way for transportation 4.Priority of modern path is given to the transportation needs. 5.Streets are not suitable for human scale and unsafe for pedestrians.	

Table 3.4. (continued) Comprition between contemporary architecture and vernacular architecture charaterstics in both urban and building scale

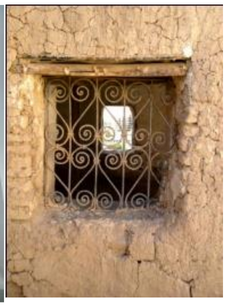
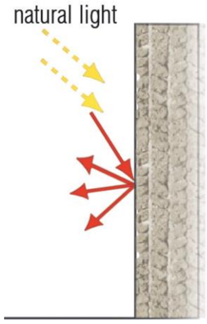
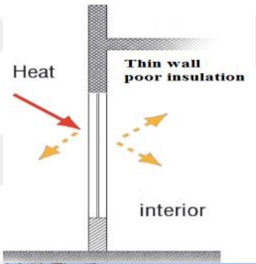
	Building Form and envelope	Illustration
Vernacular Architecture	1. Pure geometrical form. 2. Compact form of housing with flat roof 3. Courtyard house 4. Pure facade without any additives such as balconies	 
Current Architecture	1. Appearance of curvature and flexure forms 2. Different type of roof 3. Houses without Courtyard 4. The modern house façade orientations follow the directivity of grid street line	 
	Opening and windows	Illustration
Vernacular Architecture	1. Exterior windows located in the upper of the exterior wall let indoor air escape more frequently, depending on its temperature. 2. Small windows, few in number with wooden frame, bring controlled natural light, thus less heat gain is achieved.	 
Current Architecture	1. Large size exterior windows usually uncontrolled and direct sunlight, thus more heat gain of interior. with Iron frame 2. Huge screen glasses are noticed in front façade of the houses.	

Table 3.4. (continued) Comprition between contemporary architecture and vernacular architecture charaterstics in both urban and building scale

	Building Materials	Illustration
Traditional Architecture	- Local building materials (Mud Brick ,wood, palm) - Walls of mud blocks, coral stone, palm and straws act as very good insulators. -Roof consisting of mud, palm trunks, bamboo, mangrove wood and palm leaves provide good thermal insulation	 
Current Architecture	-Appearance of different type of materials - Nowadays artifical non local materials are used in construction - Reinforced concrete slab and walls -Walls from concrete block -The appearance of new alien material (e.g. aluminum panels, prefabricated screen walls, timber roofing systems)	 

4. BUILDING SIMULATION

The main interest of this chapter is about investigating thermal dynamic simulation approach of buildings. As well as, presented and evaluated the building simulation process and the selected program to be used for simulation. Furthermore, hourly weather data and description of the modeling in the simulation process is outlined. Building energy simulation and modeling can be defined as the virtual or a system that is operated or controlled by computer simulation of a building or group of buildings that concentrates on energy consumption related issues, life cycle costs of different issues such as lights, indoor air conditioning, domestic hot water and other energy consumption items (Jenkins, 2011).

4.1. Building Simulation Approach

Building energy simulation can support designing low energy building and thereby reduce electricity consumption. Building energy modeling has its original roots back in the 1920s were certain scientists developing response factor methods which are a series of algorithms and these algorithms were expanded on through the 1950s (Glotzer et al, 2009). Then through the 1960s, HVAC engineers which stand for heating ventilation and air conditioning engineers were using these algorithms to determine peak cooling loads. By the latest 1960s, the office of civil defense which is nowadays known as FEMA (Federal Emergency Management Agency) took an interest in planning for cooling requirements in a thermonuclear radioactivity shelters (Jenkins, 2011). Moving forward taking this process to the next level when the Japanese scientist Kusuda looking at the effects of sunlight and weather in a single room. Moving to the 21st century where we can see BIM building information modeling firms have been purchasing building energy modeling companies which they beginning to integrate the building information modeling with energy building modeling. Scientist expecting to see a major growth in building energy modeling in the future due to developing stringent building codes as well as carbon credits and carbon taxes were seeing an enormous growth in industry and building technology (Jenkins, 2011). According to Glotzer et al (2011), critical technologies and improvements in computer energy modeling allow enormous opportunities that are playing a significant role to ensure the building occupants satisfaction. Oden et al. (2006) portrayed that computer simulation is more spreading widely throughout the world today and having more action than at any other time. Recently, engineering and architecture engage the use of building energy modeling and computer simulations in order to solve mathematical equations and physical models of engineering. (Glotzer et al, 2011). Building energy modeling nowadays has reached a high level of predictive ability and therefore using this method as a scientific alternative by many engineering research and industrial companies without the need to use traditional methods of research such as observation and experimentation (Glotzer et al, 2011). However, in order to get a more excellently or effectively building design, it is extremely important to think carefully about whole environmental issues that influence the behavior of the building in combining with its context. On the other hand, in the last decades building energy simulation has offered assistance for architect and engineers in building design and a greater support in other issues such as thermal analysis, commissioning and buildings assessment before construction phase.

Commonly, architecture design procedure can be considered as a procedure or an arrangement of producing thoughts well ordered that include particular advancements and standards and then assessing the building execution as for the other execution contemplations inside the particular design setting. Presently, building modeling and simulation condition has been utilized widely in an enormous amount of buildings design extends in combination with engineers and architects association in step forward to achieve sustainability in the designs (Hien et al. 2003). The author argued that building simulation has the capacity to give coordinated data in light of the execution of the design to empower the design group to really 'see' and 'feel' the building before it being fabricated". Nonetheless, creating characteristic outcomes give general headings to the building designer, while simulation apparatuses have created as far as their relevance, which help to think about different space examination and estimations to speak to the execution of buildings and because of that to deliver ideal designs or to produce optimum or correctly computed designs (Hensen et al, 2004). Simulation and building modeling by using the computer considered as an effective technology for classifying the high level of interacting between architectural, mechanical and civil engineering issues in buildings as reflected in Figure 4.1.

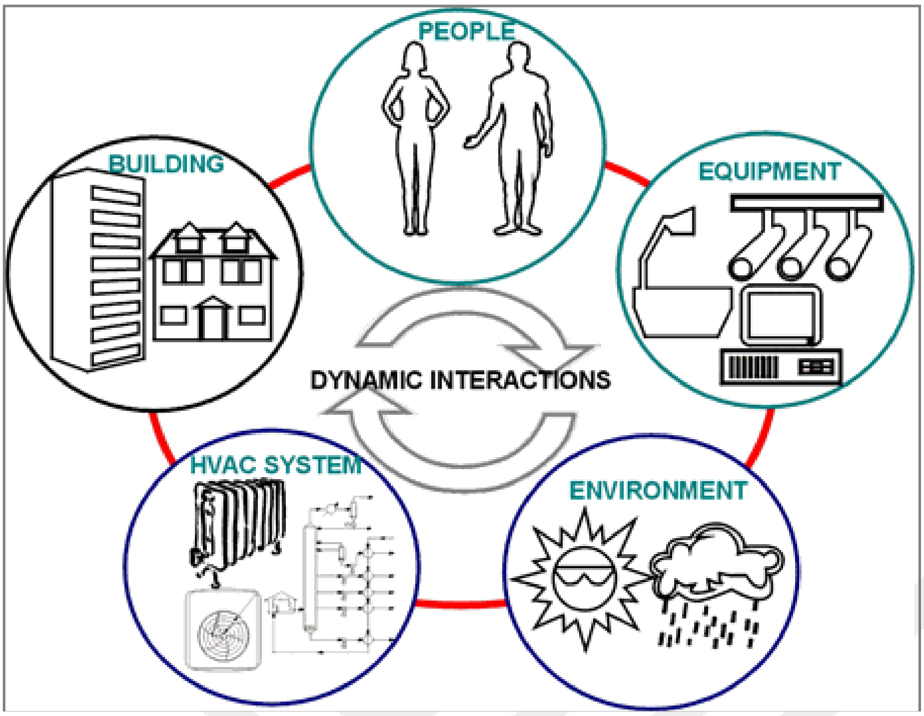


Figure 4.1. Effective interacting subsystems of the building simulation process (Hensen, et al. 2004)

Finally, building simulation can help to reduce greenhouse emissions (there are lots of gases that make up the earth atmosphere some of these gases are carbon dioxide methane and nitrous oxide these three gases are called greenhouse gases) and providing essential improvements in fossil fuel consumption. More importantly, building simulation can assist in reaching a great level of well-being environment, building user comfort and productivity (Hensen, et al. 2004). The author argued that, those achievements are possible only by taking into account dynamic interactions, as described in Figure 4.1.

4.2. Overview of the DesignBuilder Program

As described before in this chapter building energy simulation software engineers are devices principally utilized as a part of the prior period of a planned procedure which can be utilized to anticipate and to upgrade building energy execution including assessing inhabitants comfort in buildings. However, there are different simulation program and hence this research study is about thermal comfort and cooling energy load calculation a framework review of thermal behavior simulation program were investigated. A comprehensive study about available energy simulation software done by Crawley et al (2001) including number of main building energy simulation programs using the method of comparison and evaluation of the functionality, features and capabilities of each one separately. The analyst created a report that gives a strategy to the examination highlights of the building energy simulation programs including (EnergyPlus, ECOTECT, IES <VE>, BLAST, ESP-r, DeST, BSim, eQUEST, DOE-2, HAP, HEED, PowerDomus, Energy-10, TAS, SUNREL, Energy Express, TRNSYS and TRACE). However, this report depends on facts and knowledge gave by the energy simulation application engineers in the accompanying order: Building modeling highlights, cooling and heating loads,windows, infiltration, construction, daylighting, natural ventilation and zone airflow. The EnergyPlus simulation program is selected by the Crawley et al due to a high capability comparing with other simulation programs. The authors find that, EnergyPlus is a created energy simulation tool of buildings that in view of the quality or qualities of DOE and BLAST programs.

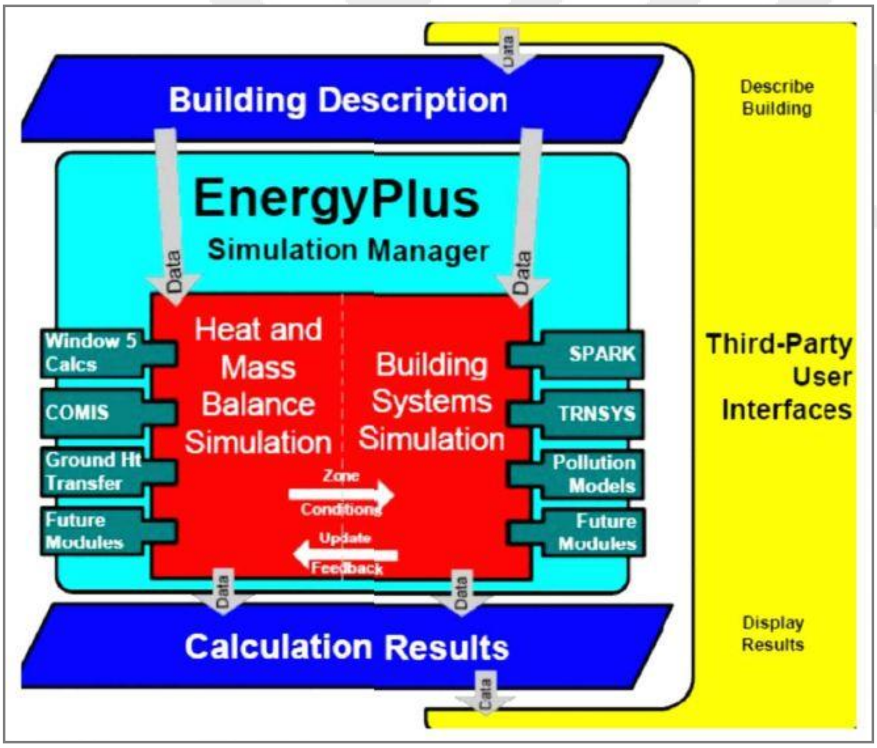


Figure 4.2. Structural diagram of EnergyPlus program (Crawley et al, 2001)

DesignBuilder is a building energy computer simulation software which is nowadays widely used by engineer and academic researchers. DesignBuilder have an enormous range of abilities especially for helping architecture designers and engineers compare different design scenarios and guide them to select the best design and the most energy efficient design option (Hensen et al, 2004). In addition to helping users of this program determine the potentials and solutions of energy saving and help to evaluate the results in terms of energy efficiency (Crawley et al, 2001). In order to get the optimum architectural design and before starting the simulation process it is necessary to recognize the climate determinants that seriously can influence the building behavior and simulation result. However, the input data in DesignBuilder should be defined accurately such as actual outdoor weather file data (EPW format) with the selection of the location and region, building geometry and building thermal zoning representing a definition of thermal performance, Building materials and construction templates and other important input data. Then again, DesignBuilder database has given an incredible help in building operation, early design decision, energy testing and simulation (Hensen et al, 2004).

4.3. Hourly Weather Data

Hourly weather data file is one of the greatest dynamic requirements data in energy modeling programs. The hourly weather data sets are loaded at site level under the simulation weather data header of the location type in DesignBuilder program (Garg et al., 2017). DesignBuilder uses EnergyPlus formats hourly weather file data to specify outdoor condition during simulation. Each geographical area has a special weather file designating the outside temperature, solar transmission, and atmospheric circumstances for every hour of the year at that location. Weather data file in DesignBuilder software is regularly typical data obtained from hourly measurements at a particular place by the meteorological office or the National Weather Service (Pyrgou et al., 2017). Simulations screen provide a weather data graph by selecting the site data option at the site level. These graphs contain hourly value of the key weather data such as outside dry bulb temperature, outside dew point temperature, wind speed, wind direction, solar attitude, solar azimuth, atmospheric pressure, and direct normal solar (Vuong, Kamel and Fung, 2015).

Energy plus formats hourly weather data has the file extension EPW by convention. DesignBuilder comes with the a large worldwide database of hourly weather data but only the weather file for the default location is initially loaded. With the DesignBuilder, the user can select the template of weather file data for the nearest location from the extensive library (Garg et al., 2017). Unfortunately, the weather file data of Iraq country is not loaded in this library. Therefore, it was necessary to find an alternative solution for this missing data.

A comparison between available weather file data cities of the nearest location in hot climate region (Yazd, Cairo, and Tehran) in the database of the DesginBuilder and Erbil city weather data was done in order to find the most closed one.

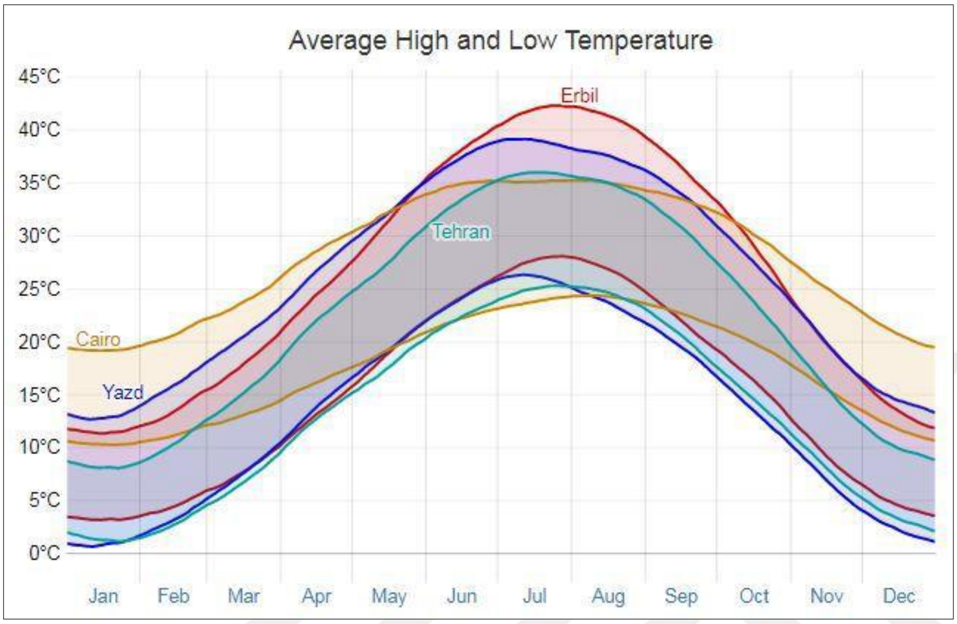


Figure 4.3. Comparison graph of the Average high and low temperature of Erbil, Yazd, Cairo, and Tehran city (https://weatherspark.com/)

As can be seen from the graph in Figure 5.46 Yazd city has almost the same sensitivity of Erbil city in terms of average high and low temperature compared with other cities. In addition, the graph in Figure 5.47 shows the average hourly temperature of the compared four cities and again Yazd city is the most adjacent and has almost the similar performance to Erbil city compared with other rest cities. Accordingly, as Yazd city weather data has almost the similar measurement of Erbil city compared with other analyzed cities, Yazd city weather file data was selected in the simulation process from weather file data database of DesignBuilder.

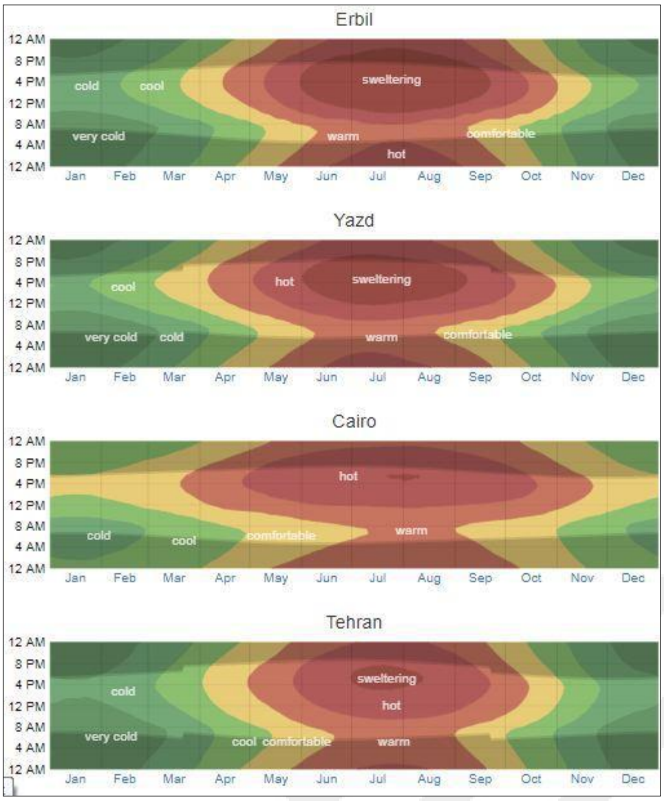


Figure 4.4. Comparison graph shows the average hourly temperature of Erbil, Yazd, Cairo, and Tehran city (https://weatherspark.com/)

4.4. Description of The Simulation Modeling

The proposed passive cooling techniques in this study evaluated in this chapter by using energy simulation method. The modeling process created to develop an energy simulation test room model and used the output result in the actual house simulation model. The selected house for modeling is one of the typical single-family houses located in an occupied residential area in Erbil as a contemporary building. The case study residential building is a prototype building which was constructed of similar construction materials including reinforced concrete structures and masonry walls representing the typical residential buildings in Erbil that also displaying the common weak performance of climatic solutions in modern residential buildings.

4.4.1. Test room model

The case study used in the energy simulation process selected to be a small test room representing a residential thermal zone within the weather conditions of the Erbil city (latitude 36.2° degrees north and 44° E). To evaluate the effect of applying passive cooling techniques in this test room a comparative simulation method used between two rooms modeled to represented the base case before applying passive cooling techniques and energy test room model after applying it. Indoor operative temperature and cooling loads are the main key parameters of the energy simulation to be compared before and after applying passive cooling techniques in the test room.

The following information provides a brief description of the basic parameters which used during the simulation process.

1. The modeled room faced south-north axis and its detentions is 3 meters high with an area of 5 × 5 m. (see Figure 5.2)
2. The energy test room model constructed of similar available building materials such as block walls and reinforced concrete roof slab representing the most used housing buildings materials in Erbil city.
3. The simulation test was conducted within one day (13 July) and with a limited time from 8:00 am to 8:00 pm to include solar radiation heat gain of the building envelopes and windows during the hottest day from sunrise to sunset.
4. Cooling load and indoor operative temperature are the two main parameters to be investigated in each scenario case.
5. The energy modeling room was mechanically ventilated using air conditioning units (Spilt no fresh air) in order to calculate the cooling loads reduction after applying the proposed passive cooling techniques.
6. Windows operation is set to be closed to avoid the fresh air changing rate impact on indoor operative temperature.
7. The test room designed without any door opening in order to neglect the effect of air infiltration and wind prevailing of the surrounding environment on indoor operative temperature.

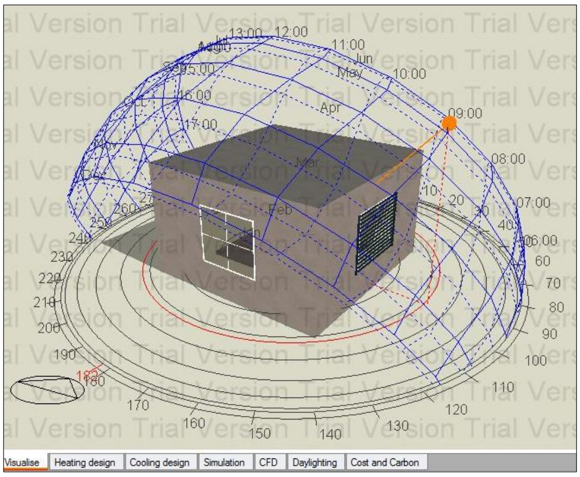


Figure 4.5 Render view of the energy simulation room model using Design Builder

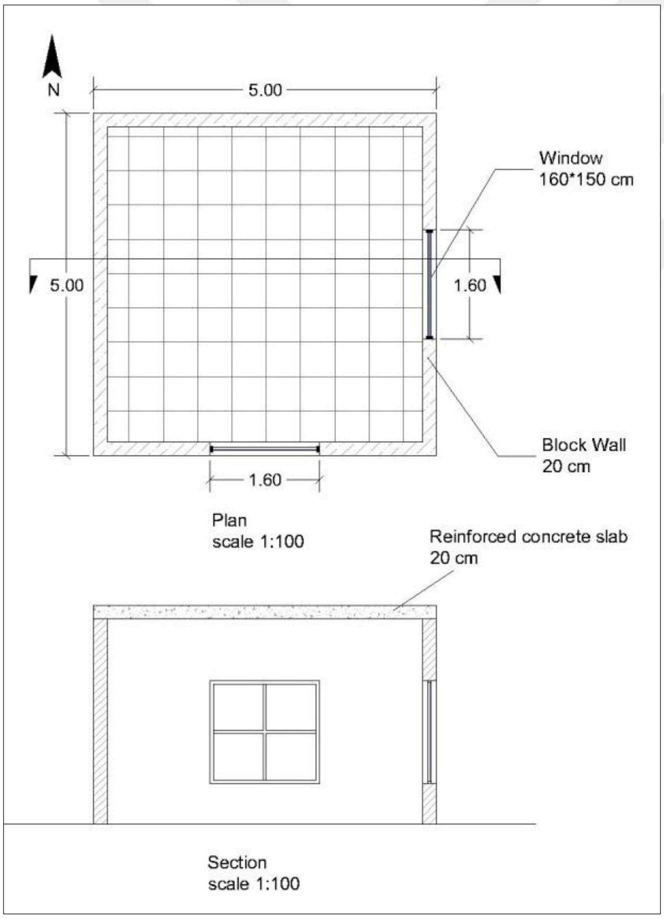


Figure 4.6. Two dimensional drawing (plan and section) of the modeled test room to be used in the energy simulation (drawn by using AutoCAD)

It shall be clarified that test room modeling refers to the task of extracting a best thermal performance of different scenarios deal with the dynamic heat transfer responses of the room model simulated at time steps of 12 hour from 8 am till 8 pm (from sun rise to sunset). Whereas the real house case modeling refers to passive cooling techniques value compared with the base case house with the dynamic heat transfer responses of the house model simulated at summer season focusing on the result of the peak cooling load in July.

4.4.2. Base case actual house model

The house used as the base case for energy modeling in this work is a typical contemporary two-story building occupied by one family (detached house) located in Erbil city. Its main construction materials are the ones generally used in Erbil City such as brick/block walls and reinforced concrete roof slabs. Table 4.1 describes the base case's main features.

Table 4.1. The general components descriptions of base case model

Building Detais	Descriptions
Main structure type	Heavy weight concrete structure
Plot area	300 m² with front garden and car park
Built area	192 m²
Height of floor	3 m
Ground Floor	Descriptions
Glazing template	Single glazing, clear, no shading
Exterior wall materials	Concrete block
Roof type	Flat roof
Roof materials	Reinforced concrete slab
Thermal zone	7 Thermal zones (Entrance, living zone, kitchen zone, circulation zone, two bed rooms and bath room zone)
First Floor	Descriptions
Exterior wall materials	Concrete Block
Roof type	Flat Roof
Roof materials	Reinforced concrete slab
Thermal zone	6 Thermal zones (Balcony, living zone, circulation zone, two bed rooms and bath room zone)

The first step on the model building was drawing a two-dimensional house plan using AutoCAD and converting the file to DXF format to be imported into DesignBuilder program (see Figure 4.7).

Figure 4.7. Two dimensional drawing (floor plans) of the energy simulation by using AutoCAD

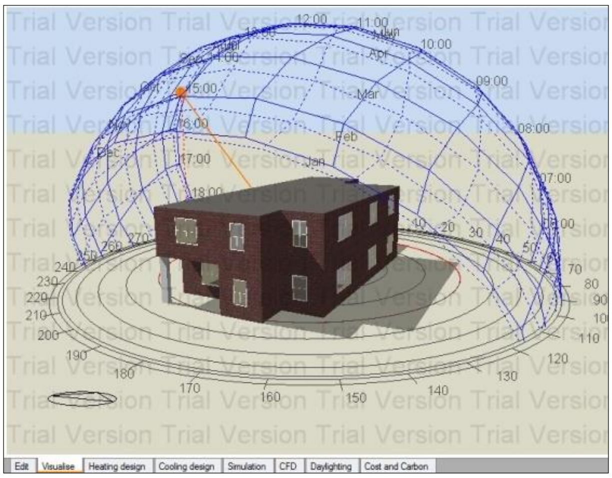


Figure 4.8. Render view of the energy simulation model by using DesignBuilder

5. SIMULATION ANALYSIS AND RESULT DISCUSSION

This doctoral research seeks to find natural methods to reduce energy consumption in a residential building. After investigating various research studies focusing on the most effective methods for reducing dependency on mechanical air conditioning, I found that passive cooling techniques offer extremely good thermal comfort and decrease energy consumption significantly. As mentioned in the literature review (section 2.1 Fundamentals of Passive Cooling)**,** passive cooling system of buildings is broadly classified into three sections (1) prevention of heat gains; (2) modulation of heat gains and (3) heat dissipation or remove internal heat. However, the energy simulation process simulates the proposed passive cooling techniques in different scenarios focusing on the first two stages; therefore, third strategy which is focusing on remove internal heat techniques by natural ventilation is neglected, since the simulated models using mechanical air conditioning system for ventilation. Table 5.1 shows the different passive cooling strategies and the simulation test scenarios under each scenario in detail.

The main methods of the simulation process in this chapter can be clarified in two steps :

First: To develop an energy simulation test room model and used the output result in the actual house simulation model, In another word, the small test room model is developed for the specific following purposes:

1. Analysis of the thermal mass performance of different wall construction materials to find out the best wall materials.
2. To propose a thermal dynamic optimum model that can aid thermal mass design decisions in terms of thermal insulation layer position in building walls and roofs.

Second: To develop an actual house simulation model using the best thermal simulation scenarios extracting from the small test room model in order to achiev the following purpose:

1. To compare the base case actual house model with the proposed energy efficient house model after applying the passive cooling techniques in order to find out the cooling load reduction rate.

2. After finishing the simulation analysis, the outcomes of the simulation and passive cooling scenarios are then analyzed in order to provide the answer to the research hypothesis and questions and develop the final recommendation of the study.

Table 5.1. The matrix of energy simulation process showing applied passive cooling technique with simulation scenarios

Strategy 1. Prevent heat gains	
Applied Passive Cooling Techniques	Simulation Scenarios
1. Shading	a) Windows Shading b) Roof Shading c) Wall Shading
2. Glazing	a) Single clear glass, 6mm (base case) b) Double clear glass, 6mm/13mm c) Triple clear glass, 3mm/13mm d) Double low-E colored glass, 6mm/6mm
Strategy 2. Modify heat gains	
Applied Passive Cooling Techniques	Simulation Scenarios
3. Wall Thermal Mass and Insulation Layer Position	a) Solid brick wall b) Hollow brick wall c) Solid concrete block wall d) Hollow concrete block wall e) Thermostone wall
4. Roof Thermal Mass and Insulation Layer Position	a) Roof without insulation (base case) b) Roof with exterior insulation c) Roof with interior insulation

5.1. Passive Cooling Techniques Simulation in the Test Room Model

While the energy simulation process looking at the thermal performance of the test room during the summer season the fundamental principles of heat exchange between the room and its environment should be explained. Heat is transferred between the building and its surrounding environment through the building envelope. There are three methods of heat transfer: convection, conduction, and radiation. Heat flow depends on temperature difference, surface areas involved, distance traveled, and surface characteristics (Yang, Zhu and Liu, 2017). Heat is transferred by conduction within building envelope components such as the wall, roof, floor, and windows. The primary source of radiant heat is the sun which significantly increases heat gain if the building is exposed to direct sun rays. Building material absorbs solar radiant heat and re-radiates it inside the building since heat is always transferred from hotter to cooler areas.

Thermal performance of a building envelope depends on many parameters such as design variables, internal heat gain through light and equipment, material thermal features, weather conditions, and occupancy profile. All these parameters should be carefully taken into account when assessing the thermal performance of the simulated building. Cooling design calculations in DesignBuilder use periodic steady-state external temperatures calculated using the maximum and minimum design summer weather conditions. The simulation calculates half-hourly temperatures and heat flows for each zone and determines the cooling capacities required to maintain any cooling temperature set points in each zone (Garg et al., 2017). The calculation assumes still ambient air conditions (no wind), includes solar gain through windows and natural ventilation along with internal gains from occupants lighting and other equipment, and considers heat conduction and convection between zones of different temperatures (Garg et al., 2017).

Result of the first strategy (reduce heat gain technique)

Solar heat gain of buildings located in hot climate regions is caused mainly by the solar rays during hot summer days. In sunny hot climates, air conditioning is the main system to cool the building and solution should be taken to prevent building solar heat gain in order to reduce air conditioning usage. Although the location and the position of the building have a great effect on its solar heat gain, there are many steps we can take to reduce building heat gain. Passive solar design principles are the main solution to reduce building heat gain being proposed in this simulation work.

Reduce heat gain is the first step to achieve passive cooling of the buildings (Santamouris and Kolokotsa, 2013). Control solar radiation and minimizing heat reaching the building can be achieved under two scales: microclimate scale and building scale. Reduce heat gain techniques under microclimate scale are neglected in the energy simulation process.

Shading scenarios using vernacular Mashrabiya concept

Appropriate external solar shading can significantly help to reduce cooling energy consumption and improved indoor thermal comfort. One of the proposed passive cooling techniques in this work is the re-designed traditional Mashrabiya elements. The proposed Mashrabiya elements is used in three different shading scenarios (windows shading scenario, wall shading scenario and roof shading scenario). To provide a better understanding of the suggested solution in this step, a specific characteristics of the re-designed new Mashrabiya is described as follows:

1. The proposed Mashrabiya designed to prevent direct solar radiation heat gain whilst ensuring natural lighting and ventilation through its opening (see Figure.
2. It is effective in controlling direct summer sun through providing shading without reducing internal daylight acceptable levels.
3. It is a portable shading device that can be removed to maximize solar gain during the winter season.
4. It is a local traditional element which redesigned in the contemporary form to act as a climate control element whilst enhancing local architecture identity. This design concept corresponds with the philosophy of Hassan Fathy as he encourages architects to learn lessons from vernacular architecture to be as a source of inspiration in modern architecture context. The proposal new Mashrabiya applied by three different scenarios as follows.

5.1.1. Windows shading scenario

As mentioned in literature review, one of the most effective elements to provide shading and enhance thermal comfort which traditionally used in housing building is Mashrabiya element. The main function of this traditional element is its ability on controlling of direct solar radiation on windows and outdoor passage air, thus it will be efficient to utilize natural ventilation and daylighting (Abdelsalamand Rihan, 2013). Regarding its role in controlling both the outdoor air and natural light, it could help to reduce cooling loads of indoor spaces which investigated in room test modeled by running a thermal performance simulation using DesignBuilder software. The energy simulation was run based on a comparison analysis method between tow room models, the base case room, and the energy efficient room model which represent the case after applying Mashrabiya to cover the exterior windows.

Outcomes and results from running the simulation analyzed to evaluate the influence of using the proposed cooling methods on indoor operative temperature and cooling energy performance.

Table 5.2. The case study in this step of the simulation (windows shading)

First Strategy : Reduce heat gains techniques				
Applied Passive Cooling Techniques	Simulation Scenarios			
1.Shading	Windows Shading		Roof Shading	Wall Shading
2.Glazing	Base case Single clear glass (6mm)	Double Clear Glass 6mm/13mm Air	Triple Clear Glass 3mm/13mm Air	Double Low-E Colored Glass 6mm/6mm Air

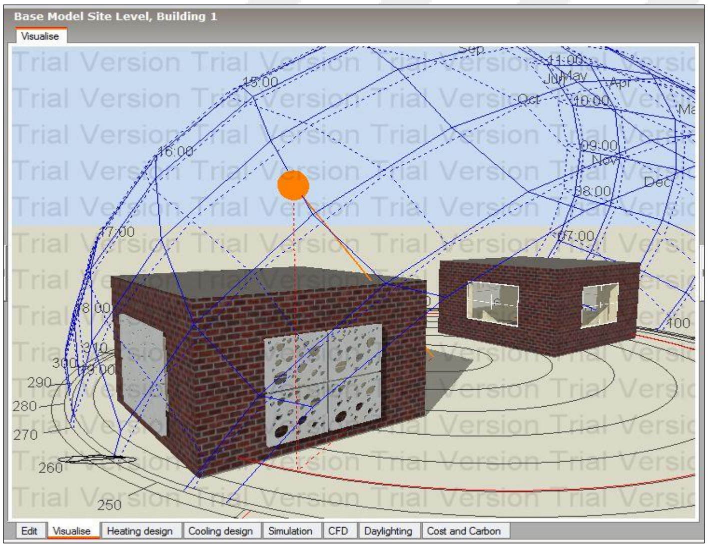


Figure 5.1. Render view showing the base case room and the energy efficient room model (after applying Mashrabiya to cover the exterior windows) modeled by DesignBuilder software

Solar gain through exterior windows has been reduced from 150 kW in the base room to approximately 30 kW in the energy efficient room after adding Mashrabiya as reflected in figure 5.2 and 5.3. Accordingly, the cooling load of the modeled energy efficient room recording a great reduction from 100 kW to 60 kW during the peak cooling load due to the proposed shading solution which preventing a huge amount of heat gain to pass through exterior windows of July month.

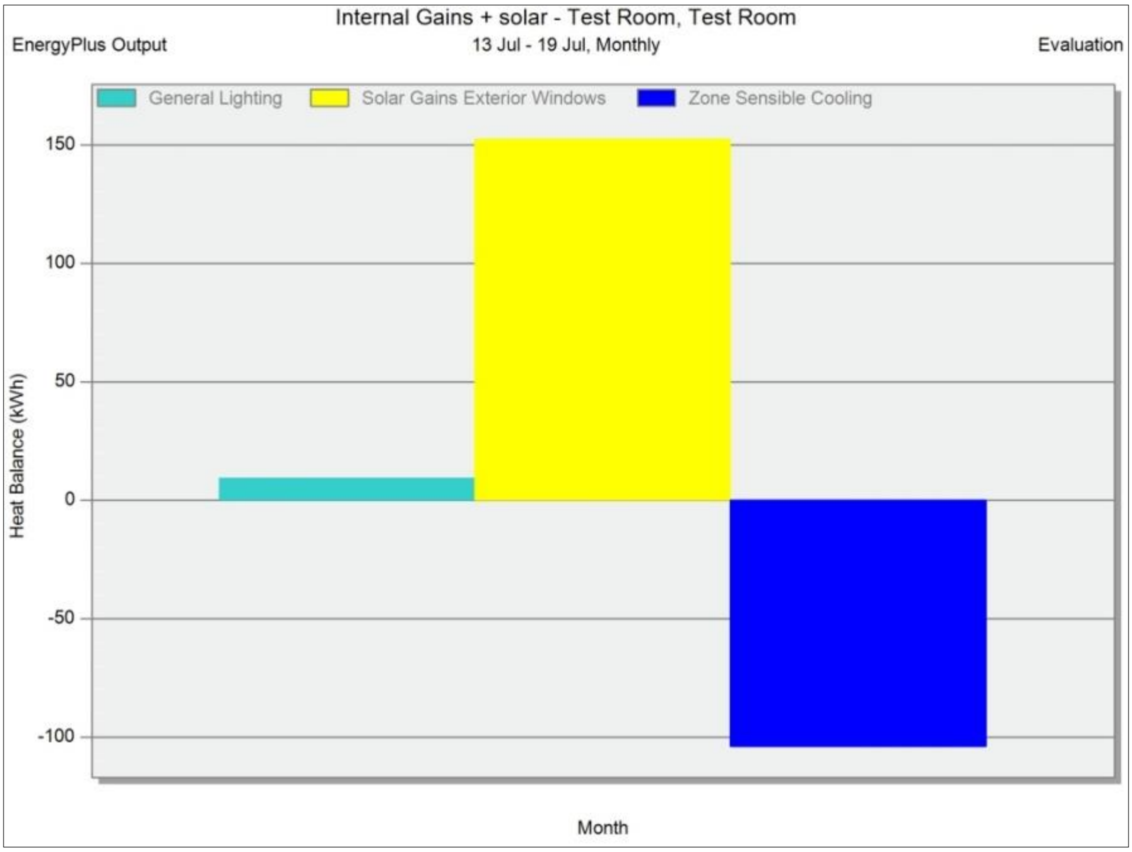


Figure 5.2. Simulation result showing internal gain through the exterior windows before adding proposal screen shading (Mashrabiya)

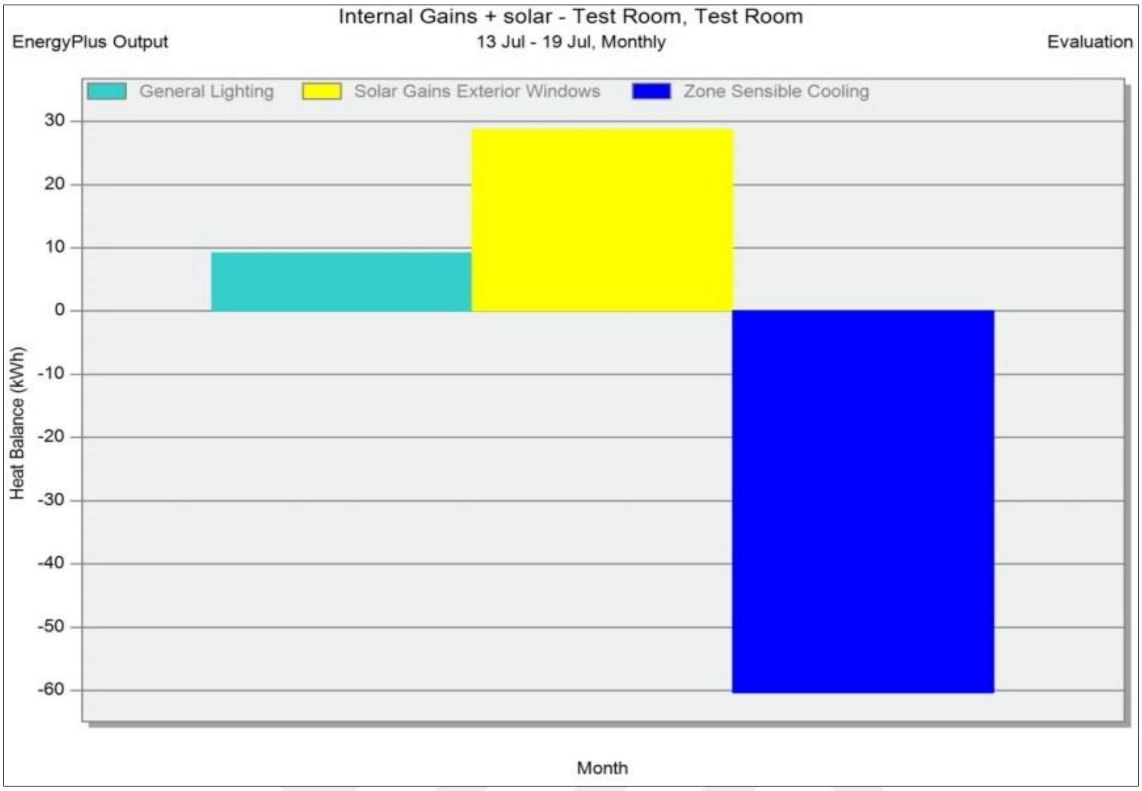


Figure 5.3. Simulation result showing internal heat gain through the exterior windows after adding proposal screen shading (Mashrabiya)

Indoor operative or sometimes called comfort temperature is a combination of the air and the radiant temperature which was set as the correct control parameters in the simulation analysis. It is a measure of the average perceived temperature in each zone. Graph in Figure 5.4 and 5.5, shows the performance of the tested two rooms in terms of indoor operative temperature. Adding exterior Mashrabiya shading elements has significantly reduced the indoor operative temperature in a range of 1~ 2K. This reduction in the rate of indoor operative temperature has, in turn, reducing the cooling load from approximately 4.89 kW in the base room to about 3.15 kW in the energy efficient room after adding Mashrabiya.

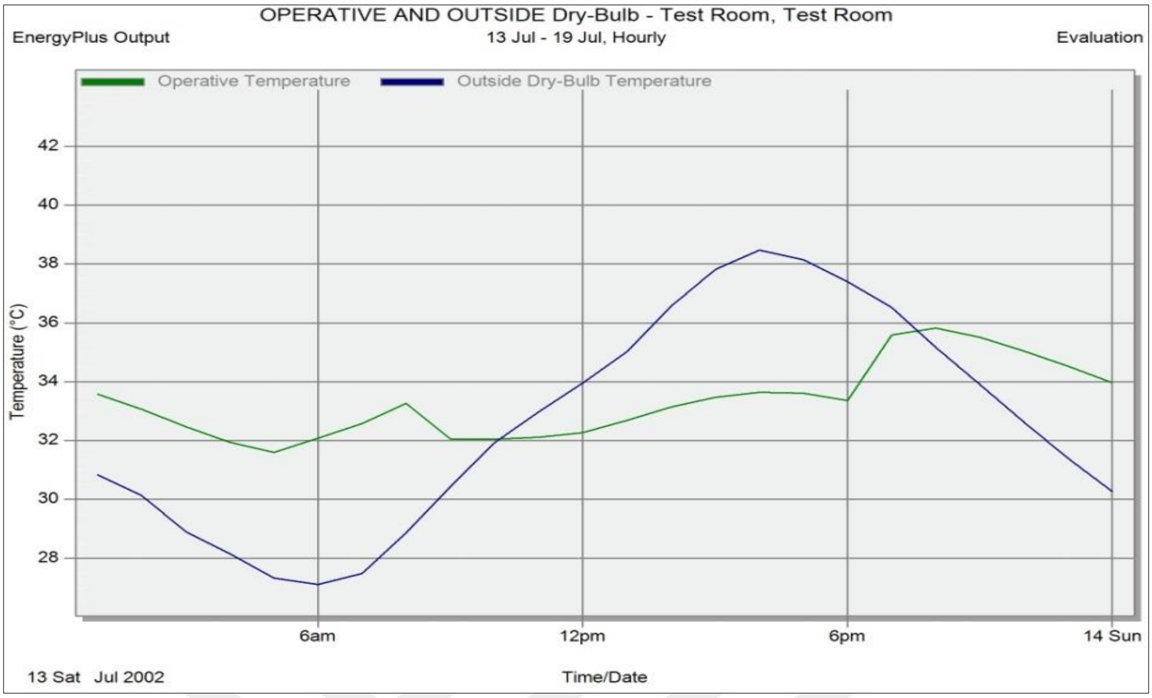


Figure 5.4. Simulation result showing internal gain through the exterior windows before adding proposal screen shading (Mashrabiya)

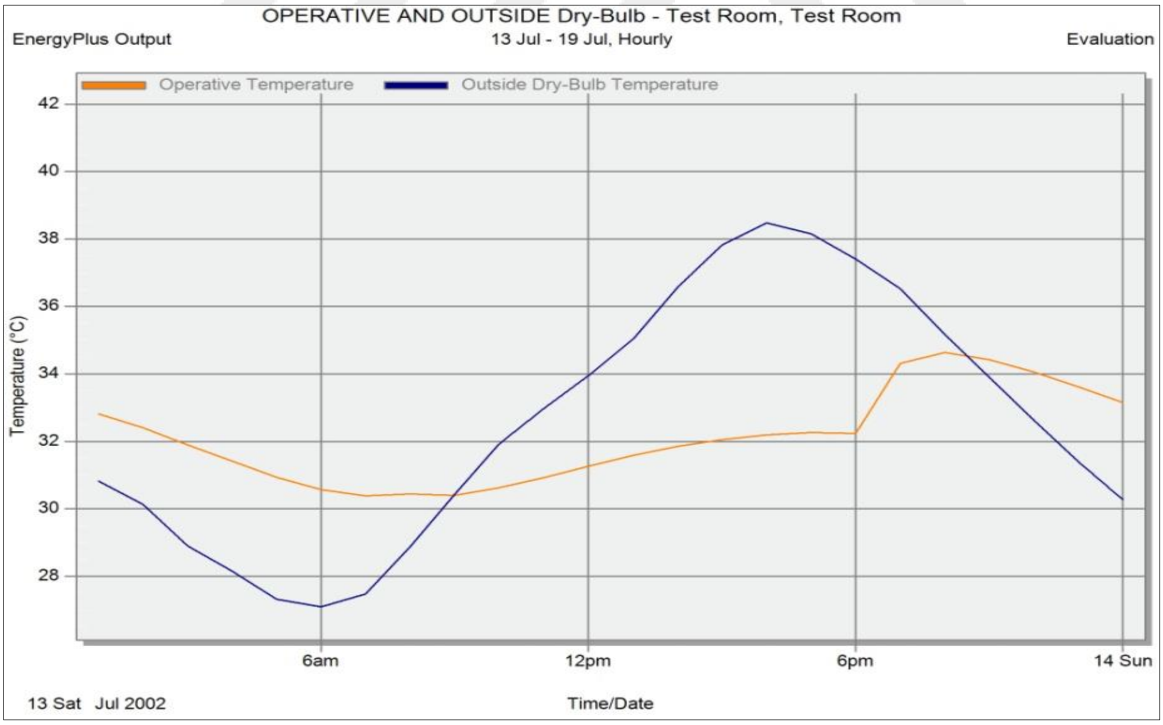


Figure 5.5. Simulation result showing internal heat gain through the exterior windows after adding proposal screen shading (Mashrabiya)

In addition, simulation of using Mashrabiya at each orientation has been done separately in order to find out the effectiveness of using this solution in each direction. As can be seen from the graph in Figure 5.6 simulation results showing the effect of applying Mashrabiya at East and West orientation approximately has the same influence reflected in indoor operative temperature fluctuate between 36- 43 °C in 24 hours simulation day . Similarly, applying Mashrabya on North and South orientation has the same influence on indoor operative temperature in the room model zone. If we compare between all the orientation scenarios, it's clear that applying Mashrabya on west and East orientation has decreased the indoor operative temperature approximately 1-1.5 °C more than applying it in the North and South facade orientation. Therefore shading the exterior windows in West and East facade are most effective than North and South facade.

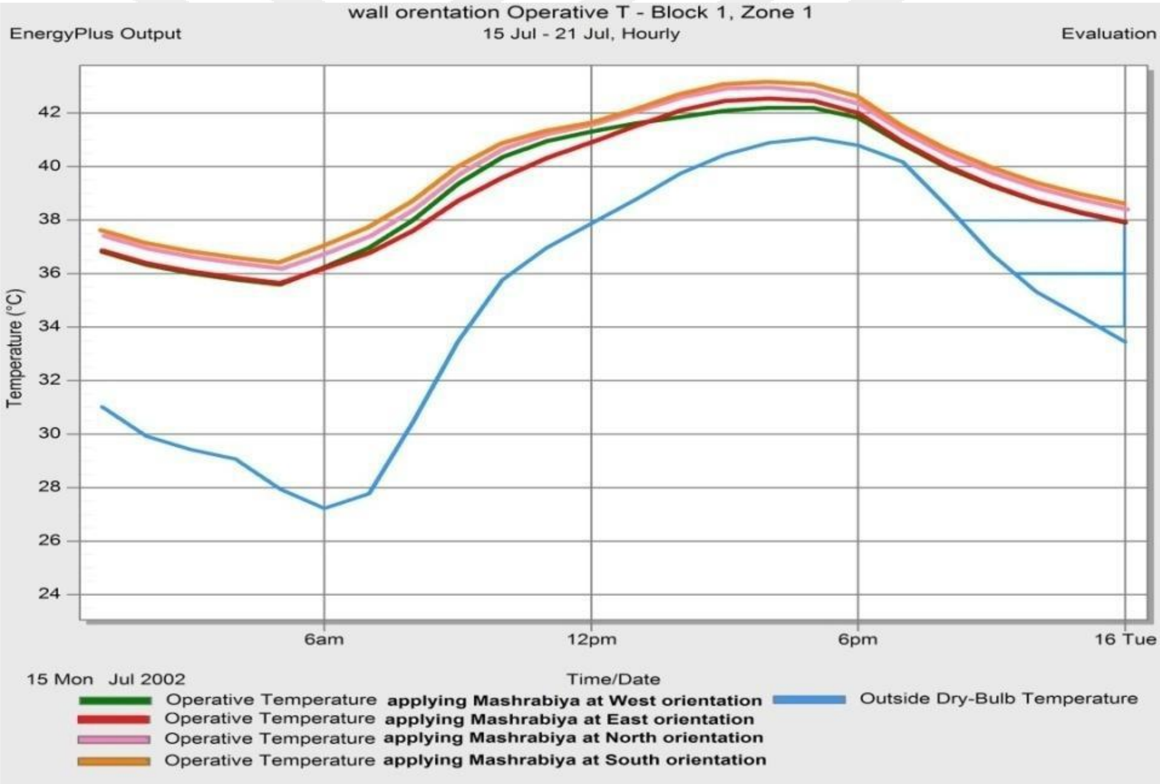


Figure 5.6. Simulation results showing the effect of applying Mashrabiya at East, West, North and South orientation on indoor operative temperature in the chamber model zone on 15 July

Table 5.3. Output data of the windows shading scenarios shows the effect of each scenario on cooling load reduction

Scenario	Max Indoor Operative Temperature	Total Cooling load (kW)	Cooling load Reduction %
Base case Room	33.7	4.89	-
Energy efficient Room Applying Mashrabya in all direction	32.1	3.15	1.74 %
Applying Mashrabya in South direction	33.4	4.58	0.31 %
Applying Mashrabya in North direction	33.7	4.81	0.08 %
Applying Mashrabya in East direction	32.6	4.26	0.63 %
Applying Mashrabya in West direction	32.4	4.21	0.67 %

The result showed in Figure 5.7 shows that there is a slightly different cooling load amount between east and west but a significant difference comparing with north and South facade orientation.

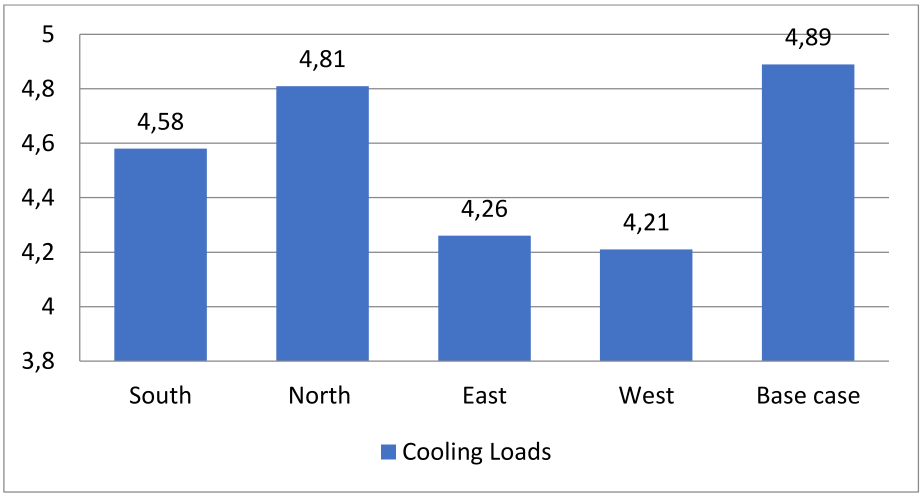


Figure 5.7. Result data showing the effect of using Mashrabiya on cooling loads in each facade orientation

5.1.2. Roof shading scenario

The flat roof of the houses located in Iraq is considered as the most exposed building envelope component to the impacts of solar radiation, therefore, flat roof receives sunlight for almost the whole of the day time. Heat gain through flat roof surface causes an increase in indoor temperature of the under-roof spaces. In this situation, it is necessary to apply or suggest a solution toward preventing heat flux from flat roof surface toward indoor spaces. Flat roof shading is one of the passive cooling design solutions due to the great shading provided by roof covering. Minimize heat gain from the flat roof and improve indoor thermal comfort through using roof covering can be considered as one of the easy to install strategies (Zinzi and Agnoli, 2012). When a house roof exposed all the day time to direct solar radiation on a hot summer day, heat is transfer by radiation mode of heat transfer processes to the flat roof surface and then from roof to internal space by conduction as shown in Figure 5.8. Excess solar gain may result in increased thermal discomfort and therefore increased cooling energy consumption.

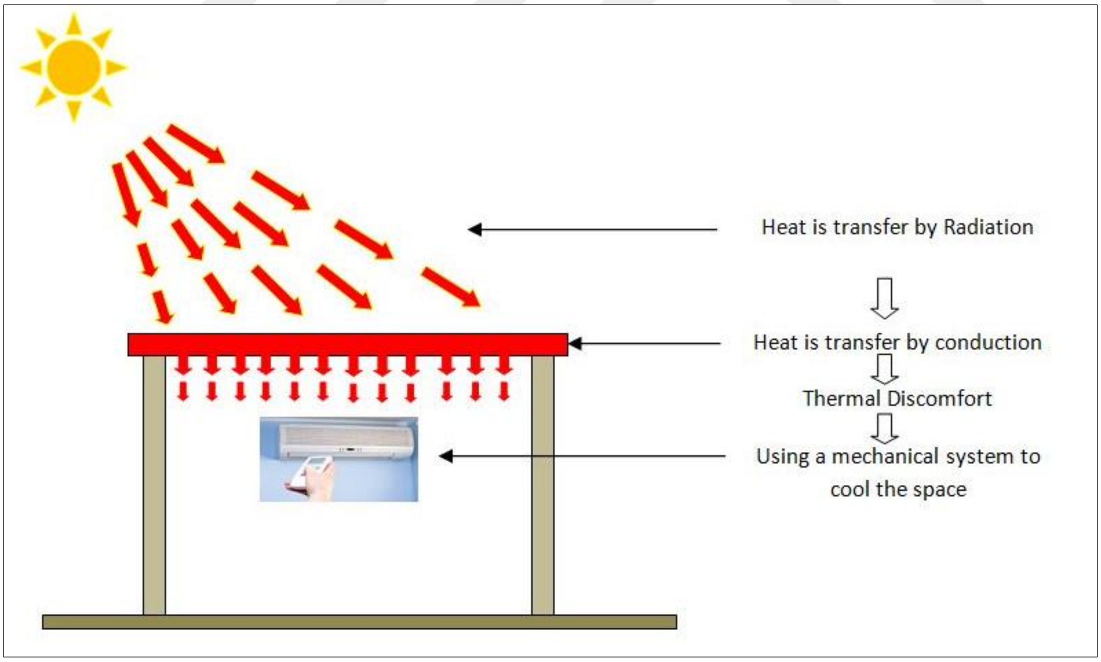


Figure 5.8. Diagram showing heat flux through the flat roof result in increased thermal discomfort and thus increase cooling energy consumption, details by author

Overhangs roof shading techniques are very effective at blocking solar radiation heat during the summer period especially when the sun angle is higher in the sky at midday time. one of the essential design decision is to shading any exterior windows from direct sun breakthrough and to minimize the heat transportation through the building skin such as walls and roof which are exposed to direct sun radiation (Madhumathi, Radhakrishnan and Shanthipriya, 2016). Direct solar radiation can be blocked by using overhang shading screen which is one of the sun control shading techniques. Using roof shading techniques reduce heat from solar radiation and that's reduction will result in reduce heat transfer by conduction and improve thermal comfort. (see Figure 5.9)

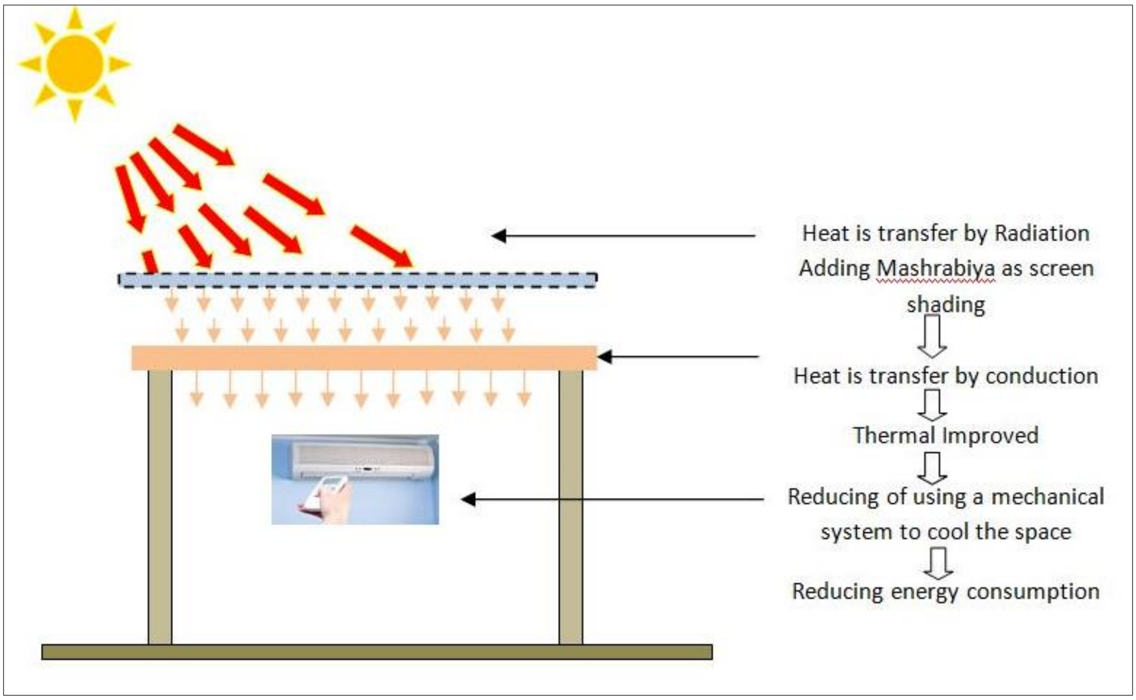


Figure 5.9. Diagram showing heat flux through the flat roof result in decrease thermal discomfort and thus decrease cooling energy consumption

The proposed screen shading of the flat roof in this study has flexibility for using the materials type of the screen shading (fabric, aluminum sheet, plastic, lightweight cement board). However, consideration about the glare from sunlight and the noise from rain or wind when selecting the materials should be considered. In addition, screen shading should not block the heat transfer from re-radiation during night time. Therefore, the most effective roof shading screen types for hot climate regions is a ventilated screen. In this type of screen shading which has an opening to allow air movement flow through it, the heat between the flat roof and screen shading is removed by the air flow crossing the roof space by the prevailing winds. Because of the opening in the screen shading which is playing as the outlet opening, the heat is reduced during daytime while air is moving through the roof space and removes by re-radiation during the night. (See Figure 5.10)

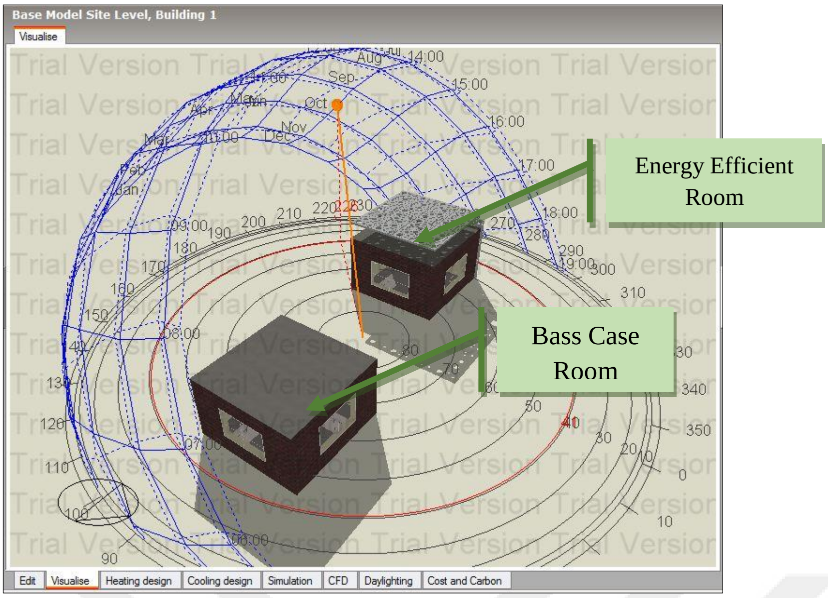


Figure 5.10. Render view showing the bass case room and the energy efficient room after applying Mashrabiya roof shading, modeled by DesignBuilder software

Table 5.4. The case study in this step of the simulation process (roof shading)

First Strategy : Reduce heat gains techniques				
Applied Passive Cooling Techniques	Simulation Scenarios			
1.Shading	Windows Shading	Roof Shading	Wall Shading	
2.Glazing	Base case Single clear glass (6mm)	Double Clear Glass 6mm/13mm Air	Triple Clear Glass3mm/13mm Air	Double Low-E Colored Glass 6mm/6mm Air

For the purpose of simulation, two rooms modeled under the same design variables such as construction materials, orientation, windows size and direction. The only different parameter between the two modeled rooms is the roof cover shading by using the proposed Mashrabiya screen. Simulation of the thermal performance of both modeled rooms is compared to find out the evaluation parameters (indoor operative temperature and cooling load) changing rate. Looking to the graph shown in Figure 5.11 and 5.12, the simulation results detected that, by adding screen shading up to the flat roof and create shading from direct solar radiation, there was a great effect in lowering indoor operative temperature about 1 ~ 1.5 K from 34~32.5 °C comparing with indoor operative temperature before adding the proposal screen shading.

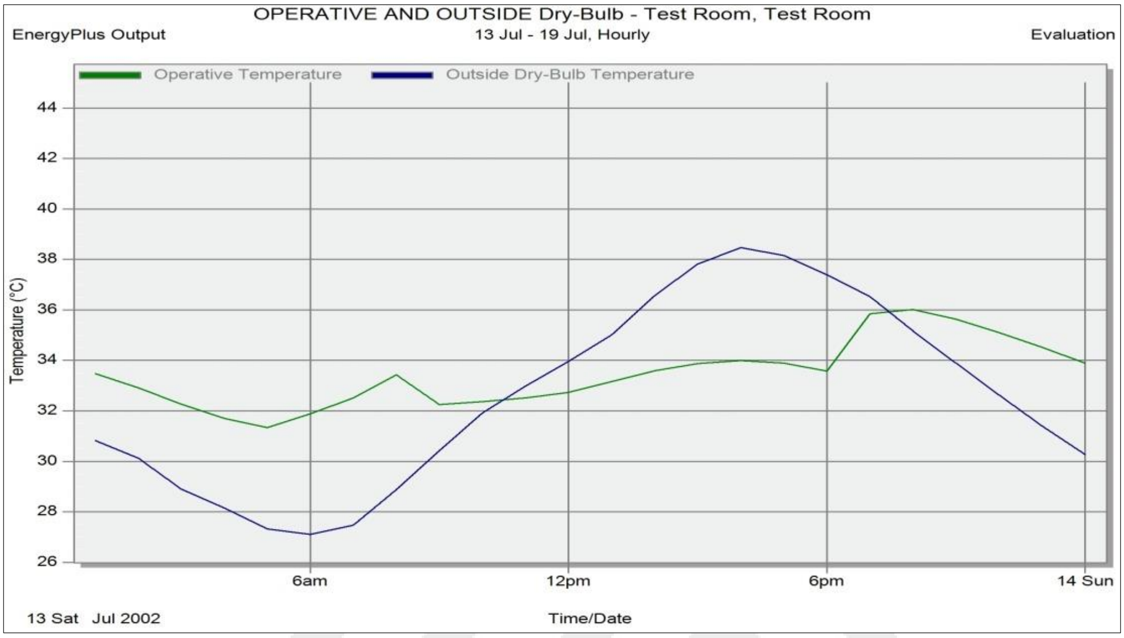


Figure 5.11. Simulation results of the base case room shows indoor operative temperature performance before using the flat roof screen shading.

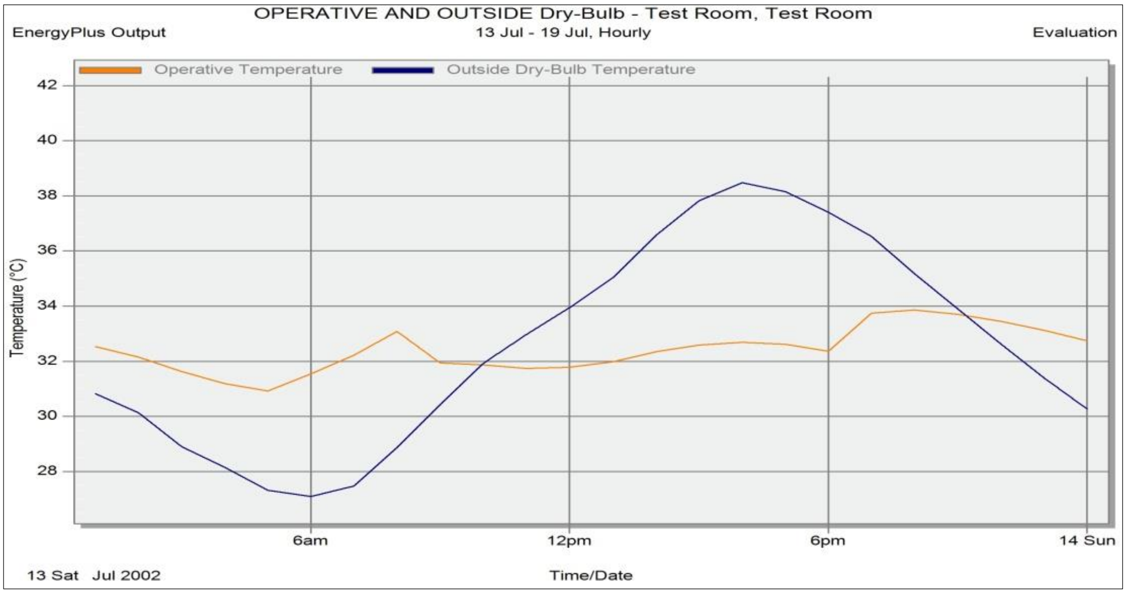


Figure 5.12. Simulation results of the energy efficient room shows indoor operative temperature performance after using the flat roof screen shading

The detailed simulation result graph in Figure 5.13 has shown the heat balance at the building envelope and structure. We can see the beneficial effect of shading the flat roof as it prevents heat flows during daytime which helps reduce the peak cooling loads. Heat conduction through the flat roof results in the most significant fabric heat gain of the base case room recorded more than 2 kW at around 6:00 pm in the base case room simulation result. Running the simulation again after shading the flat roof by using the proposed Mashrabiya has reduced the heat conduction through the flat roof from 2 kW to 0.5 at around 6:00 pm as can be seen in Figure 5.13 and 5.14. The mechanical ventilation operation scheduled period of the daytime has recorded the maximum amount of cooling load 5 kW at around 4:00 pm as can be seen in Figure 5.13. Indoor operative temperature in the base case room (before shading the flat roof by Mashrabiya) was higher than indoor operative temperature in energy efficient room throughout the time of mechanical system operation time from 8:00 am till 8:00 pm as shown in Figure 5.11 and 5.12. Therefore, In the base case room the mechanical ventilation operation scheduled of the daytime has recorded the maximum amount of cooling load at around 5.04 kW at 4:00 pm (as can be seen in Figure 5.13) whereas the maximum amount of cooling load at around 2.92 kW at 4:00 pm in the energy efficient room (after shading the flat roof by Mashrabiya). This means that shading the flat roof by using Mashrabiya has reduced the cooling loads from 5 kW at 4:00 pm to 2.8 kW at the same time.

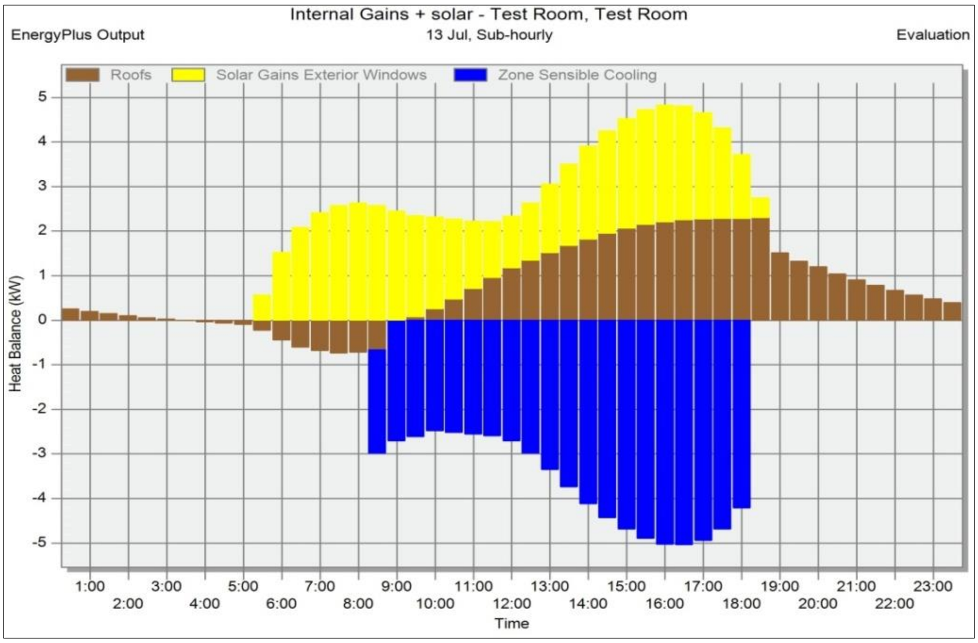


Figure 5.13. Simulation results graph of the base case room shows the roof heat gain and its effect on cooling load

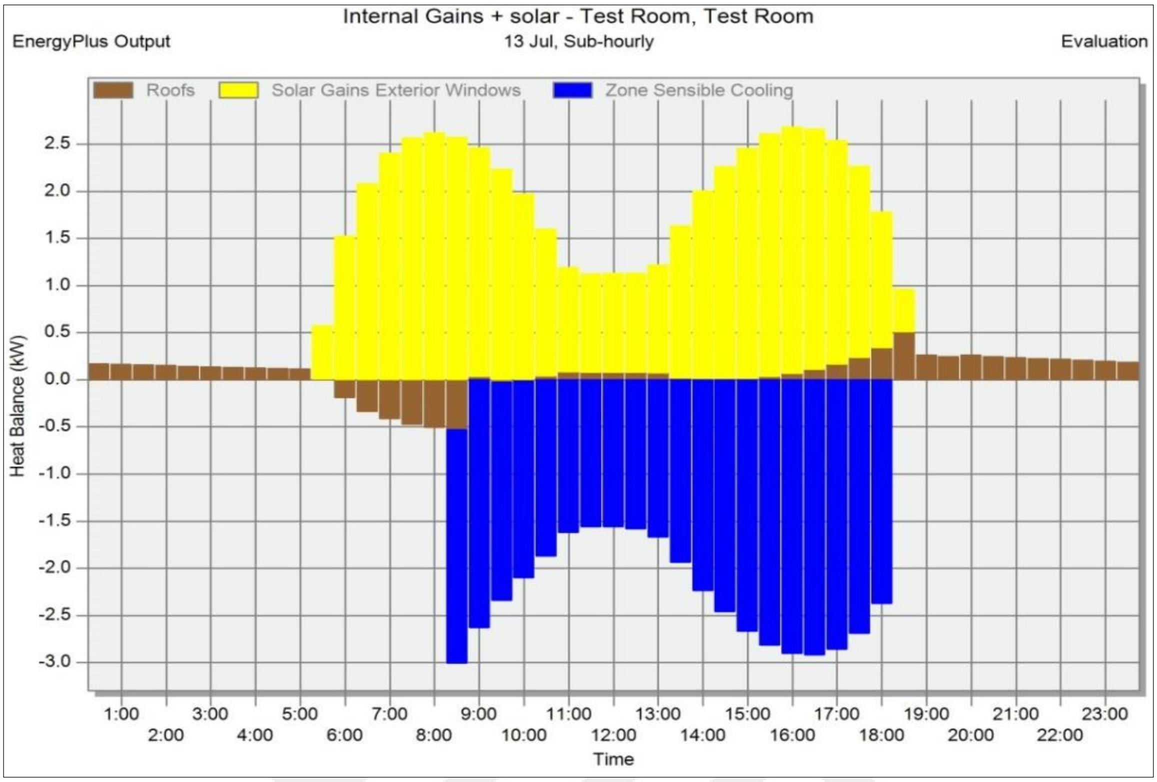


Figure 5.14. Simulation results graph of the energy efficient room shows the roof heat gain and its effect on cooling load

Positively, the proposed solution of applying screen shading to cover the flat roof show variation in indoor operative temperature compared with the base case room, that decreasing resulted to minimize the cooling loads from 5.04 kW to 2.92 kW as shows in Figure 5.15 and 5.16 which is approximately 2.12 % reduction.

Test Room, Test Room

Analysis | Summary

Zone	Design Capacity (kW)	Design Flow Rate (m3/s)	Total Cooling Load (kW)	Sensible (kW)
Test Room				
Block1:Zone1	**5.80**	**0.5318**	5.04	5.04
Totals	**5.80**	**0.5318**	**5.04**	**5.04**

Figure 5.15. Simulation results of the base case room shows the cooling load calculation started from 8:00 am to 8:00 pm on 13 of July

Test Room, Test Room

Analysis | Summary

Zone	Design Capacity (kW)	Design Flow Rate (m3/s)	Total Cooling Load (kW)	Sensible (kW)
Test Room				
Block1:Zone1	**3.36**	**0.2419**	2.92	2.92
Totals	**3.36**	**0.2419**	**2.92**	**2.92**

Figure 5.16. Simulation results of the energy efficient room shows the cooling load calculation started from 8:00 am to 8:00 pm on 13 of July

Direct solar radiation control techniques can be reduced energy consumption by minimizing the dependency on mechanical air conditioning system. Some other techniques might be effective and less costly to install such as: using a highly reflective surface on the outer surface of the flat roof to minimize the amount of solar energy absorption, high reflective metal sheet and light colored finishing are the most common technological solution (Zinzi and Agnoli, 2012).

5.1.3. Walls shading scenario

The element of nature and the weather have always a quite affect in our daily life and thermal comfort issue. To limit the negative impact of overheating by solar heat gain during hot summer days, external wall shading as a passive cooling technique is proposed in this step to evaluate its effect on lowering indoor operative temperature which leads to decrease the amount of energy cooling consumption. In Iraq the external wall surface areas are quite large, and become really hot during summer under the effect of direct sun radiation. As mentioned before the basic construction material in Iraq is a masonry wall (brick or block) which is a heavyweight material considered as high thermal mass materials and normally stores the heat during summer daytime. Usually, a wall which is exposed to the direct sun will receive solar radiation heat throughout the day. This heat will build up inside the wall and gradually increase with the amount of time exposed. The walls not only observed heat but also reradiate the trucked heat back to the surrounding environment. In this case, the wall reradiates the heat it absorbs at night which raises the indoor air temperature although it is cool outdoor (sometimes indoor temperature even higher than the outdoor temperature).

Therefore, the suggested passive cooling solution here is to add another layer outside the wall to act as a skin to already existing walls. This skin is mainly created to protect and shade the main wall surfaces from direct solar radiation. The form concept of the proposed skin is derived from traditional Mashrabiya elements, so it has an opening to allow natural air and daylight to pass through it. In addition, this opening will help to play a significant role in cooling the main wall by natural ventilation. In addition, there is an air gap between the main wall and the proposed outside skin layer which helps to cool both of them by natural air pass-through the small opening of the outer proposed skin. If there is a free area (more than one meter) this air gap could be designed as a buffer space which increases thermal comfort and could provide privacy for house occupants which was one of the main purposes of the traditional Mashrabya element.

The proposed second skin should be constructed from a lightweight material such as cements cellulose fiber and installed directly onto the surface of the main existing walls. It is also painted in white in order to reduce heat observation. A comparative thermal dynamics simulation to examine whether this proposed skin will help to decrease the indoor operative temperature and decrease cooling load is analyzed as follows.

The same previous test room models used in two scenarios. The first scenario of the base case room will evaluate the thermal performance of the room without adding the proposed skin and the second scenario run the simulation with adding the proposed skin covering the external wall surfaces in all orientation to compare between the two output results in terms of indoor operative temperature and cooling loads. (see Figure 5.17)

Table 5.5. The case study in this step of the simulation process (wall shading)

<table>
<tr><td colspan="6">First Strategy : Reduce heat gains techniques</td></tr>
<tr><td>Applied Passive Cooling Techniques</td><td colspan="5">Simulation Scenarios</td></tr>
<tr><td>1.Shading</td><td>Windows Shading</td><td colspan="2">Roof Shading</td><td colspan="2">Wall Shading</td></tr>
<tr><td>2.Glazing</td><td>Base case
Single clear glass (6mm)</td><td>Double Clear Glass 6mm/13mm Air</td><td colspan="2">Triple Clear Glass3mm/13mm Air</td><td>Double Low-E Colored Glass 6mm/6mm Air</td></tr>
</table>

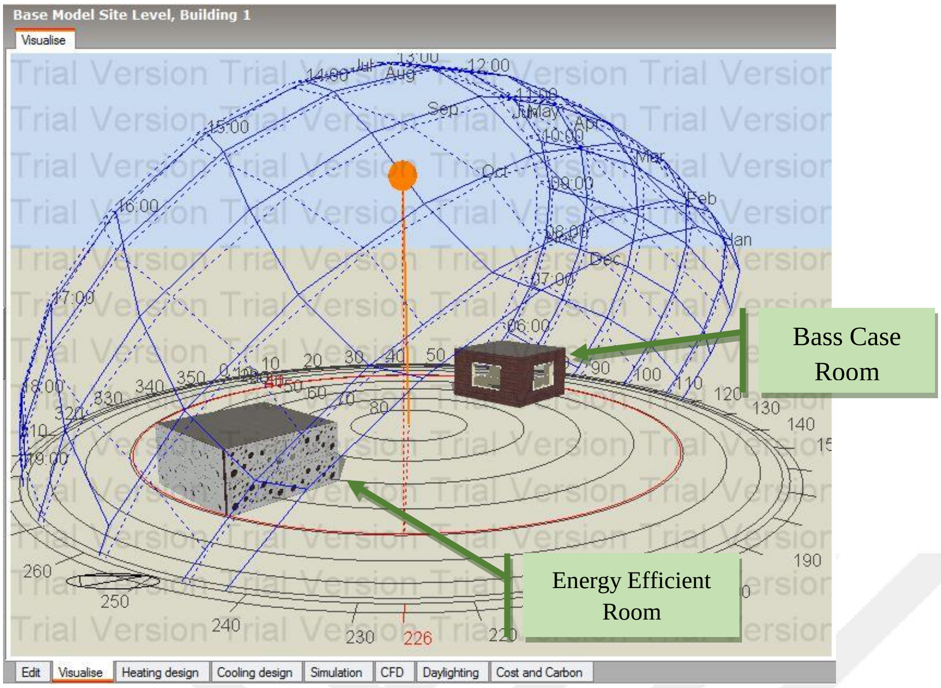


Figure 5.17. The two-room model expressing the two different scenarios within and without the proposed Mashrabiya layer

If we compare between the simulation result of the base case room against the energy efficient room shown in Figure 5.18 and 5.19, we can recognized that, by adding external skin to shadow the main wall, there was a slightly effect in lowering indoor operative temperature about 0.4 ~ 0.8 K from 32.6~31.8 °C at 6:00 pm comparing with indoor operative temperature before adding the proposal screen shading.

Heat conduction through the wall of the base case room recorded more than 1 kW at around 6:30 pm in the base case room simulation result as can be seen in Figure 5.20. After shading the external wall by using the proposed Mashrabiya simulation result shows that there is a small reduced of heat conduction through the wall recorded 0.75 kW at around 6:30 pm as can be seen in Figure 5.21.

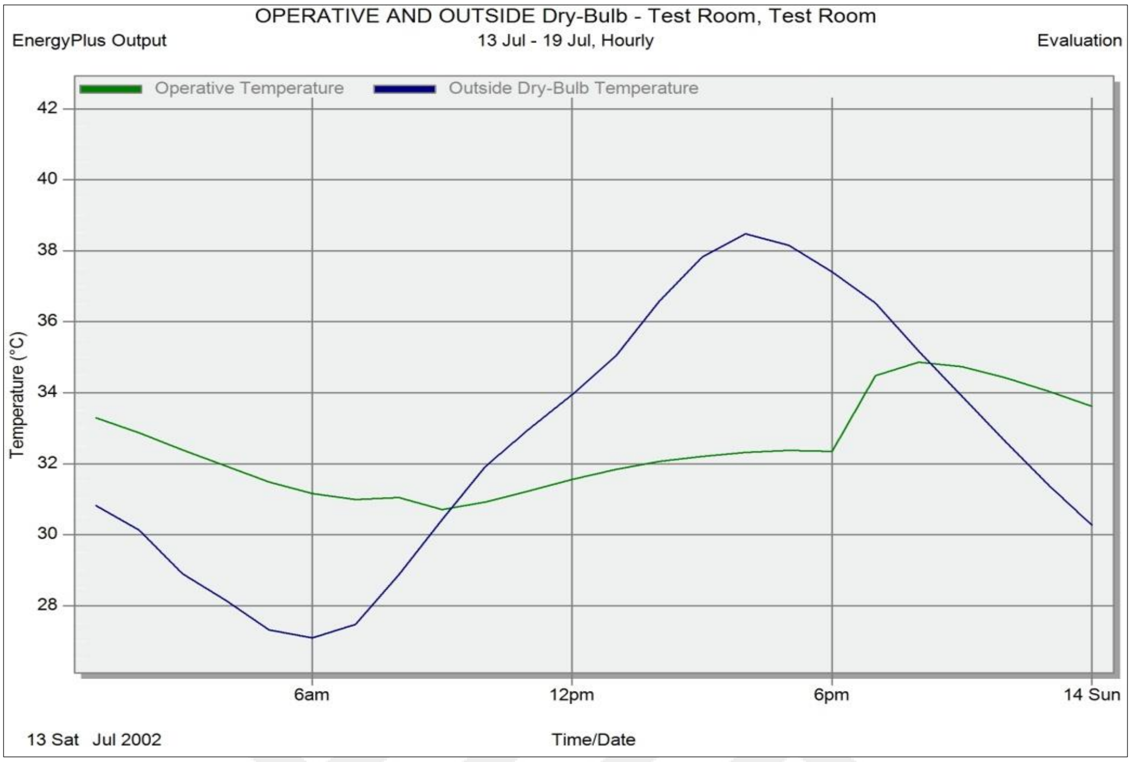


Figure 5.18. Simulation results of the base case room shows indoor operative temperature performance before using Mashrabiya to shadow the main wall

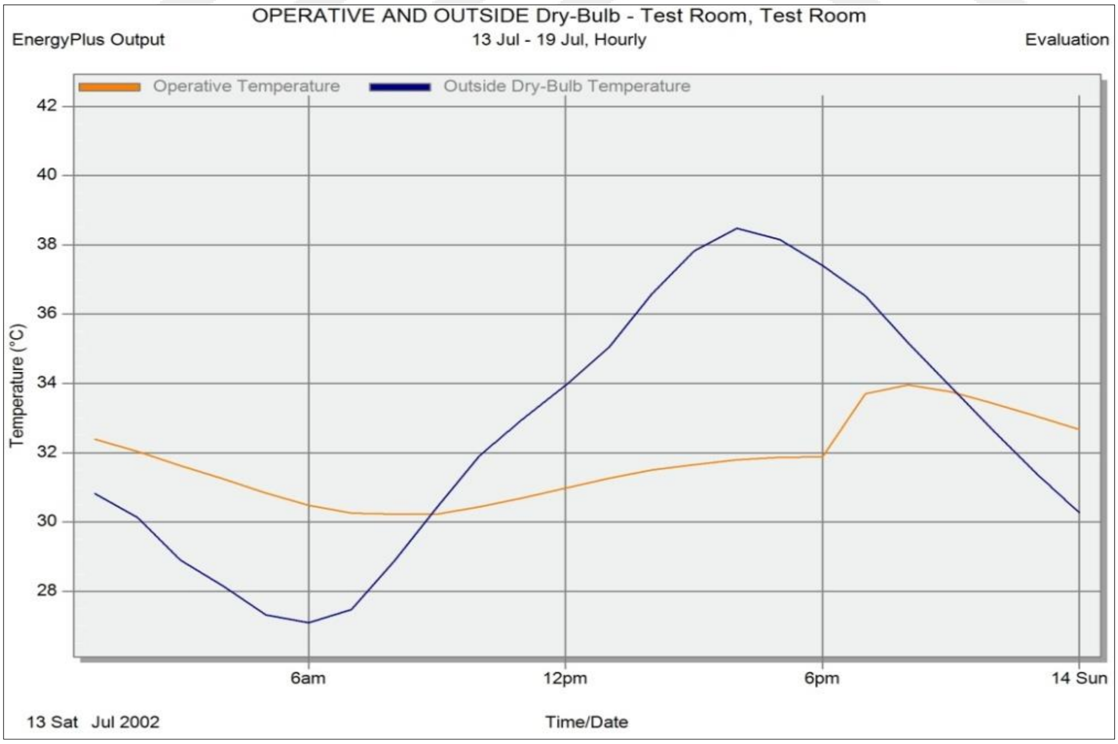


Figure 5.19. Simulation results of the energy efficient room shows indoor operative temperature performance after using Mashrabiya to shadow the main wall

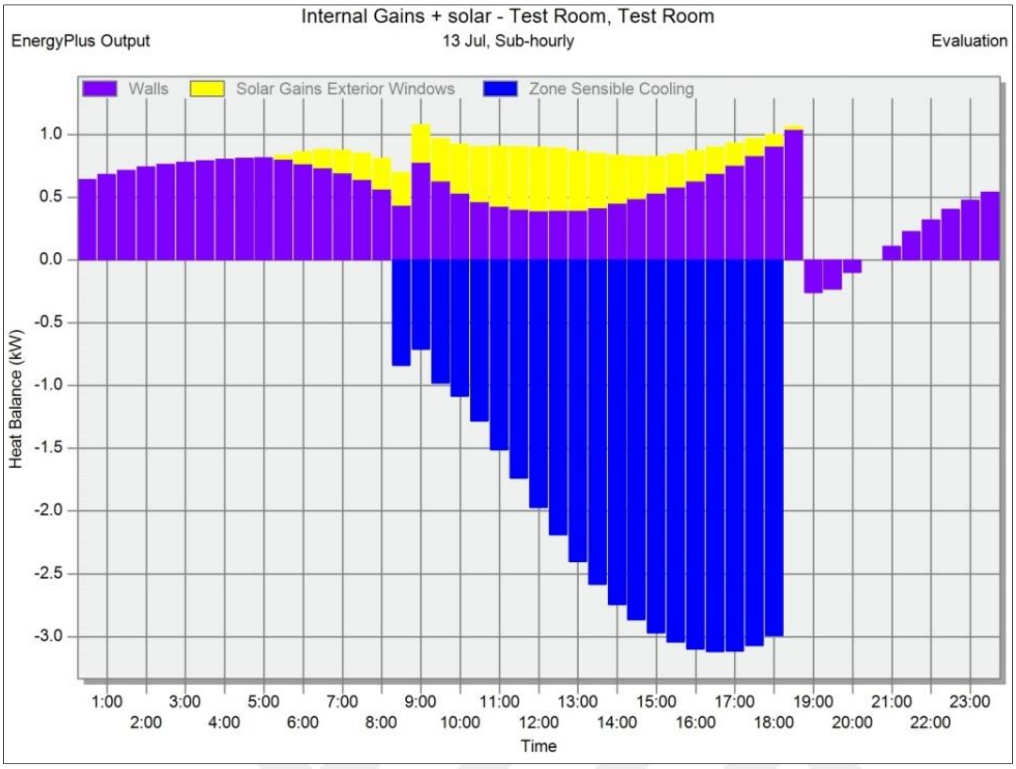


Figure 5.20. Simulation results graph of the base case room shows the external wall heat gain and its effect on cooling load

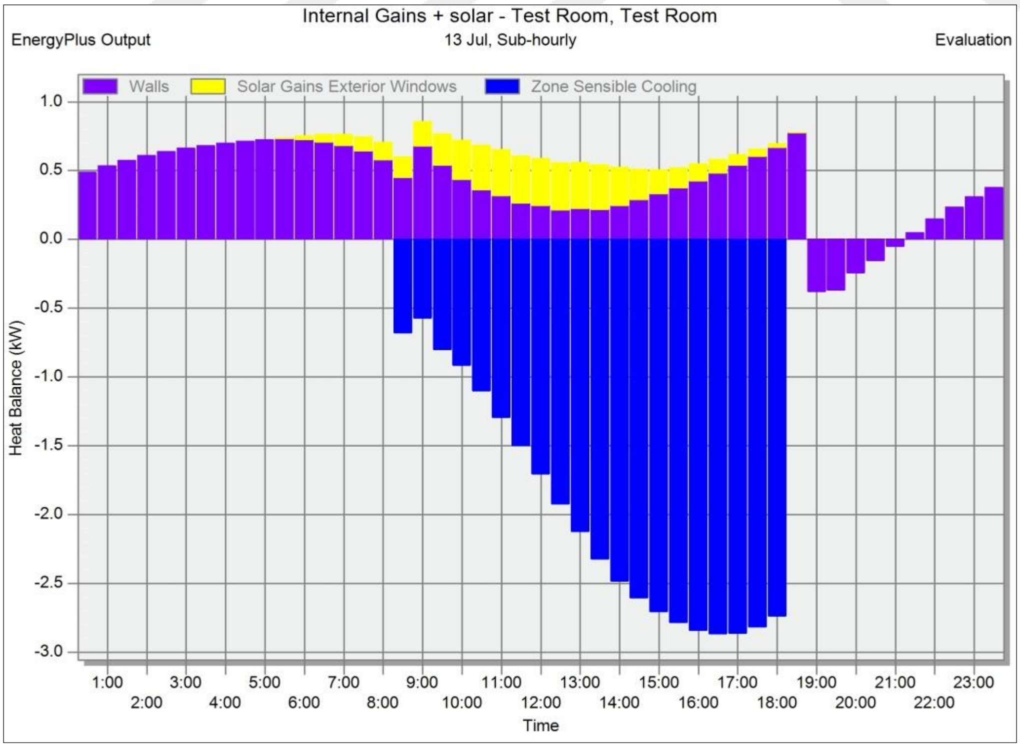
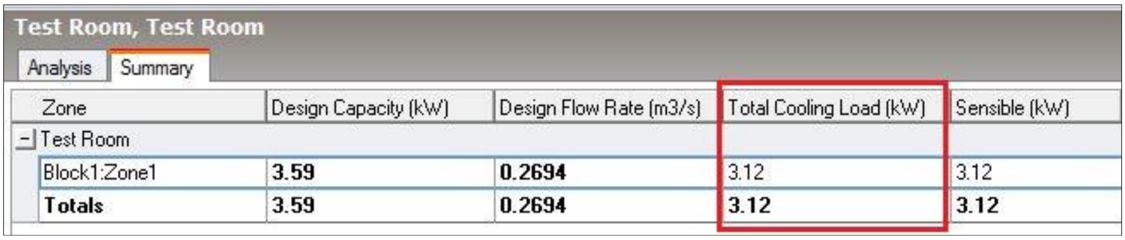


Figure 5.21. Simulation results graph of the energy efficient room shows the external wall heat gain and its effect on cooling load

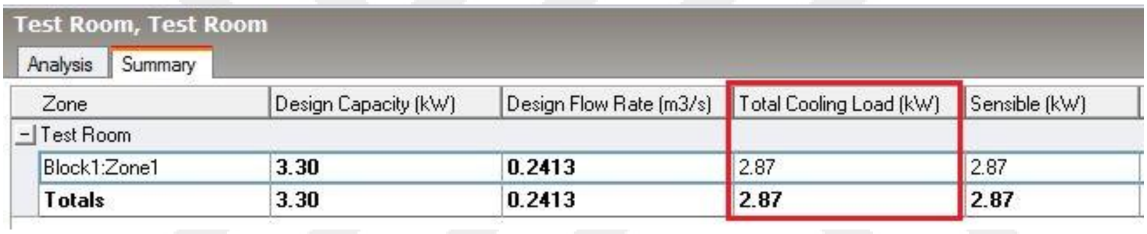
The proposed solution of applying screen shading to cover the external wall show a small variation in indoor operative temperature compared with the base case room, that decreasing resulted to minimize the cooling loads slightly from 3.12 kW to 2.87 kW as shows in Figure 5.22 and 5.23 which is approximately 0.25 % reduction.


Test Room, Test Room

Analysis | Summary

Zone	Design Capacity (kW)	Design Flow Rate (m3/s)	Total Cooling Load (kW)	Sensible (kW)
Test Room				
Block1:Zone1	**3.59**	**0.2694**	3.12	3.12
Totals	**3.59**	**0.2694**	**3.12**	**3.12**

Figure 5.22. Simulation results of the base case room shows the cooling load calculation started from 8:00 am to 8:00 pm on 13 of July


Test Room, Test Room

Analysis | Summary

Zone	Design Capacity (kW)	Design Flow Rate (m3/s)	Total Cooling Load (kW)	Sensible (kW)
Test Room				
Block1:Zone1	**3.30**	**0.2413**	2.87	2.87
Totals	**3.30**	**0.2413**	**2.87**	**2.87**

Figure 5.23. Simulation results of the energy efficient room shows the cooling load calculation started from 8:00 am to 8:00 pm on 13 of July

This proposed solution of having an external skin to shadow the main wall has produced a not significant reduction in cooling load comparing with roof shading case. Therefore, a combination between shading the roof and in the same time shading the wall is contribute to reduce solar heat gain more efficient. In Erbil, during the middle of the afternoon in summer, the outside air temperature is frequently reached more than 42 C; therefore, building envelope should be less exposed to direct solar radiation to avoid overheating concerns. During winter, this solution could be not more sufficient according to solar heat need. For that reason, the proposed skin designed in a flexible way to be not fixed and could be adjusted to be open or closed. Therefore, the house dwellers can easily control the levels of light and ventilation they desired for different spaces.

5.1.4. Glazing scenarios

Heat gain through windows is one of the most effective design issues to be considered especially with the large size open glazing building type. There are two main considerations for solar radiation, solar transmitted through building envelope and solar transmitted through windows (Green, 2016). Certainly that solar transmission through the windows has the potential to impact energy use to cool or heat the indoor spaces. Glazing is directly responsible for the heat transfer rates inside the building. Windows can also serve as a source of air leakage which affects the cooling or heating load of the indoor spaces. The figure 7.3 showing the mechanism related to solar radiation transfer through the glazing portion of untreated glass type.

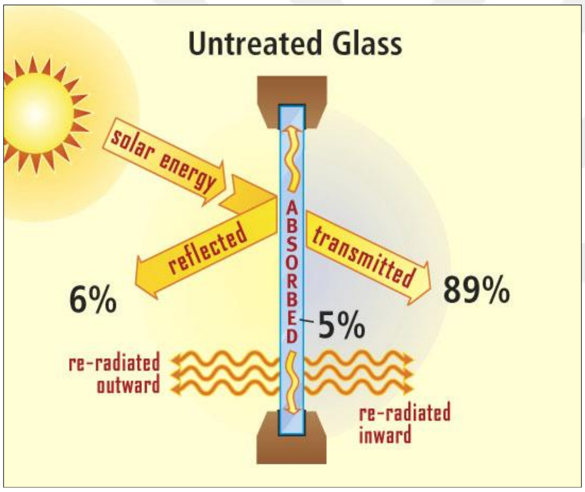
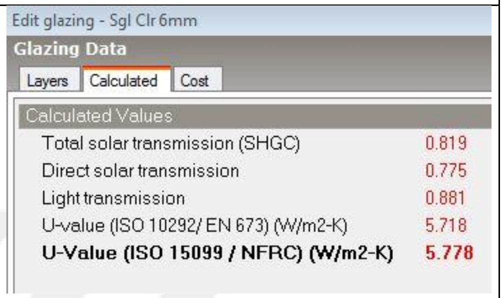
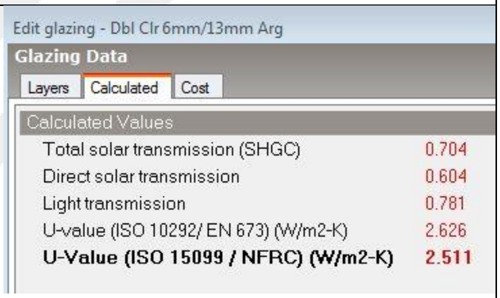
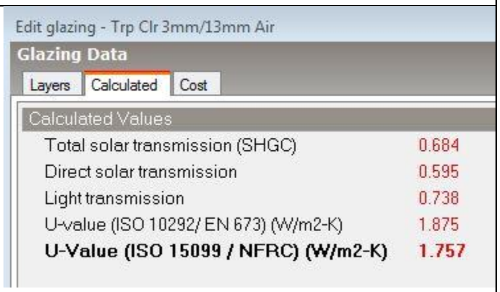
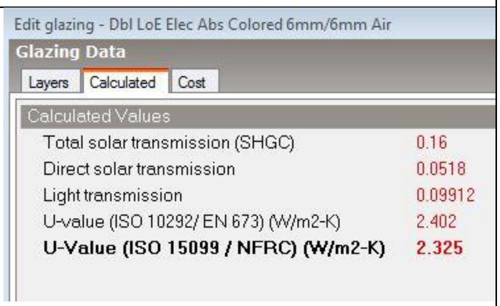


Figure 5.24. The solar radiation transfer mechanism of untreated glass (Marchwiński, 2014).

It's clear from the diagram reflected in Figure 5.24 that a very high rate of solar rays is transmitted (89%) through the glass whereas only a small amount of solar rays is absorbed (5%) or reflected (6%). Therefore, the higher amount of solar radiated upward should be minimized to reduce heat gain through windows. Nowadays, there are many glass type produced aiming to reduce the amount of solar energy transmitted to reach the interior spaces such as low-e glass. Treating the building windows with solar shading screen or reflective film coatings are a passive solution which could significantly reduce the solar heat gain through windows (Marchwiński, 2014). Ordinary glass hasn't changed for more than half a century and nowadays technology has come a long way with a high performance glass type. Unfortunately, in Iraq, most of the housing building are using a single clear glass which is a totally non-energy efficient type as reflected in the base case simulation case. There are many research in the topic of the technology of glazing and solar protection measurements detected that, film coated energy-efficient glass windows are one of the solutions could be applied in hot climate regions to reduce heat gain significantly (Al-Shukri, 2007). Double layered glass and triple glazing type are also suggested by other experimental works after testing the glass performance with the issue of energy efficient glass in a hot climate region. Another option of windows treatment by reducing heat gain transmitted by is representing worldwide by using transparent selective films (He and Tjong, 2016). Transparent films and coatings option are being an effective strategy used by all of the glazing manufactured nowadays. In addition, some recent new technology based on nano material have been explored and increasingly used to develop glazing performance. There are many research investigate the concept of reducing heat gain through glazing layer to produce an energy-efficient windows. Gorgolis and Karamanis (2016) evaluated the benefit of integrating innovative transparent components in windows glazing in terms of energy savings. They concluded that using glazing integrated coatings with double glazing system are the best option type due to heating and cooling loads reduction and energy savings. The big concentration of any climate when designing a window is heat game through the windows. Nowadays there are many advanced technologies produced glass reflect heat while it's provide an acceptable amount of light to illuminate the interior space efficiently.

For the dynamic thermal simulation process four rooms was modeled. These rooms were constructed with same construction materials and orientation. In addition, windows to wall ratio, windows size, and mechanical ventilation system operation schedual are the same in all rooms. The only changeable parameter is the glass type. However, in this step of the simulation, a compression analysis to find out the best thermal performance between the base case room with ordinary untreated glass used nowadays in modern housing and other rooms after applying three different type of glass as reflected in Table 5.9. It is essential to understand how heat is transferred through the windows in order to evaluate the thermal performance of the modeled room. Solar gain through the exterior windows is one of the main parameters to be compared between the four modeled rooms. Solar heat gain coefficient is the measure of the fraction of solar radiation admitted through the windows. Solar heat gain coefficient (SHGC) includes the heat that is directly transmitted as well as heat that is absorbed and subsequently released into the indoor spaces. SHGC is expressed as a number between zero and one and value is typically range from 0.25- 0.8. The lower the SHGC number the more the windows is blocking solar heat gain. The following table showing the SHGC value of each glass type which used in the simulation process.

Table 5.6. Room types and glazing characteristics to be used in the simulation process

Room	Glazing Type	SHGC	U value	Template
Base case	Single clear glass (6mm)	0.819	5.778	
Room 1	Double Clear Glass 6mm/13mm Air	0.704	2.511	
Room 2	Triple Clear Glass 3mm/13mm Air	0.684	1.757	
Room 3	Double Low-E Colored Glass 6mm/6mm Air	0.16	2.325	

The solar gain through the exterior windows results in great impacts on the internal heat gain. Therefore, the first step in the simulation was comparing the solar gain through the exterior windows of each room using different glass type. Looking to heat balance graph in Figure 5.25, 5.26, 5.27 and 5.28, we can compare between the four rooms result in terms of solar gain through the exterior windows and its effects on lowering the cooling load. Simulation result showing that there is a variation between the 4 type modeled rooms. Each glazing type has different reaction on reducing solar gain through windows. The best performance was detected in Room 4 due to the glass type used in.

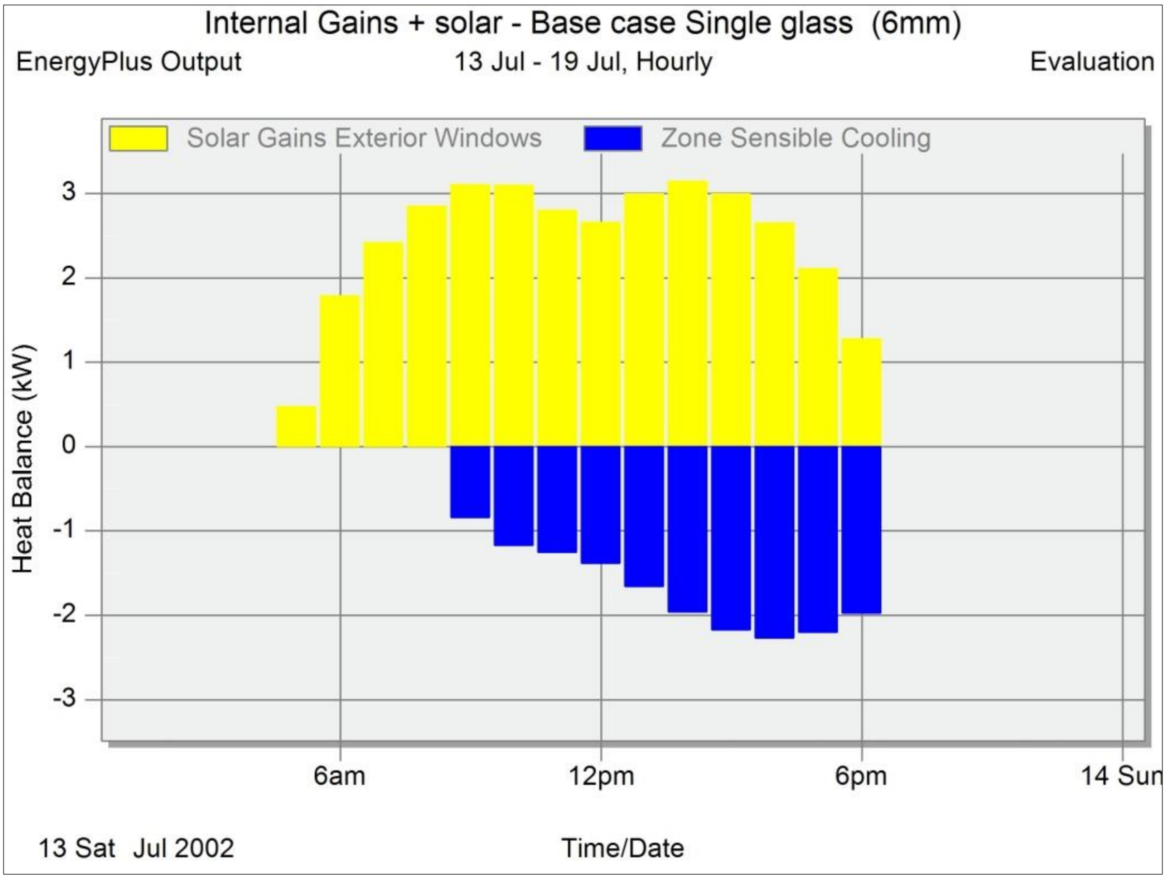


Figure 5.25. Base case room simulation result showing the solar gain through the exterior windows and its effects on cooling load started from 9:00 am to 6:00 pm on 13 of July

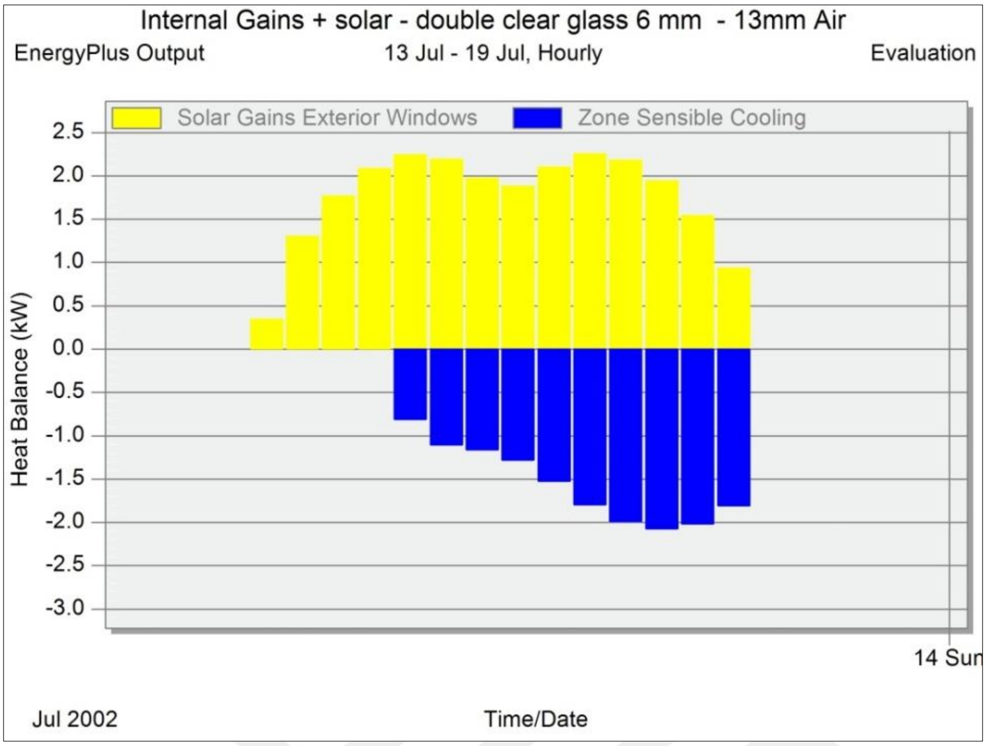


Figure 5.26. Room 1 simulation result showing the solar gain through the exterior windows and its effects on cooling load started from 9:00 am to 6:00 pm on 13 of July

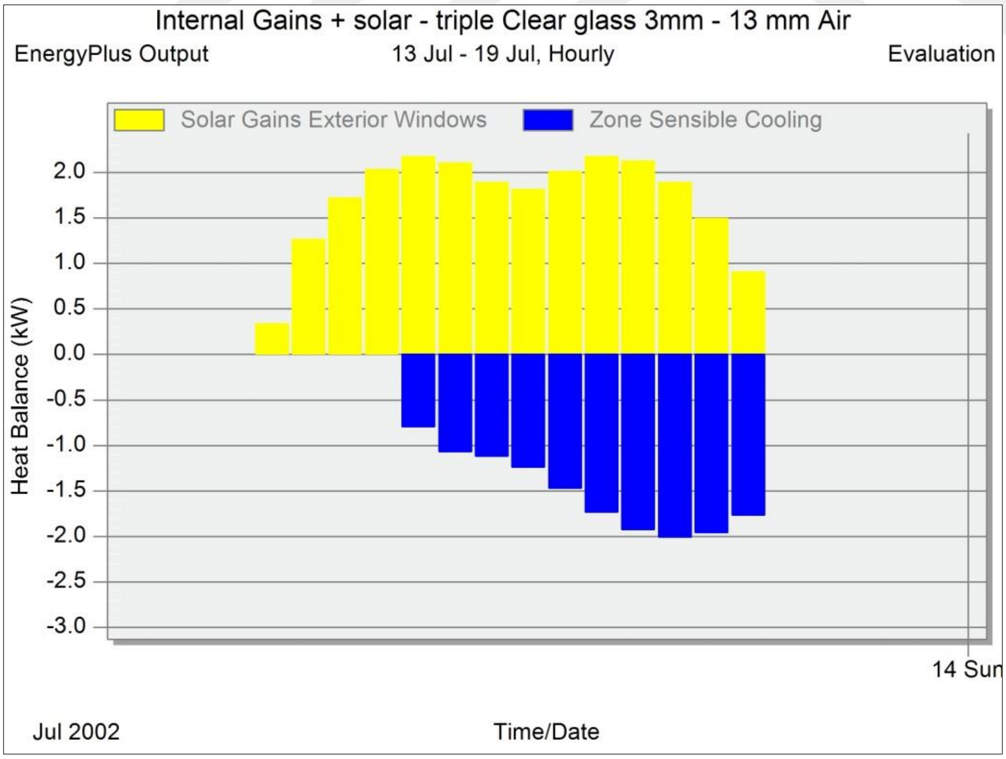


Figure 5.27. Room 2 simulation result showing the solar gain through the exterior windows and its effects on cooling load started from 9:00 am to 6:00 pm on 13 of July.

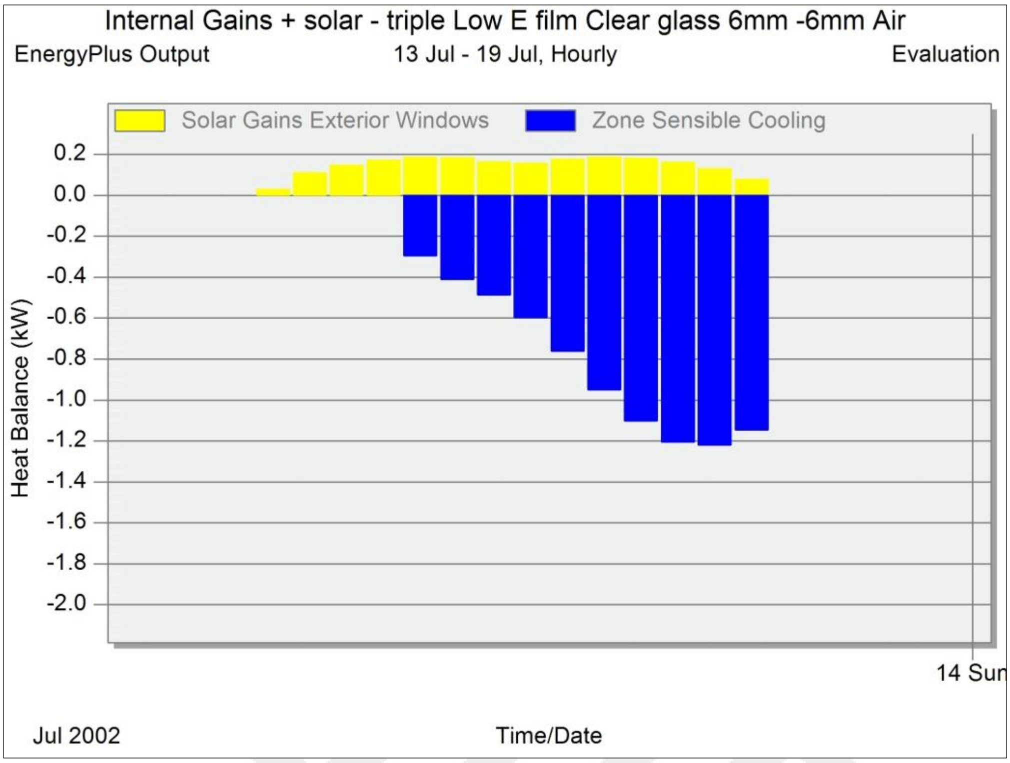
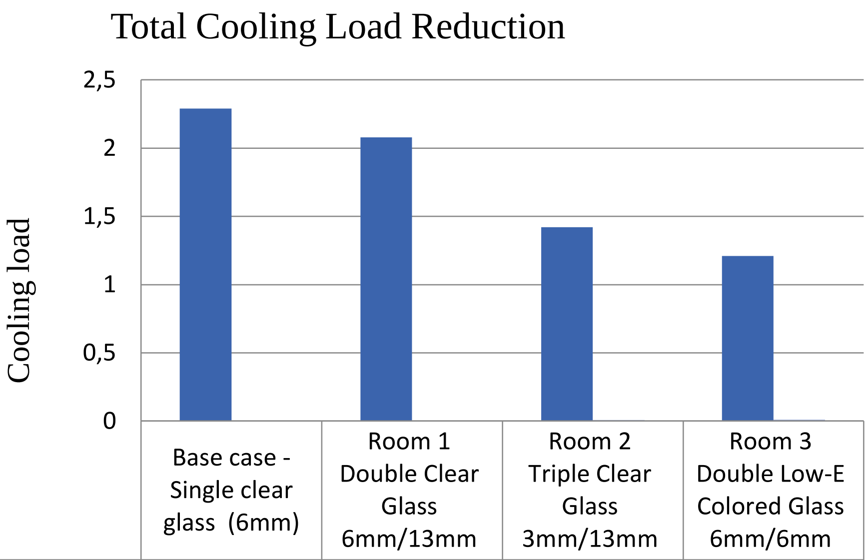


Figure 5.28. Room 3 simulation result showing the solar gain through the exterior windows and its effects on cooling load started from 9:00 am to 6:00 pm on 13 of July

Using double low-e colored glass 6mm/6mm in Room 3 has reduced the cooling load greatly comparing with other rooms because of its effectiveness in terms of blocking solar gain through exterior windows. This type of glass has the lowest solar heat gain coefficient at amount of 0.16 kW (as can be seen in Table 5.7) which significantly prevent solar heat to pass through windows. Comparison between the simulated four rooms in terms of cooling loads shows in Table 5.7 Cooling load in Room 1 was reduced slightly in amount of 0.21% comparing with the base case. Whereas Room 2 recorded 0.87 % cooling load reduction comparing with the base case. Maximum cooling load reduction is noticed in room 3 by using the double low-e glazing type lowering the cooling load about 1.08 comparing with the base case with single clear glass.

Table 5.7. Glazing type alternatives and cooling load comparison



	Base case - Single clear glass (6mm)	Room 1 Double Clear Glass 6mm/13mm	Room 2 Triple Clear Glass 3mm/13mm	Room 3 Double Low-E Colored Glass 6mm/6mm
Cooling Loads	2,29	2,08	1,42	1,21
Cooling load Reduction %		0,21%	0,87%	1,08%

However, treating the existing windows with solar screens or reflective film coating can also significantly reduce the solar heat gain coefficient without replacing the windows.

<u>Result of the second strategy (modify heat technique)</u>

Prevent heat from reaching our indoor space is the first step is to be considered by architect and engineer to minimize heat gain. Modify heat gain are the second stage for achieving passive cooling methods in building design which discussed in this section. While this research seeks to find out the most effective solution for reducing cooling load in a residential building, traditional architecture passive cooling methods had been offered significant techniques for reducing our full dependency on air conditioning to provide thermal comfort. Heat could be reflected by shading the building, but another great amount of heat absorbed by building mass and construction materials. Therefore, the thermal mass of the building is the key point to be investigated at this stage. Generally, during a sunny hot day building envelope absorbs heat from solar radiation, store it for a certain time and finally release it to our indoor environment and outdoor spaces at night as well. Thermal mass can be described simply as the ability of the building materials to observe and store heat energy.

The main concept of thermal mass is basically about the ability of construction materials to store heat and then release it later on (Lechner, 2015). Pyrgou et al (2017) argued that, thermal mass is very tricky. It is actually a real benefit if the designer has used it in the right place but if he uses it in the wrong place it's could be like a thermal liability. For example on a hot summer's day storing the heat all day and then releasing it at night could greatly maximize heat of indoor spaces and then more cooling loads will be needed to cool the interior spaces. Therefore, heavyweight material such as concrete slab and masonry wall should be shaded to prevent heat storing during the daytime. Unfortunately, the main construction materials used in housing building are un-shaded and un-insulated heavyweight material. In the cold climate regions, it is make sense to have some thermal mass in the houses because of the cold weather condition. But in hot climate region thermal mass is critical to be used without considering the heat absorbed from Sun. In summer with the thermal mass by keeping the building envelope shaded all day as its heating up outside any access of remaining heat should be observed by that thermal mass and keep the indoor spaces cooler. Used of poor thermal mass happened when the designer does not have the thermal mass position correctly or insulated correctly.

5.1.5. Thermal mass performance analysis of wall (assessment of insulation layer position in five wall scenarios)

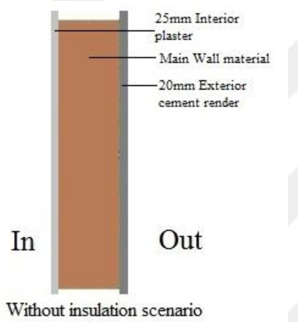
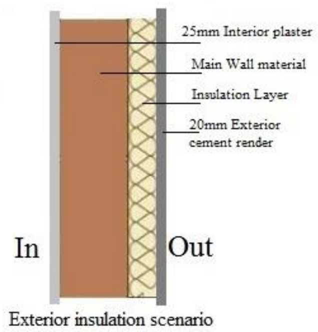
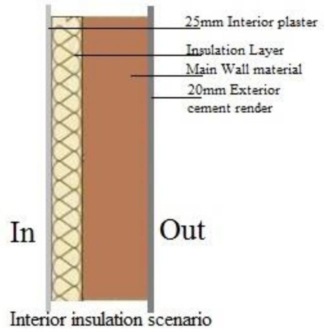
The simulation in this is step is seeking to find out the best wall construction materials in terms of thermal performance in modern residential building in Iraq. Therefore, the most commonly used building materials in Iraq simulated while the finishing materials and insulation layer fixed in all of the scenario tests. The construction materials as shown in Table 5.8 have been locally used for several decades in the construction of various buildings and have a different thermal performance behavior.

Table 5.8. Currently wall construction materials and it main characteristics

External wall Materials	U value ($W/m^2 K$)	Density kg/m^3	Render view
Solid Brick	0.85	1360	
Hollow Brick	0.77	1040	
Solid Concrete Block	1.49	2300	
Hollow Concrete Block	1.28	1440	
Thermostone	0.21	760	

It is significant to understand the main envelope building materials thermal performance to meet the thermal comfort of building occupants. In addition, to identify the best wall construction materials to be selected for using in the real case house simulation. The concept of thermal mass and heat storage mechanism in cold season is different if compared to summer hot season. In simple word, high thermal mass materials in cold climate zone are likely to be used in building envelope construction whereas in a hot climate it is not. Heavyweight materials in the hot climate stores heat from solar radiation and release it when the source of heat absence causing high indoor air temperature. This heating mechanism is preferred in the cold winter time. Therefore, thermal insulation is required to prevent heat storage in building construction materials to increase the thermal comfort of building users. Thermal insulation is considered one of the heat prevention strategies which classified by many experimental studies as passive cooling methods. The simulation processes performed by carrying out five wall composition scenarios of wall materials. Each wall analyzed in three different rooms as follows: room with exterior insulation, room with interior insulation and room without insulation as reflected in Table 5.9 In the simulations process only the main wall material is changeable and other wall layers such as interior plaster render and exterior cement render remain fixed.

Table 5.9. Three different scenarios of external walls showing the position of the insulation layer

Scenarios	Room Without Insulation	Room With Exterior Insulation	Room With Interior Insulation
Wall Section			
Details And Thickness	1. Exterior cement render 20mm 2.Main Wall material 3.Interior plaster render 25mm	1.Exterior cement render 20mm 2. Main Wall material 3. Insulation layer 50mm 4.Interior plaster render 25mm	1.Exterior cement render 20mm 2. Insulation layer 50mm 3.Main wall material 4. Interior plaster render 25mm

<u>Fixed simulation parameters in all room scenarios</u>

1. To represent a residential thermal zone and to reduce heat gain from windows, only two windows (single clear glass -6mm) designed and located at the center of the north-south axis wall with 1.6 x1.6 m dimensions.
2. Roof slab and floors are designed to be concrete slab without insulation layer.
3. The test rooms mechanically ventilated using (split) indoor air conditioner units with the same power and cooling system seasonal coefficient factor.
4. The rooms are stimulated without any kind of shading such as (roof shading, windows shading and adjustable building shading)

5. Indoor operative temperature and cooling load is the key perimeter to be compared in all wall scenarios.
6. Thermal insulation is EPS Expanded polyurethane with 50 mm thickness.

Changeable simulation parameters in all room scenarios

1. Wall main construction material.
2. Thermal insulation layer position.

Scenario 1: solid brick wall

Solid brick wall materials is a common construction material in Iraq used both in internal and external wall construction. Common dimensions of this wall material are 24 cm x7 cm x12 cm. This type of brick is produced basically from clay, and that's why it has a good thermal resistance comparing with the block concrete material. Red brick materials are widely used in Iraq because of its features such as acoustic properties, low cost, thermal properties and simplicity of using.

The simulation analyses will focus on the thermal insulation positioning on the walls to determine the best performance that can make an improvement to the indoor comfort temperatures. According to Byrne and Ritschard (2002), the impact of thermal insulation location related to mass layer affected by two factors: the first one is the time lag of the heat flux through a wall and the second factor is the ability to reduce interior air temperature fluctuation.Figure 5.28 showing the result of the simulation which investigated the insulation layer position impacts on indoor operative temperature in the summer season at 13 of July as the hottest summer day.

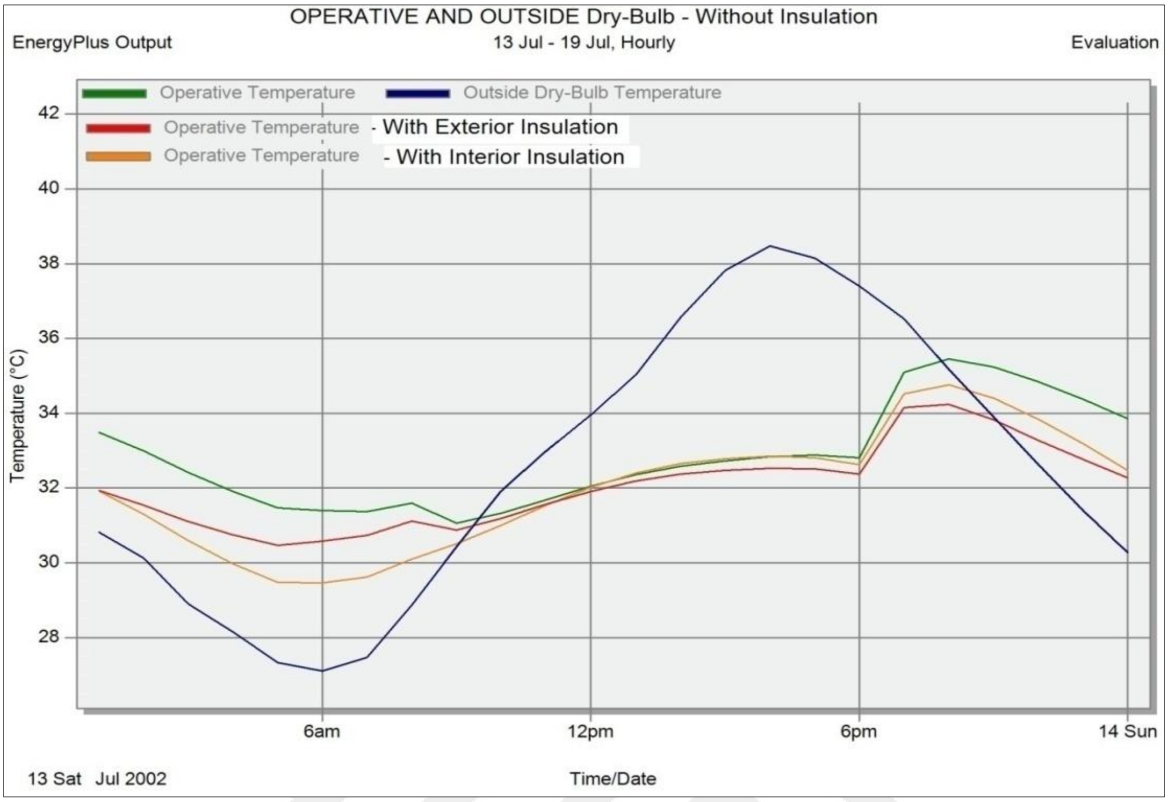


Figure 5.29. Simulation graph showing the result of solid brick wall applied in three different rooms in the hottest day (at 13 July)

Simulation graph in Figure 5.29 showing the indoor operative temperature dropped down after 7 am because of the effect of mechanical air conditioning operation which is starting from 8:00 with sunrise until 18:00 with sunset. As can be seen, adding exterior 50 mm insulation layer has the highest effect on reducing indoor operative temperature against the base case reference room which has no thermal insulation and room with interior insulation wall. This result also can be seen in Figure 5.30 which compare between the three room scenarios.

Test Room, Solid Brick Wall, With Exterior Insulation

Analysis | Summary

Zone	Total Cooling Load (kW)	Max Op Temp in Day (°C)	Air Temperature (°C)	Humidity (%)	Time of Max Cooli...
− Solid Brick Wall					
WthExtrInsltn:Zone1	2.76	35.1	25.1	18.9	Jul 16:30
WthIntrInsltn:Zone1	2.85	36.0	25.0	19.0	Jul 16:30
WithoutInsulation:Zone1	3.55	37.2	24.1	20.0	Jul 17:00
Totals	**9.16**	**37.2**	**24.7**	**19.3**	**N/A**

Figure 5.30. Simulation result showing the total cooling load and maximum operative temperature in three different rooms scenarios of solid brick wall

The second consideration to find out in the simulation is the difference of cooling loads between the base case room and other room scenarios. DesignBuilder cooling design simulations calculate the cooling loads of the mechanical air conditioning used in the three model rooms separately; therefore, we can easily recognize the impact of each scenario on the cooling load. The total cooling load has been reduced from 3.55 kW in the base case room without insulation to about 2.85 kW with interior insulation and 2.76 kW with exterior insulation. This variation of cooling load is occurred because of the insulation layer impact on reducing the indoor operative temperature. The maximum operative temperature in the room with external insulation recording the less average which is 35.1kW compared with other two rooms. The cooling load results in Figure 5.29 showing that there is no great difference in cooling load between room scenario with interior insulation and room scenario with exterior insulation due to the fact that, both of the room scenarios have the same wall section thickness and the same u-value (0.512 kW/m2 K) as can be seen in Table 5.10. However, there is a significant effect of adding an insulation layer whether inside or outside the wall section comparing with the base room without insulation.

Table 5.10. Cooling load reduction result and details of solid brick wall

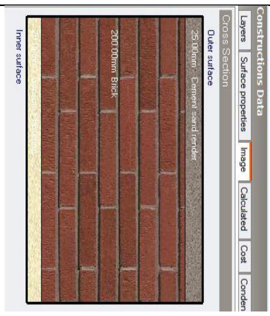
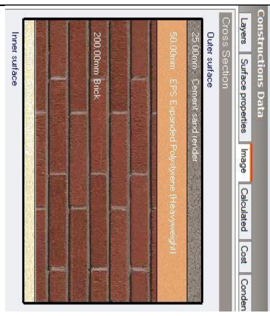
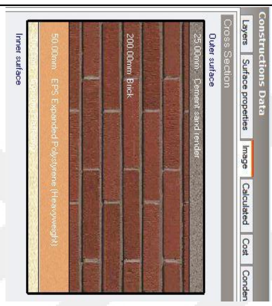
Solid Brick Wall				
Simulation Scenarios	Wall Section Showing Insulation Layer Position	U-value (kW/m2 K)	Total Cooling load	Cooling load Reduction%
Base Case Room Without Insulation		1.913	3.55	-

Table 5.10. (continued) Cooling load reduction result and details of solid brick wall

Simulation Scenarios	Wall Section Showing Insulation Layer Position	U-value (kW/m2 K)	Total Cooling load	Cooling load Reduction%
Room with Exterior Insulation		0.512	2.76	1.24%
Room with Interior Insulation		0.512	2.85	1.15%

The total cooling load has been reduced from 3.55 KW of the base case room to 2.76 KW of the room with exterior Insulation representing 1.24% and to 2.85 KW of the room with interior insulation representing 1.15% of total cooling load reduction. Accordingly, applying 50 mm insulation layer at the outer surface of the room wall is the best scenario in terms of reducing cooling load comparing with other room scenarios.

Scenario 2: hollow brick wall

Another kind of available locally used material in Iraq is hollow brick. As mentioned before the dynamic thermal performance of wall section is affected by two factors. One of them is the time lag of the heat flux through the wall section. The hollow brick material is designed to reduce the time lag amount of heat transfer due to the opening in the material section. Figure 5.31 showing the result of the simulation comparing between the three room scenarios in terms of indoor operative temperature.

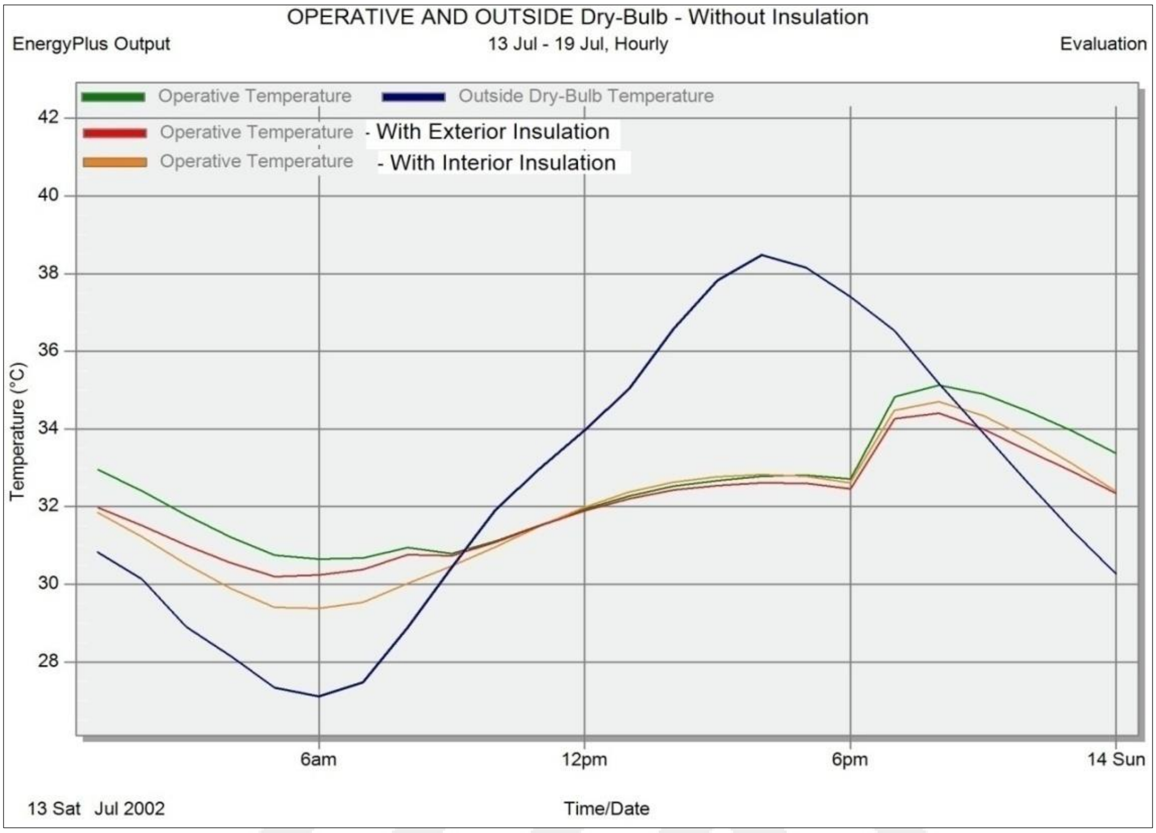


Figure 5.31. Simulation graph showing the result of hollow brick wall applied in three different rooms in the hottest day (at 13 July)

The simulation result of the room with exterior insulation and room with interior insulation has proven to be almost having the same sensitivity to indoor operative temperature in early morning time. Whereas, after the zone temperature is become higher due to the heat of solar radiation after 12:00 pm room with exterior insulation has recorded the lowest operative temperature comparing with other rooms.

Test Room, Hollow Brick Wall

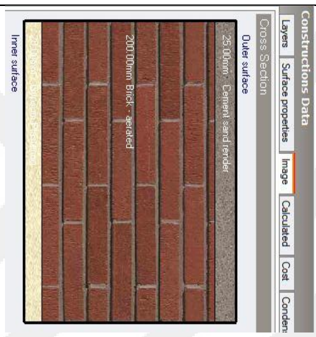
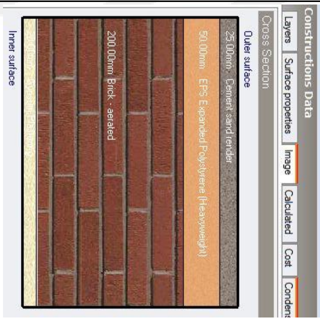
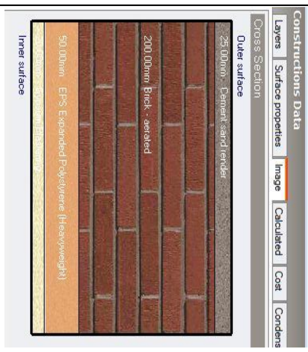
Analysis | Summary

Zone	Total Cooling Load (kW)	Max Op Temp in Day (°C)	Air Temperature (°C)	Humidity (%)	Time of Max Cooli...
Hollow Concert Block Wall					
WthExtrrInsltn:Zone1	2.74	35.3	25.1	18.8	Jul 16:30
WthIntrrInsltn:Zone1	2.81	35.9	25.0	18.9	Jul 16:30
WithoutInsulation:Zone1	3.18	36.5	24.6	19.5	Jul 17:00
Totals	**8.72**	**36.5**	**24.9**	**19.1**	**N/A**

Figure 5.32. Simulation result showing the total cooling load and maximum operative temperature in three different room scenarios

As can be seen in Figure 5.32 the minimum operative temperature has recorded in the room with external insulation which is about 35.3 °C. This positively affects reducing the cooling load from 3.18 KW in the base room without insulation to 2.74 kW in the room with the external insulation.

Table 5.11. Cooling load reduction result and details of hollow brick wall

Hollow Brick Wall				
Simulation Scenarios	Wall Section Showing Insulation Layer Position	U-value (kW/m2 K)	Total Cooling Load	Cooling Load Reduction%
Base case room without insulation		1.097	3.18	-
Room with exterior insulation		0.427	2.74	1.23%
Room with interior insulation		0.427	2.81	1.11%

The total cooling load has been reduced from 3.18 KW of the base case room to 2.74 KW of the room with exterior insulation representing 1.23 % and to 2.81 KW of the room with interior insulation representing 1.11% of total cooling load reduction. As is evident from the Figures 5.32 and Table 5.11 , in terms of the difference between the wall scenarios insulation position, it clearly appears that the thermal insulation in room with the exterior insulation has the great influence on the reduction rate of indoor operative temperature.

<u>Scenario 3: solid concert block wall</u>

Figure 5.33 showig the result of the simulation which investigated the insulation layer position impacts on indoor operative temperature in the summer season at 13 of July as the hottest summer day.

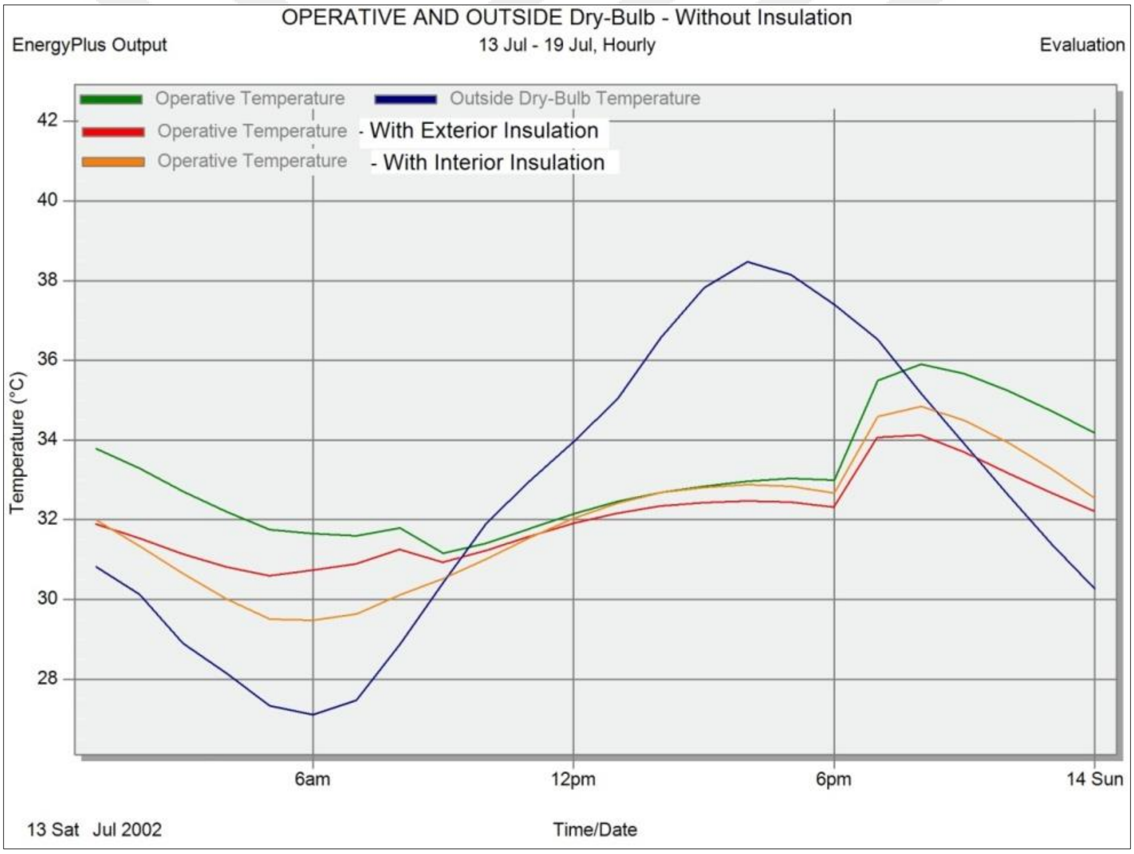


Figure 5.33. Simulation graph showing the result of solid concrete block wall applied in three different rooms in the hottest day (at 13 July)

Simulation graph in Figure 5.33 showing the indoor operative temperature dropped down after 8:00 am because of the effect of mechanical air conditioning operation which is starting from 8:00 with sunrise until 18:00 with sunset. As can be seen, adding exterior 50 mm insulation layer has the highest effect on reducing indoor operative temperature against the base case reference room which has no thermal insulation and room with interior insulation wall. This result also can be seen in Figure 5.34 which compare between the three room scenarios.

Test Room, Solid Concret Block Wall

Analysis | Summary

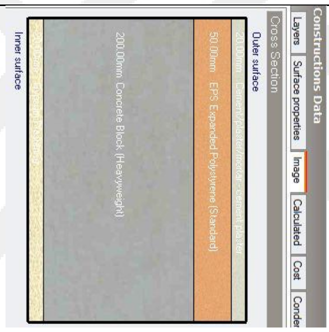
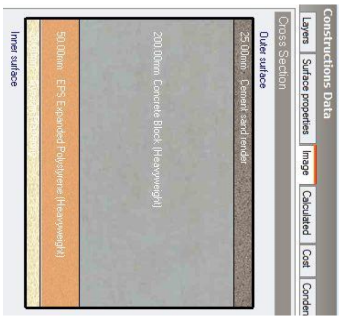
Zone	Total Cooling Load (kW)	Max Op Temp in Day (°C)	Air Temperature (°C)	Humidity (%)	Time of Max Cooling
Solid Concret Block Wall					
WthExtrrInsltn:Zone1	2.77	35.1	25.1	18.9	Jul 16:30
WthIntrrInsltn1:Zone1	2.89	36.1	24.9	19.1	Jul 16:30
WithoutInsulation:Zone1	4.00	37.8	23.6	20.7	Jul 17:00
Totals	**9.66**	**37.8**	**24.5**	**19.6**	**N/A**

Figure 5.34. Simulation result showing the total cooling load and maximum operative temperature in three different room scenarios

The second consideration to find out in the simulation is the difference of cooling loads between the base case room and other room scenarios. DesignBuilder cooling design simulations calculate the cooling loads of the mechanical air conditioning used in the three model rooms separately; therefore, we can easily recognize the impact of each scenario on the cooling load. The total cooling load has been reduced from 4.00 kW in the base case room without insulation to about 2.89 kW with interior insulation and 2.77 kW with exterior insulation. This variation of cooling load is occurred because of the insulation layer impact on reducing the indoor operative temperature. The maximum operating temperature in the room with external insulation recording the less average which is 35.1kW compared with other two rooms.

The cooling load results in Figure 5.34 showing that there is no great difference in cooling load between room scenario with interior insulation and room scenario with exterior insulation due to the fact that, both of the room scenarios have the same wall section thickness and the same u-value (0.557 kW/m2 K) as can be seen in Table 5.12. However, there is a significant effect of adding an insulation layer whether inside or outside the wall section comparing with the base room without insulation.

Table 5.12. Cooling load reduction result and details of solid concrete block wall

Solid Concrete Block Wall				
Simulation Scenarios	Wall Section Showing Insulation Layer Position	U-value (kW/m2 K)	Total Cooling load	Cooling load Reduction%
Base case room without insulation		2.699	4.00	-
Room with exterior insulation		0.557	2.75	1.25%
Room with interior insulation		0.557	2.92	1.08%

The total cooling load has been reduced from 4.00 KW of the base case room to 2.77 KW of the room with exterior insulation representing 1.23% and to 2.89 KW of the room with interior insulation representing 1.11% of total cooling load reduction. This mean applying 50 mm thermal insulation layer in room with the exterior insulation is the best scenario due to lower indoor operative temperature comparing with other room scenarios.

<u>Scenario 4: hollow concert block wall</u>

Hollow concrete block also is known as masonry block, cement or concrete block which composite from sand cement and coarse aggregates with a dimension of 20 x 20 x 40 cm which is weight approximately 11 kg. Due to its characteristics, such durability, capability of carrying loads and its low cost compared with other walls materials it considers the most used wall materials in Iraq. The simulation result in Figure 5.35 showing the averages of indoor operative temperature fluctuates between about 31-32.5°C in the room with the exterior and interior insulation layer. Whereas the un-insulated wall in the base case room scenario showing a different range of indoor operative temperature fluctuates between 31-33.5°C which is approximately in the range of 0.5-1 K comparing with other room scenarios.

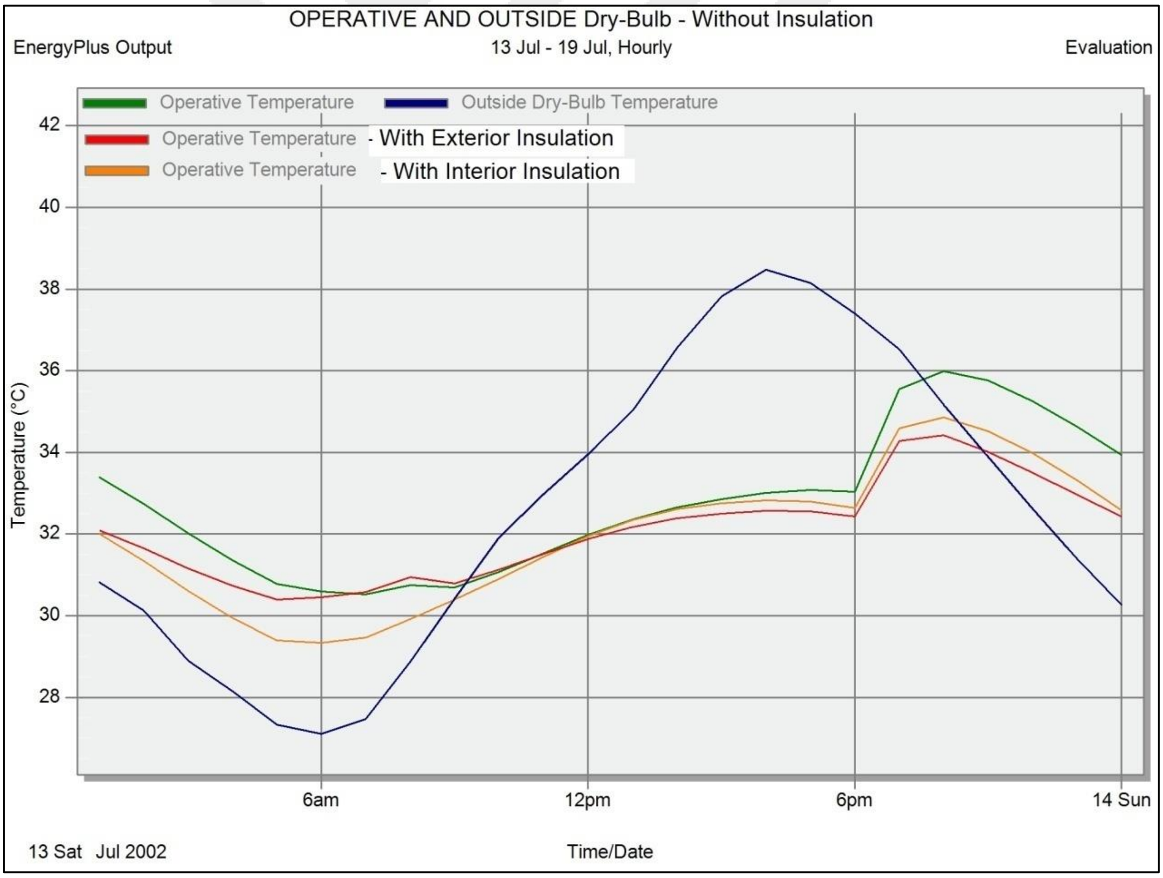
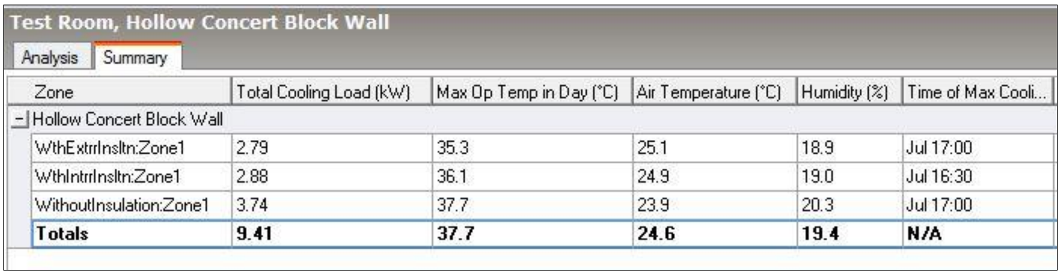


Figure 5.35. Simulation graph showing the result of hollow concrete block wall applied in three different rooms in the hottest day (at 13 July)



Test Room, Hollow Concert Block Wall

Analysis | Summary

Zone	Total Cooling Load (kW)	Max Op Temp in Day (°C)	Air Temperature (°C)	Humidity (%)	Time of Max Cooli...
− Hollow Concert Block Wall					
WthExtrrInsltn:Zone1	2.79	35.3	25.1	18.9	Jul 17:00
WthIntrrInsltn:Zone1	2.88	36.1	24.9	19.0	Jul 16:30
WithoutInsulation:Zone1	3.74	37.7	23.9	20.3	Jul 17:00
Totals	**9.41**	**37.7**	**24.6**	**19.4**	**N/A**

Figure 5.36. Simulation result showing the total cooling load and maximum operative temperature in three different room scenarios of hollow concrete block wall

Coming to the second consideration of the simulation process which is about cooling loads, as can be seen in Figure 5.36, the total cooling load has been reduced from 3.74 KW of the base case room without insulation to 2.88 KW of the room with interior insulation and to 2.79 KW of the room with exterior insulation.

Table 5.13. Cooling load reduction result and details of hollow concrete block wall

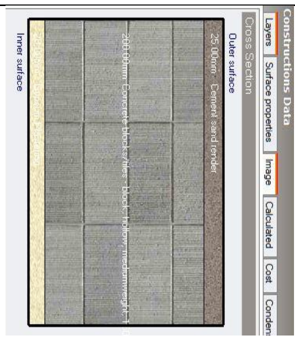
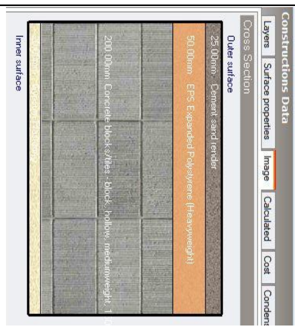
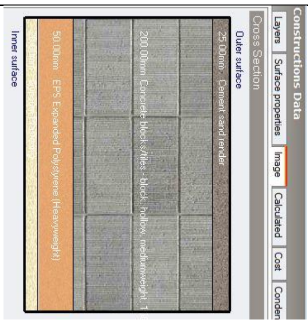
Hollow Concert Block Wall				
Simulation Scenarios	Wall Section Showing Insulation Layer Position	U-value (kW/m2 K)	Total Cooling load	Cooling load Reduction%
Base case room without insulation		1.762	3.74	-
Room with exterior insulation		0.501	2.79	0.95%

Table 5.13. (continued) Cooling load reduction result and details of hollow concrete block wall

Room with interior insulation		0.501	2.88	0.86%

As can be seen in Table 5.13 the total cooling load has been reduced from 3.74 KW of the base case room to 2.79 KW of the room with exterior insulation representing 0.95% and to 2.88 KW of the room with interior insulation representing 0.86% of total cooling load reduction. The result shows that when the insulation was applied outside the structures of the wall, it has recorded the top cooling load reduction.

<u>Scenario 5: Thermostone block wall</u>

Thermostone which is also known as Autoclaved Aerated Concrete (AAC block) is simply combined with water, cement, lime with an aggregate such as sand or other material. It is 50% lighter yet 30% larger than conventional masonry blocks. Thermostone is widely recommended to use in wall construction due to its advantages such as high thermal insulation power, environmentally friendly, fire resistant and it's lightweight. In spite of its advantages, it is the most expensive wall construction material compared with other conventional masonry blocks. Simulation result of applying thermostone block wall in three different room scenarios to figure out the effective on indoor operative temperature is shown in Figure 5.37. The simulation result graph shows the average of indoor operative temperature when applying interior insulation is higher than the average of indoor operative temperature when applying exterior insulation scenario in spite of the same value of thermal conductivity (U-value 0.439).

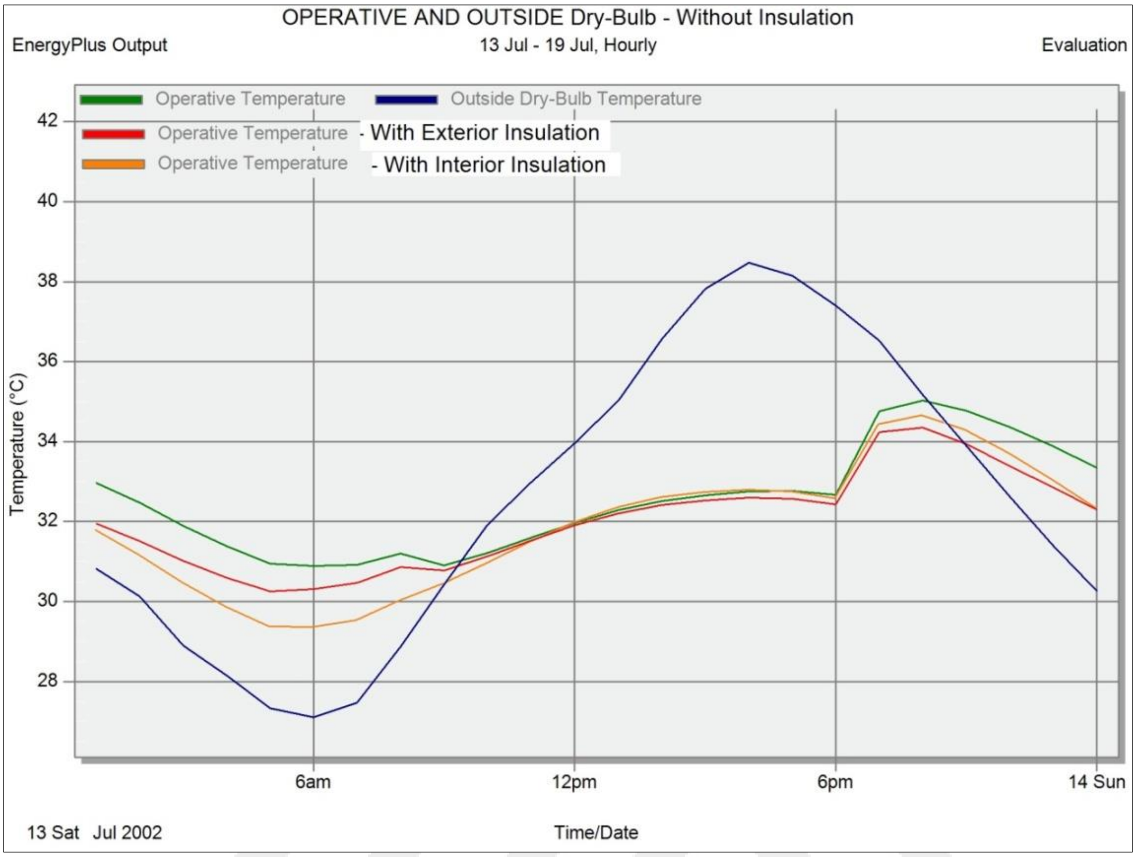


Figure 5.37. Simulation graph showing the result of thermostone block wall applied in three different rooms in the hottest day (at 13 July)

As can be seen in Figure 5.38, room with interior insulation scenario recorded 32.9 °C slightly more than the room with exterior insulation scenario which recorded 30.7 °C. whilst, the average of indoor operative temperature when applying insulation whether inside or outside the wall surface is dropped down about 1~ 1.5K in the range of temperature approximately between 36.4°C ~ 35.3°C compared with the base case room without insulation.

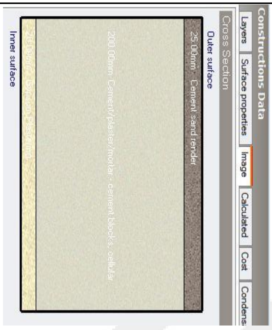
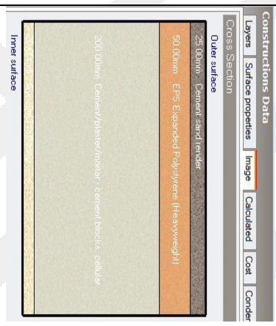
Test Room, Thermostone Block Wall

Analysis | Summary

Zone	Total Cooling Load (kW)	Max Op Temp in Day (°C)	Air Temperature (°C)	Humidity (%)	Time of Max Cooling
− Building					
WthExtrInsltn:Zone1	1.67	30.7	23.1	21.3	Jul 17:30
WthIntrInsltn:Zone1	1.79	32.9	23.0	49.9	Jul 18:00
WithoutInsulation:Zone1	2.71	35.3	23.0	21.4	Jul 18:00
Totals	**6.17**	**35.3**	**23.0**	**31.8**	**N/A**

Figure 5.38. Simulation result showing the total cooling load and maximum operative temperature in three different room scenarios of thermostone block wall

Table 5.14. Cooling load reduction result and details of Thermostone block wall

Thermostone Block Wall				
Simulation Scenarios	Wall Section Showing Insulation Layer Position	U-value (kW/m2 K)	Total Cooling load	Cooling load Reduction%
Base case room without insulation		1.175	2.71	-
Room with exterior insulation		0.439	1.67	1.04%
Room with interior insulation		0.439	1.79	0.92%

Similarly, the average of indoor operative temperature when applying exterior insulation layer is less than the average of indoor operative temperature when applying interior insulation layer. As can be seen in Table 5.14 the total cooling load has been reduced from 2.71 kW of the base case room to 1.67 kW of the room with exterior insulation representing 1.04% and to 1.79 kW of the room with interior insulation representing 0.92% of total cooling load reduction.

To summarize the results of the above simulation wall scenarios which investigated the effect of thermal insulation position on indoor operative temperature and cooling load. The analysis in all room scenarios show that applying exterior thermal insulation is the best comparing with applying interior thermal insulation layer on wall section. As a result, to select the best thermal insulation position from three insulation scenario given in three different room, it is clearly seems room with exterior wall insulation has recorded the lower indoor operative temperature and thus the lower cooling load. In spite of the same thickness of the wall material and insulation layer there is a difference between the thermal performances of room with exterior insulation layer comparing with room with interior insulation layer. Therefore, it can be concluded that located the thermal insulation on thermal mass of the building is affected the cooling load significantly. In another side, if we compare between all wall scenarios the result of Thermoston wall with exterior insulation can be considered as the best option in terms of thermal performance manner. As can be seen in Table 5.15 Thermostone wall with exterior insulation has recorded the lowest indoor operative temperature and cooling load as well. Therefore, this wall scenario used in the real case house simulation.

Table 5.15. Wall thermal mass type and simulation scenarios showing the cooling load reduction in each scenario

Wall Thermal Mass Type	Simulation Scenarios	Total Cooling Load (kW/h)	Cooling Load Reduction%
Solid Brick Wall	Base case room without insulation	3.55	-
	Room with exterior insulation	2.76	1.24%
	Room with interior insulation	2.85	1.15%
Hollow Brick Wall	Base case room without insulation	3.18	-
	Room with exterior insulation	2.74	1.23%
	Room with interior insulation	2.81	1.11%
Solid Concrete Block Wall	Base case room without insulation	4.00	-
	Room with exterior insulation	2.75	1.25%
	Room with interior insulation	2.92	1.08%
Hollow Concrete Block Wall	Base case room without insulation	3.74	-
	Room with exterior insulation	2.79	0.95%
	Room with interior insulation	2.88	0.86%
Thermostone Block Wall	Base case room without insulation	2.71	-
	Room with exterior insulation	1.67	1.04%
	Room with interior insulation	1.79	0.92%

As mentioned before, the best thermal insulation layer position is achieved in all thermal mass types when it was used in the outer surface of the wall section. According to this result all thermal mass type with only exterior insulation scenarios was simulated to find out the best thermal mass type in terms of cooling load reduction. Result graph in Figure 5.39 and 5.40 shows the comparisons of all thermal mass type in relation to cooling loads and total energy consumption. As clearly can be seen the result of all wall scenarios has shown that Thermostone wall with exterior insulation is the best option.

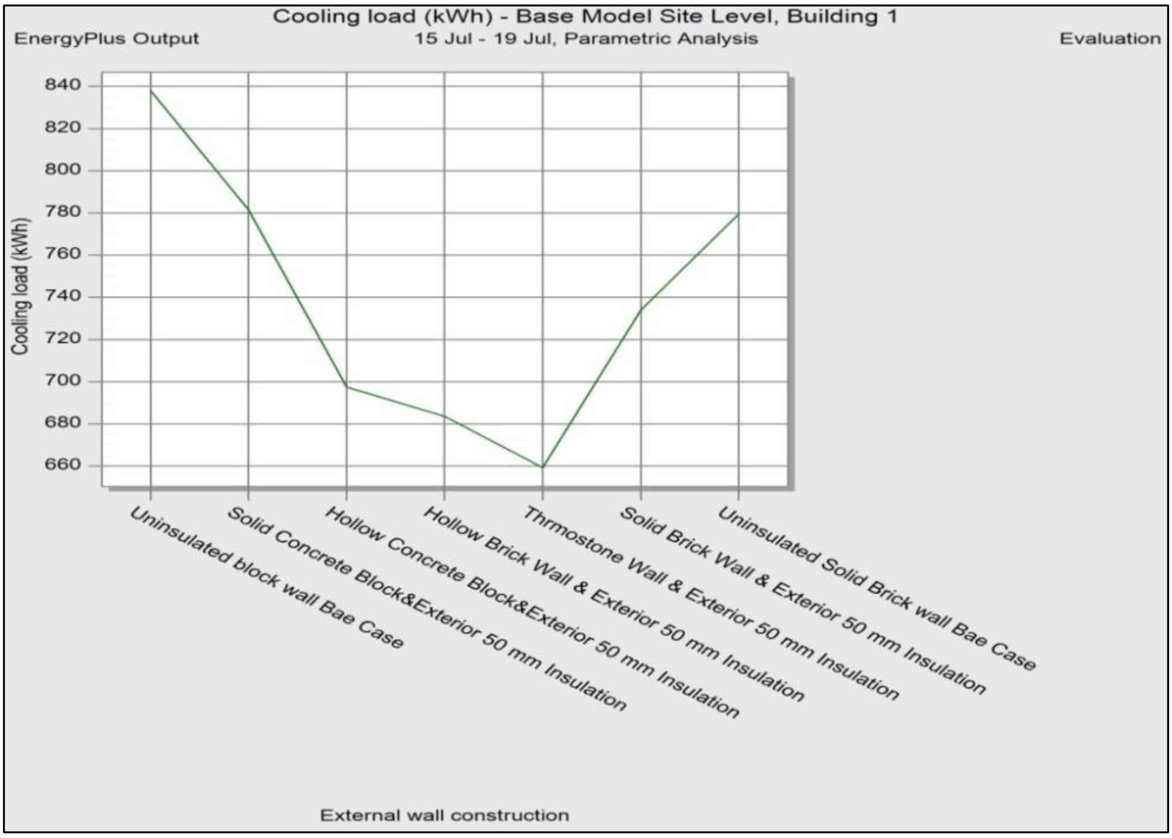


Figure 5.39. Comparative simulation analysis of all proposed wall thermal mass with exterior insulation in relation with cooling load calculation

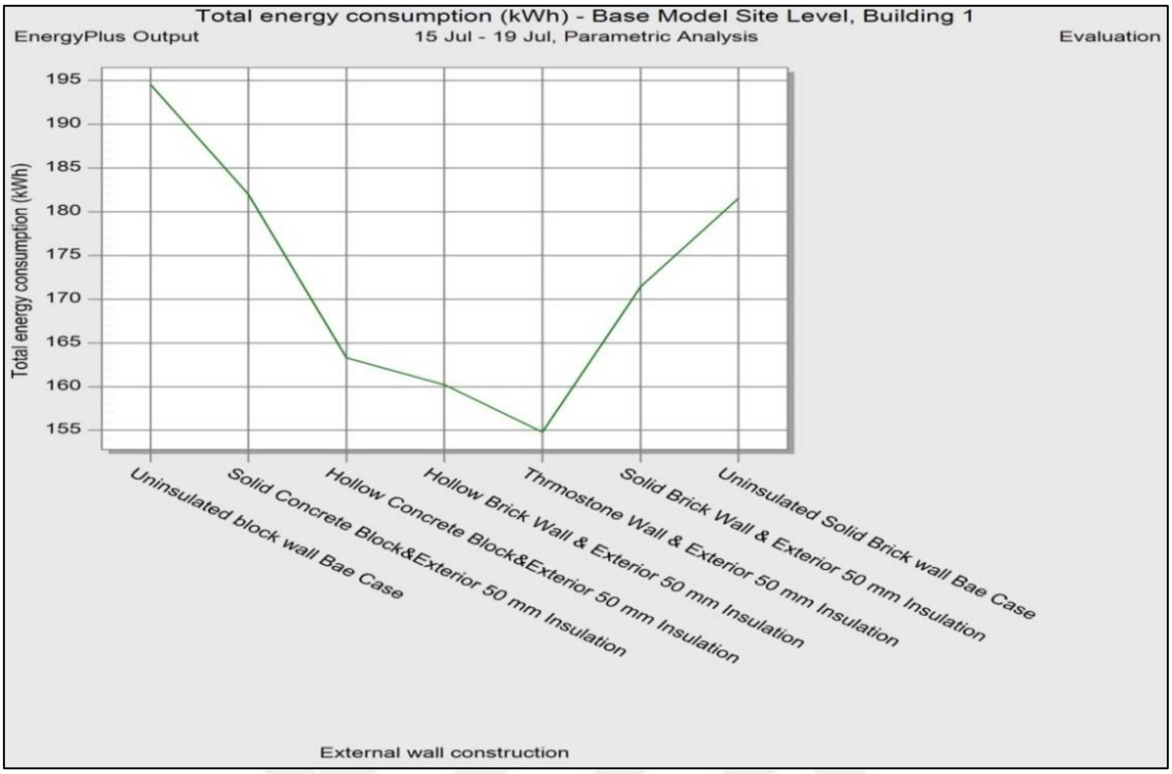


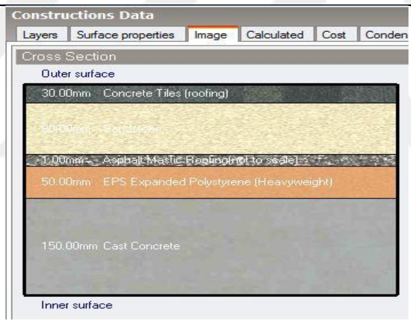
Figure 5.40. Comparative simulation analysis of all proposed wall thermal mass with exterior insulation in relation with total energy consumption

As a conclusion, the result of the simulation shows that there are great different amount of cooling load between the Thermostone block wall and all other simulated wall types. Throughout all wall scenarios, Thermostone wall with exterior insulation has recorded the lowest energy consumption rate as can be seen in Figure 5.40.

5.1.6. Thermal mass performance analysis of roof (assessment of insulation layer position in two roof scenarios)

Most of the houses in Erbil city covered by a horizontal flat roof exposed to the sun all the daytime. Therefore, this component of the building envelope is receiving a large amount of solar heat from the sun during summer days leading to increase indoor air temperature especially for space under this extremely heated flat roof. It is essential to find out a solution for preventing heat flow throughout the flat roof in step forward to lower down the heat build-up and improve indoor thermal conditions. In this case, the simulation analyses will focus on the thermal insulation positioning on the flat roof to determine the best performance that can be thermally-effective by minimize heat gain in step forward to lower the indoor operative temperature during summer periods. Roof thermal simulation analysis considered to be into two different scenario of insulation position as reflected in Table 5.16. Scenario A applying 50 mm of expanded polystyrene that are placed above the concrete slab and scenario B applied the same thickness of thermal insulation but under the concrete roof slab.

Table 5.16. Three type of roof scenarios and roof details

Scenario	Roof section and thickness	Total Roof Thickness	U value (W/m^{2}K)
Base case: Roof without thermal insulation		150 mm	3.655
Scenario A: Roof with applying exterior 50 mm thermal insulation		215 mm	0.566
Scenario B: Roof with applying interior 50 mm thermal insulation		215 mm	0. 566

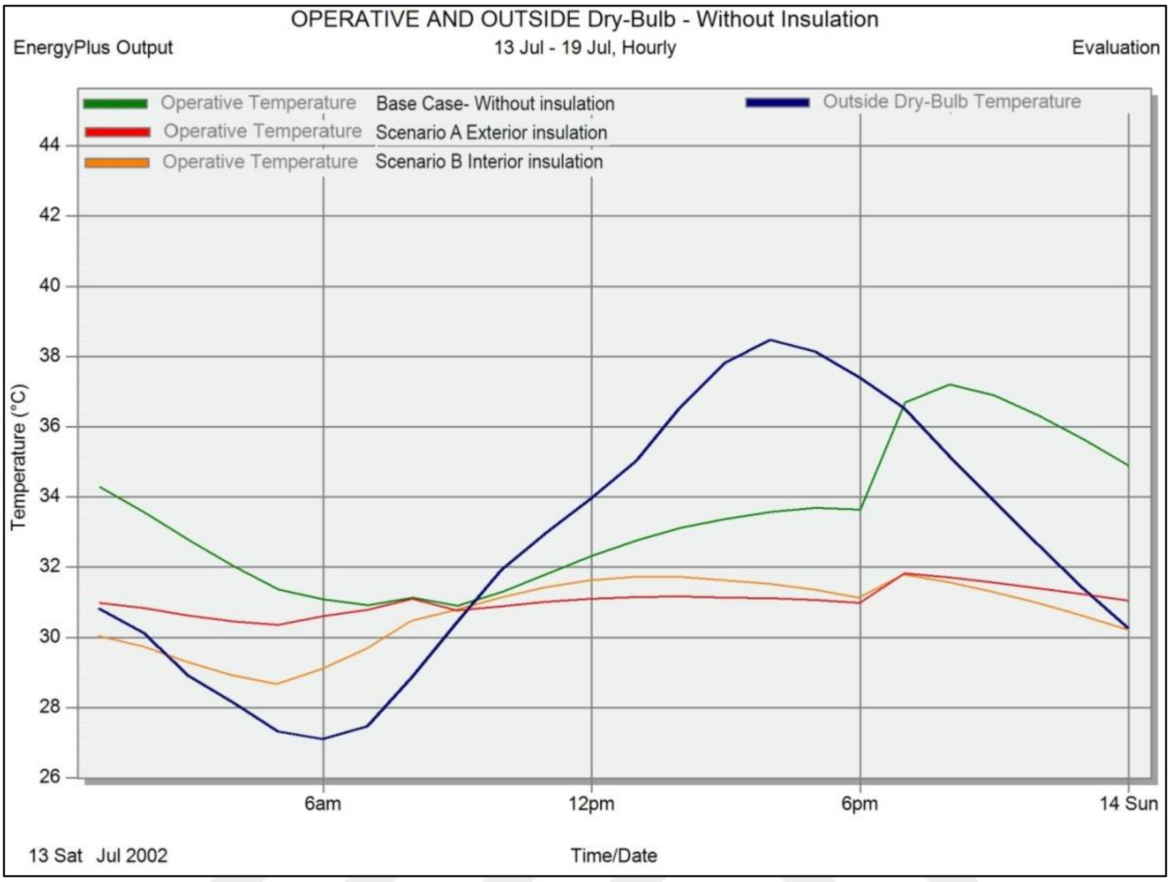


Figure 5.41. Simulation results showing the effect of all roof thermal insulation scenarios on indoor operative temperature

Simulation graph in Figure 5.41. showing the indoor operative temperature dropped down after 8am because of the effect of mechanical air conditioning which is designed to be operated from 7 am with sunrise until 7 pm with sunset. Adding exterior 50 mm insulation on the outer surface of the flat roof slab has a great effect on reducing indoor operative temperature against the base case roof which has no thermal insulation. The averages of the indoor operative temperature of scenario A fluctuate between about 31-31.5°C where the base case wall showing a different range of indoor operative temperature fluctuates between 31.5-37.5°C which is approximately in the range of 0.5-6.5 K comparing with the base case roof scenario.

As well as the results detected that, by applying scenario A there is a great effect in lowering indoor operative temperature about 0.1 ~ 0.8 K comparing with scenario B. Regarding the simulation result we can come to this conclusion: There is no a significant difference between those two roofs insulation scenarios: applying thermal insulation on the top of concrete roof slab results in effecting indoor operative temperature decreasing about

0.5-6.5 K, whereas applying thermal insulation under concrete roof slab results approximately in the same amount of indoor operative temperature reduction. This means there is a very slight reduction of indoor operative temperature when applying scenario A compared with scenario B, but a great reduction of indoor operative temperature is obtained against the base case roof with no insulation. The following step of simulation is to figure out the influence of thermal insulation position on cooling load which is reflected in Figure 5.42. Positively, applying thermal insulation on the concrete roof slab show variation in indoor operative temperature compared with the base case, that decreasing resulted to minimize the cooling loads from 3.06 kW in the base case roof without insulation to 2.62 kW in scenario A and to 2.79 kW in scenario B.

Test Room, Building

Analysis | Summary

Zone	Total Cooling Load (kW)	Max Op Temp in Day (°C)	Air Temperature (°C)	Humidity (%)	Time of Max Cooli...
Building					
WthExtrrInsltn:Zone1	2.62	32.3	30.0	14.2	Jul 14:00
WthIntrrInsltn:Zone1	2.79	32.6	30.0	14.2	Jul 14:00
WithoutInsulation:Zone1	3.06	41.4	30.0	14.2	Jul 17:30
Totals	**4.46**	**41.4**	**30.0**	**14.2**	**N/A**

Figure 5.42. Simulation result showing the total cooling load and maximum operative temperature in three different roof scenarios

As can be seen from the details of cooling load reduction in table 5.17 scenario A achieved the best cooling load reduction comparing with B scenario. The total cooling load has been reduced from 3.06 kW of the base case roof to 2.62 kW of the room with exterior insulation representing 0.44% and to 2.79 kW of the room with interior insulation representing 0.27% of total cooling load reduction. This results shows that there is significant impact of reducing indoor operative temperature when using thermal insulation layer especially on the top of the roof slab.

Table 5.17. Output data of the three different roof scenarios shows the effect of each scenario on cooling load reduction

Roof Scenarios	U value (W/m^2K)	Total Cooling Load (kW/h)	Cooling Load Reduction%
Base case: Roof without thermal insulation	3.655	3.06	-
Scenario A: Roof with applying exterior 50 mm thermal insulation	0.566	2.62	0.44%
Scenario B: Roof with applying interior 50 mm thermal insulation	0. 566	2.79	0.27%

5.2. Passive Cooling Techniques Simulation in the Actual House Model

In this stage, the actual housing building model in DesignBuilder was constructed according to building materials of the typical housing as described previously. Then, the building was oriented towards north-south. The proposed passive cooling techniques applied in the actual house model and evaluated in terms of cooling load reduction

5.2.1. Simulation template of the base case house

The energy simulation models run based on a comparison analysis method between the base case and the proposed case model after applying the proposed cooling methods through different scenarios. Before running the simulations in DesignBuilder, there are many parameters affecting the indoor operative temperature such as: solar heat gains through exterior windows, lighting, equipment, occupancy profile, total fresh air delivery rate, infiltration level or air tightness of building fabric, and ventilation whether it is mechanical cooling air system or natural ventilation. All these parameters were kept constant while running the proposed simulation scenarios to obtain more accurate simulation results, thereby ensuring that the variations in cooling load resulted only from applying the proposed passive cooling techniques. The model building is set to be facing the north-south orientation. The parameters and thermal characteristics of the both base case model house and the proposed energy efficient case house which in turn has a major impact on the building heating; cooling and ventilation are described in Table 5.18.

Table 5.18. The simulation templates details of the two house scenarios

Simulation Templates		Base Case House	Proposed Energy Efficient House
Construction Data	Wall	Uninsulated concrete block wall	Thermostone Block Wall with 50mm exterior insulation (EPS Expanded Polystyrene)
	Roof	Uninsulated cast concrete slab	Cast concrete slab with 50mm exterior insulation (EPS Expanded Polystyrene)
	Infiltration	0.7 on 24/7	0.7 on 24/7
HVAC Template		• Split no fresh air with 1.8 cooling systems seasonal coefficient. • Operation schedule: turn on from 7:00 am-7:00 pm. • Cooling set point temperature: 26 ◦C. • cooling setback : 32 ◦C	• Split no fresh air with 1.8 cooling systems seasonal coefficient. • Operation schedule: turn on from 7:00 am-7:00 pm. • Cooling set point temperature: 26 ◦C. • cooling setback : 32 ◦C
Activity Template	Standard Template	ASHRAE 62.1 - Residential - Dwelling unit (with kitchen) Space by Space Definition for Lighting, Occupation, and Gains	ASHRAE 62.1 - Residential - Dwelling unit (with kitchen) Space by Space Definition for Lighting, Occupation, and Gains
	Occupancy profile	Four members, single family	Four members, single family
Opening Template	Glazing type	single glazing /clear /no shading	Double Low-E Colored Glass 6mm/6mm Air
	Windows to wall ratio %	30%	30%
	Operation schedule	set to be closed from 7:00 am-7:00 pm	set to be closed from 7:00 am-7:00 pm

For the purpose of the energy simulation process, the energy model was designed to be mechanically ventilated using air conditioning units (AC with no fresh air) to calculate the cooling loads. Air changes rate per hour (ac/h) under AC with no fresh air operating pressures (Pa) is left as the DesignBuilder program automatically calculated as 1.7 ac/h @ 50 Pa. DesignBuilder calculates the air rate flow in accordance with ASHRAE standards.

5.2.2. Simulation results of the base case house

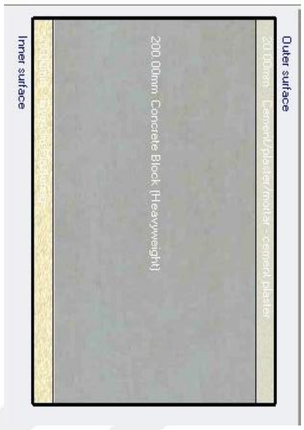
In the past few decades, an increase in energy demand has been witnessed in the city of Erbil because of new construction projects especially in the housing sector due to urban growth in general. Unfortunately, most of the architects, engineers, and housing construction companies are designing these new houses without taking into account the local climate conditions. A large number of these houses are built without proper insulation, un-shaded and large glazed openings without regard of natural ventilation and daylight. Therefore, people are using huge amounts of energy, especially for air conditioning devices for cooling during hot summer days to ensure satisfactory indoor thermal conditions. The energy simulation mainly based on thermal comparative method between the base case model (As built house) and the proposal energy efficient house model after applying passive cooling methods through different scenarios, and then new thermal result and cooling energy performance evaluated. Table 5.19 highlighted the simulation scenarios and building construction data of the base case house model.

Table 5.19. Base case house simulation scenarios and construction data

<table>
<tr><td colspan="9">First Strategy : Reduce heat gains techniques</td></tr>
<tr><td>Applied Passive Cooling Techniques</td><td colspan="8">Simulation Scenarios</td></tr>
<tr><td>1.Shading</td><td colspan="2">Windows Shading</td><td colspan="2">Roof Shading</td><td colspan="4">Wall Shading</td></tr>
<tr><td>2.Glazing</td><td colspan="2">Base case
Single clear glass 6mm</td><td colspan="2">Double Clear Glass 6mm/13mm</td><td colspan="2">Triple Clear Glass 3mm/13mm</td><td colspan="2">Double Low-E Colored Glass 6mm/6mm</td></tr>
<tr><td colspan="9">Second Strategy: Modify heat gains techniques</td></tr>
<tr><td rowspan="2">Applied Passive Cooling Techniques</td><td colspan="8">Simulation Scenarios</td></tr>
<tr><td colspan="3">Wall Scenarios</td><td colspan="5">Insulation Layer Position</td></tr>
<tr><td>1. Wall Thermal Mass</td><td colspan="3">• Solid brick wall
• Hollow brick wall
• Solid concrete block wall
• Hollow concrete block wall
• Thermostone wall</td><td>without insulation</td><td colspan="2">with exterior insulation</td><td colspan="2">with interior insulation</td></tr>
<tr><td rowspan="2">2.Roof Thermal Mass</td><td colspan="3">Roof Scenarios</td><td colspan="5">Insulation Layer Position</td></tr>
<tr><td colspan="3">Cast Concrete Slab</td><td>without insulation</td><td colspan="2">with exterior insulation</td><td colspan="2">with interior insulation</td></tr>
</table>

The construction template In DesignBuilder software specify the main building fabric properties which indicate the thermal performance of the internal and external surface of the building and can have a significant impact on comfort condition and cooling loads. Table 5.20 simply shows the wall and roof construction data and thermal properties which used in the model of the simulation process of the base case house. As mentioned earlier, the base case house modeled based on the current construction materials which are used for construction modern residential building in Erbil city in order to represent the reality.

Table 5.20. Construction data details and thermal properties of the base case house

Envelop component	Materials and Thickness (mm)	U-Value (W/m^{2}K)	Template
Wall	1- Cement sand render (20 mm) (Out) 2-Concret block (200mm) 3- Plastering (20 mm) (In)	1.582	
Roof	1- Concrete Slab (200mm) (Out) 2- Plastering (20 mm) (In)	2.725	

As this simulation work concerned with cooling load, summer month profile (from 1 April till 30 of September) is selected in the simulation process to determine the total cooling energy consumption during summer season. The base case house simulated without any kind of shading such as the window, roof or wall shading. Furthermore, glazing type is selected to be as most of the modern building house glazing type in Erbil city which is single clear glass without external shading. The base house model was created with the same building characteristic and construction material features as shown in Table 5.20.

The challenge of energy simulation processes arises in identifying the simulation utilization parameters; such as the ventilation system parameters whether it is natural or mechanical, cooling and heating set-points temperature and occupancy operation schedule of different zones. These parameters have a significant effect on the average of indoor operative temperature and overall cooling load as well as energy consumption of any simulated model (Friess et al., 2012). The occupancy levels in the base case model and other scenarios are the same which is four family members (2 parents and 2 young children).To ensure the accuracy of the simulation process the same air conditioning ventilation system was selected as HVAC template in the base case house and the proposed energy efficient house models. The commonly used air conditioning system during summer in Iraq is selected to be applied in the simulation process (AC, split indoor air conditioner units) with the same power and cooling system seasonal coefficient factor (1.8) as reflected in Table 5.19.

To understand and compare the output results of cooling energy consumption of the base case house with the energy efficient case house model, the cooling energy performance during summer from 1 April till 30 September is analyzed. Additionally, the energy simulations were employed to pick out and emphasize summer peak month for cooling energy performance and its impact on the total electricity requirement reduction. As can be seen from the result graph in Figure 5.43 which shows the cooling load performance of the base case house during summer, peak cooling load was recorded in July month and the total cooling load is about 6997.36 kWh. This high amount of cooling load in July resulted in increasing the usage of electricity which recorded the highest rate of energy consumption in amount of 9408.98 kWh in July as shown in Figure 5.44. Note that total energy consumed only by the cooling load in the simulation due to neglecting other sources of heating such as lighting and other types of equipments. Consequently, every month has different sensitivity in the amount of cooling load due to the variations of outdoor temperature in each month.

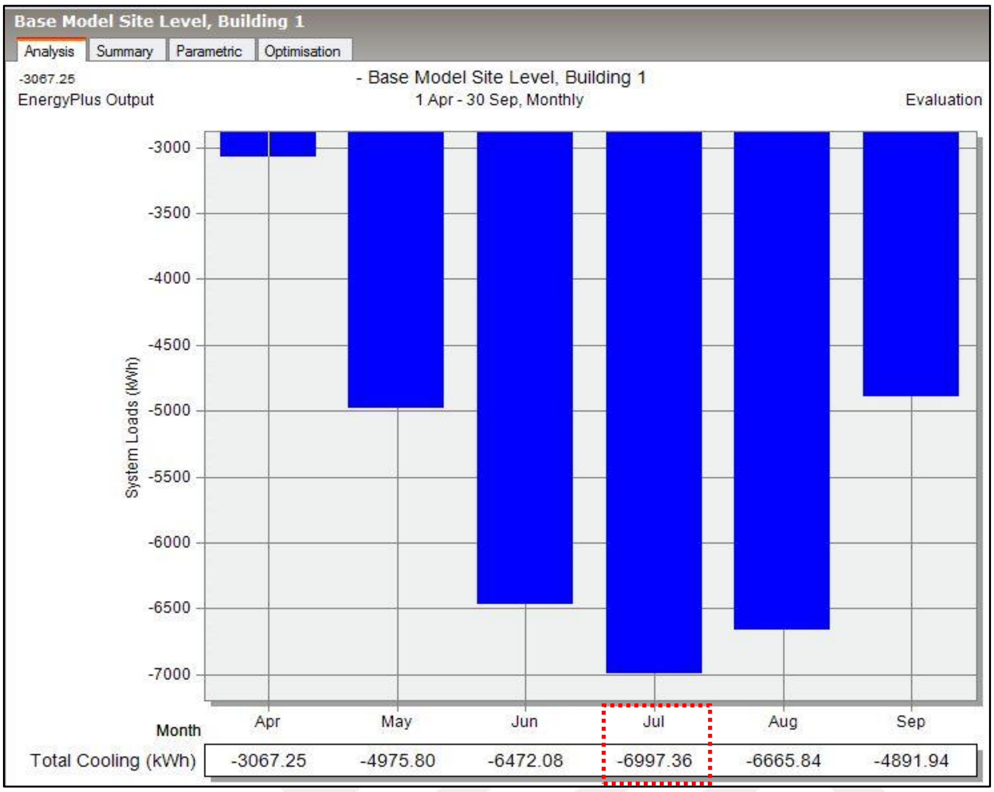


Figure 5.43. Total cooling load performance of the base case house during summer from April to September showing the peak cooling load in July

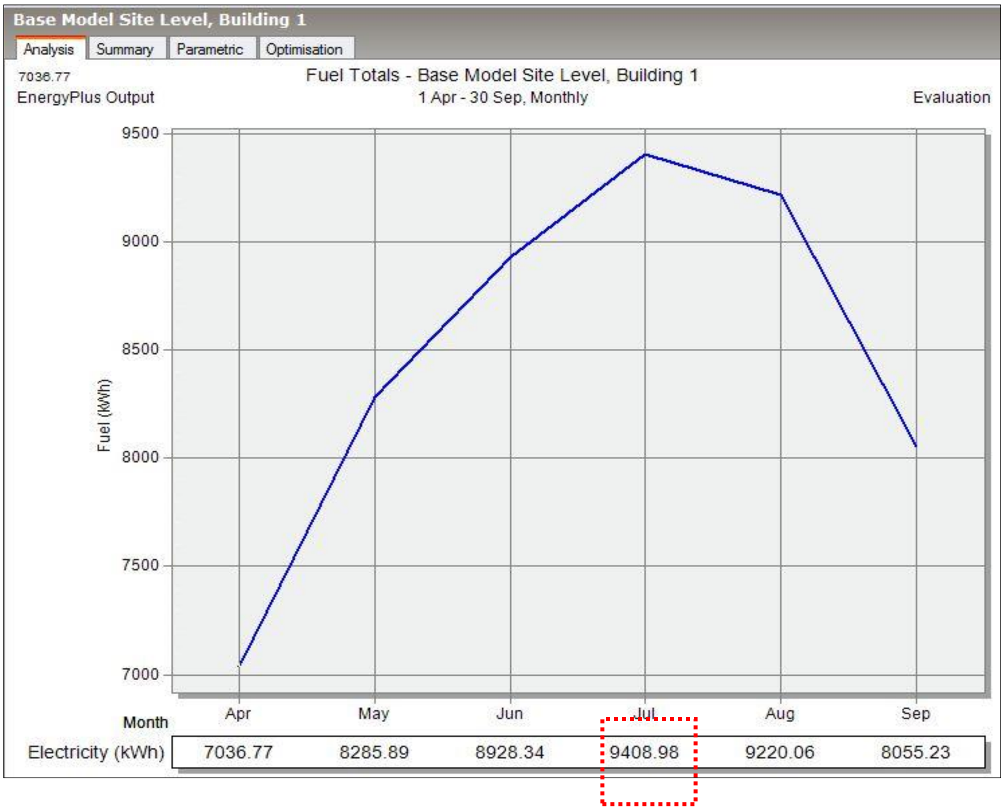


Figure 5.44. The total energy consumption (Electricity) during the summer season of the base case house showing the highest amount of energy consumption in July

5.2.3. Simulation results of the proposed energy efficient house

Minimizing heat gain and controlling solar heat from entering the indoor spaces is the key challenge of architecture design during the summer session. There are many strategies can be adopted in building design to reduce heat gain, however ,in this simulation work only two techniques was investigated as follows.

1. Using traditional Mashrabiya as exterior barriers to block solar heat gain used in three different scenarios as shown in Table 5.19.
2. Improving glazing type from single clear glass to advanced treated high-quality glass type (double low-E colored glass).

5.2.4. Assessment the effect of using mashrabiya in windows, roof and wall shading on cooling load

Appropriate external solar shading can help to significantly minimize cooling energy consumption and improve indoor operative temperature. One of the proposed passive cooling methods in this work is the re-designing model of the traditional Mashrabiya elements as a step forward to reduce cooling load in modern housing buildings.

This design concept corresponds with the philosophy of Hassan Fathy as he encourages architects to learn lessons from vernacular architecture and holds it as a source of inspiration in the modern architecture context. The flat roofs of the houses located in Iraq are considered as the most exposed building envelope component to the impacts of solar radiation. In this situation, it is necessary to apply or suggest a solution for preventing heat flux from flat roof surface toward indoor spaces. Minimizing heat flux through the flat roof caused by direct solar radiation is a vital key for reducing the need of indoor space cooling.

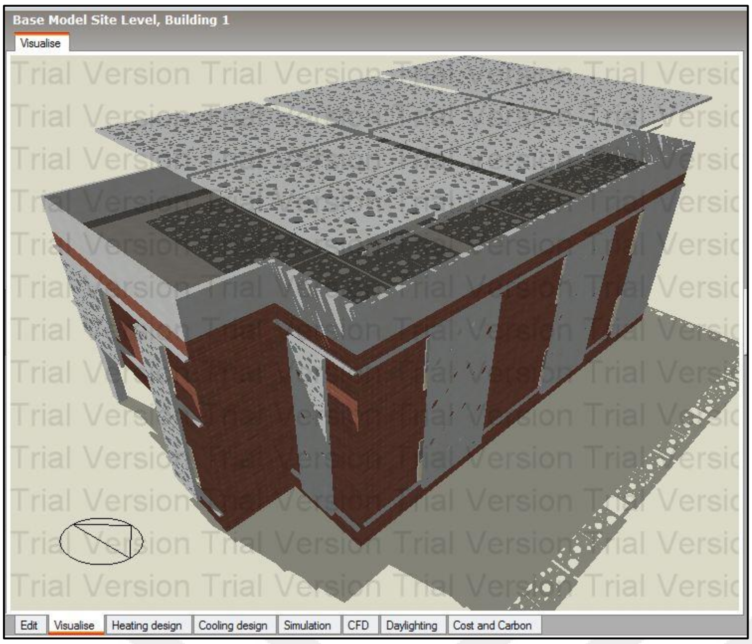


Figure 5.45. Proposed Mashrabiya model as external shading device of roof and windows (modeled by DesignBuilder)

Another solution to reduce heat gain is proposed by using Mashrabiya covering the windows in order to reduce solar radiation during the summer session. The proposed Mashrabya was positioned in the South, East, and Western façades of the modeled house building in order to block direct solar gain during daytime from 7:00 am to 7:00 pm. The proposed screen shading was designed in a flexible way; it is a movable screen designed to blocks the direct solar radiation in summer, yet it allows light to pass through its opening mesh into indoor spaces during the winter season as can be seen in Figure 5.50. After running the simulation of the two different scenarios one before adding the proposed screen shading (Mashrabiya) and the other without any screen ,we obtained the result shown in Figures 5.46 and 5.47. From the graph shown in Figure 5.46, it can be observed that there is heat conduction through exterior windows before applying the proposed shading screen (Mashrabiya) reaching a maximum value at morning hours during the sun rising. Internal heat gain through the exterior windows before adding Mashrabiya reached approximately maximum amount of 15 kW at the east and 11 kW at the west facades, respectively. Accordingly, the cooling load of the modeled house increased gradually because of heat gain from exterior windows recording 22 kW during the peak cooling load period. From Figure 5.44, the simulation results revealed that, due to shading from solar radiation provides by proposed screen, heat gain through exterior windows was decreased from 15 kW to approximately 8 kW in the morning and from 11kW to 6 kW afternoons.

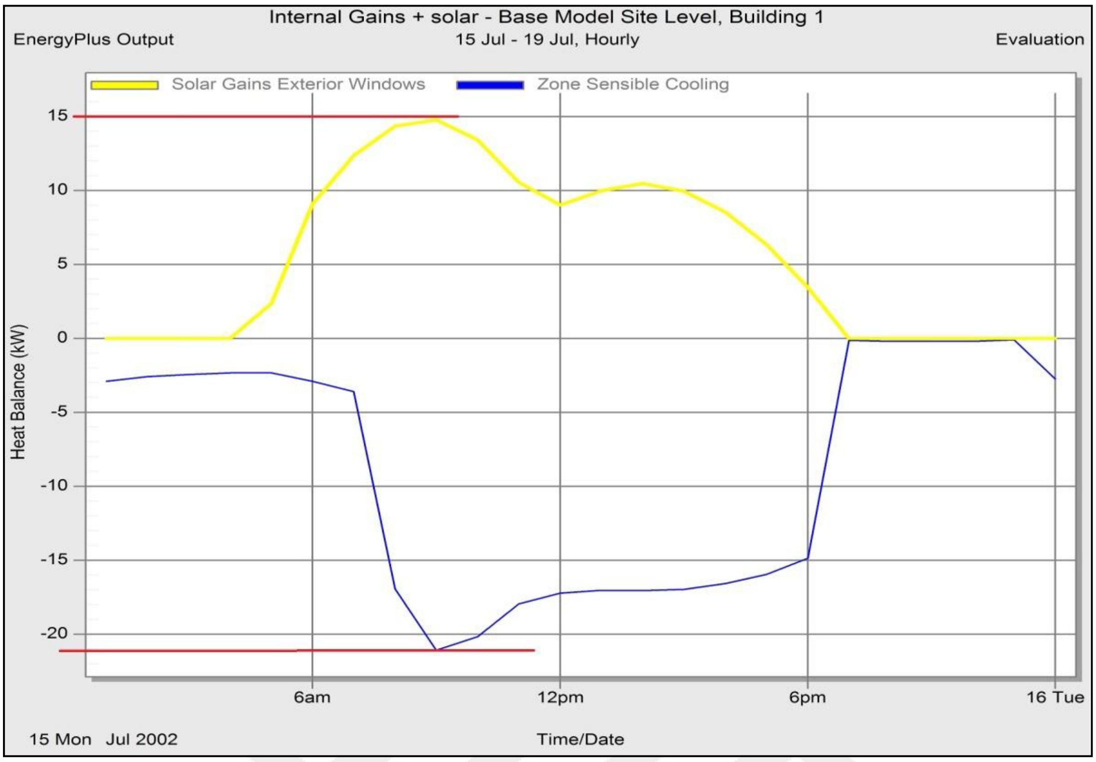


Figure 5.46. Simulation result showing internal gain through the exterior windows before adding proposal screen shading (Mashrabiya) started from 7:00 am to 7:00 pm on 15 of July.

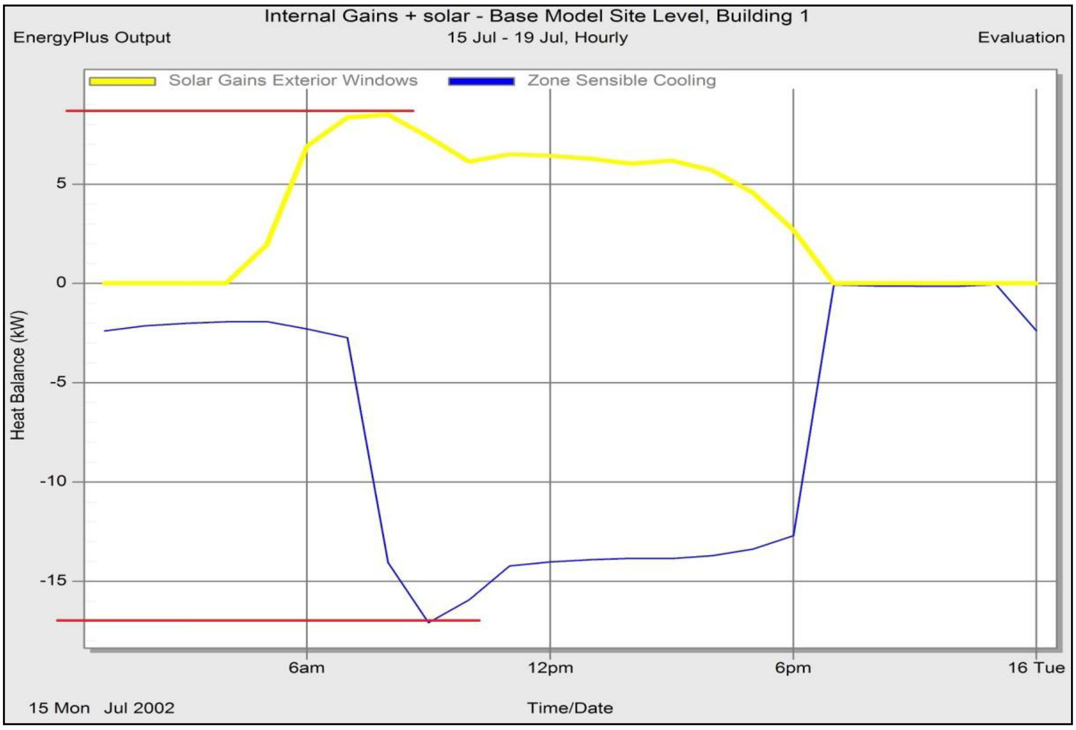


Figure 5.47. Simulation result showing internal heat gain through the exterior windows after adding proposal screen shading (Mashrabiya) started from 7:00 am to 7:00 pm on 15 of July.

The effect of using Mashrabiya as a shading screen on the exterior windows was effective in reducing the cooling load from about 6997 kWh in the base case house (Figure 5.45) to approximately 6117 kWh in the energy efficient house scenario (Figure 5.46) during the peak cooling load in July, which is play a great role in decrease the total energy consumption from 9408 kWh to about 8920 kWh during the peak cooling load in July as shown in Figure 5.49.

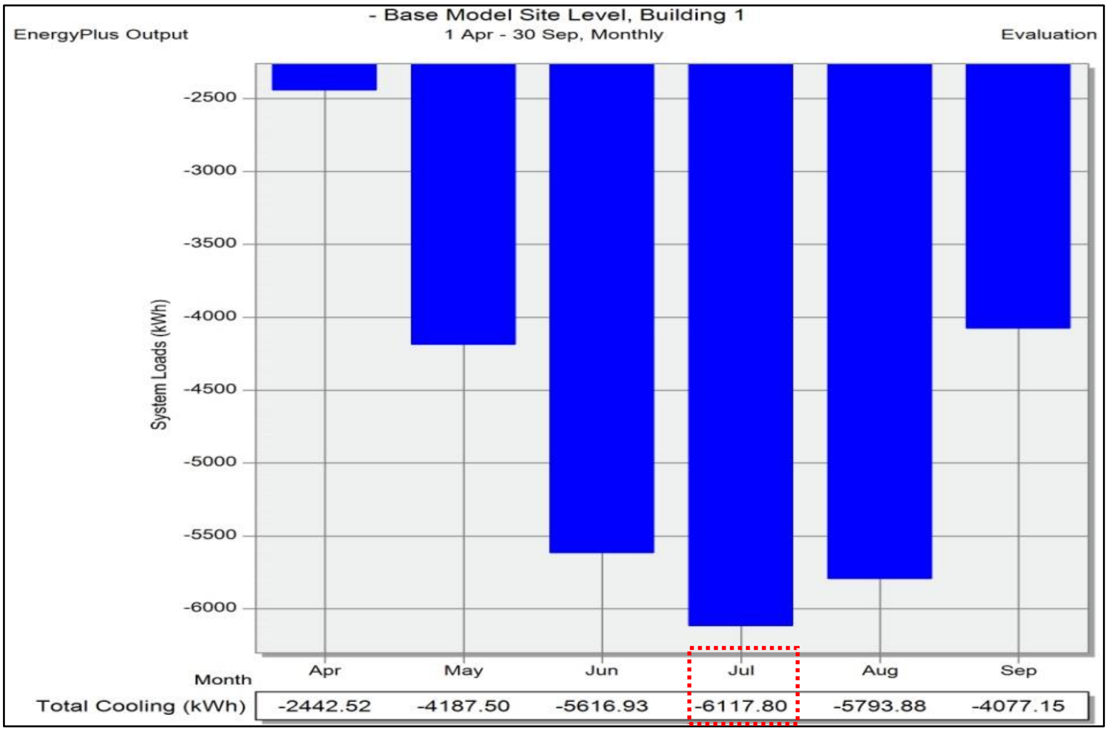


Figure 5.48. Total cooling load result after applying Mahrabyiya in the exterior windows of the proposed energy efficient house during summer from April to September

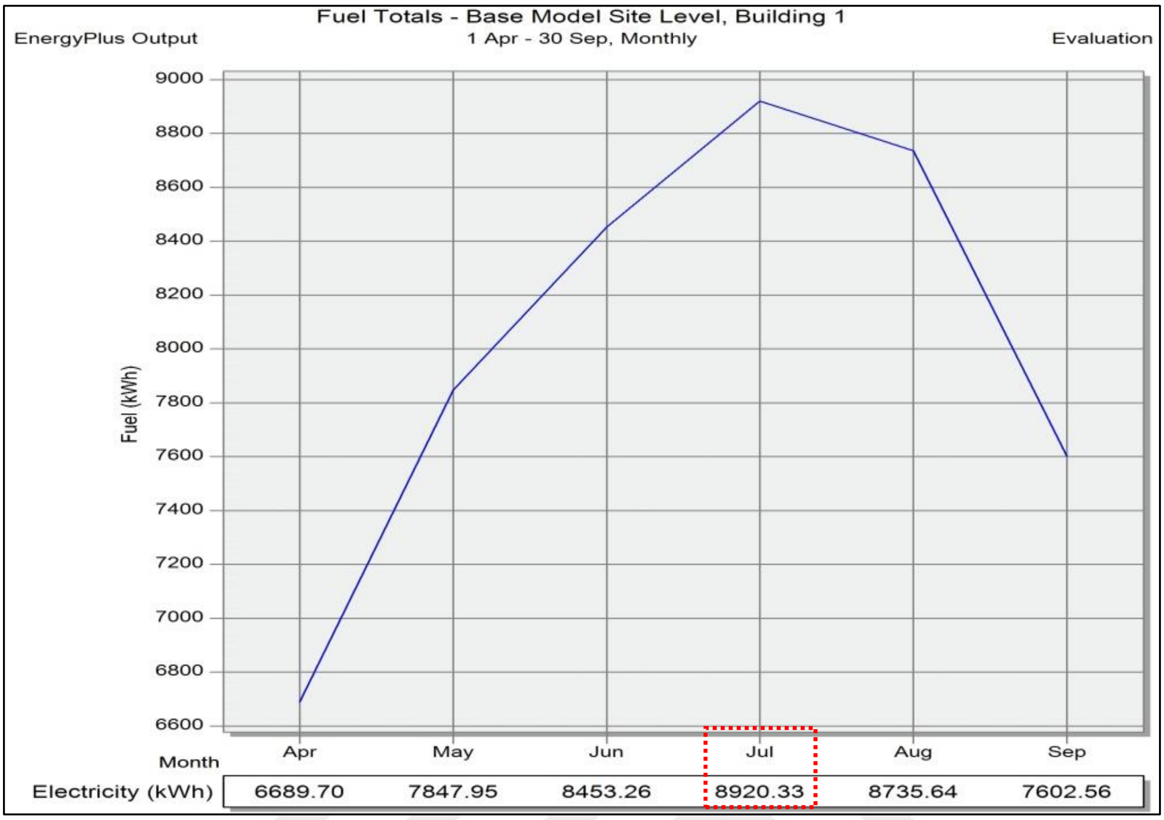


Figure 5.49. Total energy consumption (Electricity) result after applying Mahrabyiya in the exterior windows of the proposed energy efficient house during summer from April to September

As clearly can be seen from the simulation results in Figure 5.50 which shows that adding screen shading above the flat roof to create shading from direct solar radiation had a great effect in lowering the cooling load from 6997 kWh in the base case house to approximately 6497 kWh during the peak cooling load in July, which enhanced to decrease the total energy consumption from 9408 kWh in the base case house to about 9131 kWh during the peak cooling load in July as shown in Figure 5.51.

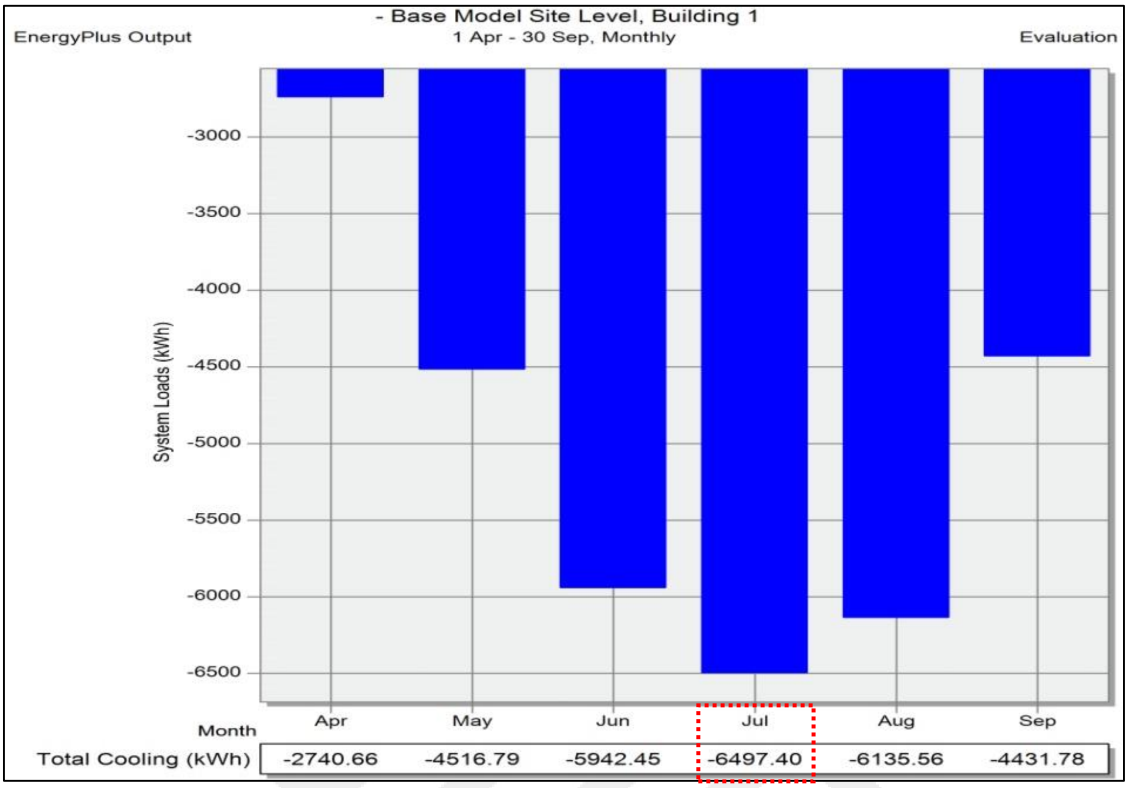


Figure 5.50. Total cooling load result after applying Mahrabyiya to cover the flat roof of the proposed energy efficient house during summer from April to September

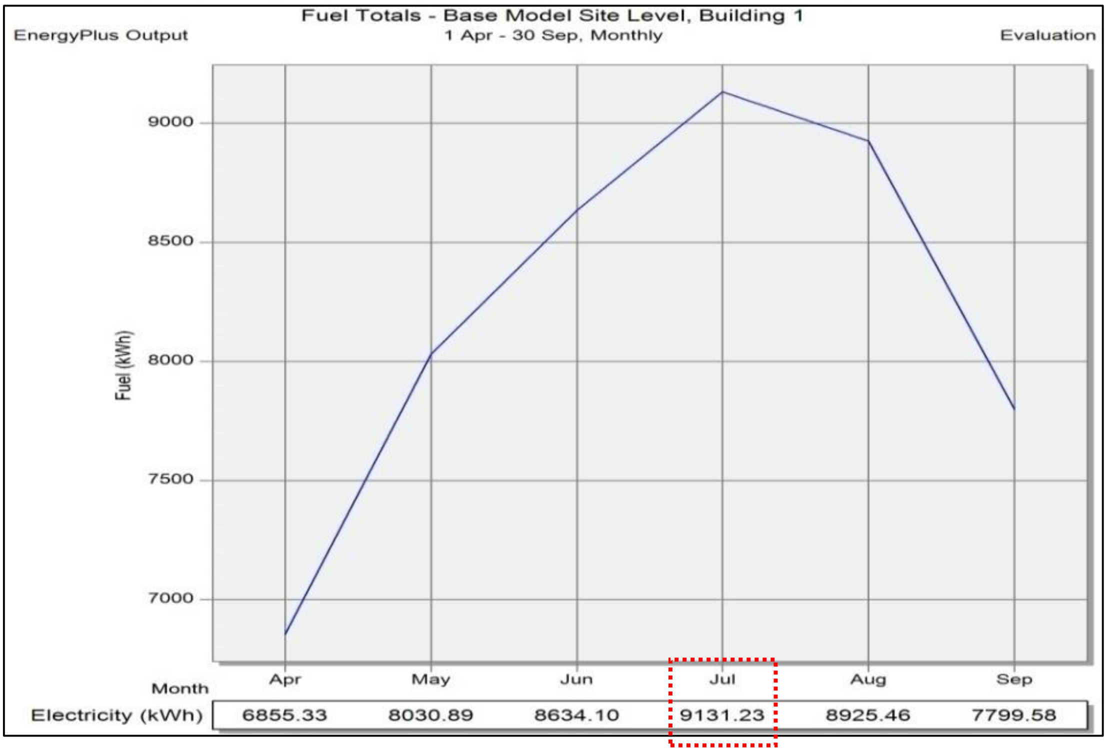


Figure 5.51. Total energy consumption (Electricity) result after applying Mahrabyiya to cover the flat roof of the proposed energy efficient house during summer from April to September

Whereas applying Mashrabiya to cover the exterior walls and provide shading has recorded the smallest amount of cooling load reduction comparing with windows and roof shading scenarios. Figure 5.52 show that adding screen shading to cover the exterior walls and prevent direct solar radiation from heating up the walls in all direction slightly lowering the cooling load from 6997 kWh in the base case house to approximately 6785 kWh in the energy efficient house scenario during the peak cooling load in July. This reduction decrease the total energy consumption from 9408 kWh in the base case house to about 9291 kWh during the peak cooling load in July as shown in Figure 5.53. Based on above results and to find out the best shading scenario, Table 5.21 compare between all proposed shading scenarios by using Mashrabiya model in terms of cooling load and total energy consumption reduction.

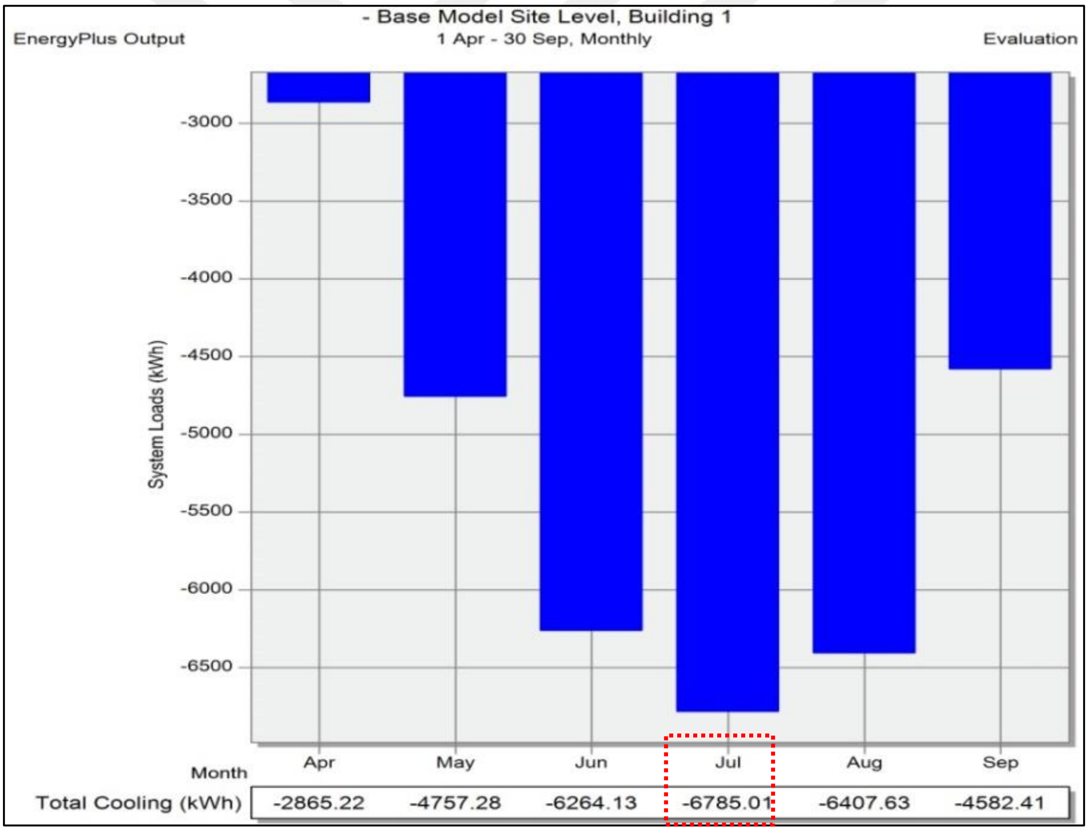


Figure 5.52. Total cooling load result after applying Mahrabyiya to cover the exterior walls of the proposed energy efficient house during summer from April to September.

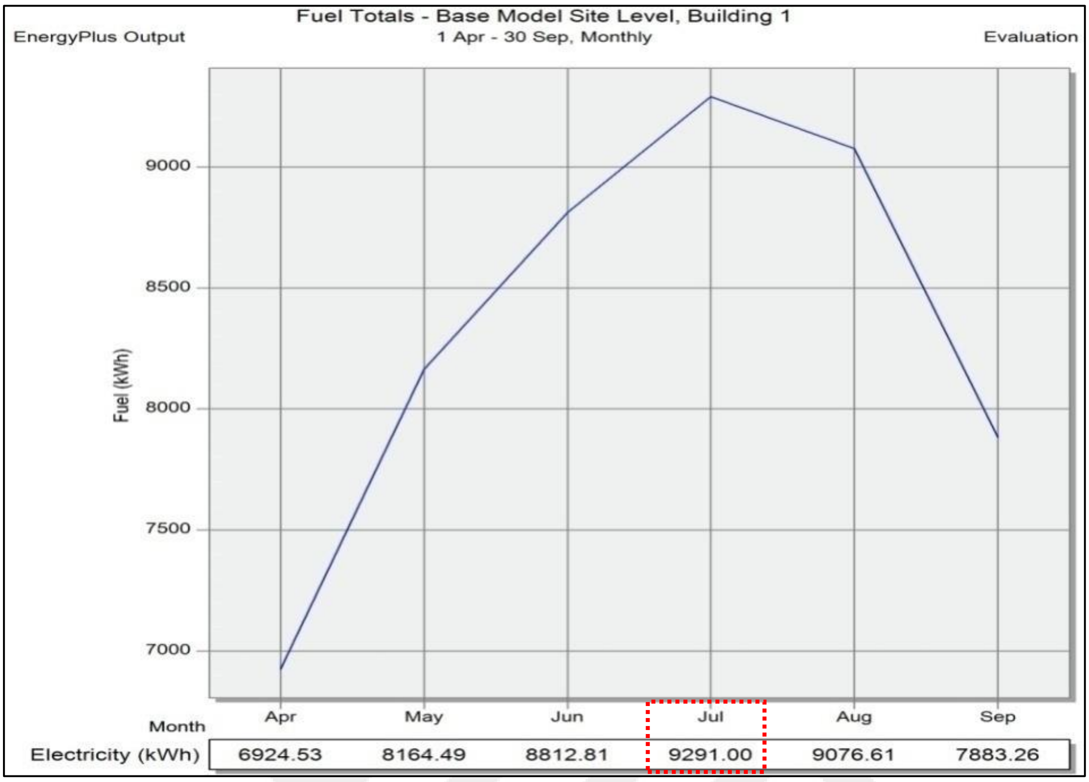


Figure 5.53. Total energy consumption (Electricity) result after applying Mahrabyiya to cover the exterior walls of the proposed energy efficient house during summer from April to September

5.2.5. Assessment the effect of improving the glazing type on cooling load

Unfortunately, in Iraq, most of the housing building are using a single clear glass which is a totally non-energy efficient type as reflected in the base case simulation case. After testing four type of glass performance in test room simulation in the previous part of the simulation in this chapter double low-e colored glass 6mm/6mm was selected as the best glazing type. Therefore, glazing type in the simulation changed from the single clear glass type to double low-e colored glass 6mm/6mm. Windows to wall ratio are fixed to be 30% in both simulation scenarios with the same dimension of windows without interior and exterior shading type. Simulation result of applying double low-E colored glass in windows has recorded a significant impact on reducing cooling load compared with the bass case which used single clear glass type. Using double low-E colored glass in the exterior windows has reduced the cooling load remarkably in the amount of 6164.00 kWh comparing with the base case which was 6997.36 kWh as shown in Figure 5.54. Double low-E colored glass has a great role in terms of blocking solar gain through exterior windows. Total energy consumption also reduced from 9408.98 kWh in the base case house to about 8946.00 kWh of the proposed energy efficient house during July as shown in Figure 5.55.

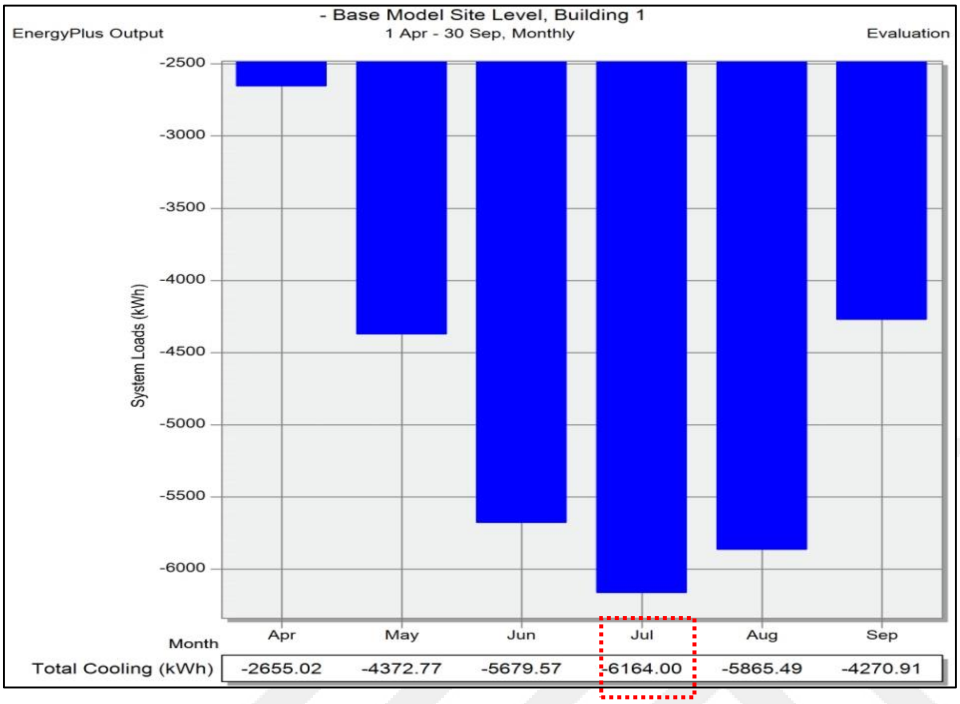


Figure 5.54. Total cooling load result after applying double low-E colored glass in windows of the proposed energy efficient house during summer from April to September

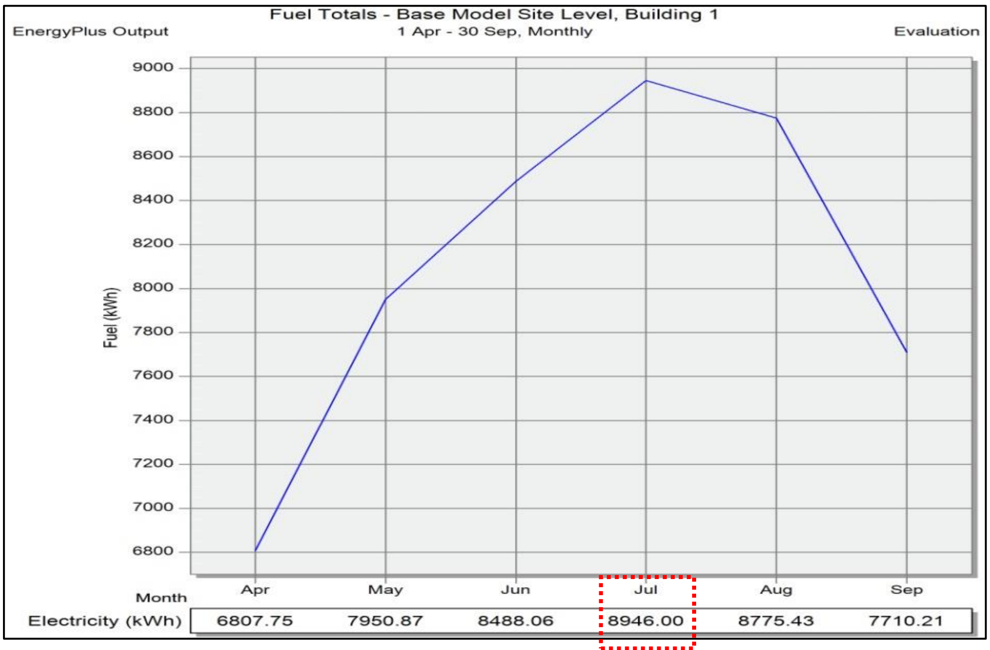


Figure 5.55. Total energy consumption (Electricity) result after applying double low-E colored glass in windows of the proposed energy efficient house during summer from April to September

5.2.6. Combinations of the best thermal mass on wall and roof scenarios

Naturally, heat flows from the hotter sides to the colder sides through the building envelope. Heat flows mechanism is depending on the temperature difference between the outside and inside of the space which is known as delta T. Heat flows also depends on the surface properties whether it is an observer or reflective surface, as well as surface area. Because the exposed surface area is build up heat more than unexposed surface area. Another factor involved in the heat exchange process is the thickness of the material which increases or decreases the time of heat transfer. In addition, during summer solar radiation heat up the building envelope which is going to store some amount of heat and allow other amounts to pass through it into indoor spaces. Therefore, improving the building envelope thermal properties is the main aim of this simulation step in order to reduce cooling load and energy consumption. Based on the results of the previous test room simulation the best wall scenario is specified to the Thermostone block wall with exterior 50mm expanded polystyrene insulation. As well as, the best roof scenario is recorded to the cast concrete slab with exterior 50 mm expanded polystyrene insulation scenario as mentioned earlier. The simulation is running in this step to illustrate the effect of combination scenario between best wall and roof scenarios on the cooling load reduction. The graph in Figure 5.56 illustrates the great effect of improving the building envelope thermal properties which reflected in reducing the cooling load from 6997.36 kWh in the base case house to 4984.71 kWh during the peak cooling load in July. This reduction of cooling load positively reduced the total energy consumption in July from 9408.98 kWh in the base case house to about 8124.14 kWh in the energy efficient house case as shown in Figure 5.57.

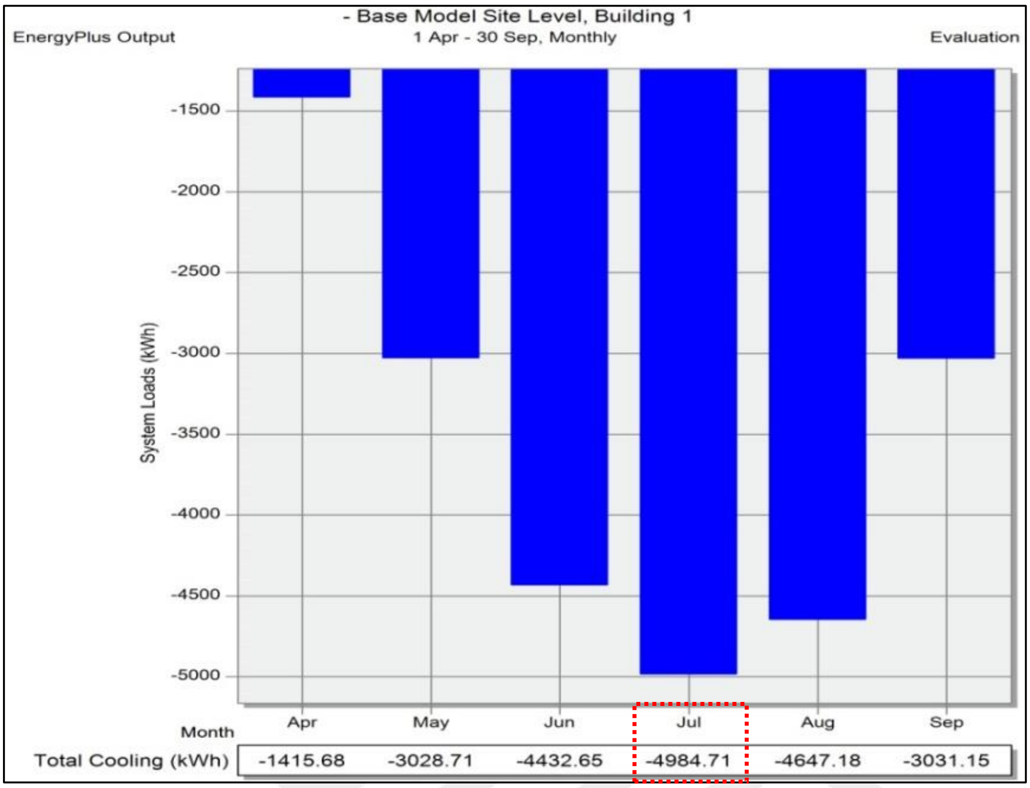


Figure 5.56. Total cooling load result after applying the proposed envelops scenarios during summer from April to September

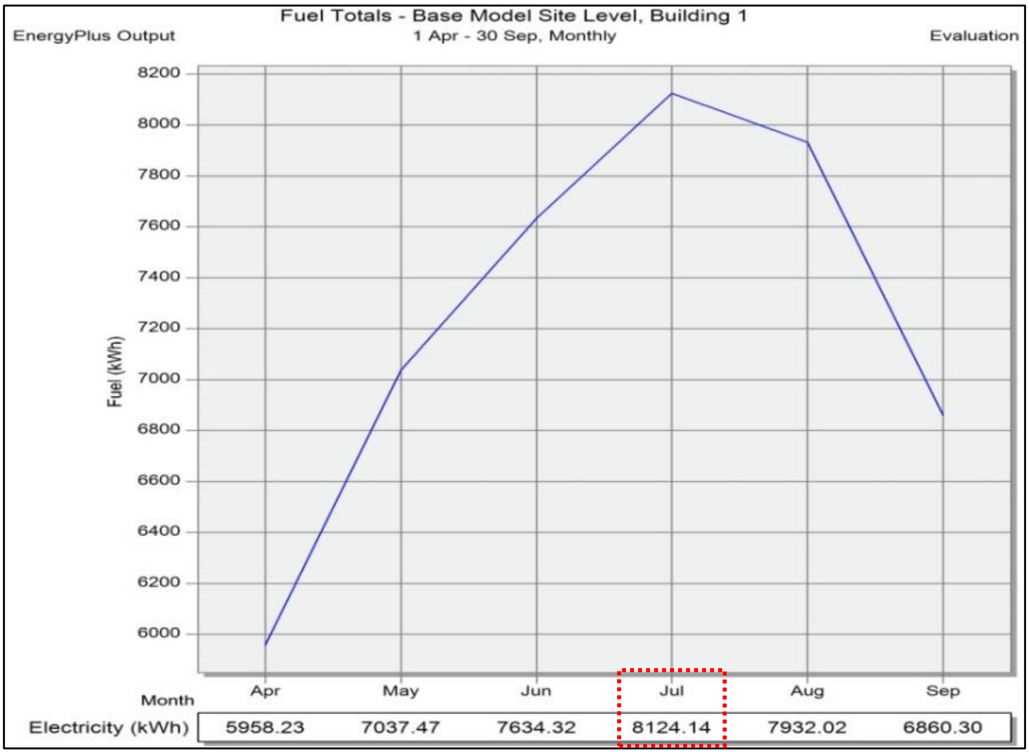


Figure 5.57. Total energy consumption (Electricity) result after applying the proposed envelops scenarios during summer from April to September

5.2.7. Assessment the effect of combination of all passive cooling scenarios on cooling load

After running the simulation for each proposed passive cooling technique scenarios separately, the next step is to combine all scenarios in one case in order to evaluate the cooling load reduction compared with the base case house. As expected integrated all of the scenarios in one case which called energy efficient house case improved the thermal performance of the simulated house model which in turn resulted in reducing cooling load from 6997.36 kWh in the base case house to 4461.28 kWh in the energy efficient house scenario during the peak cooling load in July as shown in Figure 5.63. This great reduction of cooling load has a high impact on reducing energy consumption which represented in Figure 5.63. The result of combining all proposed passive cooling scenarios at the same time shows that electricity has been reduced in July from 9408.98 kWh to 7562.32 kWh which is about 13.44% of total electricity reduction.

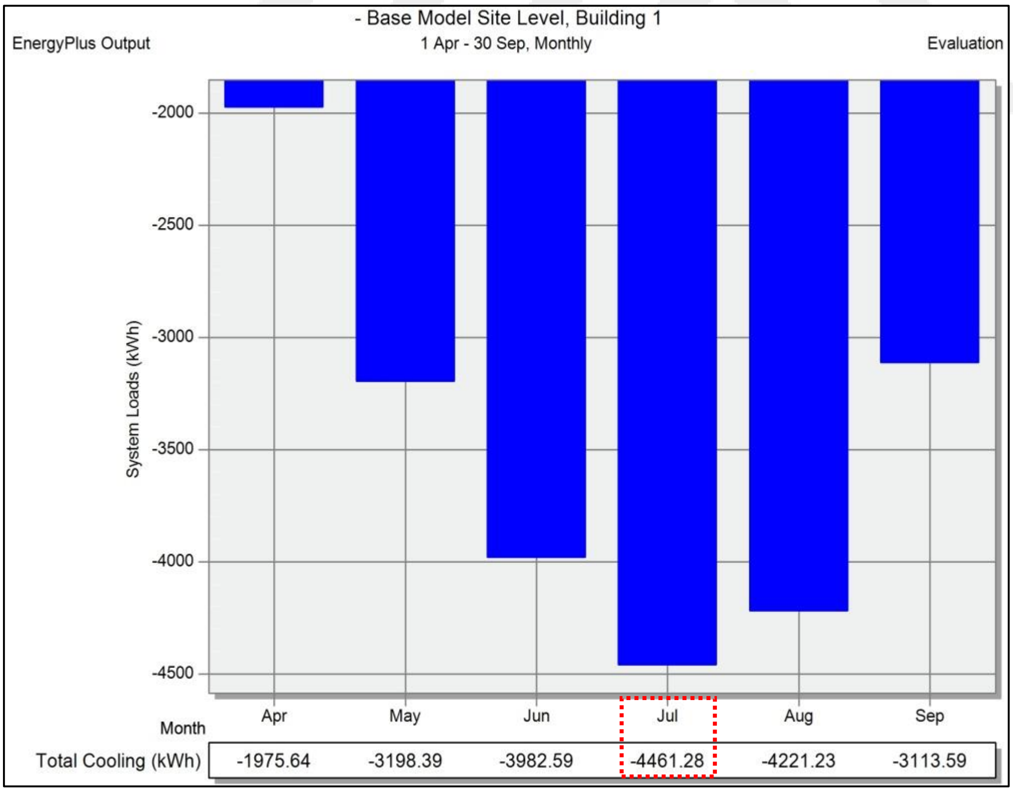


Figure 5.58. Total cooling load result after applying Mahrabyiya to cover the exterior walls, roof and windows of the proposed energy efficient house during summer from April to September

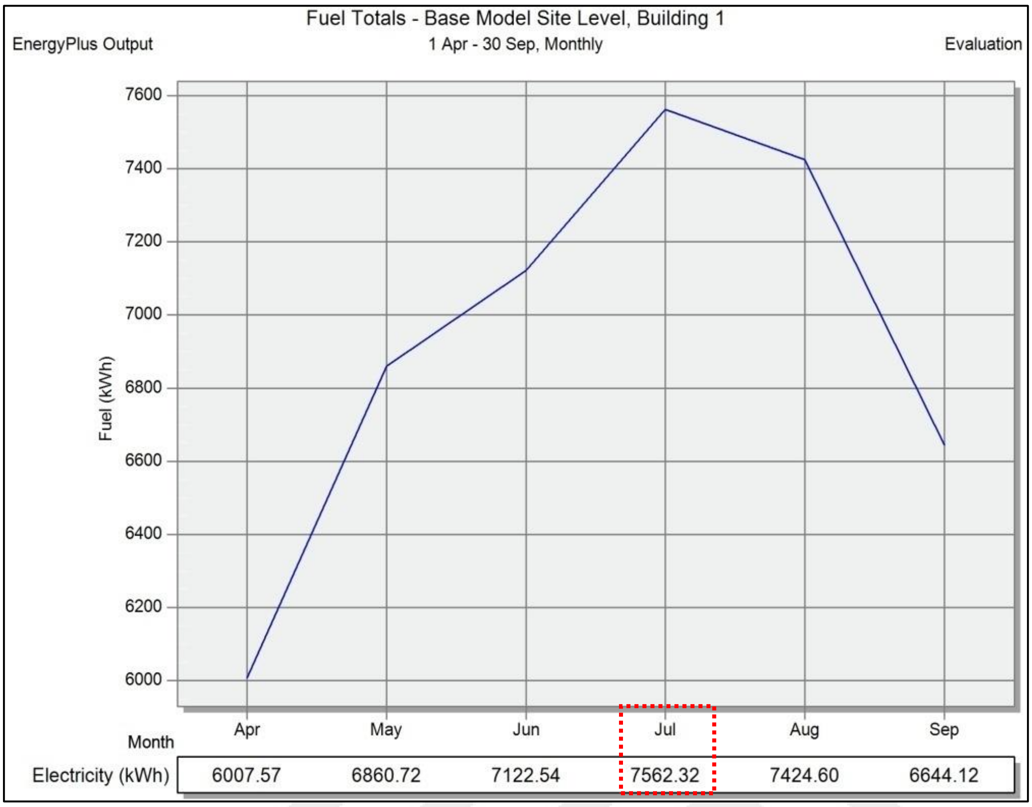


Figure 5.59. Total energy consumption (Electricity) result after applying Mahrabyiya to cover the exterior walls, roof and windows of the proposed energy efficient house during summer from April to September

To clarify the above result generally, Table 5.22 shows the total cooling load and energy reduction in each proposed passive cooling techniques separately. According to the simulation result which summarized in Table 5.24, improving thermal performance of the building envelope has recorded the lowest cooling load among other passive cooling techniques scenarios. Similarly, in the total energy consumption reduction rate, improving the thermal performance of building envelope has recorded the lowest amount among other proposed passive cooling techniques. Therefore, the combination of the building envelope (wall and roof) scenarios achieved the maximum improvement of adaptive thermal comfort in summer design simulation scenarios. In spite of this fact, increasing the thermal comfort is not limited to improving the thermal properties of the building envelope, minimize heat gain from solar absorption is the key point to enhance thermal comfort and reduce cooling load respectively.

Table 5.21. Comparative analysis of all passive cooling scenarios

Energy simulation Scenarios	Simulation Stage	Proposed passive cooling techniques	Total cooling load in July (kWh)	Total cooling load reduction % in July	Total energy consumption in July (kWh)	Total energy reduction % in July
Base case house		-	6997.36	-	9408.98	
Energy efficient house	Reduce Heat Gain	Windows shading	6117.80	12.56%	8920.33	5.18%
		Roof shading	6497.40	7.14%	9131.23	2.94%
		Wall shading	6785.01	3.03%	9291.00	1.24%
		Improve Glazing (Double Low-E Colored Glass 6mm/6mm Air)	6162.75	11.96%	8946.00	4.91%
	Modify heat gains	Wall: Thermostone wall with exterior insulation Roof: Concrete slab with exterior insulation	4984.71	28.76%	8124.14	13.65%
Combination of all scenarios			4461.28	67.38%	7562.32	27.92%

6. CONCLUSION AND RECOMMENDATIONS

This study was made in order to understand how the passive design techniques reduce energy in the residential building sector when it comes to cooling systems. The current well-known approach of energy efficient buildings attracted many building developers and architects to change over from the present ventilation method with regards to mechanical cooling systems to vernacular techniques for passive cooling strategies in a proficient modern way. However, a literature review of energy efficient, low energy methods and vernacular passive cooling techniques was done in order to re-evaluate and summarize strategies for passive cooling to be implemented in modern residential building. Traditional houses in an ancient Erbil citadel, already built and operating for hundreds of years were selected; reviewed and analyzed. Traditional neighborhood was also analyzed in terms of climate responsive strategies and compared with current neighborhood design. Finally to evaluate the proposed passive cooling techniques to be implemented in modern housing design building a thermal dynamic simulation was conducted. The energy simulation used to assess different passive cooling techniques in terms of cooling load reduction rate. The findings of the simulation study are compared in order to determine the distinguished reduction of cooling energy after using the proposed passive cooling techniques in the typical modern house in Erbil city. The following section summarize the results from Erbil citadel vernacular architecture case study analysis create the following baselines:

Key findings in terms of urban fabric analysis

Traditional settlement characterized in harmony with topography which resulted in creating an organic form of the paths, because they follow the topography of the citadel. In addition, the high density of the housing building context creates narrow shaded paths and zigzag alleys. This positively affected the ecological performance where shaded zigzag and narrow paths result in providing thermal comfort and cold air during hot summer days. Further, using animals (horse or Camel) for transportation does not need to pave streets, as nowadays, which absorbs and reflect radiant solar heat and therefore increase the air temperature of the settlement. Priority of traditional neighborhood paths and alleys is given to human needs and it is quite suitable for human scale. Whereas, in modern neighborhood priority of roads design are given to the transportation by cars. This resulted in designing unsafe streets for pedestrians and unsuitable for human scale. Furthermore, all these squares, alleys, and courtyards with different sizes and shapes interact together to provide solar access, cross ventilation and privacy satisfactory living conditions to the settlement's occupants.

Key findings in terms of houses building analysis

Generally, all of the houses have an open central courtyard. This courtyard space acts as a temperature controller and considered as the main source of natural lighting and ventilation which makes the house climatically responsive by bringing nature to the interior resulted in maintaining thermal comfort. Another climatic responsive strategy which enhances passive cooling within analyzed traditional houses is the position and size of windows. Small size, few numbers of windows located on the upper side of the external wall. Whereas more large size, acceptable numbers of windows located on the lower side of the internal wall. Hence, positioning and size of window play a significant role in allowing the required amount of daylight and fresh air which provide users thermal comfort. In contrast to that, modern housing building has a large size exterior windows with Iron frame usually uncontrolled and allow direct sunlight to pass through, thus more heat gain of the interior. During the hot summer days, underground basement level was used. Basement located under the yard and called “Sardab”, it is a traditional solution to escape from the extreme heat during the summer days. According to its location underground, it keeps the cool temperature because hot sun rays can not reach it. Generally, traditional Erbil citadel houses characterized as enclosed building mass (compact form, inward-looking).

The inward orientation of the rooms towards the open courtyard creates excellent cross natural ventilation and provide an acceptable daylight. In addition, compact form of housıng less exposure to the direct solar radiation which help to reduce heat gain during summer and heat loss during winter.Anothe great climate responsive stratigies is the application of accessible local building materials which are from the same climatic zone, fit consummately into the local climate conditions. These accessible local materials have natural favorable circumstances contrasting nowadays counterfeit non-local materials, for example, the great decrease in energy associated with material assembling and transportation, low ecological effect amid their formulation. The construction strategies and the building materials which are eco-accommodating, locally accessible and require the least energy for creation and use, furthermore play a remarkable role in giving an agreeable thermal condition in the inside independent of the outside temperature. They are naturally handled to pick up the required level of quality, durability, and strength. The heat capacity and basic thermal characteristics of these materials guaranteed the thermal comfort of the building users which considered as the main factors affecting passive cooling energy. Perceiving the microclimatic components of a place in which a building is placed can upgrade a great part of the building wind and solar energy designs. Building orientation, prevailing wind, exposure to solar radiation, vegetation and water in the site altogether affect the microclimate specification. An ideal plan or optimum design of building with the requirement of the microclimate (streets design, gardens, open spaces) significantly influences the energy performance of the building. Therefore, building site and local environment circumstances should be managed before designing the building unit. A great building material with suitable colors of exposed surfaces and an optimum orientation is not enough to ensure high reduction of energy unless building site well designed. Finally, the characteristic of the vernacular architecture built environments such as building geometry, enclosed building mass, inward-looking, an efficient orientation of building according to local climate conditions, high density of the building context and access to wind flow can play a considerable architectural role in modifying the thermal performance of the courtyards. From the ecological performance viewpoint, the courtyard layout system introduced larger areas of indoor passive zones, which can benefit from daylight and natural ventilation. The following section summarize the results from energy simulation case study analysis create the following baselines:

Preventing external heat gains

The main objective of this doctoral research was to evaluate and propose a number of passive cooling techniques to existing and future houses in Erbil for improving the indoor thermal comfort in a mechanically cooled residential zone in order to reduce cooling energy consumption. The proposed passive cooling techniques were conducted in two different strategies and result can be described as follows:

The first step to address passive cooling is by reducing and modulating the heat gains. There are a number of methods which can reduce significantly the heat entering a building. This heat stems from solar radiation and also from heat difference among the outdoor and indoor environment. Building envelope should be designed in a suitable way to minimize these heat gains during summer period; this can be accomplished with high-quality performance building envelopes. The parameters that should be taken into consideration concern the envelope's insulation, the facade's solar shading and the air infiltration.

In Erbil, during the middle of the afternoon in summer, the outside air temperature is frequently reached more than 42 C; therefore, building envelope should be less exposed to direct solar radiation to avoid overheating concerns. Therefore, this study suggested the Mashrabiya model; it comprise remodeled traditional Mashrabiya resulted in form with ventilative cavities which allow air to pass through them. Therefore, the Mashrabiya model enhance the thermal performance of the building envelope either by reducing further the U-value of the building wall and roof or by reducing significantly solar heat gains. This proposed solution of having an external Mashrabyia model to shadow the wall, roof and windows have recorded a different result in cooling load reduction of each simulated shading scenarios. For instance, external wall shading scenario has produced non significant reduction in cooling load which was 3.03% kWh comparing with roof shading scenario. This result is due to the sun angle change which creates a variation in the received amount of solar heat in different walls direction. Whereas, roof shading recording more obvious reduction of cooling loads which was 7.14% kWh, since it is the most exposed building envelop surface during the daytime from sunrise until sunset. Exterior windows shaded by implementing Mashrabiya model have been recording the greater reduction of cooling load which was 12.56% kWh comparing with wall and roof shading scenarios.

Modulation of heat gain

Modify heat gain are the second stage for achieving passive cooling methods in building design and the simulation result of this stage scenarios discussed in this section. Thermal insulation is required to prevent heat storage in building construction components to maintain the thermal comfort of building users. Thermal insulation is considered one of the heat prevention strategies which classified by many experimental studies as passive cooling methods. The simulation processes were performed by carrying out five wall composition scenarios by applying the most used local wall construction materials (solid brick, hollow brick, solid concrete block, hollow concrete block, and Thermostone block).

As well as, each wall analyzed in three different insulation layer position scenarios (with exterior insulation, with interior insulation and without insulation). The simulation results of the wall scenarios which investigated the effect of thermal insulation layer position on indoor operative temperature and cooling load showed that applying exterior thermal insulation is the best comparing with applying interior thermal insulation layer on all five wall compositions. The modeled room with exterior wall insulation has recorded the lower indoor operative temperature and thus the lower cooling load, in spite of, the same thickness of the wall material and insulation layer. The results of the five wall scenario show that there is a great different amount of cooling load between the Thermostone block wall and other wall types. Thermostone wall with exterior insulation has recorded the lowest cooling energy consumption rate. Another proposed passive cooling under this strategy was improving the glass type of the exterior windows. Treating the building windows with solar shading screen or reflective film coatings are a passive solution which could significantly reduce the solar heat gain through windows. Unfortunately, in Iraq, most of the housing building are using a single clear glass which is a totally non-energy efficient type. However, the simulation results of the different glass types show that using glazing integrated coatings with double glazing system are the best option type due to cooling loads reduction and energy savings. Maximum cooling load reduction is noticed by using the double Low-E glazing type through lowering the cooling load about 1.08% kWh compared with the base case with single clear glass.

Removing internal heat

Besides the heat which enters a building from the outside to the inside, there is also heat which is emitted in the interior of a building; that is internal heat gains which include heat emitted by people occupying a space, lighting fittings and also electric devices. There are many ways of modulating this heat. Firstly, energy efficient equipment and lighting can reduce significantly internal heat gains. However, heat gains from people are difficult to cope with, especially in spaces with high occupancy patterns. Secondly, natural ventilation strategy plays a major role for the cooling of a building, especially in the hot arid climate regions. Due to the climate profile, the outside air temperatures are usually below comfort zone, especially in peak summer months. Thus, the natural ventilation strategy can address the cooling of the building significantly. Design modifications to the actual modern house are proposed to improve its thermal performance and it has resulted that indoor thermal comfort level can be improved by the employment of various passive cooling techniques such as building envelope shading, insulation of thermal mass, utilizing night ventilation and improving glass type. However, combinations of all proposed passive cooling techniques are effective to maintain the indoor thermal comfort and reduce the cooling load significantly. Reduction energy consumption for cooling through preventing house building overheating in summer is the key point of the proposed passive cooling techniques. Finally, passive cooling of buildings is a methodical process and needs to start from the early stages of the design process. Architects together with engineers should co-operate and discover innovative methods of integrating passive cooling techniques in the design of buildings. The potential of cooling load reduction after applying all of the proposed passive cooling techniques have recorded about 67.38% kWh of total cooling load reduction in July.

Overall, this research aims to propose a methodology of passive cooling applications that determine the potential of reducing cooling energy consumption. This thesis has been developed in three phases. The first phase is concerned with identifying the main problem and illustrates the criteria required for solving this problem. The second phase explains the case study and its architecture characteristics in terms of climate-responsive strategies. The third phase represents the key findings of the proposed methodology through an energy simulation study confirming the potential solution for reducing the cooling energy of the typical modern housing building in Erbil city. According to the simulation outcomes, the author found that modern housing building has the potential to accommodate about 67% of the total cooling load reduction during the peak cooling loads in July.

Recommendations for housing design

The results of this thesis contribute to understanding the thermal behavior of the traditional dwelling in the historic core of Erbil city and how traditional people ensure their thermal comfort level without using a mechanical air conditioning system and electricity in general. It also developed an energy simulation model representing the great potential for reducing cooling load passively. In this context, the study at the end provides guidelines to develop an architectural method for designing low cooling energy houses. These guidelines contained an appropriate solutions which assists engineers and architects to think carefully about passive cooling strategies in the early stages of housing design. The conclusions derived from the results that were gathered from the field study and computer simulation work are used to identify a group of guidelines for designing low cooling energy residential buildings which summarized below.

1. The high heat gains from the building envelope shell to the indoor spaces means the high cooling load and the high energy demands.
2. As the greatest difference between day and night temperature, in summer, natural night ventilation is the more significant plan in diminishing the higher temperatures when the area of exposed thermal mass increases. Therefore, it is possible to cool the building mass by night time ventilation.
3. Clearly, thermal properties and determination of materials are essential actions for evaluating thermal performance in the residential building regarding control heat pick up in the hot atmosphere. Accordingly, architects should select insulation materials that are great at resisting the flow of heat (low U-value and high R-value).
4. According to the simulation result, the exterior insulation layer is more powerful as insulation materials position and are more profitable amid the hot season.
5. Highly insulated thermal mass of the walls should be integrating with a highly insulated roof to avoid heat flow through the envelope components. To reduce overheating during peak hours and to provide the best internal condition this point is highly recommended.
6. To avoid solar heat gain, shading of the flat roof and windows is the essential steps to be considered in the early stage of the design process. With that in mind, size, position, type of the glazing and the number of openings have another great impact on heat gains which considered highly necessary in parallel with thermal mass insulation.
7. Concrete floor slabs has an essential role to the heat capacity of a building where in summer high absorptions of heat from roof progresses from outside to inside, but heat flows can be reduced by using a high resistance to heat flow materials. Accordingly, the rooms in the top level have a primary impact of the heat gain and therefore the roof design should be considered carefully by employing exterior thermal insulation with an appropriate thickness.

The study limitation and recommendation for future studies

Even though the present dissertation has created some valuable conclusions, a number of limitations need to be mentioned as follows:

1. The study examined the shading of windows, walls and roof in general, therefore further study on specific aspects such as window size, glazing, window orientation are needed to investigate.
2. The study investigated a modern prototype house in Erbil and that is limited as one type of house (detached single-family, tow floor). Other types of residential buildings such as high rise buildings, attached from one or two sides could be considered in a future research and also, it useful to include the microclimate conditions.
3. Developing the proposed Mashrabiya to a movable exterior shading may be an area in which future study can be done. A significant amount of cooling load reduction is generated during the simulation and operation of housing after applying the proposed passive cooling techniques. In addition, integrating active and passive design methods to design low cooling energy housing can be another area of further research. For instance, using photovoltaic panels on the roof to produce energy while at the same time it works for shading the flat roof.

REFERENCES

Abdelsalam, T. and Rihan, G. (2013). The impact of sustainability trends on housing design identity of Arab cities. *HBRC Journal*, 9(2),159-172.

Abdulkareem, S. (2012). *The adaptation of vernacular design strategies for contemporary building design*. Ms.c. Thesis, Texas Tech University, USA,48-56.

Abtar .N. A. (2014*). Applicability of Smart Cities in the Middle East: A case study of Erbil.* Ms.c. Thesis, Cardiff University,Uk.

Al-Jameel, A., Al-Yaqoobi, D., and Sulaiman. W. (2015). *Spatial configuration of Erbil Citadel: It's potentials for adaptive re-use.* Paper Presented at the 10th International Space Syntax Symposium, 6 July, London.

Almssad, A., Al-musaed, A., Harith, Sh., Nathir, M. and Ameer, M. (2007*). Shading effects upon cooling house strategy in Iraq.* Paper presented at the 2nd PALENC Conference and 28th AIVC Conference on Building Low Energy Cooling and Advanced Ventilation Technologies in the 21st Century, 3-5 September, Greece.

Al-Obaidi, K., Ismail, M. and Abdul Rahman, A. (2014). Passive cooling techniques through reflective and radiative roofs in tropical houses in Southeast Asia: A literature review. *Frontiers of Architectural Research*, 3(3), 283-297.

Aloomary, R. (2014). Architectural language in Erbil Castle: An analytical study of systems engineering for residential building in Erbil Castle. *Sulaimani Journal for Engineering Sciences*, 9, 23-35.

Al-Sanea, S. (2002). Thermal performance of building roof elements. *Building and Environment*, 37(7), 665-675.

Al-Sanea, S. and Zedan, M. (2011). Improving thermal performance of building walls by optimizing insulation layer distribution and thickness for same thermal mass. *Applied Energy*, 88(9), 3113-3124.

Al-Sanea, S. and Zedan, M.(2011). Improving thermal performance of building walls by optimizing insulation layer distribution and thickness for same thermal mass. *Applied Energy*, 88(9), 3113-3124.

Al-Shukri, A. (2007). Thin film coated energy-efficient glass windows for warm climates. *Desalination*, 209(3), 290-297.

Anna-Maria, V. (2009). Evaluation of a sustainable Greek vernacular settlement and its landscape: Architectural typology and building physics. *Building and Environment* 44, 1095-1106.

Aryan, A., Ehsan, Z., Amin, S. and Masoud, K. (2010). Wind Catchers: Remarkable Example of Iranian Sustainable Architecture. *Journal of Sustainable Development*, 3(2),82-95.

Asquith, L., and Vellinga, M. (2006). *Vernacular architecture in the Twenty-First century: Theory, education and practice*. Oxon: Taylor & Francis, 68-93.

Attia, S., and Carlucci, S. (2015). Impact of different thermal comfort models on zero energy residential buildings in hot climate. *Energy and Buildings*, 102, 117-128.

Azami, A.,Yasrebi, S. and Salehipoor, A. (2005). *Climatic responsive architecture in hot and dry regions of Iran*. Presented at the 14th International conference on passive and low energy cooling for the built environment, Santorini, Greece, 19-21May.

Bahadori M., Mazidi M, and Dehghani R. (2008). Experimental investigation of new designs of wind towers. *Renewable Energy*, 33,73-81.

Bahadori, M. N. (2010). An improved design of wind towers for natural ventilation and passive cooling. *Energy*, 36, 119-129.

Baper, S. and Hassan, M. (2010). The influence of modernity on Kurdish architecture identity. *American Journal of Engineering and Applied Science.* 13, 84-95.

Bauer, M., Mösle, P., and Schwarz, M. (2010). *Green building: Guidebook for Sustainable Architecture*. Heidelberg: Springer.

Bekleyen, A. and Dalkiliç, N. (2011). The influence of climate and privacy on indigenous courtyard houses in Diyarbakır, Turkey. *Scientific Research and Essays*, 6(4), 908-922.

Bhatt, R. and Brand, J. (2008). Christopher Alexander: A review essay: The nature of order: An essay on the art of building and the nature of the Universe. *Design Issues*, 24, 93-102.

Bojić, M. and Yik, F. (2005). Cooling energy evaluation for high-rise residential buildings in Hong Kong. *Energy and Buildings*, 37(4), 345-35.

Borge-Diez, D., Colmenar-Santos, A., Pérez-Molina, C. and Castro-Gil, M. (2013). Passive climatization using a cool roof and natural ventilation for internally displaced persons in hot climates: Case study for Haiti. *Building and Environment*, 59,116-126.

Bornberg. R., Arif. M. and jaimes, M. (2014). Traditional versus a global, international style: Erbil-Iraq. *Urban Design Development and Cities,* 12(3), 46-58.

Butera, F. (1998). Chapter 3-Principles of thermal comfort. *Renewable And Sustainable Energy Reviews*, 2, 39-66.

Calautit, J., Hughes, B., and Sofotasiou, P. (2016). *Design and optimisation of a novel passive cooling wind tower*. Paper presented in 2nd International Conference on Sustainable Energy Technologies, The University of Sheffield Nottingham, UK.

Cao, X., Dai, X. and Liu, J. (2016). Building energy-consumption status worldwide and the state-of-the-art technologies for zero-energy buildings during the past decade. *Energy and Building,* 128(6), 198-213.

Carlucci, S. (2013). *Thermal comfort assessment of buildings*. Milan: Springer, Milano. 18-23.

Chandel, S. and Sarkar, A. (2015). Performance assessment of a passive solar building for thermal comfort and energy saving in a hilly terrain of India. *Energy and Buildings*, 86, 873-885.

Charles, K. (2008). *Sustainable construction: Green building design and delivery*. New Jersey: John Wiley & Sons.

Chenari, B., Lamas, F., Gaspar, A. and da Silva, M.(2017). Simulation of Occupancy and CO 2 -based Demand-controlled Mechanical Ventilation Strategies in an Office Room Using EnergyPlus. *Energy Procedia*, 113, 51-59.

Chwas , S. (2014). A study on the urban form of Erbil city as an example of historical and fast growing city. *Humanities and Social Sciences Review*, 126(3), 325-340.

Cook, J. (1989). *Passive cooling*. Cambridge: The MIT Press,124-137.

Costanzo, V., Evola, G. and Marletta, L. (2013). Cool roofs for passive cooling: performance in different climates and for different insulation levels in Italy. *Advances in Building Energy Research*, 7(2),155-169.

Crawley, D. B., Lawrie, L. K., Winkelmann, F. C., Buhl, W. F., Huang, Y. J., Pedersen, C. O., and Glazer, J. (2001). EnergyPlus: creating a new-generation building energy simulation program. *Energy and buildings*, *33*(4), 319-331.

Crinson, M. (2008). Singapore's moment: critical regionalism, its colonial roots and profound aftermath. *The Journal of Architecture* 13(2), 585-605.

Dabaieh, M. (2011). *A Future for the past of Desert Vernacular Architecture*, Ms.C.Thesis, Lund University, London, 20-36.

Dabaieh, M., Wanas, O., Hegazy, M. and Johansson, E. (2015). Reducing cooling demands in a hot dry climate: A simulation study for non-insulated passive cool roof thermal performance in residential buildings. *Energy and Buildings*, 89, 142-152.

David K. Ting. (2011). Materials for energy efficiency and thermal comfort in buildings. *International Journal of Environmental Studies*, 68 (3), 983-993.

Dehghan, A., Esfeh, M. and Manshadi, M. (2013). Natural ventilation characteristics of one-sided wind catchers: experimental and analytical evaluation. *Energy and Buildings*, 61, 366-377.

Dimoudi, A. (1996). *Passive cooling of buildings*. London: James & James, Ltd, 35-55.

Edwards, B. and Turrent, D. (2000). *Sustainable housing: Principles & Practice*. London: E & FN Spon Press.

Edwards, B., (2010). *Rough guide to sustainability: a design primer*. London: RIBA Publishing,176-181.

El-Shorbagy, A. (2016). Design with Nature: Windcatcher as a Paradigm of Natural Ventilation Device in Buildings. *International Journal Of Civil & Environmental Engineering*, 10 (03), 21-25.

Fadhil, A. M. (2011). Drought mapping using Geoinformation technology for some sites in the Iraqi Kurdistan region. *International Journal of Digital Earth*,4(3), 239-257.

Fang, Z., Li, N., Li, B., Luo, G. and Huang, Y. (2014). The effect of building envelope insulation on cooling energy consumption in summer. *Energy and Buildings*, 77, 197-205.

Fared, B., Chaaban, M., Rima, A. and Joseph, A. (2007). A century of energy conversion: an environmental overview. *International Journal of Environmental Studies* 47, 133-142.

Fathy, H. (1986). *Natural energy and vernacular architecture: Principles and examples with reference to hot arid climates*. Chicago: University of Chicago Press, 25-56.

Feeney, J (2009). The magic of the Mashrabiyas. *Saudi Aramco World: Arab and Islamic Cultures and Connection,* 25(4), 32-36.

Feriadi, H. and Wong, N. (2014). Thermal comfort for naturally ventilated houses in Indonesia. *Energy and Buildings*, 36 (7), 614-626.

Filiz, S. (2010). *Konut Tasarımına Yönelik Sürdürülebilirlik ve Teknoloji Bağlamında Bir Gelecek Tahmin Modeli*. Doktora Tezi, İstanbul Teknik Üniversitesi, İstanbul.

Foazi, U. (2006). *The cosmological genesis of the courtyard house. In Courtyard housing: Past, present & future,* ed. Brian Edwards, Magda Sibley, Mohamad Hakmi, and Peter Land. New York: Taylor & Francis, 136-138.

Foruzanmehr, A. and Nicol, F. (2014). Towards new approaches for integrating vernacular passive cooling systems into modern buildings in warm-dry climates of Iran. In: Air Conditioning and the Low Carbon Cooling Challenge. London: 120-123.

Foruzanmehr, A. and Vellinga, M. (2011). Vernacular architecture: questions of comfort and practicability. *Building Research & Information*, 39(3), 274-285.

Frampton, K. (1998). *Towards a critical regionalism: Six points for an architecture of resistance.* New York: New Press, 17-34.

Friess, W., Rakhshan, K., Hendawi, T. and Tajerzadeh, S. (2012). Wall insulation measures for residential villas in Dubai: A case study in energy efficiency. *Energy and Building*, 44, 26-32.

Friess, W., Rakhshan, K., Hendawi, T. and Tajerzadeh, S. (2012). Wall insulation measures for residential villas in Dubai: A case study in energy efficiency. *Energy and Buildings*, 44, 26-32.

Futcher, J., Mills, G., Emmanuel, R. and Korolija, I. (2017). Creating sustainable cities one building at a time: Towards an integrated urban design framework. *Cities*, 66, 63-71.

Garg, V., Mathur, J., Tetali, S. and Bhatia, A. (2017). *Building Energy Simulation: A Workbook Using DesignBuilder*. (First Edition ed). Boca Raton: CRC Press.

Geetha,N.B.,Velraj,R.. (2012). Passive cooling methods for energy efficient buildings with and without thermal energy storage: A review. *Energy Science and Research*, 29(2), 913-946.

Ghomi-Avili, Z. (2016). Traditional architecture eco-systems in Iran: the way of the sustainable architecture. *Ponte International Scientific Research Journal*, 72, 49-61.

Givoni, B. (1994). *Man, Climate and Architecture*, (Second Edition ed.). London: Applied Science Publishers Ltd, 12-47.

Givoni, B. (2011). Indoor temperature reduction by passive cooling systems. *Solar Energy*, 85(8), 1692-1726.

Glotzer, S. C. (2011). *International assessment of research and development in simulation-based engineering and science*. World Scientific.University of Michigan, Ann Arbor, USA. 32-46.

Gokarakonda, S., and Kumar,A. (2016). Passive architectural design index applied to vernacular and passive buildings. *International Journal of Environmental Studies*, 73(2), 563-572.

Gorgolis, G. and Karamanis, D. (2016). Solar energy materials for glazing technologies. *Solar Energy Materials and Solar Cells*, 144, 559-578.

Gupta, J. and Chakraborty, M. (2016). The need for vernacular mud huts of Ranchi to adapt to the changing climate of Ranchi. *International Journal of Environmental Studies* 73,584-603.

Haas, R. Stulz, Baumgartne, A. and Sigg, R. (1993). *climate responsive building Appropriate Building Construction in Tropical and Subtropical Regions*. Lund University, New Delhi.

Haggag, M. and Elmasry, S. (2011). Integrating passive cooling techniques for sustainable building performance in hot climates with reference to the UAE. *Sustainable Development and Planning*, 150, 12-23.

Haghparast, F., and Niroumand, S. (2007). Sustainablity of climate-sensitive elements in hot-arid regions; case study: Boroujerdis' house in the city of Kashan. Paper presented in the 3rd IRCEC Armenia, Yerevan, 90-97.

Hall Johnson, Zhai, Z., M. and Krarti, M. (2011). Assessment of natural and hybrid ventilation models in whole-building energy simulations. *Energy and Buildings*, 43, 2251-2261.

Hamza, N (2008). Double versus single skin facades in hot arid areas. *Energy and Buildings*, 40,240-248.

Hassan, M. K. R. (2010). Urban environmental problems in cities of the Kurdistan region in Iraq. *Local Environment*, 15(1), 59-72.

Hatıcıoğlu. H. (2012). Analysis of vernacular architecture in terms of sustainable considerations: the case of şirince; village in western turkey. *International Journal of sustainable Architecture*, 5(2), 39-48.

He, L. and Tjong, S. (2016). Nanostructured transparent conductive films: Fabrication, characterization and applications. *Materials Science and Engineering*. Reports, 109,1-101.

Hensen, J., Djunaedy, E., Radošević, M. and Yahiaoui, A. (2004). *Building performance simulation for better design: some issues and solutions*. Paper in the proceedings of the 21st Conference on Passive and Low Energy Architecture (PLEA),1185-1190.

Hien,N., Poh, K., and Feriadi, H. (2003). Computer-based performance simulation for building design and evaluation: The Singapore perspective. *Simulation & Gaming*, 34(3), 457-477.

Hughes .B, Calautit .K, and Ghani. S.(2012).The development of commercial wind towers for natural ventilation: a review. *Applied Energy*, 92,606-627.

Husein, H., and Mahmood, S. (2015). Enhancing social interaction in residential communities in Erbil. *International Journal of Engineering Technology, Management and Applied Sciences*, 3(8), 9-20.

Husein, H., and Mahmood, S. (2015). Enhancing social interaction in residential communities in Erbil. *International Journal of Engineering Technology, Management and Applied Sciences*, 3, 9-20.

Hyde, R. (2007). *Bioclimatic Housing: Innovative Designs for Warm Climates*. London: Routledge.

Ibrahim, I. (2016). Livable Eco-Architecture Masdar City, Arabian Sustainable City. *Procedia - Social and Behavioral Sciences*, 216, 46-55.

Ibrahim, R, Mushatat, S. and Abdelmonem, M. G. (2015). Erbil. *Cities*, 49, 14-25.

Ibrahim, R, Mushatat, S., and Abdelmonem, M. (2014). Authentıcıty, identity and sustaınabılıty ın post-War Iraq: Reshaping the Urban form of Erbil City. *Journal of Islamic Architecture*, 3(2), 58-72.

Internet: Jenkins, M. (2011). The History of Building Energy Modeling by Rocky Mountain Institute. Retrieved from URL: http://www.webcitation.org/query?url=https%3A%2F%2Fwww.youtube.com%2Fwatch%3Fv%3D4WSzicmQISs&date=2018-08-01, Access Date, 18.11.2017

Internet: Shuzo, M. and Toshiharu, I. (2012). *Evaluating Environmental Performance of Vernacular Architecture through CASBEE.* Institute for Building Environment and Energy Conservation (IBEC) Japan Sustainable Building Consortium (JSBC) Web: http://www.webcitation.org/query?url=http%3A%2F%2Fwww.ibec.or.jp%2FCASBEE%2Fenglish%2Fdocument%2FVernacular_Architecture_b+rochure.pdf&date=2018-08-02 , Access Date: 28.11.2016.

İnternet: Aziz, M. (2003). Agrometeorology in Kurdistan of Iraq: a contemporary history International society for agricultural meteorology. Retrieved from: http://www.webcitation.org/query?url=http%3A%2F%2Fwww.agrometeorology.org%2Ftopics%2Fhistory-of+agrometeorology%2Fagrometeorology-in-kurdistan-of-iraq-a-contemporary-history.+&date=2018-07-31, Access Date: 11.09.2016.

İnternet: Dar-Alhandasah. (2012). Erbil City Master Plan, Retrieved FromURL: http://www.webcitation.org/query?url=http%3A%2F%2Fdar.dargroup.com%2Fwork%2Fproject%2Ferbil-master-plan&date=2018-07-31 Access Date: 04.02.2016.

İnternet: Green, A. (2016). Lecture 2: Air Conditioning (Environmental Control) Systems. [podcast] ABE 474 at UIUC - Indoor Environmental Control. Available at: http://www.webcitation.org/query?url=https%3A%2F%2Fgrfilms.net%2Fch-UCk7GBRCbASq3kGRE3yQ_SwA&date=2018-07-31, Accessed Date 02.04. 2018.

İnternet: HCECR (2007). Erbil citadel. High Commission for Erbil Citadel Revitalization Revitalization Project. Retrieved From URL:http://www.webcitation.org/query?url=http%3A%2F%2Fwww.erbilcitadel.og%2FErbilCitadel%2F&date=2016-08-10, Access Date: 10.08.2016.

İnternet: HCECR. (2014). Nomination of Erbil Citadel .For Inscription on the UNESCO World Heritage List . http://www.webcitation.org/query?url=http%3A%2F%2Fwww.erbilcitadel.org%2F+&date=2018-07-31, Erişim Tarihi: 26.04.2016.

İnternet: NREL. (2011). A Method for Determining Optimal Residential Energy Efficiency Retrofit Packages. Denver. Retrieved from http://www.webcitation.org/query?url=https%3A%2F%2Fwww.nrel.gov%2Fdocs%2Ffy11osti%2F50572.pdf.&date=2018-07-31, Access Date: 18.10.2016.

İnternet: Oden, T. (2006). A Report of the National Science Foundation Blue Ribbon Panel on Simulation- Based Engineering Science: Revolutionizing Engineering Science through Simulation. Retrieved From: http://www.webcitation.org/query?url=http%3A%2F%2Fwww.nsf.gov%2Fpubs%2Freports%2Fsbes_final_report.pdf&date=2018-07-31, Access Date : 19 .09. 2017.

Jimenez-Bescos, C. (2017). An evaluation on the effect of night ventilation on thermal mass to reduce overheating in future climate scenarios. *Energy Procedia*, 122, 1045-1050.

Kamel, M. (2012). An Overview of Passive Cooling Techniques in Buildings: Design Concepts and Architectural Interventions. Acta Technica Napocensis: *Civil Engineering & Architecture,* 55(1),4-18.

Kang, D. (2011). *Advances in the Application of Passive Down-Draft Evaporative Cooling Technology in the Cooling of Buildings*, Doctoral dissertation, University of Illinois at Urbana-Champaign.

Kazem, A., Chaichan, M. and Kazem, H. (2014). Dust effect on photovoltaic utilization in Iraq. *Renewable and Sustainable Energy Reviews,* 37,734-749.

Khalid, N. (2014). *Urban heat island in Erbil City*. Ms.C. Thesis. Lund University,43-48.

Khan, S. (2016). Traditional Havelis and sustainable thermal comfort. *International Journal of Environmental Studies,* 73,573-583.

Khani, S., Bahadori, M., Dehghani-Sanij, A. and Nourbakhsh, A. (2017). Performance evaluation of a modular design of wind tower with wetted surfaces. *Energies*, 10 (7),845-852.

Khoshsima, E., Abdolhamid. M., Rao,S., and Nila. (2011). Learning from the past: Case Study of traditional architecture of southern shores of caspian Sea Region in Iran. *International Journal of Applied Science and Technology*, 1(1), 48-59.

Kim Do-Kyoung .(2005). The natural environment control system of Korean traditional architecture: comparison with Korean contemporary architecture. *Building and Environment*, 41, 05-12.

Kim, G., Lim, H., Lim, T., Schaefer, L., and Kim, J. (2012). Comparative advantage of an exterior shading device in thermal performance for residential buildings. *Energy And Buildings*, 46, 105-111.

Krishan, A., Baker, N., Yannas, S. and Szokolay, S. (1999). *Climate responsive architecture: A design handbook for energy efficient buildings*. New Delhi: Tata Mc Graw Hill Publishing Company Ltd,149-156.

Lauber, W. (2005). *Tropical architecture: sustainable and humane building in Africa, Latin America and South-East Asia*. Munich: Prestel.

Lechner, N. (2015). *Heating, cooling, lighting: sustainable design methods for architects*. (fourth edition ed). Hoboken, New Jersey: John Wiley & Sons, Inc.,285-324.

Lin Borong, Tan Gang, Zhu Yingxin and Zhai Guangkui (2014). Study on the thermal performance of the Chinese traditional vernacular dwellings in summer. *Energy and Buildings,* 36,73-79.

Liu, J., Hu, R., Wang, R. and Yang, L. (2009). Regeneration of vernacular architecture: New rammed earth houses on the upper reaches of the Yangtze River. *Frontiers of Energy and Power Engineering in China* 4, 93-99.

Liu, J., Hu, R., Wang, R. and Yang, L. (2009). Regeneration of vernacular architecture: new rammed earth houses on the upper reaches of the Yangtze River. *Frontiers of Energy and Power Engineering in China*, 4(1), 93-99.

Luu Cuong. (2007). *Methods and Technologies in Sustainable Architecture*. Paper presented in the 2nd International Conference on Sustainable Architectural Design and Urban Planning . Hanoi Architectural University . Vietnam.

Macias, M., Gaona, J., Luxan, J. and Gomez, G. (2009). Low cost passive cooling system for social housing in dry hot climate. *Energy and Buildings,* 41(9), 915-921.

Macias, M., Gaona, J., Luxan, J. and Gomez, G. (2009). Low cost passive cooling system for social housing in dry hot climate. *Energy and Buildings*, 41(9), 915-92.

Madhumathi, A., Radhakrishnan, S. and Shanthipriya, R. (2016). Thermal performance evaluation of green roofs in warm humid climates: a case of residential buildings in Madurai, India. *Key Engineering Materials*, 692, 82-93.

Manioglu, G. and Yilmaz,Z. (2007). *A comparative evaluation of the ımportance of thermal mass of traditional architecture in hot and dry region in Turkey*. Ms.C Thesis, Istanbul Technical University, Istanbul, 40-82.

Marchwiński, J. (2014). Architectural Evaluation of Switchable Glazing Technologies as Sun Protection Measure. *Energy Procedia*, 57,1677-1686.

Maria. V. (2009). Evaluation of a sustainable Greek vernacular settlement and its landscape: Architectural typology and building physics. *Building and Environment*, 44, 95-106.

Meir, I. and Raof, S. (2005). The future of the vernacular. Towards new methodologies for the understanding and optimization of the performance of vernacular buildings. In L. Asquith, Vernacular Architecture in the 21st Century: Theory, Education and Practice (1st ed.). London: Routledge.

Mendler, S., Odell, W. and Lazarus, M. (2006). *The HOK guidebook to sustainable design*. New Jersey: Hoboken, John Wiley and Sons.

Mileto, C., Vegas, F., García Soriano, L., and Cristini, V. (2014). *Vernacular Architecture: Towards a Sustainable Future*. London: CRC Press, 23-35.

Mohamed, J. (2015). *The Traditional Arts And Crafts Of Turnery Or Mashrabiya* .Ms.C. Thesis, Rutgers University, New Jersey.

Morgan W. (2008). *Earth Architecture: From Ancient to Modern*. Florida: University Press of Florida.

Morris, A. E. J. (2013). *History of urban form before the industrial revolution. Islamic cities of middle east* . London: Routledge, 65-102.

Mortada, H. (2016). Sustainable Desert Traditional Architecture of the Central Region of Saudi Arabia. *Sustainable Development*, 24(6), 383-393.

Motealleh, P., Zolfaghari, M. and Parsaee, M. (2016). Investigating climate responsive solutions in vernacular architecture of Bushehr city. *HBRC Journal*, 43, 74-88.

Muhaisen, A. (2006). Shading simulation of the courtyard form in different climatic regions. *Building and Environment*, 41(12), 1731-1741.

Naboni, E. and Edwards, B. (2014). *Green Buildings Pay*. London, GBR: Spon Press.

Nooraddin, H. (2012). Architectural Identity in an Era of Change. *Developing Country Studies*, 2(10), 81-96.

Ochoa, K. and Capeluto, I, (2008). Strategic decision-making for intelligent buildings: Comparative impact of passive design strategies and active features in hot climate. *Building and Environment*, 43(11),1829-1839.

Olgyay, V. (1993). *Design with climate: bioclimatic approach to architectural regionalism.*New Jersey: Princeton University Press, 115-129.

Oliver, P. (1998). *Encyclopedia of vernacular architecture of the world.* Cambridge: Cambridge University Press, 26-41.

Ozel, M. (2014). Effect of insulation location on dynamic heat-transfer characteristics of building external walls and optimization of insulation thickness. *Energy and Buildings*, 72, 288-295.

Ozkan, S., Summers, F. and Yannas, S. (2006). *A Comparative Study of the Thermal Performance of Building Material.* Proceedings of the 23rd Conference on Passive and Low Energy Architecture, Switzerland.

Ozorhon, G. and Fatih, I. (2014). Learning from Mardin and Cumalıkızık: Turkish Vernacular Architecture in the Context of Sustainability. *Arts,* 3(1), 175-189.

Philokyprou, M., Michael, A., Malaktou, E. and Savvides, A. (2017). Environmentally responsive design in Eastern Mediterranean. The case of vernacular architecture in the Coastal, lowland and mountainous regions of Cyprus. *Building and Environment*, 11, 91-109.

Pour Yahya . (2012). *Reinterpretation towards climate responsive architecture: possibility to implement the principles of persian vernacular housing into contemporary architecture*. Master Thesis, Universiti Kebangsaan Malaysia, Bangi, Malaysia.

Pyrgou, A., Castaldo, V., Pisello, A., Cotana, F. and Santamouris, M. (2017). Differentiating responses of weather files and local climate change to explain variations in building thermal-energy performance simulations. *Solar Energy*, 153, 224-237.

Radhi, H. (2008). *A Systematic Approach For Low Energy Buildings in Bahrain*, PhD Thesis, University of Sheffield, Sheffield.

Ralegoankar, V. Gupta,R. (2010). Review of intelligent building construction: A passive solar architecture approach. *Renewable and sustainable energy reviews*, 14(8), 2238-2242.

Ran, J. and Tang, M. (2018). Passive cooling of the green roofs combined with night-time ventilation and walls insulation in hot and humid regions. *Sustainable Cities and Society*, 38, 466-475.

Rapoport, A. (1991). *House form and culture: Englewood cliffs.* New Jersey: Prentice-Hall,192- 217.

Ravindran, M., Abraham, R. and Zacharia, S. (2007). Environmental friendly energy options for India. *International Journal of Environmental Studies* 64, 709-718.

Rijal, H. (2014). Investigation of Comfort Temperature and Occupant Behavior in Japanese Houses during the Hot and Humid Season. *Buildings*, 4(3), 437-452.

Roaf, S. (2013). *Ecohouse: A Design Guide*, (fourth edition ed). London Routledge, 63-98.

Ruiz, M. and Romero, E. (2011). Energy saving in the conventional design of a Spanish house using thermal simulation. *Energy and Buildings Journal,* 43(11),3226-3235.

Ryu, Y., Kim, S., and Lee, D. (2008).The influence of wind flows on thermal Comfort in the Daechung of a traditional Korean house. *Building and Environment,* 44, 18- 26.

Saadatian, O., Haw, C., Sopian, K., and Sulaiman, M. (2012). Review of windcatcher technologies. *Renewable and Sustainable Energy,* 16(3),1477-1495.

Salem, E. Al-Alkhalaf .(1999). The evolution of the urban built-form of a traditional settlement in southwestern Saudi Arabia'. *Building and Environment,* 34, 649-669.

Samani, P., Leal, V., Mendes, A., and Correia. N. (2017). Comparison of passive cooling techniques in improving thermal comfort of occupants of a pre-fabricated building. *Energy and Buildings*, 120, 30-44.

Samuela, L., Shiva,S., and Maiyaa, M. (2013). Passive alternatives to mechanical air conditioning of building: A review. *Building and Environment* , 66, 54-64.

Santamouris, M. (2007). *Advances in Passive Cooling*. London: Earthscan, 73-81.

Santamouris, M. and Kolokotsa, D. (2013) Passive cooling dissipation techniques for buildings and other structures: The state of the art. Energy and Buildings, 57, 74-94.

Santamouris, M., and Kolokotsa, D. (2013). Passive cooling dissipation techniques for buildings and other structures: The state of the art. *Energy and Buildings*, 57, 74-94.

Santamouris, M., Sfakianaki, A. and Pavlou, K. (2010). On the efficiency of night ventilation techniques applied to residential buildings. *Energy and Buildings,* 42(8), 1309-1313.

Sarswat, G. and Kamal, M. (2015). Passive cooling through natural ventilation techniques in green buildings: Inspirations from the Past. *Civil Engineering And Environmental Technology,* 2(2),169-173.

Sassi, P. (2006). *Strategies for sustainable architecture*. New York: Taylor, 40-52.

Sayigh, A. and Marafia, H. (1998). Vernacular and contemporary buildings in Qatar. *Renewable and Sustainable Energy Review*, 2(1), 25-37.

Sekhar, S., and Goh, S. (2011). Thermal comfort and IAQ characteristics of naturally/mechanically ventilated and air-conditioned bedrooms in a hot and humid climate. *Building And Environment,* 46(10), 1905-1916.

Serencam, H. and Serencam, U. (2013). Toward a sustainable energy future in Turkey: An environmental perspective. *Renewable and Sustainable Energy Reviews*, 27, 325-333.

Sharif Salem. M., Zain, M.F.M., and Surat, M. (2010). Concurrence of thermal comfort of courtyard housing and privacy in the traditional Arab house in Middle East. *Australian Journal of Basic and Applied Sciences* 4(8), 4029-4037.

Shi, L. and Chew, M. (2012). A review on sustainable design of renewable energy systems, *Renewable and Sustainable Energy Reviews*, 16, 192-207.

Shokouhian M. and Soflaee, F. (2005). *Natural cooling systems in sustainable traditional architecture of Iran*. Paper presented in the 1st International Conference on Passive and Low Energy Cooling for the Built Environment (PALENCE), Santorini, Greece.

Sibley, M. (2006). *The courtyard houses of North African medinas: past, present and future*. Abingdon: Taylor & Francis, 49-62.

Snyder, S. (2009). *New green home solutions: Renewable household energy and sustainable living*. Utah: Gibbs Smith, 5-12.

Taleb, H. (2014). Using passive cooling strategies to improve thermal performance and reduce energy consumption of residential buildings in U.A.E. buildings. *Frontiers of Architectural Research*, 3(2), 154-165.

Tavil, A. (2004). Thermal behavior of masonry walls in Istanbul. *Construction And Building Materials*, 18(2), 111-118.

Tewari, S. (2015). *Laurie Baker: A model for Sustainable Architectural Design*. Paper presented in the 1st International Conference on a planet of our own - a vision of sustainability with focus on water, Mumbai.

Toguyeni, D., Coulibaly, O., Ouedraogo, A., Koulidiati, J., Dutil, Y. and Rousse, D. (2012). Study of the influence of roof insulation involving local materials on cooling loads of houses built of clay and straw. *Energy and Buildings*, 50, 74-80.

Venkiteswaran, V., Liman, J. and Alkaff, S. (2017). Comparative Study of Passive Methods for Reducing Cooling Load. *Energy Procedia*, 142, 2689-2697.

Venkiteswaran, V., Liman, J., and Alkaff, S. (2017). Comparative Study of Passive Methods for Reducing Cooling Load. *Energy Procedia*, 142, 2689-2697.

Vuong, E., Kamel, R. and Fung, A. (2015). Modelling and Simulation of BIPV/T in EnergyPlus and TRNSYS. *Energy Procedia*, 78, 1883-1888.

Weber, W. and Yannas, S. (2014). *Lessons from vernacular architecture*. New York: Routledge, 15-60.

Yang, W., Zhu, X., and Liu, J. (2017). Annual experimental research on convective heat transfer coefficient of exterior surface of building external wall. *Energy and Building*, 155, 207-214.

Yannas, S., and Bowen, A. (2017). *Passive and low energy architecture*. Paper presented in the 7th international conference of PLEA, Designing to Thrive: Scottish Universities.

Yaqoobi, D. and Khayat, M. (2015). *The Role of cultural heritage in Erbil city as a motivation for Social learning, Erbil Citadel as case study.* Paper presented in the 13th PASCAL International Conference, Learning Cities 2040, Glasgow.

Zarandi, M. (2013). Analysis on Iranian Wind Catcher and Its Effect on Natural Ventilation as a Solution towards Sustainable Architecture. World Academy of Science, *Engineering and Technology*, 16(3), 48-58.

Zhang, L., Luo, T., Meng, X., Wang, Y., Hou, C. and Long, E. (2017). Effect of the thermal insulation layer location on wall dynamic thermal response rate under the air-conditioning intermittent operation. *Case Studies in Thermal Engineering*, 10, 79-85.

Zinzi, M. and Agnoli, S. (2012). Cool and green roofs. An energy and comfort comparison between passive cooling and mitigation urban heat island techniques for residential buildings in the Mediterranean region. *Energy and Buildings*, 55, 66-76.

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