ROZHGAR H. KAREIM

COMPARATIVE STUDY ON THERMAL PERFORMANCES OF TRADITIONAL AND CONTEMPORARY HOUSES, IN ERBIL, IRAQ

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A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

By
ROZHGAR HUSSEIN KAREIM

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

NICOSIA, 2018

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Approval of Director of Graduate School of Applied Sciences

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

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Name, Last name:

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To my Parents...

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Firstly, I would like to express my sincere gratitude to the head of the architectural department & My supervisor Dr. Kozan for his profound knowledge and help during research writing, without their patience and help, this thesis would not have been a success. Furthermore, I would like to express my heartfelt love to my parents for their constant support during my thesis writing and their words of encouragement. Also, I would like to thank my sisters and my brothers for their help during my studies and their constant encouragement made me reach where I am today. Lastly, I would like to thank all my friends and who supported me during my study time.

ABSTRACT

The increased use of energy in the world has brought mankind to dimensions that threaten its existence in the world. One of the key elements of this rate is the rapidly increasing number of households, with an increase in energy consumption. In many countries of the world to resolve this issue, a comprehensive energy policy provided. Recently, a large increase has been observed in the number of houses in parallel with the rapid development of the construction industry in Northern Iraq. However, lack of awareness and lack of energy conservation has led to the emergence of buildings with high energy consumption.

The aim of the thesis is to make determinations that can guide energy conservation in low-rise dwellings in northern Iraq and to improve their thermal performances and develop recommendations accordingly. In the thesis, in the northern Iraq / Erbil city, as a study area, houses built with traditional style and materials and interior courtyard houses recently selected with modern style and materials were selected and compared with the criteria of ventilation and building shell design which are important subjects of passive design.

Selected specimens were observed on site, door - window gaps, wall, and material furnishings were determined. Passive cooling facilities through natural ventilation have been analyzed on the obtained plans. The heat gain and losses caused by windows, walls, and flooring are made according to the standards of TS825. In all buildings, "U" values (total heat transfer coefficients) of building components were found and compared with standard values.

As a result, passive design strategies based on ventilation and shell design that can be used for low-rise houses in Northern Iraq / Erbil have been proposed

Keywords: Building envelope; energy efficient building; natural ventilation; passive design; psychrometric chart

ÖZET

Dünyada enerji kullanımının giderek artması,insanoğlu’nun dünyadaki varlığını tehdit eder boyutlara ulaştırmıştır. Bu artışın temel unsurlarından biri de hızla artan konut sayısı ile birlikte enerji tüketiminin de artmasıdır. Dünyanın birçok ülkesinde bu sorunu gidermek için kapsamlı enerji politikaları üretilmektedir. Son zamalarda, Kuzey Irak’ta inşaat sektörünün hızla gelişimine paralel olarak konut sayısında da büyük artış gözlemlenmiştir. Ancak enerji korunumu konusundaki ihmal ve farkındalık eksikliği enerji tüketimi yüksek binaların ortaya çıkmasına sebep olmuştur.

Tezin amacı, Kuzey Irak’ta az katlı konutlarda enerji korunumuna yön verebilecek ve termal performanslarını iyileştirebilecek tesbitler yapmak ve bu yönde öneriler geliştirmektir. Tezde, çalışma alanı olarak Kuzey Irak / Erbil kentinde geçmiş dönemlerde geleneksel tarz ve malzemelerle inşa edilmiş iç avlulu konutlarla, yakın zamanda modern tarz ve malzemelerle inşa edilmiş konutlar seçilmiş ve bu binalar pasif tasarımın önemli ögeleri olan havalandırma ve bina kabuğu tasarımı kriterleriyle karşılaştırılarak incelenmiştir. Seçilen örnekler yerinde gözlemlenmiş, kapı – pencere boşlukları, duvar ve malzeme döşemeleri tesbit edilmiştir. Elde edilen verilerle planlar üzerinde, doğal havalandırma yoluyla pasif soğutma olanakları analiz edilmiştir. Pencere, duvar ve döşeme yoluyla oluşan ısı kazanç ve kayıpları TS825 ‘teki esaslara göre yapılmıştır. Tüm binalarda yapı bileşenlerinin “U” değerleri (Toplam ısı transfer katsayıları) bulunmuş ve standart değerlerle karşılaştırılmıştır.

Sonuç olarak, Kuzey Irak /Erbil’de az katlı konutlar için kullanılabilecek havalandırma ve kabuk tasarımına esaslarına bağlı pasif tasarım stratejileri önerilmiştir.

Anahtar kelimeler: Bina kabuğu; doğal havalandırma; enerji verimli yapı; pasif tasarım; psikrometrik tablo

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CHAPTER 1
INTRODUCTION

1.1 Background

Climate changes became a great challenge for the World in the 21st century, and that what was the concern for the UN Climate Change Conference in Marrakech, November 2016. Before that Paris Climate Change Agreement adopted last year. Energy consumption is the main factor in the climate change; hence, the focus on energy conservation and energy management all around the world became a key role in overcoming this problem. Energy demand in the building sector represents a significant role in overall energy consumption around the world. Buildings represent 30-40% of worldwide energy consumption, and construction/ destruction activities drive this to more than fifty percent of worldwide energy consumption (Muhy al-din, et al., 2017). Buildings represent 9Gt (gigatons) of worldwide CO_2 emissions out of 44Gt (gigatons) aggregate worldwide emanations which is twenty percent. Urban populace in the world is predicted to increase from 47% in 2000 to 70% in the year 2050. More than 80% of worldwide populace lives in developing countries (IEA 2008). Only the Technology cannot overcome this problem. Energy consumption is affected by several human factors, for example, gender, age and socio-demographic varieties. It is predicted that consumption of energy in the built environment will increase by 34% in the next 20 years. Also, predicted for 2030, the consumption attributed to the domestic sectors will be 67% of total buildings consumption (Lombard et al., 2008).

With this context, the energy consumed within building is very important in the (CO_2) emission spreads to the atmosphere. This can cause a risk of the quality and longer-term stability of the biosphere because of undesirable request effects. These energy consumptions from the construction industry can have huge side-effects to cause rise to resource depletion and potential environmental risks to local, territorial or national scales. Energy and pollutant gases emission, for example, carbon dioxide (CO_2) might be known as ‘embedded’ energy into the materials. Therefore, embedded energy can be seen as the amount of energy needs to process, and supply to the building construction site, the material under examination. (Hammond and Jone, 2008)

In the residential building sector energy consumption contains all energy used by households, except transportation. Total released energy consumption in the commercial and residential building sectors contains electricity, liquid fuels, natural gas, coal, and renewable energy.

The building services required energy for making the building warm in the winter, cool in the summer, lighting, cooking, water heating, refrigerating, electronic entertainment and computing, needs substantial energy consumption which is around 40 quadrillion Btu (quads) annually. Energy consumption in the buildings has been totally rising up over time. In the building sectors Electricity is the main energy source, and it has grown. The Natural gas after electricity is the second biggest energy source and petroleum (predominantly heating oil) is the third.

The building construction industry causes a various environmental affect, mostly because of its huge energy consumption. The building construction industry needs the extraction of wide amounts of materials and this, therefore, brings about the use of energy resources and liberate of harmful poison gases to the biosphere. Every material must be exploited, prepared and lastly transported to its place in the construction site to be use. Concrete, aluminum, and steel are amongst the materials with the biggest embodied energy content as well as they are responsible of main amounts of CO_2 emanations in the construction sectors. For instance, 9.8 million metric tons of CO_2 are produced from the generation of 76 million metric tons of completed concrete in the United States. The construction industry represents for one 6th of worldwide fresh water consumption, one fourth of worldwide wood consumption, and one fourth of worldwide waste generation. (Hultgren, 2011).

In the same context, Heat exchange in buildings is a significant problem because it consumes a big part of the energy that produced by the building in order to perform the comfort for the occupants. Buildings heat gain and heat loss may change based on the condition of the building. The majority of the building in the north part of Iraq, and Erbil as the capital of this part are applying electricity to maintain thermal comfort in the buildings. Therefore, the majority of the energy consumption in the residential buildings uses to maintain thermal performance. This, consequently, increased the demand for energy in the region which already facing an energy shortage especially in providing the electricity power.

1.2 The Problem

Erbil as the capital of the Northern part of Iraq has witnessed a progressive increment in residential buildings. The lack of awareness about building design in term of energy performance have led to create high energy consumption buildings and created an unsustainable built environment. Furthermore, this increased the demand for energy in the region which already was suffering from energy shortage. The thesis will focus on the energy efficiency in houses as the major building sector for residential purposes in Northern Iraq. Moreover, they can be considered as the most common categories of the buildings in the region.

1.3 Aim of the Study

The thesis aims to reduce energy consumption of houses in Northern Iraq, through architectural design strategies. through improvement of U- value, and identify heat gain and heat loss in the buildings in different seasons in order to overcome the shortage of energy demands, facing this region of Iraq.

1.4 Objectives

The main objectives of this study are;

- To recommend appropriate building element section in terms of u-value for outer envelope design of houses in Erbil.
- To emphasize the importance of natural air movement in building in terms of thermal comfort.

1.5 Significance of the Study

The tremendous increment of energy usage in the world gives a warning about depleting energy sources and severe effects on the environment (global warming and climate change, etc.). According to an ecological architecture opinion, building design should be eco-friendly or environmentally friendly to overcome these environmental crises. Hence, building design should ensure that constructions and actions of today would not compromise the right of future generations' opportunities to use the earth resources. It might be workable by enhancing passive solar design strategies and energy efficiency.

1.6 Research Questions

In The thesis tries to answer the following questions;

- Whether or not the contemporary buildings in Northern Iraq are responding the climatic requirements of the region?
- What can be learnt from low-rise traditional houses of in terms of energy conservation so that this expertness can be to new contemporary houses design

1.7 Methodology

Methodology conducted in this thesis divide into two parts; firstly, the primary sources for data collection, by survey the literature, through; books, credible sources like, articles, theses, and scientific journals, as well as documentaries. Secondly, the empirical investigation by mean of field observation will be conducted in order to collect data. After data collection stage, data analysis will be carried out in order to address the problems energy consumption of buildings in Erbil city. Case study buildings are selected in order to observe and analyze building design factors in term of energy consumption in the houses and their response to the climatic characters needs in Erbil. The case studies will involve vernacular or traditional houses in Erbil as well as moderns and contemporary houses. Psychometric Chart will be used in order to identify proper solar passive strategies as per outdoor climate.

Important aspect of architectural element in vernacular architecture will be investigated such as, shape, spacing, orientation, type of building materials and construction technique as well as houses envelope. In the same context the architectural elements which uses in the contemporary architecture at Erbil nowadays will be approached. Comparative analysis has been carried out in order to find out the best design strategies and technologies for better building energy performance to solve or at least decrease energy consumption in the houses at Erbil. Thermo-physical properties or (U-Value), have been investigated for the building envelope materials in several architectural styles of houses, as well as the heat gain/loss in the building have been identified as factor to assess thermal performance. Finally, the thesis has been concluded with proposing several recommendations in the houses designs at Erbil city in order to reduce energy consumption in the houses

1.8 Limitation

There are few limitations delineate the thesis, namely;

1. The field of study will be limited to center of Erbil city, and its climatic characteristics.

2. The thesis will focus on the analyses of low-rise houses only.

3.. The residential building (houses) will be examined in terms of natural ventilation and hot transfer performance of the outer shells

CHAPTER 2
THEORETICAL FRAMEWORK

2.1 Passive Design

Passive design strategies in buildings refers to architecture which cause energy usage reduction in buildings with using technologies that are rely on natural resources. Passive design helps to reduce the energy consumption in the building within its lifetime according to microclimatic characteristics of the site and the interaction amongst the building's component. In consequence, passive design provides thermal comfort. The most important objective of passive design is to "totally terminate the needs of active mechanical systems and to keep building occupant comfort all the times" (Mikler et al., 2009).

There are numerous design strategies that can be used to achieve a passive building design. These strategies contain choose of buildings materials such as both finishing materials and structural, orientation, interior design, building size, design of the spaces surrounded by buildings, design the openings of the building, solar penetration control, drive the air flow outside the building, and the relation between the building and the ground (Baweja, 2008).

The goal of passive design is not to reach its objective in all the building to the optimum effect, however with applying its strategies can decrease the energy consumption in the building by natural resource to provide a comfortable indoor environment for its occupants by applying the passive design strategies, the needs for the mechanical devices for heating and cooling, ventilation and lighting, will be decreased. Therefore, the negative effect of the building on the environment will be reducing. Comprehension and specification the appropriate standards for thermal comfort, analyzing the microclimate, and evaluating measurable objectives for energy efficiency are the keys to successfully applying passive design buildings (Passive Design Strategies, 2014).

In passive design control the thermal comfort has an important role and it consider as main factor, which should be attain without applying mechanical systems as much as possible. Humidity, air temperature, surface temperature and velocity are the most important parameters which affect thermal comfort in the building; thermal comfort could be controlled by controlling these parameters (Attman, 2012).

Also, for thermal comfort, there are more techniques which can be used to attain passive design buildings; example of these techniques is thermal mass, natural ventilation of the buildings, open courtyards which are effective especially in hot and arid climates. Proper design of size and form of the openings also can positively affect passive ventilation.

2.2 Passive System Strategies in Energy Efficient Building Design

Passive systems can be defined as, the main methods which the buildings use natural energy sources in the nature and use their ability to enhance indoor environment of the buildings in order to provide thermal comfort. The natural energy sources like passive solar, daylight, and ventilation are considered as high-grade the World Sustainable Building Conference which held in Tokyo, 27 to 29 September 2005 (SB05Tokyo) energy sources. High-grade energy can be very easy change to effective activities without transformation or waste therefore with using of passive climate control could decrease energy consumption in the building processes and reduce greenhouse gas emissions. In addition, considerable emission reduction could result in higher quality design (Borg and Veljkovic, 2007).

Buildings are responsible to separate the outdoor environment from the indoor. The main functions of the buildings are to adjust the temperature, air movement, humidity, noise, odors, etc. in order to create comfortable ambient for the occupants. Hence, some strategies should be achieved in order to fulfill these requirements in a safe, healthy and credible way. In the previous era when the active system for cooling and heating as well as the lighting was not developed as today, the architects have been employing several strategies in the design in order to achieve comfort in the building. These strategies are known as passive solar design strategies, which are implementing the occupant’s requirement with less energy consumption. On the contrary of today contemporary buildings that are depending on the active system to achieve comfort with huge consumption of energy.

Passive system of ‘passive solar design’ connects natural effects, like dominant winds and solar energy transfer through mechanisms, with smart design to achieve significant advantages to keep a comfortable environment. If passive solar design had been applied in the begging of design process, that can result a crucial opportunity to enhance a buildings functionality and the energy efficiency. Passive solar design requires a key theory to be fixed to in order to ease positive subscription for cooling, heating, day lighting and ventilation. These concepts are depending on physical building aspects and location of that building as well as the environment parameters where the building is located.

There are many design aspects which define the energy needs of a building, and all of them can be developed in the design process of the building. For example, orientation, transparency ratio, shapes factor, thermo-physical properties of building materials and distance among the buildings. improving these criteria include the passive solar building design, getting benefit from the sun radiation and local climate aspects, reducing the buildings active energy and controlling building energy consumption, for instance, heating and cooling systems in the building. Within these criteria, orientation of the building is the most significant one. Taking into consideration that the advantages of another aspects like glazing ratio or transparency will be identify by the orientation of the building (Marin, 2017).

2.3 Orientation of the Building

Orientation and a comprehensible sight of the southern sky are basic criteria to catch solar gain during the hot season. In perfect conditions, the main glassing parts should locate towards the southern or within 30 degrees of south. Out of this area, the solar gain effect will be less, and heating needs will be more. Givoni (1969) asserted that the radiation amount received by the building depends on its orientation. Also, he demonstrated that orientation has a crucial effect on the heating/cooling load in any building. In a climate where thermal comfort is obtained through ventilation and air movement, the orientation of the building according to prevailing winds is essential. In regions where the ambient temperature has an effect on comfort more than ventilation, orientation with respect to the sun is important. Hence, the orientation of facades influences the ability of them to catch of solar radiation incidence, shown in Figure 2.1. various sides of the building, gain different level of heat from the sun radiation, for instance, west direction of the building get appreciably more heat from the sun radiation and catch less shade at the hottest period in daytime look like the south exteriors faces while exterior faces where placed in the north direction would get less sun radiation. The amounts of sun radiation are obtained by the building is defined by radiation (Marsh, 2000).

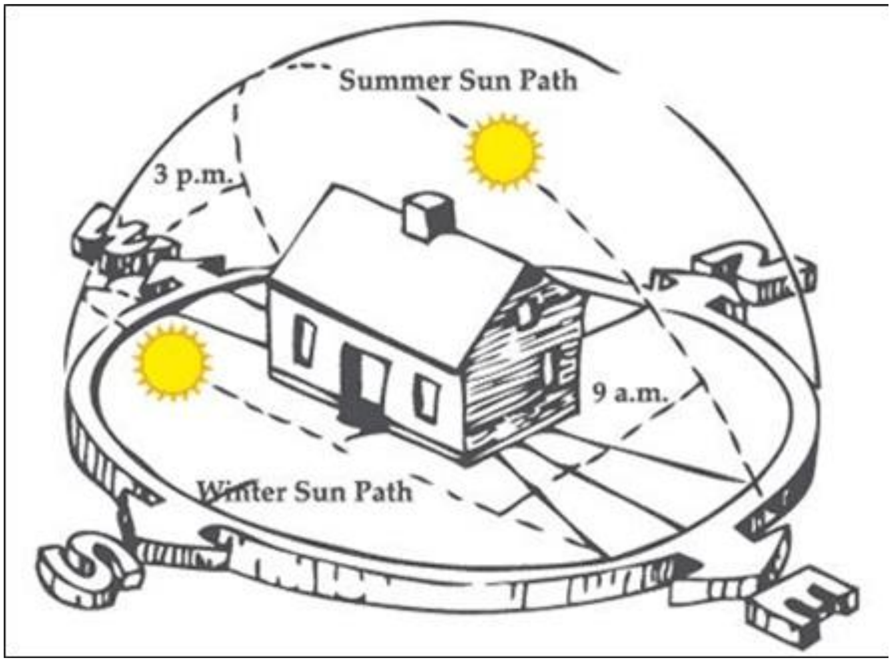


Figure 2.1: Orientation of the building and its relation with sun ecliptic (Marsh, 2000)

Selecting the correct building orientation take benefit from the seasonal sun motion through permitting the sun in winter to get in the building, however, prevent summer sun. This result on increasing comfort for working spaces to be more habitable through accessibility to the natural heating, cooling and lighting parameters, consequently, reduce energy consumption in the building.

2.4 Shading Devices

The needs for the building to be oriented in south facing in order to gain the heat in the winter can result to extreme solar gain within the hot season. This consequence can result the poor building function because of overheating cause an adverse effect on occupant's comfort. This danger can be minimizing by using shading devices which sets with the high sun angle in the hot season but does not block the sun at its lowest angle within the cold season (Atiyat, et al., 2015), shown in Figure 2.2.

Shading devices such as over-shading, similar to orientation, is related to providing a general view of the southern sky to making the solar gain easier. Whereas, it is very uncommon that a building is free from over- shading to reduce blockage. Sometime these can happen when the location of adjacent buildings, vegetation choice and site topography is improper for the building. Site plan design should be attention to these elements and refer to sun angle which is different because of site latitude (Muhy al-din et al., 2017).

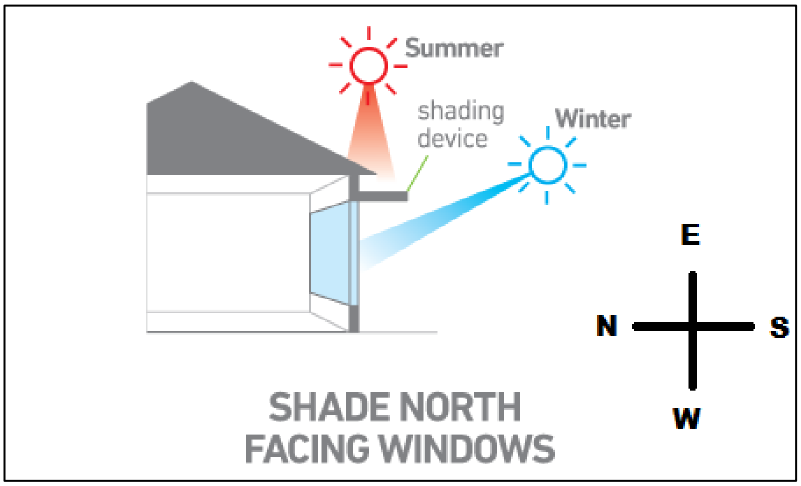
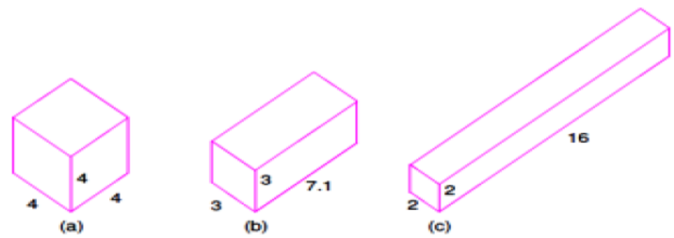


Figure 2.2: South facing window shading in summer (Atiyat, 2015)

2.5 Building Form

The prime principle in selecting the form of buildings is to maximize solar collection and to minimize heat losses through buildings envelope, where the requirement is heating. Moreover, reducing the un-required heat transfer, where the requirement is cooling. Also, the building shape influences on air penetration or cross ventilation patterns, through channeling the wind, and enhance the opportunities for using natural day-light.

Decrease the ratio between surface area and volume of the building to enhance building's thermal performance is one of the solutions, shown in Figure 2.3.



SOLID SHAPE	SURFACE AREA 'S'	VOLUME 'V'	SURFACE AREA/ VOLUME RATIO 'S/V'
a	96	64	1.5
b	103.2	64	1.61
c	136	64	2.13

Figure 2.3: Surface area to volume ratio (S/V ratio) for a few building shapes (Elaiab,2014)

According some researchers, Using H-type or L-type forms can provide self-shading of surfaces then can decrease the effect of direct solar radiation incidence on the building (Elaiab, 2014). Whereas, Szuppinger (2011), he emphasized that compact shape for a building is better than incompact one. He asserted that extended shaped buildings like L-shaped or H-shaped use more energy than cubic ones, because of the size of their wall surface causes more heat losses. The compact building form is important to use which concentrates on the close category of normally used and 'living' areas because this can help the most efficient use of passive solar design. Normal rooms which are used should be organized and grouped in the southern facade direction of the building, whereas this permits the efficient use of natural day-lighting and solar gain within a cold season (Abdulrahman, 2014). Moore (1993) mention that in response to the climate there are three forms of building type, from climate responsive through combination to climate rejecting as shown in Figure 2.4.

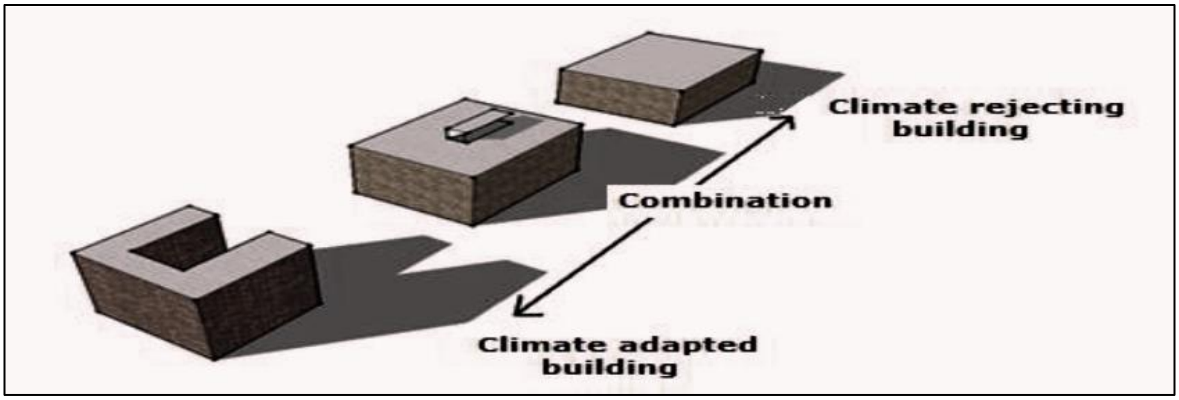


Figure 2.4: The building climate response (Moore, 1993)

The traditional house in old city of Erbil Citadel in North part of Iraq is an example on climate adapted building, which is inward looking with rooms arranged around a central courtyard, and the external walls free from windows or contain very small ones. So, houses can be built up against one another, except for the facade which faces the street.

2.6 Glazing System

Location, size and type of glass needs to be examined, also, as the effect of building orientation and shading because of their importance in day-lighting and energy loss and gain. On the north facades direction, the glass size should be reducing in order to decrease heat loss, whereas on the southern facades glasses should be more to be able to gain more heat from solar radiation among the cold season (Lapithis, 2009). In reverse, among the hot season the windows located in southern façade should be protected from the extreme sun with solar shading. Providing shading devices such as shade screens is significant to reduce the heat gain in hot climates, where it has low costs and is a proper method for controlling solar heat gain. They block or absorb and reflect a big amount of the solar radiation and prevent it to reach the windows (Lstiburek, 2004). shown in Figure 2.5.

Figure 2.5: Shade screen for absorbing direct solar radiation (Lstiburek, 2004)

2.7 Thermal Mass

Building envelope was the principle tool of controlling the thermal environment with energy consumption and the building was completely an adapted to its environment. The vernacular architects had to use the building envelope as the fundamental mediator between the exterior and interior environmental conditions (Moore, 1993). Thermal mass is a resistance of materials to change in temperature. Envelope with high thermal mass has potential to absorb and conserve heat. shown in Figure 2.6.

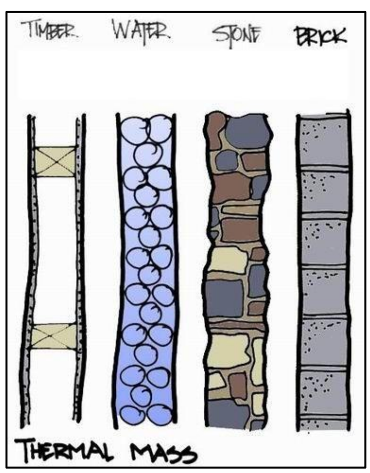


Figure 2.6: Kind of thermal mass walls (Moore, 1993)

Thermal mass is significant passive design strategy for reducing heating/cooling load on the buildings, especially in climates with high different temperature between day and night. Materials with high thermal mass absorb and retain heat, slowing the rate at which the sun heats a space and the rate at which a space loses heat when the sun is gone. Without thermal mass, heat that has entered a space will simply re-radiate back out quickly, making the space overly hot with sunlight and overly cold without.

In climates that are permanently hot or cold, the thermal mass effect can be harmful. This is because all surfaces of the mass will tend towards the average daily temperature; if this temperature is higher or lower the comfort level, it will let occupants feel more discomfort due to undesirable heat gains/ loss through the envelope. Hence, in warm - humid climates like the tropical and equatorial areas, buildings designed to be permeable and not thermal mass. In very cold and sub-polar regions, buildings are usually highly insulated with very little exposed thermal mass, even if it is used for structural reasons (Koenigsberger et al., 2010).

2.8 Natural Ventilation

On the hot season a building planned to use passive solar strategies will result to reduce solar gains and use the structure of the building to save all heat gains to keep thermal comfort inside the building. Whereas, this saved energy will naturally lose as temperature equilibrium exchange with natural night/day degree so this is not sufficient to provide the ability through the thermal mass to be effective in the following heating season. In this condition the buildings thermal mass needs to be clean from saved heat energy to supply enough capacity. This process comes from ventilation, where saved energy is cross out of the buildings structure by less temperature air transmitting through the building. The ventilation is also helps to enhance the indoor air quality by the exchange of inner air with the outer ambient surrounding.

Obviously, Natural ventilation in passive design is a precious tool for achieving energy conservation as it based on only natural airflow, and it can keep considerable quantity of fossil fuel relied on energy through decreasing the requirement for mechanical ventilation and air-conditioning. Decreasing electrical energy consumption for cooling result in the greenhouse gas emissions reduction from the electrical generating plant which producing the energy. From many years before, the building designers had used of natural airflow to achieve two primary requirements in buildings: the removal of pollutant air and moisture, and to provide individual thermal comfort (Aynsley, 2007).

The form of a building and the position of the ventilation openings both show the natural ventilation's behavior and function. Generally, there are three types of natural ventilation one differentiates amongst these three-various ventilation concept is; Single-sided ventilation, Cross-ventilation and Stack Ventilation. The ventilation principle identifies how the external and internal airflows can be relevant and therefore how the natural motive powers are used for building's ventilation. Moreover, the ventilation concept gives a sign on how the air is penetrate into the building, and how it is going out of it. Infiltration through the envelope of the building also plays an important role (Raja etal., 2001).

2.9 Single-Sided Ventilation

Openings placed on only one side of the envelope for ventilation. Fresh air gets in to the inside within the same side, such as, the rooms of a single building with windows where the openings designed in the one side and the doors on the other side. shown in Figure 2.7.

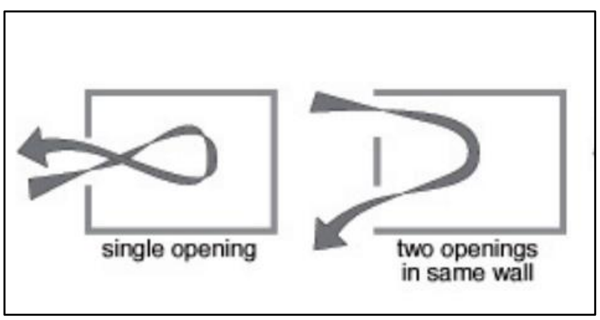


Figure 2.7: Single side ventilation (Brown and Dekay, 2001)

With a single opening for ventilation in the room, the essential movable force in summer is wind confusion. In the condition where openings for ventilation are located at various heights among the façade, the ventilation rate could be raised by the affect in flotation. The strength of thermal comfort relies upon the temperature variation amongst the inner and the outer environment, the area of the openings and the vertical distance among the openings. The more vertical distance among the openings and the higher temperature variation between the inner and the outer environment, the comfort will be implemented more (Brawn and Dekay, 2001). In this strategy in compared with another strategy, the ventilation rate is less, and the air through ventilation does not covering complete space.

2.10 Cross- Ventilation

Cross-ventilation is one of the strategy which air flows within two sides of an envelope of building by aid of drive wind pressure differentials within two sides (Raja, et al., 2001). The air ventilation enters from the windward side and leaves through to the leeward side. shown in Figure 2.8.

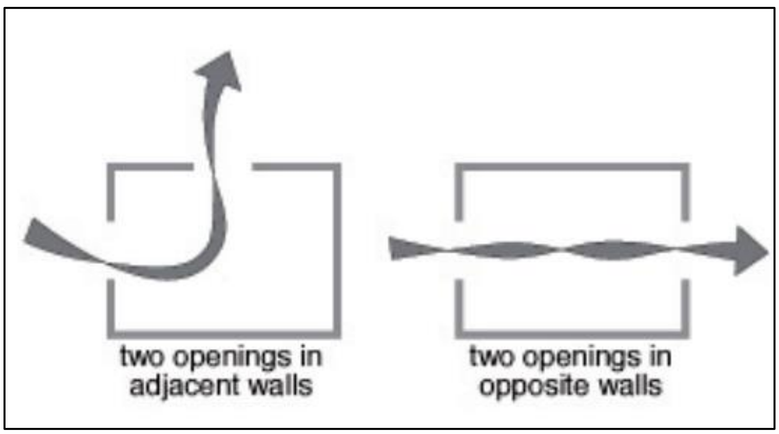


Figure 2.8: Two side ventilation (Cross- Ventilation) (Raja, 2001)

The airflow can cross between many rooms within open doors or apertures. Cross ventilation is also known when a single space where air gets into one side of the space and goes from the opposite side. In this situation the ventilation system can be either cross- or stack ventilation. When the air moves through a lived-in space, it removes heat and pollutants. Therefore, there is a limitation for the depth of a space that can help cross-ventilation be more efficient.

2.11 Stack- Ventilation

Stack ventilation happens where the stimulant powers helps an outflow from the building, in this way entering the fresh air through openings for ventilation at a lower level. Normally fresh air gets into within ventilation openings at a lower level, while used and polluted air is get outs through higher level. With locating outlet to be in a direction of wind pressure can improve the stack ventilation to be more effective (Calcerano and Cecchini , 2014).

For example, a building which has an elevated central part, warm and polluted air from the surrounding environment rises to get out from wind towers placed on the roof. According to its physical characteristics, for more effective stack ventilation needs a specified height between the inner openings and the outer openings. To achieve effective stack ventilation, it is important to increase the floor to ceiling height, using an atrium or a chimney or tilt the profile of the roof. shown in Figure 2.9.

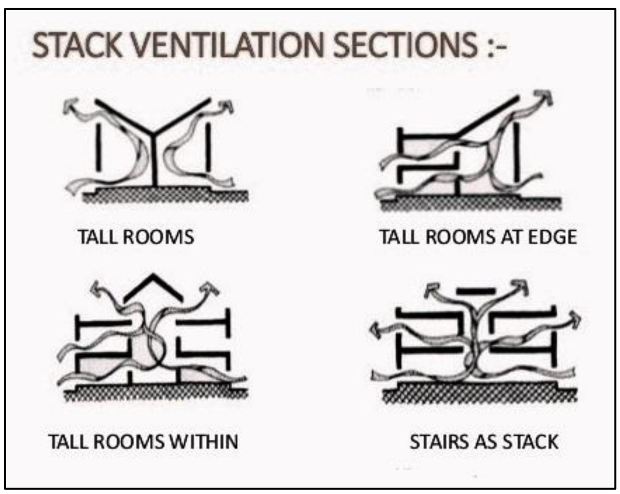


Figure 2.9: Stack ventilation types (Calcerano and Cecchini , 2014)

By its character, stack ventilation similar to cross ventilation as far as several individual areas are concerned that air get into one side of the space and gets out from the opposite side of the space. The air can flow across the total width of the building and be polluted through a chimney, or it can flow from the edges to the middle of the space to be polluted through a central chimney or atrium. (Kleiven, 2003).

Generally, window placement (location and size of opening) will affect occupant cooling if air is moving fast enough. The average interior air velocity is a function of: the exterior wind velocity; the angle at which the wind strikes the opening; and the size of the opening. The table demonstrates the relation between number and location of the openings with the Air Velocity as a Percentage of the Exterior Wind Velocity (Brown and Dekay, 2001), as shown in Figure 2.10.

opening height as a fraction of wall height	1/3		
opening width as a fraction of wall width	1/3	2/3	3/3
single opening	12-14%	13-17%	16-23%
two openings in same wall	—	22%	23%
two openings in adjacent walls	37-45%	37-45%	40-51%
two openings in opposite walls	35-42%	37-51%	47-65%

range = wind 45° perpendicular to opening

Figure 2.10: Shows the effect of size, number, and location of the openings on the air flow

2.12 Evaporative Cooling Strategy

Wind-catchers have been employed as a traditional natural ventilation tool in the buildings of the Persian Gulf region to spread the inside heat collected among the hottest, sunny days. They are generally crystallized of an empty square tower, made with the building fabric, which has openings in the upper side and inside partition to aid the wind to enter from all the directions, causing an airflow in the tower's shaft to be penetrated to the live-in building space for ventilation. The main function of wind-catchers is to improve comfortable indoor conditions, and their perfect effect has made them an important architectural element in the traditional building of the Gulf region (El-Shorbagy,2010). shown in Figure 2.10.

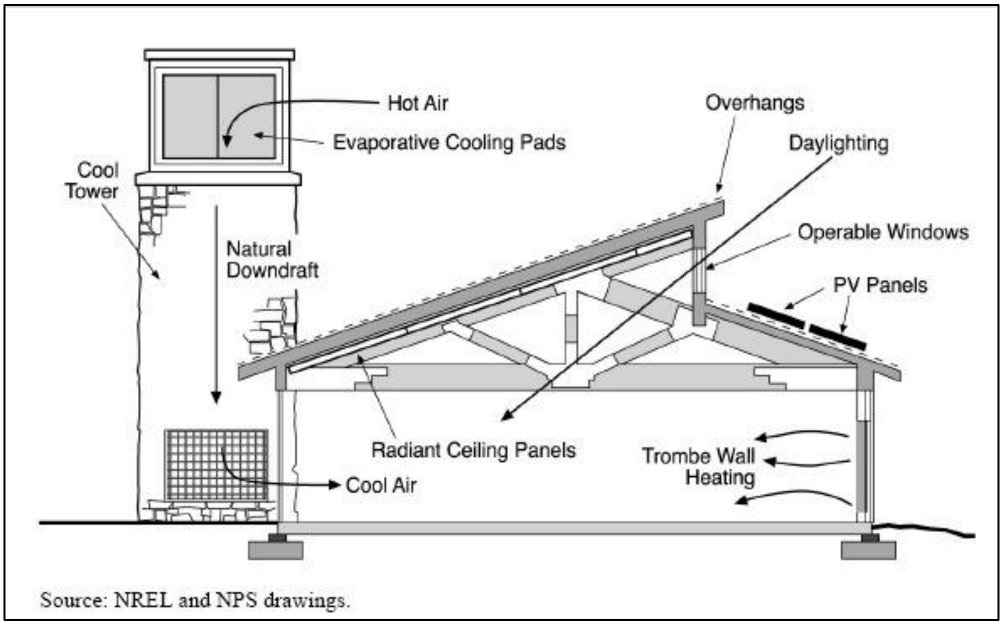


Figure 2.11: Evaporative cooling tower (El-Shorbagy, 2010)

Basically, wind-catchers mostly use for natural ventilators. The created airflow was occasionally passed within wet bodies, like a wetted porous clay. The air stream speed is belonging to the performance of the evaporative cooling machine such as the height of the tower and cross section, also the resistance to the air stream in the cooling tower (Thompson, et al, 1994). In modern design many developments for improvement of this strategy have been applied to increase their performance such as applying different wind-catcher's system (Saadatian et al, 2012).

2.13 Thermal U- Value (Heat Transfer Coefficient Value)

U value (Heat Transfer Coefficient value) can be defined as the rate of the heat is transferred within the exterior envelope of the building. Heat is consistently moves from a warms pace to a cold space and any material of the exterior envelope of the building transfers heat at various rates. As much as the material transfers heat slowly, the insulation is better. Low U-values is belonging to those materials which has slowly heat transfer compared to others, hence, they are better insulators; that is why, lower U-values are preferable. Also, heat loss has direct relation to the temperature variation between the outside and inside, and the color and texture of the external walls also in less priority.

Insulation ability of materials decreases through moisture as well as the material's conductivity is increases through damp. Even U-value can be affected and can significantly increase and reducing its insulating characteristics through mild changes in dampness. Usually the cause of moisture login is damp penetration in walls because of deficient insulation, leaking gutters and not properly fixing the frame of windows. Hence, the well maintain of building is very important to achieve low U-values. (Mohammad and Shea, 2013).

The primary stage in calculating (U-value) is to determine the thermal conductivity k (W/m K) of any single material in the envelope construction as seen following equation. Next step is to calculate the thermal resistance R (m^2K/W) for each material as follow (The Brick Industry Association, 2016);

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

in this equation (t) is the thickness of each material used in the building envelope. U-value calculate as the reciprocal of the R-value as following equation;

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

and

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

Where;

Rsi. = thermal transmission resistance for the Surface of the internal face (m2K/W).

Rse. = thermal transmission resistance for the Surface of the external face (m2K/W). (Anderson, 2006).

The following table demonstrates the recommended envelope U-value for the energy efficiency in the residential buildings in a Hot and dry climate in summer with hot summer and cold and rainy winter. Light construction refers to the conventional wood stud walls construction materials, floor, and ceiling, whereas, heavy construction refers to buildings that constructed with mass walls, a concrete masonry unit, and concrete blocks (Huang and Deringer, 2007). shown in Figure 2.12.

Bldg. envelope component		Heat transfer coefficient (W/m^2K)	
		Light Construction	Heavy construction
Roof	≥ 10 story building	≤0.4	≤0.8
	7-9 story building	≤0.4	≤0.8
	4-6 story building	≤0.4	≤0.8
	≤ 3 story building	≤0.4	≤0.6
Exterior wall	≥ 10 story building	≤0.5	≤1.0
	7-9 story building	≤0.5	≤1.0
	4-6 story building	≤0.5	≤1.0
	≤ 3 story building	≤0.4	≤0.8
Slab		≤1.5	≤1.5

Figure 2.12: Recommended U-value for the envelopes (Huang and Deringer 2007)

2.14 Descriptive Analysis for the Region - Study Area in Erbil

Erbil it is one of the ancient continuously dwelled cities in the world and could be dated back to almost 6000 BC (Khalid, 2014). The city of Erbil (36°11′28″N 44°0′33″E) is located in the north-east of Republic of Federal Iraq and it is the capital of Northern part of Iraq. The area of the city is around 130 km2, and the population within the Erbil urban area was estimated by 1,025,000, in 2008, and that rank it one of the largest cities in Iraq (Fadhil, 2011). Erbil is located in a relatively plain area and has an average elevation of 453 meters above sea level Erbil is located about 88 kilometers east of Mosul (Saeed, 2003). shown in Figure 2.11.

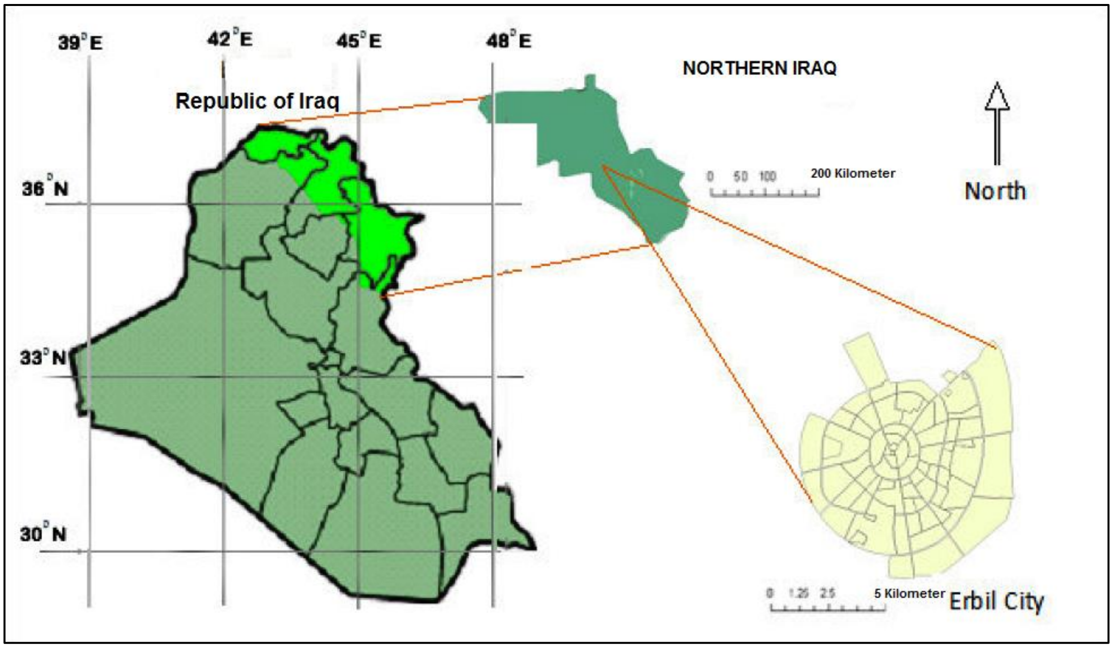


Figure 2.11: Map of the Erbil the location of the study area (Khalid, 2014)

2.15 Erbil Climatic Characteristics

The climate of Erbil can be classified as Semi-Arid Continental and is described by extreme conditions. The winter in Erbil is characterized to be very cold with rainfall and occasional snowfall, whereas the summer is very hot and dry. The maximum temperature during the day may arrive as high as 50 °C in hot summer, while the minimum daily temperature might fall under zero in cold winters (Saeed, 2012). It is significant to analyze the climatic condition of the region of Northern Iraq and understand the regular conduct of buildings in different seasons. A Thermal discomfort happen in buildings if an effective -strategy is not adopted for reducing heat gain /loss from the buildings as per the season requirements. For example, reduce heat gain in the buildings during summer should be reduced, whereas, the heat losses from buildings should be reduced during winter. Many factors can affect thermal comfort in humans; for instance, outdoor temperature, relative humidity, and air flow. Air flow could reduce the heat stress and improve thermal comfort in summer. hence, ventilation strategy could be taken into consideration for easing airflow in summer, because if there is no air flow, the rate of thermal comfort is around 44% when the temperatures below 29ºC, but if there is an air flow of 0.7m/s, then the thermal comfort can increase to 100 % (Ashen, 2009).

The north part of Iraq region is very wealthy by solar radiation. Solar radiation is significant in reducing the demands of energy for the active heating system in the winter, but it has opposite effect in summer due to increasing the energy demand for cooling in buildings. It depends on properties of the building. Solar radiation incidence through the southern direction windows in Erbil is 1205 kWh / year, whereas from the Northern direction it gains 453 kWh/ year (Husami, 2007).

2.16 Existing Power Generation Scenario in Northern Iraq

In the north part of Iraq, the needs for electricity have been raised up considerably during last decade. Total needs for electricity in the region based on official information in 2004 were 829 MW (Megawatts), while, the demand in 2012 increased to 3279 MW. Means on less than a decade the needs for the electricity raised almost four times from 2004 until 2012 (Ali, et al., 2015). The generation of electricity in Northern Iraq region has been also increased within last decade. The region was generating 482 MW in 2007, which was increased to 484 MW in 2008. Electricity generation leaped to be nearly double during one year and touch 809 MW in 2009, then in 2010 became 1047 MW, in 2011 reached 1435 MW and finally in 2012 reached 2700 MW, (Kurdish Globe, 2013).

The information demonstrates that there is an electricity shortage by 579 MW in 2012, which means approximately 82% of the total needs for electricity are generated by the government. Nowadays, the needs increased more, especially after the huge immigration of people from other places of Iraq to the north part of Iraq, since 2014 due to the IDP’s (Internal Displaced persons), because of unstable political condition. Government of Northern Iraq could supply electricity between 12 to 19 hours per day and this amount can change to less or more respecting to the needs and seasons. The remaining hours provide through private generators.

CHAPTER 3

METHODOLOGY

This chapter gives the methodological task of this research and the justification for the development of the study design.

3.1 Research Approach

To address the research question and objectives, this research applies a quantitative research method. The initial research questions as that assigned in Chapter one was;

- Whether or not the contemporary buildings in Northern Iraq are responding the climatic requirements of the region?
- How much will lesson from vernacular Architecture, assist in reducing energy consumption at the contemporary houses in Erbil?”

A quantitative method will be functional to employ because of the nature of this research which focus on the analysis of energy efficiency in a houses environment in Erbil city. This thesis is ‘descriptive and exploratory’ in nature and seeks to understand the most effective passive design strategies in the traditional houses and how could be employed or developed to be used in the contemporary houses in order to enhance energy efficiency of new houses at Erbil City. Thus, comparative analysis through comparative analysis for several elements such as the form, design, building materials, etc. will be applied and their effects on the energy consumption will be investigated. Therefore, a case study approach is used for implementation of this goal.

3.2 Multi-layer Perceptron Model

Yin (2003) addressed that 'Case study’ should be prioritized strategy when the aim of the research is to answer how and why questions. In addition to this, it should be applied when the researcher has no control over events and cannot have an effect on them. Finally, case study strategy should be conducted when the research is concentrate on a present phenomenon. The most significant technique for selecting a research strategy is identifying the type of research question being asked.

Commonly, Case studies answer questions that begin with 'how' and 'why' (Yin, 2003). Case studies can be categorized into three different strategies: explanatory, exploratory, and descriptive, (Baxter and Jack, 2008). shown in Table 3.1.

Table 3.1: Types of case study according to research approaches (Baxter and Jack, 2008)

Case Study Type	Definition
Explanatory	This type of case study would be used if you were seeking to answer a question that sought to explain the presumed casual links in real-life interventions that are too complex for the survey or experimental strategies. In intervention language, the explanations would link program implementation with program effects (Yin 2003).
Exploratory	This type of case study is used to explore those situation in which the intervention being evaluated has no clear, single set of outcomes (Yin, 2003).
Descriptive	This type of case study is used to describe an intervention or phenomenon and real-life context in which it occurred (Yin, 2003).

In order to support and reinforce the credibility of the thesis, the real-life case study will be chosen from Northern Iraq and then the data collection and analysis will gain.

3.3 Field Observation

The importance of observation is, that it let investigator investigate the subject in its own ambiance to understand the subject in more realistic condition as per investigator own sight. Observation needs from the investigators should spend enough time in the study field with applying different techniques to obtain obvious view about the particular parameters in the studies (Baker, 2006).

3.4 Research Design and Framework

Based on previous elucidation, this thesis is meeting the requirements that (Yin) debated them for selecting a case study as an approach to conduct research. Therefore, the study will select ten case studies to be analyzed; five are traditional and other five are modern or contemporary conventional house in Erbil city. Shown in table 3.2.

Table 3.2: Example for traditional and contemporary house (Kareim, 2018)

NO	Traditional Houses	Data of built	Building Materials	Contemporary Houses materials	Data of built	Building Materials
1	Jamal Afandi house	1899	Stone, Brick, Adobe, Brick & Adobe Reinforced. Brick, Clay & wood, Wood	Gullan city house	2010	Stone, Brick, Concrete Block, Block & stone. Reinforced
2	Tajil house 1	1932	Stone, Brick, Adobe, Brick & Adobe Reinforced. Brick, Clay & wood, Wood	Harsham house	2008	Stone, Brick, Concrete Block, Block & stone. Reinforced
3	Tajil house 2	1940	Stone, Brick, Adobe, Brick & Adobe Reinforced. Brick, Clay & wood, Wood	Ashty house	2010	Stone, Brick, Concrete Block, Block & stone. Reinforced
4	Arab house 1	1938	Stone, Brick, Adobe, Brick & Adobe Reinforced. Brick, Clay & wood, Wood	Ronaky house	1969	Stone, Brick, burnt brick. Reinforced, Brick& wood, Wood Ceramic tiles, Mosaic Tiles
5	Arab house 2	1938	Stone, Brick, Adobe, Brick & Adobe Reinforced. Brick, Clay & wood, Wood	Azadi house	1958	Stone, Brick, burnt brick. Reinforced, Brick& wood, Wood Ceramic tiles, Mosaic Tiles

The field observation will be conducted to investigate the strategies and the way of construction as well as building material usage, which affect the energy consumption in the buildings. A comparison between houses types including four of case studies will carry out in term of energy consumption, in order to suggest solutions to improve the energy efficiency in the contemporary buildings. Contemporary conventional houses recently are consuming significant amount of energy. The significant part of energy is consuming because of maintaining heating and cooling inside the houses. Therefore, the most effective passive design strategies to maintain thermal comfort in Erbil climate will be investigated based on applying climatic data on the Psychometric Chart, in hot and cold seasons. The study will examine the presence of these effective strategies in traditional buildings, and the possibilities to apply that in contemporary buildings. New solutions will be suggested, by comparing the materials and way of design, etc. The aim is to find solutions that meet the requirements for energy efficient buildings in Erbil city and responding to its climatic characteristic. The following diagram demonstrates the methodology frame works and the main steps of the thesis. Shown in Figure 3.1.

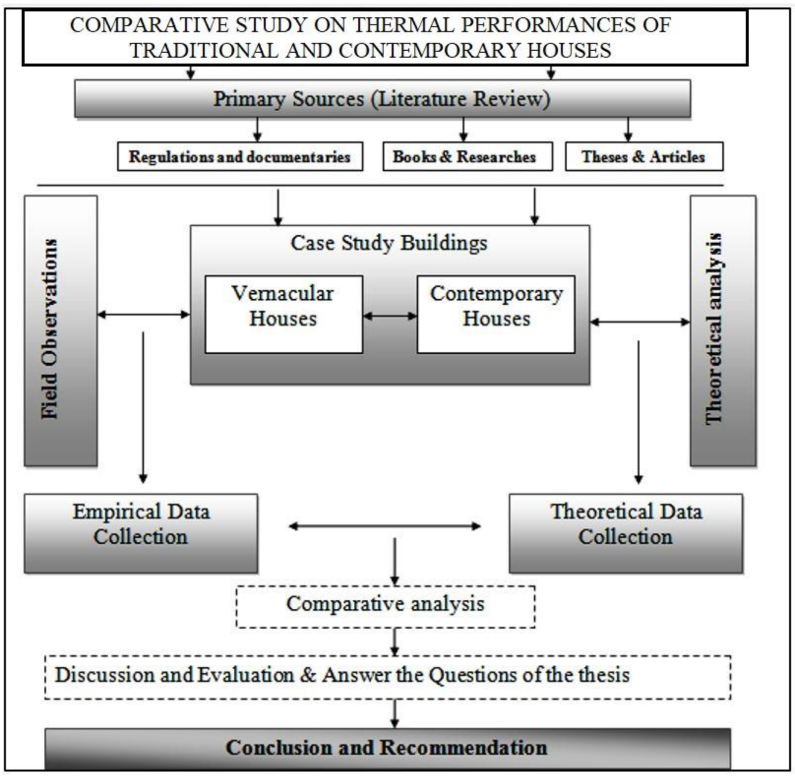


Figure 3.1: The study framework (Kareim, 2018)

3.5 Data Collection

Primary data sources were used in the study in order to validate credibility of the research by books, similar research’s, online studies, etc. And the secondary data validates credibility of the research with the halo of environmental data’s and charts which is existing.

3.6 Primary Data

To reach a sufficient understanding of the theories and ideas concerning the topic, the literature review was carried out through different sources, such as books, government reports, similar researches, credible online studies and electronic documents, metrological data, as well as architectural documents such as CAD files.

3.7 Secondary Data

The method that will be used in this part of the research is the analysis of the case studies according to environmental data collection and site observations, to assess the use of passive solar design strategies or any other strategy that can reduce or decrease the consumption of energy in the buildings.

The most effective solar passive strategies that can be applied to reduce the energy consumption in the buildings at Erbil will be assessed through apply the “Psychrometric Chart”. This chart will help to evaluate the most important passive strategies at the buildings based on environmental factors such as Higher and lower mean monthly temperature, as well as the average monthly RH (Relative Humidity).

3.8 Psychrometric Chart

Psychrometric Chart is a type of bioclimatic chart, which, aims at estimating the indoor thermal situation of the building based on the outdoor lower and higher temperature as well as relative humidity of outdoor ambient (Hosseini, et al., 2016). The chart includes the varies temperature capacity (on X- Axis) and vapor pressure, or ‘Dew point’ (on Y- Axis) of the outside air environment plotted on the chart and reconditioned with particular zones of the passive cooling/ heating techniques combined on the chart (Givoni, 1969). The passive strategies and techniques contained several passive strategies and techniques, such as Evaporative cooling, thermal mass, ventilation, and passive solar heating. In addition to that active heating and cooling system are identified, based on the relation between outside temperature and relative humidity, such as active solar heating /cooling, as shown in Figures 3.2.

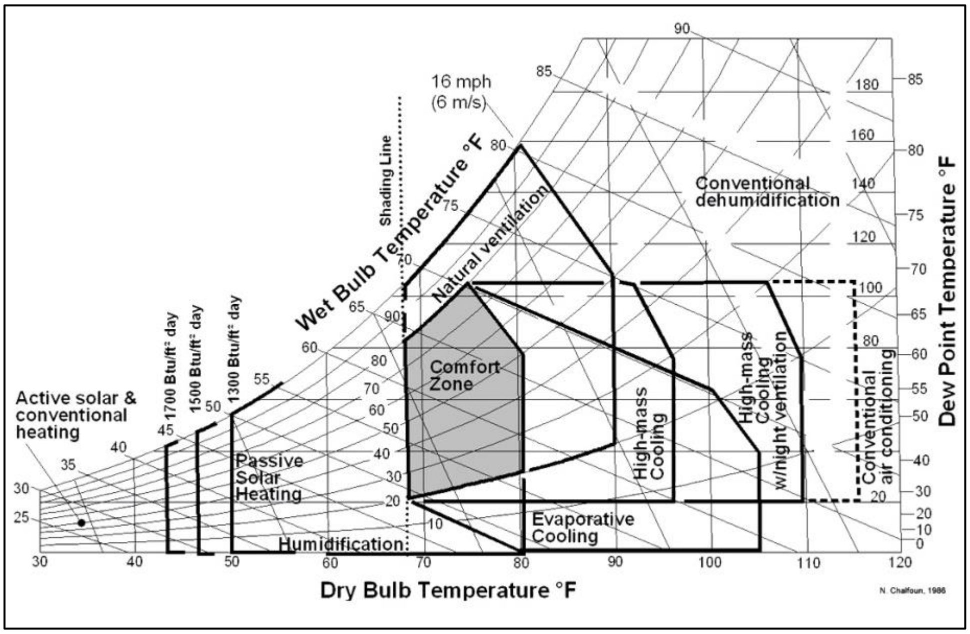


Figure 3.2: Psychrometric Chart (Givoni, 1969)

This chart employs the relationship between the average monthly temperature capacity and average monthly vapor pressure of the outside air. The thesis will apply this chart to assess the proper passive strategies in the Erbil city which, will be defined based on the climatic parameters characteristics of the Erbil that predominating outside environment.

3.9 Analysis of Metrological Data in Erbil

The climate is typified by a continental climate, hot in the summer, cold in the winter. Erbil city is in the plain areas of the Erbil region and characterize with hot summer and mild winter. The rainy season is quite unpredictable, whereas, Winds with variable speeds blow contains sometimes the dust and sand storm in the plain area, as seen in figure ‘15’. The climatic data demonstrate that the difference between the driest and wettest months in precipitation is 112 mm, along the year, and the average temperatures vary by 26.0 °C.

July is the hottest month of the year with average temperature of 33.4 °C, whereas, January has the lowest average temperature of the year, which, it is 7.4 °C. The maximum recorded temperature is in July which is 42°C, and the minimum recorded temperature is in January and was 2.4 °C. shown in Figures 3.3.

	January	February	March	April	May	June	July	August	September	October	November	December
Avg. Temperature (°C)	7.4	8.8	12.4	17.5	24	29.8	33.4	33.2	29	22.5	15	9.1
Min. Temperature (°C)	2.4	3.6	6.7	11.1	16.6	21.5	24.9	24.5	20.1	14.5	8.9	3.9
Max. Temperature (°C)	12.4	14.1	18.1	24	31.5	38.1	42	41.9	37.9	30.6	21.2	14.4
Avg. Temperature (°F)	45.3	47.8	54.3	63.5	75.2	85.6	92.1	91.8	84.2	72.5	59.0	48.4
Min. Temperature (°F)	36.3	38.5	44.1	52.0	61.9	70.7	76.8	76.1	68.2	58.1	48.0	39.0
Max. Temperature (°F)	54.3	57.4	64.6	75.2	88.7	100.6	107.6	107.4	100.2	87.1	70.2	57.9
Precipitation / Rainfall (mm)	112	98	90	69	26	0	0	0	0	12	56	80

Figure 3.3: Mean monthly last 10 years temp., and monthly average precipitation in Erbil city (Erbil Current, 2012)

According to the climatic data the average monthly relative humidity in Erbil City have been recorded as shown in Figure 3.4.

Montly Average Max&Min Relative Humidity in Arbil	Month	Morning	Afternoon
	Jan	89%	60%
	Feb	87%	53%
	March	84%	46%
	April	78%	39%
	May	60%	23%
	June	42%	15%
	July	37%	13%
	August	40%	15%
	Sep	44%	17%
	Oct	59%	28%
	Nov	79%	42%
	Dec	89%	62%

Figure 3.4: Maximum and minimum monthly relative humidity in Erbil city (Erbil Current, 2012)

The table 3.2 demonstrates that the most humid month is December and January by 89% morning time and 62%, and 60% afternoon, respectively. The lowest humidity is 37% in the morning in July and reach afternoon to 13%.

3.10 Effective Passive Solar Strategies in Erbil Climate

The comfort zone is the zone that the human being feeling no any thermal stress and it can be defined as, a thermal situation when the human within the place doesn't need any effort to fit himself to surrounding thermal environment (Panchyk, 1984). Generally, it is different from place to place based on the geographical location and climatic characteristic. But commonly, comfort zone is located between 20 to 29 °C, whereas common relative humidity for comfort zone is between 20 to 70% (Koenigsberger et al., 2010).

According to previous researches the comfort zone in Erbil city is between 20°C to 27.2 °C in, and the relative humidity is ‘between’ 20% to 80%, (Mandilawi, 2012). By applying the climatic data of Erbil on the Psychrometric chart, such as; the minimum and maximum monthly temperature and relative humidity for extreme months June, July and August as hottest months, also, for December, January, and February as coldest months; then the most effective passive strategies or techniques can be identified for these extreme months in the day (with maximum temperature) and in the night (with minimum temperature), as shown in Figures 3.5.

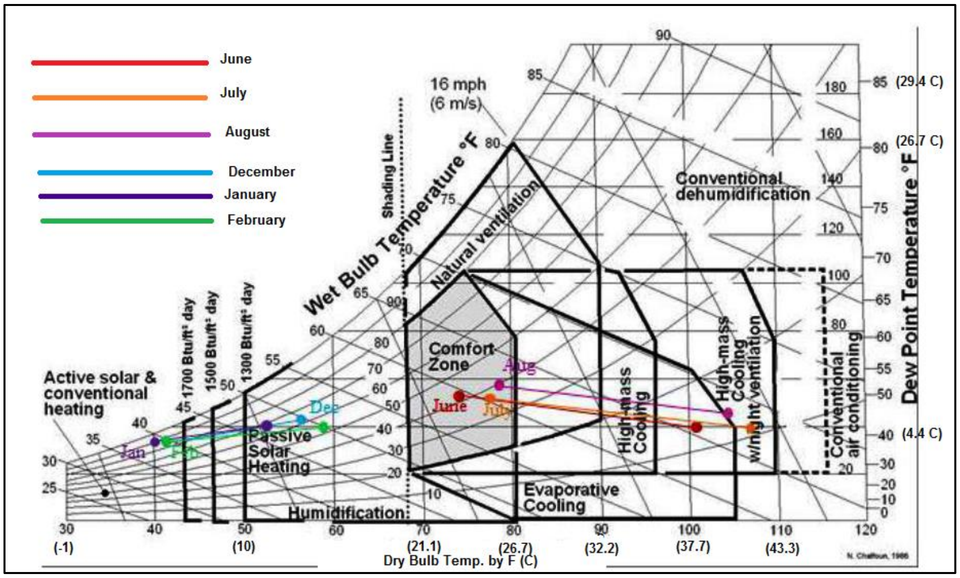


Figure 3.5: Maximum and minimum temperature and relative humidity as extreme months applied on the Psychrometric Chart (Kareim, 2018)

According to the climatic data of Erbil, like minimum and maximum monthly temperature, as well as relative humidity the "Psychrometric Chart", demonstrated that in the hottest month (June, July, and August), in the minimum temperature the thermal condition is within the comfort zone, whereas in maximum temperature times several passive techniques are required, such as; evaporative cooling, high thermal mass. In July and August, the techniques are similar to each other, where in the minimum temperature; the thermal condition is within comfort zone and in the maximum temperature, the high thermal mass and night ventilation are recommended to achieve thermal comfort. In the coldest months (December, January, and February), the techniques to maintain thermal comfort is (active solar), and conventional heating is required during all these months when the temperatures are minimum (Auliciems, and Szokolay, 2007). During the maximum temperature passive solar heating strategies are required to maintain thermal comfort, such as walls thermal mass, direct sun radiation gain. This means takes advantage of a building location, climate, and building materials to minimize the using of energy (Brawn and Dekay, 2001).

According to the previous analysis for active and passive solar strategies in Erbil city based on maximum and minimum outside temperature as well as the relative humidity of the ambient air, the results demonstrated the following;

1. Thermal Mass in the buildings is one of the most important passive strategies, because it is usable in both hottest and coldest weather.

2. Only night ventilation is active in July and August as cooling strategy for summer time.

3. Evaporative cooling is effective strategy in summer as cooling technique.

Therefore, the study will focus on thermal mass as most effective strategy because it is including hot and cold seasons. Whereas, other type of strategies is could be applied only in one season or part of the season in Erbil houses to reduce energy uses in these buildings.

3.11 Selected Case Studies

Ten case study buildings (houses) have been selected to be investigated and analyzed in term of energy consumption performance half of them are Vernacular or Traditional houses, and another half are Modern or contemporary conventional house, and all of them within Erbil city.

3.12 Case Study 1 Inside Citadel of Erbil - Jamal Afandi House

A historic courtyard house known by Shekh Jamil Afandi house is one of the traditional houses that located in the historic neighborhood of (Saraie) in the old citadel at Erbil city, north part of Iraq. shown in Figures 3.6.

Figure 3.6: Erbil old citadel and Jamal Afandi house location inside the citadel (Google Earth, 2014)

Until the middle of the 20th century, major part of the houses were formed by courtyard and as well as other architectural heritage of many towns in the territory of the hot- dry climates" (AI-Azzawi, 1969). shown in Figures 3.7.

Figure 3.7: (Jamal Afandi House) at citadel area in Erbil (Kareim, 2018)

The house had been designed by Kurdish Iranian architect (Osta Ismail) and a group of architects from 'Sena' (an Iranian town), who participated in building the main entrance of Erbil Citadel.

The age of the house is almost 110 years, where it established between 1899 and 1909. Masonry brick in the Ottoman style was used in the building.

The house contains a central rectangular shape courtyard dimensioned by (14.8 x 8.80) meters surrounded by unites of the building with two floors (Conservation Master Plan-Erbil City, 2007).

In the plan, the ground floor includes four sides built around the courtyard. The northern part looks on the courtyard next to the main central entrance of the house, as shown in Table 3.4.

For building the roofs they used timber joists and brick vaults for roofing semi-basements. The walls inner surfaces were plastered by gypsum "Spikari" and had several shelves and niches, decorated with colorful features and patterns, as shown in Figures 3.8.

Figure 3.8: Inner walls showing the plastering with ‘Spikari’ and several shelves and niches (Kareim, 2018)

The ceilings had been boarded with wooden planks and painted with bright colors and floral ornaments. In simpler houses and rooms ceilings were left to expose tree trunks and matting. shown in Figures 3.9. Commonly the basement slab height reaches almost 3 meters, whereas the ceiling of the rooms above the semi-basement is almost 4.5 meter.

Figure 3.9: Roofs boarded with wooden planks (Kareim, 2018)

On the right side of the entrance, there is a corridor, which in turn leads to the curved corridor which serves as a cross point of two parts as well, as shown in Figure 3.10.

Figure 3.10: Entrance to the courtyard (Kareim, 2018)

The entrance from the alley-way lead to the open courtyard from which one either takes to an upper floor or goes down to a semi-basement level, as shown in Figure 3.11.

Figure 3.11: Multi entrance to semi-basement or upper floor (Kareim, 2018)

The semi-basement is lower than courtyard level by about (1 to 1.5) meters, whereas, upper floors are higher than courtyard level by about the same amount. This difference in the levels between semi-basement roof and the ground of courtyard allowed fixing the windows for the semi-basement floor.

The house had contains a terrace ‘Tarma’ with arches or with columns overlooking the courtyard and act as an intermediate space to upper floor rooms, as shown in Figures 3.12.

Figure 3.12: Terrace or ‘Tarma’ (Kareim, 2018)

The terrace ‘Tarma’ can be accessed directly through steps from the courtyard. Behind the arches and columns, which are placed on the courtyard, the main rooms of the house are positioned. These rooms are directly reached from the terrace and planned with a longitudinal axis orthogonal to the terrace. The rooms contain several windows to received natural daylight and ventilation which are facing the terrace, the windows are in the lower level for cross- ventilation and upper level for stuck- ventilation. shown in Figures 3.13. Generally, the opening windows are not big and almost very little from outside of the building, whereas increases when opening toward the courtyard.

Figure 3.13: Windows facing courtyard for stack and cross- ventilation (Kareim, 2018)

The courtyard contains fountain in the center surrounded by the trees, for evaporation of air to make the dry hot air passing above water body cooler by convection in the summer and alleviate the heat by passing inside the rooms. shown in Figures 3.14.

Figure 3.14: Water body (Fountain) and Trees in the courtyard for evaporative cooling, shading (Kareim, 2018)

The building has very thick walls (thermal mass) reaches 70-80 cm and some area reaches 1 meter, as shown in Figures 3.15.

Figure 3.15: Thermal Mass building walls (Kareim, 2018)

This is useful during the summer and the winter as cooling and heating strategy. It has the ability to store the incident sun radiation inside the wall along all the day time and re- radiate it to the atmosphere in the night when the temperature drops outside. This strategy will prevent heat gain during the summer. In the same context, these walls as thermal mass can insulate the low temperature outside in the winter to inter the inside of the buildings and drop down inner temperature because it has low conductivity and high U-value (heat transfer coefficient value) (Koenigsberger et al., 2010). Table 3.2, demonstrates important information about the first case study.

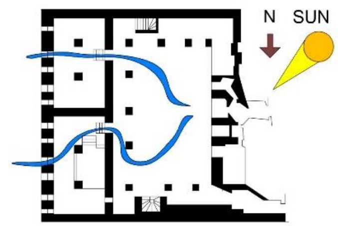
Table 3.4: Case study 1 Showing ventilation and sun path also showing used materials.

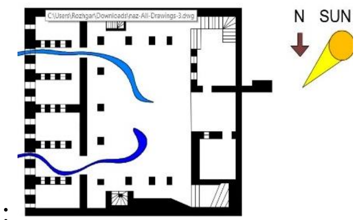
Case study 1: Jamil Afandi House example for Traditional building

Address: Erbil center at citadel Area in Erbil

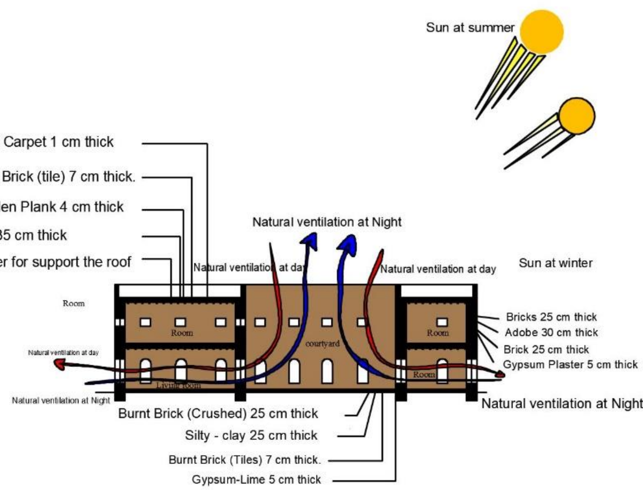
Location: 

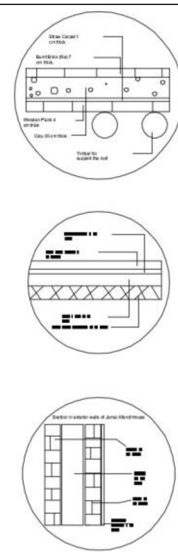
Facade: 

Plan: 

Plan: 

Remarks: Started to Build in 1899 and completed in 1909, at Citadel district, at Erbil, Northern Iraq. Total building area:225 m², Total area for courtyard:60 m², ratio of courtyard/building: %27. Total for wall:765m², Total Area for window:18m², Total Area for roof:143m².

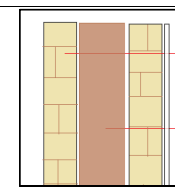




Construction System Description

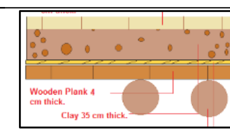
External wall: Stone, Brick,

Adobe, Brick & Adobe.

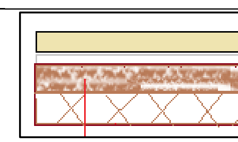


Roof: Reinforced. Brick,

Clay & wood, Wood



Floor: Burnt Brick.



Comment: In the case study 1 shape (U) has been used in the plan, it's one of the best shapes in planning for ventilation. The materials of the roof and walls is very good for transferring heat and really reducing energy consumption.

2. Traditional house in Tajil district (Case study 2).

This house building is located in Tajil district western-south of citadel area in Erbil, and south of Arab sector. shown in Figure 3.16.

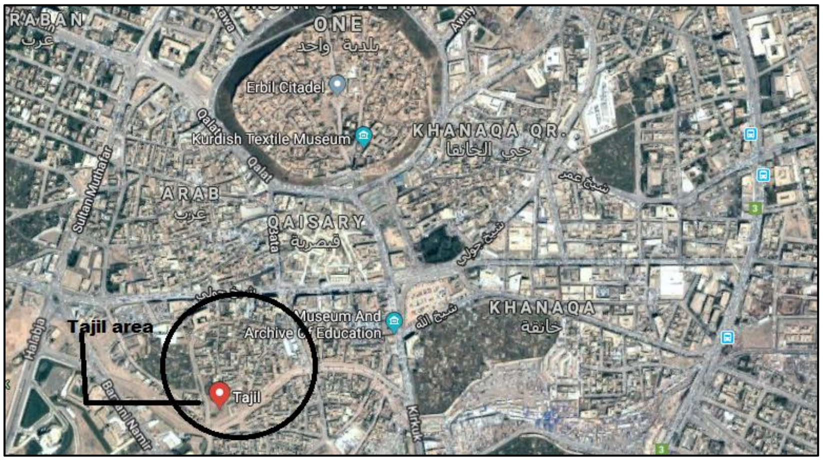


Figure 3.16: Location of the Tajil district in Erbil (Google earth, 2014)

The building function is residential and built in 1932. The house could be classified as traditional building because of using exposed burnt brick have been used and mixed with Adobe within the external walls and roofs, as demonstrated in the Figure 3.17.

Figure 3.17: The facade of the building demonstrated exposed burnt brick (Kareim, 2018)

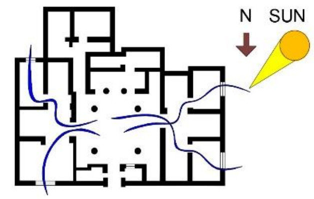
The courtyard is used in the building, and the opening of the building inward, which gives the building traditional style.

Table 3.5: Case study 2 Showing ventilation and sun path also showing used materials.

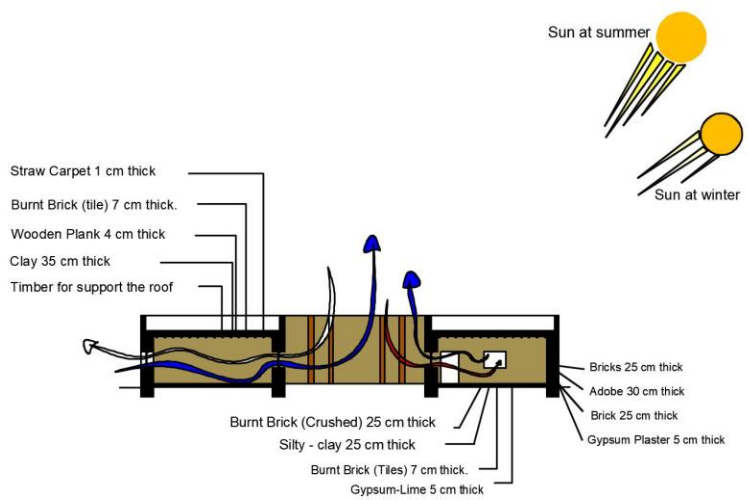
Case study 2: Tajil House example for Traditional building

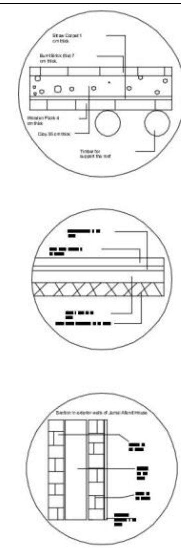
Address: Erbil- Center south of Tajil sector

Location: 

Facade: 
Plan: Plan: 

Remarks: Started to Build in 1932, at Arab & Tajil district near Citadel of Erbil, Northern Iraq. Total area for building: $180m^2$, total area for courtyard: $36m^2$, ratio of courtyard/building: %20. Total Area for wall: $305m^2$, Total Area for window: $28m^2$, Total Area for roof: $250m^2$

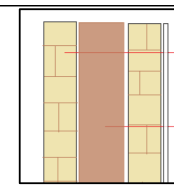




Construction System Description

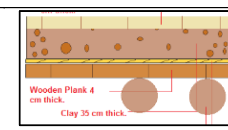
External wall: Stone, Brick,

Adobe, Brick & Adobe.

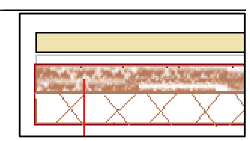


Roof: Reinforced. Brick,

Clay & wood, Wood



Floor: Burnt Brick.



Comment: In this plan square shape has been used in the center there is a courtyard which is very helpful for ventilation. The materials of the roof and walls is very good for transferring heat and really reducing energy consumption

The house had been built in forties of twentieth century, as shown in Figures 3.20, and located in Tajil district which is western south of arab sector as well as Citadel of Erbil, as demonstrated in figure 3.18 previously. It is established 1940's, of twentieth century. Shown in Table 3.6.

Figure 3.18: Facade of vernacular house in Tajil district (Kareim, 2018)

The plan of the house demonstrates that the building is very old, and the opening of the rooms is toward the central court yard. shown in Table 3.6.

The following table demonstrates the information about architectural elements and the location of the building.

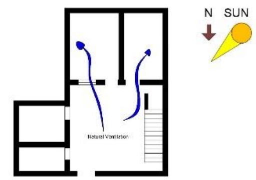
Table 3.6: Case study 3 Showing ventilation and sun path also showing used materials**.**

Case study 3: Tajil House example for Traditional building

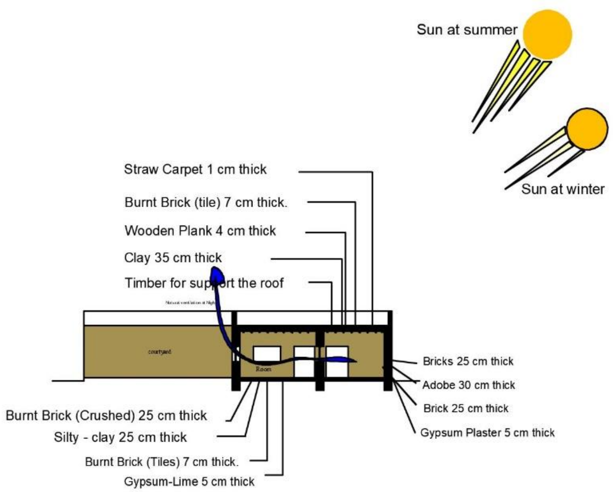
Address: Erbil- Center south of Tajil sector

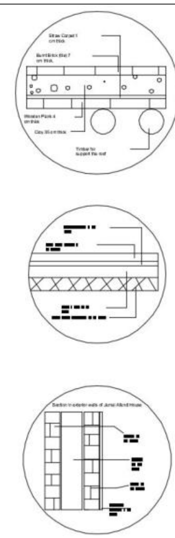
Location: 

Facade: 

Plan: Plan: 

Remarks: Started to Build in 40es of twentieth century, at Tajil district closed to Arab sector from southern of Citadel. Total building: 90 m², Total courtyard: 30 m², ratio of courtyard/building: %33. Total Area for wall:165m², Total Area for window:9m², Total Area for roof:55m²

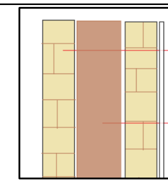




Construction System Description

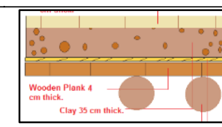
External wall: Stone, Brick,

Adobe, Brick & Adobe.

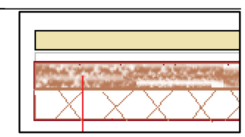


Roof: Reinforced. Brick,

Clay & wood, Wood



Floor: Burnt Brick.



Comment: In this plan square shape has been used and, in the center, there is a courtyard which is very helpful for ventilation. But the rooms surrounding the courtyard there isn't any Windows in the back or sides so we can't really get much ventilation. The materials of the roof and walls is very good for transferring heat and really reducing energy consumption

4. Traditional house in Arab sector (Case study 4).

The building is established in Arab sector adjacent to Erbil citadel from western side, as shown in Figure 3.19.

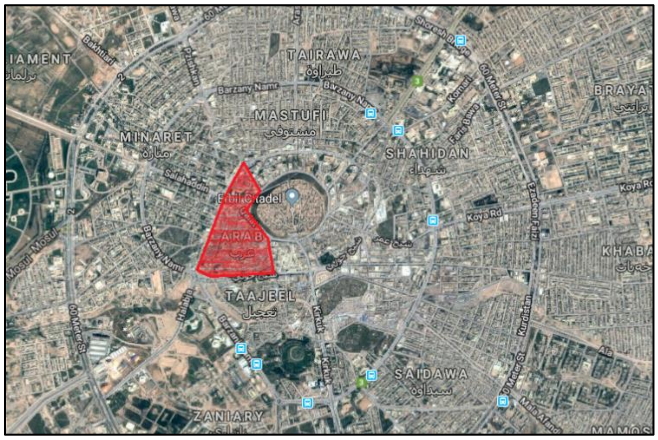


Figure 3.19: The location of Arab sector from citadel area in Erbil (Google Earth, 2014)

The building has been built in 1938, and have the same characteristic of the case study (2), through using bricks and adobe in the masonry works and having courtyard, and the exposed burnt bricks, as masonry units can be noticed in the facade. shown in Figure 3.20.

Figure 3.20: Traditional house facade in Arab sector (Kareim, 2014)

The buildings have been designed based on traditional houses in the region, where it has a courtyard in the mid of the house and all the rooms are opened on that courtyard, as shown in Table 3.7. The Table 3.7, gives the information about case study (4) in Arab sector.

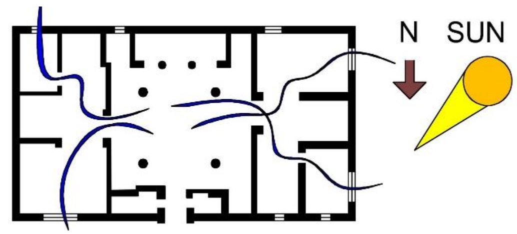
Table 3.7: Case study 4 Showing ventilation and sun path also showing used materials.

Case study 4: Arab sector House example for Traditional building

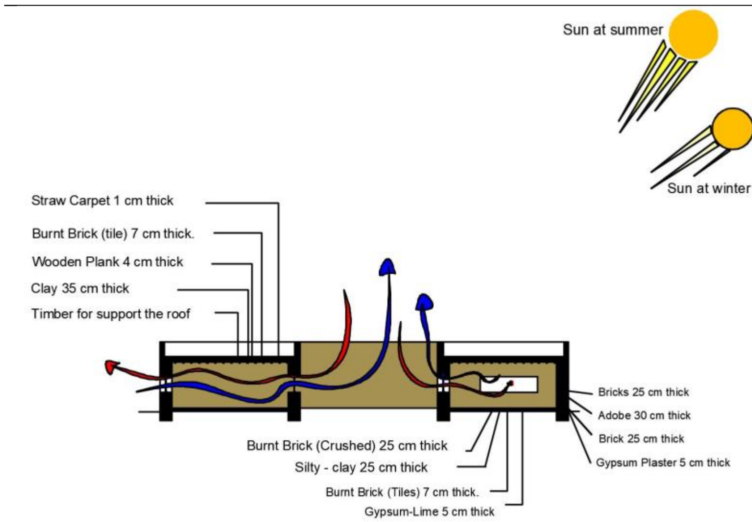
Address: Arab sector, western side from Erbil citadel

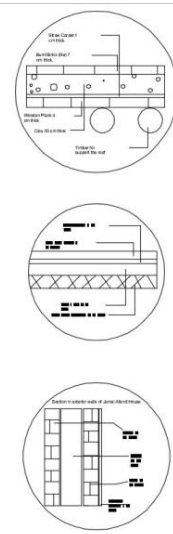
Location: 

Facade: 

Plan: Plan: 

Remarks: Started to Build in 1938, at Arab district near Citadel of Erbil, Northern Iraq. Total area for building:180 m². Total area for courtyard: 30 m², ratio of courtyard/building: %16. Total Area for wall:238m², Total Area for window:16.2m², Total Area for roof:144m².

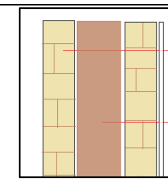




Construction System Description

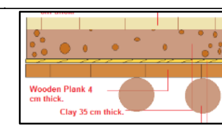
External wall: Stone, Brick,

Adobe, Brick & Adobe.

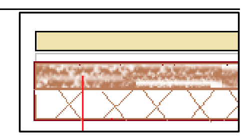


Roof: Reinforced. Brick,

Clay & wood, Wood



Floor: Burnt Brick.



Comment: In this plan square shape has been used in the center there is a courtyard which is very helpful for ventilation. The materials of the roof and walls is very good for transferring heat and really reducing energy consumption.

5. Vernacular House in Arab sector- (Case study 5).

The building is established in Arab sector which is between Citadel of Erbil and ‘Tajil’ district, as demonstrated previously (shown in Figures 3.22). It is established 1940’s, of twentieth century. shown in Figure 3.21.

Figure 3.21: Facade of the vernacular house in Arab sector (Kareim, 2018)

The roof had been containing wooden planks and painted with bright colors and the ceiling and the ceilings were held by tree trunks. shown in Figure 3.22.

Figure 3.22: Roof of the building made by wood, burnt brick and clay (Kareim, 2018)

The plan of the house demonstrated that the house has very small opining to the street and it is opened to the inner space inside the house as courtyard and the stair case are within this open space. shown in Figure 3.6.

The details of the house elements and material have been described in the table 3.8.

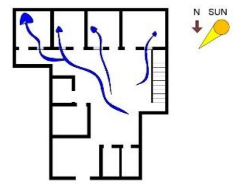
Table 3.8: Case study 5 Showing ventilation and sun path also showing used materials.

Case study 5: Arab sector House example for Traditional building

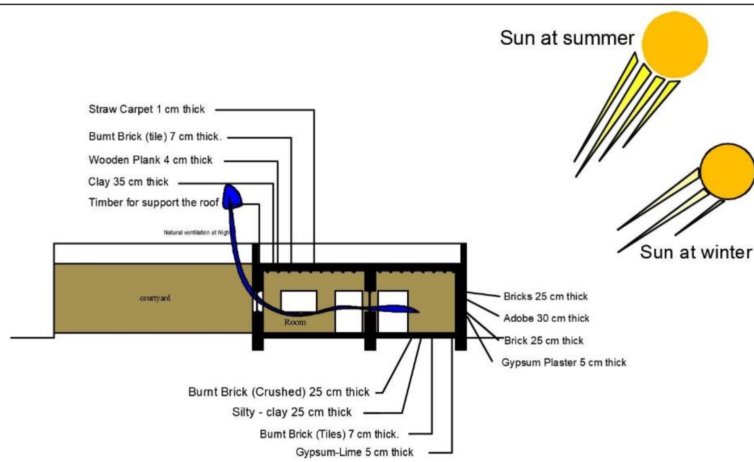
Address: Arab sector between Citadel of Erbil and 'Tajil'

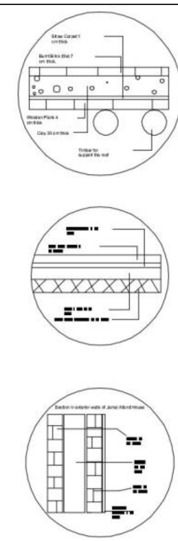
Location: 

Facade: 

Plan: Plan: 

Remarks: Started to Build in 1938, at Arab district near Citadel of Erbil, Northern Iraq. Total Area for wall:221m², Total Area for window:14.4m², Total Area for roof:194m². Total area for building: 120m², Total area for courtyard:30m², Ratio of courtyard/building:%25.

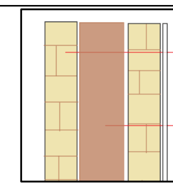




Construction System Description

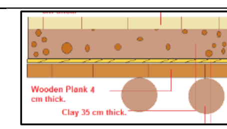
External wall: Stone, Brick,

Adobe, Brick & Adobe.

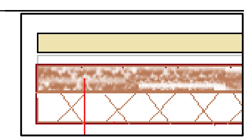


Roof: Reinforced. Brick,

Clay & wood, Wood



Floor: Burnt Brick.



Comment: In this plan square shape has been used and, in the center, there is a courtyard which is very helpful for ventilation. But the rooms surrounding the courtyard there isn't any Windows in the back or sides so we can't really get much ventilation. The materials of the roof and walls is very good for transferring heat and really reducing energy consumption.

3.13 Contemporary or Modern Conventional Case Study Houses

1. (Gullan City Society) in Erbil –Case Study 6

The project is located at Erbil City near ‘Ankawa’ sector, and 5.27 km far from Erbil Citadel as shown in Figure 3.23.

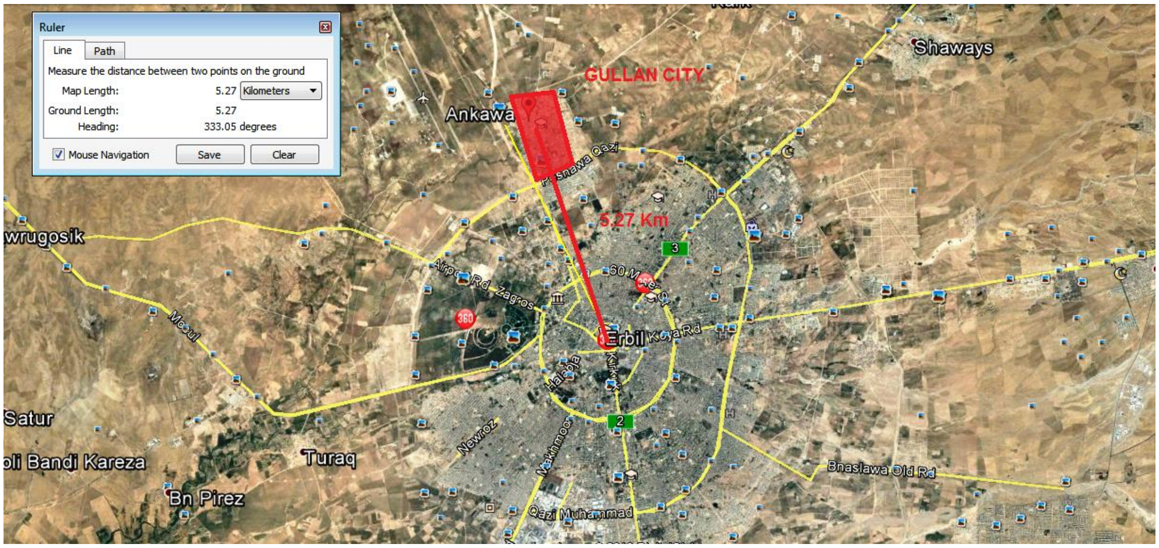


Figure 3.23: The location of Gullan city project (Google Earth, 2018)

The project needed two years to finish from 2008 until 2010, which contains 610 houses. One house from this project has been selected as contemporary conventional house. The house No (241/13) is semi- detaches house has been selected as a case study. shown in Table 3.9.

The total land area for the house is 200 m²; building area divided to two floors, the ground is 165 m2. shown in Table 3.9. Whereas, the first floor of the house is 90 m2, as shown in Table 3.9.

The material that used in this house is contemporary building and construction materials such as reinforced concrete and cement mortar as well as plain concrete. The finishing is also containing new materials like Ceramic for the floors. shown in Figure 3.24.

Figure 3.24: The floor of the houses covered by ceramic (Kareim, 2018)

The roof of the house is coated by gypsum plastering as shown in figure 3.25.

Figure 3.25: The slab from inside covered by gypsum plastering (Kareim, 2018)

The windows in this house are made by plastic (PVC) and the glass in single as shown in Figure 3.26.

Figure 3.26: Type of windows in Gullan house (Kareim, 2018)

The table below describe the architectural elements and material of the building and its location with general data. shown in Table 3.9.

Table 3.9: Case study 6 Showing ventilation and sun path also showing used materials.

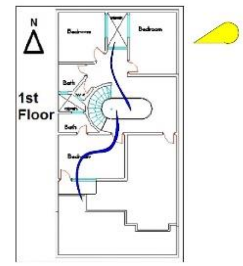
Case study 6: Gullan City House example for contemporary building

Address: Near Ankawa

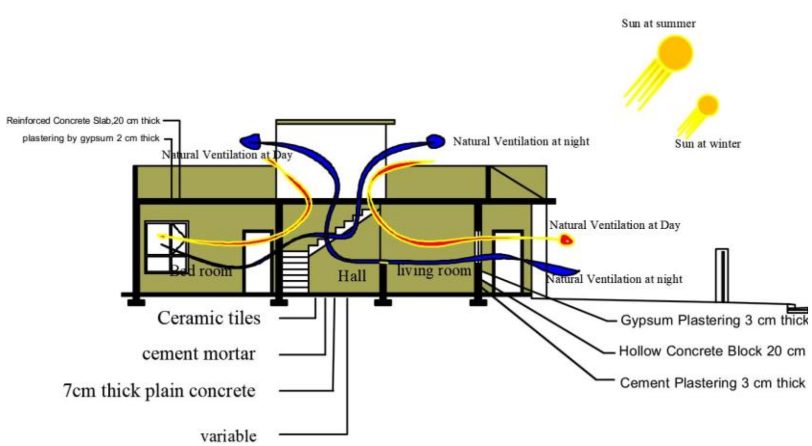
Location: 

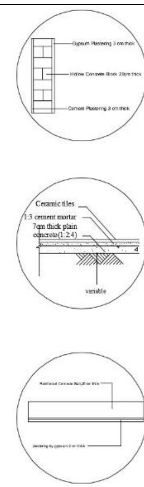
Facade: 

Plan: 

Plan: 

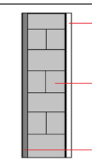
Remarks: Built in 2010, and the total land area for the house is 200 m^2, and the floors area is 165 m^2. Total building area:165 m^2, Total area for courtyard: 4 m^2, Ratio of courtyard/building: %2.5. Total Area for wall:540m^2, Total Area for window:32m^2, Total Area for roof:165m^2



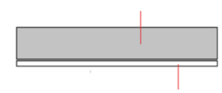


Construction System Description

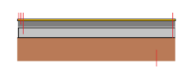
External wall: Stone, Brick, Concrete Block, Block & stone.



Roof: Reinforced, Brick& wood, Wood.



Floor: Ceramic tiles, Mosaic Tiles



Comment: In this house the courtyard is quite small and located in the rear section of the house hence we can't really get much ventilation from it. Also, the materials U-value is not much in the walls and roofs. But the floor it's acceptable there for we need very law energy in winter and summer.

2. Contemporary Conventional House in (Harsham City Society) in Erbil –Case study 7

The project established in 2009 and finished in end of 2011, and located at West-North part of Erbil city, almost 11 km from Citadel of Erbil, shown in Figure 3.27.

Figure 3.27: Location of Harsham residential projects (Google earth, 2014)

The raw house number (377), has been selected as case study for this thesis. shown in Figure 3.28.

Figure 3.28: Harsham project house (Kareim, 2018)

The houses are raw housing system, and total land area for each plot is 200 m2, while, the building area is 147 m², one floor. shown in Table 3.10.

The windows of the house are single glass with plastic (PVC) system, as shown in Figure 3.29.

Figure 3.29: PVC windows for Harsham houses (Kareim, 2018)

The finishing of this houses is similar to what is mentioned in the “Gullan” houses and it has the same construction and building materials as well. shown in Table 3.10.

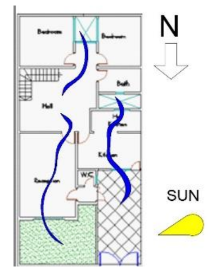
Table 3.10: Case study 7 Showing ventilation and sun path also showing used materials.

Case study 7: Harsham House example for contemporary building

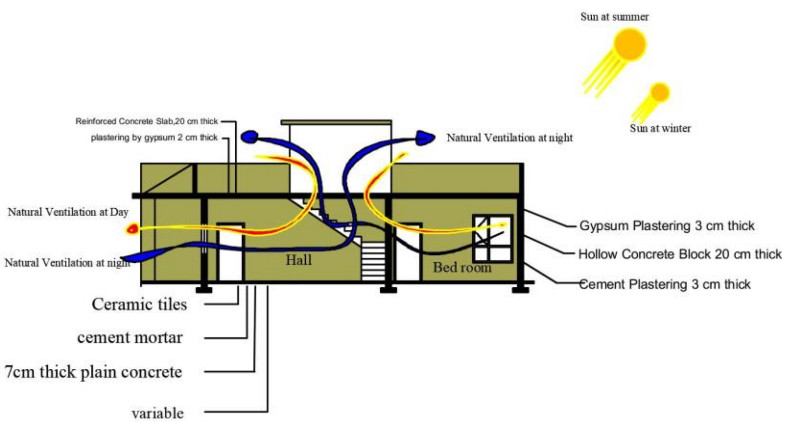
Address: Erbil international airport street

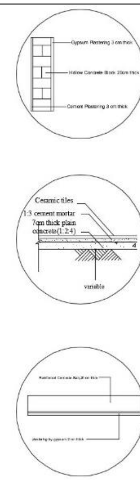
Location: 

Facade: 

Plan: 

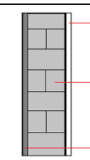
Remarks: Built in 2008 far from Citadel of Erbil by almost 5 km. the house is two floor ground floor area 147 m^2, Total area for building:147m^2, Total area for courtyard:4.5m^2, Ratio of courtyard/Building: %3. Total Area for wall:165m^2, Total Area for window:28m^2, Total Area for roof:147m^2.



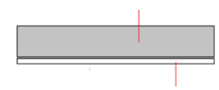


Construction System Description

External wall: Stone, Brick, Concrete Block, Block & stone.



Roof: Reinforced, Brick& wood, Wood.



Floor: Ceramic tiles, Mosaic Tiles

Comment: In this house the courtyard is quite small and located in the rear section of the house hence we can't really get much ventilation from it Also, the materials U-value is not much in the walls and roofs. But the floor it's acceptable there for we need very law energy in winter and summer.

4. Ashty contemporary conventional House in (Ashty sector- Case study 8)

The house is located in the south part of Erbil citadel as shown in the figure 3.30.

Figure 3.30: Ashty city location on the outer skirt of Erbil city (Google Earth, 2018)

The building is a house from Ashty Society, implemented in 2010, and has contemporary style in architectural design, as shown in Table 3.11.

The total area of the building is 300 m² and it contain two floors, and the building have been constructed by concrete block walls, and reinforced concrete slab, in addition to the ceramic tile floor. shown in Table 3.11.

The following list focus on the information about this house in the location and architectural material levels, as shown in Table 3.11.

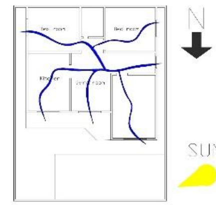
Table 3.11: Case study 8 Showing ventilation and sun path also showing used materials**.**

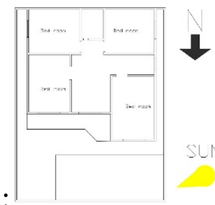
Case study 8: Ashty House example for contemporary building

Address: Erbil- Center, Bahrka street

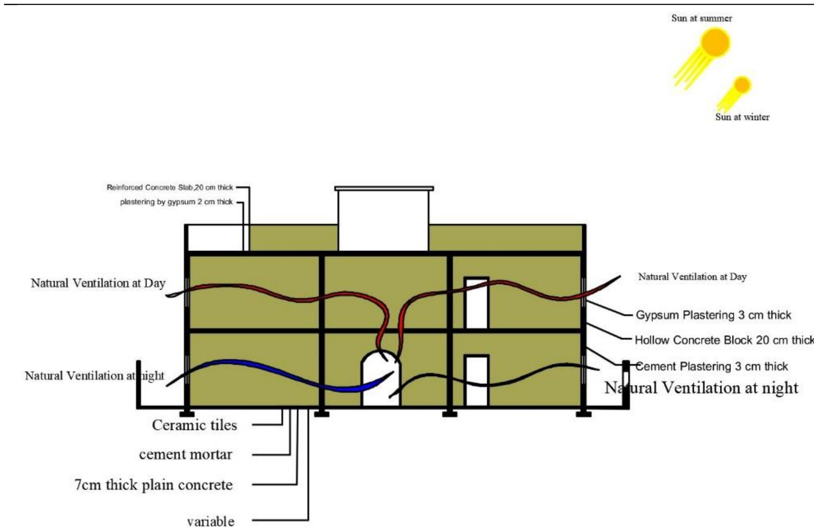
Location: 

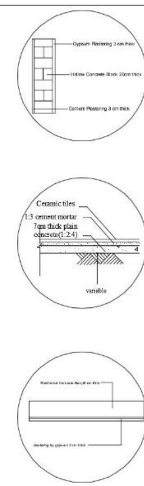
Facade: 

Plan: 

plan: 

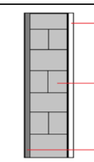
Remarks: Built in 2010, and the total floor area for the house is 300 m^2. Total area for building:300m^2, Total area for courtyard:0 m^2, Ratio of Courtyard/Building: %0, Total Area for wall:442m^2, Total Area for window:51m^2, Total Area for roof:300m^2



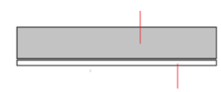


Construction System Description

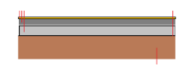
External wall: Stone, Brick, Concrete Block, Block & stone.



Roof: Reinforced, Brick& wood, Wood.



Floor: Ceramic tiles, Mosaic Tiles



Comment: This plan doesn’t have any courtyard it’s a modern house but, in the back, and sides has windows for ventilation. Also, the materials U-value is not much in the walls and roofs. But the floor it's acceptable there for we need very law energy in winter and summer.

5. Early Modern House (1960's-1970's) in (Ronaki Sector) in Erbil – Case study 9

The project is located in the South-East of the city of Erbil, and far from Erbil Citadel by 3.25 Km, as shown in Figures 3.31.

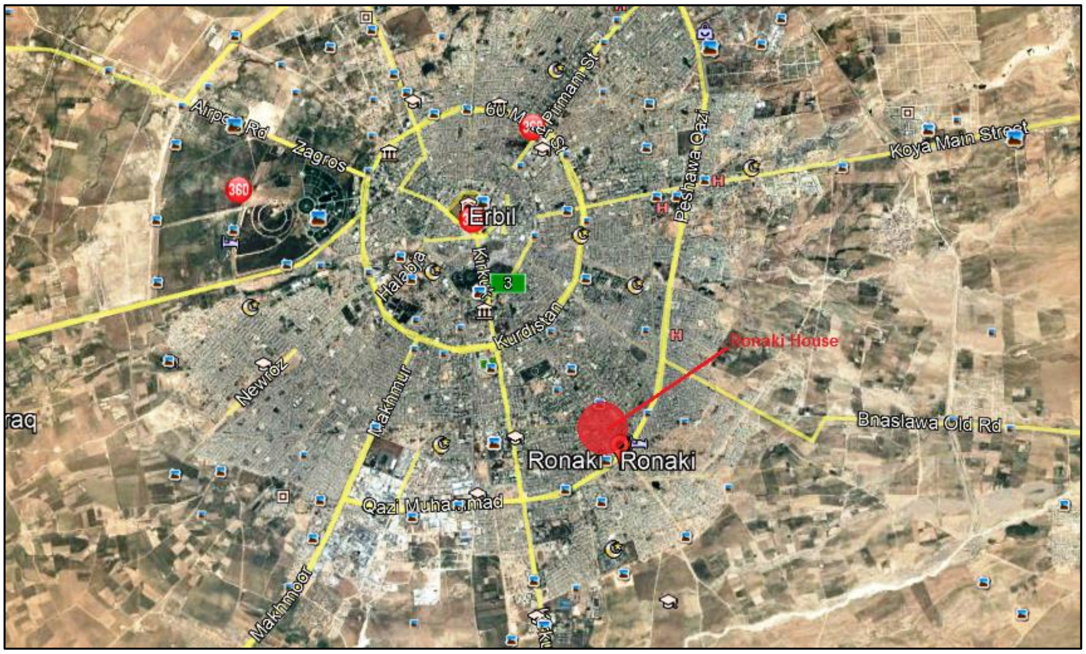


Figure 3.31: Location of the Ronaki house in erbil city (Kareim, 2018)

The age of the building of "Ronaki" house is returns to end of 60's and beginning of 70's of twentieth century. The building designed with influence of early modernist architecture movement. shown in Figures 3.32.

Figure 3.32: Early modern house in Ronaki at erbil city (Kareim, 2018)

The walls which are bearing walls had been constructed by burnt bricks, and covered from outside by cement plastering and from inside by gypsum plastering, as shown in Figures 3.33.

Figure 3.33: wall of the Ronaki house from inside (Kareim, 2018)

The total land area for the house is 900 m², the building area is 400 m2 which is only one floor. shown in Figures 3.34.

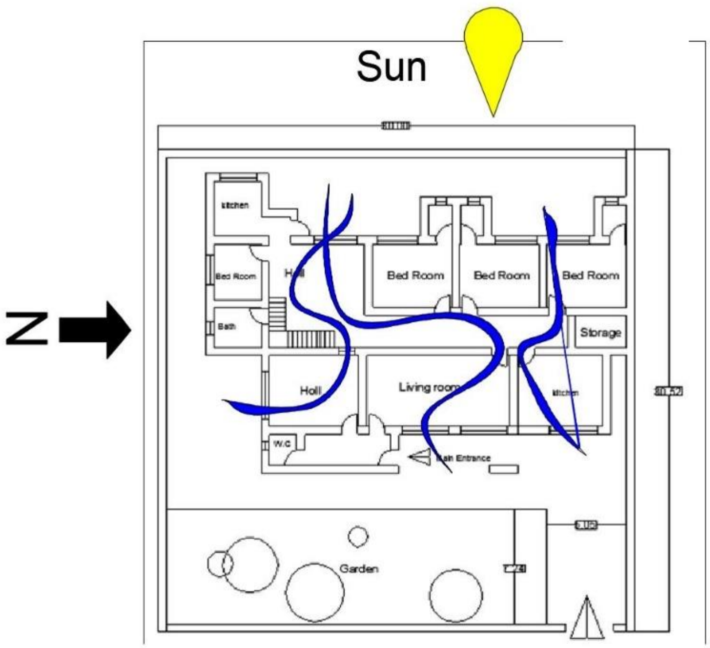


Figure 3.34: Plan of the Ronaki house (Kareim, 2018)

Different type of materials has been used in this building which is returns to that era. For example; the floor covered by mosaic as shown in Figure 3.35.

Figure 3.35: The floor of the Ronaki house covered by mosaic (Kareim, 2018)

The slab of the building is made by reinforced concrete and covered from inside by white gypsum plastering. The building contains big windows which had been made originally by Iron frames and single glass, as shown in Figure 3.36.

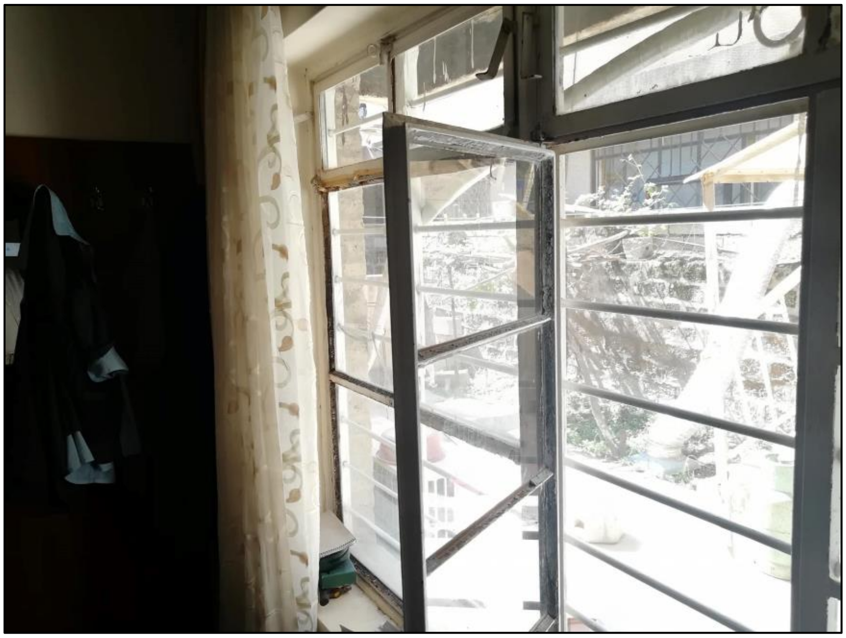


Figure 3.36: Original windows of Ronaki house (Kareim, 2018)

The following table illustrates the information about this building and its materials or location as well as elements. shown in Table 3.12.

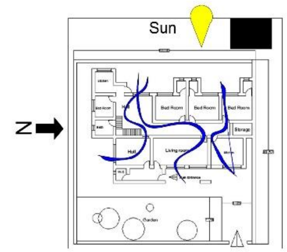
Table 3.12: Case study 9 Showing ventilation and sun path also showing used materials.

Case study 9: Ronaki House example for contemporary building

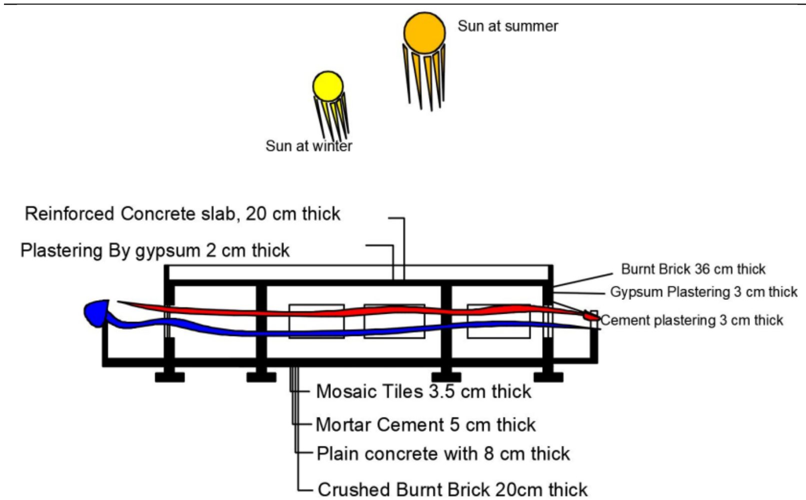
Address: Ronaki street, near Rudaw T.v

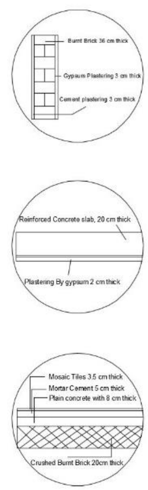
Location: 

Facade: 

Plan: 

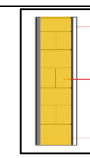
Remarks: "Ronaki" house is returns to end of 60's and beginning of 70's of twentieth century, with 900 m^2 floor area. Total area for building:410m^2, Total area for courtyard: 0m^2, Ratio of Courtyard/Building: %0. Total Area for wall:340m^2, Total Area for window:56m^2, Total Area for roof:410m^2.



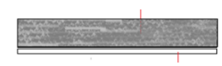


Construction System Description

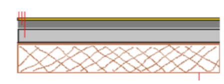
External wall: Stone, Brick, Concrete Block, Block & stone.



Roof: Reinforced, Brick& wood, Wood.



Floor: Ceramic tiles, Mosaic Tiles



Comment: This plan doesn't have any courtyard it's a modern house but, in the back, and sides has windows for ventilation and the materials of the roof and walls are have very u-value but the window frames are made of steel which are very bad because of heat transferring (the worst type of windows).

5. Modern House (1958) in (Azadi Sector) in Erbil – Case study 10

The house is located in the azadi district south of Citadel of Erbil, as shown in Figure 3.37.

Figure 3.37 Azadi district in erbil city (Google Earth, 2014)

Azadi modern house is similar to the Ronaki modern house, the walls are built by burnt brick and the structure system is bearing wall. The roof has been built with reinforced concrete. shown in Table 3.13.

The floor of the building is made by mosaic, as shown in Figure 3.38.

Figure 3.38: Mosaic tile floor of Azadi house (Kareim, 2018)

The The plan of the house shows that the design and division of the spaces were arranged based on the modern style in architecture, through opening from inside to outside with big windows and putting the building in the center of the plot, as shown in Table 3.13. The table below shows more details about the location, shape, and building materials of this house. shown in Table 3.13.

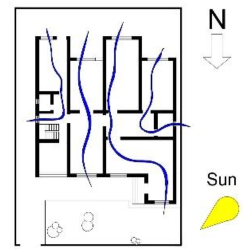
Table 3.13 Case study10 Showing ventilation and sun path also showing used materials.

Case study 10: Azadi House example for contemporary building

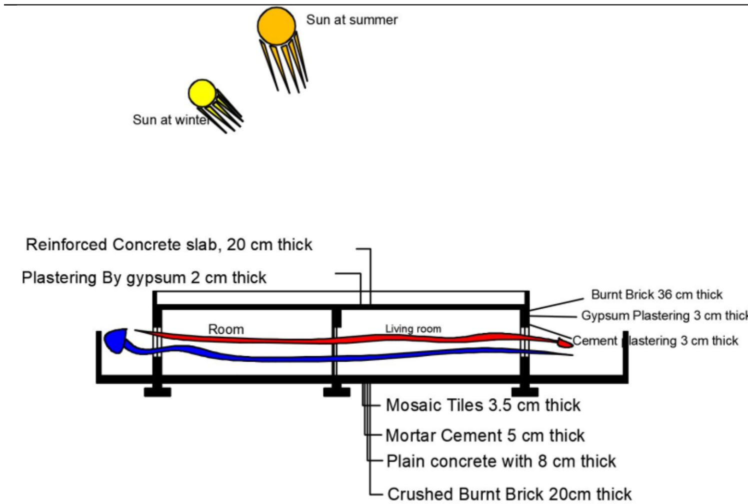
Address: Azadi street, near firanso Hariri stadium

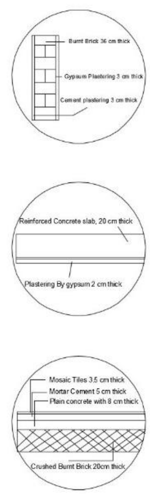
Location: 

Facade: 

Plan: 

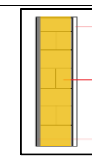
Remarks: Built in 1958 in Azadi with 630 m^2 floor ground floor area in Azadi district south of Citadel of Erbil. Total area for building:400m^2, Total area for courtyard: 0m^2, Ratio of Courtyard/Building: %0. Total Area for wall:290m^2, Total Area for window:50m^2, Total Area for roof:400m^2



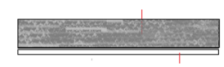


Construction System Description

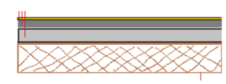
External wall: Stone, Brick, Concrete Block, Block & stone.



Roof: Reinforced, Brick& wood, Wood.



Floor: Ceramic tiles, Mosaic Tiles



Comment: This plan doesn't have any courtyard it's a modern house but, in the back, and sides has windows for ventilation and the materials of the roof and walls are have very u-value but the window frames are made of steel which are very bad because of heat transferring (the worst type of windows)

CHAPTER 4
METHODOLOGY

4.1 Analysis of a Traditional or Vernacular Buildings in Erbil

Five case study buildings (Houses) from different districts of Erbil have been selected in (Citadel, Tajil, and Arab sector). The analysis will be based on the main strategy of thermal mass that have been discussed and identified through 'Psychrometric Chart' as per the investigation based on collected climatic data for Erbil. Thermal mass strategy will be considered as most effective strategy to reduce heat gain/ loss in the buildings, because it is effective strategy in both (hottest and coldest) extreme seasons. Consequently, this strategy will result to reducing energy consumption in the buildings through thermal prosperities of building materials especially the envelope of the building. Take in consideration, that the majority of the energy is uses to maintain heating or cooling in the houses. Help of 'Psychrometric Chart', the Thermal Mass envelope element will be investigated in this thesis in order to see its effect on the energy consumption in this house.

4.2 Analysis of a Traditional or Vernacular Buildings in Erbil

The building envelope materials in this house have been investigated and determined. Envelope is consisting of three main parts, which are (Exterior walls, Floor, and Roofs, as well as Windows).

1. Exterior Walls:

It is consisting of three types of materials, which are Bricks, Adobe, and Gypsum 'Juss' shown in Figure 4.1.

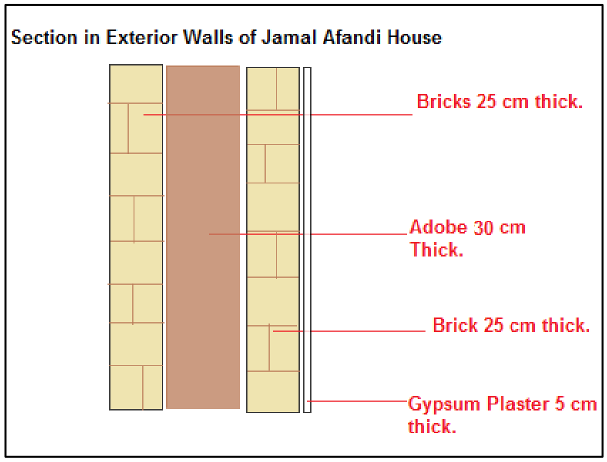


Figure 4.1: The types of material in Exterior walls of the building (Kareim, 2018)

Heat transfer coefficient value (U-value) was calculated for the exterior walls materials have as listed in the table 4.1, according to the field observation.

Table 4.1: Calculation of the U- values for the exterior walls in Jamal Afandi house

No.	The Material	Material Thick (t) by meter	Conductivity(k) (W/mK)	Resistance (R) (m^2 K/W). See2.2	U-Value(W/m^2K). See 2.2
1	Exposed Burnt Brick(Farshi)	0.25	0.77	0.32	U wall=1/(Rsi. + R1+R2+R3+R4+Uwall= 0.70(W/m^2K)
2	Adobe[2]	0.30	0.755	0.4	
3	Protected Burnt Brick(Farshi)	0.25	0.56	0.44	*Rse & Rsi values = 0.13, are respectively, they are obtaining (Anderson, 2007, P,7)
4	Plaster made by only gypsum (with aggregate)	0.25	0.50	0.1	

2. Roof:

For the roof of the building the thick soil layer above the straw mat, supported from bellow by wood boards, which are supported by the timbers, and all the roof covered by burnt clay tiles, as shown in Figure 4.2.

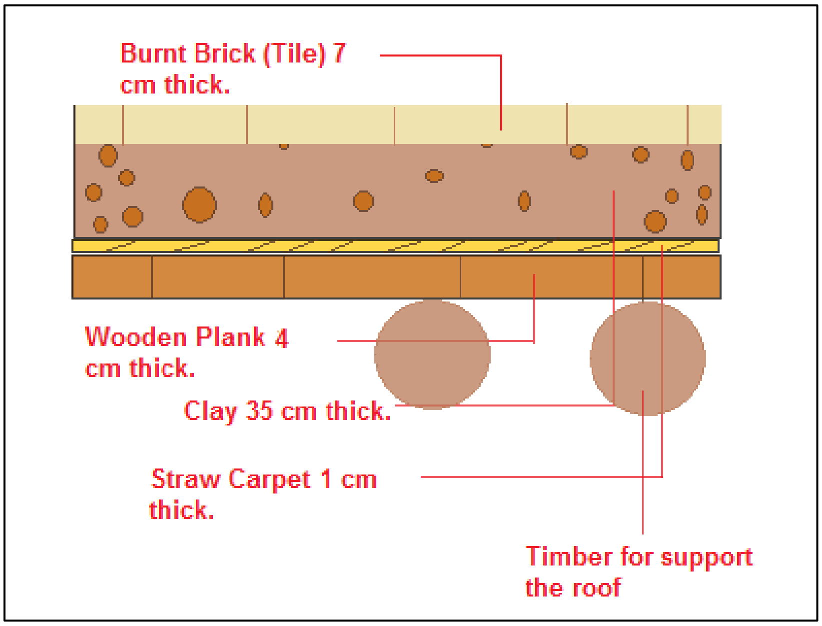


Figure 4.2: Section in the roof of the house (Kareim, 2018)

U value for the roof also calculated according to the type and thickness of the materials used in the house. shown in Table 4.2.

Table 4.2 Calculation of the U- values for the roofs in the vernacular buildings

No.	**The material**	**Material Thick. (t) by meter**	**Conductivity (k) (W/mK)**	**Resistance(R) (m^2K/W). See2.2.**	**U-Value (W/m^2K). See 2.2.3**
1	Straw[1]	0.01	0.056	0.18	U wall=1/ (Rsi. +R1+R2+R3+ R4+Rse.) Uwall=1.11 (W/m^2K)
2	Silty Clay[2]	0.35	1.48	0.24	
3	wooden plank [3]	0.04	0.16	0.25	*****Rse & Rsi values= 0.10 and 0.04, respectively. they are obtained from (Anderson, 2007, P.7)
4	Exposed Burt Brick (Tile) [4]	0.07	0.77	0.09	

3. Floor:

The floors in this house consist of four types of materials which are; Crushed burt bricks, embanked soil, compacted and covered by thin layer of Gypsum mortar, and covered by Burnt flat bricks (tiles) with 7 cm thickness, all of which laid on. shown in Figure 4.3.

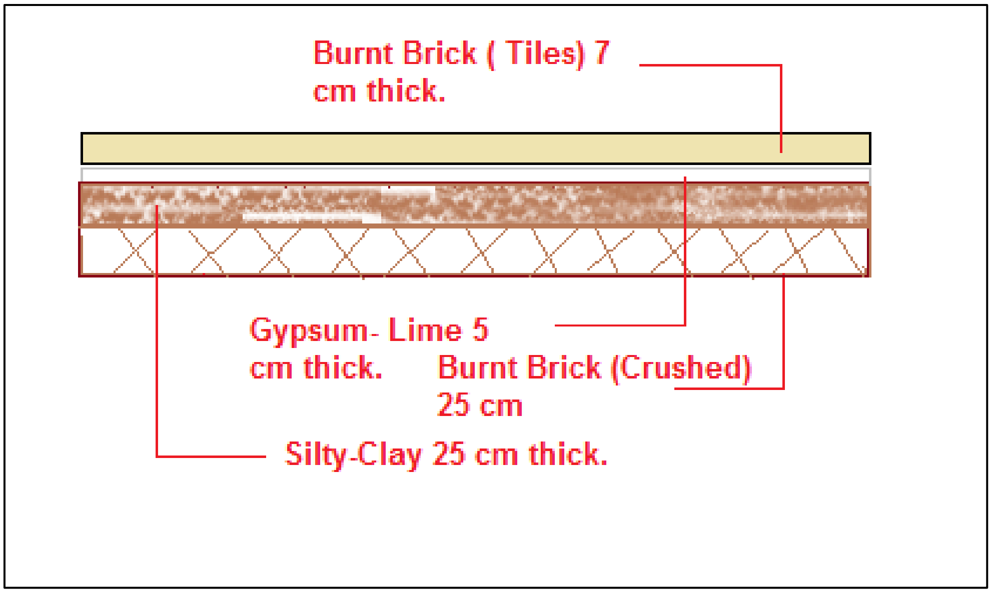


Figure 4.3: Section in the floor of house (Kareim, 2018)

U value for the floor calculated according to the type and thickness of the materials used in the house. shown in Table 4.3

Table 4.3: Calculation of the U- Value for the floors in the house

No.	The material	Material Thick. (t) by meter	Conductivity (k) (W/mK)[1]	Resistance(R) (m^2K/W). See2.2.	U-Value (W/m^2K). See 2.2.3
1	**Burnt Brick (Crushed)**	0.25	0.56	0.44	U Floor=1/ (Rsi +R1+R2+R3+R4+ Rse) U_{Roof}=0.99 (W/m^2K)
2	**Silt- Clay** [2]	0.25	1.48	0.17	
3	**Gypsum mortar, lime-based gypsum mortar**	0.05	0.50	0.10	*Rse & Rsi values= 0.17 and 0.04, respectively. they are obtained from (Anderson, 2007, P.7)
4	Exposed Burt Brick (Tile)	0.07	0.77	0.09	

4. Window:

The windows in this house had single glass and sometime colorful, and the frames of the windows are almost wooden. Hence, the U- Value of the windows in this building obtained according to the Turkish Standard Institute, is equal to (4.9 W/m2K), as shown in Figure 4.3.

Window heat conductivity (Up) coefficients prepared to be used in the selection of the glass appropriate to the heat regions in Turkey W/m²K		SINGLE GLASSED WINDOW	DOUBLE GLASSED WINDOW (uncoated glass)				DOUBLE GLASS LOW-E COATED WINDOW			
			INTERSTITIAL SPACES (mm)				INTERSTITIAL SPACES (mm)			
			6	9	12	16	6	9	12	16
	UNPROCESSED	5,7	3,3	3,0	2,9	2,7	2,6	2,1	1,8	1,6
PROCESS TYPE	WOODEN PROCESSING (oak, ash tree/hard woods)	5,1	3,3	3,1	3,0	2,8	2,8	2,3	2,2	2,0
	WOODEN PROCESSING (coniferous soft trees)	4,9	3,1	2,9	2,8	2,6	2,6	2,2	2,0	1,8
	PLASTIC PROCESSING (having 2 compartments)	5,2	3,4	3,2	3,0	2,9	2,9	2,4	2,3	2,1
	PLASTIC PROCESSING (having 3 compartments)	5,0	3,2	3,0	2,8	2,7	2,7	2,2	2,1	1,9
	ALUMINUM PROCESSING	5,9	4,0	3,9	3,7	3,6	3,6	3,1	3,0	2,8
	ALUMINUM PROCESSING (with insulation bridge)	5,2	3,4	3,2	3,0	2,9	2,9	2,4	2,3	2,1

Figure 4.4: Table shows the U-value for some types of glass with process types (Turkish Standard Institute, 2008)

The evaluation of (U-Value), for the traditional or vernacular houses in Erbil represented by selected case study buildings, in Citadel, Tajil, and Arab sector area demonstrates the following;

1. The envelope U-Value demonstrates very high climatic responding envelope thermal properties for the exterior walls and relatively less responsive with the roof according to the required U-value in the houses (Huang, and Deringer 2007). See (2.2. U-Value, in Chapter Two).

2. The Floor demonstrated good U-value and responsive with the climatic characteristic and requirement in Erbil.

3. The windows according to Turkish Standard Institute, which suppose the U-value for windows should not exceed 2.4(W/m^{2}K) (Turkish Standard Institute, 2008), showed the weak response to the climatic needs

4.3 Analysis of a Modern or Contemporary Conventional Houses (Gullan & Harsham City Project, and Ashty Sectors) in Erbil

According the documented (Cad files, architectural drawings, working drawings) of the houses and based on site visit.

4.4 Thermal Mass of the Envelope

The houses envelope (exterior walls, roofs, and floor) materials and thickness has been determined.

1. Exterior Walls:

The walls are bearing system walls and consist of; exterior face coated with cement plastering; and interior walls has been coated by gypsum plastering. The main masonry unit is hollow concrete blocks with 20 cm thickness. shown in Figure 4.4.

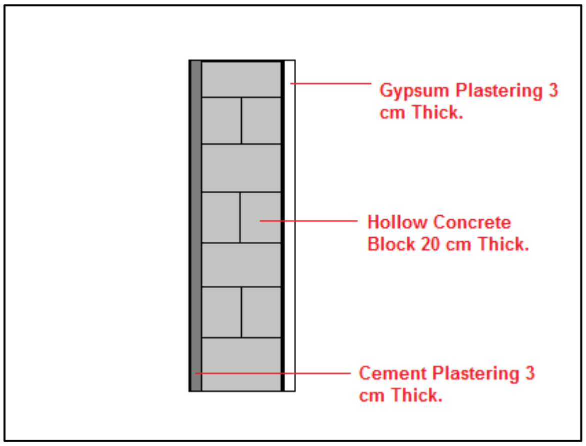


Figure 4.5: Section in exterior wall of Gullan & Harsham city houses (Kareim, 2018)

(U-value) was calculated for the exterior walls materials for Gullan, Harsham, and Ashty Houses as listed in the table 4.5, according to the field observation.

Table 4.4: Calculation of the U- values for the exterior walls in Gullan, Harsham and Ashty Houses

No.	The material	Material Thick. (t) by meter	Conductivity (k) (W/mK)	Resistance(R) (m^2K/W). See2.2	U-Value (W/m^2K). See 2.2.3
1	Cement Plastering[1]	0.03	0.72	0.04	U wall=1/ (Rsi. +R1+R2+R3 Uwall=2.44 (W/m^2K)
2	Hollow Concrete Block[2]	0.20	1.44	0.14	
3	Gypsum mortar, lime-based gypsum mortar [3]	0.03	0.50	0.06	*Rse & Rsi values =0.13, an respectively. they are obtaine (Anderson, 2007, P.7)

2. Roof:

The roof of the house is flat and reinforced concrete slab with 20 cm thickness. The interior face of the roof is plastered with gypsum, whereas, the exterior face is exposed to outer environment. shown in Figure 4.5.

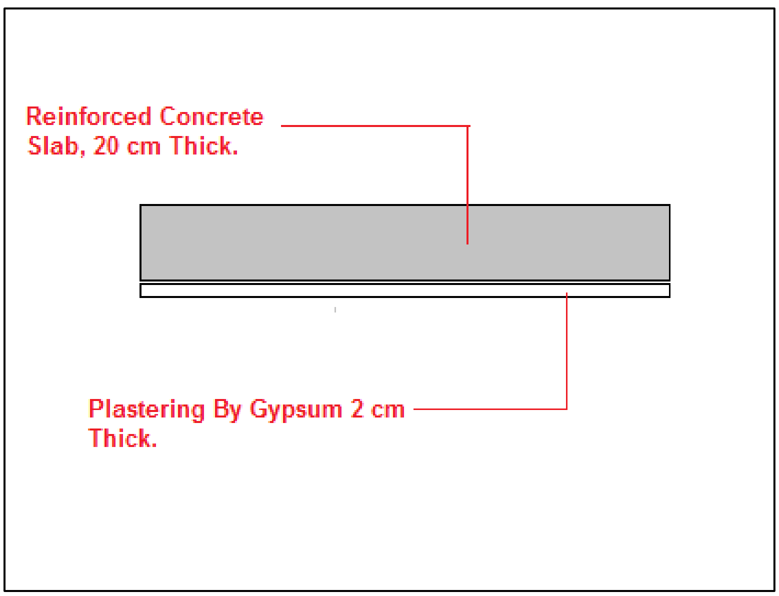


Figure 4.6: Section in the roof of Gullan & Harsham houses (Kareim, 2018)

U value for the roof in Gullan , Harsham and Ashty houses calculated according to the type and thickness of the materials used in the house as demonstrated in the table 4.5.

Table 4.5: Calculation of the U- values for the Roof in Gullan House

No.	The material	Material Thick. (t) by meter	Conductivity (k) (W/mK)	Resistance(R) (m^2K/W). See2.2	U-Value (W/m^2K). See
1	Reinforced Concrete [1]	0.20	1.58	0.13	U wall=1/ (Rsi. +R1+R2
3	**Gypsum mortar, lime-based gypsum mortar** [2]	0.02	0.50	0.04	Uwall=3.33 (W/m^2K) *Rse & Rsi values= 0. 0.04, respectively. the obtained from (An 2007, P.7)

3. Floor:

As the roofs and the exterior walls, the floor of 'Gullan, Harsham, and Ashty' houses have been constructed by contemporary materials too. Four types of materials involved in the floor, which are; compacted soil with 25 cm thickness, covered by nylon membrane, and over that 8 cm thickness of plain concrete has been laid. Mortar cements (1:3) Cement and sand, has been laid on the plain concrete with 5 cm thickness. The finish is with porcelain tiles with 2 cm thickness. shown in Figure 4.6.

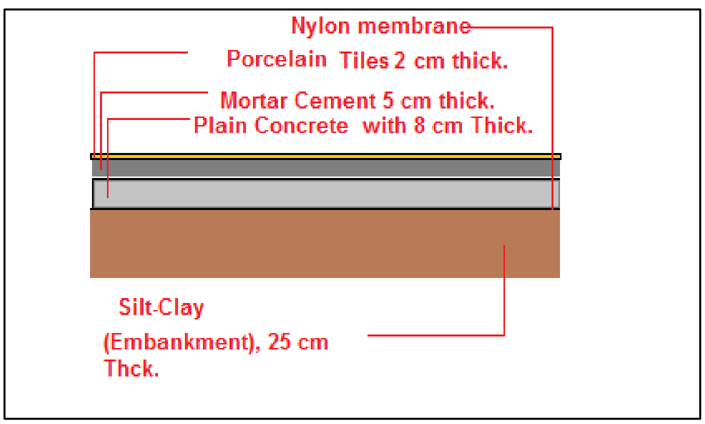


Figure 4.7: Section in the floor of Gullan & Harsham houses (Kareim, 2018)

U value for the floor in Gullan, Harsham and Ashty houses calculated according to the type and thickness of the materials used in the house, as written in the table 4.7, according to the field observation.

Table 4.7: U- Value calculation for the Floor of Gullan, Harsham, and Ashty Houses

No.	The material	Material Thick. (t) by meter	Conductivity (k) (W/mK) [1]	Resistance(R) (m^2K/W). (See2.2. Chapter (2))	U-Value (W/m^2K). See 2.2.3
1	Porcelain tiles[2]	0.02	1.484	0.013	U Floor=1/ (Rsi +R1+R2+R3+R4 U_{Floor}=1.94 (W/m^2K)
2	Mortar Cement	0.05	0.72	0.07	
3	Dense Concrete	0.08	1.74	0.05	*Rse & Rsi values= 0.17 a respectively. they are obtain (Anderson, 2007, P.7)
4	Nylon[3]	0.0005	0.25	0.002	
5	Silt- Clay [4]	0.25	1.48	0.17	

4. Windows:

The windows in this house are single glass, and the frames of the windows are plastic PVC. Hence, the U- Value of the windows in this building obtained according to the Turkish Standard Institute is equal to (5.2 W/m^2K), as seen in Figure 4.7.

Window heat conductivity (Up) coefficients prepared to be used in the selection of the glass appropriate to the heat regions in Turkey W/m²K		SINGLE GLASSED WINDOW	DOUBLE GLASSED WINDOW (uncoated glass)				DOUBLE GLASS LOW-E COATED WINDOW			
			INTERSTITIAL SPACES (mm)				INTERSTITIAL SPACES (mm)			
			6	9	12	16	6	9	12	16
	UNPROCESSED	5,7	3,3	3,0	2,9	2,7	2,6	2,1	1,8	1,6
PROCESS TYPE	WOODEN PROCESSING (oak, ash tree/hard woods)	5,1	3,3	3,1	3,0	2,8	2,8	2,3	2,2	2,0
	WOODEN PROCESSING (coniferous soft trees)	4,9	3,1	2,9	2,8	2,6	2,6	2,2	2,0	1,8
	PLASTIC PROCESSING (having 2 compartments)	5,2	3,4	3,2	3,0	2,9	2,9	2,4	2,3	2,1
	PLASTIC PROCESSING (having 3 compartments)	5,0	3,2	3,0	2,8	2,7	2,7	2,2	2,1	1,9
	ALUMINUM PROCESSING	5,9	4,0	3,9	3,7	3,6	3,6	3,1	3,0	2,8
	ALUMINUM PROCESSING (with insulation bridge)	5,2	3,4	3,2	3,0	2,9	2,9	2,4	2,3	2,1

Figure 4.8: Table shows the U-value for some types of glass with process types (Turkish Standard Institute, 2008)

The estimation of heat transfer coefficient value (U-Value), for contemporary conventional houses represented by selected case study house in Gullan, Harsham, and ashty projects demonstrates the following;

1. The U-value of the envelope demonstrates very weak ability for the exterior walls, roofs and the floor according to the required U-value in the houses (Huang, and Deringer 2007). See (2.2. U-Value, in Chapter Two).

2. Windows and Glasses demonstrated weak U-Value = 5.2 (W/m^2K) as per the Turkish standard Institute, which it is recommended to be less than 2.4, as per Turkish standards TS-825, (Turkish Standard Institute, 2008).

4.5 Analysis of an Early Modern House (Ronaki, and Azadi Sector) in Erbil

Based on site visit and data collection through physical observation, the characteristic of the houses envelope has been identified.

4.6 Analysis of an Early Modern House (Ronaki, and Azadi Sector) in Erbil

The houses envelope (exterior walls, roofs, and floor) has been determined based on on-situ measurements and observation, to identify the thickness and type of materials that applied in these houses which is returns as mentioned previously to 50's, 60's and 70's of twentieth century.

1. Exterior Walls:

The walls are bearing system walls same the one in Contemporary house case study. But the materials used in the walls masonry is relatively different, where; The main masonry unit is burnt clay bricks with 36 cm thickness, while the exterior face of the house are covered by cement plastering with 3 cm thickness, and in some small portions were using stone cladding for aesthetic purposes. Therefore, the study will consider the outside material as mortar cement plastering as majority of the covered outside area. The interior face of the walls is covered by gypsum plastering with 3 cm thickness. shown in Figure 4.8.

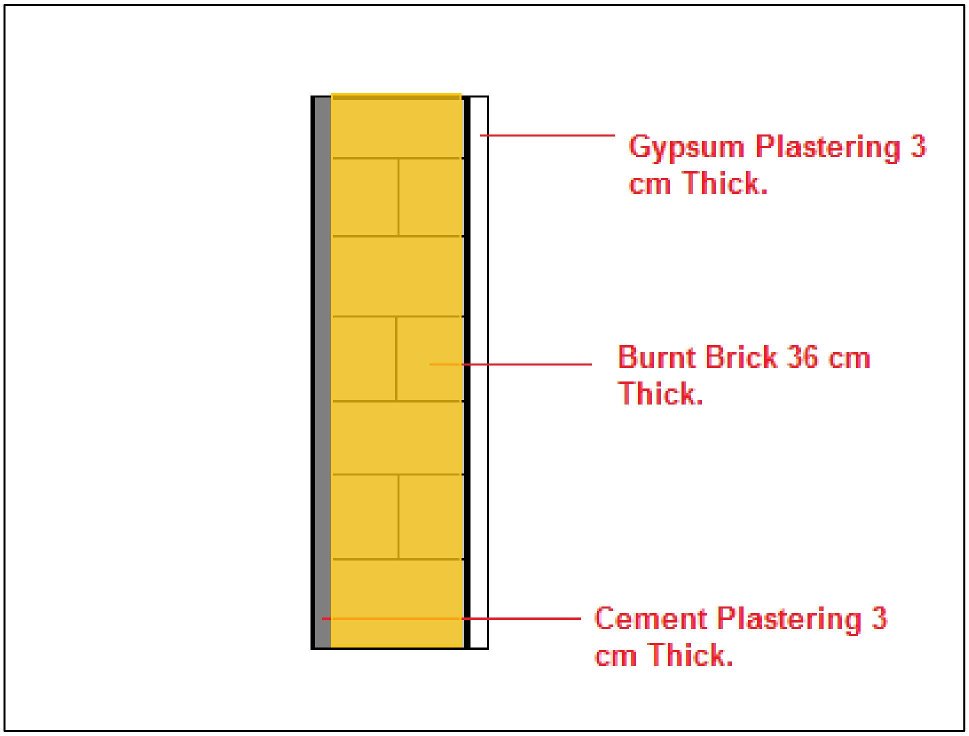


Figure 4.9: Section in the exterior walls of Ronaki house (Kareim, 2018)

(U-value) for exterior walls for Ronaki and Azadi houses was calculated according to the applied materials in building as mentioned in the table 4.8, based on field observation.

Table 4.8: Calculation of the U- values for the exterior walls in Ronaki and Azadi house.

No.	The material	Material Thick. (t) by meter	Conductivity (k) (W/mK)	Resistance(R) (m^2K/W). (See2.2. Chapter (2))	U-Value (W/m^2K). See 2.2.3
1	**Cement Plastering**[1]	0.03	0.72	0.04	U wall=1/ (Rsi. +R1+R2+R3 - Uwall=1.10 (W/m^2K)
2	**Burnt Brick**	0.36	0.56	0.64	
3	**Gypsum mortar, lime-based gypsum mortar** [2]	0.03	0.50	0.06	***Rse & Rsi values =0.13, and respectively. they are obtained (Anderson, 2007, P.7)

2. Roof:

The roof of the house is reinforced concrete slab with 20 cm thickness. The interior face of the roof is plastered with gypsum plastering, whereas, the exterior face is exposed surface. shown in Figure 4.8.

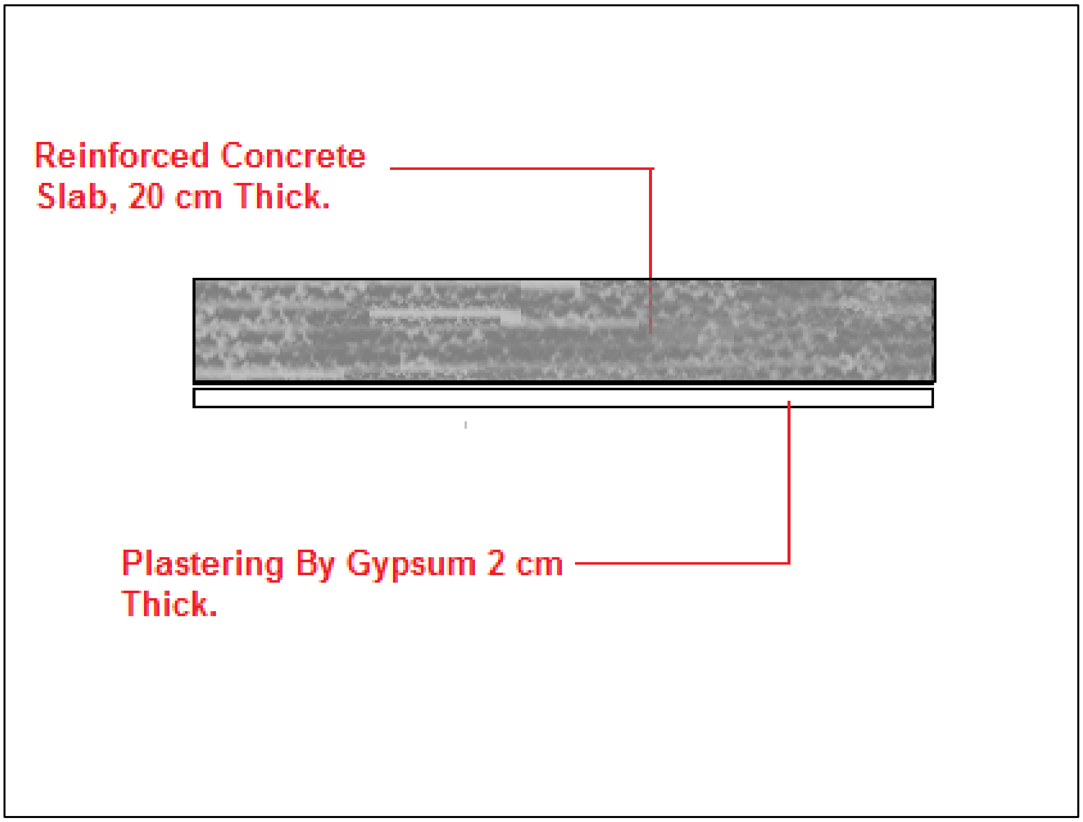


Figure 4.10: Section in the slab of Ronaki house (Kareim, 2018)

U- value for the roof in 'Ronaki & Azadi' houses calculated based on the thickness and type of the materials applied in the house roof as shown in the table 4.9.

Table 4.9: Calculation of the U- values for the Roof in Ronaki & Azadi House

No.	The material	Material Thick. (t) by meter	Conductivity (k) (W/mK)	Resistance(R) (m^2K/W). See2.2	U-Value (W/m^2K). See 2.2.3
1	Reinforced Concrete [1]	0.20	1.58	0.13	U wall=1/ (Rsi. +R1+R2 +Rse.) Uwall=3.33 (W/m^2K) *Rse & Rsi values= 0.10 and 0.04, respectively. they are obtained from (Anderson, 2007, P.7)
2	Gypsum mortar, lime-based gypsum mortar [2]	0.02	0.50	0.04	

3. Floor:

The floor of 'Ronaki and Azadi' houses have been constructed by the following materials; a) layer of crushed burnt brick with 20 cm thickness; b) 8 cm thickness of plain concrete has been laid over the crushed bricks; c) Mortar cements (1:3) Cement and sand, has been laid on the plain concrete with 5 cm thickness; d) the finish layer is with Mosaic tiles with 35 cm thickness. shown in Figure 4.9.

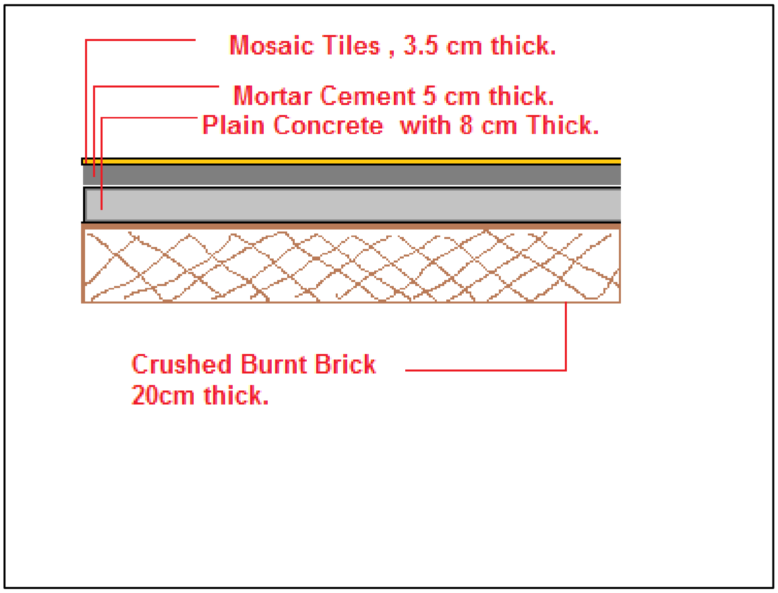


Figure 4.11: Section in the floor of Ronaki & Azadi houses (Kareim, 2018)

U- value for the floor in 'Ronaki and azadi' house calculated based on the thickness and type of the materials used in the floor construction, as seen in the table 4.10, based on the field observation.

Table 4.10: U- Value calculation for the floor of Gullan house (Kareim, 2018)

No.	The material	Material Thick. (t) by meter	Conductivity (k) (W/mK) [1]	Resistance(R) (m^2K/W). See2.2.	U-Value (W/m^2K). See 2.2.3
1	Mosaic tiles[2]	0.035	1.196	0.03	U Floor=1/ (Rsi +R1+R2+R3+R4R5+ I U_{Floor}=1.39 (W/m^2K)
2	Mortar Cement	0.05	0.72	0.07	
3	Dense Concrete	0.08	1.74	0.05	*Rse & Rsi values= 0.17 and (respectively. they are obtained f (Anderson, 2007, P.7)
4	Burnt Brick (Crushed)	0.20	0.56	0.36	

4. Windows:

The windows in Ronaki and Azadi houses are single glass, and the frames of the windows are aluminum. Hence, the U- Value of the windows in this building obtained according to the Turkish Standard Institute is equal to (5.9 W/m^{2}K). shown in Figure 4.10.

Window heat conductivity (Up) coefficients prepared to be used in the selection of the glass appropriate to the heat regions in Turkey W/m²K		SINGLE GLASSED WINDOW	DOUBLE GLASSED WINDOW (uncoated glass)				DOUBLE GLASS LOW-E COATED WINDOW			
			INTERSTITIAL SPACES (mm)				INTERSTITIAL SPACES (mm)			
			6	9	12	16	6	9	12	16
	UNPROCESSED	5,7	3,3	3,0	2,9	2,7	2,6	2,1	1,8	1,6
PROCESS TYPE	WOODEN PROCESSING (oak, ash tree/hard woods)	5,1	3,3	3,1	3,0	2,8	2,8	2,3	2,2	2,0
	WOODEN PROCESSING (coniferous soft trees)	4,9	3,1	2,9	2,8	2,6	2,6	2,2	2,0	1,8
	PLASTIC PROCESSING (having 2 compartments)	5,2	3,4	3,2	3,0	2,9	2,9	2,4	2,3	2,1
	PLASTIC PROCESSING (having 3 compartments)	5,0	3,2	3,0	2,8	2,7	2,7	2,2	2,1	1,9
	ALUMINUM PROCESSING	5,9	4,0	3,9	3,7	3,6	3,6	3,1	3,0	2,8
	ALUMINUM PROCESSING (with insulation bridge)	5,2	3,4	3,2	3,0	2,9	2,9	2,4	2,3	2,1

Figure 4.12: Table shows the U-value for some types of glass with process types

The estimation of heat transfer coefficient value (U-Value), for Early Modern house demonstrates the following;

a. The U-value of the envelope demonstrates relatively good ability for the exterior walls compared with contemporary houses in (Gullan, Harsham, and Ashty). (U value should be less or equal to 0.8(W/m^{2}K)), floor U-value in the houses had very weak ability (where U value should be less or equal to 0.6(W/m^{2}K)), (Huang, and Deringer 2007), and the slab also demonstrated very weak ability according to the required (where U value should be less or equal to 1.5(W/m^{2}K)). See (2.2. U-Value, in Chapter Two).

b. Windows and Glasses demonstrated weak U-Value = 5.9 (W/m^{2}K) as per the Turkish standard Institute, which it is recommended to be less than 2.4(W/m^{2}K), as per Turkish standards TS-825, (Turkish Standard Institute, 2008).

4.7 Discussion of the Findings

Comparative analysis will be carried out in order to find the different in thermo-physical properties for the envelope building materials in the ten case studies according to the previous calculation. Where, building envelope elements in the three different types and periods of houses at 'Erbil' had been assessed through evaluating thermo-physical properties by calculating U-value for (external walls, roofs, floors, as well as windows) in order to examine the potential of heat gain/loss of the buildings, then expect the ability of the buildings to conserve the energy. Considering that the heat gain/loss in the building is the main consumer of energy in the houses at Erbil city. The result had been compared with the international standards and requirements for optimum U-value in the houses, as shown in table 4.12.

Table 4.12 : Comparison between the International standards of required U-value

No.	Items	U_{wall} (W/m^2K)	U_{Roof} (W/m^2K)	U_{Floor} (W/m^2K)	U_{Window} (W/m^2K)
1	Jamal Afendi House, Arab sector, Tajil (Vernacular or Traditional)	0.70	1.11	0.99	4.9
2	Traditional house in Tajil district	0.70	1.11	0.99	4.9
3	Vernacular House in Tajil district	0.70	1.11	0.99	4.9
4	Traditional House in Arab sector	0.70	1.11	0.99	4.9
5	Vernacular house in Arab sector	0.70	1.11	0.99	4.9
6	Ronaki House (Early Modern style)	1.10	3.33	1.39	5.9
7	Azadi House (Early Modern style)	1.10	3.33	1.39	5.9
8	Gullan House (Contemporary)	2.44	3.33	1.94	5.2
9	Harsham House (Contemporary)				
10	Ashty House (Contemporary)	2.44	3.33	1.94	5.2
	International requirements and Standards	0.8	1.5	0.6	2.4

The evaluation of U-value of the different elements of the building envelope for the four types of selected case studies which are considers examples in three different ages demonstrate that; generally, the only traditional house was responding (relatively) with the environmental requirements, based on the international standards. The results obtained through the investigation on the construction materials for different parts of the buildings envelopes carried out.

The findings demonstrated that the U- value of the exterior walls in vernacular buildings is highly responsive to the environmental requirement regarding heat gain and heat loss, as per international standards. Where u- value for the exterior walls for the traditional houses (Jamal Afendi House, vernacular and traditional houses in Tajil and Arab sector) met the standards and registered 0.70 (W/m^2 K), while the requirement U- value was 0.8(W/m^2 K). The reason behind that was the effect of ‘Adobe bricks’ as masonry unit used in the exterior walls. In the same context, the roof (slab) of the traditional building demonstrated response with environmental requirements in the performance of heat gain and heat loss, where the U-value have been evaluated by 1.11(W/m^2 K), when the required U-value was not more than1.5 (W/m^2 K). The floor in Traditional house demonstrated slightly weak responding to the heat gain and heat loss as per the international standards, which evaluated the U-value by 0.99 (W/m^2 K), while the required maximum U-value was 0.6 (W/m^2 K). According to the findings in the Traditional house, the building demonstrated a very good response to heat gain and heat loss as per thermo-physical properties of the envelope materials which are an old type of materials and not apply anymore nowadays.

For the contemporary or modern types of buildings five buildings have been selected from a different era; the first houses from mid of the twentieth century as the example of the early modern style two houses, (Ronaki and azadi House); another three from the second type is from contemporary conventional houses which have been constructed recently (Gullan, Harsham, and Ashty Houses). The first type demonstrated the weak potential of heat gain/ loss in the envelope because of using new materials, and only the potential to control heat gain or heat loss was obtained relatively good through the material of exterior walls. Where, the U- value has been evaluated by 1.10(W/m^2 K), while the standards requirement is 0.8 (W/m^2 K). But other elements such as roof and floor, demonstrated very weak ability to control heat loss/ gain, as illustrated in the table '27', above. The reason behind the relatively successful U-value for the exterior walls in the Modern house (Ronaki and Azadi Houses), was the thickness of the wall (thick mass strategy), and using 'Burnt Brick', as masonry unit, which developed the potential of the exterior wall to get better thermo-physical properties. The slab in this type of buildings using reinforced concrete with 20 cm thickness as modern types of construction materials demonstrated very weak ability to control heat gain and heat loss.

Another type of contemporary houses is (Gullan, Harsham, and Ashty Houses), which are considers a very new house that constructed recently (2008- 2010 “Gullan” & 2009-2011” Harsham”, and 2010 “Ashty”). Similar or worse than early modern types, this building are shown, very weak ability to control heat gain/loss and demonstrated worse responding to the environment, due to the weak ability of the envelope elements in term of heat efficiency. The reason for this is that the recent conventional houses using the concrete hollow block as masonry units for the exterior walls which 20 cm thickness. This showed very weak ability to control heat gain and heat loss through the exterior walls, where the U-value exterior walls in this type were the worse compared with the traditional and modern houses. The U- value for the exterior wall was 2.44(W/m^2 K), in time the required U- value for exterior walls should not exceed 0.8 (W/m^2 K), as per international standards.

The roof demonstrated the same weakness in controlling thermal performance for the modern house of (Ronaki and Azadi) and contemporary houses (Gullan & Harsham, and Ashty), because they are using the same materials and technique until today, since 60es or beginning of 70's of last century. The same condition for the floors where the contemporary or recently constructed house in (Gullan, Harsham, and Ashty) demonstrated worse U-value compared even with the floor of modern style house in (Ronaki and Azadi). the reason is, that of using 'Porcelain Tiles’ as floor finish which has less thermo-physical potential, than 'Mosaic tiles' to control heat gain/loss, through the floor. Hence, the U-value in the floor of (Gullan, Harsham, and Ashty Houses - which are using Porcelain Tiles) are the worse among the selected houses, where they evaluated by 1.94 (W/m^2 K), while the required as per standards should not exceed 0.6 (W/m^2 K).

Regarding the windows and window systems, the recent new material application in windows such as PVC could not show better development in heat gain/loss control, compared with traditional systems of windows. while the traditional buildings registered 4.9(W/m^2 K), based on the standards, as wooden frame, single glass window system, the contemporary conventional house (Gullan, Harsham, and Ashty) window system with PVC frame and single glass demonstrated 5.2(W/m^2 K). U-value in the window system for modern style building with metal or (aluminum) frame and single glass was the poorest potential for thermal control, where evaluated by 5.9 (W/m^2

K). if we take Turkish standards 825, (2008), as a guide in order to reach the required U-value which is 2.4(W/m^2 K), this means, that the minimum requirements to reach proper U-value is to use double glazing windows and E-Low coated glass with minimum 9mm thickness for each glass, which is practically difficult and expensive for the houses. shown in Figure 4.11.

Window heat conductivity (Up) coefficients prepared to be used in the selection of the glass appropriate to the heat regions in Turkey W/m²K		SINGLE GLASSED WINDOW	DOUBLE GLASSED WINDOW (uncoated glass)				DOUBLE GLASS LOW-E COATED WINDOW			
			INTERSTITIAL SPACES (mm)				INTERSTITIAL SPACES (mm)			
			6	9	12	16	6	9	12	16
	UNPROCESSED	5,7	3,3	3,0	2,9	2,7	2,6	2,1	1,8	1,6
PROCESS TYPE	WOODEN PROCESSING (oak, ash tree/hard woods)	5,1	3,3	3,1	3,0	2,8	2,8	2,3	2,2	2,0
	WOODEN PROCESSING (coniferous soft trees)	4,9	3,1	2,9	2,8	2,6	2,6	2,2	2,0	1,8
	PLASTIC PROCESSING (having 2 compartments)	5,2	3,4	3,2	3,0	2,9	2,9	$\boxed{2,4}$	2,3	2,1
	PLASTIC PROCESSING (having 3 compartments)	5,0	3,2	3,0	2,8	2,7	2,7	2,2	2,1	1,9
	ALUMINUM PROCESSING	5,9	4,0	3,9	3,7	3,6	3,6	3,1	3,0	2,8
	ALUMINUM PROCESSING (with insulation bridge)	5,2	3,4	3,2	3,0	2,9	2,9	2,4	2,3	2,1

Figure 4.13: Required window system to reach standard U-value in the houses at Erbil city

4.8 Heat Gain/ Loss in the Buildings

When Heat flow rate through a wall of given area can be calculated using QC = condition heat flow rate in W (Koenigsberger et al., 2010).

Qc=A*U*ΔT…………………………………………………………………………… (4)

A = surface area in m^2

U = transmittance value in w/m^2

ΔT = temperature difference between inside and outside

According to the metrological data that collected from the metrological authorities of Erbil city, in order to evaluate the average heat gain or heat loss in each case study. The result demonstrated that as much as the difference in temperature increased, the heat loss/gain increases. When, the area of the envelope increase, the heat gain/loss increases as well, and vice versa. The results are shown in Appendix as explained below;

a. For the External walls the vernacular or traditional buildings demonstrated better capability for controlling heat gain and heat loss compared with modern or contemporary buildings. Where, the results showed that the traditional or vernacular building external walls with 60 m^2 external walls the average rate of heat gain/loss is 472.5 w (watt), which means 7.88 w per one square meter. While the modern houses the average rate for heat gain/loss is 12.37 w per square meter. This means that external walls in early modern houses are less controlling heat gain or heat loss that vernacular houses. Whereas, the contemporary buildings demonstrated worse heat gain/loss control through the external walls. Where the contemporary external walls heat flow, rates were 27.45 w per square meter See Appendix.

b. Regarding the roofs, the results demonstrated that the best roof to control heat gain/ loss is the roof of vernacular and traditional buildings. The results showed that the average rate of heat flow through the roof is 12.49 w/m^2. While the roof in early modern houses and contemporary houses demonstrated less ability than vernacular or traditional houses to control heat gain/loss. Where, the heat flow rate in modern and temporary houses were, 37.46 w/m^2. See Appendix 'A-table 30'. The results exposed that vernacular or traditional roof are almost three time better than modern or contemporary roofs in controlling heat gain/loss.

c. For the floor of the case study buildings the rate of heat flow in vernacular or traditional houses was 11.14 w/m^2. Regarding early modern houses, the floor heat flow rates was 16.64, whereas the contemporary houses floors registered 21.82 w/m^2. The results demonstrate that the best floor to control heat loss and heat gain is vernacular and traditional houses, and the modern houses come the second, whereas, the worse floor regarding controlling heat gain/loss was the contemporary houses, which demonstrated almost 50% of the ability to control heat flow comparison with vernacular or traditional houses floor See Appendix.

d. The windows ability to control heat gain or heat loss in the case study buildings demonstrated that the better types of windows to control heat gain or heat loss, were in the vernacular or traditional houses windows were had heat flow rate 55.12 w/ m^2. Where the materials that used in contemporary windows showed that the heat flow through them is 58.5 w/ m^2. While the worse was the windows that used in early modern houses because it is metals or aluminum, which, registered 66.38 w/ m^2. See Appendix

e. According to the climatic condition and sun irradiation on the top of the roofs in all types of the building’s styles, the calculation demonstrated that July is the higher month that the heat gain is occurs. Where, the vernacular houses demonstrated lower heat gain whereas the modern and contemporary houses demonstrated the higher heat gain Show in figure in Appendix.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The massive increment of energy usage in the world is one of the challenges that the humanity facing and alert about exhausting energy sources which affect severely on the environment. This condition is causing many serious climatic phenomena such as global warming and climate change, etc., which have negative effects on the living on the earth. Therefore, building design should overcome this environmental crisis or reduce their impacts. Hence, building design should serve the world through reducing the depletion of earth sources and reduce the pollution in the environment. Enhancing passive solar design strategies and energy efficiency is one of the keys to reach this aim.

The buildings and especially houses in Northern Iraq, are consuming a huge part of the energy. This is returned to the lack of awareness about the design of buildings in term of energy performance. The region suffering from a shortage in power because of the incomplete infrastructure of the power supply and that led to import powers from neighbor countries such as Iran and Turkey to cover the needs of power in the region. The majority of energy consumes in the houses at Erbil is to maintain thermal comfort in different seasons. The houses commonly, and especially the contemporary ones maintaining thermal performance inside the houses through active heating/cooling system. This led to increase the energy consumption and increase the demands for energy, and consequently increase the electricity cut-off hours day by day, especially in peak seasons (summer and winter).

Erbil is the capital of Northern Iraq and one of the oldest cities in Middle East was selected as a case study area.

The study selected ten case studies to be analyzed; five were traditional or (vernacular), and another five were modern or contemporary houses; two of them were modern style, and three were contemporary conventional houses) in Erbil city from different periods. The field observation has been done to identify the methods or the ways for construction and types of applied construction material, and their role on the energy consumption in the buildings. A comparison between both types of houses through involving three samples of case studies had been made to examine energy consumption, in order to suggest solutions to improve the energy efficiency in the new house buildings. Contemporary houses recently are the most consumers of energy compared with traditional houses. This is because of maintaining heating and cooling inside the houses. Thus, the study focused on the most effective passive design strategies to maintain thermal comfort inside the houses in Erbil and investigated based on applying climatic data on the Psychometric Chart, in hot and cold seasons. The study identified the effective strategies in traditional buildings, and the possibilities to apply that in contemporary buildings.

The study focused on the thermo-physical properties of the building envelope elements, such as; the exterior walls, roofs, floors and windows, in two main types of houses, namely; Traditional houses and Modern houses. Based on this idea, four houses from different periods have been selected; one was traditional house from citadel area which is considers as ancient Erbil city. Another one was modern type of houses from 60s and 70s of twentieth century, and the remaining two were contemporary recently constructed (the first decade of twenty first century).

The aim of these case studies are to assess the energy efficiency in them based on the potential of controlling heat gain or heat loss in these buildings responding to the climatic needs as per the seasons.

The study demonstrate that the construction materials were used in the building of traditional or vernacular houses envelope in Erbil city have good potential and ability to control heat gain and heat loss in these buildings, and consequently, reduce the needs for active heating and cooling system to maintain thermal comfort in the houses along the year.

Whereas, the modern types of the houses were not responding to heating and cooling performance except the envelopes, since the 50's of the twentieth century (Ronaki and Azadi houses). While the recent contemporary houses in (Gullan, Harsham, and Ashty) projects which they are very new houses demonstrated the weakest ability to control heating and cooling at houses. This shows that as much as new materials starting to be used in Erbil, in the house's construction, the poorest responding to climatic characteristic, and poor potential to control heat gain and heat loss with surrounding environment in Erbil city have been obtained. This was the cause to increase the demands on energy usage in the modern styles of houses compared with the traditional ones. Thus, the study demonstrates that traditional buildings is the most effective buildings thermally, the only one that meet the standards regarding thermo-physical properties of the envelope materials. The modern (50 to70es of twentieth century houses), showed only relative climatic respond and thermal performance control through external walls material. While, the contemporary houses were demonstrating weakest thermal performance potential.

Hence the study found that the traditional or vernacular houses which hold many vernacular features in the design, in term of form and construction materials, are more energy efficient houses than modern or contemporary houses in term of thermal performance. Also, the most contemporary houses are weaker than even the modern houses in meeting the required thermo-physical properties for the house's envelopes, which indicates that as much as the houses designs and constructions are newer, the energy efficiency of the houses are less because of the weak thermal performance.

Depending on the international standards, several U-values were evaluated and compared in the selected case study houses.

The U-value of the different elements in the house's envelopes in the ten case studies which are representing two main types of houses, namely; traditional, and contemporary showed that the U-value of the traditional house envelope materials are having good thermal ability, and help in controlling thermal performance. In the same time, the contemporary houses materials in two different eras, demonstrated weak ability for thermal performance as per international standards and requirements. The assessment demonstrated that as much as the houses are recently constructed and the new materials used, as much as the thermo-physical properties are worse. However, some of the envelope materials in the modern houses showed good thermo-physical properties such as (Burnt Brick) as masonry unit in the modern houses in the 50's, 60's or 70's of the twentieth century, where was regularly used with 36 cm thickness for the exterior walls. While, the contemporary masonry units that are applying nowadays (Hollow concrete Block) demonstrated very weak thermo-physical properties to control heat gain/loss in the houses, and this is the reason that new buildings in Erbil consuming more energy in order to maintain successful thermal performance. The reinforced concrete as per existing design condition in the modern and contemporary buildings demonstrated very poor ability to control heat exchange between inside and outside. The windows consider one of the weak places to control thermal performance in the houses at Erbil city along the history of the houses from traditional and contemporary houses. But, traditional houses designers tried to reduce that effect through reducing the size of the windows especially in eastern and western directions.

The reason behind this weakness in U-value amount in modern and contemporary houses, returns to, that the designer or the builders depended day by day on the active system to achieve thermal comfort, neglecting the passive system which needs more effort during the construction stage. Hence, the consumption of the energy in the recent constructed buildings is more comparing with older constructed buildings.

According the results of the heat gain and heat loss calculation in the case study buildings, the results demonstrated that the best houses envelope for controlling heat gain or heat loss were the vernacular or traditional houses. In time the second one come the envelope of early modern except the windows, where it showed the poorest. The worse envelope to control heat gain or heat loss were the contemporary houses. This explain finally why the amount of energy consumption in contemporary houses at Erbil is more than that consumes in early modern houses, and that consumes in vernacular or traditional houses. Also demonstrates that with higher difference between inside and outside temperature, the higher heat flow occurs, the same is true when the area of the building envelope is more.

5.1 Recommendations

The Based on the research discussion and findings the researcher tries to suggest some recommendation to develop the existing and future envelopes for the houses in Erbil city in order to reduce the needs for active systems for heating and cooling and consequently, reduce the impact of energy consumption in the houses. The suggested recommendations are;

1. Introduction of the insulation material to improve thermo-physical properties of the envelope materials in contemporary houses. Also keeping the reinforced concrete slab exposed to the outside directly as seen in modern and contemporary slabs (roofs) reduce thermal performance in these houses. Covering exposed concrete slab with insulation material will increase the energy effecting of these buildings. In traditional building heat transfer through slab is reduced by laying burnt brick tiles. Shown in figure 4.2 and 4.3.

2. Using the burnt bricks in traditional houses, as well as first stage in modern houses demonstrated good alternative to control heat gain/loss through the exterior walls. Therefore, using this material as masonry unit instead of hollow concrete block is recommended in Erbil houses.

3. Reduce the area of the windows in the eastern and western direction walls, as experienced from traditional or vernacular designs of houses in Erbil, in order to increase the ability of the buildings thermally efficient. However, according to the estimations and calculations, the required window system is PVC, with double glass windows, and e-low coated glass are effective in responding to climatic needs, but required to increase the thickness of the glasses to be not less than 9mm, which is relatively costly for the houses.

4. One of the important outcomes of this research was that, the ratio of courtyards area to building area in traditional building came out as between 16-33% and people feel themselves better in terms of thermal comfort. One the other hand, in most of the examined contemporary building there are no courtyards and very few of them has 2-3% courtyard ratio. People in these houses does not feel themselves thermally comfort unless they use air-conditioners. Therefore, it can be recommended that for new contemporary buildings, courtyard plan types must be encouraged together with insulated envelopes.

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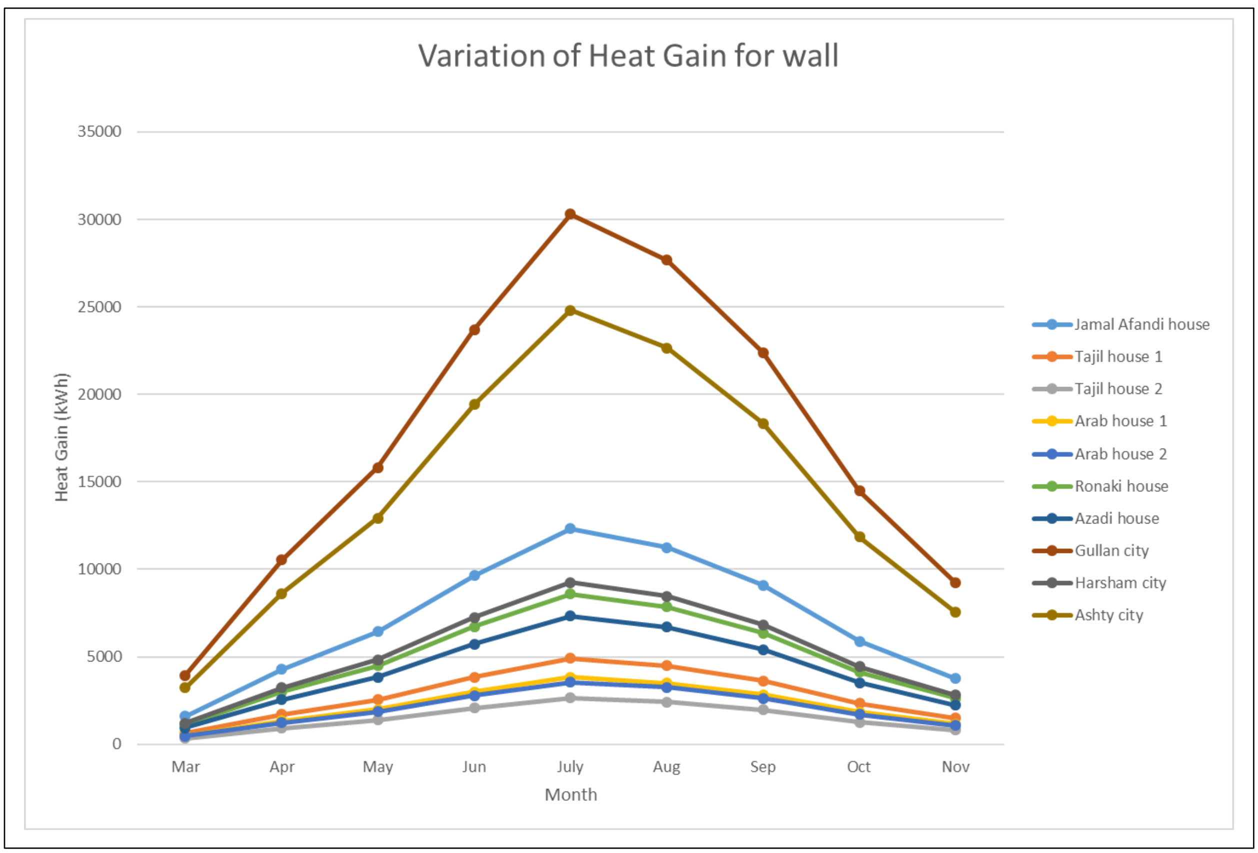
APPENDIX 1

HEAT GAIN & HEAT LOSS CALCULATION LISTS

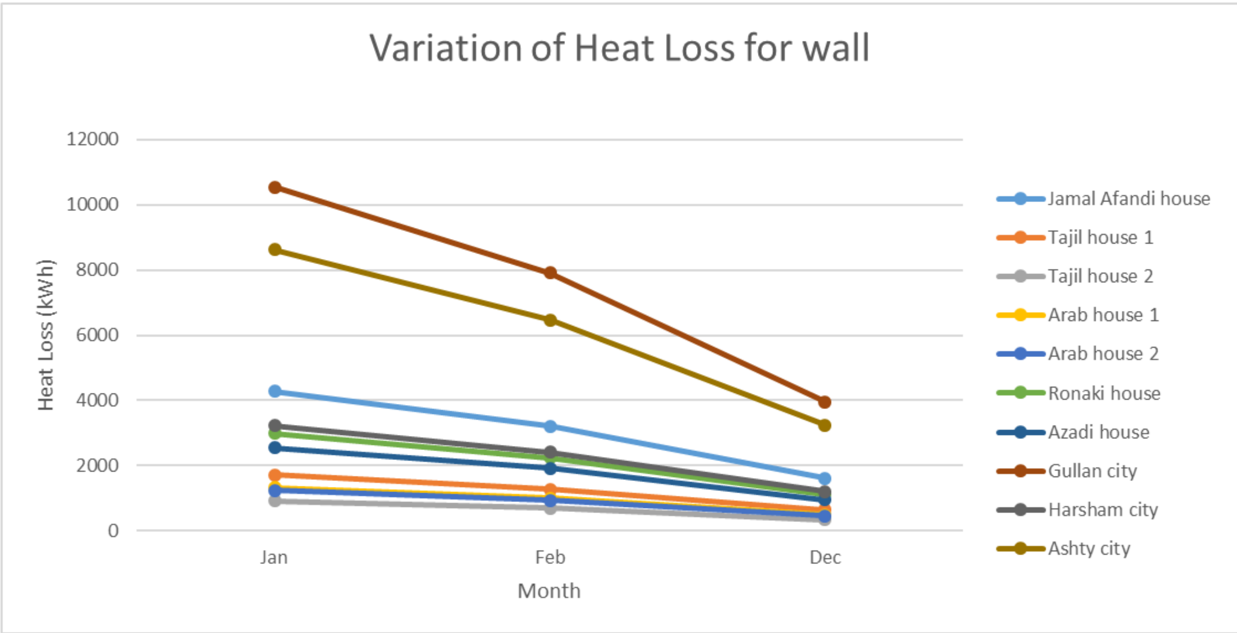
Heat Gain in through External walls in the case study buildings

			Month	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov
			Out Tem.	23	28	32	38	43	41	37	31	27
			In Tem.	20	20	20	20	20	20	20	20	20
Cases Study	U-value wall	Total Area	ΔT	3	8	12	18	23	21	17	11	7
Jamal Afandi house	0.7	765		1607	4284	6426	9639	12317	11246	9104	5891	3749
Tajil house 1	0.7	305		641	1708	2562	3843	4911	4484	3630	2349	1495
Tajil house 2	0.7	165		347	924	1386	2079	2657	2426	1964	1271	809
Arab house 1	0.7	238		500	1333	1999	2999	3832	3499	2832	1833	1166
Arab house 2	0.7	221		464	1238	1856	2785	3558	3249	2630	1702	1083
Ronaki house	1.1	340		1122	2992	4488	6732	8602	7854	6358	4114	2618
Azadi house	1.1	290		957	2552	3828	5742	7337	6699	5423	3509	2233
Gullan city	2.44	540		3953	10541	15811	23717	30305	27670	22399	14494	9223
Harsham city	2.44	165		1208	3221	4831	7247	9260	8455	6844	4429	2818
Ashty city	2.44	442		3235	8628	12942	19413	24805	22648	18334	11863	7549



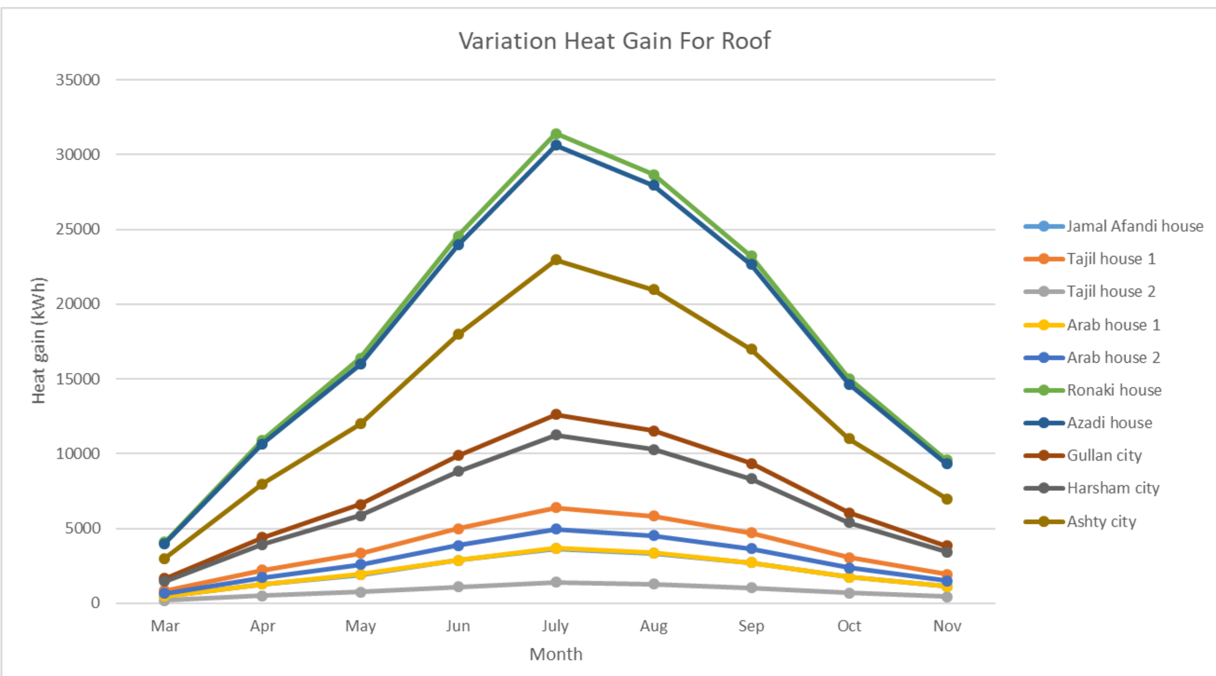
Heat Loss in through External walls in the case study buildings

			Month	Jan	Feb	Dec
			Out Tem.	12	14	17
			In Tem.	20	20	20
Cases Study	U-value wall	Total Area	ΔT	8	6	3
Jamal Afandi house	0.7	765		4284	3213	1607
Tajil house 1	0.7	305		1708	1281	641
Tajil house 2	0.7	165		924	693	347
Arab house 1	0.7	238		1333	1000	500
Arab house 2	0.7	221		1238	928	464
Ronaki house	1.1	340		2992	2244	1122
Azadi house	1.1	290		2552	1914	957
Gullan city	2.44	540		10541	7906	3953
Harsham city	2.44	165		3221	2416	1208
Ashty city	2.44	442		8628	6471	3235



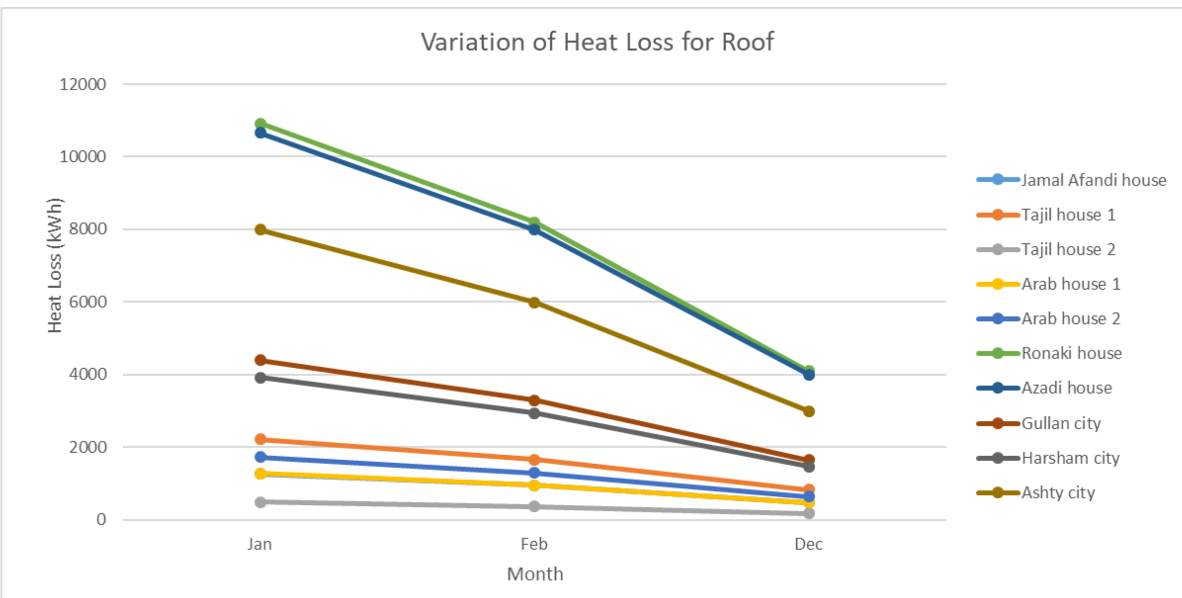
Heat Gain in through the roofs in the case study buildings

			Month	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov
			Out Tem.	23	28	32	38	43	41	37	31	27
			In Tem	20	20	20	20	20	20	20	20	20
Cases Study	U-value Roof	Total Area	ΔT	3	8	12	18	23	21	17	11	7
Jamal Afandi house	1.11	143		476	1270	1905	2857	3651	3333	2698	1746	1111
Tajil house 1	1.11	250		833	2220	3330	4995	6383	5828	4718	3053	1943
Tajil house 2	1.11	55		183	488	733	1099	1404	1282	1038	672	427
Arab house 1	1.11	144		480	1279	1918	2877	3676	3357	2717	1758	1119
Arab house 2	1.11	194		646	1723	2584	3876	4953	4522	3661	2369	1507
Ronaki house	3.33	410		4096	10922	16384	24575	31402	28671	23210	15018	9557
Azadi house	3.33	400		3996	10656	15984	23976	30636	27972	22644	14652	9324
Gullan city	3.33	165		1648	4396	6593	9890	12637	11538	9341	6044	3846
Harsham city	3.33	147		1469	3916	5874	8811	11259	10280	8322	5385	3427
Ashty city	3.33	300		2997	7992	11988	17982	22977	20979	16983	10989	6993



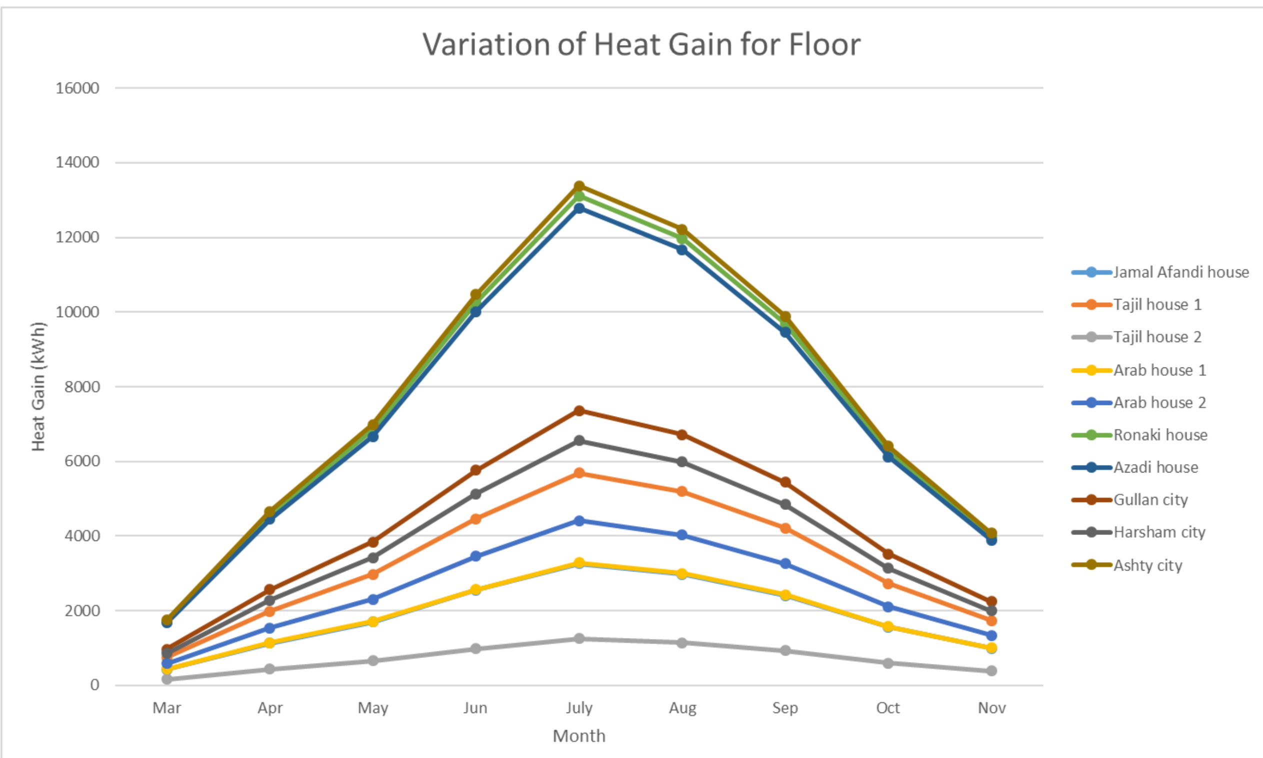
Heat Gain in through the roofs in the case study buildings

			Month	Jan	Feb	Dec
			Out Tem.	12	14	17
			In Tem.	20	20	20
Cases Study	U-value Roof	Total Area	ΔT	8	6	3
Jamal Afandi house	1.11	143		1269.84	952.38	476.19
Tajil house 1	1.11	250		2220	1665	832.5
Tajil house 2	1.11	55		488.4	366.3	183.15
Arab house 1	1.11	144		1278.72	959.04	479.52
Arab house 2	1.11	194		1722.72	1292.04	646.02
Ronaki house	3.33	410		10922.4	8191.8	4095.9
Azadi house	3.33	400		10656	7992	3996
Gullan city	3.33	165		4395.6	3296.7	1648.35
Harsham city	3.33	147		3916.08	2937.06	1468.53
Ashty city	3.33	300		7992	5994	2997



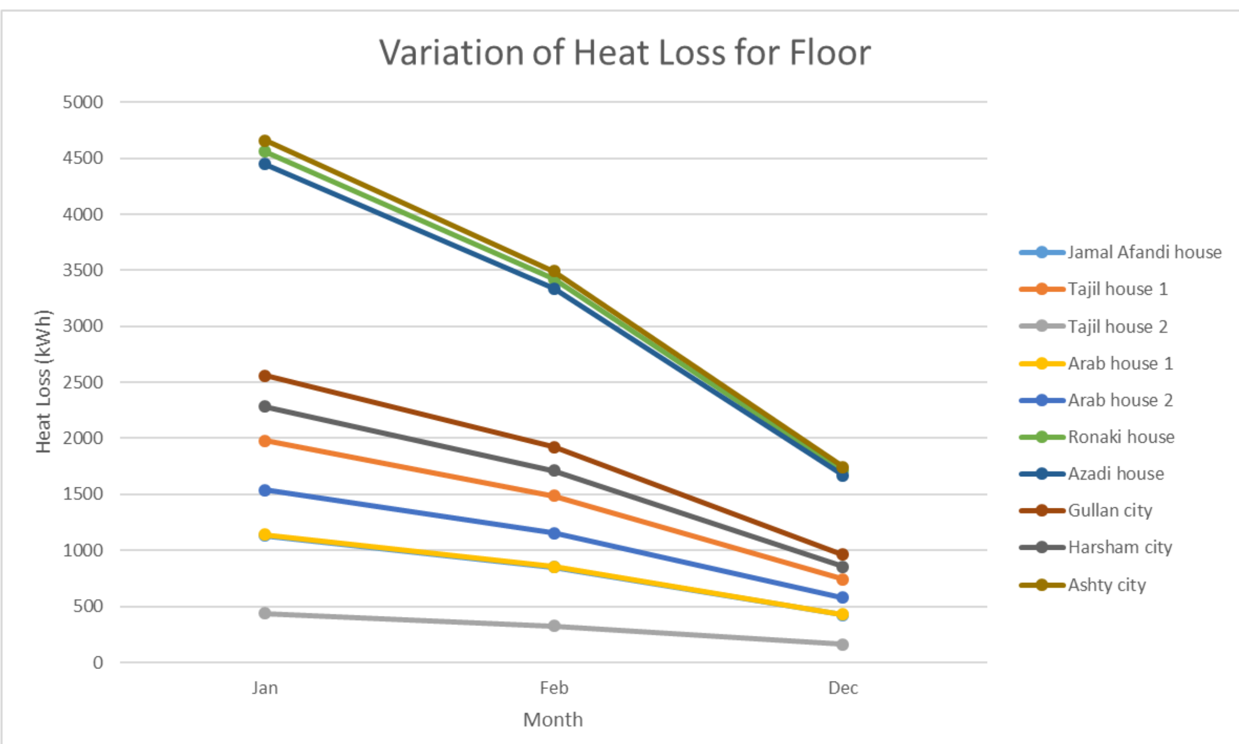
Heat Gain in through the floor in the case study buildings

			Month	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov
			Out Tem.	23	28	32	38	43	41	37	31	27
			In Tem.	20	20	20	20	20	20	20	20	20
Cases Study	U-value Floor	Total Area	ΔT	3	8	12	18	23	21	17	11	7
Jamal Afandi house	0.99	143		425	1133	1699	2548	3256	2973	2407	1557	991
Tajil house 1	0.99	250		743	1980	2970	4455	5693	5198	4208	2723	1733
Tajil house 2	0.99	55		163	436	653	980	1252	1143	926	599	381
Arab house 1	0.99	144		428	1140	1711	2566	3279	2994	2424	1568	998
Arab house 2	0.99	194		576	1536	2305	3457	4417	4033	3265	2113	1344
Ronaki house	1.39	410		1710	4559	6839	10258	13108	11968	9688	6269	3989
Azadi house	1.39	400		1668	4448	6672	10008	12788	11676	9452	6116	3892
Gullan city	1.94	165		960	2561	3841	5762	7362	6722	5442	3521	2241
Harsham city	1.94	147		856	2281	3422	5133	6559	5989	4848	3137	1996
Ashty city	1.94	300		1746	4656	6984	10476	13386	12222	9894	6402	4074



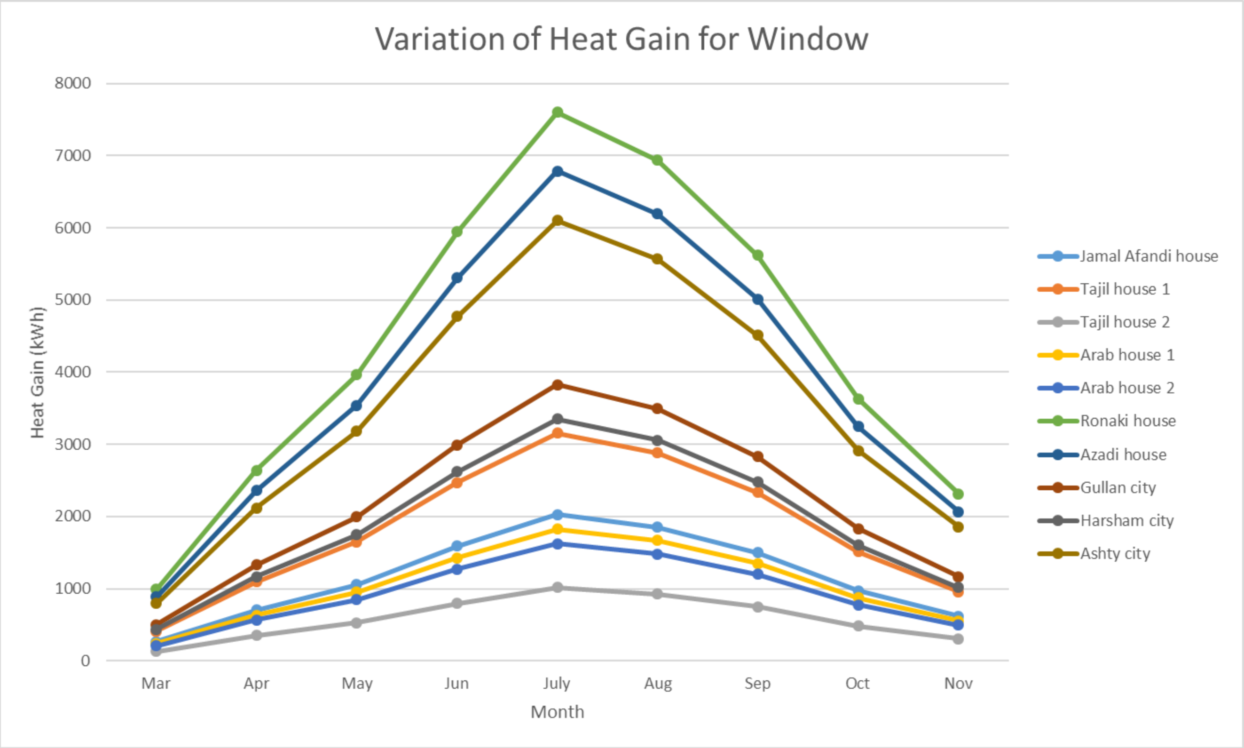
Heat Loss in through the floor in the case study buildings

			Month	Jan	Feb	Dec
			Out Tem.	12	14	17
			In Tem.	20	20	20
Cases Study	U-value Floor	Total Area	ΔT	8	6	3
Jamal Afandi house	0.99	143		1132.56	849.42	424.71
Tajil house 1	0.99	250		1980	1485	742.5
Tajil house 2	0.99	55		435.6	326.7	163.35
Arab house 1	0.99	144		1140.48	855.36	427.68
Arab house 2	0.99	194		1536.48	1152.36	576.18
Ronaki house	1.39	410		4559.2	3419.4	1709.7
Azadi house	1.39	400		4448	3336	1668
Gullan city	1.94	165		2560.8	1920.6	960.3
Harsham city	1.94	147		2281.44	1711.08	855.54
Ashty city	1.94	300		4656	3492	1746



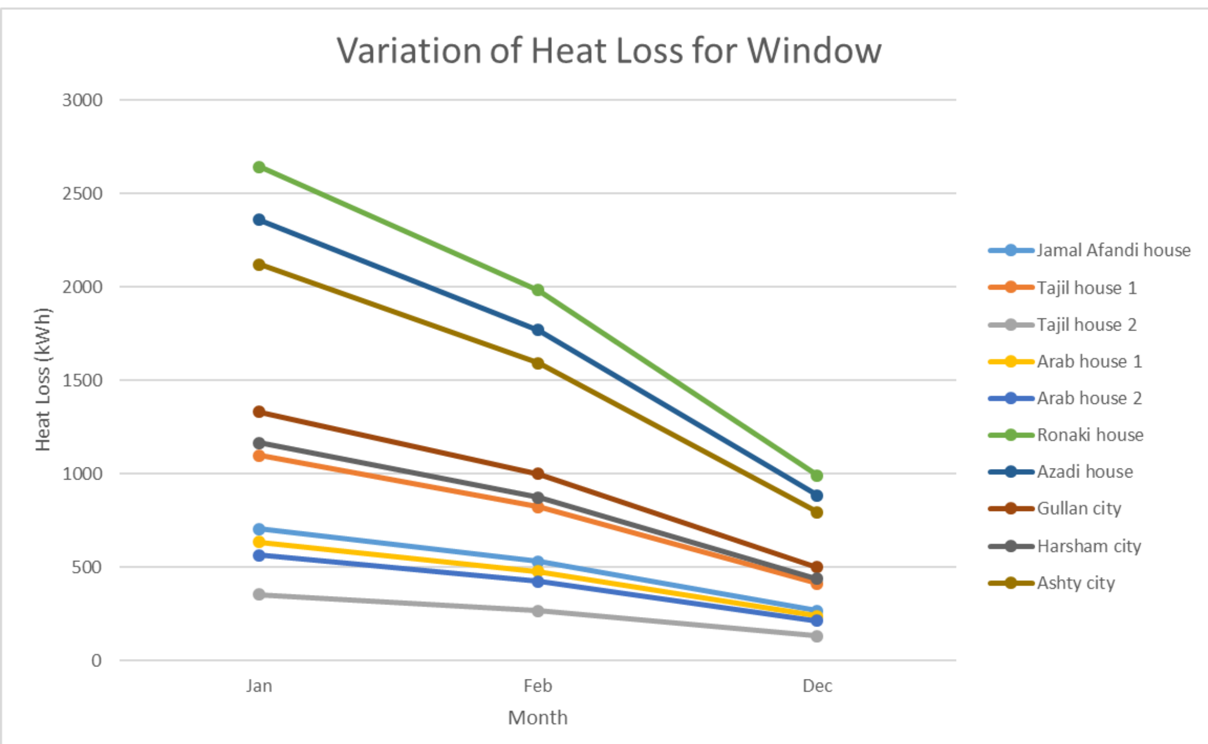
Heat Gain in through the window in the case study buildings

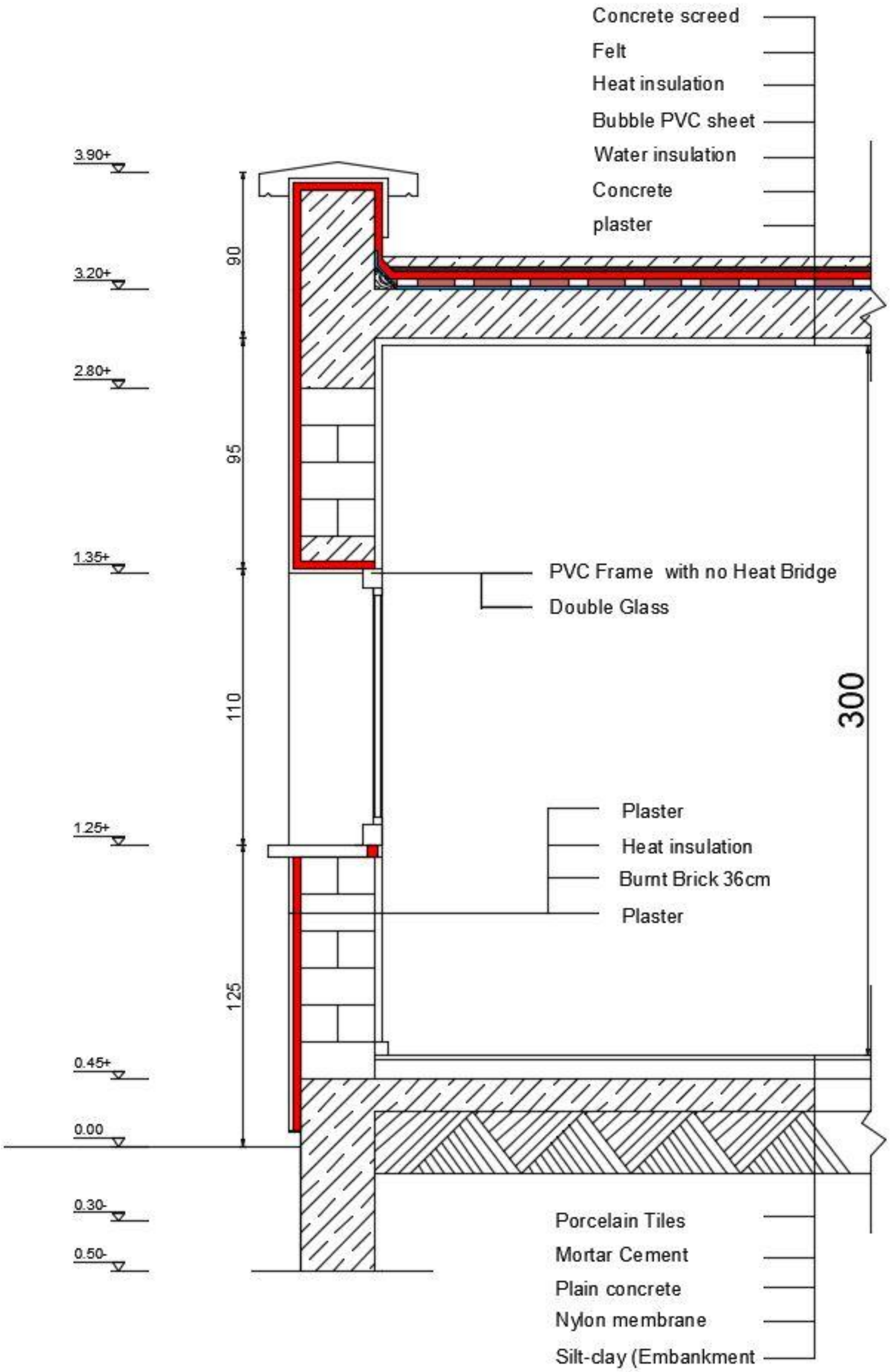
			Month	Mar	Apr	May	Jun	July	Aug	Sep	Oct	Nov
			Out Tem.	23	28	32	38	43	41	37	31	27
			In Tem.	20	20	20	20	20	20	20	20	20
Cases Study	U-value Window	Total Area	ΔT	3	8	12	18	23	21	17	11	7
Jamal Afandi house	4.9	18		265	706	1058	1588	2029	1852	1499	970	617
Tajil house 1	4.9	28		412	1098	1646	2470	3156	2881	2332	1509	960
Tajil house 2	4.9	9		132	353	529	794	1014	926	750	485	309
Arab house 1	4.9	16.2		238	635	953	1429	1826	1667	1349	873	556
Arab house 2	4.9	14.4		212	564	847	1270	1623	1482	1200	776	494
Ronaki house	5.9	56		991	2643	3965	5947	7599	6938	5617	3634	2313
Azadi house	5.9	50		885	2360	3540	5310	6785	6195	5015	3245	2065
Gullan city	5.2	32		499	1331	1997	2995	3827	3494	2829	1830	1165
Harsham city	5.2	28		437	1165	1747	2621	3349	3058	2475	1602	1019
Ashty city	5.2	51		796	2122	3182	4774	6100	5569	4508	2917	1856



Heat Gain in through the window in the case study buildings

			Month	Jan	Feb	Dec
			Out Tem.	12	14	17
			In Tem.	20	20	20
Cases Study	U-value Window	Total Area`	ΔT	8	6	3
Jamal Afandi house	4.9	18		706	529	265
Tajil house 1	4.9	28		1098	823	412
Tajil house 2	4.9	9		353	265	132
Arab house 1	4.9	16.2		635	476	238
Arab house 2	4.9	14.4		564	423	212
Ronaki house	5.9	56		2643	1982	991
Azadi house	5.9	50		2360	1770	885
Gullan city	5.2	32		1331	998	499
Harsham city	5.2	28		1165	874	437
Ashty city	5.2	51		2122	1591	796





Recommended system section for contemporary buildings in Erbil