Comparison of the Traditional and Contemporary Construction Techniques in Terms of Thermal Comfort and Energy Efficiency-in North Cyprus Case

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We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Master of Science in Architecture.

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ABSTRACT

According to the importance of the occupants' satisfaction with indoor quality, providing thermal comfort is one of the main headlines of the architecture's duties. While we have faced with technology improvement, it is conceived that the residents' relative satisfaction of thermal comfort in the past had been dramatically more than nowadays. In other hand, nowadays one of the main global issues is energy crisis which forces all industries to fallow some politics in order to reduce energy consumption and increase energy efficiency. Thus providing thermal through air conditioning system seems unacceptable and unjustifiable. In this study, selected traditional

and contemporary construction systems compared in terms of thermal comfort and energy efficiency. Traditional construction techniques selected from Ottoman and British periods and contemporary construction techniques were evaluated in the conditions during the indoor environment not air conditioned and continuously air conditioned cases.

Keywords: Thermal comfort, Energy efficiency, Building modeling, TAS, PMV, thermal load, thermal behavior.

ÖZ

Bina iç mekanında, kullanıcı memnuniyetini etkileyen başlıca faktörlerden biri olan ısıl konfor koşullarının oluşturulması, mimarların sağlaması gereken en önemli görevlerden biridir. Bina yapım teknolojilerinde yaşanan gelişmelere karşın, kullanıcılar geçmişte geleneksel yapım teknikleri ile inşa edilmiş bimalarda ısıl konfor yönden kendilerini daha fazla konforda hissettiklerini düşünmektedir. Günümüzde, özellikle fosil kaynaklı enerji kaynaklarının giderek azalması, enerjinin daha etkin kullanılması ve dolayısıyla enerji tüketimini azaltması hedeflenmektedir. Bu nedenle, ısıl konforun iklimlendirme sistemleriyle gerçekleştirilmesi, enerji tüketimini artıracağından kulanımının azaltılması hedeflenmektedir. Bu araştırmada, çeşitli geleneksel ve güncel bina yapım sistemleri ile inşaa edilmiş konutların ısıl konfor ve enerji korunumu yönünden karşılaştırılması yapılmıştır.

Kuzey Kıbrıs'ta yer alan, Osmanlı ve İngiliz döneminde kullanılan yapım teknikleri ve güncel olarak kullanılan yapım sistemlerinden seçilen örnekler iç mekanın iklimlendirilmediği ve sürekli iklimlendirildiği koşullarde karşılaştırılmıştır.

Anahtar Kelimeler: Isıl konfor, Enerji etkinliği, TAS, PMV, Isıl yük, Isıl davranış

To My Lovely Family

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INTRODUCTION

1.1 Introduction

Nowadays, we face with growing universal interest in the human activities' influence on the nature and environment. Having considered to the built environment and human activities, the main concern is based on sustainability in the building industry developing and energy consumption of building (Ikrom Zakaria, Woods, 2002). This fact shows the importance of attention to the climatic and environmental effect on the building behaviour in order to provide the comfort condition for inhabitants. This reality is one of the reasons which forced designers to involve many studies related to climatic design to increase indoor comfort with efficient energy usage (Lewis, Joseph, 2009).

The outdoor climate has always been known as the main determinative factor in air-conditioned building for the level of the occupants indoor thermal gratification. Before the air conditioning invention, the ambient temperature was considered as a regular change and a common part of life. So they tried to be incorporated with passive design principles during the design stage before considering any mechanical systems in order to adopt themselves by climatic changes (Vladimir, 2005).

As it is usual, the baseline heat load is calculated by the building's function and architectural decisions about structure orientation, solar shading devices of the windows and glazing parts of building. Then considered to those taken decisions, the designer determines the level of those baseline loads, which gained by building and then mechanical designer indicates how to decrease the remaining loads (Lewis, Joseph, 2009). Thus, in order to reach ideal result in design phase, some climatic aspects should be strongly considered. This survey attempts to find the relation between occupants satisfaction with indoor thermal comfort and building characteristics.

In other words, common building's problem in hot climates will be considered to compare the level of thermal comfort in various constructions. For this aim, firstly all indictors influencing on thermal comfort of building in case of building envelops will be reviewed. After that, all types of the building envelops should be analyzed based on their thermal behavior in various period of time in a specific region. Finally the reasonable method will be created by comparison the evaluated results.

1.2 Identification of the Problem

Thermal comfort is known as an initial factor in human satisfaction of a built environment which is influenced by the thermal interaction between inside and outside. During the time, people have tried to overcome the bad climatic condition by various techniques as climatic architectural design. In the traditional construction methods in spite of lake of technology in material and construction techniques, there was high contentment for inhabitants. In compare with traditional building, contemporary ones have supported by new and modern material and improved technology. It is expected the more technology progress makes more comfort and quality in indoor condition but there are more occupants' complains about thermal comfort in nowadays buildings.

Moreover, one of the unsuccessful outcomes of modern development has been the invention and general acceptance of the mechanical devices usage to provide desired temperature for building inhabitants. This modern outcome has caused a huge amount of energy consumption in the building stock. Nowadays, about building industry is one of the biggest consumers of fossil (Taleghani, 2013). So the main existed problem is to overcome the state of discomfort with least energy utilization and find the reasons of this reduction of indoor condition quality (Djamila, Chu, Kumaresan, 2013).

1.3 Aims and Objectives

As it is expected architects consider greatly in building performance by forecasting the issues which may occur during whole phases of constructing. One of the biggest issues in the contemporary researches among architects is how to create effective strategies and methods to provide comfort condition in any climatic zones by considering to energy efficiency. For this aim thermal simulation software and programs are the best supportive sources which can explain why people in same area receive various levels of temperatures. Thus these simulation programs would be as an initial part in designing process by their positive effects on designers' decision making (Solomon, 2007).

In this study, the influences of the building envelop on thermal comfort and indoor condition would be considered in hot and dry climate in specific location. Therefore, the aim of this survey is examination the building thermal behavior through its envelopes in various types of construction methods and materials.

The aim of this study is answering to these questions:

- Why did inhabitants feel more comfortable in their building in past?
- Was that thermal comfort satisfaction related to the physical aspect or psychological aspect?
- Despite the technology development, why do not inhabitants satisfy with the indoor condition yet in term of thermal comfort?
- Which applied construction techniques seem more adaptable to this region?

The main objectives of this research considered in North Cyprus are in followings:

- To find the reasons of the difference between the levels of the indoor comfort desire for inhabitants in past and today.
- To discover how the construction specification of building envelope would be able to change the indoor condition.
- To evaluate the in used material in case of thermal behavior.
- To distinguish the contemporary buildings issues and compare it with vernacular building problem.
- To compare the thermal comfort in traditional and contemporary buildings with specific construction method.
- To determine reasonable and efficient alternative in building construction based on the simulation program results.

1.4 Research Scope and Limitation

This investigation consists of some parts such as thermal comfort definition and related indicators, analyzing vernacular residential building and contemporary one via TAS program in case of thermal behavior to consider how various building envelopes have impacts on indoor thermal comfort and comparing all result to achieve the best and efficient alternative. This survey has been carried out during academic year 2013-2014.

While this study accomplished to reach its aim and objectives in all steps, some imitations and barriers were appeared throughout the research as well. Thermal comfort includes of many criteria and there are lots of aspects influencing on indoor thermal comfort such as building layout, orientation and form of building. Although, the existence of courtyard in traditional building of North Cyprus had great impression on thermal behavior of building, this survey has disregarded it. Since there is wide range of building typology in various period of history, the final evaluation and comparison based on thermal behavior of building envelope seems complex. This aspect would be followed in future researches.

1.5 Research Methodology

This research tend to make clear to what extent the construction methods and materials used in building envelopes and shells would be effective in indoor thermal comfort quality throughout the history of North Cyprus. In this way this study traversed two main parts as theoretical step and computational step. To process the theoretical part, the gathered data was supplied through observations, previous studies and researches, related articles and books and internet data bases around this field of study. For the next part, all raw data were gained by observation and measuring which were applied in TAS program to evaluate the level of thermal comfort and energy usage of residential buildings in North Cyprus. TAS software was used to achieve real data through several simulations with various parameters based on different construction methods. All outcomes of this survey are according to the TAS simulation's analyzed results and environmental data monitoring.

1.6 Organization of the Thesis

The current survey includes four chapters which followed the research process step by step. Firstly, there is an introduction to offer general information about the subject, then statement of problem, aim and objectives, research scope and limitation, research methodology and thesis organization are provided respectively. In second chapter, the comprehensive related information and definitions in this field are organized based on the previous studies and researches by reviewing the literature. In next step, the third chapter maintains the TAS simulations of the chosen case study and all achieved results are offered plus analyzing and discussing about them.

In last chapter, conclusion formed by a summary of the research based on the aim and objectives and all gathered data in literature review section. Conclusion is followed by results of the discussion and comparison in third chapter and ends by the future research suggestions according to the limitations of this study.

Chapter 2

HISTORICAL DEVELOPMENT OF BUILDING CONSTRUCTION TECHNIQUES IN NORTH CYPRUS CASE

The harmony among human beings, natural environment and sources has been accepted as a fact which has made human to be alive by interrelating with its surrounded environment with no harm to the nature. Regard to the refuge demand to guard them from rain, snow, wind and all possible risks, one of the main effectual factors in architectural designing is the climatic condition. This impact can show itself by making some positive and negative influences on building which finally causes considerable effect on building performance and the way it consumes energy. This part has played the vital role in designing and creating an adaptable building with comfort condition for inhabitants (Ozay,2005).Thus for each process of designing, there is a kind of earlier step to determine and analyse the environmental aspects which results in various architectural solutions and designing outputs (Hui SCM, 2000).

2.1 Traditional Construction Techniques in North Cyprus

All over different time periods, various architectural designs have been improved in order to prepare climatic comfort in built environment in North Cyprus. What make this various types of architectural pattern in this region are cultural, socio economic, technological and political aspects. Houses as the core living parts, have demonstrated the general ideas and concepts of the technological system, socio-cultural and physical structure in that period of time (Ozay, 2005). In this part the residential building of North Cyprus in rural and urban area, are going to be considered under the influences of climatic factor in various time (Dincyurek, 1998).

The main periods of architectural history of North Cyprus are Ottoman (1571–1878), British (1878–1960) and Modern (1960-present) which determine the architectural development of this region by reflecting the considerable characteristics of architectural and historic status. In one hand, to evaluate the climatic condition on the designing pattern some principles such as location of building, designing layout and building properties should be noticed, on the other hand the effective factors such as socio economy, culture, technology, management strategies and politics must be discussed in each specific period and region to determine how they effect on climatic design. In compare with these mentioned criteria which are variable with respect to the time and each period's condition, the local weather and climate is actually invariant indicator (Ozdeniz, 2002).

Cyprus as same as other societies has perceived a various civilization periods which form the development process of Cypriot architecture. During these years North Cyprus has experienced eastern and western architectural patterns because of its history and culture (Dincyurek, 2002). This reality causes different architectural features and designing approaches in various periods of time. In addition to historical agents, the geographical and climatic aspects have forced some specific strategies in local designing (Ozay, 2005).

2.1.1 Ottoman Period (1571–1878)

This period is the beginning of the familiarity with Turkish culture. According to the political and historical aspects in this stage, the administrative and religion institution, aqueducts, mills, inns, educational and commercial buildings were established by imperial architectural team consisting of architects and local members (Figure 1) (Yildiz, 2001). After the Cyprus conquest by Ottomans, the island faced with a new designing pattern caused by the lifestyle of the new comers (Albrecht, 1994). Regardless of similarities among this imported architectural design and Turkish one, there were some differences caused by the climate specifications. Climate resulted in plan organization, orientation and construction methods. Courtyard was the significant feature of this period (Kucukerman, 1991).The variety in building material was because of the various climatic conditions in this region. Adobe and stone infill structures were replaced with wooden structure. The remained ancient foundations were reapplied for new ones. Most of the floors were covered by marble in respect to the climatic reasons (Salvator, 1983). In following there are some examples of construction methods (Figure 2-7) with their material properties (Table 1-6) during ottoman period.

Figure 1: Ottoman architecture in Nicosia- North Cyprus (URL 1)

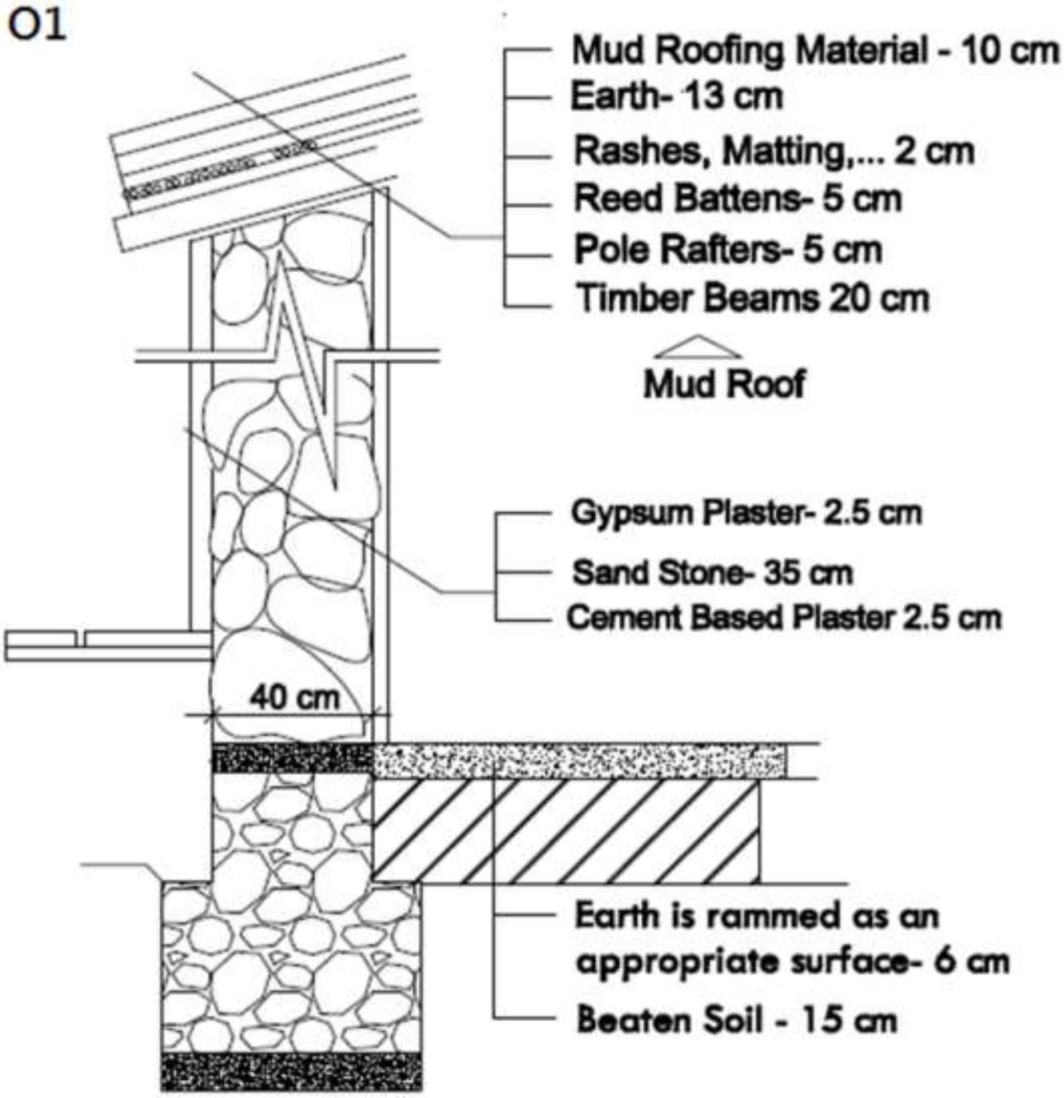

Figure 2: Construction Technique in Ottoman period- Stone wall- O_1

Table 1: Material properties of construction technique O_1

Construction element		Floor		Wall			Roof					
Material		Earth	Beaten Soil	Gypsum Plaster	Sand Stone	Cement	Timber	Pole Rafter	Reed	Rash	Earth	Mud Roofing
Width (mm)		60	150	25	350	25	200	50	50	20	130	100
Conductivity (W/m.C)		1.298	1.5	0.30	2.3	1.4	0.144	0.13	0.067	0.067	0.067	0.45
Specific Heat (J/Kg.C)		1000	1000	1000	1000	850	142	1500	1000	1000	1000	800
Density (kg/m3)		1000	1000	900	2600	2000	480	500	300	300.0	300	1700
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		99999	9999	9999	9999	0.0	11.4	9999	2.9	2.9	2.9	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.30	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.30	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

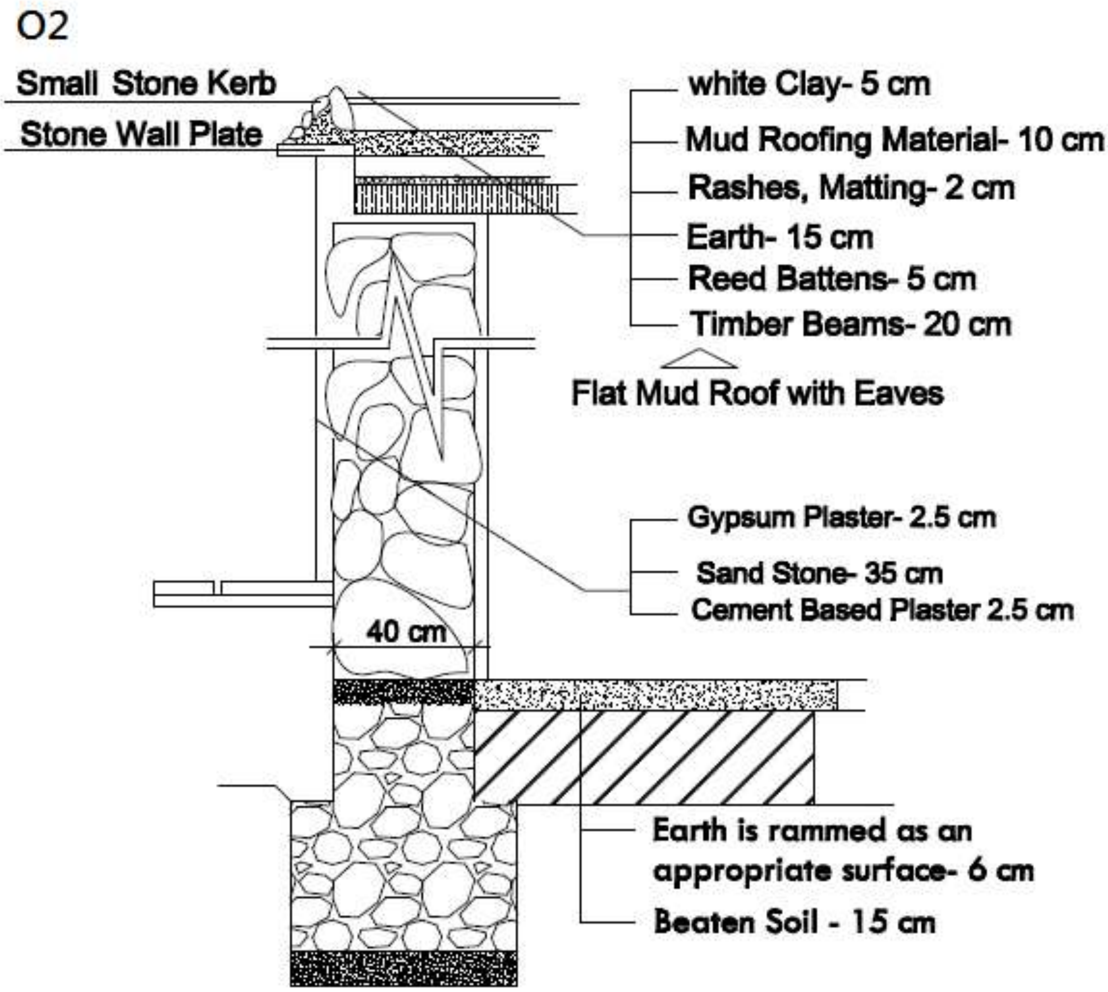

Figure 3: Construction Technique in Ottoman period- Stone wall- O_2

Table 2: Material properties of construction technique O_2

Construction element		Floor2		Wall2			Roof 2					
Material		Earth	Beaten Soil	Gypsum Plaster	Sand Stone	Cement	Timber	Reed	Rash	Earth	Mud Roofing	White Clay
Width (mm)		60	150	25	400	25	200	50	150	20	100	50
Conductivity (W/m.C)		1.298	1.5	0.30	2.3	1.4	0.144	0.067	0.067	0.067	0.45	1.5
Specific Heat (J/Kg.C)		1000	1000	1000	1000	850.0	142	1000	1000	1000	800	2085
Density (kg/m3)		1000	1000	900	2600	2000	480	300	300.0	300	1700	1500
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		99999	9999	9999	9999	0.0	11.4	2.9	2.9	2.9	9999	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.30	0.30	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.30	0.30	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

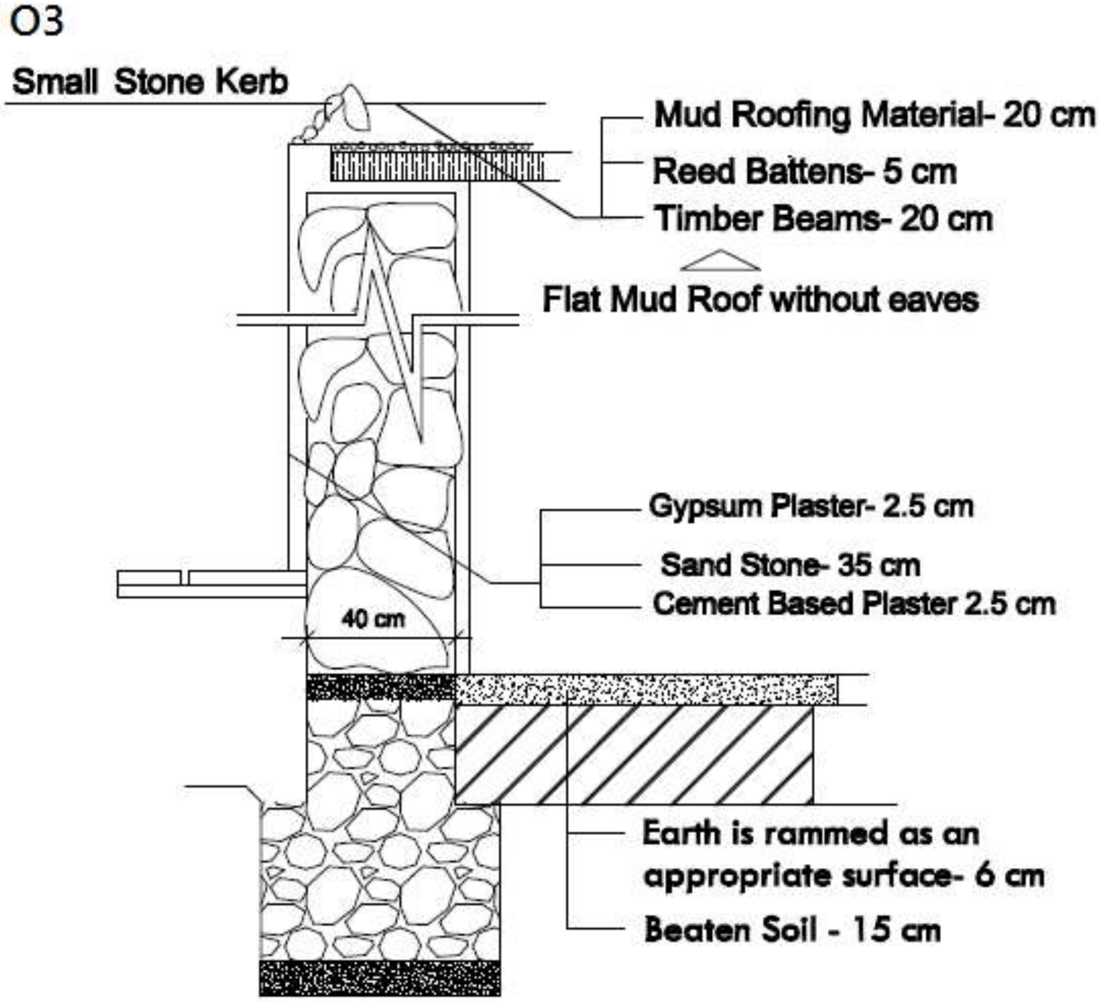

Figure 4: Construction Technique in Ottoman period- Stone wall- O_3

Table 3: Material properties of construction technique O_3

Construction element		Floor2		Wall2			Roof 3		
Material		Earth	Beaten Soil	Gypsum Plaster	Sand Stone	Cement	Timber	Reed	Mud Roofing
Width (mm)		60	150	25	350	25	200.0	50	200.0
Conductivity (W/m.C)		1.298	1.5	0.30	2.3	1.4	0.144	0.067	0.45
Specific Heat (J/Kg.C)		1000	1000	1000	1000	850.0	142.0	1000	800
Density (kg/m3)		1000	1000	900	2600	2000	480.0	300	1700
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		99999	9999	9999	9999	0.0	11.4	2.9	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.40	0.40	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.40	0.40	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

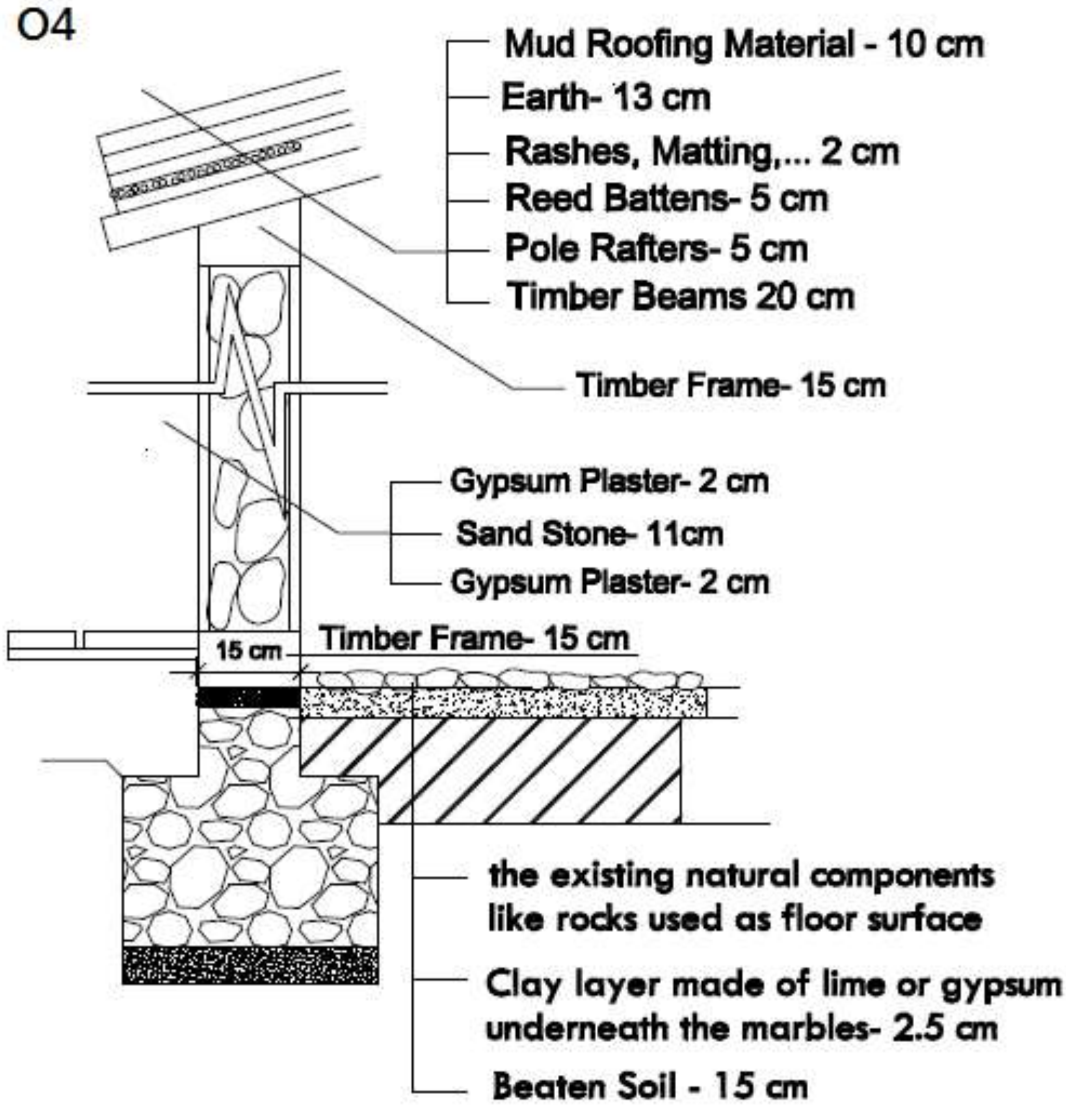

Figure 5: Construction Technique in Ottoman period- Timber Frame- O_4

Table 4: Material properties of construction technique O_4

Construction element		Floor1			Wall3				Roof 1					
Material		Slate	Clay	Beaten Soil	Gypsum Plaster	Sand Stone	Cement	Timber	Timber	Pole Rafter	Reed	Rash	Earth	Mud Roofing
Width (mm)		50.0	25.0	150	20	110	20	150	200	50	50	20	130	100
Conductivity (W/m.C)		1.0	1.5	1.5	0.30	2.3	1.4	0.144	0.144	0.13	0.067	0.067	0.067	0.45
Specific Heat (J/Kg.C)		1464	2085	1000	1000	1000	850	142	142	1500	1000	1000	1000	800
Density (kg/m3)		1602	1500	1000	900	2600	2000	480	480	500	300	300	300	1700
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		9999	9999	9999	9999	9999	0.0	11.4	11.4	9999	2.9	2.9	2.9	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.40	0.30	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.40	0.30	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

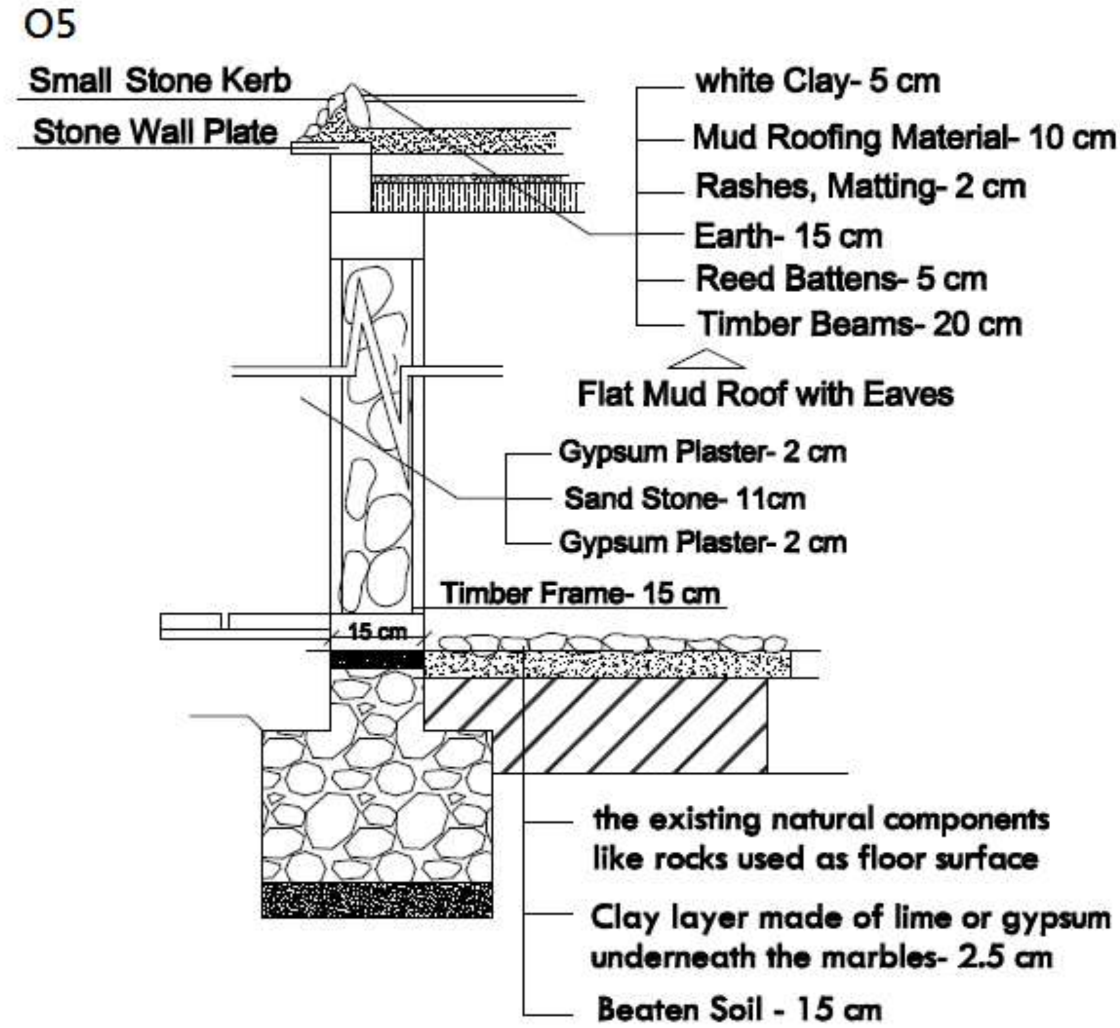

Figure 6: Construction Technique in Ottoman period- Timber Frame- O_5

Table 5: Material properties of construction technique O_5

Construction element		Floor1			Wall3				Roof 2				
Material		Slate	Clay	Beaten Soil	Gypsum Plaster	Sand Stone	Cement	Timber	Timber	Reed	Rash	Earth	Mud Roofing
Width (mm)		50	25	150	20	110	20	150	200	50	20	20	100
Conductivity (W/m.C)		1.0	1.5	1.5	0.30	2.3	1.4	0.144	0.144	0.067	0.067	0.067	0.45
Specific Heat (J/Kg.C)		1464	2085	1000	1000	1000	850.0	142	142.0	1000	1000	1000	800
Density (kg/m3)		1602	1500	1000	900	2600	2000	480	480.0	300	300.0	300	1700
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		9999	9999	9999	9999	9999	0.0	11.4	11.4	2.9	2.9	2.9	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.30	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.40	0.30	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

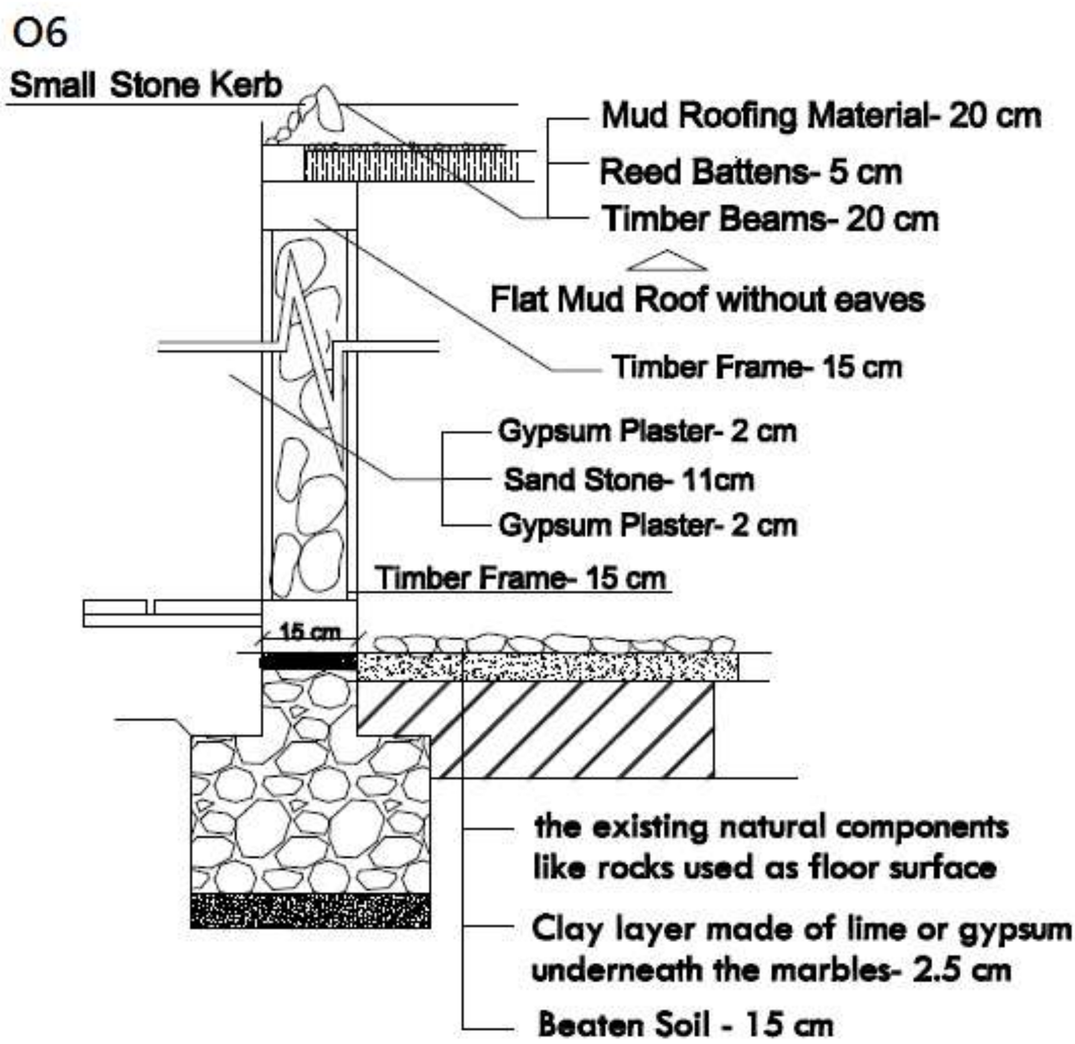

Figure 7: Construction Technique in Ottoman period- Timber Frame- O_6

Table 6: Material properties of construction technique O_6

Construction element		Floor1			Wall3				Roof 3		
Material		Slate	Clay	Beaten Soil	Gypsum Plaster	Sand Stone	Cement	Timber	Timber	Reed	Mud Roofing
Width (mm)		50.0	25.0	150	20	110	20	150	200	50	300
Conductivity (W/m.C)		1.0	1.5	1.5	0.30	2.3	1.4	0.144	0.144	0.067	0.45
Specific Heat (J/Kg.C)		1464	2085	1000	1000	1000	850.0	142	142.0	1000	800
Density (kg/m3)		1602	1500	1000	900	2600	2000	480	480.0	300	1700
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		9999	9999	9999	9999	9999	0.0	11.4	11.4	2.9	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.30	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.30	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

2.1.2 British Period (1878–1960)

The British period was begun nearly hundred years after the Ottoman era which was one of the most effective steps of the Cypriot civilization process. The new materials and techniques were introduced to the Cypriot architects in this time (Numan& Dincyurek& Pulhan, 2001), These materials and methods (Figure 8) shaped the new architectural style by changing the construction regulation. The British colonial Public Works Department (the colonial PWD) was the designer and builder of many public Cypriot buildings which have been accommodated as public organization like the agricultural department, departments of education and health and the some buildings for judicial purposes and postal organizations (Ozay, 2002).

The private building as residential ones (Figure 8) were designed based on the simple manner and symmetrical way in order to have no great impact on the environment or any attraction for the people (Schaar, Given, 1998). In this period you can find some specific feature related to the British style in Cyprus as architectural elements in building envelops and planning. The British period consists of two main parts, the first one started from 1878 to 1930 which was affected by the Ottoman architectural patterns also and the other continued between 1930 and 1960 (Ozay, 1998).

Adobe and yellow limestone were common characteristics of in used material in the buildings. In addition, marble and wood were applied to flooring. These methods have all been used as proper climatic materials (Figure 8) (Dagli, 1990).

In compare with the first part, the second period developed in using new material, technologies and new functional understanding because of the technology and science improvement. Even though the climatic design principles were the effective base for architectural methods, the yellow limestone usage and roof structure were sustained together with the new materials and structures as reinforced concrete (Figure 8) (Ozay, 2005).

In following there are some examples of construction methods (Figure 9-14) with their material properties (Table 7-12) during British period.

Figure 8: British architecture in Nicosia- North Cyprus (URL 2)

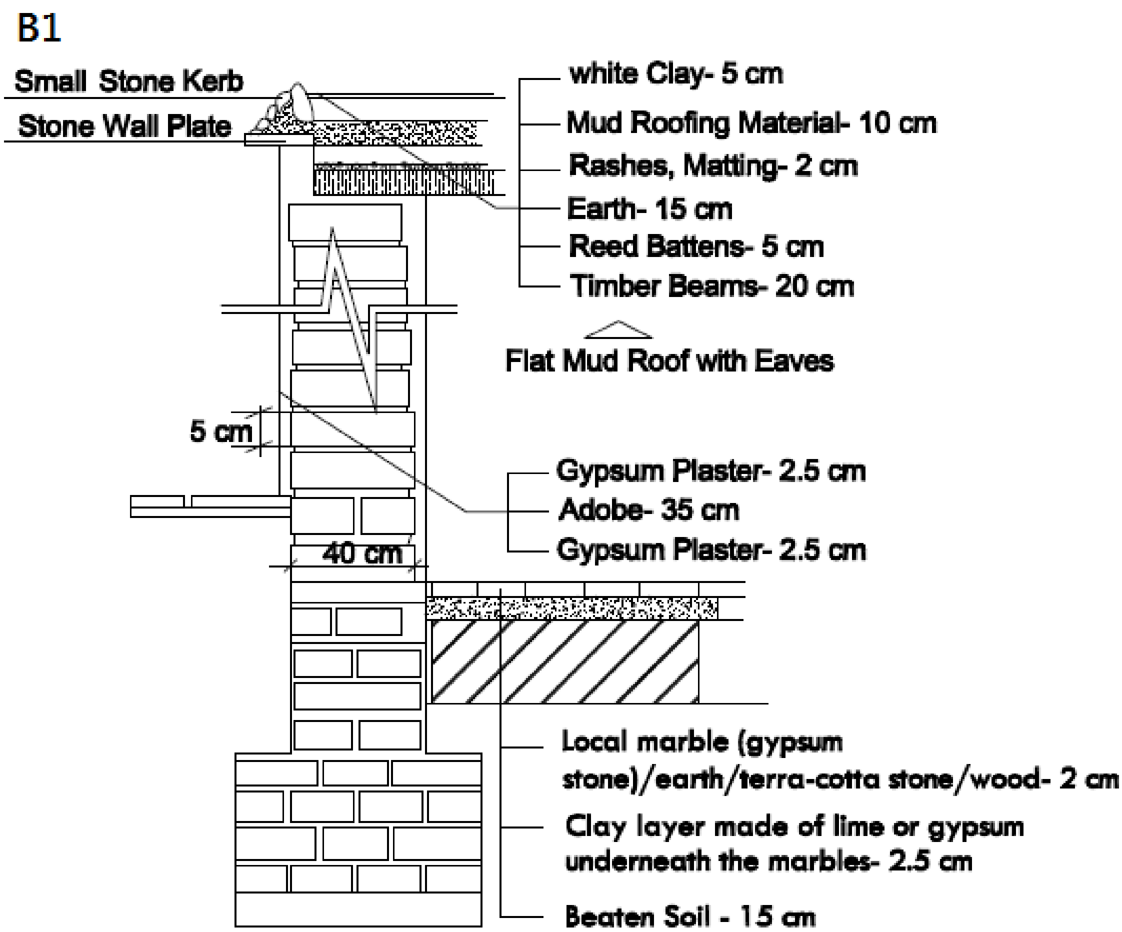

Figure 9: Construction Technique in British period- Adobe wall- B_1

Table 7: Material properties of construction technique B_1

Construction element		Floor3			Wall1		Roof 2						
Material		Local Marble	Clay	Beaten Soil	Gypsum Plaster	Brick(Local Adobe)	Timber	Reed	Rash	Earth	Mud Roofing	White Clay
Width (mm)		20	25	150	25	350	200	50	20	150	100	50
Conductivity (W/m.C)		2.4	1.5	1.5	0.30	0.77	0.144	0.067	0.067	0.067	0.45	1.5
Specific Heat (J/Kg.C)		840.0	2085	1000	1000	1000	142.0	1000	1000	1000	800	2085
Density (kg/m3)		2600	1500	1000	900	1700	480.0	300	300.0	300	1700	1500
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		38.0	9999	9999	9999	9999	11.4	2.9	2.9	2.9	9999	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.30	0.30	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.30	0.30	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

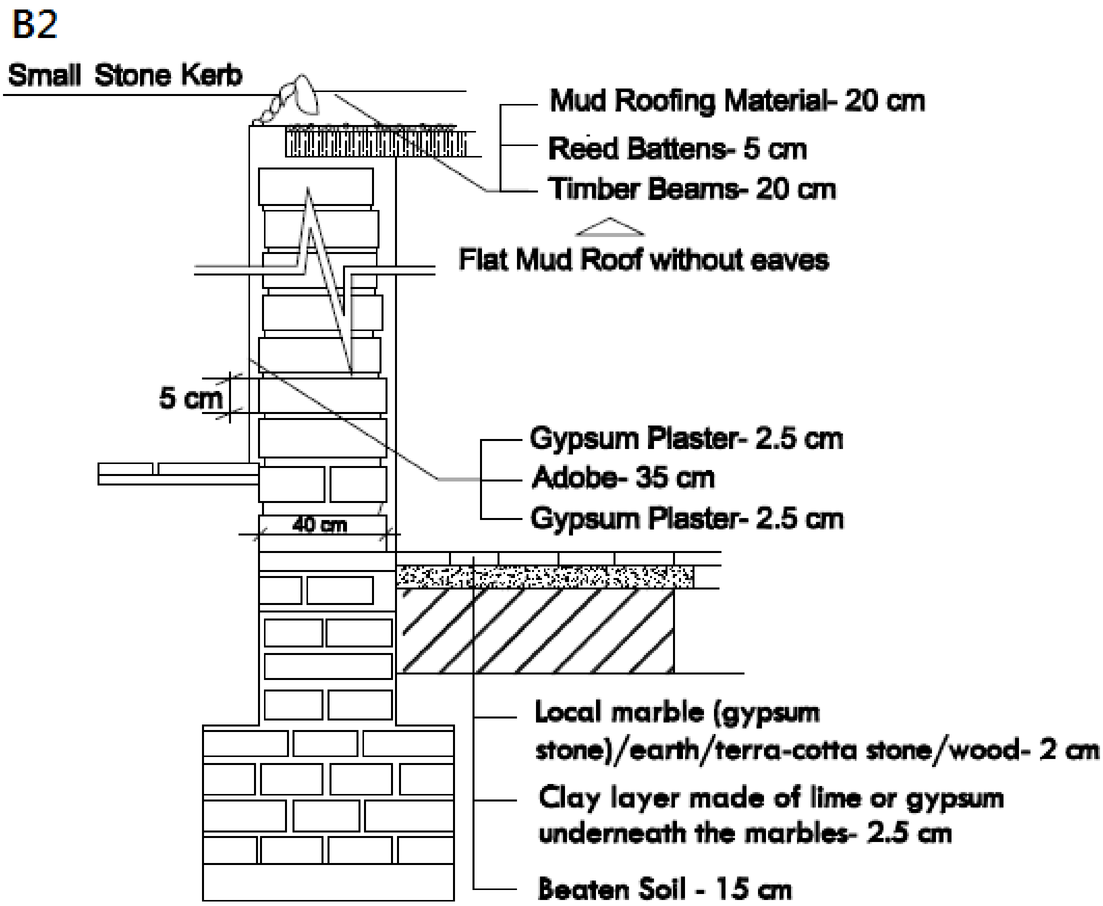

Figure 10: Construction Technique in British period- Adobe wall- B_2

Table 8: Material properties of construction technique B_2

Construction element		Floor3			Wall1		Roof 2		
Material		Local Marble	Clay	Beaten Soil	Gypsum Plaster	Brick(Local Adobe)	Timber	Reed	Mud Roofing
Width (mm)		20	25	150	25	350	200.0	50	200
Conductivity (W/m.C)		2.4	1.5	1.5	0.30	0.77	0.144	0.067	0.45
Specific Heat (J/Kg.C)		840.0	2085	1000	1000	1000	142.0	1000	800
Density (kg/m3)		2600	1500	1000	900	1700	480.0	300	1700
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		38.0	9999	9999	9999	9999	11.4	2.9	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

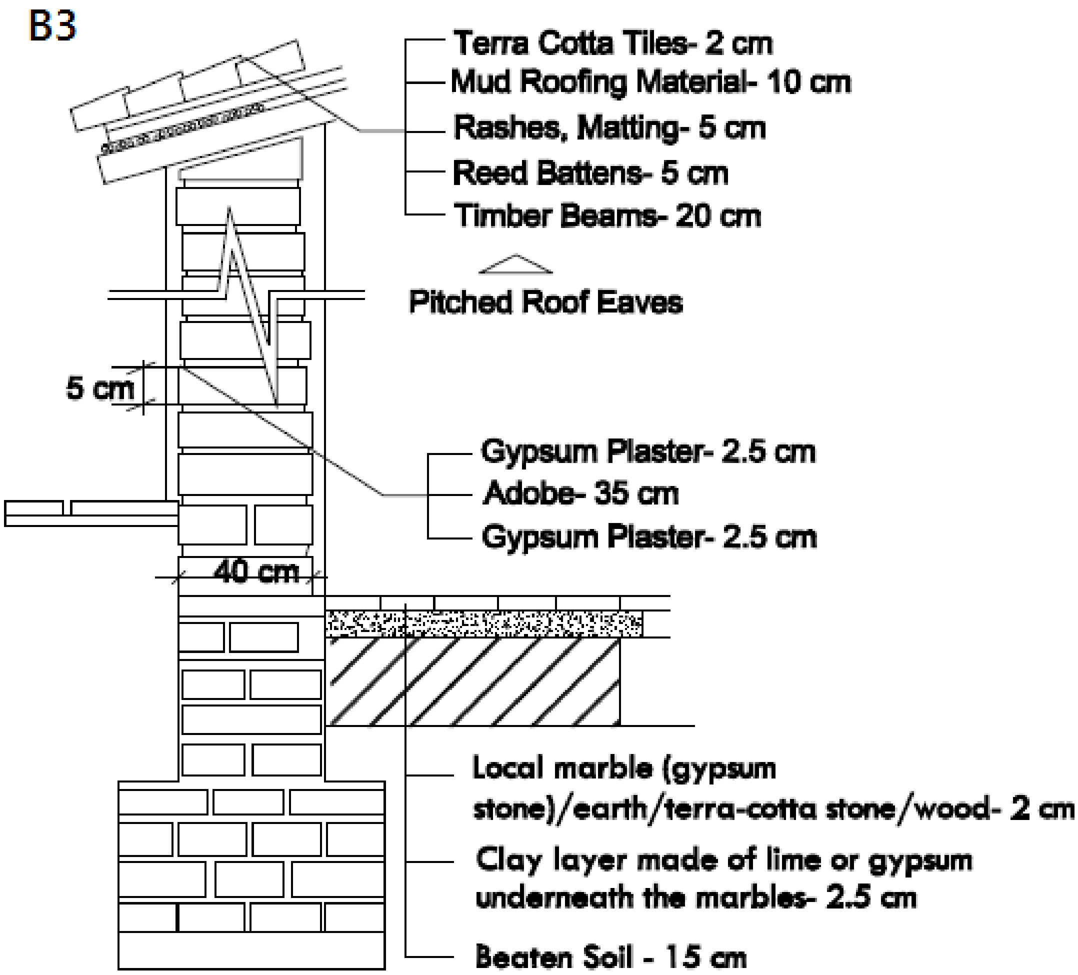

Figure 11: Construction Technique in British period- Adobe wall- B_3

Table 9: Material properties of construction technique B_3

Construction element		Floor3			Wall1		Roof 4				
Material		Local Marble	Clay	Beaten Soil	Gypsum Plaster	Brick(Local Adobe)	Timber	Reed	Rash	Mud Roofing	Terra Cotta Tiles
Width (mm)		20	25	150	25	350	200	50	50	100	20
Conductivity (W/m.C)		2.4	1.5	1.5	0.30	0.77	0.144	0.067	0.067	0.45	0.85
Specific Heat (J/Kg.C)		840.0	2085	1000	1000	1000	142.0	1000	1000	800	837
Density (kg/m3)		2600	1500	1000	900	1700	480.0	300	300.0	1700	1900
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		38.0	9999	9999	9999	9999	11.4	2.9	2.9	9999	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.30	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.30	0.40	0.40	0.30	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

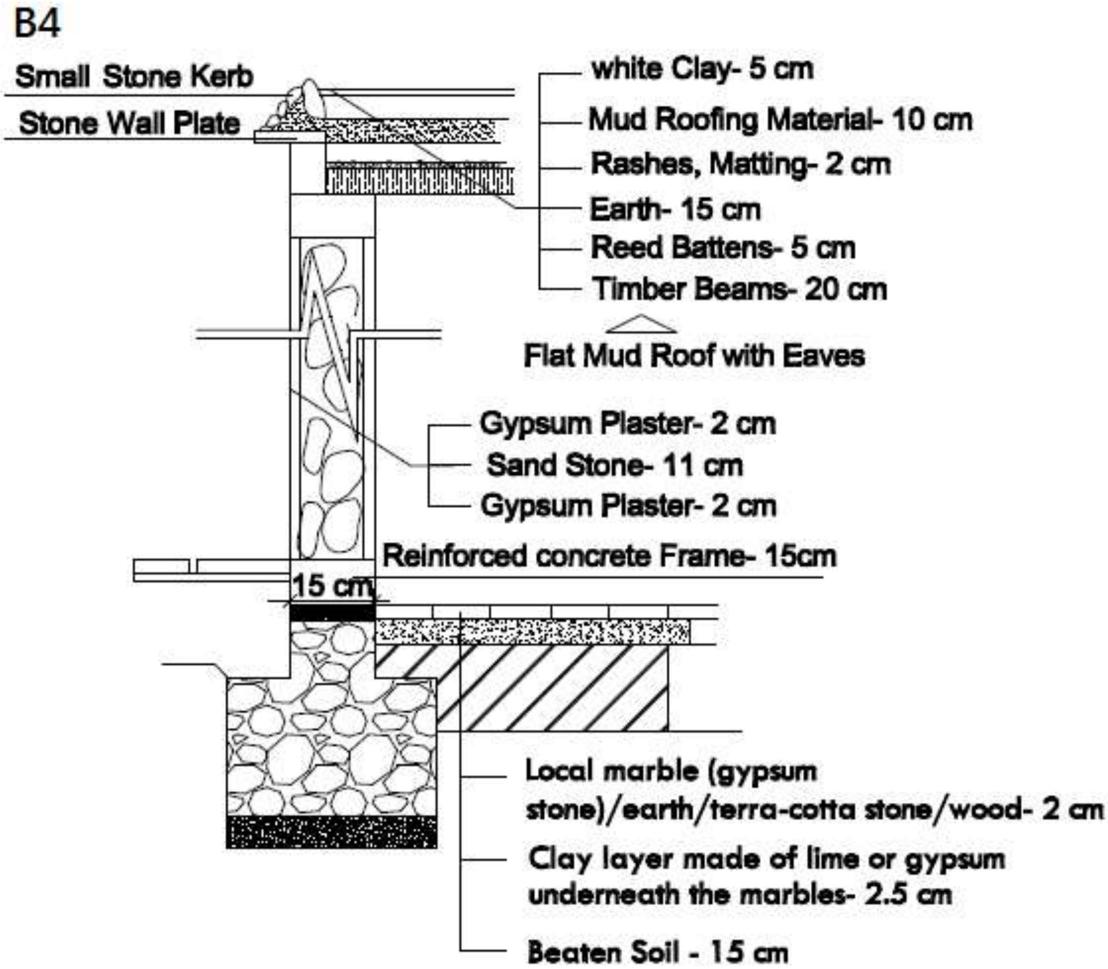

Figure 12: Construction Technique in British period- Stone walls and Concrete Structure- B_4

Table 10: Material properties of construction technique B_4

Construction element		Floor3			Wall5			Roof 2					
Material		Local Marble	Clay	Beaten Soil	Gypsum Plaster	Brick(Local Adobe)	Concrete (frame)	Timber	Reed	Rash	Earth	Mud Roofing	White Clay
Width (mm)		20	25	150	20	110	150.0	200	50	50	150	100	50
Conductivity (W/m.C)		2.4	1.5	1.5	0.30	0.77	0.30	0.144	0.067	0.067	1.298	0.45	1.5
Specific Heat (J/Kg.C)		840.0	2085	1000	1000	1000	920.0	142.0	1000	1000	1699.84	800	2085
Density (kg/m3)		2600	1500	1000	900	1700	1000.0	480.0	300	300.0	1900.0	1700	1500
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		38.0	9999	9999	9999	9999	14.8	11.4	2.9	2.9	99999	9999	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.35	0.35	0.40	0.40	0.18	0.18	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.35	0.35	0.40	0.40	0.18	0.18	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.91	0.91	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.91	0.91	0.90	0.90

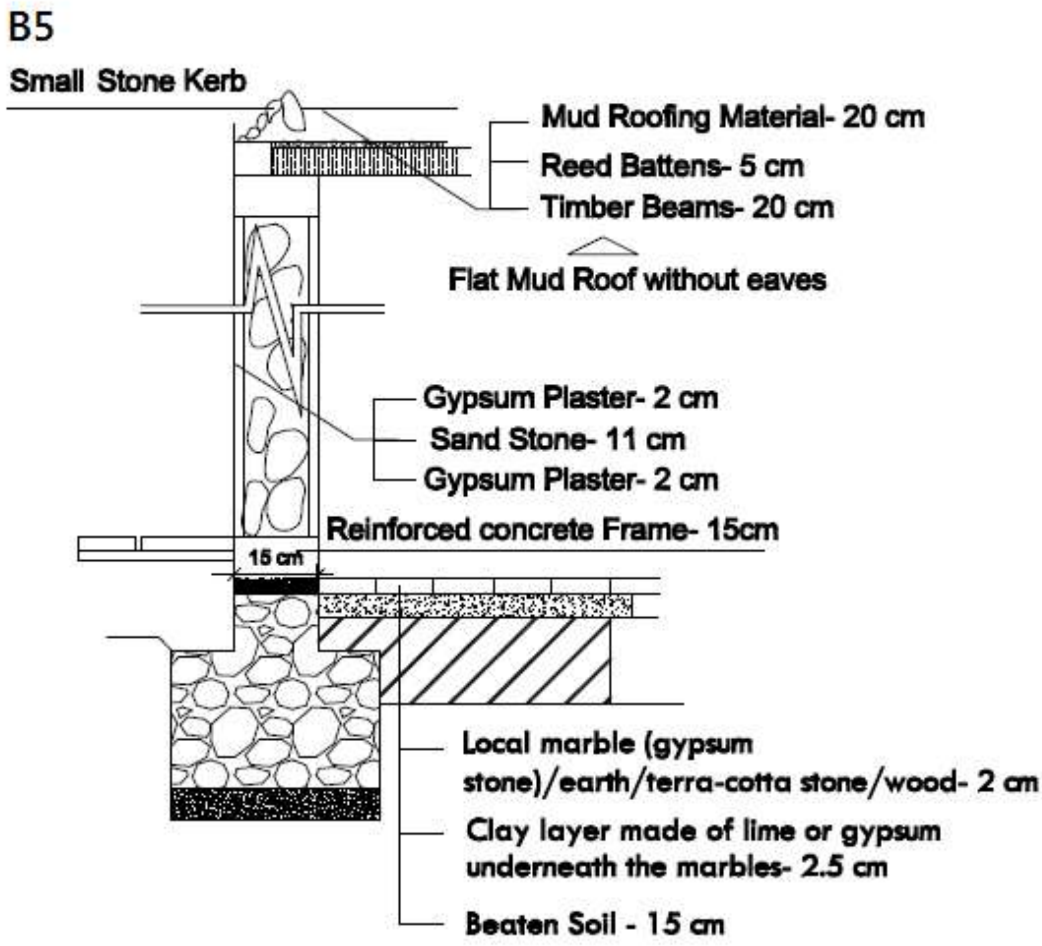

Figure 13: Construction Technique in British period- Stone walls and Concrete Structure- B_5

Table 11:Material properties of construction technique B_5

Construction element		Floor3			Wall5			Roof 2		
Material		Local Marble	Clay	Beaten Soil	Gypsum Plaster	Brick(Local Adobe)	Concrete (frame)	Timber	Reed	Mud Roofing
Width (mm)		20	25	150	20	110	150	200	50	200
Conductivity (W/m.C)		2.4	1.5	1.5	0.30	0.77	0.30	0.144	0.067	0.45
Specific Heat (J/Kg.C)		840.0	2085	1000	1000	1000	920	142	1000	800
Density (kg/m3)		2600	1500	1000	900	1700	1000	480	300	1700
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		38.0	9999	9999	9999	9999	14.8	11.4	2.9	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.35	0.30	0.30	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.35	0.30	0.30	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

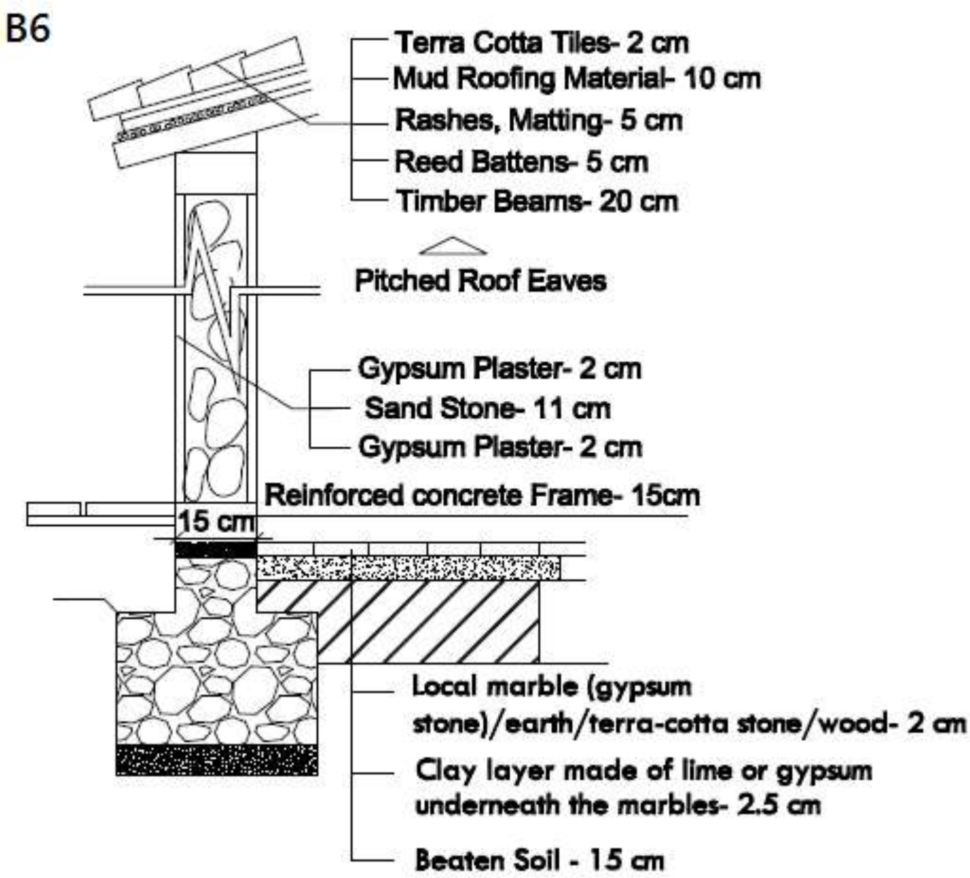

Figure 14: Construction Technique in British period- Stone walls and Concrete Structure- B6

Table 12: Material properties of construction technique B_6

Construction element		Floor3			Wall5			Roof 4				
Material		Local Marble	Clay	Beaten Soil	Gypsum Plaster	Brick(Local Adobe)	Concrete (frame)	Timber	Reed	Rash	Mud Roofing	Terra Cotta Tiles
Width (mm)		20	25	150	20	110	150.0	200	50	50	100	20
Conductivity (W/m.C)		2.4	1.5	1.5	0.30	0.77	0.30	0.144	0.067	0.067	0.45	0.85
Specific Heat (J/Kg.C)		840.0	2085	1000	1000	1000	920.0	142.0	1000	1000	800	837
Density (kg/m3)		2600	1500	1000	900	1700	1000.0	480.0	300	300.0	1700	1900
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Vapour Diffusion Factor		38.0	9999	9999	9999	9999	14.8	11.4	2.9	2.9	9999	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.30	0.35	0.35	0.40	0.40	0.30	0.30	0.30
	Int.	0.30	0.30	0.30	0.30	0.35	0.35	0.40	0.40	0.30	0.30	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90

2.2 Contemporary Construction Techniques in Cyprus Republic Period and T.R.N.C Period

After the British domination, the Republic of Cyprus was begun in 1960. There was a great war among the Greek and Cyprus which caused the Turkish Cypriot part in 1963. This division has resulted in various architectural patterns in north and south of the Cyprus. The settlements in the northern area of the island were mostly built by the Turkish Cypriots while the other part was largely belongs to the Greek Cypriots. In fact modern period would be divided in to different stages in the perspective of architectural developments which has been accrued in this region. Each part provides different climatic design considerations and sensitivity. Between 1960 and 1970, most of the buildings were built in one and two story (Figure 15). Although introducing the reinforced concrete structure to the Cypriot construction industry decreased the popularity of local materials and vernacular construction methods, the level of sensitivity of type of opening, orientation, shading devices and green area was increased. After this period most of the residential buildings were constructed by personal clients. One of the greatest features of this time was the inclined roofs instead of the flat roof which reduced the level of the climatic comfort in buildings. In order to promote the level of the comfort and eliminate the disadvantages of apartments, some building elements were applied. In 1980 decade, the Social Housing Unit started to work in Northern Cyprus to perform the construction projects (Ozderen, 2001). Because of the poverty of the users, the Social Housing Unit decided to build the residential building with low standards causing the uncomfortable indoor condition (N.C.P.O., 2002). In the same period some users with high level of economy, built their houses with more consideration in to the material and construction's quality. By the way most of these buildings were in efficient in the perspective of climatic view. The large glass surfaces and openings, improper flat roofs, inappropriate shading devices, false orientation and wrong material selections were the main reasons of lack of comfort inside the building. Recently years, the growing population of this island has resulted shortage of accommodation. Regard to erase this issue, mass housing production industry developed. In this time the existed buildings referred the unawareness of the climatic design which was so far from the architectural quality. In addition to the lack of consideration to the form and orientation of building, miss-use of structural systems and materials also made this undesirable indoor quality by increasing the heat gain. The 1990s structural systems of building, some differences have been seen among mass housing and private ones which have been made by different material usage and construction principles. Nowadays, the lack of the climatic attention in buildings forces inhabitants to use more mechanical heating, cooling and air conditioning (Figure 15) (Ozay, 2005). The common construction element in this period is double skin roof sloped shape which behave as an improved thermal insulation. This ability can reduce both cooling demand in summer and heating demand in winter (Halil & Mesut, 2011).

In following there are some examples of construction methods (Figure 16- 31) with their material properties (Table 13-28) during T.R.N.C period.

Figure 15: Modern architecture in North Cyprus (photos by author)

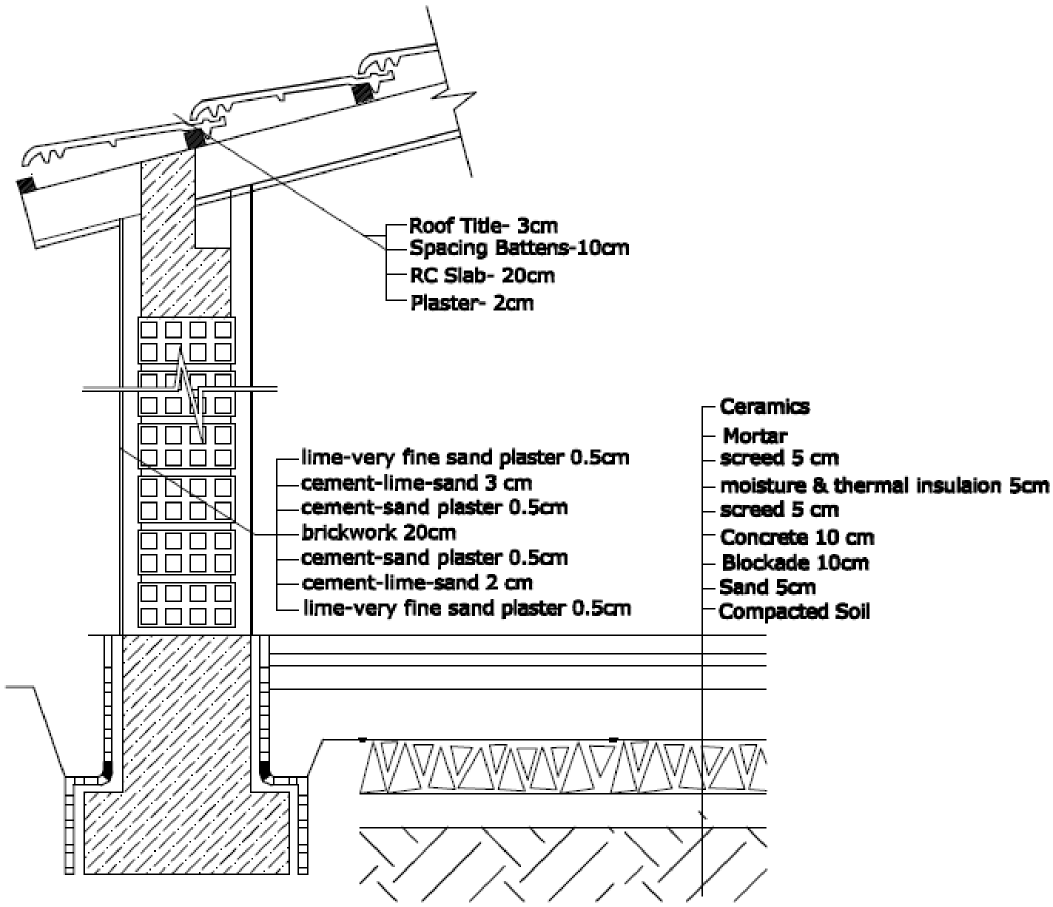

Figure 16: Construction Technique in contemporary period- Brick wall- C_1

Table 13: Material properties of construction technique C_1

Construction element		Floor1						Wall1				Roof 1			
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement-sand Plaster	Brick work	Plaster	Reinforced Concrete slab	Spacing Battens	Roof tiles
Width (mm)		10	10	100	100	50	200	5	30	5	200	20	200	100	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.079	2.3	-	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920	769	800	837	1000	-	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300.0	1700	400	2300	-	1900
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.96	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11	34	19.2	8	11	9999	1.0	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	-	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	-	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90

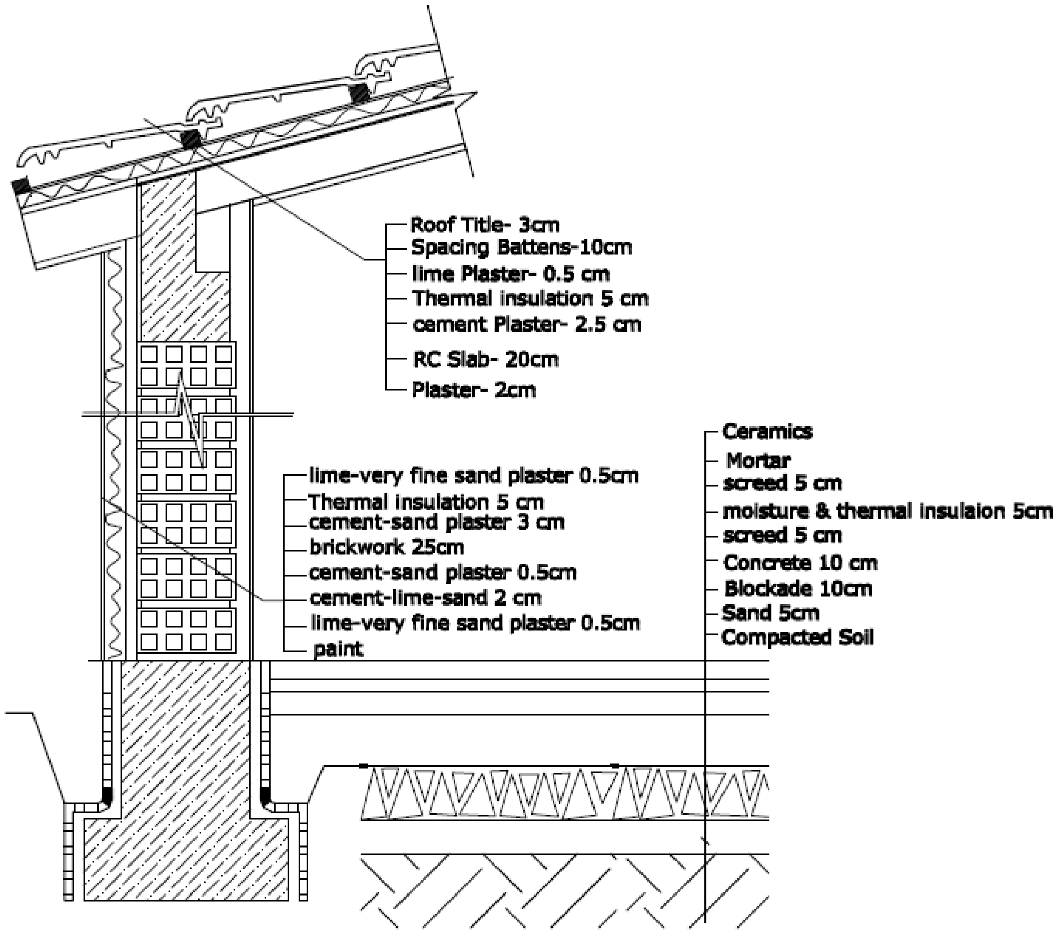

Figure 17: Construction Technique in Contemporary period- Brick wall- C2

Table 14: Material properties of construction technique C_2

Construction element		Floor1						Wall1				Roof 1			
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cemen t-sand Plaster	Brick work	Plaster	Reinforced Concrete slab	Spacing Battens	Roof tiles
Width (mm)		10	10	100	100	50	200	5	30	5	200	20	200	100	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.079	2.3	-	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920	769	800	837	1000	-	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300.0	1700	400	2300	-	1900
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.96	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11	34	19.2	8	11	9999	1.0	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	-	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	-	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90

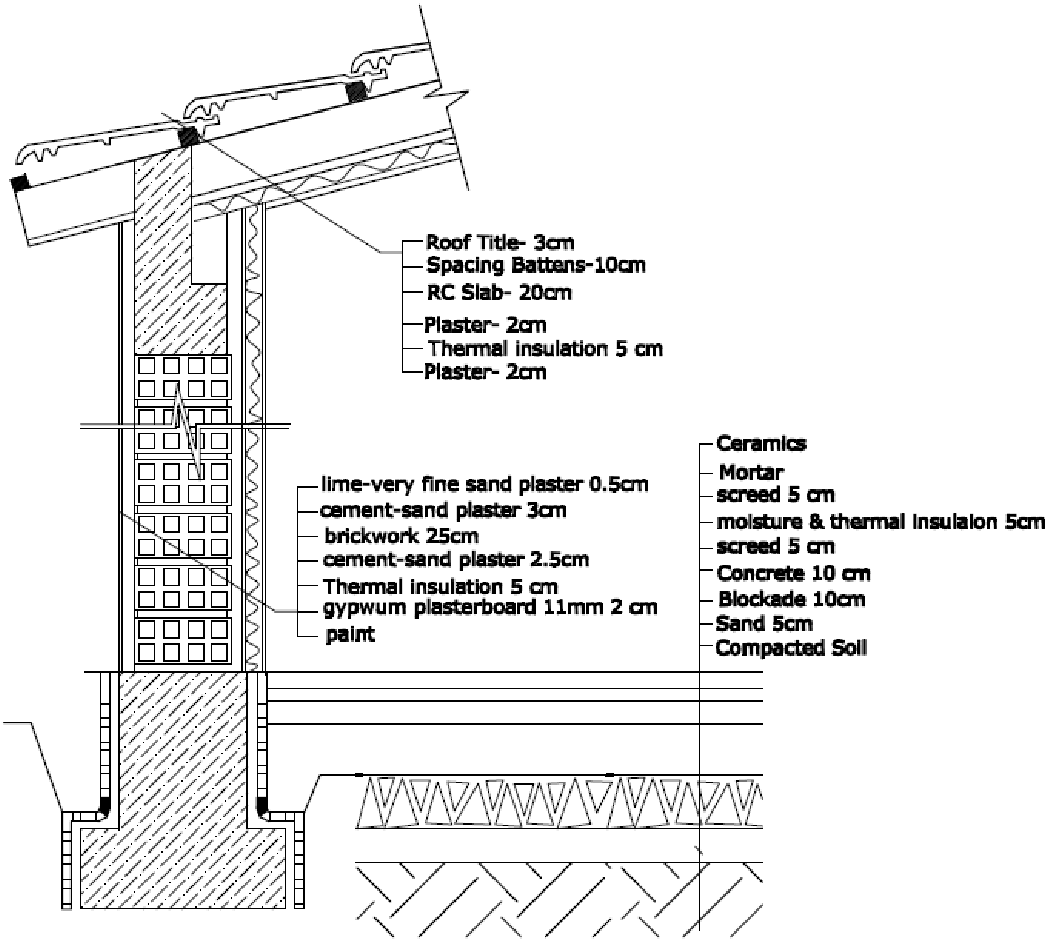

Figure 18: Construction Technique in Contemporary period- Brick wall- C_3

Table 15: Material properties of construction technique C_3

Construction element		Floor1						Wall1				Roof 1			
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement-sand Plaster	Brick work	Plaster	Reinforced Concrete slab	Spacing Battens	Roof tiles
Width (mm)		10	10	100	100	50	200	5	30	5	200	20	200	100	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.079	2.3	-	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920	769	800	837	1000	-	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300.0	1700	400	2300	-	1900
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.96	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11	34	19.2	8	11	9999	1.0	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	-	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	-	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90

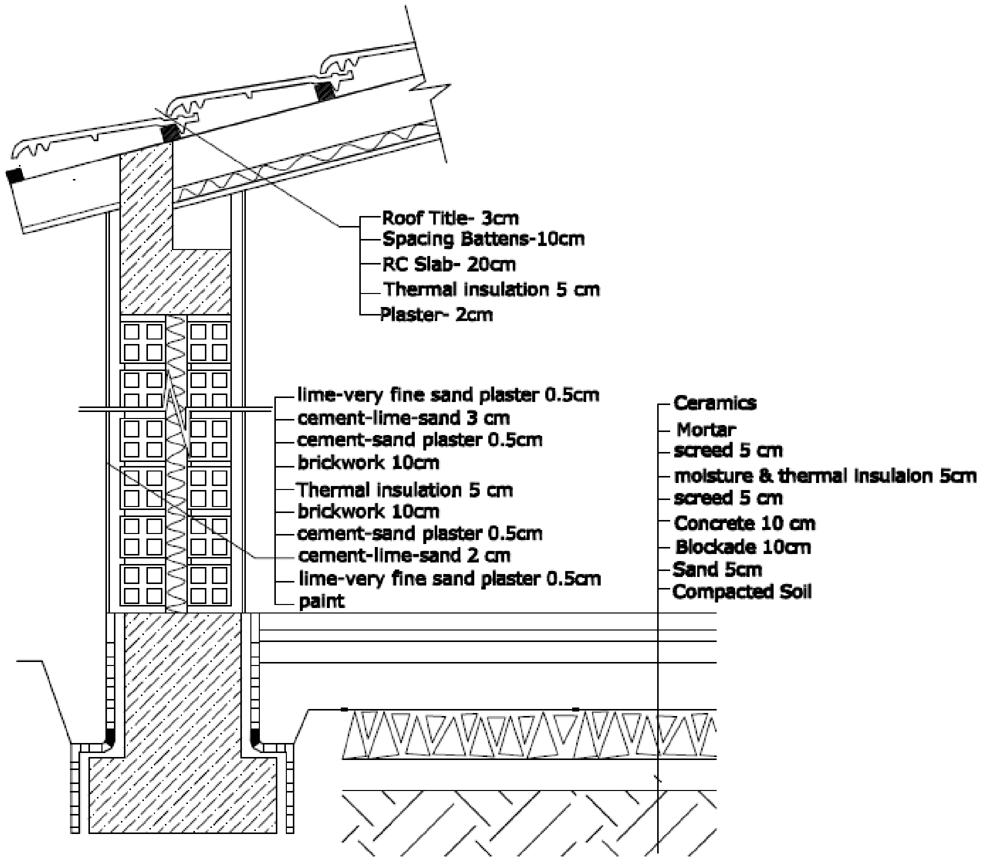

Figure 19: Construction Technique in Contemporary period- Brick wall- C_4

Table 16: Material properties of construction technique C4

Construction element		Floor1						Wall1				Roof 1			
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cemen t-sand Plaster	Brick work	Plaster	Reinforced Concrete slab	Spacing Battens	Roof tiles
Width (mm)		10	10	100	100	50	200	5	30	5	200	20	200	100	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.079	2.3	-	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920	769	800	837	1000	-	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300.0	1700	400	2300	-	1900
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.96	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11	34	19.2	8	11	9999	1.0	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	-	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	-	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90

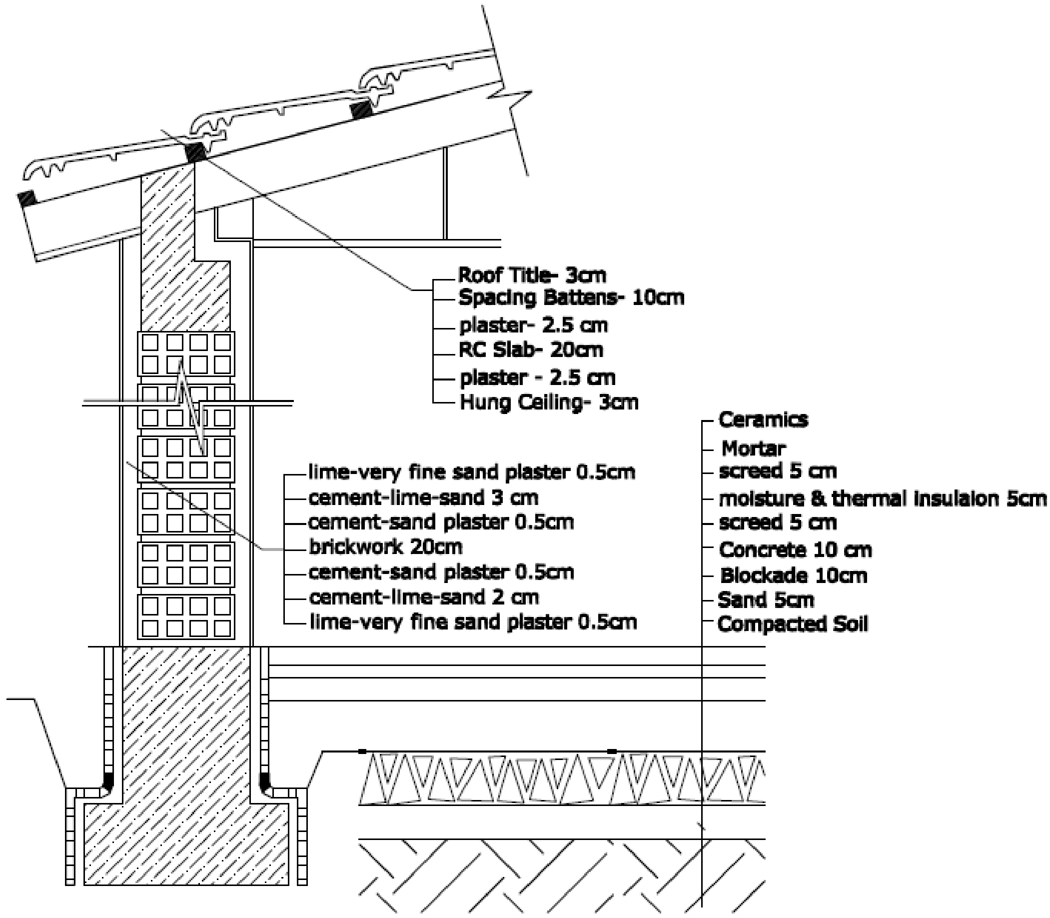

Figure 20: Construction Technique in Contemporary period- Brick wall- C_5

Table 17: Material properties of construction technique C_5

Construction element		Floor1						Wall1				Roof 1			
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement-sand Plaster	Brick work	Hung Ceiling	Reinforced Concrete slab	Spacing Battens	Roof tiles
Width (mm)		10	10	100	100	50	200	5	20	5	200	30	200	100	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.7	1.3	0.5	0.7	0.09	2.3	-	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920.0	769.0	800	1000	1000	-	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300	1700	250	2300	-	1900
Convection Coefficient (W/m2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.96	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11	34	19.2	8	9999	9999	1.0	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.30	0.30	-	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.30	0.30	-	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90

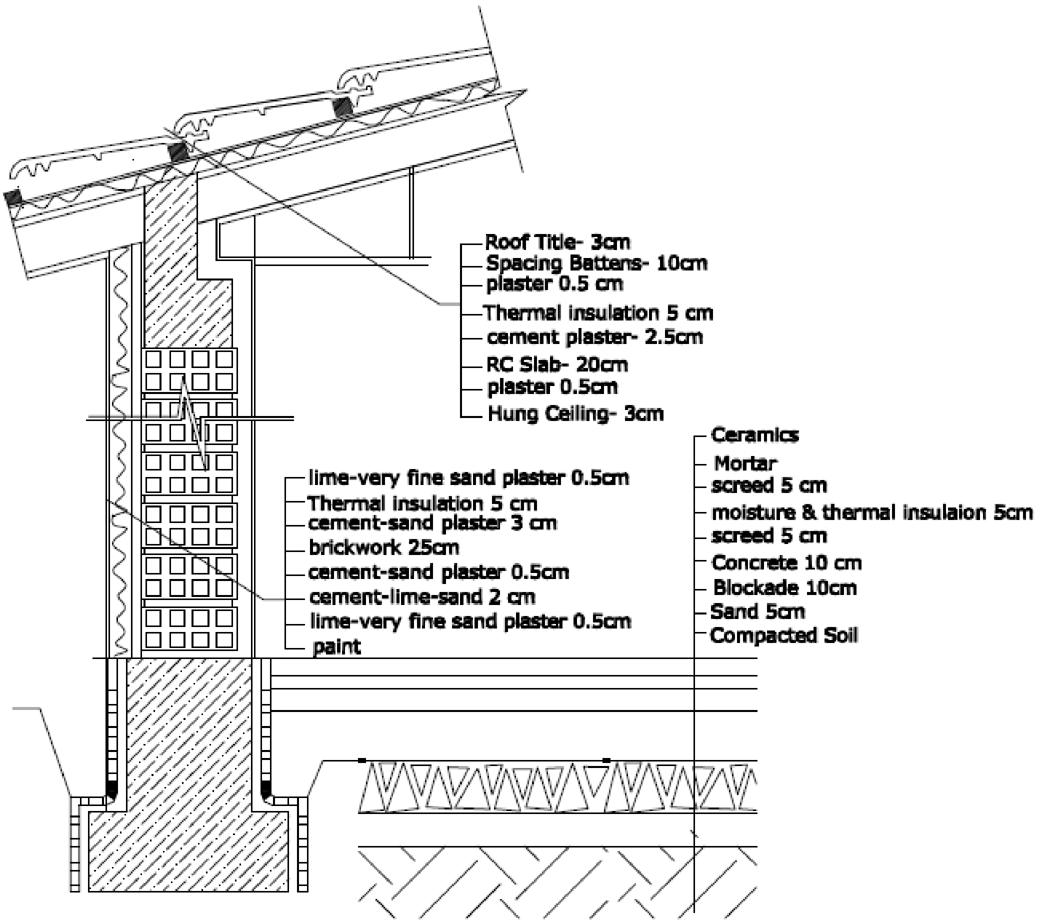

Figure 21: Construction Technique in Contemporary period- Brick wall - C_6

Table 18: Material properties of construction technique C_6

Construction element		Floor1						Wall1				Roof 1			
Material		Caramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement -sand Plaster	Brick work	Hung Ceiling	Reinforced Concrete slab	Spacing Battens	Roof tiles
Width (mm)		10	10	100	100	50	200	5	20	5	200	30	200	100	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.7	1.3	0.5	0.7	0.09	2.3	-	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920.0	769.0	800	1000	1000	-	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300	1700	250	2300	-	1900
Convection Coefficient (W/m2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.96	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11	34	19.2	8	9999	9999	1.0	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.30	0.30	-	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.30	0.30	-	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90

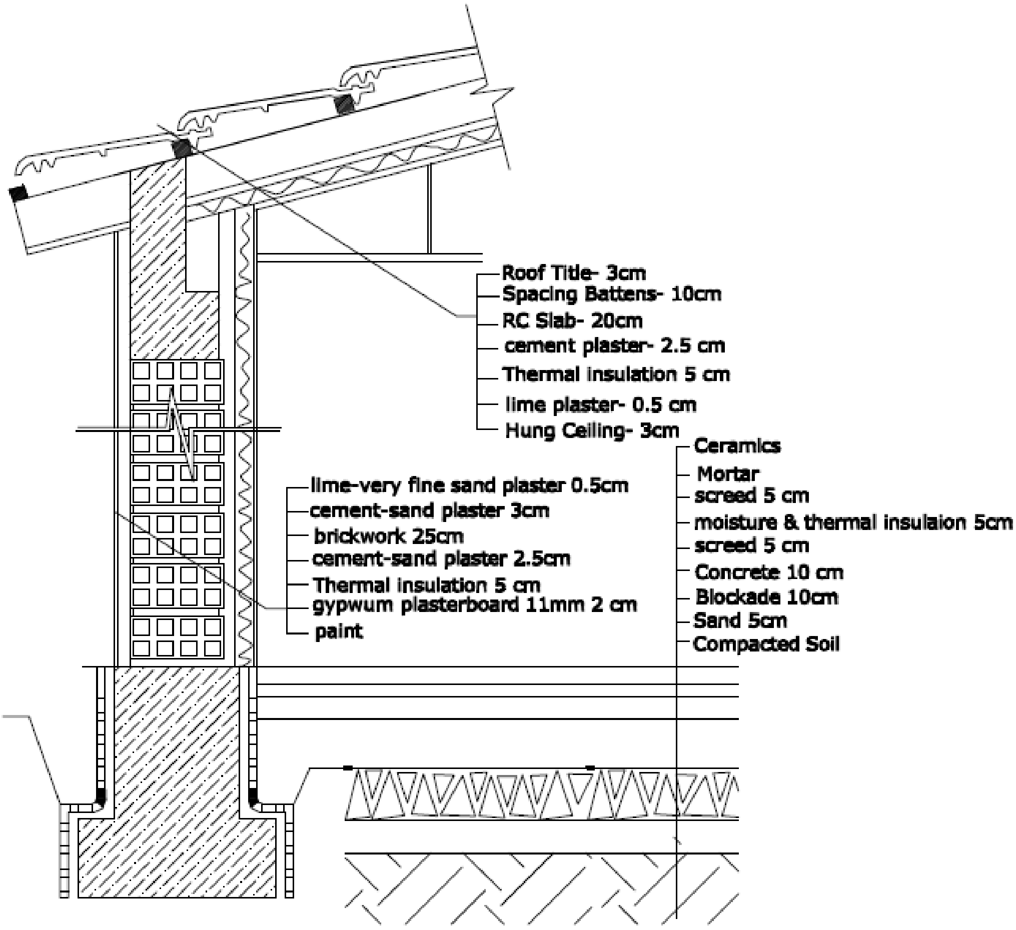

Figure 22: Construction Technique in Contemporary period- Brick wall - C_7

Table 19: Material properties of construction technique C_7

Construction element		Floor1						Wall1				Roof 1			
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement-sand Plaster	Brick work	Hung Ceiling	Reinforced Concrete slab	Spacing Battens	Roof tiles
Width (mm)		10	10	100	100	50	200	5	20	5	200	30	200	100	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.7	1.3	0.5	0.7	0.09	2.3	-	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920.0	769.0	800	1000	1000	-	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300	1700	250	2300	-	1900
Convection Coefficient (W/m2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.96	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11	34	19.2	8	9999	9999	1.0	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.30	0.30	-	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.30	0.30	-	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90

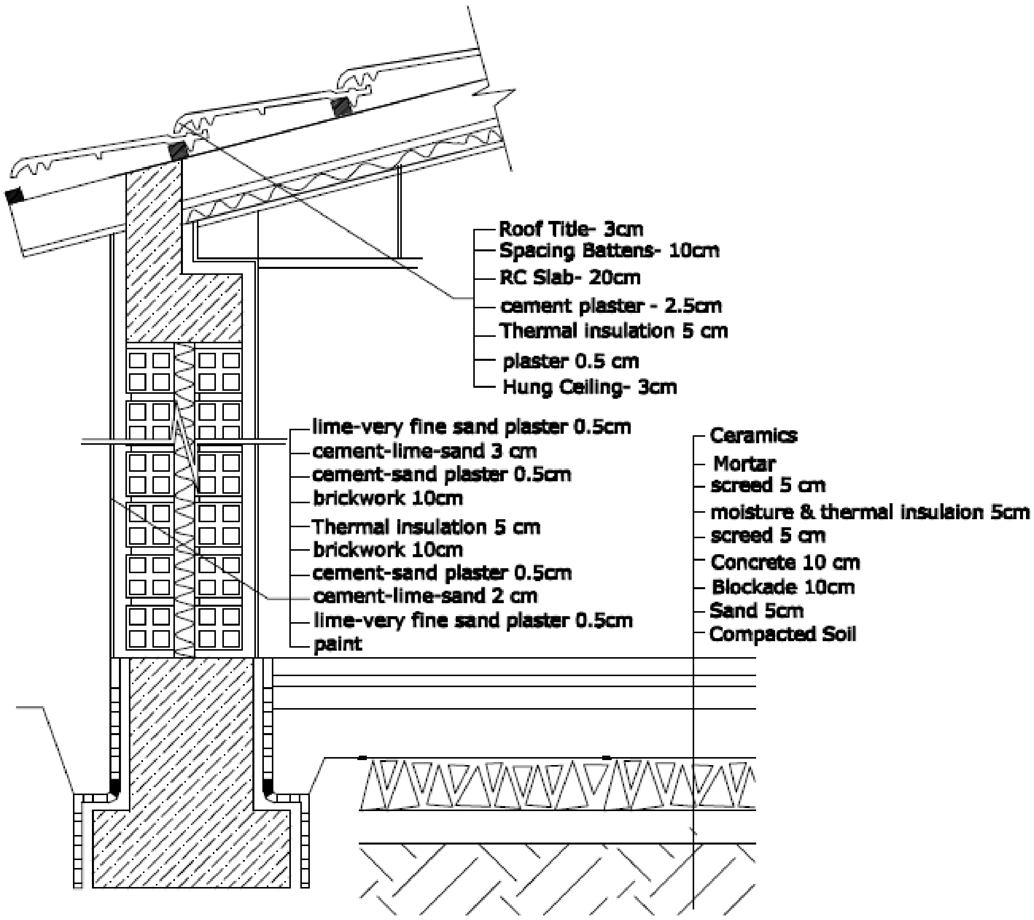

Figure 23: Construction Technique in Contemporary period- Brick wall - C_8

Table 20: Material properties of construction technique C_8

Construction element		Floor1						Wall1				Roof 1			
Material		Caramic Tiles	Morter	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement -sand Plaster	Brick work	Hung Ceiling	Reinforced Concrete slab	Spacing Battens	Roof tiles
Width (mm)		10	10	100	100	50	200	5	20	5	200	30	200	100	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.7	1.3	0.5	0.7	0.09	2.3	-	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920.0	769.0	800	1000	1000	-	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300	1700	250	2300	-	1900
Convection Coefficient (W/m2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.96	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11	34	19.2	8	9999	9999	1.0	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.30	0.30	-	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.30	0.30	-	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	-	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	-	0.90

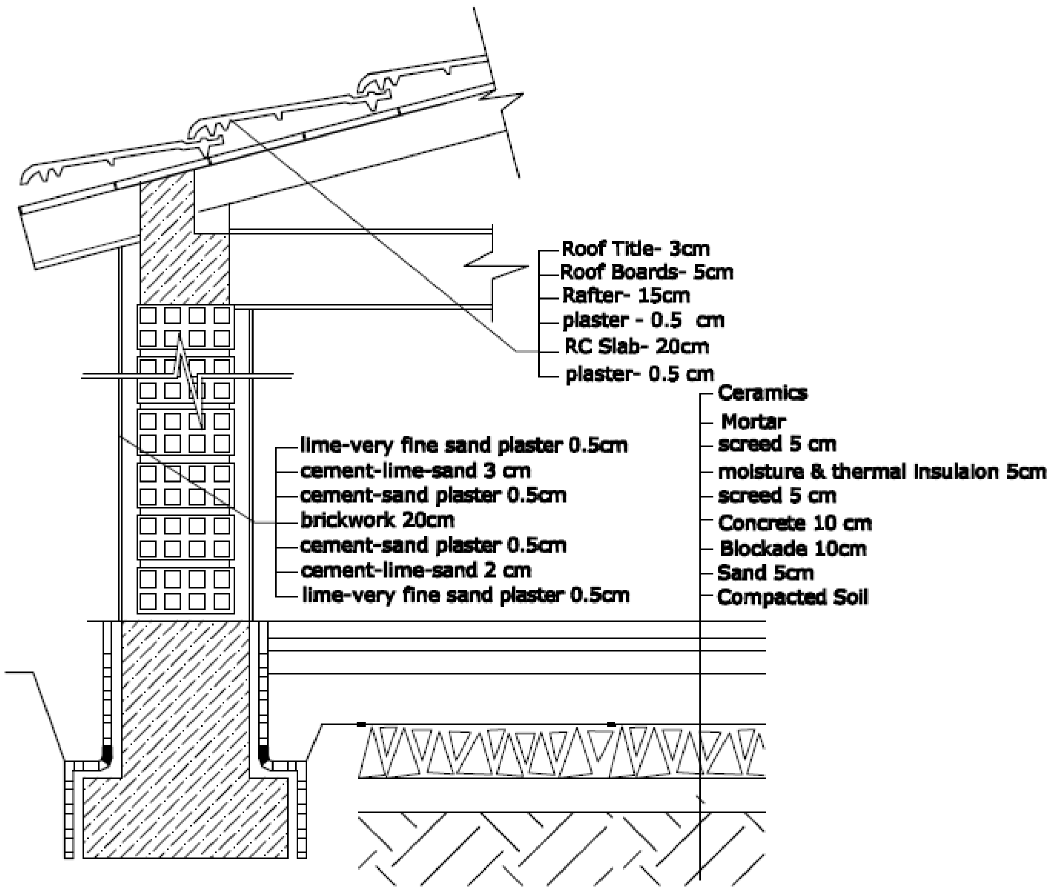

Figure 24: Construction Technique in Contemporary period- Brick wall - C_9

Table 21: Material properties of construction technique C_9

Construction element		Floor1						Wall1				Roof 1					
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement-sand Plaster	Brick work	Plaster	Reinforced Concrete slab	Rafter	Roof board	Insulation	Roof tiles
Width (mm)		10	10	100	100	50	200	5.0	20.0	5.0	200	20	200	150.0	50	5.0	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.079	2.3	0.144	0.164	0.4	0.85
Specific Heat (J/kg.C)		1000	1000	1000	1090	837	1000	837	920	769	800	837	1000	1420	1465.38	850	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300	1700	400	2300	560	1121.29	30	1900
Convection Coefficient (W/m2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.001	0.001	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11.0	34	19.2	8	11	9999	11.4	48	30	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	0.22	0.30	0.44	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	0.22	0.30	0.44	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90	0.90	0.90	0.90

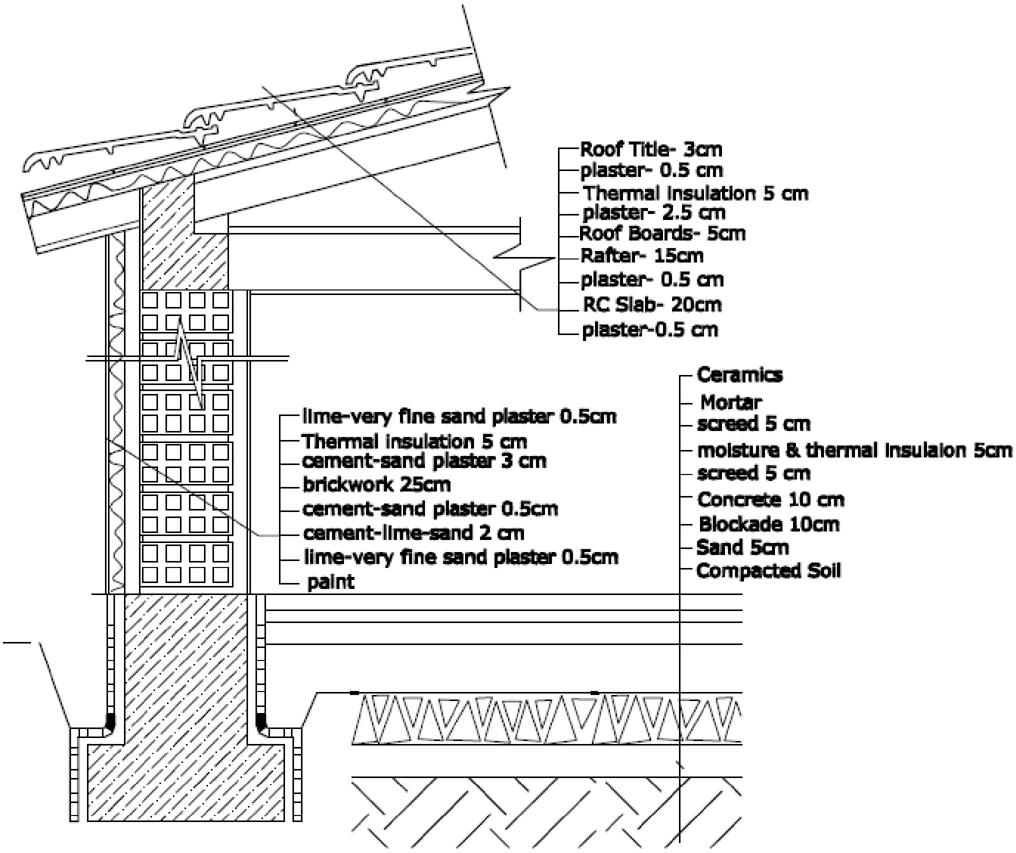

Figure 25: Construction Technique in Contemporary period- Brick wall – C_{10}

Table 22: Material properties of construction technique C_{10}

Construction element		Floor1						Wall1				Roof 1					
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement-sand Plaster	Brick work	Plaster	Reinforced Concrete slab	Rafter	Roof board	Insulation	Roof tiles
Width (mm)		10	10	100	100	50	200	5.0	20.0	5.0	200	20	200	150.0	50	5.0	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.079	2.3	0.144	0.164	0.4	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920	769	800	837	1000	1420	1465.38	850	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300	1700	400	2300	560	1121.29	30	1900
Convection Coefficient (W/m2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.001	0.001	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11.0	34	19.2	8	11	9999	11.4	48	30	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	0.22	0.30	0.44	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	0.22	0.30	0.44	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90	0.90	0.90	0.90

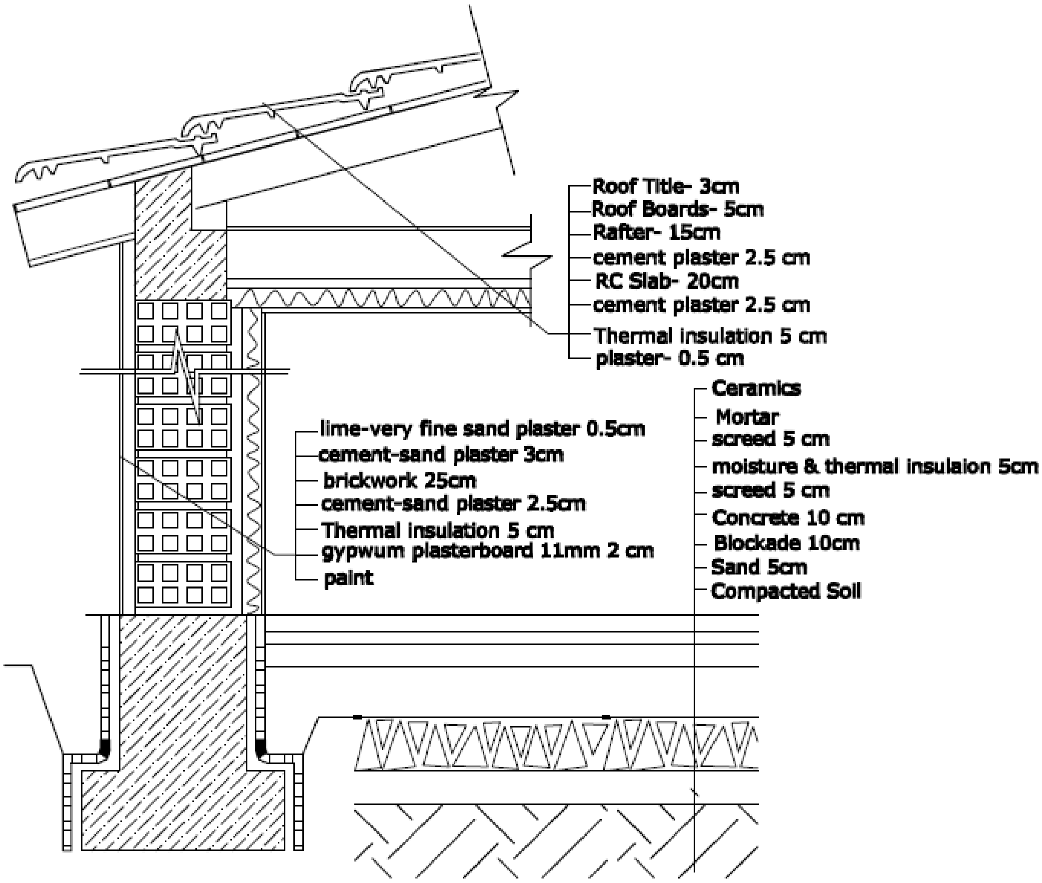

Figure 26: Construction Technique in Contemporary period- Brick wall – C_{11}

Table 23: Material properties of construction technique C_{11}

Construction element		Floor1						Wall1				Roof 1					
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement-sand Plaster	Brick work	Plaster	Reinforced Concrete slab	Rafter	Roof board	Insulation	Roof tiles
Width (mm)		10	10	100	100	50	200	5.0	20.0	5.0	200	20	200	150.0	50	5.0	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.079	2.3	0.144	0.164	0.4	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920	769	800	837	1000	1420	1465.38	850	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300	1700	400	2300	560	1121.29	30	1900
Convection Coefficient (W/m2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.001	0.001	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11.0	34	19.2	8	11	9999	11.4	48	30	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	0.22	0.30	0.44	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	0.22	0.30	0.44	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90	0.90	0.90	0.90

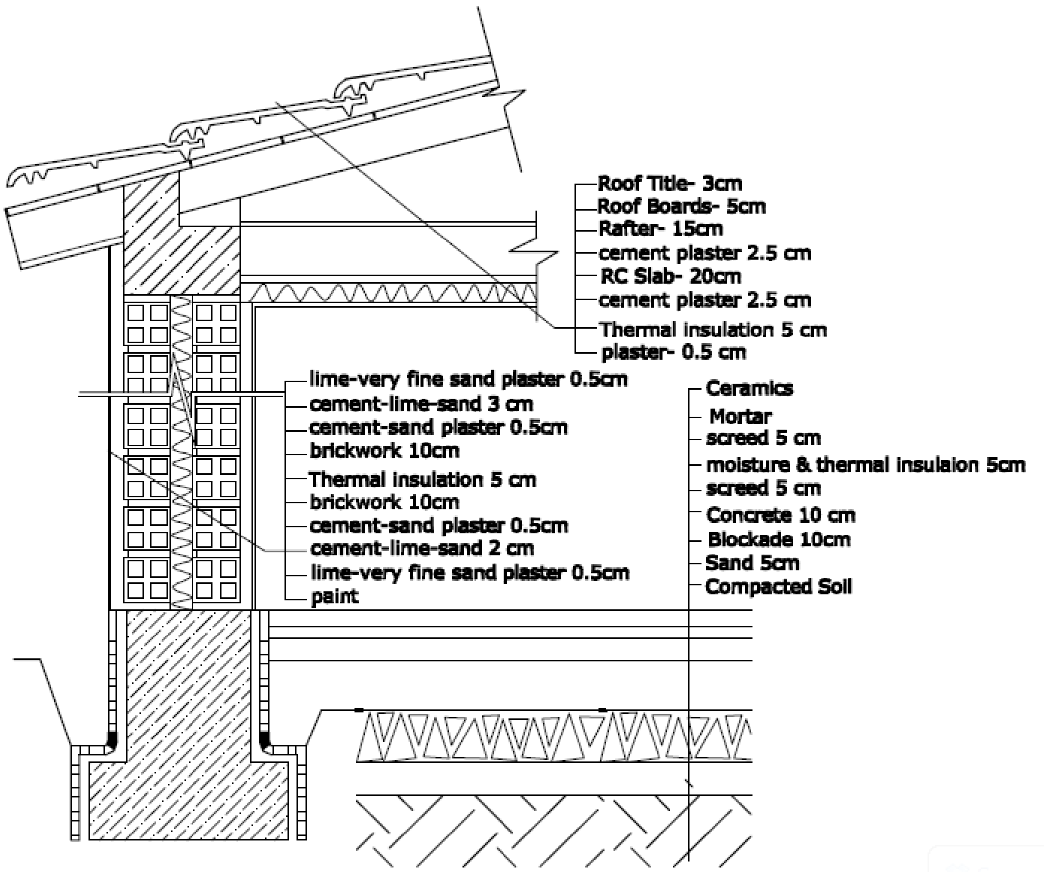

Figure 27: Construction Technique in Contemporary period- Brick wall – C_{12}

Table 24: Material properties of construction technique C_{12}

Construction element		Floor1						Wall1				Roof 1					
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement-sand Plaster	Brick work	Plaster	Reinforced Concrete slab	Rafter	Roof board	Insulation	Roof tiles
Width (mm)		10	10	100	100	50	200	5.0	20.0	5.0	200	20	200	150.0	50	5.0	30
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.079	2.3	0.144	0.164	0.4	0.85
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837	920	769	800	837	1000	1420	1465.38	850	837
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600	2240	1300	1700	400	2300	560	1121.29	30	1900
Convection Coefficient (W/m2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.001	0.0	0.001	0.001	0.0
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11.0	34	19.2	8	11	9999	11.4	48	30	52
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	0.22	0.30	0.44	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.60	0.30	0.22	0.30	0.44	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90	0.90	0.90	0.90

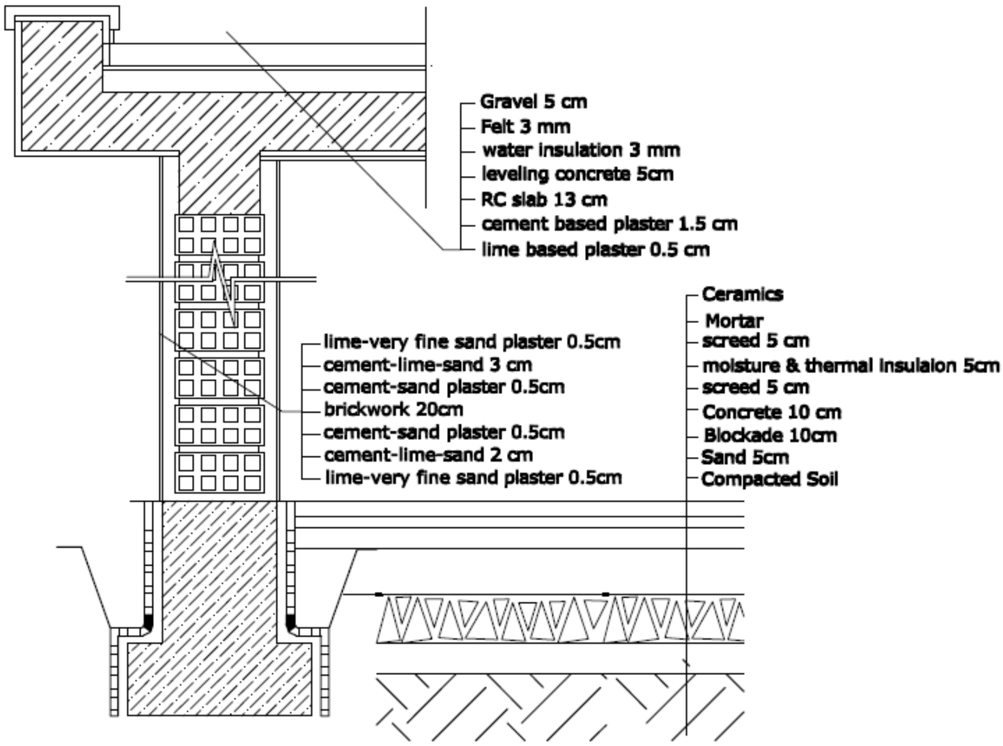

Figure 28: Construction Technique in Contemporary period- Brick wall – C_{13}

Table 25: Material properties of construction technique C_{13}

Construction element		Floor1						Wall1					Roof 5	
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement -sand Plaster	Brick work	Insulation	Plaster	Reinforced Concrete slab
Width (mm)		10	10	100	100	50	200	5.0	20.0	5.0	200	50.0	25	300
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.039	0.079	2.3
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837.0	920.0	769.0	800.0	840.0	837	1000
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600.0	2240.0	1300.0	1700	150.0	400	2300
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.001
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11.0	34.0	19.2	8.0	1.1	11	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.40	0.60	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.40	0.60	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90

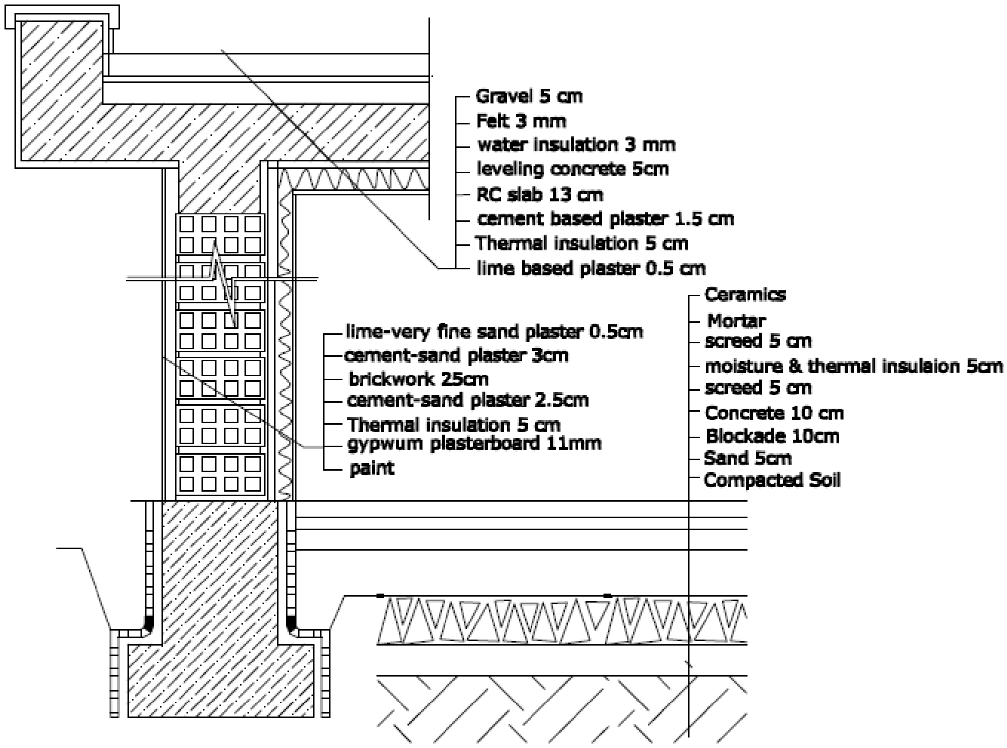

Figure 29: Construction Technique in Contemporary period- Brick wall – C_{14}

Table 26: Material properties of construction technique C_{14}

Construction element		Floor1						Wall1					Roof 5	
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement -sand Plaster	Brick work	Insulation	Plaster	Reinforced Concrete slab
Width (mm)		10	10	100	100	50	200	5.0	20.0	5.0	200	50.0	25	300
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.039	0.079	2.3
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837.0	920.0	769.0	800.0	840.0	837	1000
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600.0	2240.0	1300.0	1700	150.0	400	2300
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.001
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11.0	34.0	19.2	8.0	1.1	11	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.40	0.60	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.40	0.60	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90

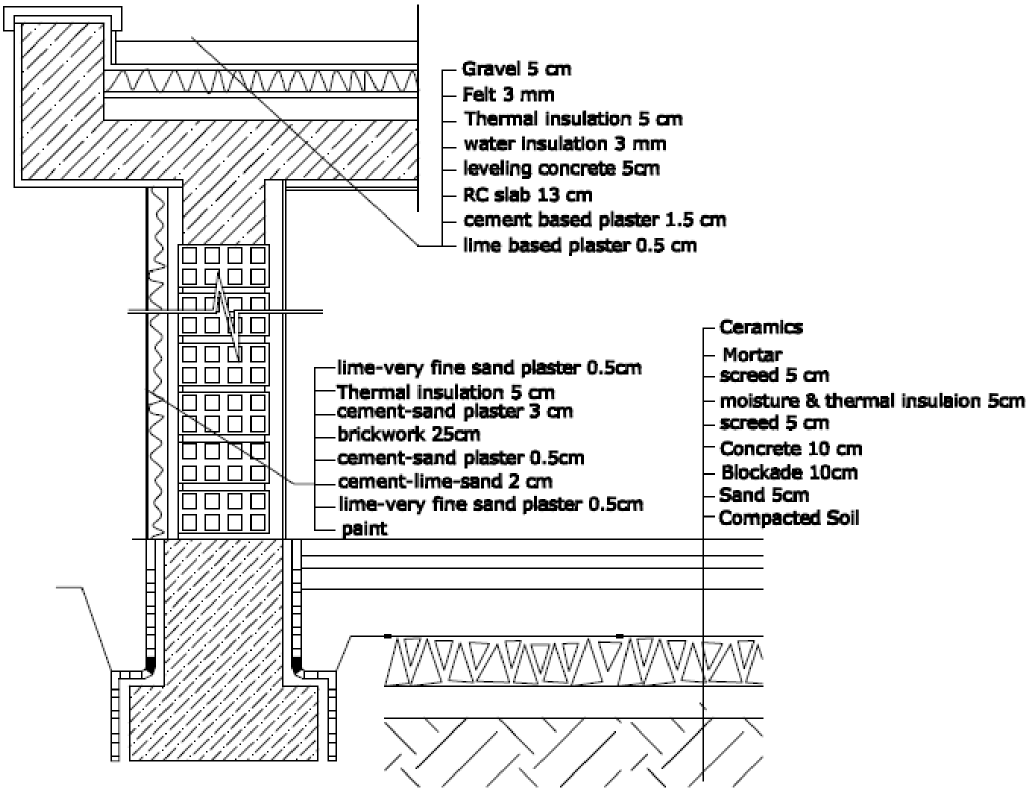

Figure 30: Construction Technique in Contemporary period- Brick wall – C_{15}

Table 27: Material properties of construction technique C_{15}

Construction element		Floor1						Wall1					Roof 5	
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement -sand Plaster	Brick work	Insulation	Plaster	Reinforced Concrete slab
Width (mm)		10	10	100	100	50	200	5.0	20.0	5.0	200	50.0	25	300
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.039	0.079	2.3
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837.0	920.0	769.0	800.0	840.0	837	1000
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600.0	2240.0	1300.0	1700	150.0	400	2300
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.001
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11.0	34.0	19.2	8.0	1.1	11	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.40	0.60	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.40	0.60	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90

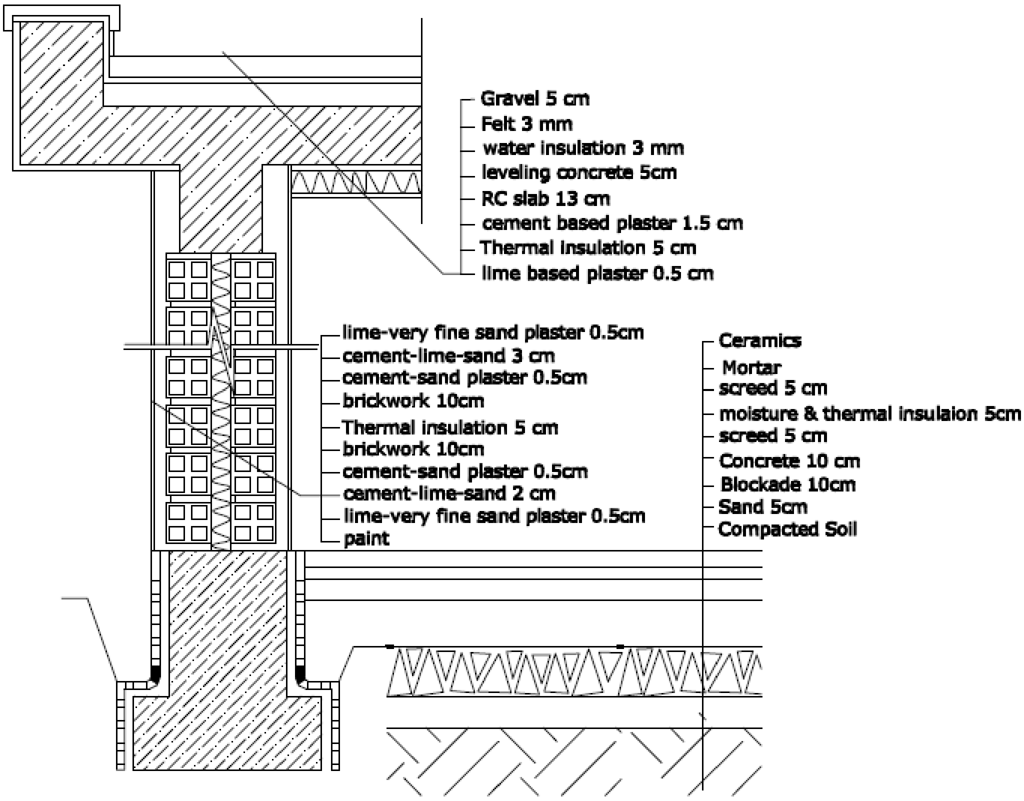

Figure 31: Construction Technique in Contemporary period- Brick wall – C_{16}

Table 28: Material properties of construction technique C_{16}

Construction element		Floor1						Wall1					Roof 5	
Material		Ceramic Tiles	Mortar	Concrete	Blockade	Sand	Compacted Soil	Lime fine sand plaster	Cement-lime-sand	Cement-sand Plaster	Brick work	Insulation	Plaster	Reinforced Concrete slab
Width (mm)		10	10	100	100	50	200	5.0	20.0	5.0	200	50.0	25	300
Conductivity (W/m.C)		1.3	0.88	2.3	1.44	2.0	1.5	0.70	1.3	0.5	0.7	0.039	0.079	2.3
Specific Heat (J/Kg.C)		1000	1000	1000	1090	837	1000	837.0	920.0	769.0	800.0	840.0	837	1000
Density (kg/m3)		2300	1750	2300	2480	2243	1000	1600.0	2240.0	1300.0	1700	150.0	400	2300
Convection Coefficient (Wm2.C)		0.001	0.001	0.001	0.0	0.001	0.001	0.0	0.0	0.0	0.0	0.0	0.0	0.001
Vapour Diffusion Factor		9999	9999	9999	34.0	9999	9999	11.0	34.0	19.2	8.0	1.1	11	9999
Solar Reflection	Ext.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.40	0.60	0.30
	Int.	0.30	0.30	0.30	0.35	0.30	0.30	0.60	0.35	0.60	0.28	0.40	0.60	0.30
Light Reflectance	Ext.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Int.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Emissivity	Ext.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90
	Int.	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.93	0.90	0.90	0.90

2.3 Thermal Comfort as an Evaluation Criterion in Buildings

These days, environmental crisis caused by overuse of fuels and fossil energy source, the energy supplies shortage and the dramatically growing of energy price are known as global concerns. Hence, all subjects related to this field such as energy management and energy renewable in all manufacturing sectors are essential challenging of governments to be able to save more energy, increase energy efficiency and prepare comfort conditions for users (Hastings ,Wall, 2007). For this aim, in construction industry, architects and contractors investigate on finding some solutions to speed up the process of energy saving (Sadeghi ,Shavvalpour, 2006).

To prepare comfort conditions for occupants, constructors deal with high energy consumption so the proper ways offering these conditions in buildings and adopted by human demands and environmental criteria can be the answer. Accordingly, considering to climatic design and vernacular architecture in order to achieve the energy efficiency and low environmental pollution seems so essential and important (Mendes, Scoffham, 1998)

"Vernacular architecture are typical examples which show how local climate conditions, materials, techniques, building systems and living style, traditions and socioeconomic conditions shaped people lived in the region. These buildings show harmony in every respect with the region where they were built." (Şerefhanoğlu Sozen, Gedík, 2007).

During designing process, designers analysis all concepts and ideas in terms of various architectural aspects categorized in some groups as sustainable, comfort condition, aesthetic and etc. "Comfort condition perspective involves the building typology, the form, the materials, thermal behaviour of the building shell, the thermal and the visual comfort conditions.” (Nguyen, Tran, Tran, Reiter, 2011)

Comfort condition is known as a package of factors defining the environmental conditions in terms of feeling wellbeing. The term of comfort would be persuaded as the lack of discomfort. People would complain about their states if weather is so hot or so cold and the air is odorous and antiquated. The sense of comfort or discomfort should be understood by a network of sense consists of ear, eye, nose, heat feelers, tactile sensors and at the head of them the brain.

The effective factors of pleasant feeling or unpleasant feeling include radiant temperatures, surrounding temperature, moisture, air motion, dust, odours, acoustics, lighting and aesthetics. In order to be in comfort, the human body requires a fairly narrow range of these factors.

The first four describe the thermal interactions among human body and its environment. To illustrate how thermal interactions influence the human comfort, the below explanation defines the thermal behaviour of human body in the vicinity the environment. So for achieving the ideal result in designing process considering to the climatic aspects in specific zone is as essential as the aesthetic aspect. Comfort thermal has been determined by air temperature, radiant temperature, air speed, humidity and some personal factors such as clothing insulation and metabolic rate. The main criterion in thermal comfort branch is air temperature controlled and rated easier (Michael, Bougiatioti, Oikonomou, 2010).

Human thermal comfort in built environment is gained by considering to the basic bioclimatic design's principles. The chief aim of bioclimatic design is to preserve indoors' thermal comfort conditions. Thermal comfort would be reached when there is a heat balance between a human body and environment. Thermal comfort is an effective part of satisfaction that is determined with the individual and a set of indirect factors (Meltzoff, Keith Moore, 1994).

Designers are interested in those climatic aspects affecting human comfort inside the built environment. They include means, variations and extremes of temperature, the differences of temperature among day and night, damp, incoming and outgoing radiation, rainfall and all types of air movements (Mallick, 1996).

Actually one of the main responsibilities of designer is to create the top possible indoor climate for the occupants to judge the design quality from emotional as well as physical point of view (szokolay, 1995). "The atmosphere in which people are in bio-climatically comfortable conditions consists of: relative humidity between 30 and 65%, temperature between 21 and 27.5 C, and wind speed up to 5 m/s."(Zengin, Kopar, Karahan, 2009)

The factors effecting human comfort would be categorized in to two parts:

1-Personal indicators such as human activity, types of clothing, level of sweat, dieting human habits, etc,

2-Environmental criteria such as air velocity and temperature mean radiant temperature, and humidity. In the built environment the second set directly depends on the building designing and its mechanical air conditioner system (szokolay, 1995)

- Air temperature

The temperature and mean radiant temperature of a standardized environment have lots of impacts on exchanging the "dry" heat between human body and surrounding environment by radiation and convection (Figure 32). The level of this heat exchange is based on the air velocity and the type of clothing. Under stable level of air velocity and vapor pressure: a growth in the temperature is responded to by a rise of skin temperature and amount of sweat. This amount of sweat also depends on the level of air velocity and moisture level (Givony, 1969).

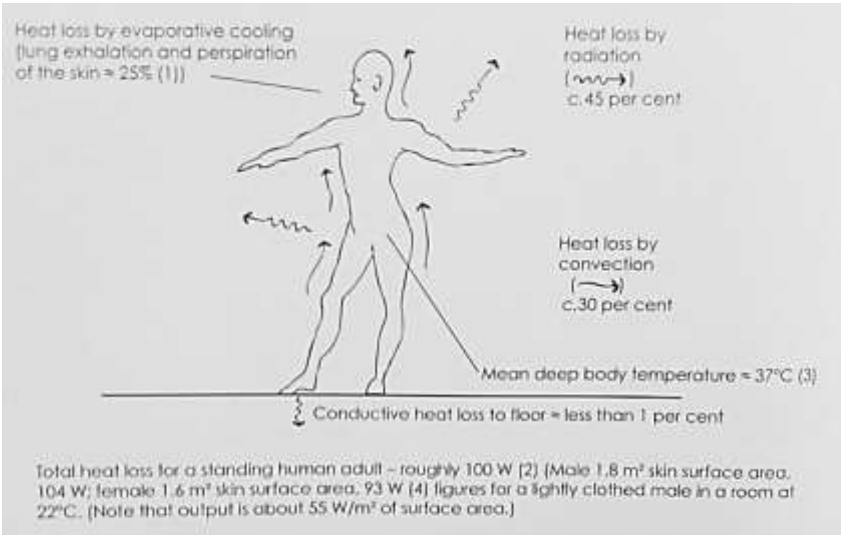

Figure 32: Heat transferring, (Thomas, Garnham, 2007)

- Humidity

Actually the humidity of the air indirectly influences on the human thermal comfort determines the capacity of the air evaporation. Considering to Givoni, when the temperature is between 20-25 °C and relative humidity is in the range 30-85%, the humidity does not affect the physiological reactions and it is almost invisible. But if the temperature is over 25 °C, the humidity's impact becomes gradually perceptible especially on the sweating level and skin temperature. A low level of relative humidity allows heat loss of the body through evaporation (Szokolay, 1974).

- Air Movement

Air velocity affects thermal comfort by both the air capacity of evaporation and the body‘s convective heat exchange. Air velocity’s impacts on the evaporative capacity are interrelated with the effects of humidity. The effects of air temperature, air velocity and convective heat exchanges are interrelated. If the air temperature is under skin temperature, these two effects work in the same direction. On the other hand, when the air temperature is above the skin temperature, these two effects operate opposite way (Thomas, Garnham, 2007).

Hence, it seems increasing the air velocity leads to the increase of evaporative capacity and cooling efficiency; though air velocity increase warms the body and causes higher convective heat exchange. There is an optimal value of the air velocity at high temperatures, which depends on the rat of temperature metabolic, clothing and humidity (Givony, 1969).

- Radiation

The thermal effects of solar radiation on the human body depend on clothing, wind velocity, body exposure to the sun and surroundings reflectivity. Clothing intercepts the solar rays, so that part of the heat is disintegrate to the environment and some part to the skin surface. The amount of solar heat dissipated is based on color and the clothing material (Szokolay, 1974). On the other hand other factors which take into account while talking about thermal comfort conditions are personal variables.

Human comfort pertains mainly to the ease with which the body can preserve a normal body temperature (about 37C). Everyone also have own comfort levels based on their individual physiology, experience and lifestyle. The final test of buildings performance is not decided by physical measurements or computer simulations; it should be done by the building occupants' reactions (Mallick, 1996).

Regarding different peoples clothing, it seems every people have different comfort level, but there is a common base for all. There is a conditions level where most people are comfortable. Normally, two main factors are taken into consideration while analyzing personal variables that are consist of activity and clothing.

- Activity

The amount of energy produced by the conversion of food per unit of time is the metabolic rate. Activity level influences on metabolic rate. The level of activity is expressed in Mets, which are watts per square meter of body surface area. 1 met is the metabolic rate a seated person when relaxing. (1met=58 W/m2) The average body surface area of an adult is about 1.8 m2 (Goulding, 1992).

- Clothing

Clothing offers man thermal insulation against his environment. This thermal insulation can be expressed in terms of m2 K/ W or clo units (Mallick, 1997). The thermal insulation properties of various types of clothing are given in "Table 29".

Table 29: Thermal comfort and clothing, (Hawkes, 2001)

Men		Women	
Clothing	clo	Clothing	clo
Underwear		Underwear	
Sleeveless	0.06	Girdle	0.04
T-shirt	0.09	Bra and panties	0.05
Briefs	0.05	Half slip	0.13
Long underwear, upper	0.10	Full slip	0.19
Long underwear, lower	0.10	Long underwear, upper	0.10
		Long underwear, lower	0.10
Shirt		Blouse	
Light, short sleeve	0.14	Light, long sleeve	0.20
long sleeve	0.22	Heavy, long sleeve	0.29
Heavy, short sleeve	0.25	Dress, light	0.22
long sleeve	0.29	Dress, heavy	0.70
(Plus 5% for tie or turtleneck)			
Vest, light	0.15	Skirt, light	0.10
Vest, heavy	0.29	Skirt, heavy	0.22
Trousers, light	0.26	Slacks, light	0.10
Trousers, heavy	0.32	Slacks, heavy	0.44
		Sweater	
Sweater, light	0.20	Light, sleeveless	0.17
Sweater, heavy	0.37	Heavy, long sleeve	0.37
Jacket, light	0.22	Jacket, light	0.17
Jacket, heavy	0.49	Jacket, heavy	0.37
Socks		Stockings	
Ankle length, thin	0.03	Any length	0.01
thick	0.04	Panty hose	0.01
Knee high	0.10		
Shoes		Shoes	
Sandals	0.02	Sandals	0.02
Oxfords	0.04	Pumps	0.04
Boots	0.08	Boots	0.08
Hat and overcoat	2.00	Hat and overcoat	2.00

As a conclusion, some of the factors that affect the adequate comfort in spaces were given above, by this way, it is understood that creating comfort in spaces has lots of factors including thermal comfort conditions. In addition, climate, human needs and such aspects are other conditions for providing comfort.

2.3.1 Conventional Models of Thermal Comfort

Researchers explore the human psychological, physiological and thermal response in different condition to predict human responses to level of environment's thermal quality by developing mathematical models. "Thermal comfort" is a circumstance of mind which shows people's satisfaction with the environment thermal (ANSI/ASHRAE 55, 2004). Indeed, thermal comfort is a combination of parameters related to human body and environment condition. (ANSI/ASHRAE 55, 2004)

2.3.2 Fanger's Approach

Fanger advanced the thermal comfort model for first time (Fanger, 1970), and specified that the thermal comfort condition is such situation that skin temperature is close to sweat secretion. Fanger used data from climate experiments in which human sweat rate and skin temperature were measured, he wants to know how much the level of their thermal comfortable condition is. Then he determined an estimation of sweat secretion and skin temperature as a metabolic rate, it was done by regression analyzing the measured data. Hence, optimal thermal comfort would be inferred to metabolic rate, wear insulation and environmental circumstances. The thermal environment involves the air temperature, the radiant temperature mean, and water vapor partial pressure in air. To sum up, satisfying of the comfort equation is a condition for optimal thermal comfort.

Additionally, Fanger offered a method to forecast the real thermal sensation of people in a random climate where the variables may not satisfy the equation: the Predicted Mean Vote (PMV). This parameter is the difference between the internal heat production and the heat loss in a real environment for a person that is comfort values for skin temperature and sweat production ". (Fanger, 1970)

2.3.3 International Standards on thermal comfort

The PMV and PPD indices are used in the ISO 7730 that is an International Standard to predict the human thermal sensation exposed to moderate thermal environments, like when acceptable thermal environmental circumstances are specified for feeling comfort (ISO 7730, 2005).

2.3.4 Remarks on current methods

The PMV and PPD are described upon on stable state of laboratory experiment mostly people who wear standardized and normal uniforms (Jones, 2000), (Stoops,2004) and (Humphreys, Nicol, 2002).

Sometime the effect of adaptation on PMV or PPD parameters is disregarded. There are various adaption forms, which are connected and can influence one another (Brager, Dear 1998) and (Kurvers, S., 2007)

Psychological adaptation is based on indoor environment, experiences and expectations. This type of adaption involves genetic adaptation and acclimatization (Humphreys , Hancock, 2007), (Shove, 2004)and (Holmes , Hacker,2007).

Genetic adaptation is related to effects on timescales that is beyond the individual's lifetime. Acclimatization adaption changes the settings of the system of physiological thermoregulation during a period such as a few days or a few weeks.

Behavioural thermoregulation, or adjustment, contains modifications that people may make consciously or unconsciously, which can turn mass fluxes and modify heat of the body's thermal balance (Brager, Dear 1998): personal, technological or environmental and cultural adjustment (Fiala , Lomas , 2001).

2.4 Energy Efficiency in Building

Todays, Because of decreasing the level of energy resources and oil crisis and increasing the energy price, human have been forced to use another alternative energy sources and also attempt to access more energy efficiency (Arthus-Bertrad, 2009).

Efficient energy use which is called simply Energy Efficiency (EE) aims to decrease the required energy and relevant costs. Energy efficiency developments and related actions and decision makings are so critical in construction industry (Urge-Vorsatz, Tirado Herrero, 2012). Though the implementing energy costs of efficient technology are high, the energy savings can offset any additional costs and the investment of energy (Granderson, Piette, Ghatikar 2011).

Energy efficiency is the output and quality measurement of a project or product per unit of energy input which can be achieved by reducing the required energy or by increasing the quantity or quality of products' output while keeping the level of energy uses.

International Energy Agency (IEA) stated that energy efficiency improvement in building and construction industry can reduce required energy of the world by one third until 2050 (Gustavsson, Joelsson, 2010). In order to achieve energy efficiency in construction projects, several approaches have been followed by countries around the world. For instant the Asia and China governments try to ensure that new buildings are built to high standards of energy efficiency with improving building equipment and materials. Furthermore, using solar cells and traditional and vernacular design in buildings is now a popular in Japan's residential buildings. Thailand's government held training courses in order to make both owners and contactors more familiar with the potential of energy savings in buildings using vernacular architecture (Wu, Ren, Tang, 2009).

European Commission to access more energy efficiency in building prepared energy efficiency certificate and instrument for every building to enforce owner to consider more to traditional architecture (Doukas, Nychtis, Psarras, 2009). Also in the United States, over the last decade, the Californian new buildings have been designed to achieve 30-40 percent of energy savings by changing some basic material (Zehner, 2012).

Studding and focusing on material components in a building over the design phase and using more natural potential of energy saving in a building causes more energy efficiency. The aim of applying energy efficiency techniques such as building modeling is to simulate material and natural attitude of a building to reduce indoor heating demand (Ries, Jenkins, wise, 2009). By building modeling, designer can infer that how plan would be in accordance with environment, on the other hands designers can fit their plan with natural condition that provide more Energy efficiency (Zhou, Levine, Price, 2010).

2.4.1 Basic Thermal Terminology for Building Materials

To discuss about energy consumption, heat transfer, energy efficiency and all related fields, there are some terms, definitions and criteria as following.

2.4.1.1 Thermal Conductivity

Thermal conductivity identified as Lambda (λ), is the specific measure of how easily heat moves through a specific material, without considering to the thickness of the material. The lower the thermal conductivity of a specific material causes better thermal performance. (Van Geem, 1987)

2.4.1.2 R-VALUES

The R-value is known as a measure of resistance to heat movement through a specific thickness of material. So the higher R-value results in more thermal resistance of the material and therefore causes better insulation properties. The R-value is a simple way to compare two insulation materials. Unfortunately, as heat movement occurs in and out of the building through several various ways and R-values only take into conduction so it does not include radiation and convection. (Yılmaz, 2007)

2.4.1.3 U-VALUES

The U-value is determined as a measure of how much heat is transferred through the thickness of a particular material. Unlike R- Value, U- value includes the three main ways of heat transfer: convection, conduction and radiation. Whatever U- value is lower, the material is better as a heat insulator. (Yılmaz, 2007)

2.4.1.4 Thermal mass

Thermal mass has been defined as a kind of ability belonging to the materials to store considerable amounts of thermal energy and postpone the heat transfer. Thermal mass often determined by “building envelope” as following:

Masonry, Concrete and insulating materials (Kalogirou, Florides, Tassou, Energ, 2002)

2.4.2 Evaluation Methods in Buildings for Energy Efficiency

Energy efficiency requirements can be calculated in many ways:

- Prescriptive: This technique assesses requirements of energy efficiency separately for each building part and for each equipment part.
- Trade-off: Values are fixed for each building part, but a trade-off made some better and worse values than the requirements.
- Model building: Values are fixed in the trade-off, and a model in accordance with real shape which is calculated by these values. A calculation reveals that the real building will be as well as the building model.
- Energy frame: A general structure forms the standard for maximum energy loss of a building. Assessing the building shows this maximum amount is respected.

- Performance: The requirements of Energy performance upon on overall consumption of energy or emissions of greenhouse gas of a building.

2.4.2.1 Prescriptive

The requirements of energy efficiency are fixed for each building component by using the prescriptive technique.

It is a thermal value (U-value) of windows, walls or roofs. The prescriptive techniques include efficiency values for installation in terms of technical aspects, building orientation and ventilation, solar gains, window's number and size. To obey a prescriptive standard, all parts of a building should have their specific value. For instant a simple prescriptive building code covers thermal values for the 5–10 parts of building, essentially.

In the most cases, the requirements of energy efficiency are set for each building's part and installations, containing heating installation, cooling parts, fans, pumps, and lighting. These requirements also can be adjusted based on the equipment's size or the windows' size rather than the area of the floor or wall.

In general, instructions for the prescriptive technique can be implemented easily. U-values can be implemented by typical constructions descriptions which leads some requirements such as requirements for equipment which including products labeling. In some cases, a prescriptive technique requires to be labeled A or B, or valued through energy stars.

2.4.2.2 Trade-off

The trade-off technique sets values for each individual part of building and / or for each installation's part, as well as the prescriptive technique. Generally, the trade-off is made in simple terms. Trade-off is made between U-values of building shell or between the building shell and the requirements of energy efficiency for heating and cooling fittings and installation. The trade-off model is able to provide more flexibility than the prescriptive techniqe.in this method, the calculations are always simple and it can be done by hand (Granderson, Piette, Ghatikar 2011).

2.4.2.3 Model Building

In the model of building technique, values are determined for each building part and / or for the parts of the technical installations. A model building is analyzed by values of losses and efficiency based on all actual building values and characteristics. The real building is then assessed by the similar method by using the real values of the individual parts of the building, heating, cooling, and ventilation systems. The total result of the calculation is compared with the model building and the actual building must be performed as well as or better than the model building (Gustavsson, Joelsson, 2010).

The most complicated models include all parts of the technical systems in these calculations, including all parts of heating systems, ventilation, cooling, lighting, built in equipment etc. Renewable energy can be included in the calculations, to make a solar collector, for instance, reducing the general efficiency requirements for the heating system or even the insulation level.

The model building gives more freedom and flexibility for building designers and constructors than a prescriptive model. Expensive systems can be changed with improved efficiency in parts of the building or installations where efficiency will be more cost effective (Arthus-Bertrad, 2009).

2.4.2.4 Energy Frame

The maximum of energy loss from a building is set for Energy Frame of that building. This is typically as building's total frame. The energy frame focus on calculating the energy losses by simple values, for instant the u-values, temperature, surface and heat that gained from sunlight etc. This model does not use the values of individual parts; they are just set for total loss or energy usage. This method enables the constructor to build parts of the buildings that are less energy efficient when other parts are made better than typical constructions.

This method can avoid limiting the window size, as improve windows or increase insulation. Moreover, energy frame can be determined as an overall thermal value (adjusted u-value), pr. square meter of the area of building floor or something such this (Granderson, Piette, Ghatikar 2011).

2.4.2.5 Energy Performance

By the energy performance technique, the building's requirements are set in accordance with energy supply or the results of environmental impacts. This method needs to use a complete method for calculating the energy performance of a building based on standard values of climate and use of the different types of buildings. An advanced computer based model is required to be applied for the calculations, in order to integrate all parts and also installations of the building.

Values of energy performance should be matched based on an overall value consumption pr. m^2, for different usage or different buildings types. Installations in order to access renewable energy in the building can be calculated as improvement in performance method. In this method, there is a need to handle multiple factors as gained solar, energy losses recovery, installations shading and efficiency. Energy performance method provides optimal freedom for designers to decrees energy consumption through the frame (Arthus-Bertrad, 2009).

2.4.2.6 Mixed models, hybrids

In some cases designer use a mix of models. For example, an energy frame for the building might be combined with prescriptive values for installed products. Therefore, designers can use a simple model to or select a more complicated model with more flexibility and freedom.

2.4.2.7 Development

Some countries start prescriptive values for the cases that energy efficiency requirements raised and more elements required. Today, using the energy performance models and computer applications increased in designing. International standards have been provided to develop and harmonize models for energy performance calculation.

2.5 Thermal Comfort and Energy Efficiency Simulation

Regarding to the technology development, the opportunity for quantitative calculation of thermal comfort is provided by improving computer software and various energy simulation methods. The computer modeling programs provide a condition for designers to estimate, analyze and compare their buildings simulations according to their actual parameters of design. The main purpose of these simulation applications is to determine and select the best design alternative based on more energy saving, decreasing energy usage and providing the indoor comfort conditions.

This goal can be obtained by modeling the building, materials and stature in details. Various simulation computer programs make ability for constructors to evaluate their projects by lots of methods. Among them TAS software is a simulation software for modeling the building exactly and calculate its thermal performance based on the environmental conditions and the structure specification of building and provide an ability for designer to evaluate building according to ASHARE standards to define the comfort zone for users (Figure 33).

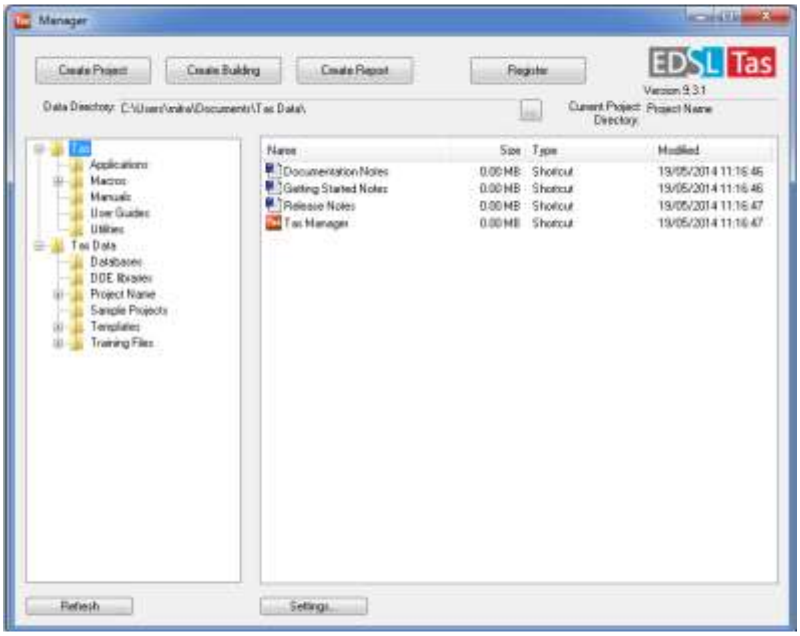

Figure 33: TAS simulation program

Chapter 3

EVALUATION

3.1 Evaluation of the Residential Building in Cyprus in terms of Thermal Comfort and Energy Efficiency

According to the previous steps, this study will focus on the various construction techniques throughout the history of Northern Cyprus. There are twenty one construction techniques classified in three categories: Ottoman period, British period and modern period. They are different in materials, properties and structure which cause different level of thermal comfort and energy consumption. These construction methods are also can be categorized in two main groups, vernacular and contemporary.

The main goal of this level is to analyze why inhabitants were more satisfied with indoor thermal comfort in compare with nowadays. For this aim, one simple square (5.5*6.5) room is modeled as a living area with the walls to a height of 3 meter and all 28 construction techniques are applied to it considering to specific and similar condition in order to compare the thermal behavior of each construction method. All this process is followed through TAS simulation program in view of the Famagusta climate to evaluate thermal comfort and energy usage based on equal parameters (Figure 34-37).

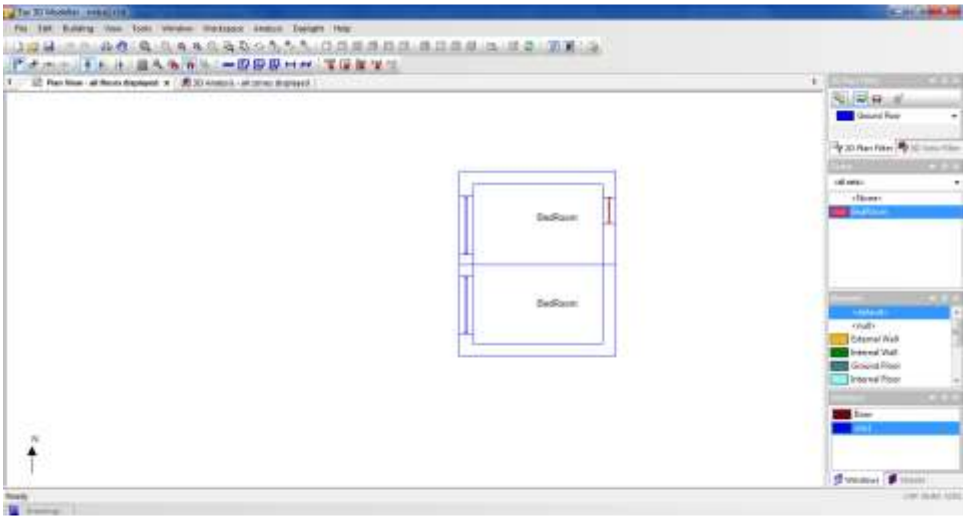

Figure 34: the modeling – planning phase

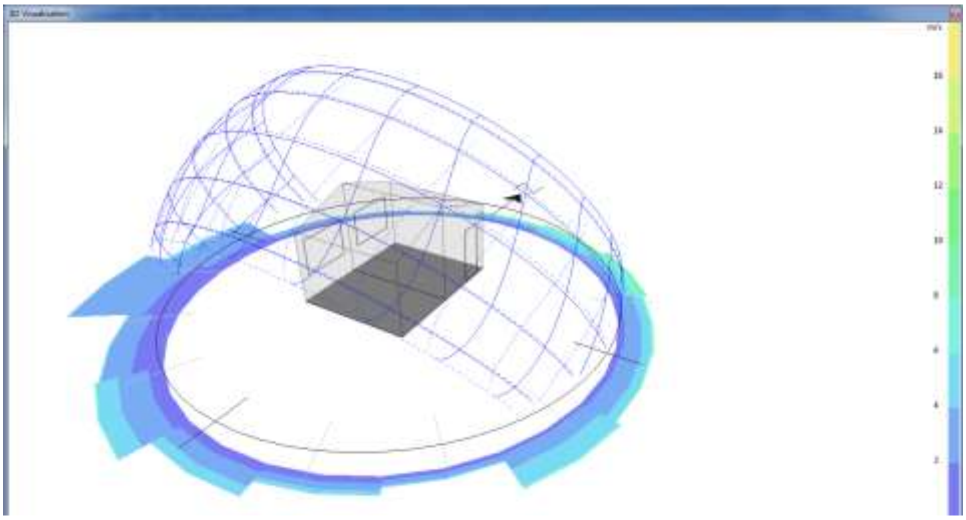

Figure 35: 3D view of modeling- construction technique with slope roof

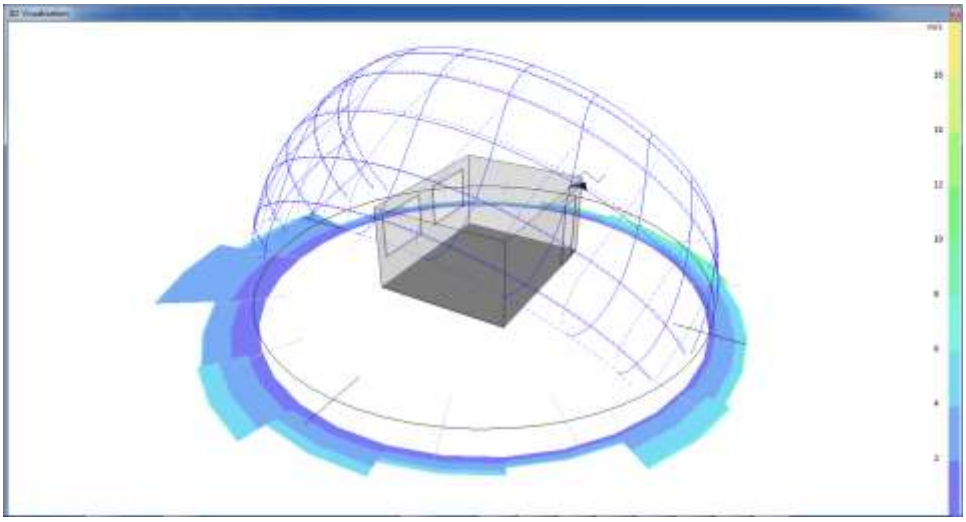

Figure 36: 3D view of modeling- construction technique with flat roof

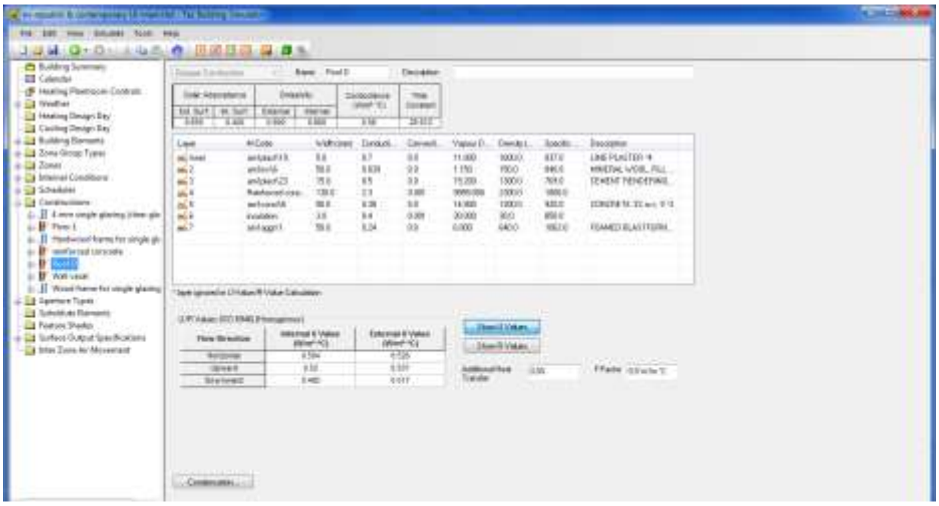

Figure 37: the modeling- applying the construction materials

The evaluations will be done in 2 main steps, thermal comfort and Energy loads, and will be supported by the third step, thermal behavior. The first step presents the absolute PMV hours for each construction method under the naturally ventilated indoor environment condition which gives this opportunity to distinguish which one is more adoptable for this climate. For this aim in modeling phase two windows and one door are considered which are assumed to be opened half of the day during the year. Then the natural ventilated condition is applied for internal condition (Figure 38).

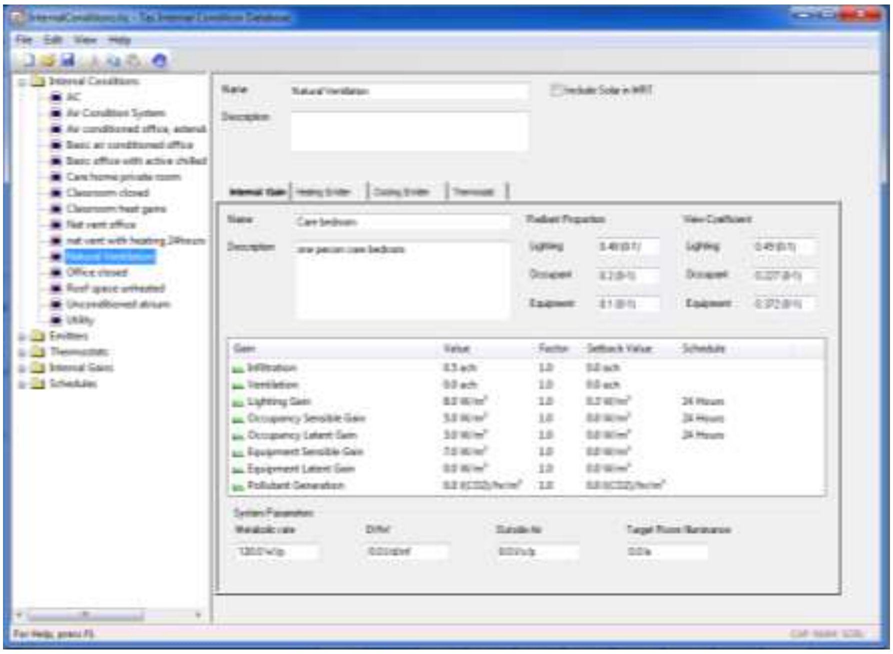

Figure 38: the modeling- naturl ventilation as internal condition

The second stage illustrates the level of energy loads considering to the indoor specifications to prepare comfort zone for inside. This step helps to find out how much energy loads would be requested for cooling and heating system to preserve the indoor temperature between 21-24 °C according to the construction technique. (Figure 39).

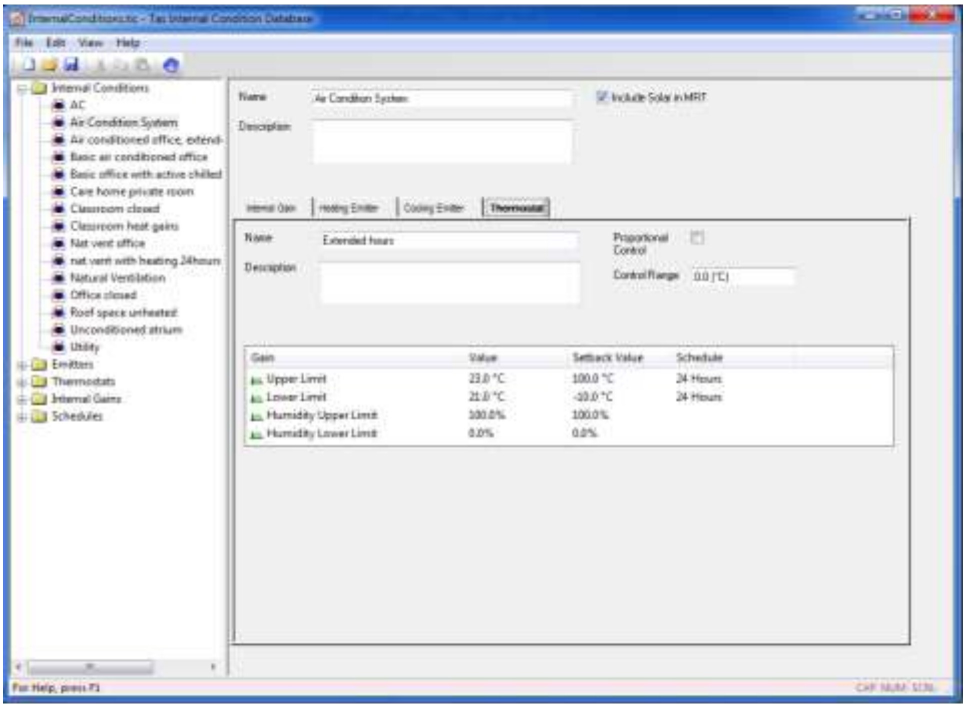
Figure 39: the modeling- air conditioned condition as internal condition

The third stage is a supportive step for the previous ones releasing the thermal behavior of each construction technique by simulating the heat transfer among indoor and outdoor during the specific days. This stage would explain about the different performance of each building elements of various construction methods during the simulation process by comparing their internal surface temperature.

3.1.1 Evaluation of the Construction Systems in Terms of Thermal Comfort with Naturally Ventilated Indoor Environment

In this step all of construction techniques are analyzed regarding to natural ventilation to find out how long each one can provide PMV between -0.5 and 0.5. This range is identified as absolute PMV. The square room (5.5 * 6.5) is modeled with 2 windows and one door which are assumed 50% opened during the day. This modeled room is presumed as doweling with one inhabitant and located in Famagusta.

In this phase all 28 construction techniques will be compared based their annual absolute PMV hours to distinguish which one is more able to prepare thermal comfort for occupants. Then the absolute PMV hours would be calculated during the different seasons and compare all construction methods based on seasonal absolute PMV hours. All assumptions are equivalent for all 28 construction techniques in order to make comparable base for evaluation.

3.1.1.1 Annual Thermal Comfort

The first comparison part (Figure 40-41) is annual to have an overview evaluation. As it is vividly noticed in table, the vernacular construction techniques offer more thermal comfort during the year. At the first level, O5 and O6 preserve indoor PMV between -0.5 and 0.5 about 47% of the year. In the following, the O2 and O3 provide absolute PMV around 44% of the year. All of the remained vernacular construction methods generate absolute PMV between 37% and 43%. In compare with vernacular techniques, contemporary ones act poor in this case by providing best PMV 31% of the year. Overall, among all construction techniques, C_{13} causes less annual absolute PMV hours than others.

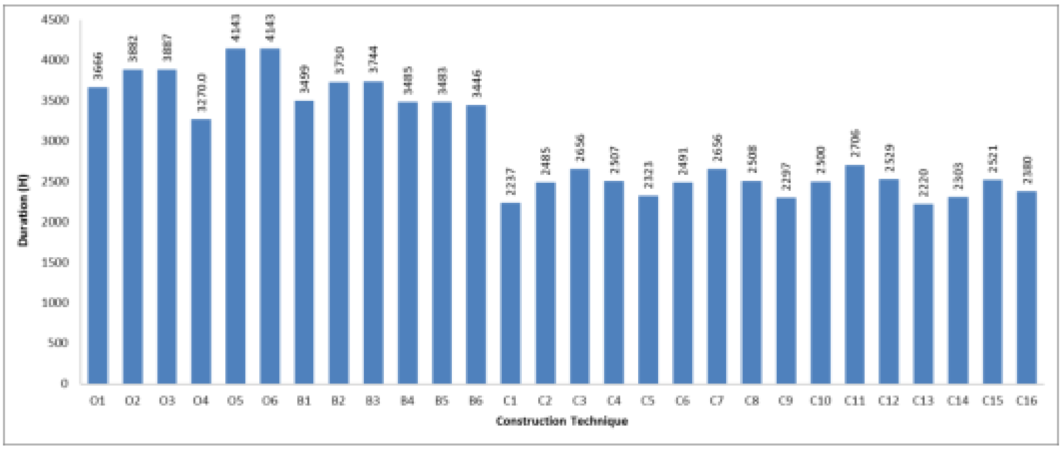

Figure 40: Annual duration of thermal comfort through various construction techniques (-0.5< PMV< 0.5)

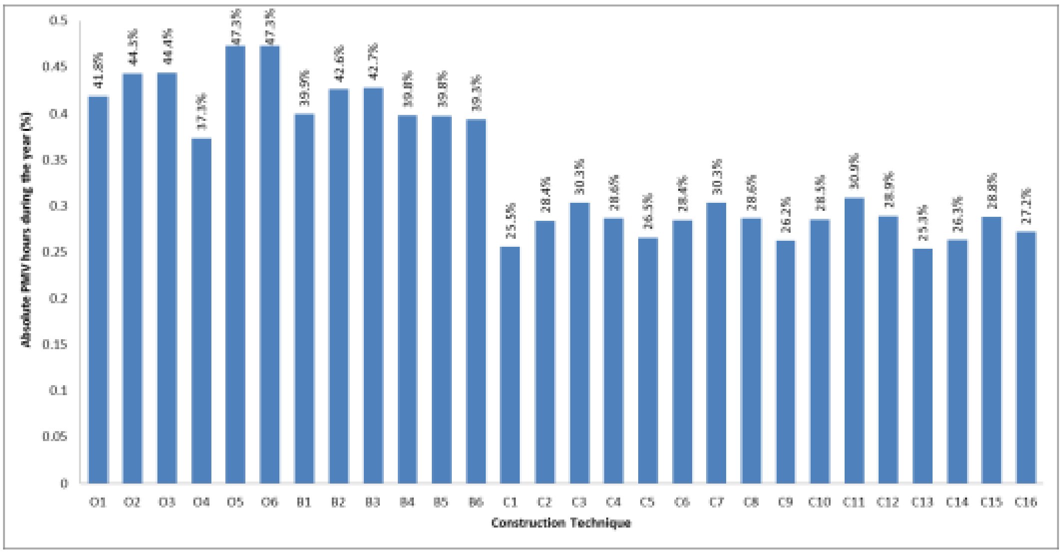

Figure 41: the percentage of annual thermal comfort duration through various construction techniques (-0.5< PMV< 0.5)

According to the PMV definition, there is another range between (-1, -0.5) and (0.5, 1) which is known as comfort zone with the rarely cold and hot weather. The “Figure 42” and “Figure 43” indicate the PMV between -1 and 1. As it is vividly seen, although the trend of the graph is as previous ones they seem more uniform and they have decreased about 20% in compare with the previous simulation.

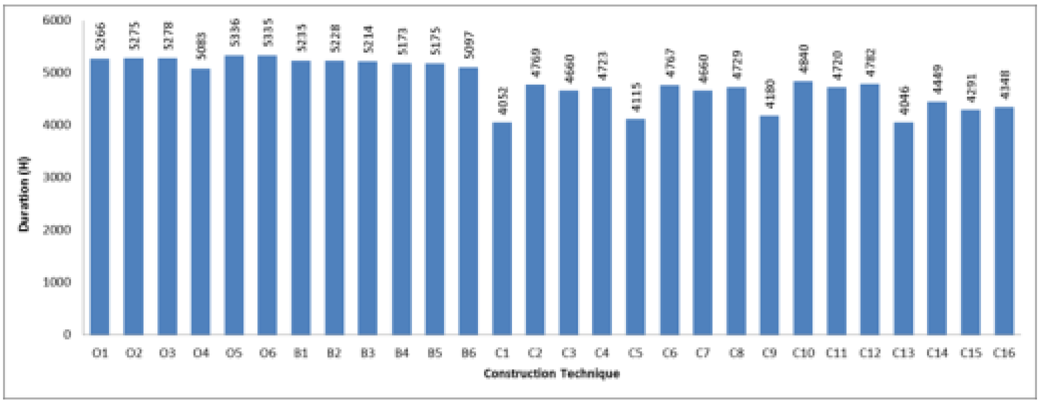

Figure 42: Annual duration of thermal comfort through various construction techniques (-1< PMV< 1)

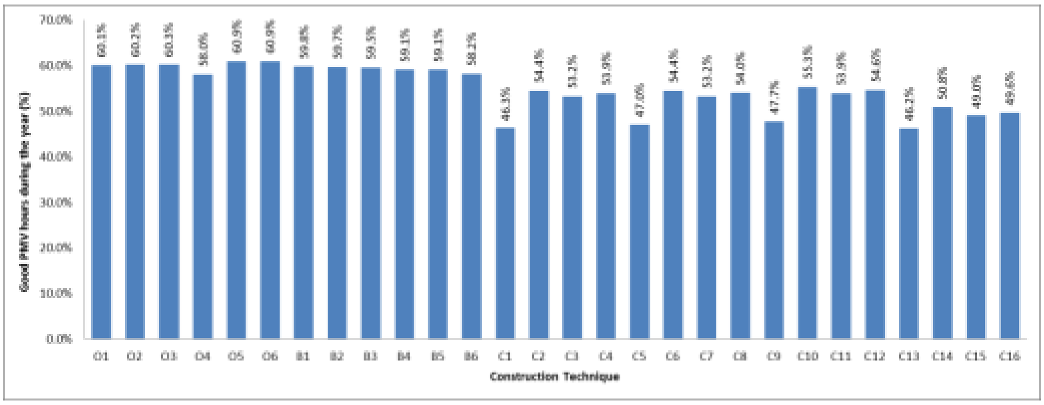

Figure 43: the percentage of annual thermal comfort duration through various construction techniques (-1< PMV< 1)

3.1.1.2 Seasonal Thermal Comfort

In addition to the annual results, seasonal results of the PMV calculation seem so important to realize which construction technique is more appropriate for each season and to understand the effect of seasonal variations in weather on related PMV of each technique.

To gain the seasonal perspective, months are classified in four groups:

A. December, January, February, March (winter)

B. June, July, August, September (summer)

C. April, May (spring)

D. October, November (autumn)

A. Thermal Comfort during winter

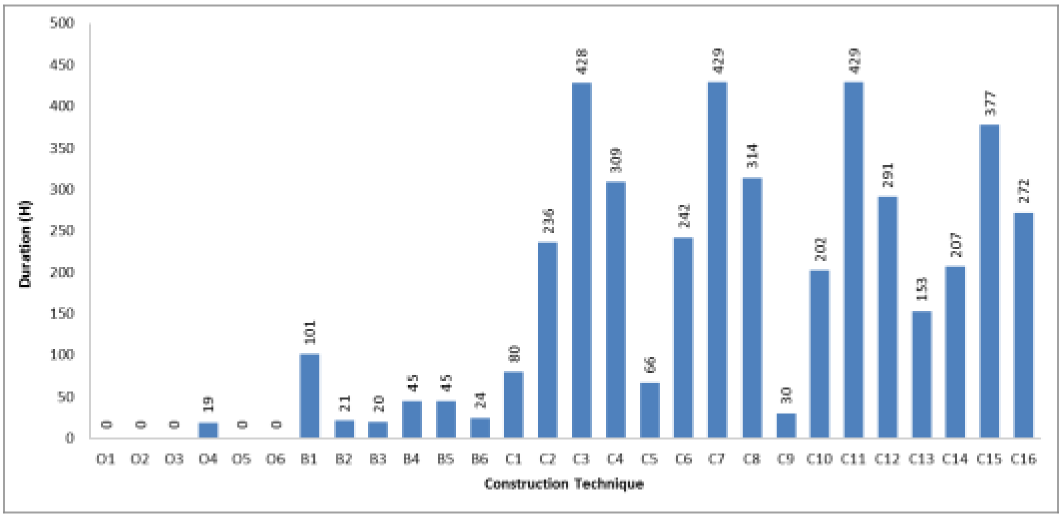

Figure 44: the duration of thermal comfort through various construction techniques during winter (-0.5< PMV< 0.5)

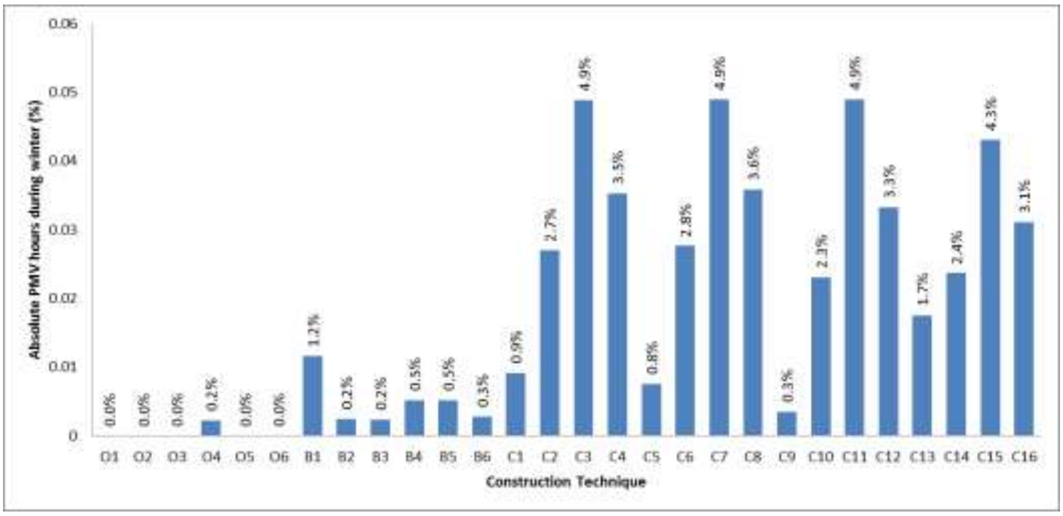

Figure 45: the percentage of thermal comfort duration through various construction techniques during winter (-0.5< PMV< 0.5)

Contrast to the annual result the contemporary construction techniques are more successful in creating absolute PMV during the winter. The result (Figure 44-45) illustrates that 5% of the winter is in the range of -0.5 to 0.5 PMV by applying the C_3, C_7, C_{11} and C_{15} which is the most adoptable construction technique compare with others in this season. The different level of provided thermal comfort between contemporary construction techniques and vernacular ones indicates that there are some significant different in material properties. Heavier thermal mass, higher R-value and lower U-value are some of the considerable features of the traditional materials which prevent the construction elements to transfer the solar energy in winter.

O_1, O_2, O_3, O_5 and O_6 are the worst construction techniques during winter in terms of thermal comfort. The heavy thermal mass, high R-value and low U- value increase time lag and avoid the solar gains flow inside through construction elements which result in indoor thermal comfort decreasing.

Unlike O_1, O_2, O_3, O_5 and O_6, C_3, C_7 and C_{11} as the contemporary construction technique and best methods with high level of thermal comfort during winter have light thermal mass, low R-value and high U-value. These characteristics result in easily heat flowing during the winter from outside to inside and decreasing indoor temperature. This kind of thermal behavior of traditional and contemporary material is the main reason of different levels of provided thermal comfort during this season.

This bar graph also releases that in contemporary techniques the insulation and its position are determinant the level of indoor thermal comfort. The closer the insulation layer is to the inner surface the better outcomes.

While most of vernacular construction provided no absolute PMV during the winter, B_1 seems more satisfactory in comparison with other vernacular construction methods.

The new range of PMV for winter case seems so different with the previous one. The "Figure 46" and "Figure 47" show that thermal comfort is introduced in this interval during the summer which means the absolute thermal comfort would not be supposed in this season. By the way, considering to the new wide of PMV, contemporary construction techniques seem more adoptable to the climate.

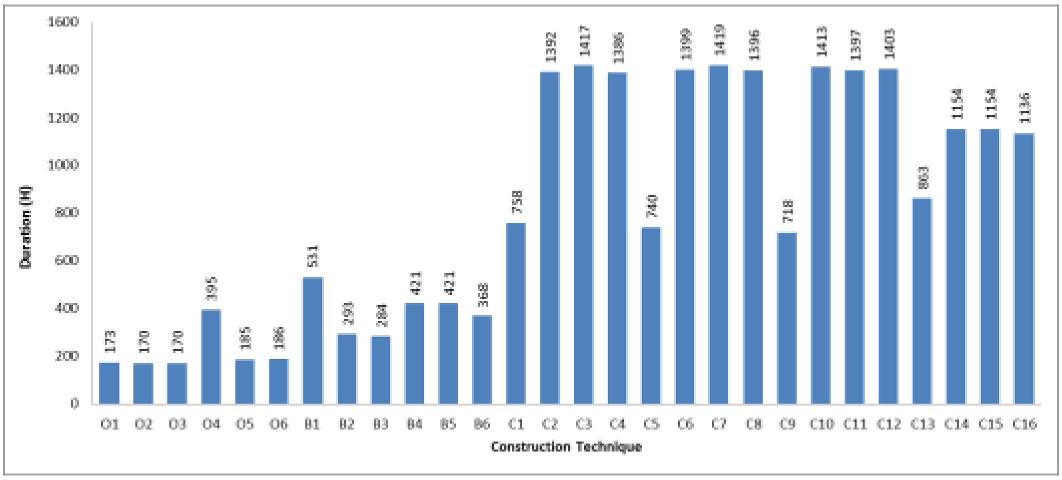

Figure 46: the thermal comfort duration through various construction techniques during winter (-1< PMV< 1)

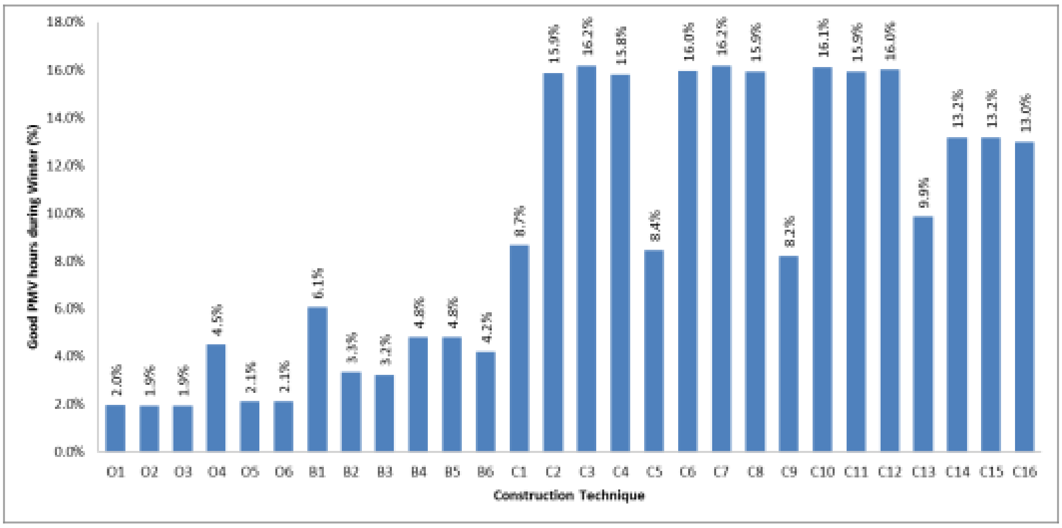

Figure 47: the percentage of thermal comfort duration through various construction techniques during winter (-1< PMV< 1)

B. Thermal Comfort during summer

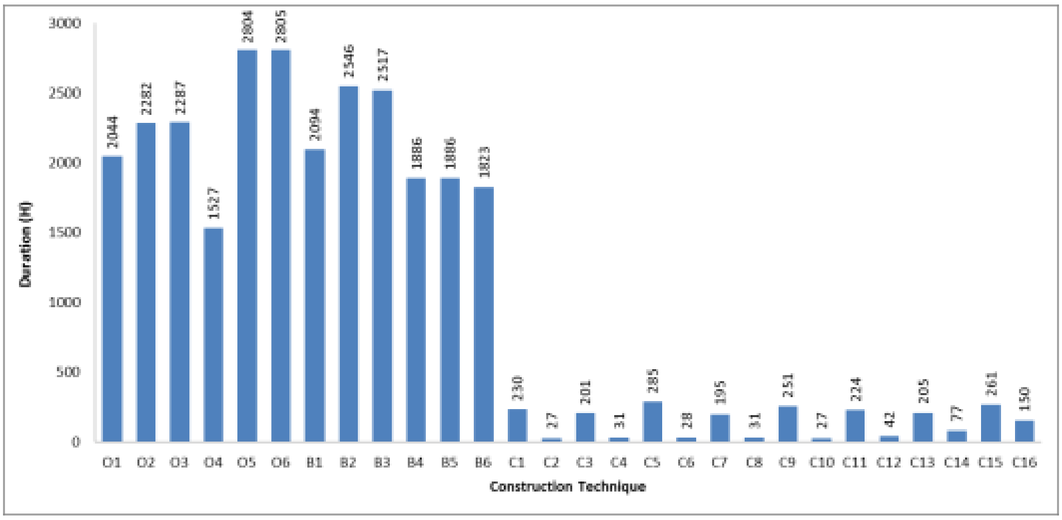

Figure 48: the thermal comfort duration through various construction techniques during summer (-0.5< PMV< 0.5)

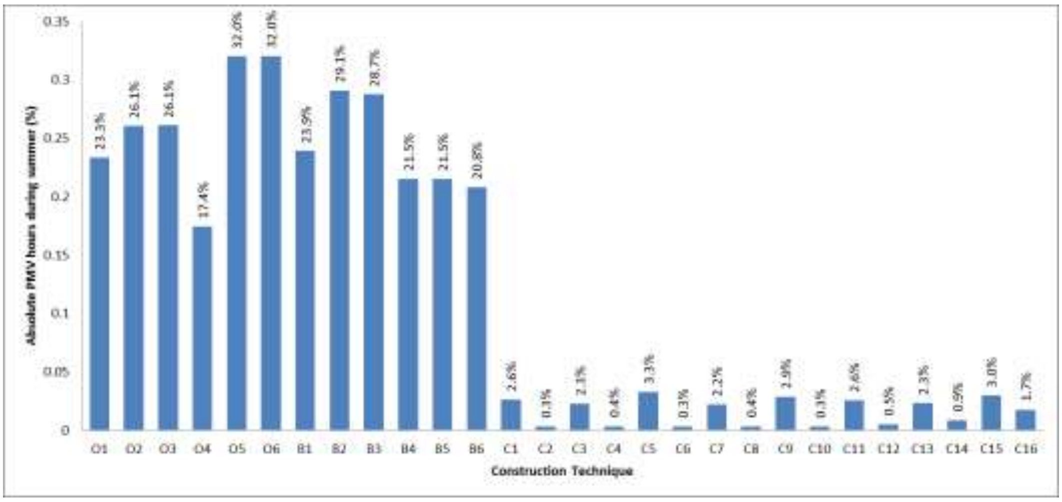

Figure 49: the percentage of thermal comfort duration through various construction techniques during summer (-0.5< PMV< 0.5)

According to the "Figure 48" and "Figure 49", it is understood that the contemporary construction techniques are less adoptable in compare with vernacular ones. They produce absolute PMV between 0.3% and 3.3% of the summer period. As it has been analyzed in winter, there are different levels of provided thermal comfort between contemporary construction techniques and vernacular ones in summer indicating that there is some significant dissimilarity in material properties. According to the summer results, lighter thermal mass, lower R-value and higher U-value are some of the considerable features of the contemporary materials which allow the construction elements to absorb the solar energy more and transfer the heat sooner than traditional materials. O_6 and O_5 are the best construction techniques in terms of thermal comfort. It means the heavy thermal mass, high R-value and low U- value increase time lag and indoor thermal comfort by absorbing heat and avoiding easily heat transferring.

Unlike O_6, C_{12} as the contemporary construction technique and poorest one in providing thermal comfort has light thermal mass, low R-value and high U-value. These characteristics result in easily heat flowing during the summer and decreasing indoor temperature. This kind of thermal behavior of traditional and contemporary material is the main reason of different levels of provided thermal comfort.

Although the position of the insulation layer has certain influence on PMV in winter, this criterion does not play any role in indoor thermal comfort during the summer. Among contemporary construction methods, C_3 seems more fruitful during the summer which is result of the lofts space in this technique. Against contemporary techniques, the vernacular ones preserve interior PMV between -0.5 and 0.5 around 17.4% to 32% of the summer.

The best and worse contemporary construction methods in creating absolute PMV belong to the ottoman period. In a short glance, it is noticed that flat roof with stone walls and adobe walls are more adoptable to this climate during warm months. In the wider PMV interval (Figure 50- 51), the trend of the initial graph deals with a little change. Although the vernacular construction methods seem more appropriate than the contemporary ones, the ratio of the growth in the new simulation is not equal between contemporary and vernacular methods.

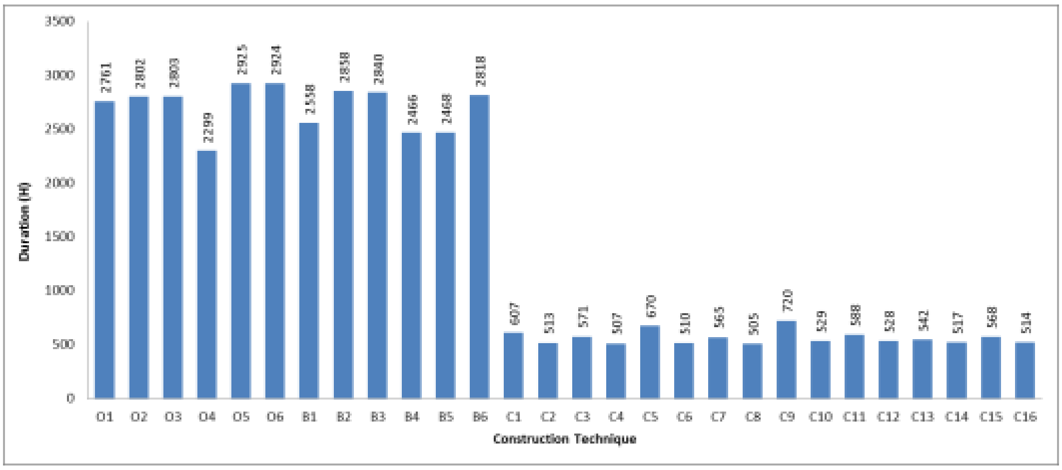

Figure 50: the thermal comfort duration through various construction techniques during summer (-1< PMV< 1)

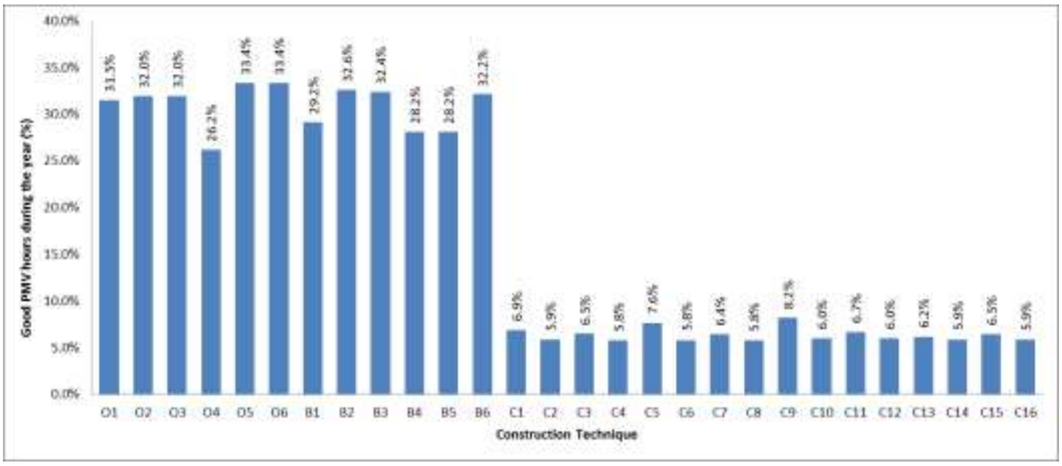

Figure 51: the percentage of thermal comfort duration through various construction techniques during summer (-1< PMV< 1)

C. Thermal Comfort during spring

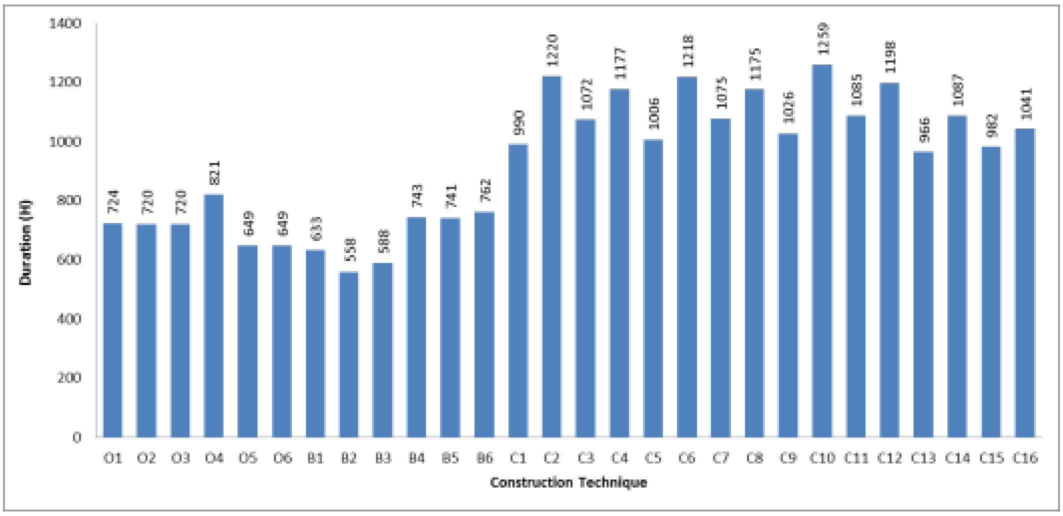

Figure 52: the thermal comfort duration through various construction techniques during spring (-0.5< PMV< 0.5)

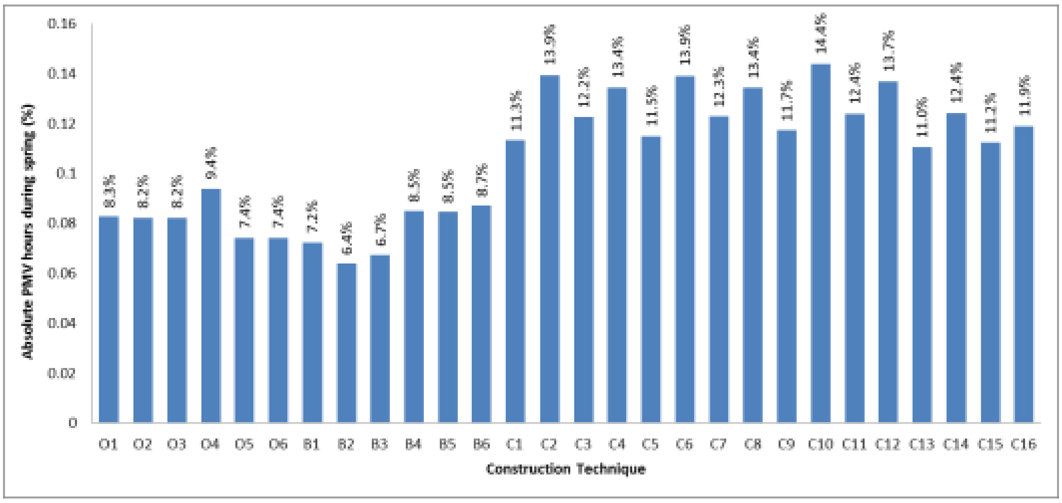

Figure 53: the percentage of thermal comfort duration through various construction techniques during spring (-0.5< PMV< 0.5)

Totally based on the definition of absolute PMV, it is supposed to deal with more absolute PMV hours in spring and autumn in compare with other seasons. The "Figure 52" and "Figure 53" indicate all Cypriot houses are in the best range of PMV more than 6.4% of the spring by applying each construction techniques. In an overall view, the contemporary construction methods prepare more hours with absolute PMV. The C_2, C6 and C10 the construction package with outer insulation layer, is in the first level in creating indoor thermal comfort by keeping the indoor condition in range of absolute PMV around 14% of the spring. On the other hand, B_2 and B_3, adobe walls, are weaker in making indoor thermal comfort during this season.

In addition to the increasing trend of thermal comfort duration in wider range of PMV (Figure 54-55), the gap between construction techniques thermal comfort levels decreases. This graph shows they seem more equal if the absolute PMV is not the purpose.

According to the graph and the analyzed thermal behaviors of traditional and contemporary materials in previous parts, this similarity in level of comfort condition is caused by the moderate weather of this season.

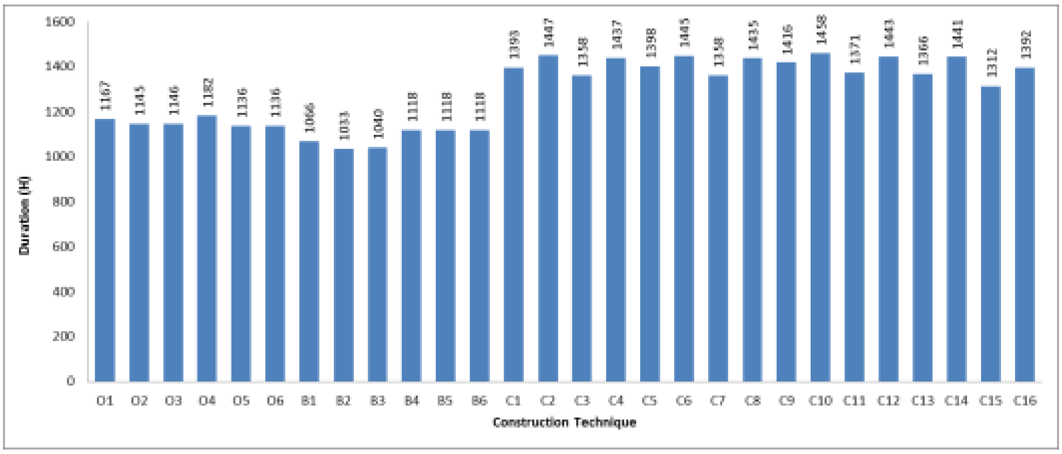

Figure 54: the thermal comfort duration through various construction techniques during spring (-1 < PMV< 1)

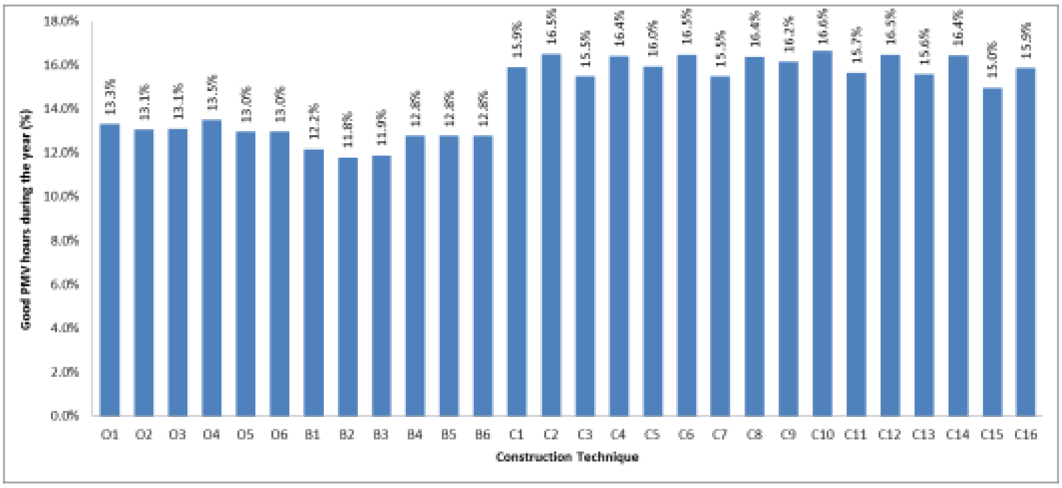

Figure 55: the percentage of thermal comfort duration through various construction techniques during spring (-1< PMV< 1)

D. Thermal Comfort during autumn

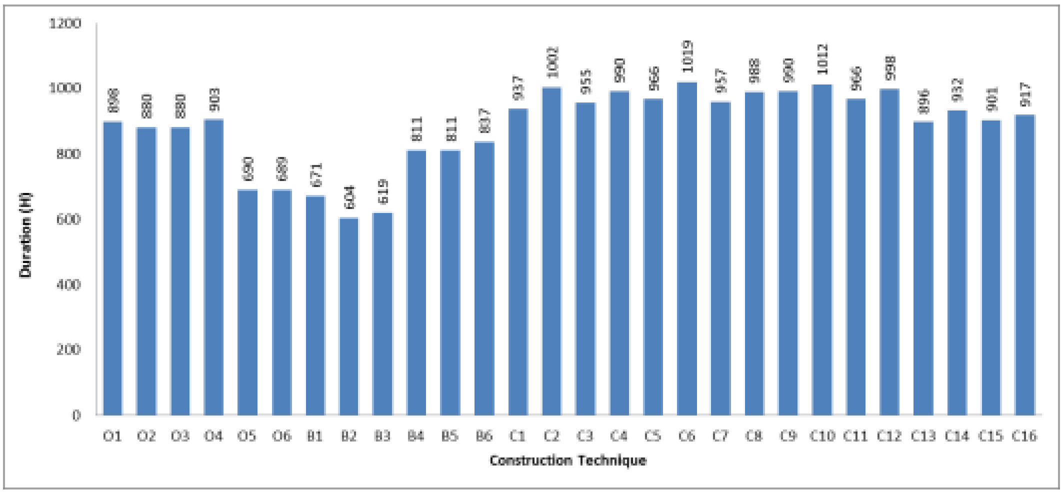

Figure 56: the thermal comfort duration through various construction techniques during autumn (-0.5< PMV< 0.5)

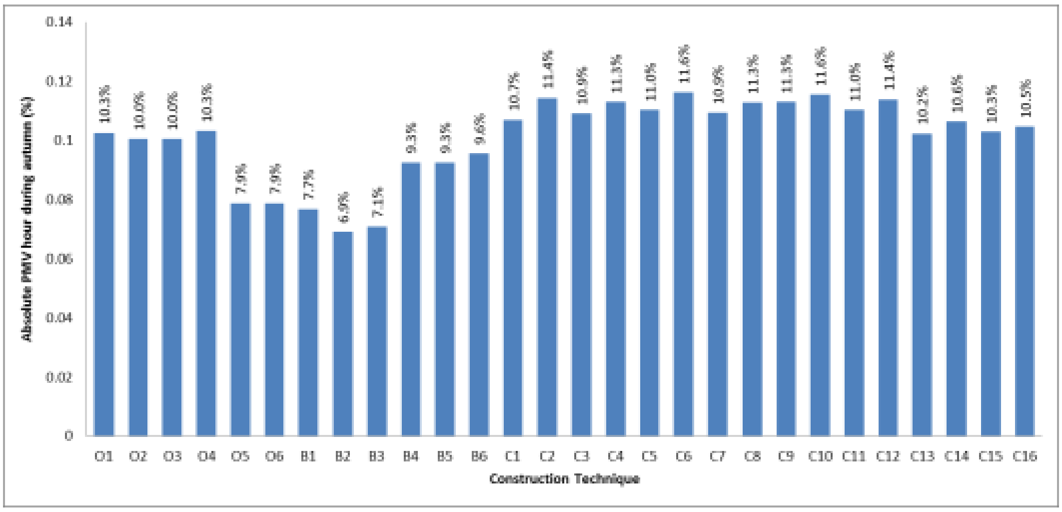

Figure 57: the percentage of thermal comfort duration through various construction techniques during autumn (-0.5< PMV< 0.5)

As what has been observed in previous part, the construction techniques are more successful generating absolute PV for inhabitant during autumn. According to the “Figure 56” and “Figure 57”, nowadays 11% of October and November has best PMV between -0.5 and 0.5 with each applied contemporary technique. Among vernacular construction methods which are less responder to indoor thermal comfort, O1, O2, O3, O4, B4, B5 and B6 with stone walls would be able to save indoor thermal comfort about 10% of the autumn. According to the “Figure 58” and “Figure 59”, the wider PMV interval, does not increase all construction techniques with equal ratio which causes the fluctuate trend.

According to the graph and the analyzed thermal behaviors of traditional and contemporary materials in previous parts, this similarity in level of comfort condition is caused by the moderate weather of this season.

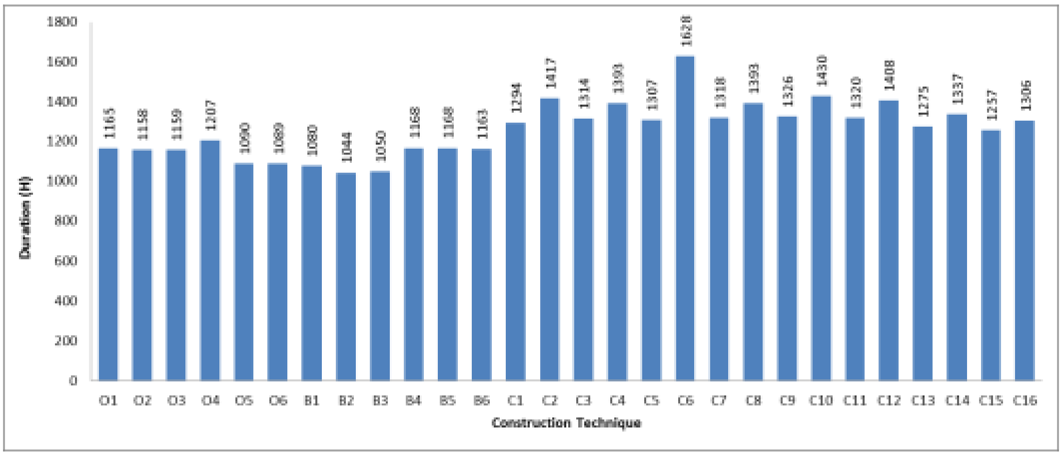

Figure 58: the thermal comfort duration through various construction techniques during autumn (-1< PMV< 1)

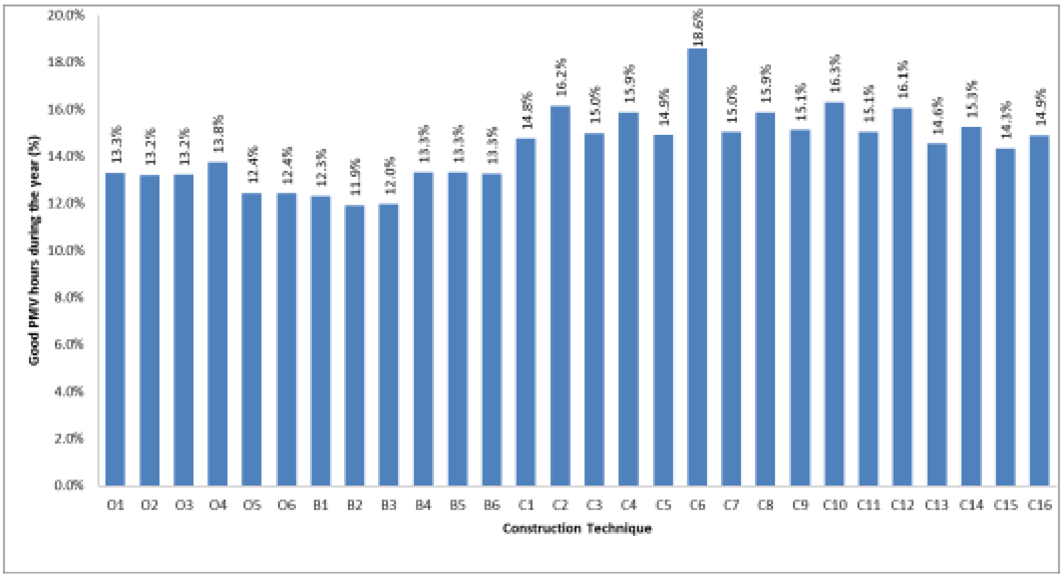

Figure 59: the percentage of thermal comfort duration through various construction techniques during autumn (-1< PMV< 1)

3.2 Evaluation of the construction systems in terms of thermal comfort and energy efficiency with continuously air condition indoor environment

In this stage all of construction techniques are analyzed regarding to continuously air condition indoor environment to determine how much energy would be consumed to keep inside desirable and reserve the temperature in 21-24 °C. As what has been done in previous step, the modeled square room (5.5 * 6.5) is presumed as doweling with one inhabitant and located in Famagusta.

In this phase all 28 construction techniques will be compared based their annual energy loads to distinguish which one is more efficient to prepare thermal comfort for occupants during the year. Then the energy loads would be calculated during the different seasons and compare all construction methods based on seasonal energy consumption. In this step also all assumptions are equivalent for all 28 construction techniques in order to make comparable base for evaluation.

3.2.1 Annual Energy Consumption

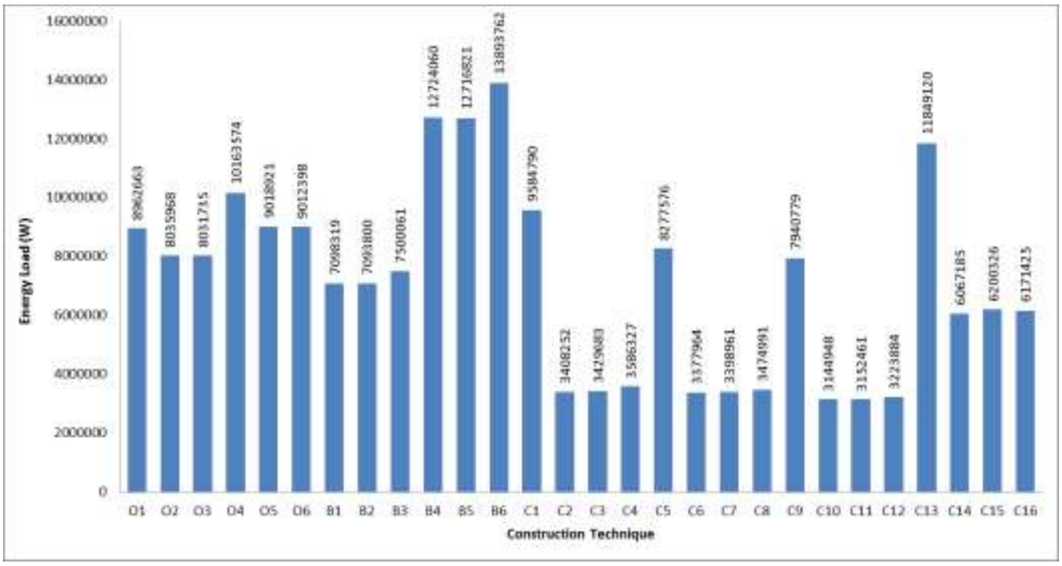

Figure 60: Annual energy loads based on various construction techniques

The “Figure 60” indicates the amount of annual energy consumption. As it is clearly seen the energy consumption would be increase by applying B_6 as construction technique more than other alternatives. The minimum energy usage is 3144948 W which is related to C_{10}. In graph 2 all construction methods are compared with C_{13} as the most common contemporary construction technique to find out how many percent other methods are more efficient or less. The “Figure 61” illustrate that at the first level, C_{10} and C_{11} are more efficient than C_{13} around 73.5%. In addition, except B_4, B_5 and B_6 all construction techniques are more efficient in compare with C_{13}. While vernacular construction techniques are same as contemporary one, there are three methods which are similar to C_{13} in terms of energy usage, B_4, B_5 and B_6.

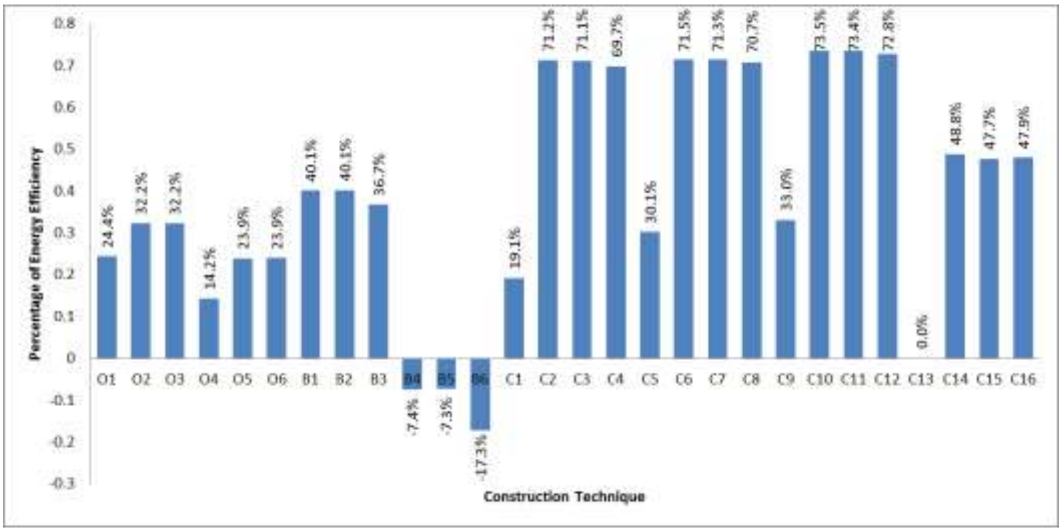

Figure 61: the percentage of energy loads based on various construction techniques during the year in compare with C_{13}

3.2.2 Seasonal Energy Consumption

In addition to the annual outcomes, seasonal simulations of the energy consumption seem so important to realize which construction technique is more adoptable for each season and to find out the influence of seasonal variations in weather on related PMV of each technique.

To gain the seasonal perspective, months are classified in four groups:

A. December, January, February, March (winter)

B. June, July, August, September (summer)

C. April, May (spring)

D. October, November (autumn)

A. Energy Consumption in winter

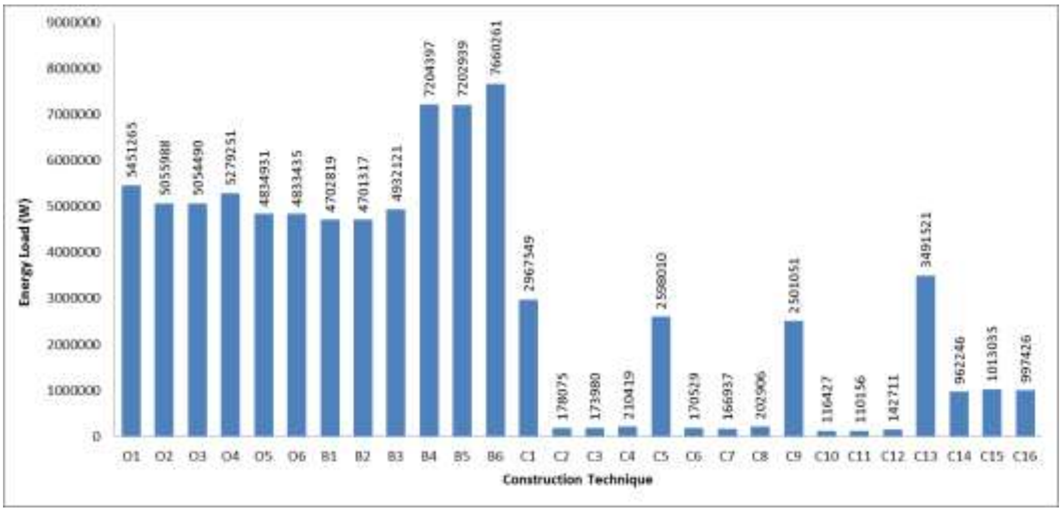

Figure 62: the level of energy loads based on various construction techniques during winter

The “Figure 62” illustrates the amount of energy consumption of each construction during winter. As it is clearly seen, the level of energy load decreases during the history. B_6 causes building as the biggest energy consumer during the winter. As it is vividly noticed, all contemporary construction techniques are efficient in compare with C_{13}. All construction techniques with insulation layer are more efficient than the others in energy saving. In a short glance contemporary methods seem more efficient than vernacular ones during the winter.

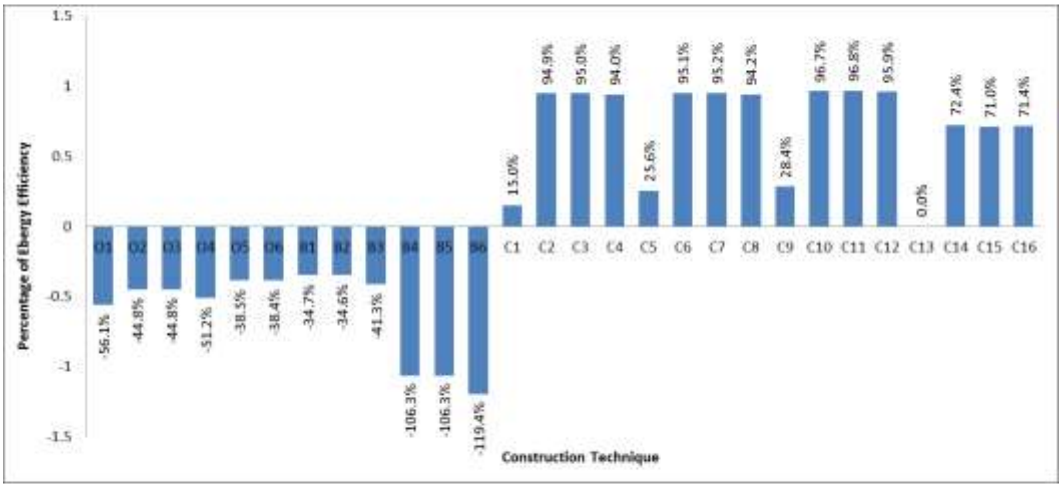

Figure 63: the percentage of energy loads based on various construction techniques during winter in compare with C_{13}

According to the construction technique B_6 as the biggest energy consumer, it seems that high thermal heat capacity increase the heat absorption, so for create indoor temperature in the proper temperature range lot of energy is needed. In the other words a huge amount of energy loads is waste by construction element's heat absorption.

According to the construction technique C_{11} as the most efficient energy consumer, it seems in one hand low thermal heat capacity reduces the heat absorption and on the other hand the low R-value, high U-value and heavy thermal mass decrease the heat transfer. Although it is supposed the energy loads grows through the contemporary methods, the consumed amount of energy is less than traditional ones. Moreover adding the insulation layer works as a dam in front of the heat flow (Figure 63).

B. Energy Consumption in summer

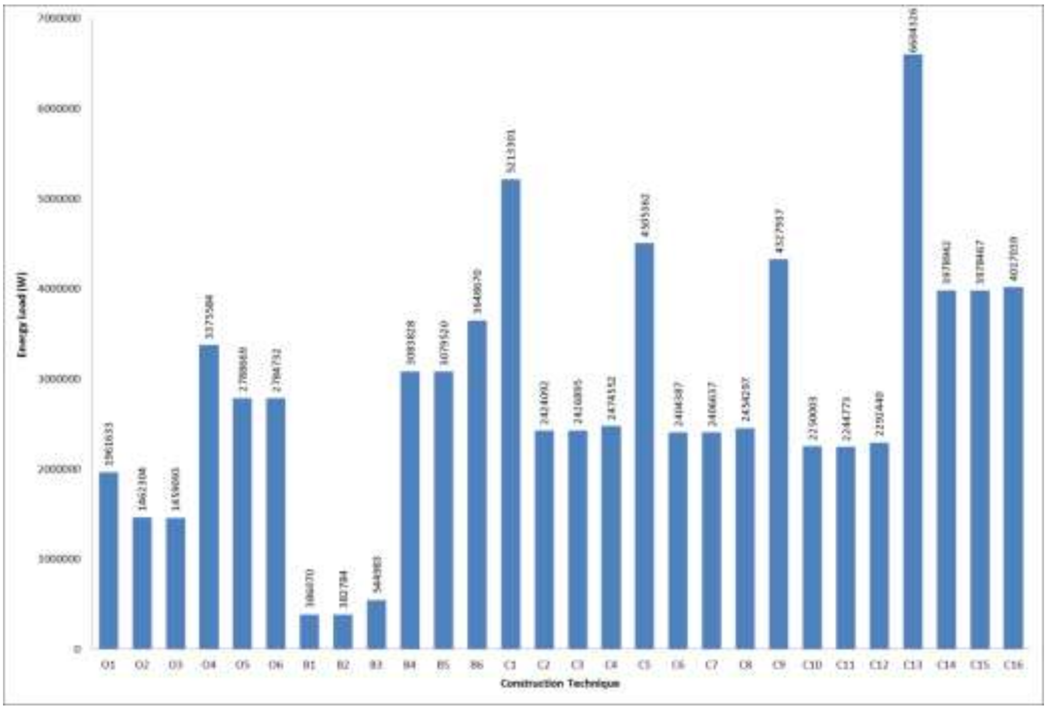

Figure 64: the level of energy loads based on various construction techniques during summer

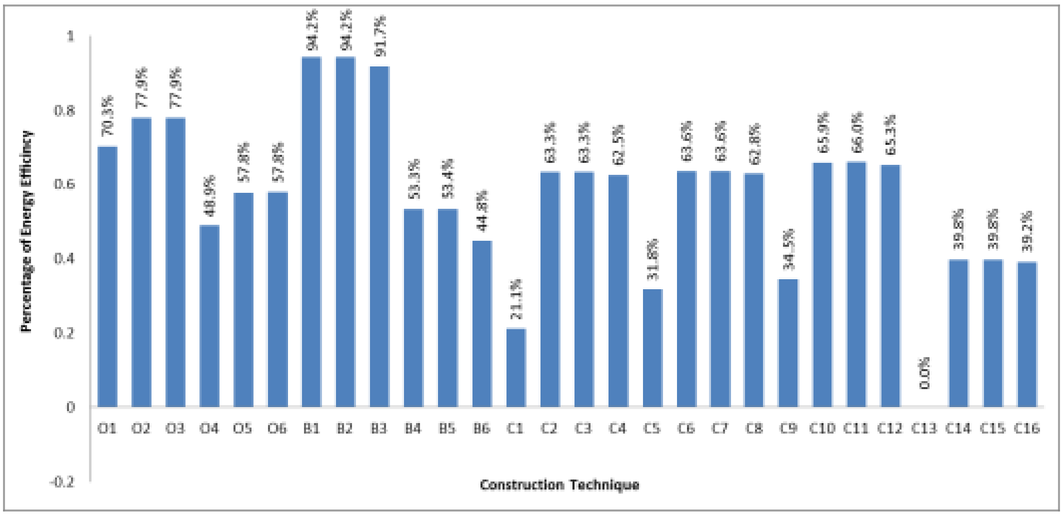

Figure 65: the percentage of energy loads based on various construction techniques during summer in compare with C_{13}

Unlike the decreasing tendency of "Figure 63", the trend of "Figure 64" is increasing which indicates the contemporary construction techniques result in more energy consumption. In summer the biggest energy consumer is the building with C_{13} as construction method which is the base for energy efficiency in "Figure 65". At the first level, B_1, B_2 and B_3 seem more efficient than C_{13} about 94%. O_1, O_2 and O_3 with stone walls are in the second level of efficiency. On the opposite side, there are some construction methods with less efficiency such as C_1, C_5 and C_9. According to the comparison between them and other contemporary construction techniques, it is clearly noticed the insulation layer plays essential role in decreasing the energy consumption during the summer.

According to the construction technique B_1 as the most efficient energy consumer, it seems that high thermal heat capacity, heavy thermal mass, high R-value and low U-value increase the heat absorption and time lag, so for create indoor temperature in the proper temperature range a few amount of energy is needed. The properties of traditional materials prevents of heat transferring through construction elements so the high temperature of outdoor would not have any impact on indoor.

According to the construction technique C_{13} as the biggest energy consumer, it seems low thermal heat capacity, low R-value, high U-value and light thermal mass decrease the heat transfer. So it is supposed the energy loads grow through the contemporary methods and the consumed amount of energy be more than traditional ones to prepare indoor thermal comfort during the summer.

C. Energy Consumption in spring

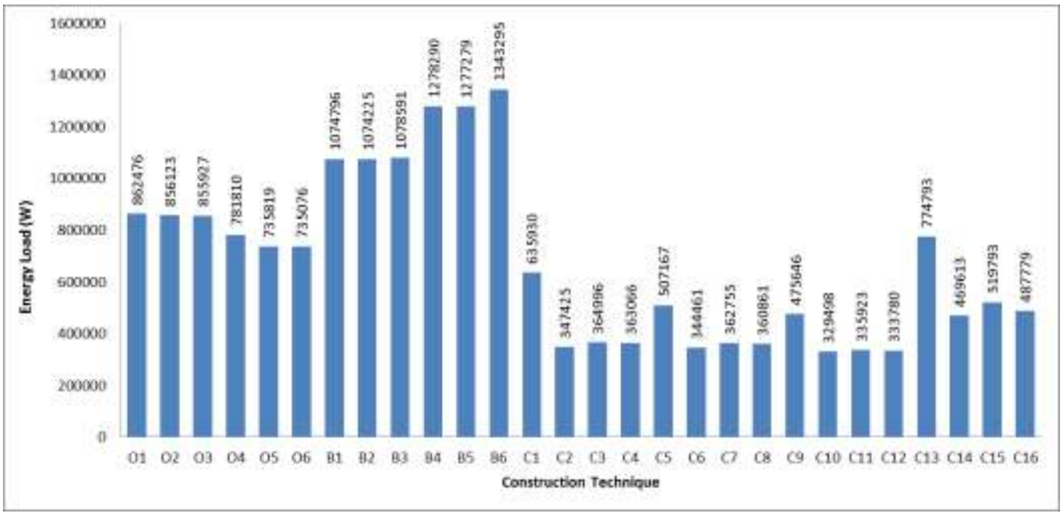

Figure 66: the level of energy loads based on various construction techniques during spring

As it is seen in “Figure 66”, against summer, the contemporary construction techniques decrease the amount of energy consumption during the spring. Among all construction techniques, British ones deal with high level of energy consumption during these two months. B_6 again is known as the biggest energy user similar to winter. Regarding to the “graph 67”, C_{11} and C_{12} are the most efficient construction techniques in compare with C_{13}.

The vernacular construction methods can be divided in four groups, construction techniques with huge stone walls belong to Ottoman period are less efficient than timber frame and stones wall ones in that period. Also in British period, the concrete structure buildings are less efficient than adobe walls during this season.

In a short glance, it is vividly noticed that construction techniques with insulation layer are more efficient than all vernacular and traditional construction methods during spring.

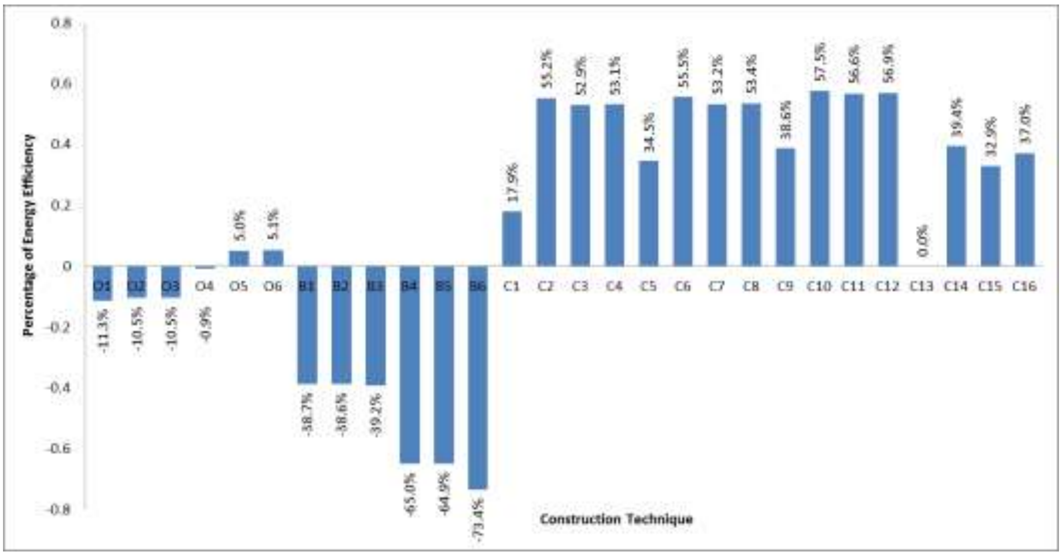

Figure 67: the percentage of energy loads based on various construction techniques during spring in compare with C_{13}

A. Energy Consumption in autumn

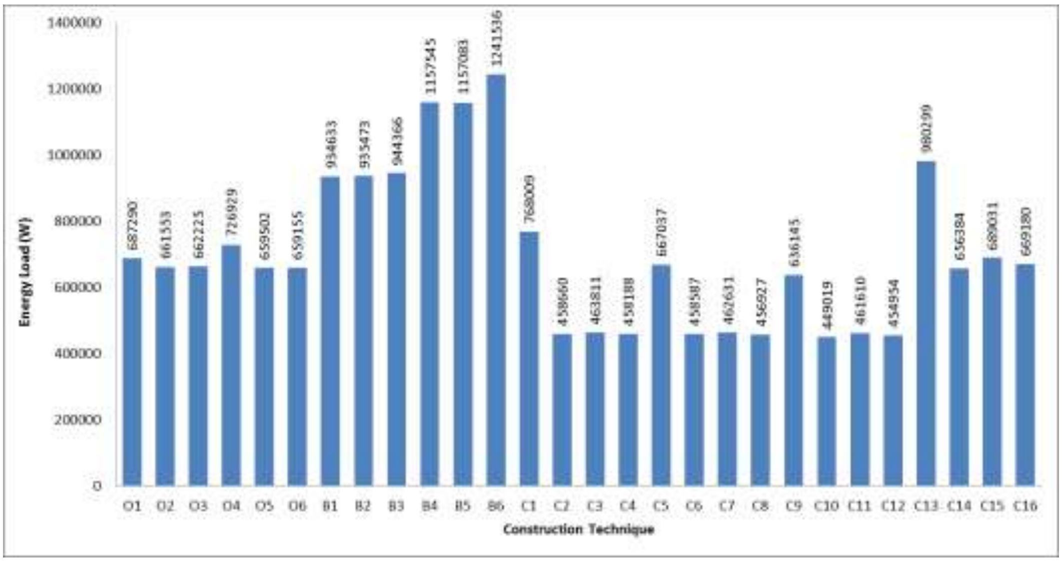

Figure 68: the level of energy loads based on various construction techniques during autumn

The "Figure 68" depicts the energy load of each construction technique during the autumn. Compare to the spring, all constructions in autumn act as same as April and May. The hugest energy consumer is B_6 as other seasons. The "Figure 69" represents the percentages of each construction technique's energy efficiency considering to C_{13}.

As what was seen in autumn graph, all construction techniques with insulation layer have best performance in terms of energy efficiency during this season. Among vernacular construction Ottoman period with stone walls and timber structure are more efficient than British period with adobe and concrete structure.

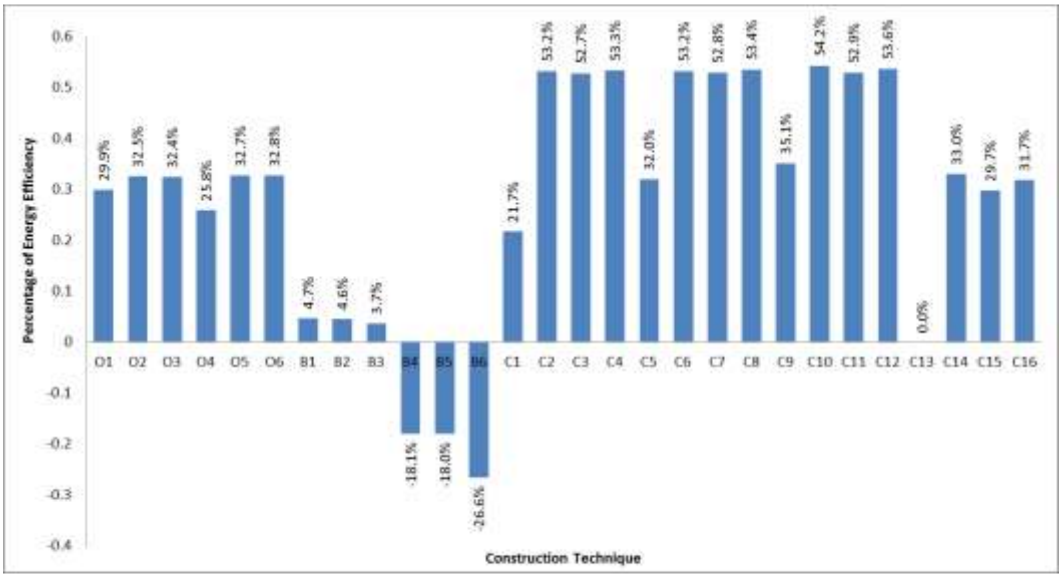

Figure 69: the percentage of energy loads based on various construction techniques during autumn in compare with C_{13}

3.3 Evaluation of the Building Elements in Terms of Thermal Comfort

In this step in order to discuss about the reason of the various responds of pervious evaluation, the internal temperature of each surface are calculated. According to the modeling assumption about the internal temperature in summer (23 º C) and in winter (21º C), the best range of the internal temperature for each surface should be 18-25 º C. This criteria would determine which surface is more effective on providing and preserving the indoor thermal quality.

3.3.1 Construction Technique O_1

The “Figure 70” illustrates the annual duration of internal temperature of each surface via construction technique O_1. Accordingly, roof obtains best internal temperature whole of the year while the east surface is the worse by having the best inner temperature 79.5% of the year (Figure 71).

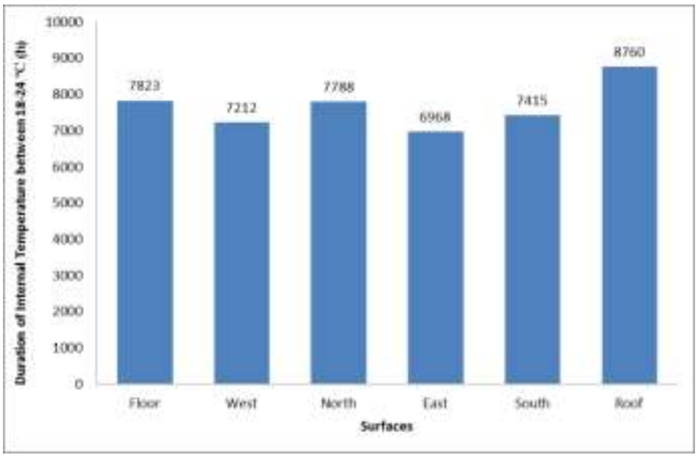

Figure 70: the annual duration of internal temperature (18-24 ºC) of each surface through applying O_1

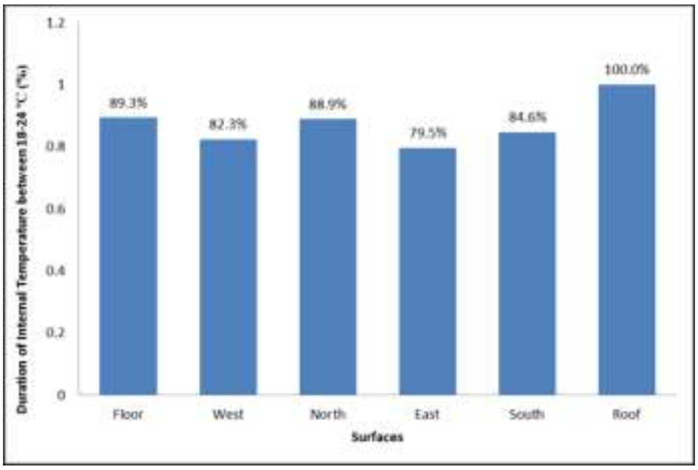

Figure 71: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying O_1

3.3.2 Construction Technique O_2

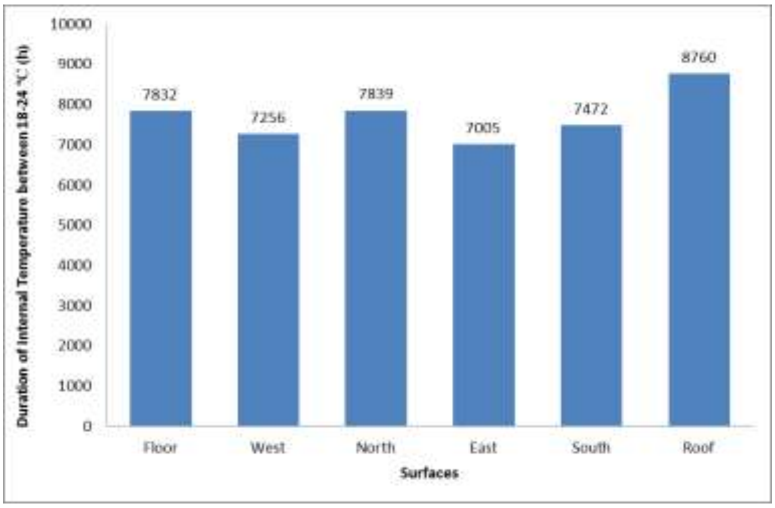

Figure 72: the annual duration of internal temperature (18-24 ºC) of each surface through applying O_2

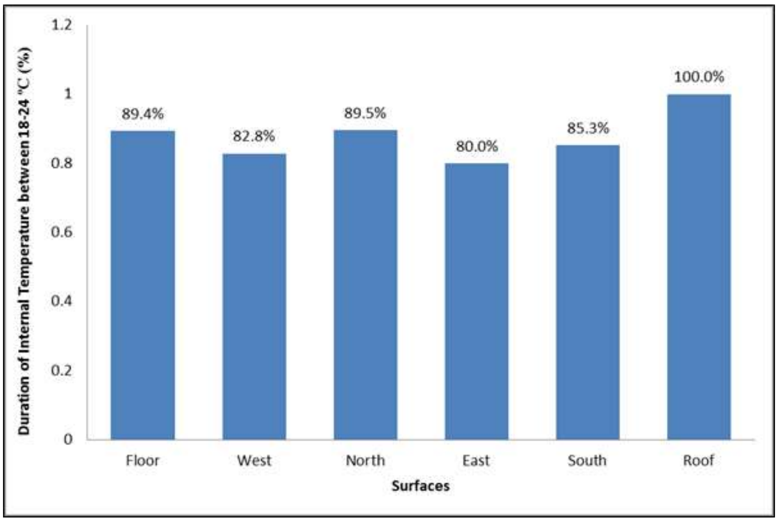

Figure 73: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying O_2

According to the "Figure 72" containing the annual duration of best inner temperature of each surface, roof, floor and northern wall are in the best range of temperature longer than other surfaces (Figure 73).

3.3.3 Construction Technique O_3

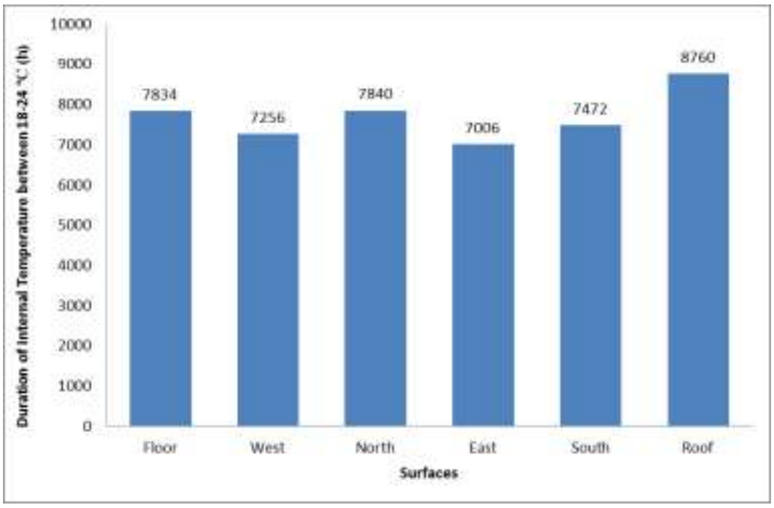

Figure 74: the annual duration of internal temperature (18-24 ºC) of each surface through applying O_3

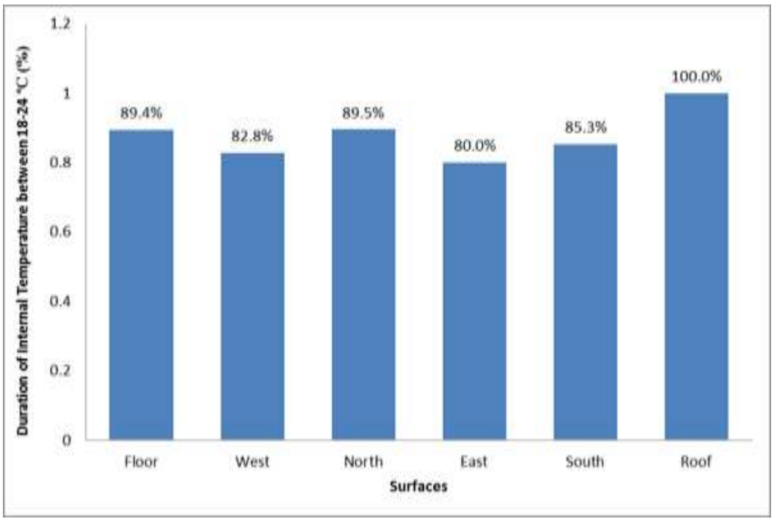

Figure 75: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying O_3

The “Figure 74” and “Figure 75” represent the annual internal temperature of O_3 the in the range of 18 to 25 ºC. It shows roof, floor and north surface are in this range longer than other surface which indicates these parts behave more proper.

3.3.4 Construction Technique O_4

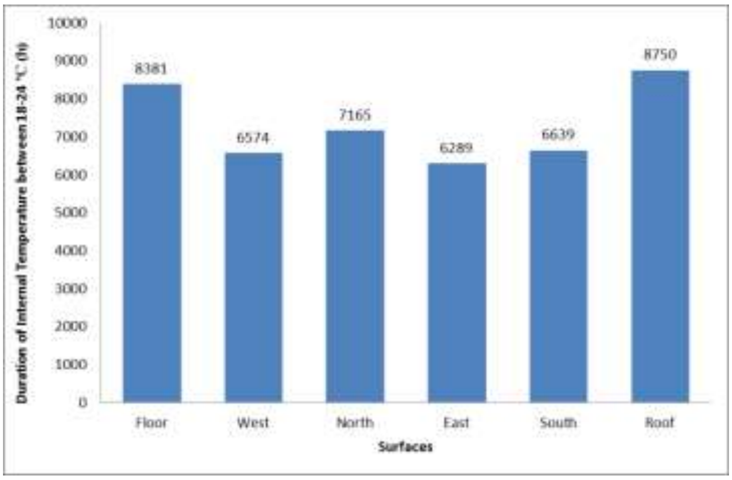

Figure 76: the annual duration of internal temperature (18-24 ºC) of each surface through applying O_4

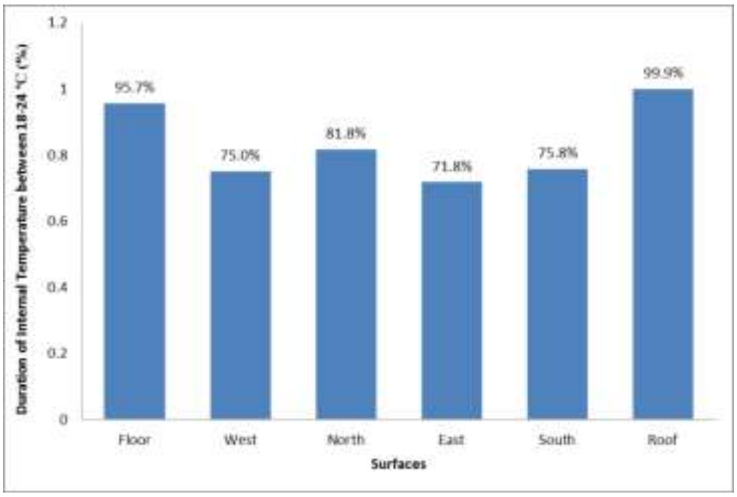

Figure 77: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying O_4

The "Figure 76" and "Figure 77" infer the annual inner temperature of O_4 in the range of 18 to 25 ºC. In compare with roof, floor and north surface which are in this range around 90% of the year, other surfaces provide this temperature less. According to this graph roof and floor are more effective in preserving indoor temperature more in this range.

3.3.5 Construction Technique O_5

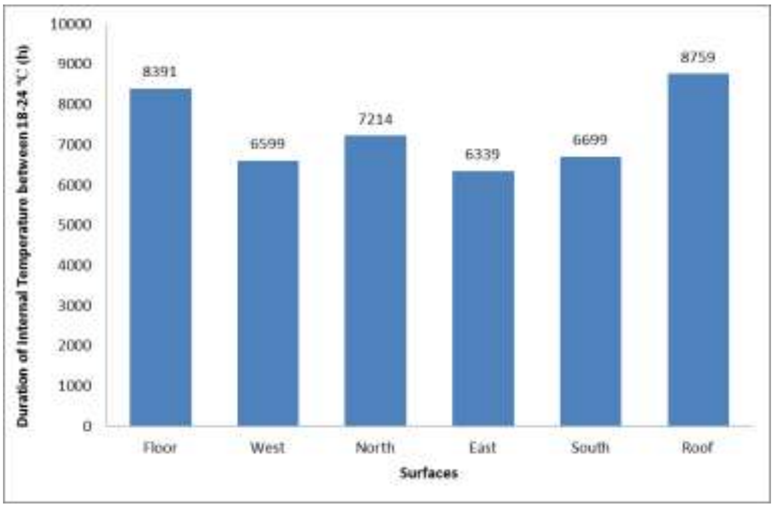

Figure 78: the annual duration of internal temperature (18-24 ºC) of each surface through applying O_5

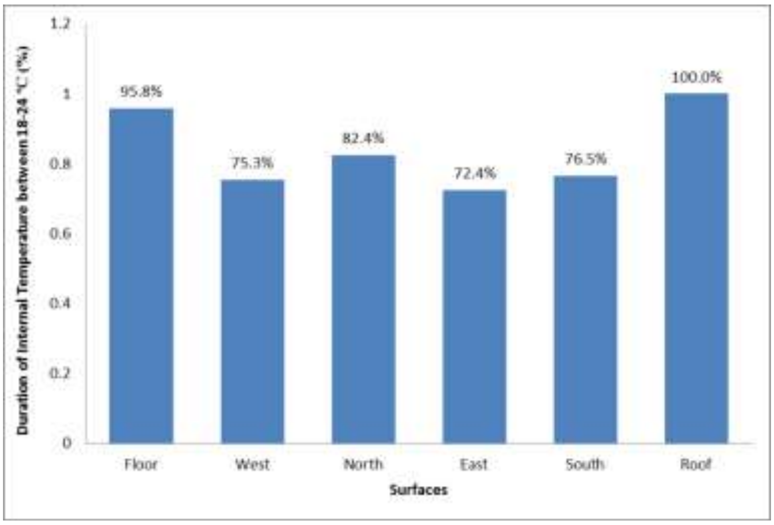

Figure 79: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying O_5

According to the "Figure 78" and "Figure 79" which show the annual inner temperature of O_5 in the range of 18 to 25 ºC, roof, floor and north surface are in this range around 83 to 100% of the year. On the other hand other surfaces provide this temperature less than 80% of the year. According to this graph roof and floor are more effective in preserving indoor temperature more in this range.

3.3.6 Construction Technique O_6

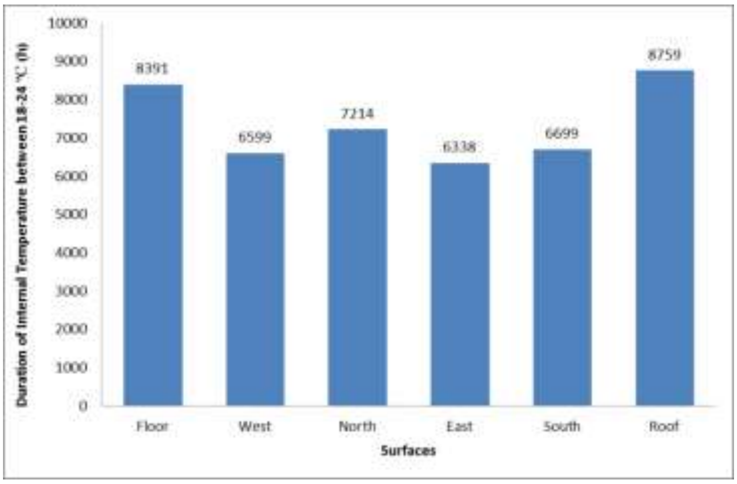

Figure 80: the annual duration of internal temperature (18-24 ºC) of each surface through applying O_6

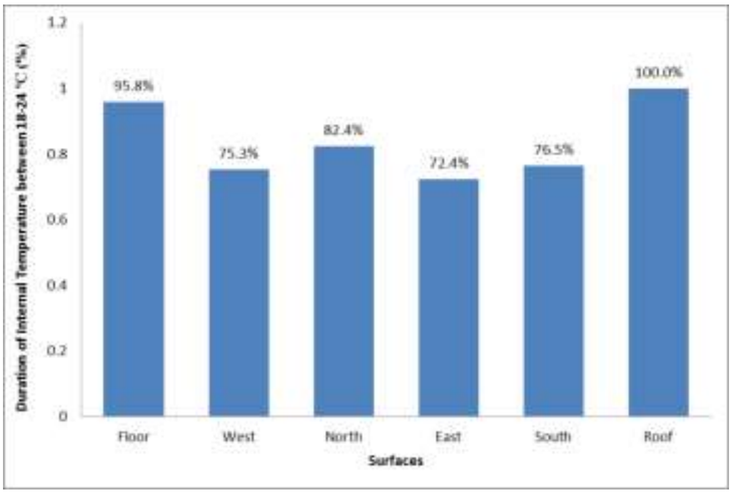

Figure 81: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying O_6

As it is vividly noticed in the "Figure 80" and "Figure 81" which illustrate the annual internal temperature of O_6 in the range of 18 to 25 ºC, roof, floor and north surface are in this range around 83 to 100% of the year like other Ottoman construction techniques. Also other surfaces prepare this temperature less than 80% of the year. Accordingly, roof, floor and northern surface are more influential in keeping indoor temperature longer in this range.

3.3.7 Construction Technique B_1

The "Figure 82" and "Figure 83" illustrate the annual duration of internal temperature of each surface via construction technique B_1. Accordingly, in compare with floor obtaining the least duration of internal temperature in the year all the other construction techniques keep inner temperature in the appropriate temperature whole of the year.

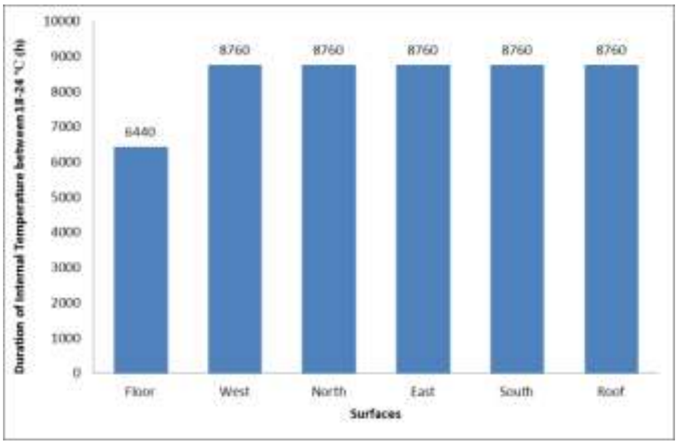

Figure 82: the annual duration of internal temperature (18-24 ºC) of each surface through applying B_1

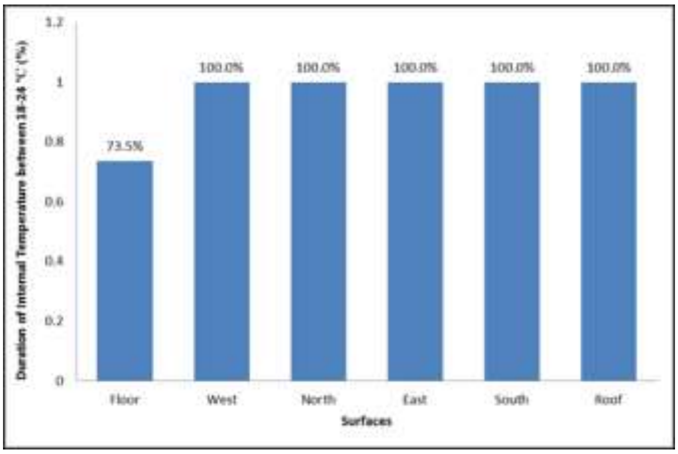

Figure 83: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying B1

3.3.8 Construction Technique B_2

As it is clearly seen in the "Figure 84" and "Figure 85" representing the annual duration of internal temperature of each surface via construction technique B_2, while floor provides the least duration of internal temperature in the year, all the other construction techniques keep inner temperature in the appropriate temperature whole of the year.

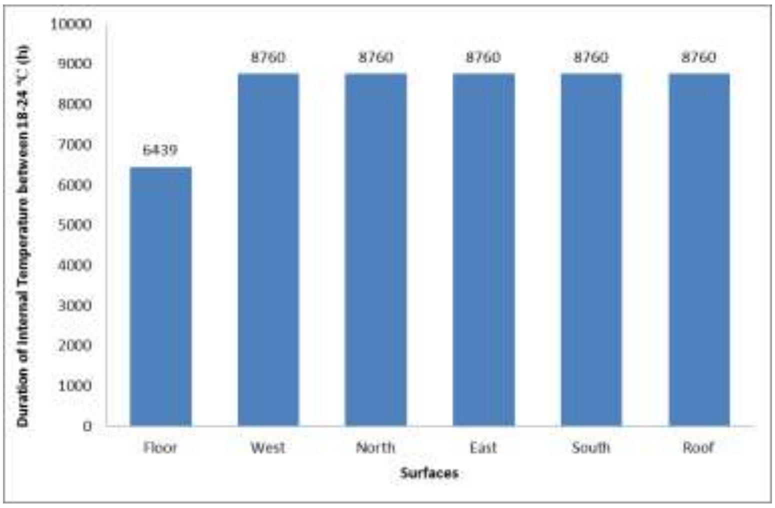

Figure 84: the annual duration of internal temperature (18-24 ºC) of each surface through applying B_2

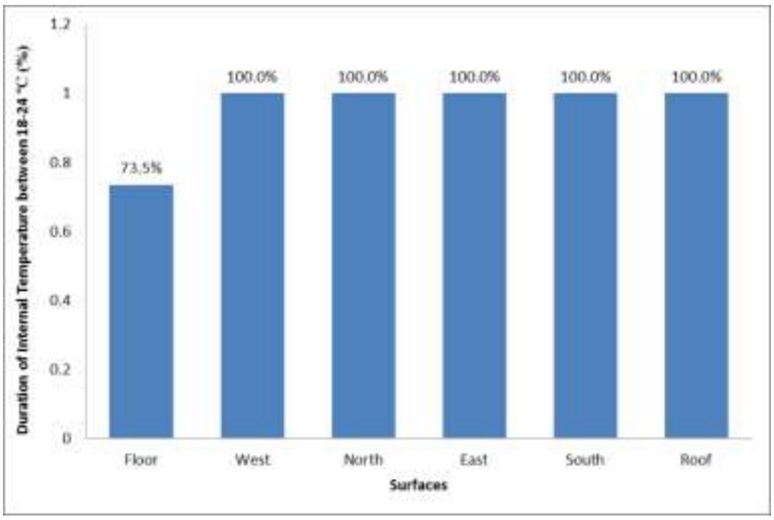

Figure 85: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying B_2

3.3.9 Construction Technique B_3

As what is vividly noticed in the “Figure 86” and “Figure 87” which determine the annual duration of inner temperature of each surface through construction technique B_3, the floor has the least duration of inner temperature in the year. On the other hand, all the other construction techniques retain inner temperature in the appropriate temperature whole of the year.

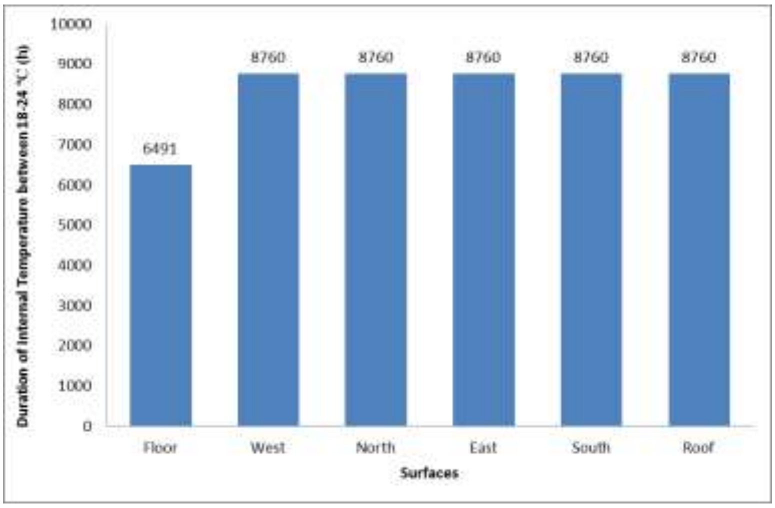

Figure 86: the annual duration of internal temperature (18-24 ºC) of each surface through applying B_3

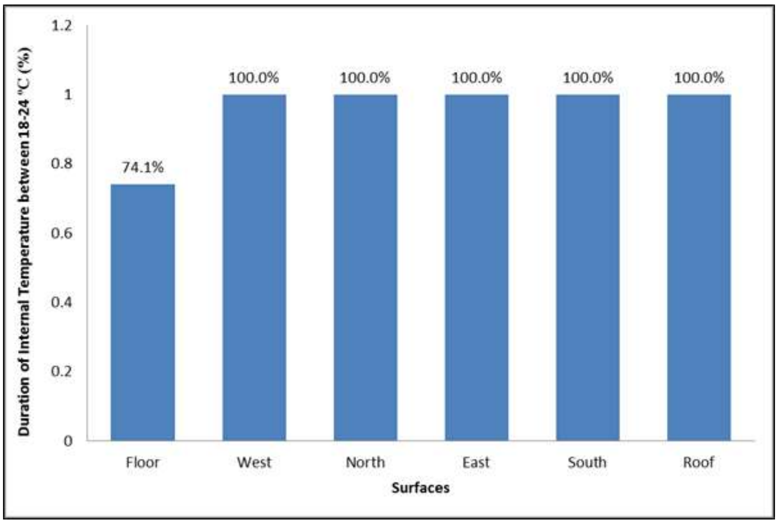

Figure 87: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying B_3

3.3.10 Construction Technique B_4

Based on what in the "Figure 88" and "Figure 87" is presented the roof has the longest duration of inner temperature in the proper range during the year. In the second level, north surface obtains inner temperature between 18 and 25 around 80.5% of the year. All the other construction techniques are in the equal level.

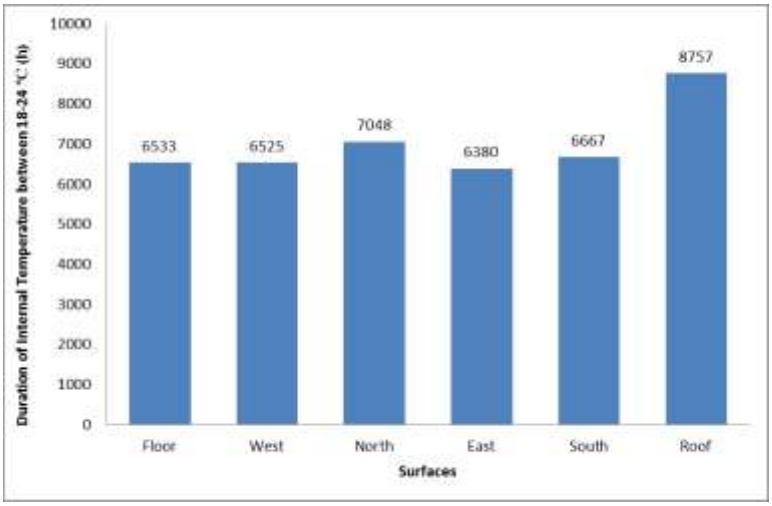

Figure: 88: the annual duration of internal temperature (18-24 ºC) of each surface through applying B_4

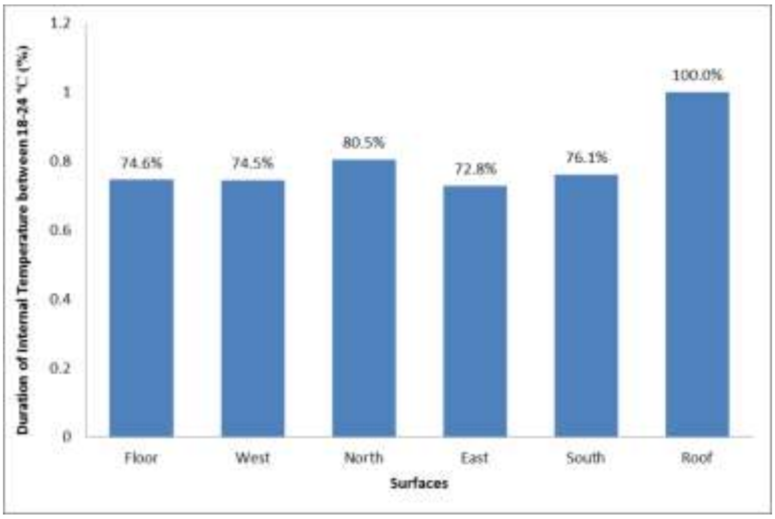

Figure 89: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying B_4

3.3.11 Construction Technique B_5

As it is vividly noticed in the "Figure 90" and "Figure 91" which illustrate the annual internal temperature of B_5 in the range of 18 to 25 ºC, northern surface and roof are in this range around 83 and100% of the year respectively. Additionally, other surfaces prepare this temperature equally during the year. Accordingly, roof has more influential role in keeping indoor temperature longer in this range.

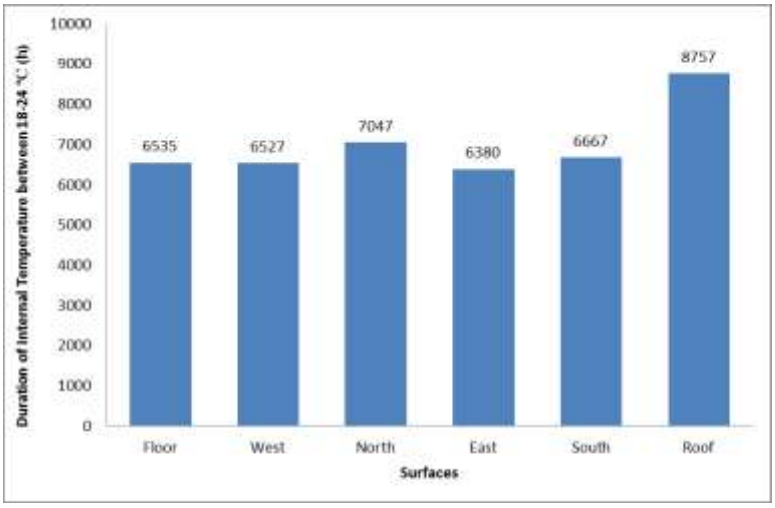

Figure 90: the annual duration of internal temperature (18-24 ºC) of each surface through applying B_5

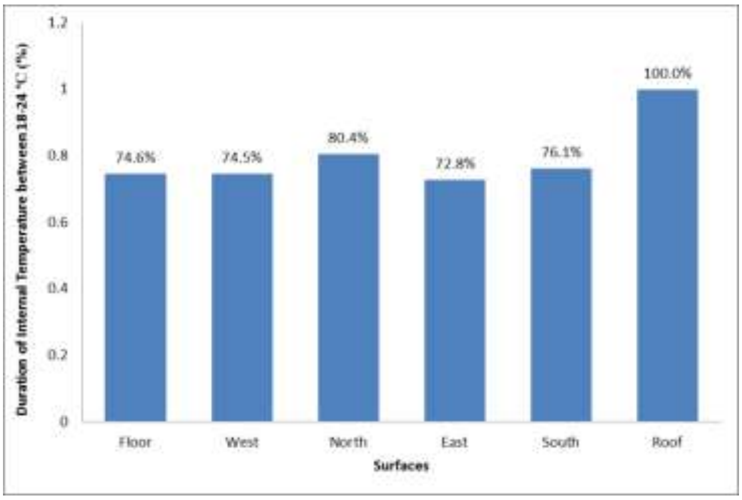

Figure 91: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying B_5

3.3.12 Construction Technique B_6

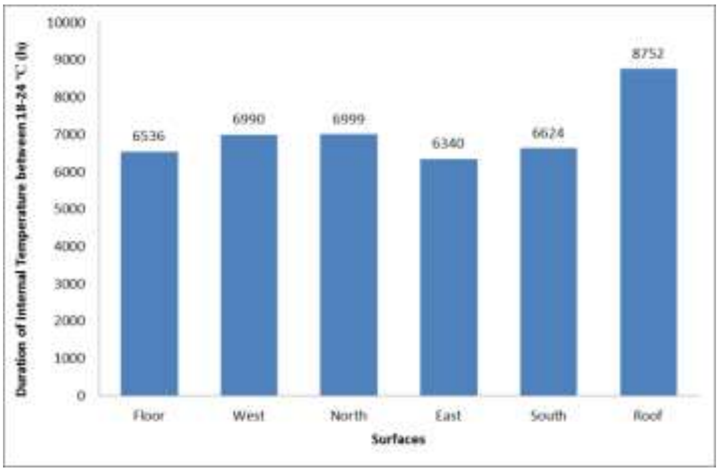

Figure 92: the annual duration of internal temperature (18-24 ºC) of each surface through applying B_6

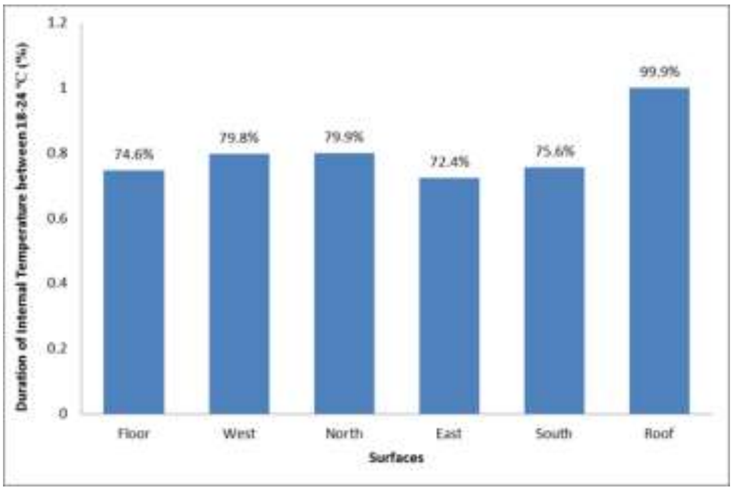

Figure 93: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying B_6

Similar to B_4 and B_5, the related graph of the B_6 illustrates the annual internal temperature in the range of 18 to 25 ºC in the same trend (Figure 92-93). The northern surface and roof are in this range around 80 and100% of the year respectively. Additionally, the western surface behaves in the same way as northern surface. In the next level, other surfaces prepare this temperature equally during the year. Accordingly, roof has most influential role in keeping indoor temperature longer in this range.

3.3.13 Construction Technique C_1

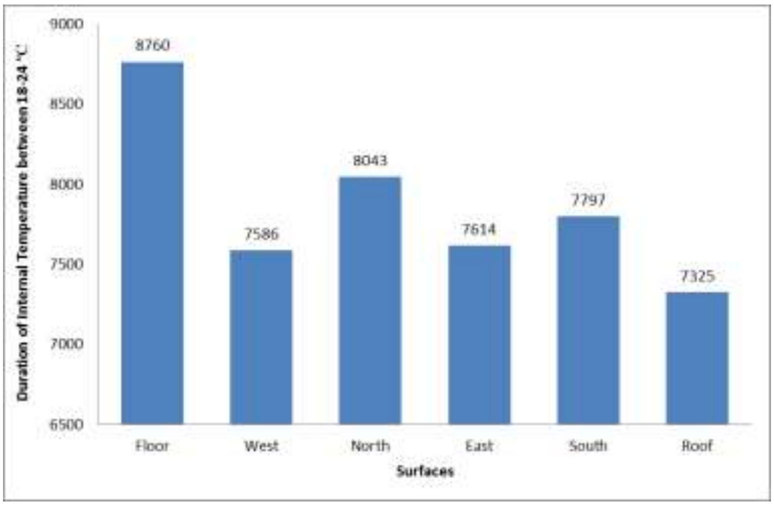

Figure 94: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_1

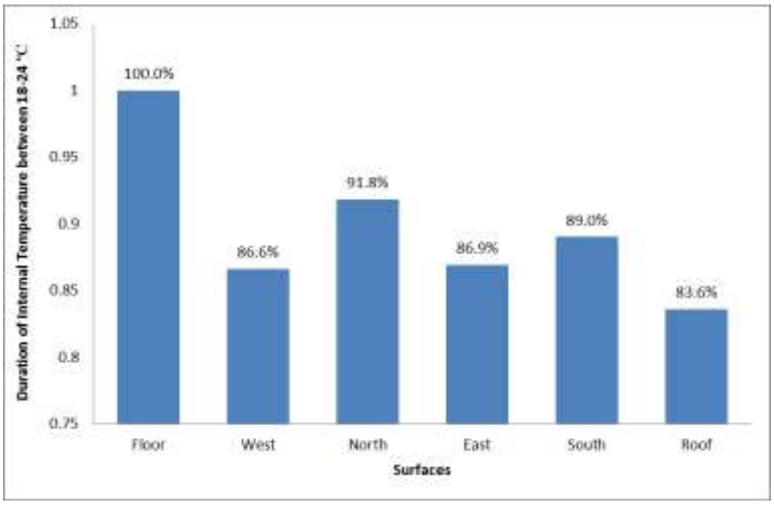

Figure 95: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying C_1

The "Figure 94" and "Figure 95" infer the annual inner temperature of C_1 in the range of 18 to 25 ºC. In compare with north surface and floor which are in this range around 93and 100% of the year respectively, other surfaces provide this temperature in 80s percent of the year. According to this graph roof is the most effective factor in preserving indoor temperature more in this range.

3.3.14 Construction Technique C_2

As it is vividly considered in the "Figure 96" and "Figure 97" which show the annual inner temperature of C_2 in the range of 18 to 25 ºC, all surfaces prepare this temperature equally whole of the year. Accordingly, all construction elements have influential role in keeping indoor temperature longer in this range.

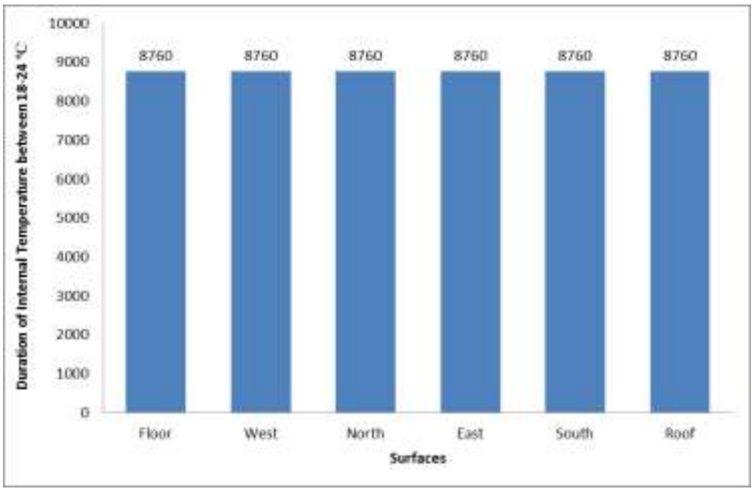

Figure 96: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_2

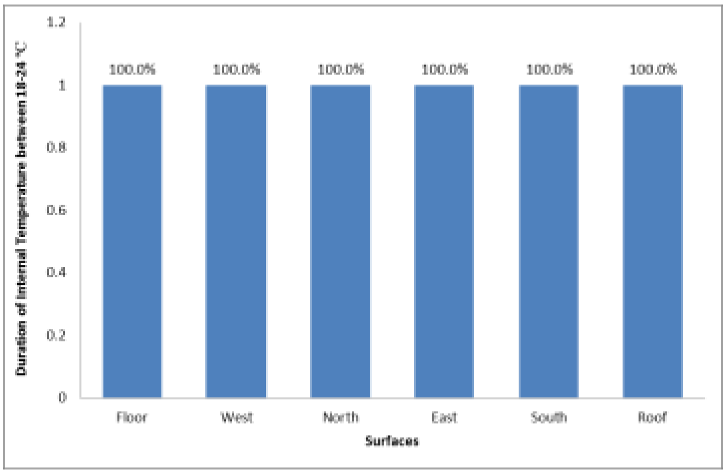

Figure 97: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying C_2

3.3.15 Construction Technique C_3

Based on what is presented in the "Figure 98" and "Figure 99", all construction elements are in the proper range of inner temperature whole of the year. According to these graphs the orientation of each surface does not have influence on keeping their inner temperature in this range.

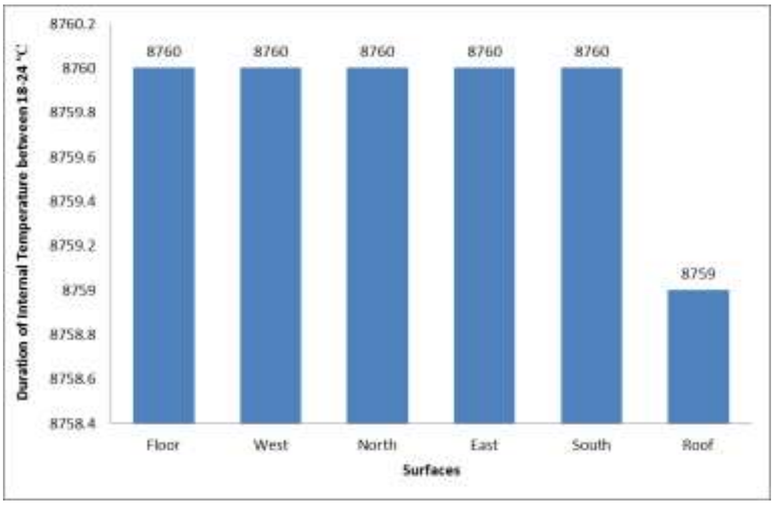

Figure 98: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_3

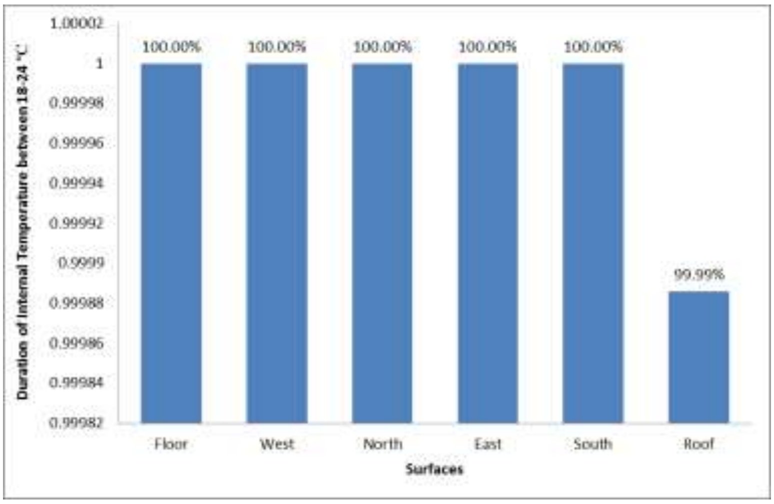

Figure 99: the annual percentage of internal temperature duration (18-24 ºC) for each surface through applying C_3

3.3.16 Construction Technique C_4

The "Figure 100" and "Figure 101" present roof and floor have the longest duration of inner temperature in the proper range during the year. In the second level, north surface obtains inner temperature between 18 and 25 around 93% of the year. The western surface is the worse one.

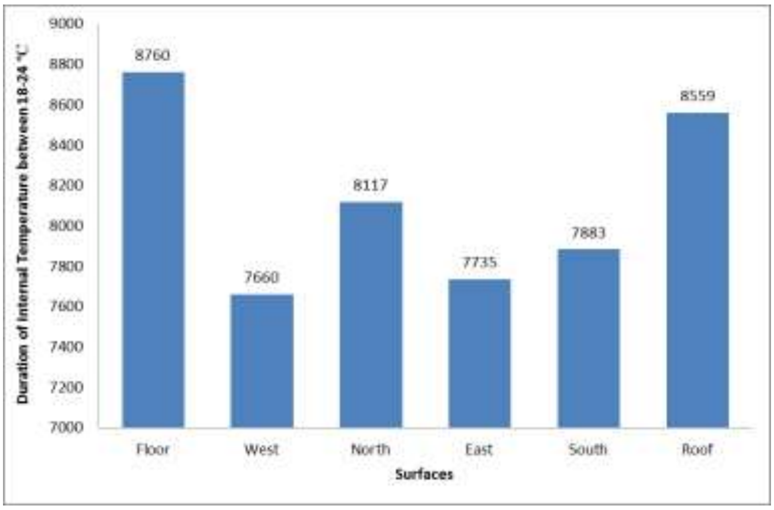

Figure 100: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_4

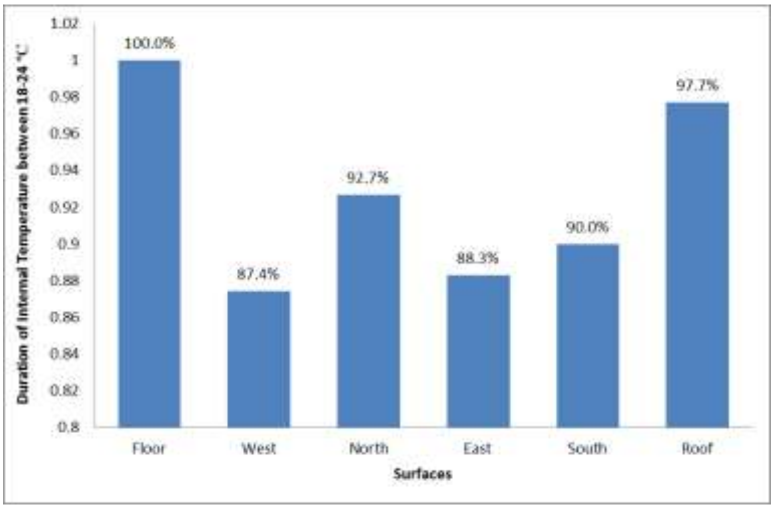

Figure 101: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_4

3.3.17 Construction Technique C_5

As it is vividly noticed in the “Figure 102” and “Figure 103” which displays the annual inner temperature of M_5 in the range of 18 to 25 ºC, northern surface, floor and roof are in this range around 93%, 98% and100% of the year respectively. Additionally, other surfaces prepare this temperature above 85% during the year which determines all construction elements are influential in keeping the indoor temperature in the proper temperature.

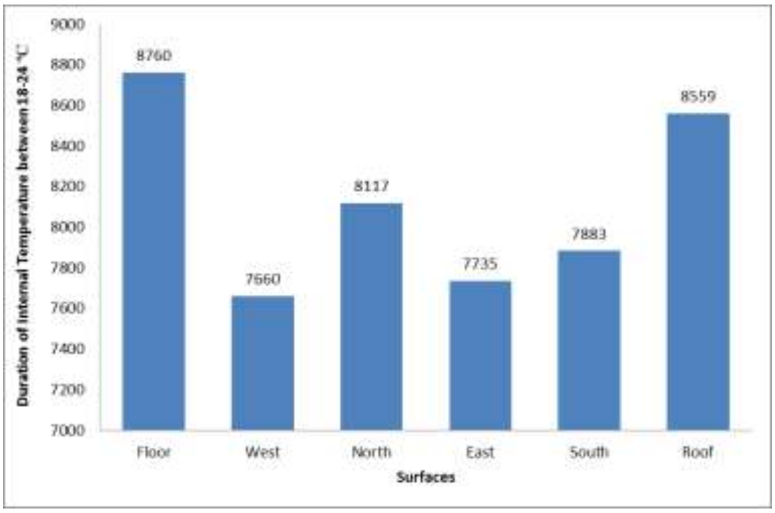

Figure 102: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_5

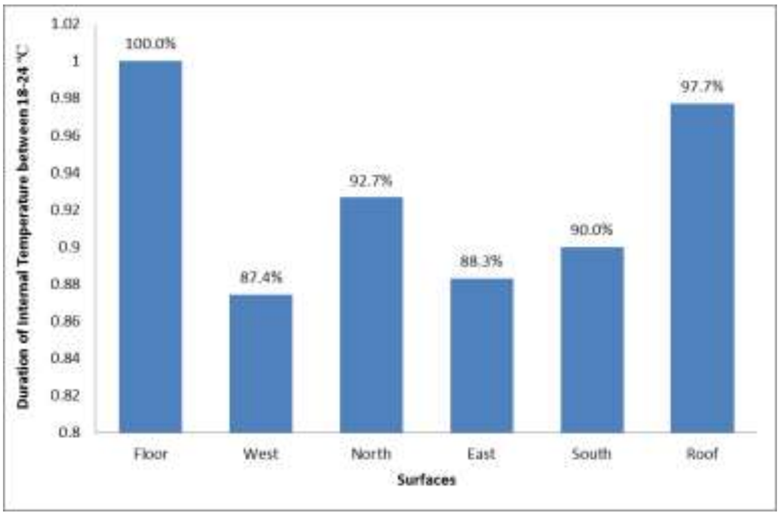

Figure 103: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_5

3.3.18 Construction Technique C_6

The “Figure 104” and “Figure 105” infer the annual inner temperature of C_6 in the range of 18 to 25 ºC. All of the surfaces provide this temperature whole of the year. According to the construction properties, it seems the insulation layer in the wall plays the essential role in preserving indoor temperature more in this range.

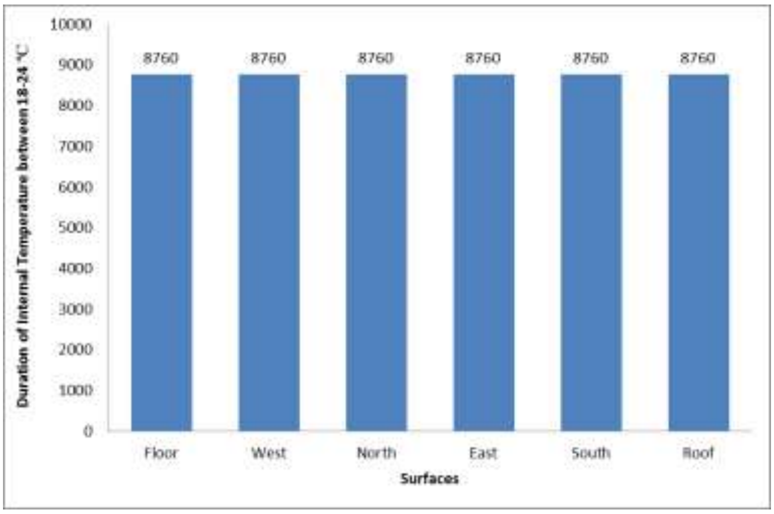

Figure 104: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_6

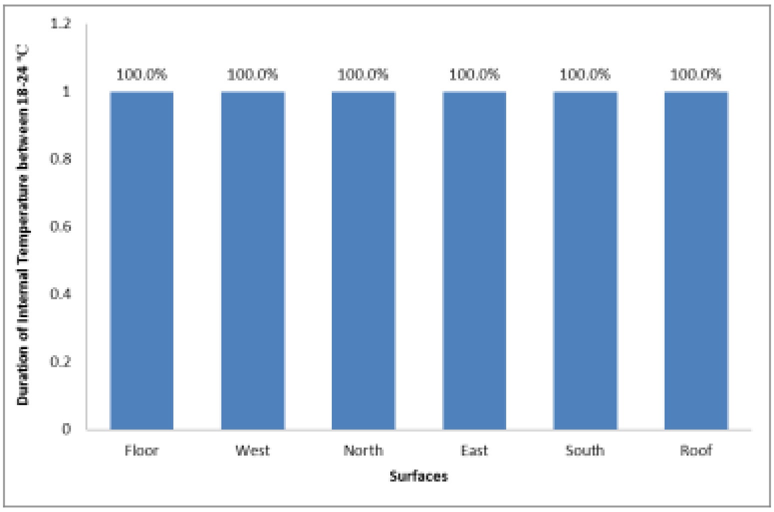

Figure 105: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_6

3.3.19 Construction Technique C_7

According to the “Figure 106” and “Figure 107” illustrating the annual inner temperature of C_7 in the range of 18 to 25 ºC, all of the surfaces provide this temperature whole of the year. Based on the construction detail, it seems the insulation layer in the wall plays the essential role in preserving indoor temperature more in this range.

According to the C_6 with the outer insulation layer, this graph indicates the inner insulation layer is also has the same impact.

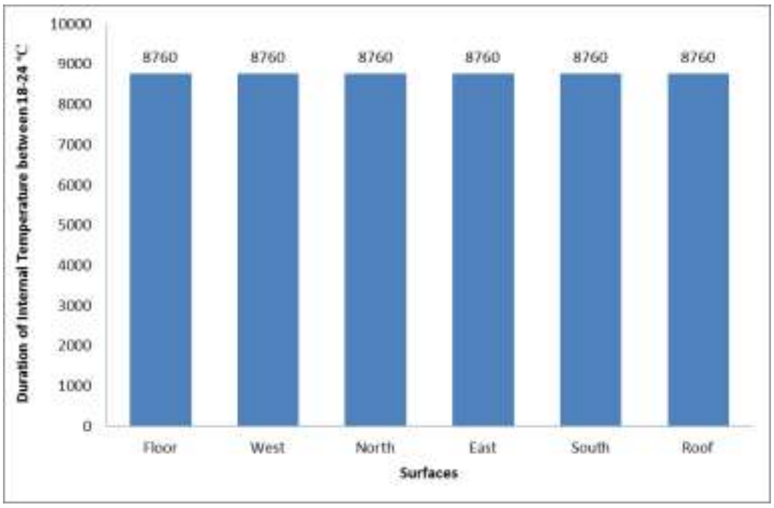

Figure 106: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_7

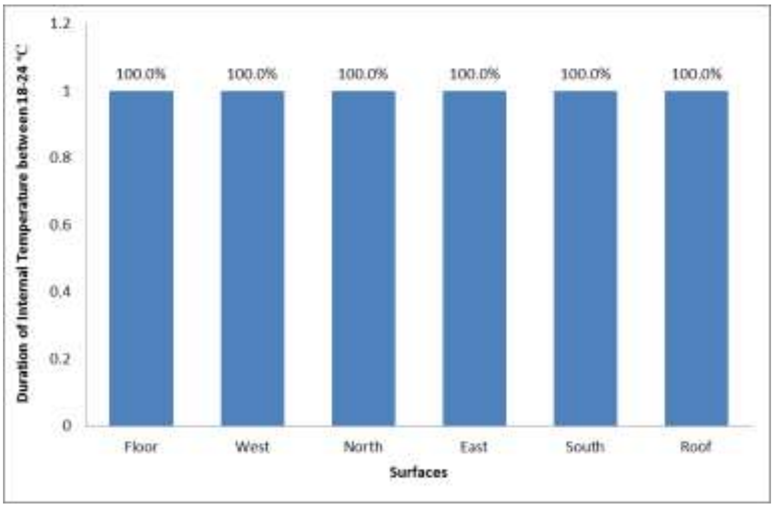

Figure 107: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_7

3.3.20 Construction Technique C_8

In compare the M_6 and M_7 with insulation layer, C_8 behaves in similar way. The "Figure 108" and "Figure 109" determines building elements provide the desirable temperature whole of the year. All of the walls in different orientation are in this range of temperature 100% of the year.

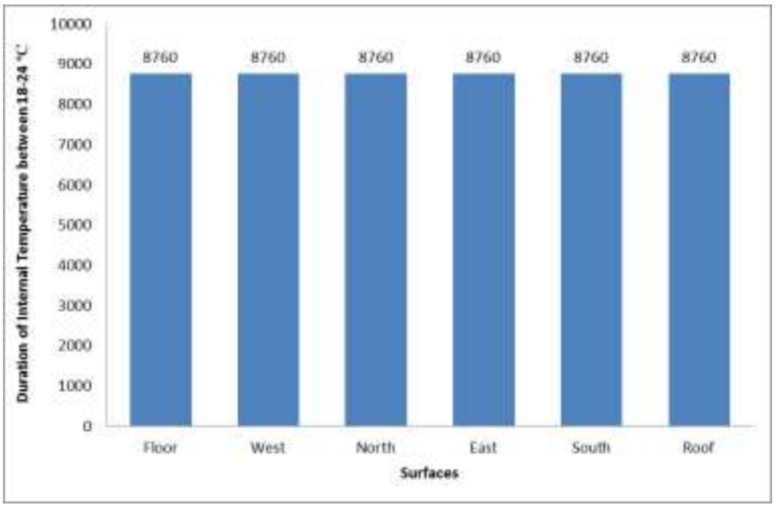

Figure 108: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_8

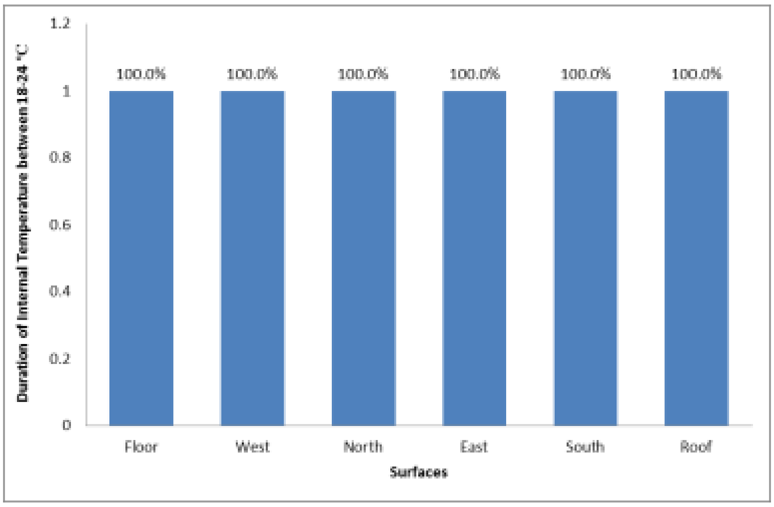

Figure 109: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_8

3.3.21 Construction Technique C_9

According to the "Figure 110" and "Figure 111" which illustrate the annual inner temperature of C_9 in the range of 18 to 25 ºC, in compare with floor and roof which is in this range around 100% of the year, all the other surfaces provide this temperature more than 85% of the year. Among different orientation of the walls, west and east act poorer in preserving indoor temperature more in this range. Totally according to the lack of insulation layer in this construction technique, the thermal performance of each elements decrease except floor and roof.

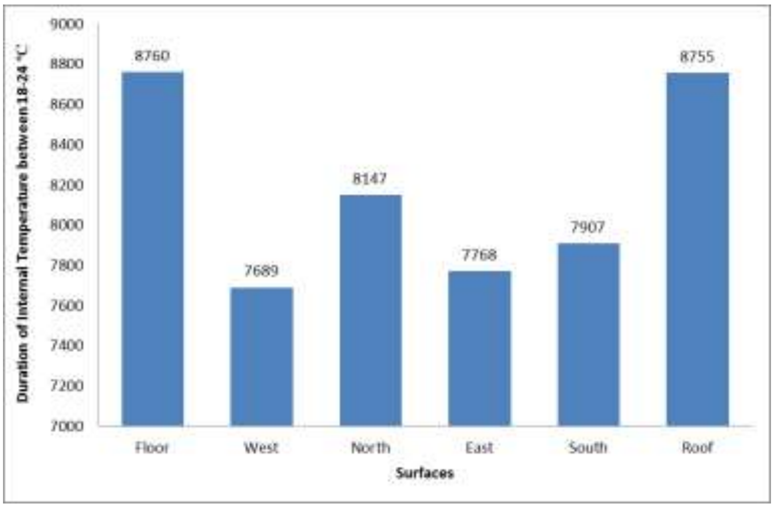

Figure 110: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_9

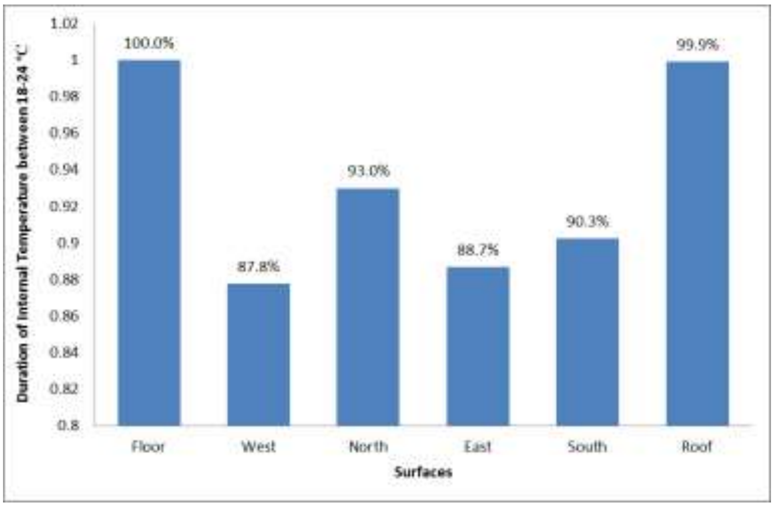

Figure 111: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_9

3.3.22 Construction Technique C_{10}

According to the "Figure 112" and "Figure 113" illustrating the annual inner temperature of C_{10} in the range of 18 to 25 ºC, all of the surfaces provide this temperature whole of the year. Based on the construction detail, it seems the insulation layer plays the essential role in preserving indoor temperature more in this range.

According to the C_9 without the insulation layer, this graph indicates the inner insulation layer is the effective material in this region.

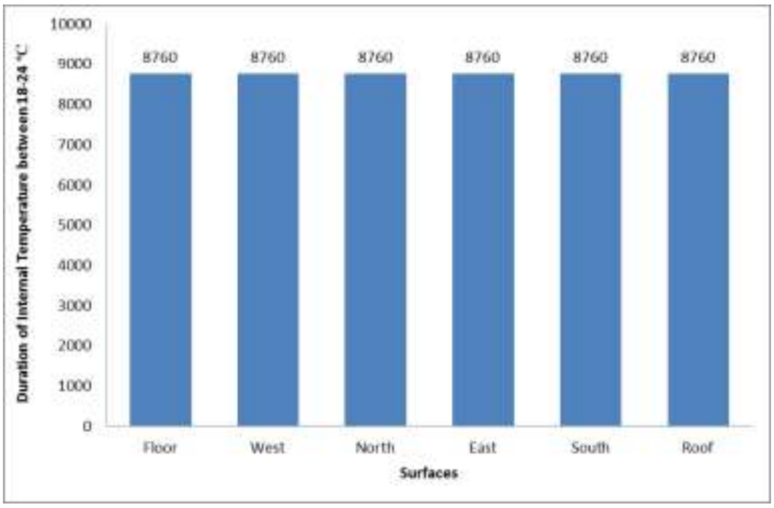

Figure 112: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_{10}

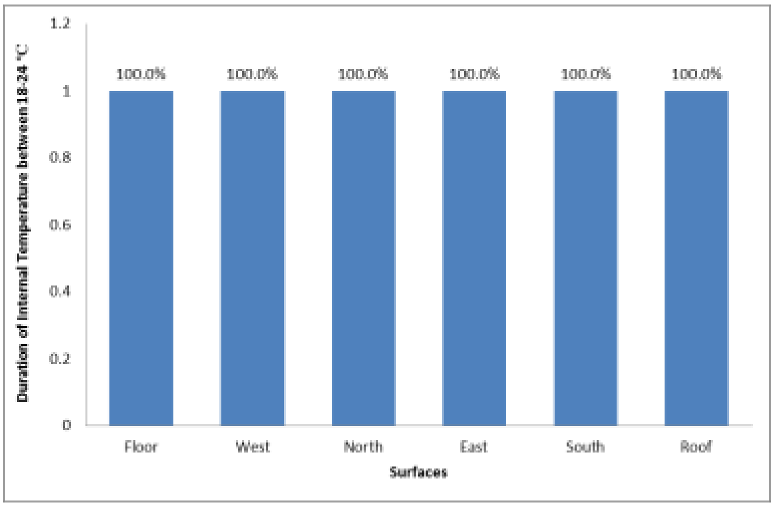

Figure 113: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_{10}

3.3.23 Construction Technique C_{11}

As it is vividly considered in the “Figure 114” and “Figure 115” which show the annual inner temperature of C_{11} in the range of 18 to 25 ºC, all surfaces prepare this temperature equally whole of the year. Accordingly, all construction elements have influential role in keeping indoor temperature longer in this range.

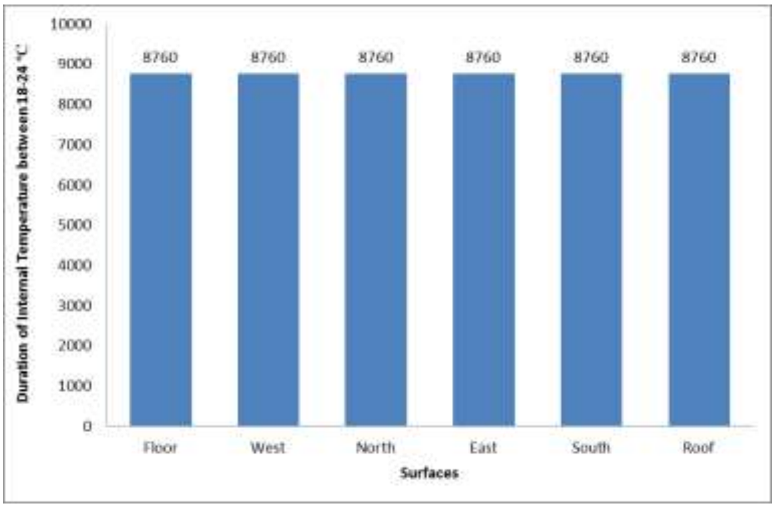

Figure 114: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_{11}

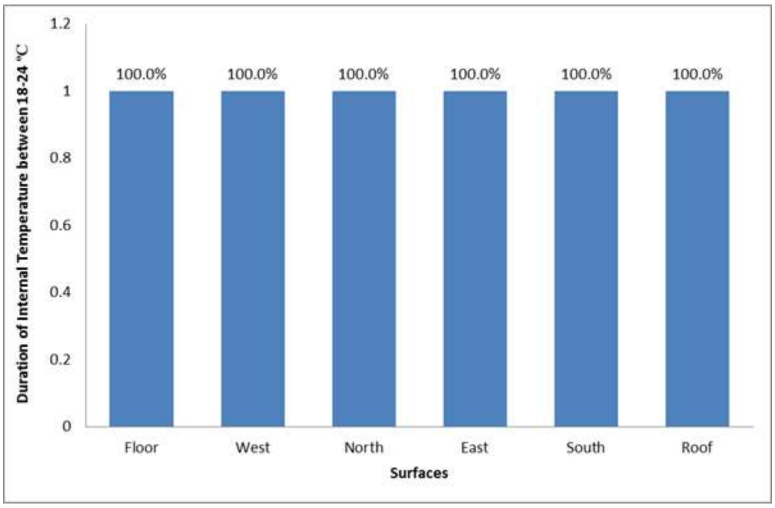

Figure 115: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_{11}

3.3.24 Construction Technique C_{12}

According to the "Figure 116" and "Figure 117" illustrating the annual inner temperature of C_{12} in the range of 18 to 25 ºC, all of the surfaces provide this temperature whole of the year. Based on the construction detail, it seems the insulation layer in the wall plays the essential role in preserving indoor temperature more in this range.

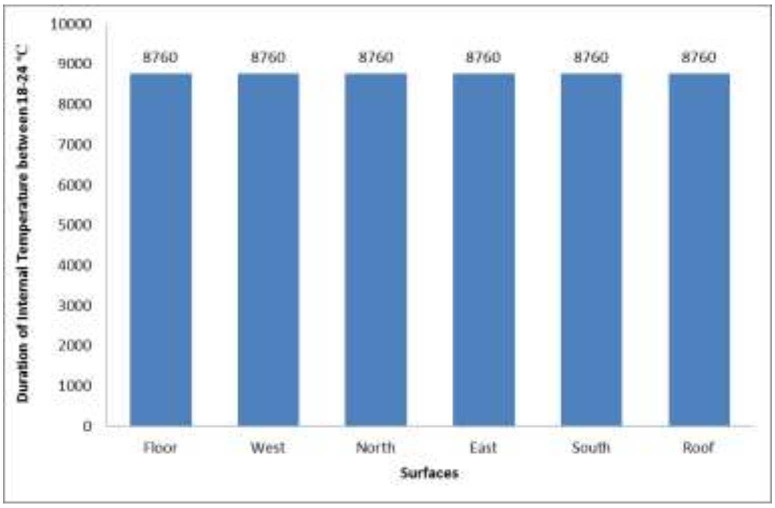

Figure 116: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_{12}

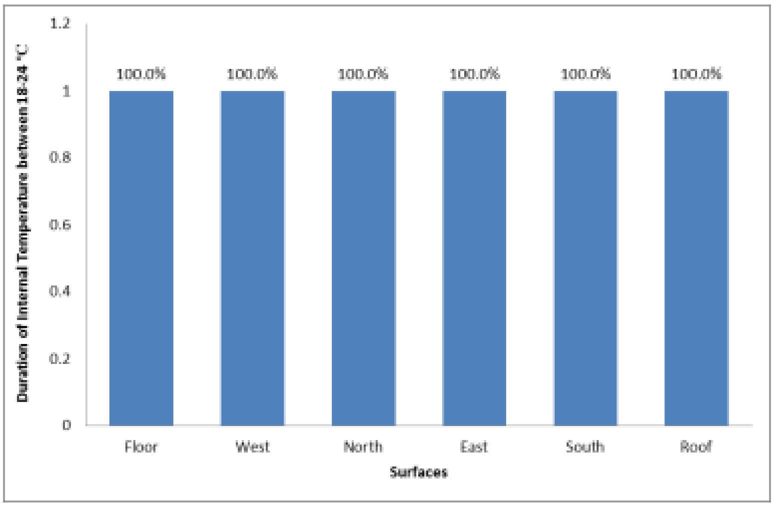

Figure 117: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_{12}

3.3.25 Construction Technique C_{13}

As it is vividly noticed in the "Figure 118" and "Figure 119" which displays the annual inner temperature of C_{13} in the range of 18 to 25 ºC, northern surface and floor are in this range around 90% and 100% of the year respectively. Additionally, other surfaces prepare this temperature above 84% during the year except roof which is known as the worst one.

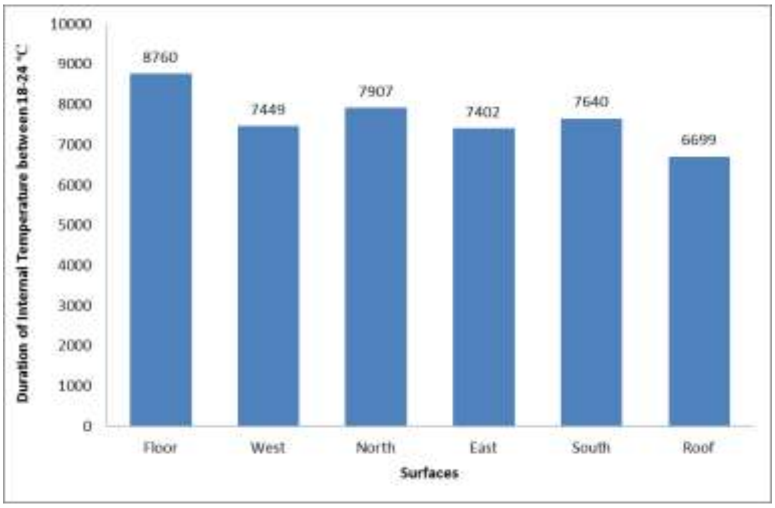

Figure 118: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_{13}

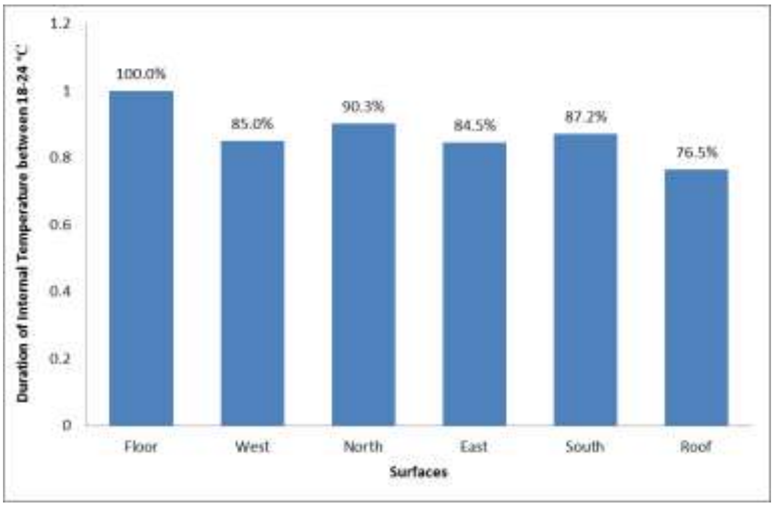

Figure 119: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_{13}

3.3.26 Construction Technique C_{14}

As it is clearly seen in the “Figure 120” and “Figure 121” illustrating the annual inner temperature of C_{14} in the range of 18 to 25 ºC, all of the surfaces provide this temperature whole of the year. Based on the construction detail, it seems the insulation layer plays the essential role in preserving indoor temperature more in this range and flat roof with external insulation layer can be improved in compare with C_{13}.

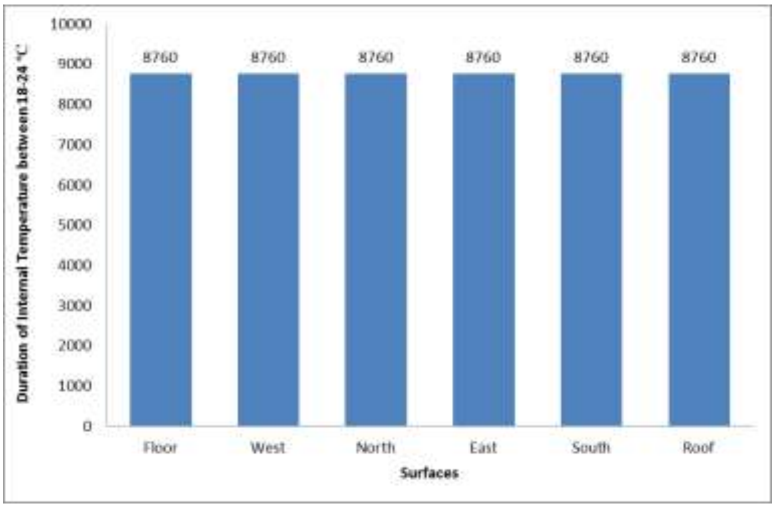

Figure 120: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_{14}

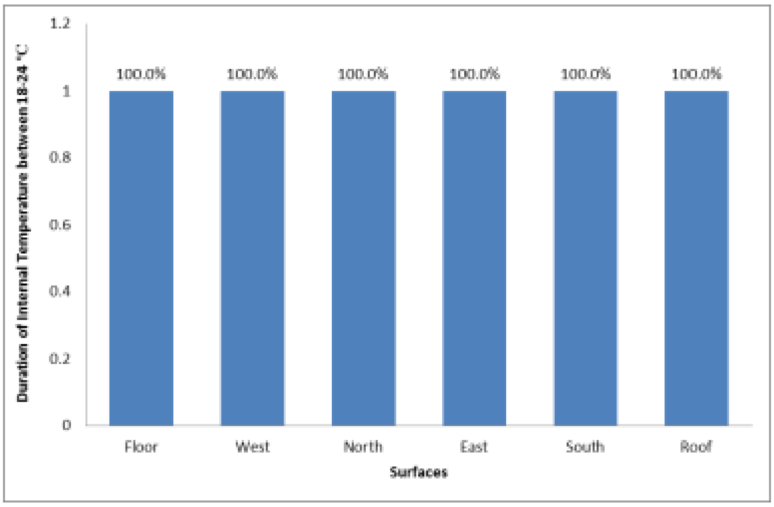

Figure 121: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_{14}

3.3.27 Construction Technique C_{15}

As it is vividly considered in the “Figure 122” and “Figure 123” which show the annual inner temperature of C_{15} in the range of 18 to 25 ºC, all surfaces prepare this temperature equally whole of the year. Accordingly, all construction elements have influential role in keeping indoor temperature longer in this range, but roof seems a little weak.

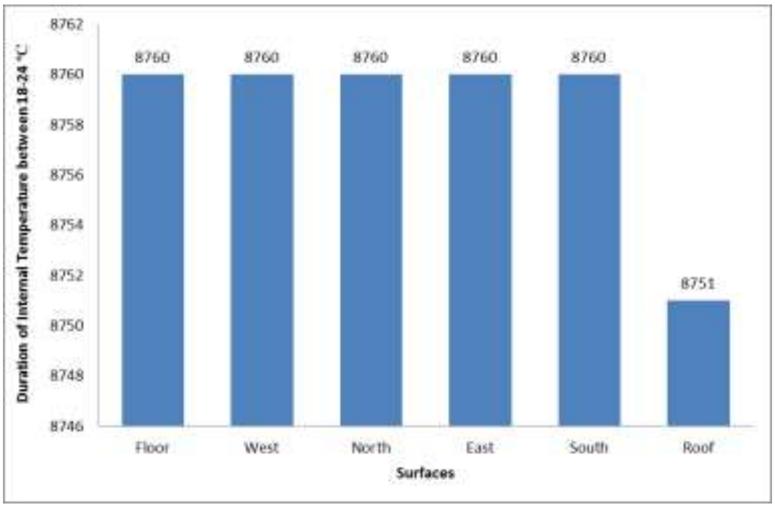

Figure 122: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_{15}

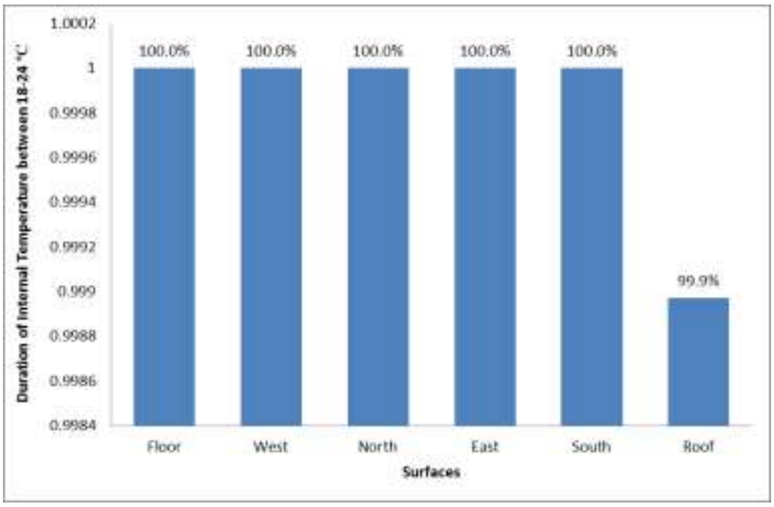

Figure 123: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_{15}

3.3.28 Construction Technique C_{16}

As it is vividly considered, like previous consideration technique, the "Figure 124" and "Figure 125" showing the annual inner temperature of C_{16} in the range of 18 to 25 ºC, all surfaces prepare this temperature equally whole of the year. Accordingly, all construction elements play influential role in keeping indoor temperature longer in this range, but roof seems a little weak.

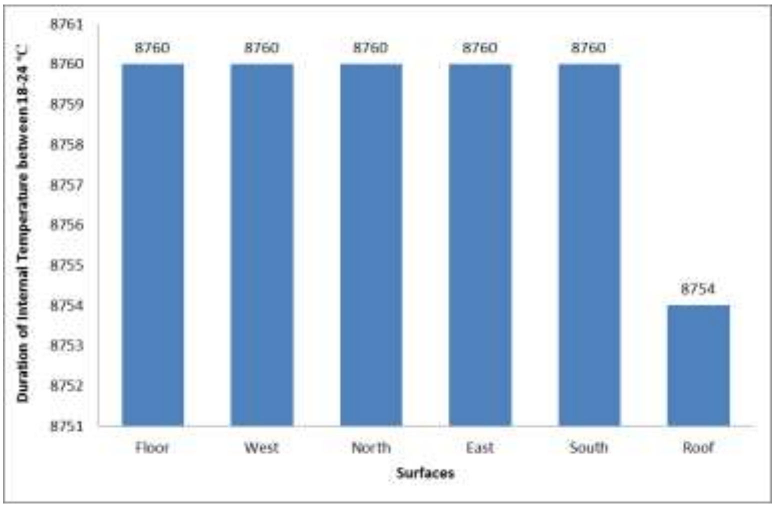

Figure 124: the annual duration of internal temperature (18-24 ºC) of each surface through applying C_{16}

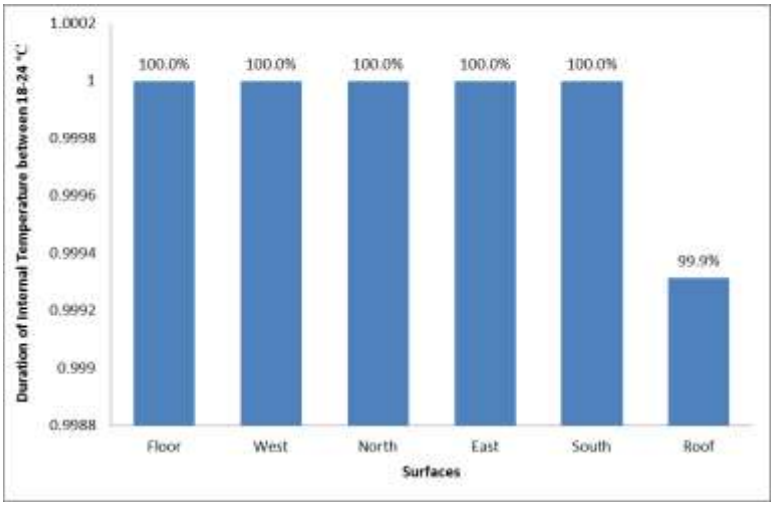

Figure 125: the annual percentage of internal temperature duration (18-24 ºC) of each surface through applying C_{16}

Chapter 4

CONCLUSION

According to the nowadays universal interest in protecting nature and environment from the pollution caused by fossil energy, the main concern is based on sustainability in the building industry developing and energy consumption of building. This concern is one of the forces which persuade designers to involve many studies associated to climatic design to efficient energy in terms of thermal comfort. One of the main factors in determining the level of thermal comfort and energy loads is building properties and construction techniques. For this purpose, this survey aims to discover the relation between occupants' satisfaction with indoor thermal comfort and building construction method to answer the following questions:

- Why did inhabitants feel more comfortable in their building in past?
- Was that thermal comfort satisfaction related to the physical aspect or psychological aspect?
- Despite the technology development, why do not inhabitants satisfy with the indoor condition yet in term of thermal comfort?
- Which applied construction techniques seem more adaptable to this region?

All construction techniques from ottoman period up to now are analyzed in terms of thermal comfort, energy efficiency and internal surface's temperature.

In the first step, all construction techniques are evaluated in terms of thermal comfort. Totally, in compare with contemporary construction methods, the vernacular ones which provide thermal comfort 40-50% of the year, seems more appropriate. Among traditional techniques which with massive roofs are located at the first level after that ones with massive walls are located. Among contemporary the construction techniques with insulation layer are better than the simple ones, also the inner insulation layer behaves better than others.

On shorter timescales as seasons the construction methods result in different outcomes. During winter, contemporary buildings are more successful, especially the inner insulation layer is the best. Among all techniques which have the light weight elements react better than massive ones.

During summer, the heavy weigh methods are in the first step. Among traditional ones which supported by massive roofs are the best and then the massive walls. Among contemporary methods, which ones are without insulations material and with inner insulation layer have the best performance.

Totally contemporary construction techniques are more successful than vernacular ones during all seasons except summer. In the other words, vernacular construction methods are more responder to the climate during the hot months and whatever the weather turns to cold the contemporary ones seems more proper (Figure 126-128).

The reason of this reaction to the hot and cold weather is found in material properties. The heavy thermal mass, high R-value and low U-value of the traditional do not let high temperature of outside influence the indoor. These characteristic would not be positive in winter by preventing of heat transferring from outside to in.

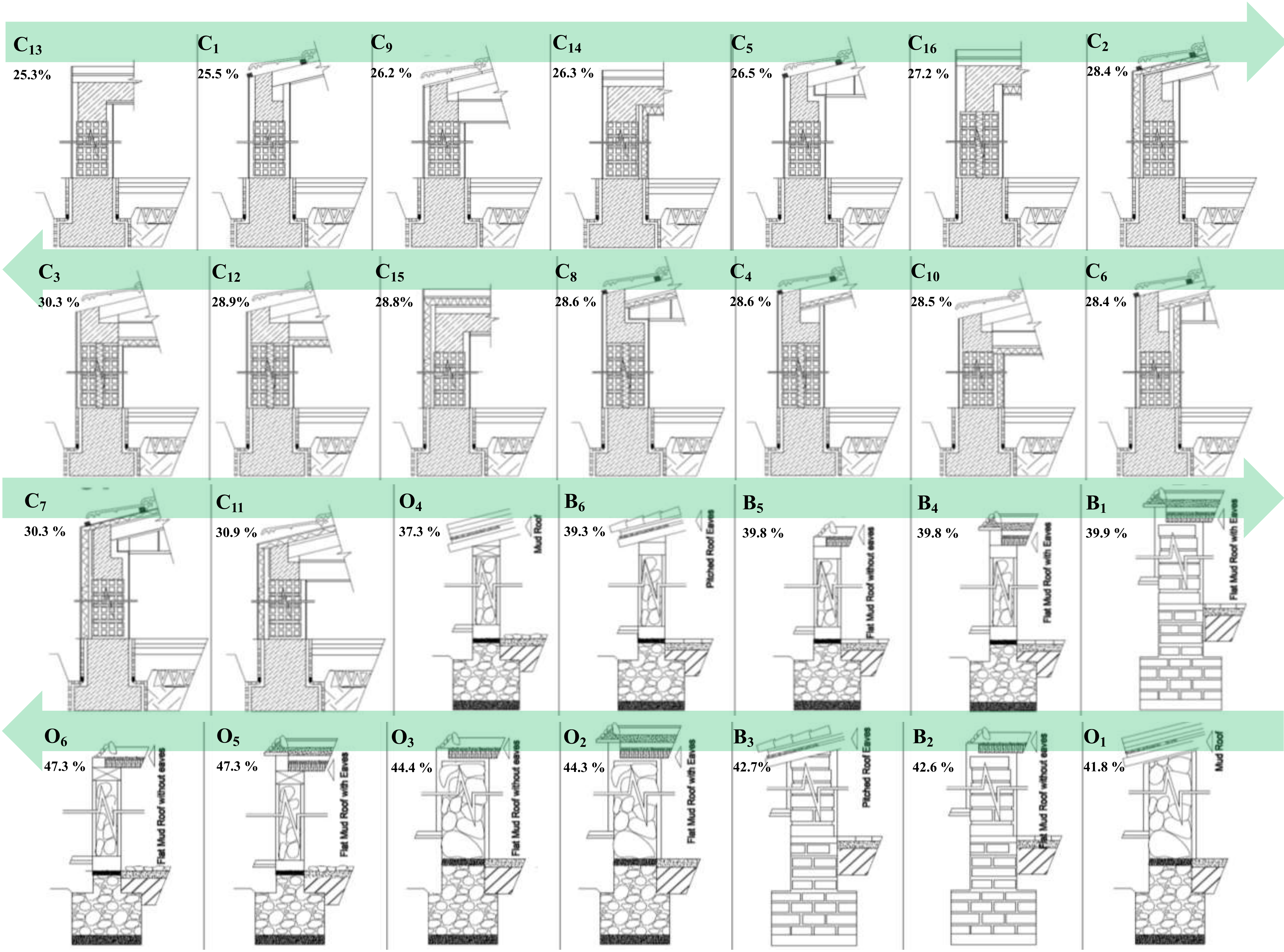

Figure 126: Annual performance of the construction techniques in terms of thermal comfort under naturally ventilated indoor environment

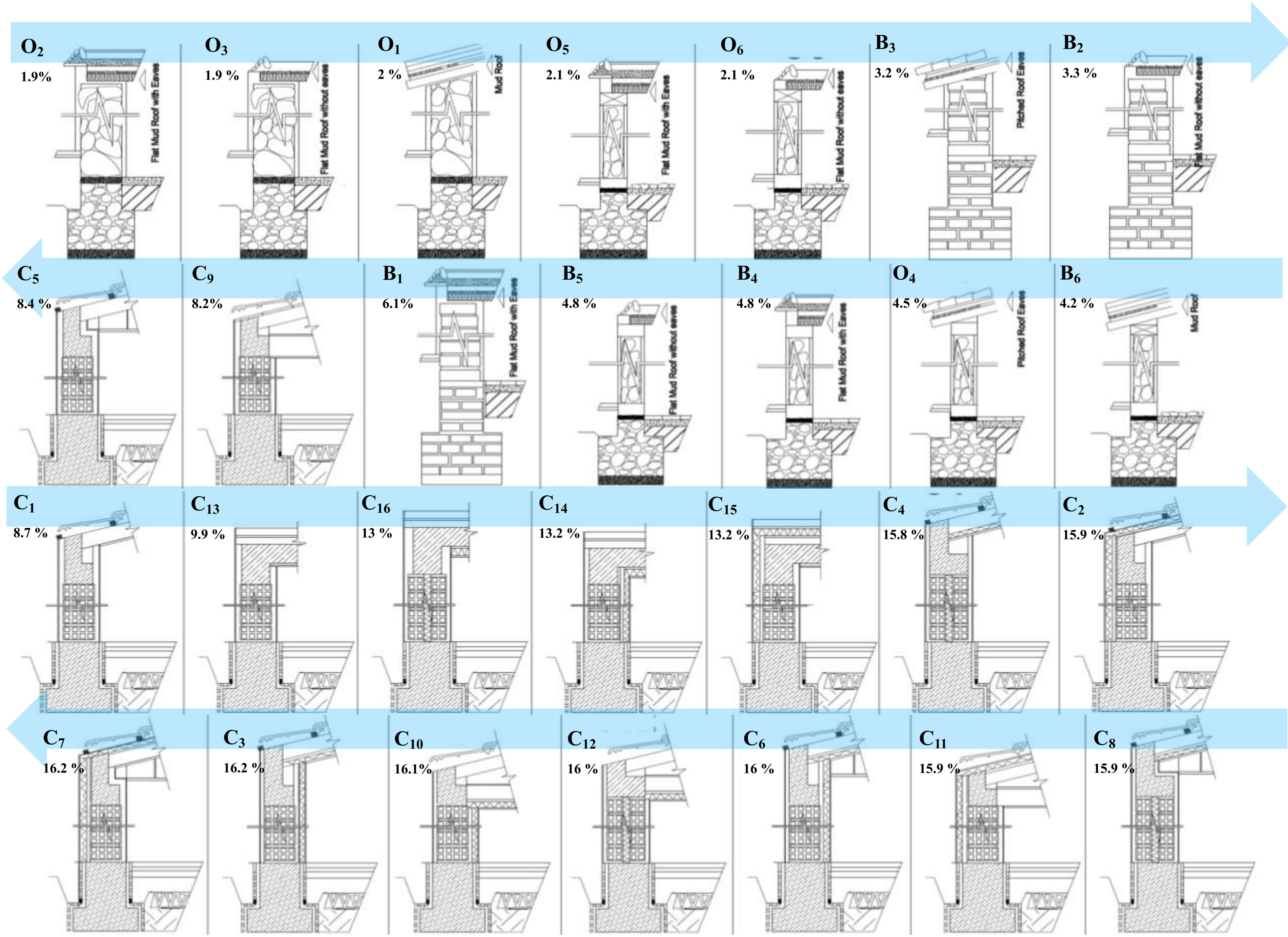

Figure 127: performance of the construction techniques in terms of thermal comfort under naturally ventilated indoor environment in under heated period

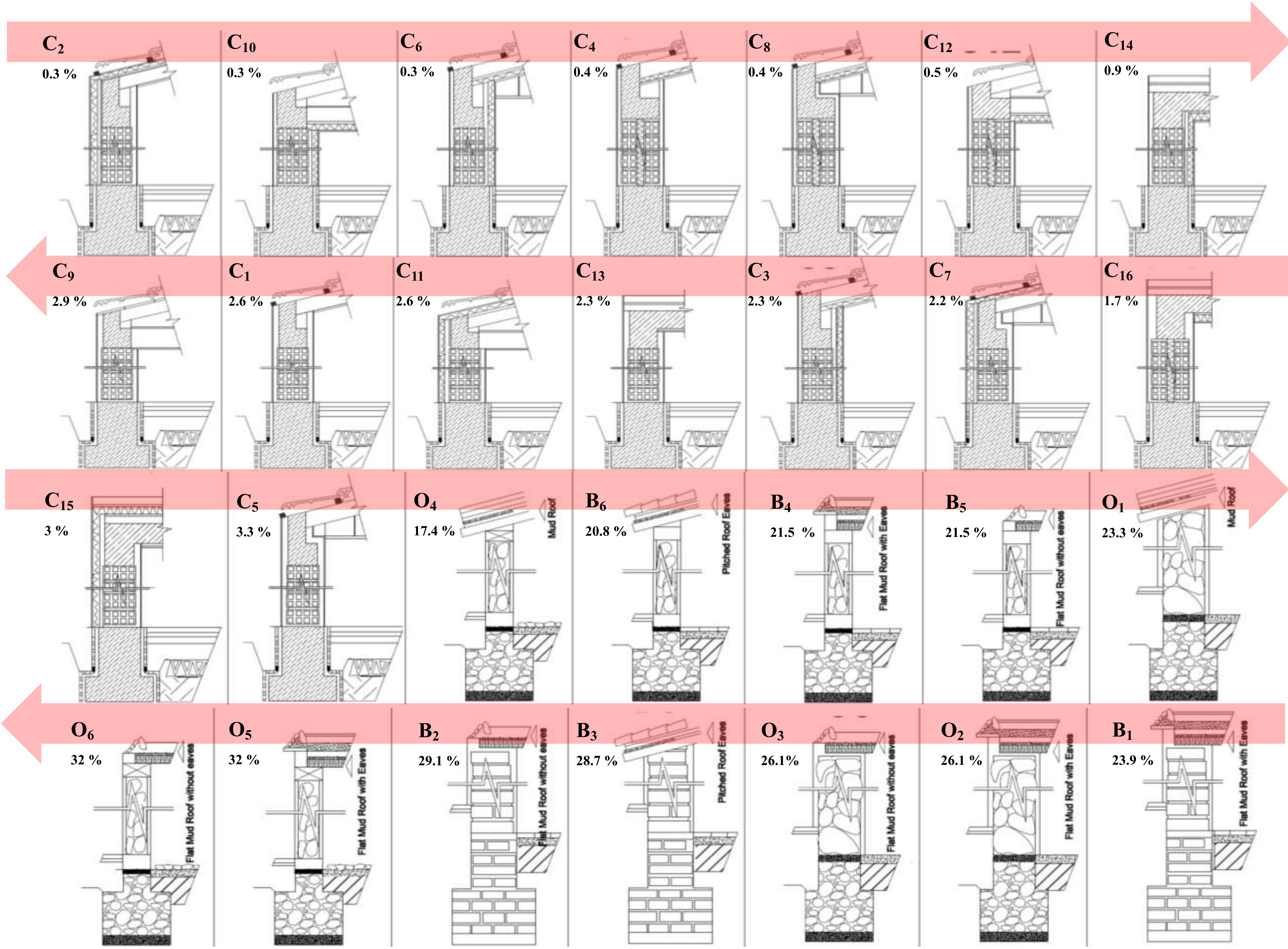

Figure 128: performance of the construction techniques in terms of thermal comfort under naturally ventilated indoor environment in over heated period

In the next step, all construction techniques are evaluated in terms of energy efficiency to determine the amount of energy consumption via each construction methods to preserving the indoor temperature in desirable temperature. This simulation inferred that vernacular construction technique cause approximately more energy consumption than contemporary ones during the year. During the year, among contemporary methods, those have slope roofs seem more efficient than flat ones, and those have insulation layer are the best which indicates the essential role of insulation layer in decreasing the amount of energy usage. Among traditional ones the construction techniques with adobe walls and heavy weight roofs have better performance. During under heated months, the contemporary ones are so better and among contemporary methods those have insulation layer are the best. Among traditional construction techniques, the adobe walls and massive roofs are the best. In over heated months, the contemporary ones seem worse than others, especially those without insulation layer. After that the slope roofs work more efficient than flat ones. Among traditional techniques those with massive walls are so better than others.

On shorter timescales as seasons the results are different. Except summer, all seasons influence on increasing energy loads of the vernacular methods in compare with the contemporary ones. The survey indicates that whatever the weather turns to cold, contemporary techniques seem more appropriate for this climate in terms of energy efficiency (Figure 129-131).

The reason of different level of energy consumption in hot and cold weather is found in material properties. The heavy thermal mass, high R-value, low U-value and high thermal heat capacity of the traditional materials absorb heat from inside and keep it so a huge volume of produced heat would be stored in construction elements which results in increasing energy loads during winter. These characteristic would be positive in summer by preventing of heat transferring from outside to in.

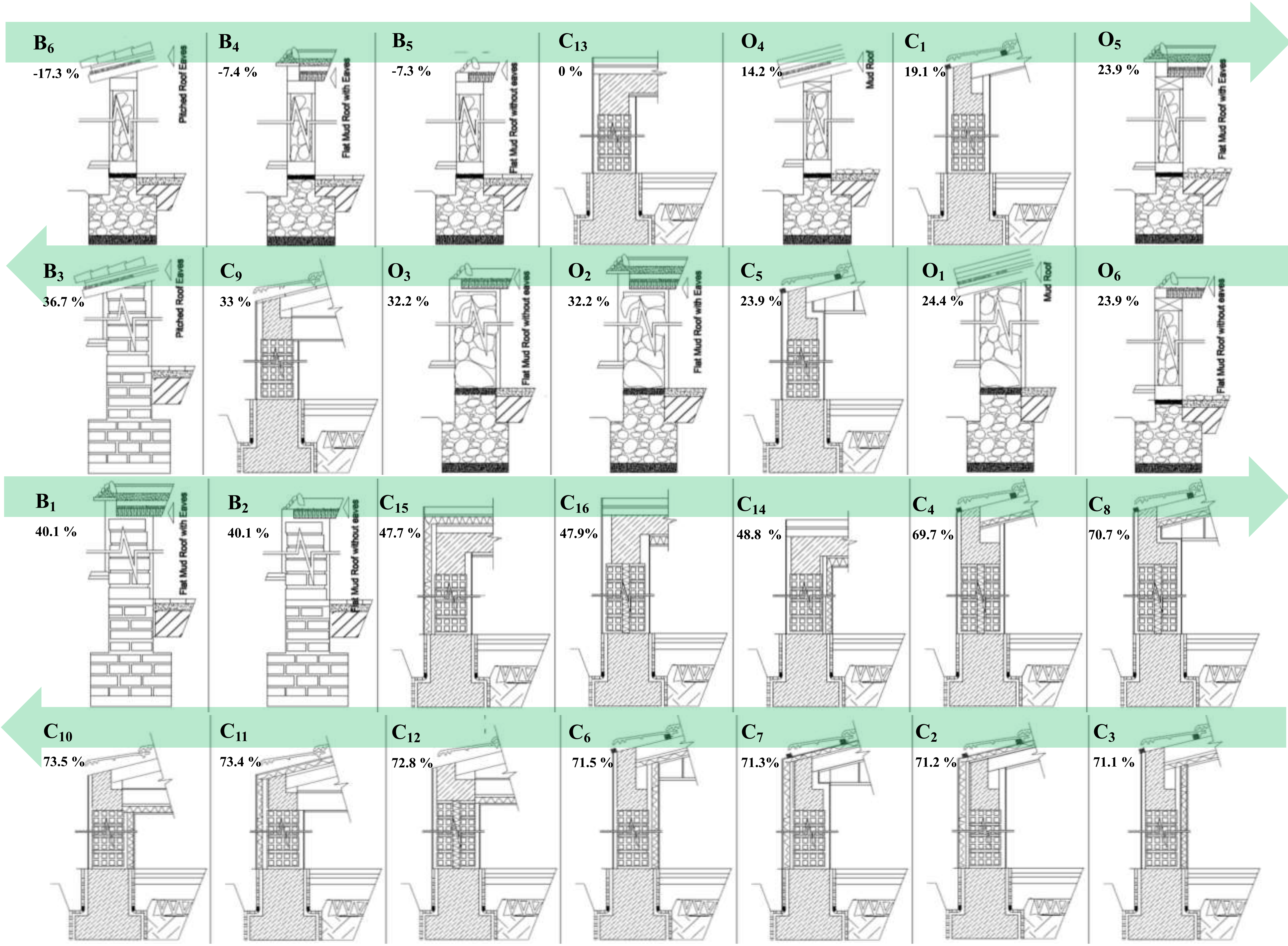

Figure 129: annual performance of the construction techniques in terms of energy efficiency under continuous air conditioning region- the performances have been compared with the worst performance of contemporary construction techniques (C_{13})

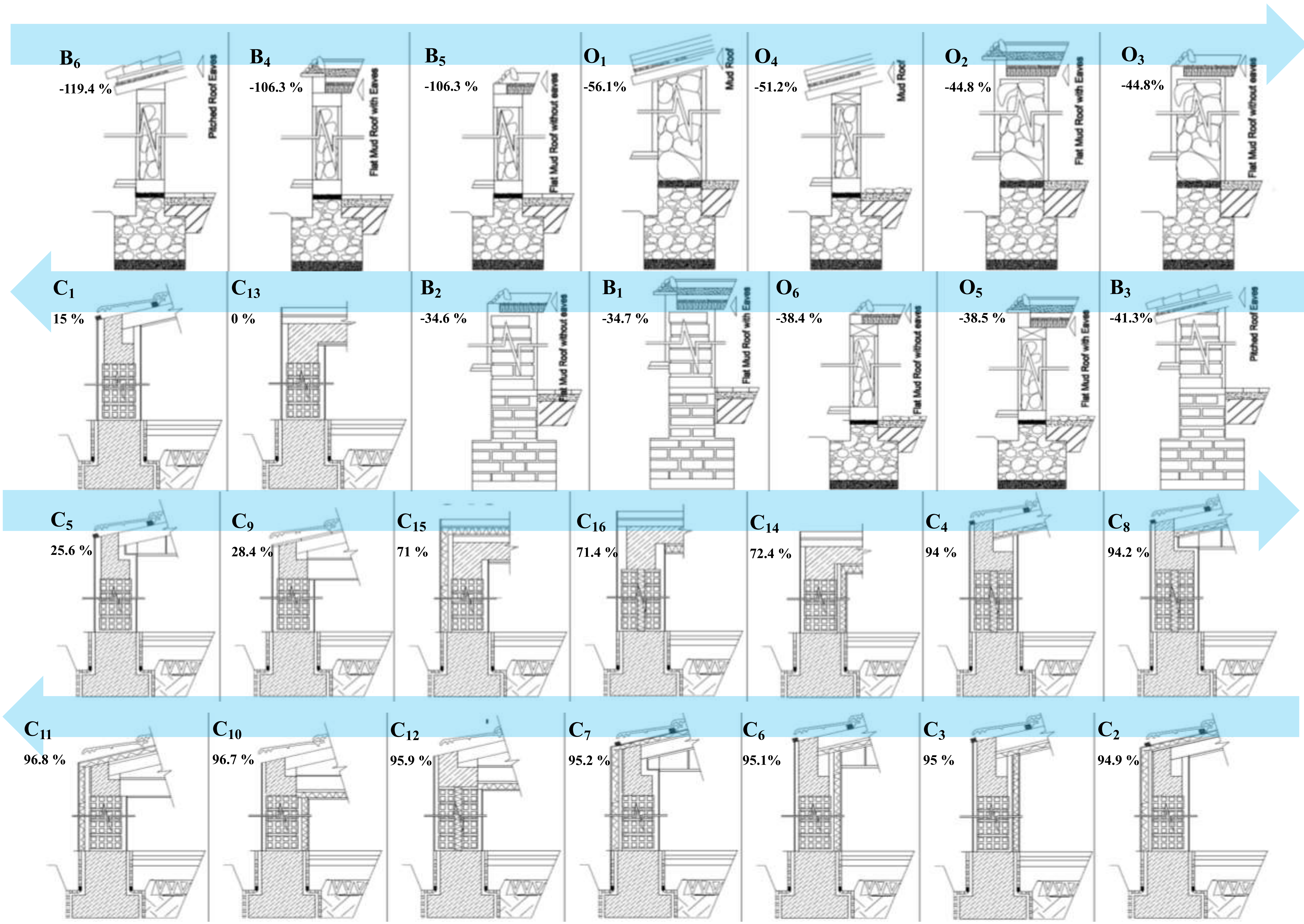

Figure 130: performance of the construction techniques in terms of energy efficiency under continuous air conditioning region in under heated period- the performances have been compared with the worst performance of contemporary construction techniques (C_{13})

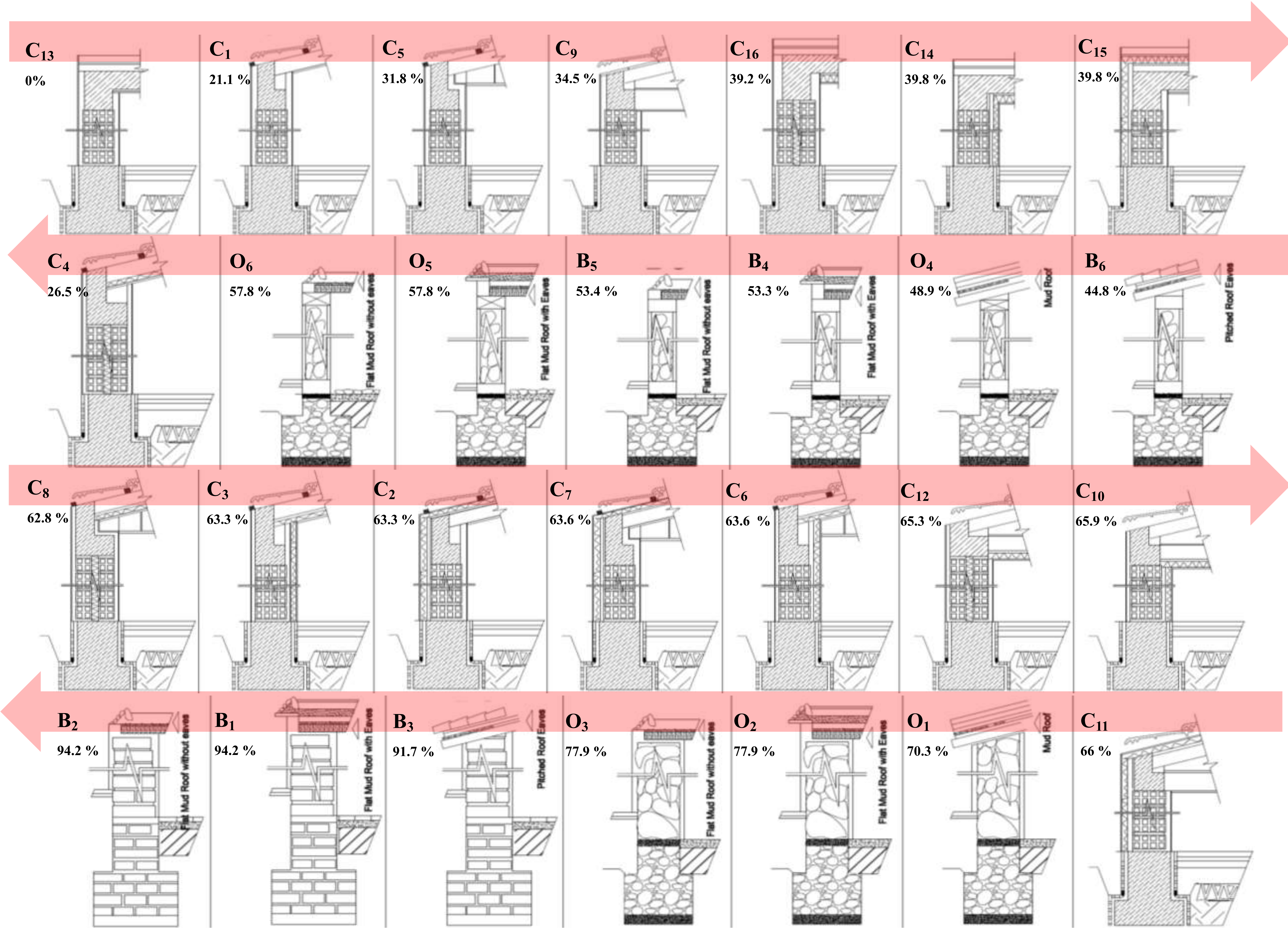

Figure 131: annual performance of the construction techniques in terms of energy efficiency under continuous air conditioning region in over heated period- the performances have been compared with the worst performance of contemporary construction techniques (C_{13})

In third step the construction elements are analyzed one by one to recognize which surface is more effective in the level of energy consumption. This evaluation is based on the internal temperature of each surface. These evaluations indicate that among all construction elements roof has the best adoptable role in reserving inside proper temperature through vernacular methods. Unlike the vernacular techniques, floor is the most appropriate element in indoor temperature. Also the insulation layer is able to increase the utility of the walls regardless of its position. This fact shows that this climate needs the construction technique with the appropriate insulation layer. The dual effect of material behavior in different weather demonstrates that preparing indoor thermal comfort considering to the energy efficiency would not be fulfilled just by proper material. Architect as a decision maker, designer and performer should be aware of material properties to be able to design in an innovative way. Finding some architectural solution such as open spaces, semi open spaces, courtyards, proper orientation and forms can be as the supportive actions which eliminate the weak aspects of the material and construction techniques.

Although this survey infers that traditional construction techniques provide more thermal comfort during the year, it should be considered that this amount of thermal comfort (50% of the year) is not considerable and it is needed to use mechanical heating and cooling systems to make indoor condition more proper. So according to the second step of analyzing the contemporary ones are more efficient than the traditional construction techniques. Although the contemporary construction techniques with slope roofs and insulation layer especially inner insulation layer seems more adoptable with this climate feeling, nowadays inhabitants deal with unsatisfied condition and high level of energy consumption which indicates nowadays buildings are built by improper techniques and without applying insulation materials. Also it should be considered being comfortable is a relative sense which is determined in comparing with uncomfortable condition. The meaning of thermal comfort has been revolute through the years by perceiving new shapes of comfort, so people expect different level of thermal comfort to be satisfied. This fact causes the high level of thermal dissatisfaction among Cypriot inhabitants while technology has been improved and construction techniques are promoted. This demonstrates the necessity of construction methods and materials' reviewing regarding to climatic aspects.

According to this survey, objectives and study limitations there are some recommendations and future study:

- Considering to the plan layout to evaluate comprehensively.
- Considering to the different level and the effect of height of the building on thermal comfort and energy efficiency.
- Evaluate more in detail and specific material to determine the proper material for the specific climate and create a kind of national and local regulation.
- Considering to the number and characteristics of windows and doors.
- Considering to the architectural aspects and solutions.
- Assign various material and construction technique regarding to the space and its function.

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