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ENGINEERING AND TECHNOLOGY

**A STUDY ON THE INVESTIGATION OF THE ENERGY EFFICIENT
BUILDING ENVELOPE IN TERMS OF HEAT, LIGHT AND SOUND**

M.Sc. THESIS

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ABBREVIATIONS

ASHRAE: American Society of Heating, Refrigerating and Air Conditioning Engineers

BRE : Building Research Establishment

CIE : Commission Internationale de l'Eclairage

DF : Daylight Factor

ET : Effective Temperature

ERC : Externally Refected Component

IESNA : Illuminating Engineering Society of North America

IRC : Internally Refected Component

MRT : Mean Radiant Temperature

NC : Noise Criteria

NCB : Balanced Noise Criteria

PMV : Predicted Mean Vote

PPD : Predicted Percentage of Dissatisfied

RC : Room Criteria

SC : Direct (Sky) Component

SC1 : Scenario 1

SC2 : Scenario 2

SC3 : Scenario 3

SC4 : Scenario 4

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A STUDY ON THE INVESTIGATION OF THE ENERGY EFFICIENT BUILDING ENVELOPE IN TERMS OF HEAT, LIGHT AND SOUND

SUMMARY

The main purpose of a building envelope is to continually satisfy the occupants' thermal, visual and acoustic comfort for human health and higher to provide productivity in work. On the other hand a great demand of energy is consumed for providing comfort conditions in buildings. Because of the limited energy sources in the world, comfort requirements of the occupants should be met by reducing energy consumption. From the energy conservation point of view, one of the most important functions of the building envelope is to control physical environmental factors such as heat, light and sound in order to ensure comfort conditions for the user with a minimum energy consumption. Therefore, the aim of this study is to evaluate building envelope in terms of heat, light and sound in order to achieve energy efficiency.

In this study, different building envelope alternatives have been developed for a selected building that has been assumed as a passive system. Each set of alternatives, have been improved in terms of physical environmental control parameters. For each alternative energy simulations have been executed and results have been compared.

As it is known the economic, social, environmental and energy related problems such as rapid growth of human population, depletion of the energy sources and agricultural lands, global warming and increasing level water, damaged the ecosystems and biological diversity have necessitated the determination of sustainable design solutions.

Today one of the most important problems in the world is energy conservation. The energy demand increases due to comfort requirements related to population increases in spite of the fact that energy sources are depleted rapidly. A great portion of energy is consumed in existing residential buildings to achieve comfort conditions in most of the countries in the world. Efficient use of energy in residential buildings is minimizing the energy need and therefore the energy load without compromising from social welfare, comfort conditions, required performance level and quality. In regards to national energy economics, as it is essential to evaluate energy efficiency and to develop suggestions to decrease energy loads during the design phase of residential buildings, it is also an up to date topic which should continually be researched and produced solutions on

energy consumption should be determined.

One of the most important design parameters affecting energy consumption is building envelope. In other words building envelope is the major element of a building system with the aim of optimal performance in controlling heat and reducing energy consumption and energy expenses to a minimum. This study aims to introduce a study which serves the purpose of producing a set of building envelope alternatives for a residential building controlling physical environmental factors in order to reduce energy consumption.

ÖZET

Bina kabuğu, bina içi çevre ile bina dışı çevreyi ayıran bina elemanları ve bileşenlerinin tümü olarak tanımlanabilmektedir. Isı, ışık, ses gibi fiziksel çevresel parametrelerin kontrolü, kullanıcı sağlığı ve konforu açısından bina kabuğunun en önemli işlevi,

- Dış çevredeki iklimsel koşulları kontrol altına alarak iç çevrede ısısal (termal) konfor koşullarını
- Doğal ışığı kontrol altına alarak,iç çevrede görsel konfor koşullarını,
- Dış çevredeki gürültü düzeyini kontrol ederek iç çevrede işitsel konfor koşullarını sağlamaktır.

Diğer taraftan dünyadaki en önemli sorunların başında çevre ve enerji sorunlarının geldiği bilinen bir gerçektir. Günümüzde artan dünya nüfusu ve teknolojik gelişmelere bağlı olarak konforlu ortamlarda yaşam isteğinin giderek atması enerji gereksinimi de artmaktadır. Buna karşılık dünyadaki tükenebilir enerji rezervlerinin azalması, enerji konusunun gerek gelişmiş gerekse gelişmekte olan ülkelerin gündeminde sürekli olarak yer almasına yol açmaktadır. Ülkemizde enerji tüketiminin sektörsel dağılımı incelendiğinde bina sektörünün önde geldiği bilinmektedir. Bu nedenle binalarda enerjinin etkin kullanımı öncelikli olarak ele alınmalıdır. Binalarda enerji harcamalarının önemli bir bölümü, konfor koşullarını sağlamak amacıyla özellikle ısıtma, soğutma ve aydınlatma amaçlı olmaktadır. Binalarda kullanıcı sağlığı ve konfor koşullarından ödün vermeden enerjinin etkin kullanımının gerçekleştirilebilmesi için, binanın en etkin ögesi olan bina kabuğunun ısısal, görsel ve işitsel konfor koşullarını ısı ışık ses gibi fiziksel çevresel parametreleri minimum enerji harcanmasıyla kontrol altına alarak sağlayacak şekilde tasarlanması ve değerlendirilmesi gerekmektedir.

Bu açılarından bu tez çalışması, bina kabuğunun ısısal, görsel ve işitsel konfor koşullarını ısı ışık ses gibi fiziksel çevresel parametreleri control altına almada enerji etkinliği açısından en uygun performans sağlayacak şekilde değerlendirilmesini hedeflenmiştir. Bu hedef doğrultusunda çalışmada ele alınan bir referans bina için bina kabuğu alternatifleri geliştirilmiş, mevcut bina kabuğu ve geliştirilen alternatifler fiziksel çevresel parametreler (ısı, ışık, ses) ve enerji etkinliği açısından irdelenmiştir. Çalışmada referans bina olarak, GAP bölgesi içerisinde Şanlıurfa İli tarım-köy projesi kapsamında Başbakanlık Toplu Konut İdaresi Başkanlığı (TOKİ) tarafından geliştirilmiş olan bir tarım-köy konutu ele alınmıştır. Gelişmekte olan ve ülkemiz için önem taşıyan bu bölgede yer alan konutların enerji etkin geliştirilmesi ile sağlıklı, konforlu az enerji harcanarak sağlanabilecek yerleşmeler ülkemiz enerji tasarrufu açısından da önem taşımaktadır.

Ayrıca enerji etkin önlemlerin küçük ölçekli, maliyeti düşük binalarda uygulanabilirliğinin gösterilmesi ve bu değerlendirmenin de diğer binalara örnek teşkil ederek ı ışık tutabilmesi hedeflenmiştir.

Tez kapsamında, birinci bölüm olan giriş bölümünde, bina kabuğunun tanımı ile fiziksel çevresel parametreler ve kullanıcı konforu açısından önemi açıklanmış, bina kabuğu çevresel etki ve enerji harcamaları arasındaki ilişki irdelenmiş ve irdelemeler doğrultusunda tezin amacı açıklanmıştır. İkinci bölümde, bina kabuğunun en önemli işlevi olan ısısal, görsel ve işitsel konfor koşulları ele alınmış.

Üçüncü bölümde, enerji etkin sistemler olarak pasif sistemler ayrıntılı olarak açıklanmıştır. Kullanıcı konforunun sağlanması açısından bina sistemleri aktif ve pasif sistemler olarak iki ana grupta ele alınmaktadır. En genel tanımı ile aktif sistemler, aktif (mekanik, elektrik enerjisi) enerji kullanarak bina içi çevrede konfor koşullarını sağlayabilen sistemlerdir. Pasif sistemler ise her tür aktif enerji tüketen sistemleri işin dışında tutarak, yönlendiriliş durumu, form, bina kabuğu özellikleri gibi yapısal tasarım parametrelerine doğal kaynaklardan yararlanmada optimum değerler kazandırma yolu ile fiziksel çevresel parametreleri kontrol altına almayı ve istenen konfor koşullarını sağlamayı hedefleyen sistemlerdir. Günümüzdeki çevre ve enerji sorunları ve aktif sistemlerin yapım ve kullanım maliyetlerinin yüksek oluşu göz önünde bulundurulduğunda binaların öncelikle pasif sistemler olarak tasarlanması ve değerlendirilmesi zorunlu olmaktadır. Bu nedenle bu bölümde pasif sistemlere yer verilmiştir.

Dördüncü bölümde sunulan çalışmanın yöntemi ve uygulama çalışması açıklanmıştır. Çalışmanın başlıca adımları aşağıdaki gibidir:

- 1.Referans binaya (mevcut bina) ilişkin verilerin açıklanması.
- 2.İklimsel verilerin derlenmesi.
- 3.Referans (mevcut) binanın yıllık enerji yüklerinin simülasyon programı aracılığı ile hesaplanması ve irdelenmesi.
- 4.Referans bina için güneş ışığı analizlerini yapılması.
- 5.Referans binanın akustik performansının değerlendirilmesi.
- 6.Bina kabuğu senaryolarının geliştirilmesi.
- 7.Geliştirilen senaryolar için enerji yüklerinin hesaplanması ve güneş ışığı analizlerinin yapılması.
- 8.Hesaplama sonuçlarının karşılaştırılması.

Yöntemin uygulanması yukarıda açıklanan adımlar doğrultusunda gerçekleştirilmiştir. Seçilen referans binanın kabuğu için geliştirilen senaryoların fiziksel çevresel parametrelere bağlı olarak ısısal, görsel, akustik açıdan gösterdiği performans ve enerji yüklerine etkisinin araştırılabilmesi hedeflenmiştir.

Uygulama çalışmasında geliştirilen senaryolar aşağıdaki gibidir,

1. Saydam bileşenin değiştirilmesi –SC1.
2. Yeni bir opak bileşen önerilmesi- SC2.
3. Binanın güney ve batı cephelerine güneş kontrolü elemanlarının eklenmesi-SC3.
4. Önceki senaryolarının birlikte uygulanması-SC4(SC1+SC2+SC3).

Referans bina ve oluşturulan senaryolar için karşılaştırma sonuçları tablolar şeklinde derlenerek, alternatiflerin enerji performansı irdelenmiştir. Bu amaçla, önerilen her bir senaryo için enerji simülasyonları ECOTECT 5.6V simülasyon programı ile gerçekleştirilmiştir. ECOTECT 5.6V görsel arayüzü ile kullanıcıların erken tasarım evrelerinde enerji performansını değerlendirmek üzere geliştirilmiş bir program olup, çizim programları ile uyumu nedeni ile özellikle mimarlara yönelik bir araç olarak kabul edilmiştir.

Beşinci bölüm olan sonuç bölümünde çalışmada varılan sonuçlar tartışılmış, ısı, ışık ve ses kontrolü açısından binanın en etkin ögesi olan bina kabuğu aracılığı ile harcanan enerji miktarının azaltılmasının zorunlu olması gerek mevcut binalarda gerekse yeni tasarlanacak binalarda fiziksel çevresel parametreleri kontrol ederek, kullanıcının sağlık ve konfor koşullarından ödün vermeden enerji harcamalarının azalmasına yönelik çalışmaların geliştirilmesinin önemi irdelenmiştir.

Sonuç olarak, bu çalışmada sınırlı sayıda bina kabuğu alternatifi üzerinde bir değerlendirme yapılmıştır. Tasarımcı, yapımcı ve kullanıcı isteklerini gözönünde bulundurarak kullanıcıların ısısal, görsel, işitsel konfor koşullarını minimum enerji harcayarak sağlamak ve dolayısıyla, bina kabuğunun ısı, ışık, ses kontrolü açısından optimum performans gösteren sistemler olarak tasarlanması için çok sayıda alternatifin geliştirilmesi, değerlendirilmesi ve bu yönde yeni çalışmaların yapılması önem taşımaktadır. Ayrıca yapımcıları bu tür projelerin gerçekleştirilmesi için zorlayacak yaklaşımların geliştirilmesi özellikle ülkemizde çok hızlı gelişen konut sektöründe elde edilecek kazançların ülke ekonomisinin gelişmesine sağlayacak katkıları açısından gerekli görülmektedir.

1. INTRODUCTION

In order to meet the requirements of performance for a built environment, optimum values of design parameters should be determined. One of the most important design parameter is building envelope because it is the totality of building elements made up of components that separate the indoor environment of the building from the outdoor environment. Although, the overall performance of the building envelope itself is a very important element and is affected by other components of the building and the environment, the performance of building envelope needs to be considered from different aspects like its energy efficiency and comfort. Building envelop has a major effect on energy loads such as heating, cooling, lighting and includes the most important factors of the building's energy consumption, In addition to the impact of energy loads the building envelope plays important roles in order to achieve climatic, visual and acoustic comfort which affects required comfort conditions of the users in the spaces.

To provide a comprehensive performance evaluation and optimization of the building envelope for the physical environmental and energy goals should be an approach based on all of comfort characteristics.

The main function of building envelope according to the physical environmental factors (heat, light, sound) should be provided thermal comfort, visual comfort and acoustic comfort by controlling environmental factors at a certain level of that is acceptable.

In the building envelope design to reduce energy consumption, energy costs should be taken into consideration. From the energy conservation point of view, built environment may be classified into two main groups such as passive systems and active systems. A building, itself, excluding the active systems works as a set of the passive systems on controlling physical environmental impacts such as heat, light, sound. When the passive systems are not sufficient or feasible alone for

achievement of human comfort active systems become necessary, therefore active systems should be considered as supplementary systems and buildings should be designed as passive systems firstly.

Energy saving is carried out mainly by passive strategies, which improves thermal comfort conditions and indoor environmental quality. In passive strategy there are basic principles that improve building performance such as building form, orientation and optical and thermophysical properties of building envelope.

•Purpose of Thesis

The aim of this thesis is to introduce a study which serves the purpose of evaluating building envelope for a selected residential building to reduce energy consumption related to physical environmental factors.

To achieve this goal, first process is to understand physical environmental factors, in particular, the role of their effects in envelope design.

To ensure permanence of healthy environment for the user and optimal performance in his activities, the conditions in the indoor environment must be adjusted as to ensure the desired comfort conditions by controlling physical environmental factors. The thermal, visual and acoustic comfort conditions are therefore the basis on which to design and evaluate the performance of the buildings.

In the light of the energy problem another objective must be the reduction of energy consumption and energy expenses to a minimum. This requires a design and evaluate building envelope as an element of a passive system with the optimal performance in its control of heat, light and sound [1]. As it is known the importance of passive controls in reducing the energy requirements of buildings constitutes an important issue, with a focus on passive systems strategies.

Especially the modern façade systems, including the construction of performance aspects, material selection assembly and energy efficiency, the application will be taken at the same time from the controlling physical environmental factors such as heat, light, and sound in order to realise defined comfort condition for the user with a

minimum of energy consumption. An evaluation of the building envelope as passive system will result in an increased performance of its passive system which in turn will reduce the load of active systems costs in envelope design and a sustainable building envelope.

On the other hand, the simulation programs used in the building envelope design, and some comprehensive theory of social development would provide a conceptual design on those strategies that have proven most effective for achieving those results.

Therefore in this study, firstly thermal, visual and acoustic comfort conditions and passive systems have been explained secondly different building envelope alternatives have been developed, and for each alternatives energy simulation have been executed and results have been compared.

2. HUMAN COMFORT: THERMAL, VISUAL, ACOUSTIC COMFORT CONDITIONS:

The development of a holistic building evaluation model must begin with an understanding of the factors, which influence energy efficiency.

A survey of the current literature has been reviewed to assess the relevance of previous researches and to collate all empirical evidence that fits pre-specified eligibility criteria in order to answer a specific research question. In this thesis the review of the literature includes main topics such as: thermal comfort, visual comfort, acoustic comfort, passive systems, building envelope design strategies for buildings.

In the study of literature review it is intended to enhance the understanding of the theories and practice that underlie the purpose and objectives of building envelope design related to built environment and passive systems. This chapter will focus on a review and study of the buildings in human comfort and the energy efficiency initiatives. Environmental factors may play important roles for energy efficiency, human living standards and the economy. Based on that knowledge, energy efficiency savings can be adjusted to gain reduction in the energy used to fulfill the human needs (heating, lighting).

To be able to evaluate the envelope from the sustainable built environment design point of view, it is worthwhile to understand the comfort conditions for buildings and factors that play a role within the design processes. The process can be quite complex with a number of sub-processes that may have varying levels of importance depending on the characteristics of the built environment project.

The major phases begin with the early evaluation and acquisition of the necessary condition for human comfort. Besides being aesthetically pleasing, the human environment must provide comfort conditions such as, thermal, visual and acoustic comfort.

Even though each stage has some sustainability influence usually the early stages of acquisition and design will play the most important role in the life cycle sustainability implications of the property. Thus, the major opportunities to design the built environment for sustainability buildings that occur at early phases must be understood and provided user requirement.

It is widely believed that sustainable building design strategies create improved indoor environmental quality and should be associated with improved occupant comfort, satisfaction, health, and work performance relative to buildings designed around standard practices. Environment control is the most important design factor in sustainable building design strategies. The aim of environmental control is human comfort. Comfort may be defined as the sensation of complete physical and mental well-being .In a built environment a group of user requirement such as :

-Thermal

-Visual

-Acoustic

are met by environmental control system.

Therefore the main function of the building envelope with respect to physical environmental factors and user comfort requirements are to ensure:

- Thermal comfort by controlling the influence of climatic elements,
- Visual comfort by controlling the natural light and
- Acoustic comfort by reducing the noise level to an acceptable level.

2.1 Thermal Comfort

One of the main goals of building design is to provide a comfortable space. Thermal comfort for a building's human occupants is the primary objective of heating and cooling system designs.

There are numerous studies regarding thermal comfort in different climates around the world. The significant studies that are recognized world-wide, which are related to this field of study include: the studies of the Effective Temperature index (ET) , ASHRAE, the heat balance equation including the “Predicted Mean Vote” (PMV), and the “Predicted Percentage of Dissatisfied” (PPD) by Fanger (1972); the ASHRAE comfort charts and other significant thermal comfort studies such as Givoni (1976, 1994, and 1998), Nevins et al. (1975), Berglund and Fobelets (1987), McIntyre (1978), Arens et al. (1980), Tanabe (1987), Wu (1988), Busch (1992), Berglund (1995), Dear and Brager (1998), and Rohles Jr. (2007).

Thermal comfort is a condition that is neither too warm nor too cold, or thermal neutral in which the strain on the body's thermal regulatory system is minimal [2]. There are many factors that can influence occupants thermal comfort in the built environment. These may include indoor air temperature, air humidity, air movement, mean radiant temperature (MRT), as well as occupant's activity level (measured in MET), clothing level (measured in clo), age and sex etc. Considering any of these factors affecting thermal comfort independently is not possible. Thermal comfort can be achieved by combination of these variables and use of many different technical systems.

To intervene positively in achieving thermal comfort in a building starts with the knowledge of the climate in question and passive strategies to control this climate in order to provide the right design approaches for maintaining thermal comfort.

2.1.1 Definitions of thermal comfort and comfort conditions

Thermal comfort is defined as “the condition of mind which expresses satisfaction with the thermal environment; it requires subjective evaluation.” [3]. In general, comfort occurs when body temperatures are held within narrow ranges, skin moisture is low, and the physiological effort of regulation is minimized” [4].

In alternative definition may be that comfort is the conscious subjective recognition and approval of a state of minimum thermoregulatory effort for the current metabolic rate. The environmental conditions conducive to thermal comfort are not absolute, but rather vary with the individual's metabolism, the nature of the activity engaged in, and the body's ability to adjust to a wider or narrower range of ambients.

For thermal comfort and efficiency, the human body need to adapt to a wide range of environmental conditions compared with the full scope of those found in nature. The indoor climatic factors that affect humans pleasantly or adversely include are temperature of the surrounding air, radiant temperatures of the surrounding surfaces, humidity of the air, air velocity. It has been demonstrated that with the appropriate design measures, a modification of internal temperature environment can be achieved which will influence thermal comfort within the structure, such as to bring the internal temperature to within the range of comfort neutrality, and even such as to achieve passive design.

Performance standards for the thermal resistance of building envelope are proposed. These measures and other design measures, are proposed which will meet comfort standards, and provide buildings which can be conditioned effectively, with a reasonably low energy cost.

One of the requirement to obtain thermal comfort for a person is that he is in a state of thermal neutrality. This means that for the body as a whole, he is satisfied with the temperature level, i.e. he can not tell whether he would prefer a warmer or cooler environment. To obtain this condition one has to look at and control all those variables that influence the heat balance of a person with the surroundings.

The body has the ability to balance its temperature by various means. This thermal balance is determined, on the other hand by the "internal heat load" and on the other, by the energy flow (thermal exchange) between the body and the environment. The thermal exchange between the body and the environment takes place in four different ways: conduction, convection radiation and evaporation (perspiration and respiration).

Heat exchange by conduction depends on the thermal conductivity of the materials in immediate contact with the skin. Conduction usually accounts for only a small part of the whole heat exchange. When the body comes into contact with materials which are good conductors, particular parts of the body will be cooler or warmer.

Heat exchange by convection depends primarily on the temperature difference between the skin and the air and on air movement. It can be controlled by adequate clothing. The insulation effect of clothing can be expressed by a clothing - value (clo - value).

Radiation takes place between the human body and the surrounding surfaces such as walls and windows, and in the open air, the sky and sun. In this process temperature, humidity and air movement have practically no influence on the amount of heat transmitted. This amount of heat depends mainly on the difference in temperature between the person's skin and the surrounding or enclosing surface.

During evaporation water absorbs heat, and as humans normally lose about one liter of water a day in perspiration, a fair amount of heat is taken from the body to evaporate it. The lower the vapour pressure (dry air) and the greater the air movement, the greater is the evaporation potential.

The heat produced in the body is determined by the activity level of the person. This heat is exchanged to the surroundings through convection, radiation and evaporation of sweat from the body [5].

Convection depends on the temperature and the velocity of the surrounding air. Radiation depends on the surface temperatures. Evaporation depends on the air humidity and the air velocity. Figure 2.1 shows effect of the environmental factors on body comfort.

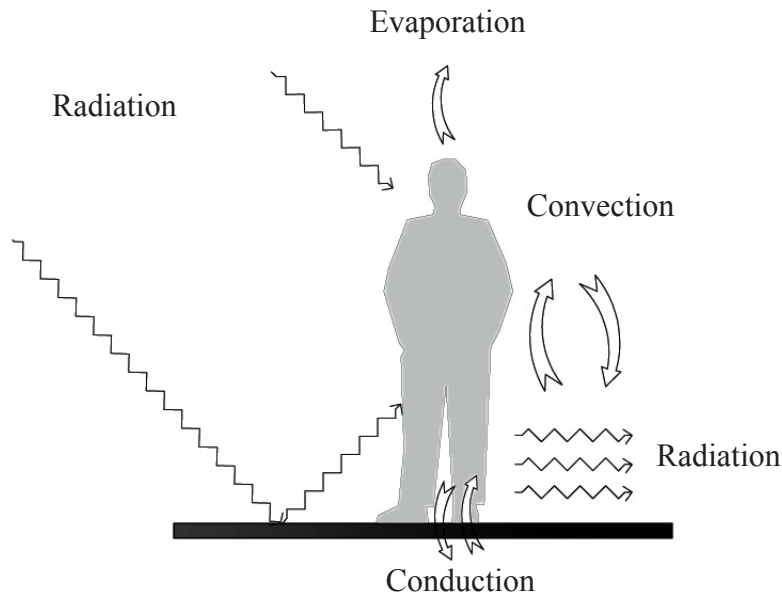


Figure 2.1: Effect of the environmental factors on body comfort

2.1.2 The Parameters affecting thermal comfort

The important parameters for thermal comfort are considered as two groups; individual parameters and environmental parameters. Individual parameters are:

- Activity
- Clothing

Environmental parameters are:

- Air temperature
- Surface temperatures (surface temperatures in an enclosure are usually represented by the concept of mean radiant temperatures)
- Air humidity
- Air velocity

All these factors have a simultaneous influence on a person's sensation of thermal comfort.

The insulation value or heat resistance of clothing is measured in a unit called clo, 1 clo is equal to 0.155 square meters °C per watt ($1 \text{ clo} = 0.155 \text{ m}^2 \text{ }^\circ\text{C} / \text{W}$).

The activity level M , is a measure of the internal heat production of a human being. It is measured in met, where an activity level of 1 met corresponds to a heat production of 588 Watt per square meter of surface area of body.

Air temperature, air humidity, surface temperatures, air movement are the main climatic elements, besides many other psychophysical and physiological factors, determine the comfort zone are. These are the climatic elements of indoor climate. Different values of indoor climatic elements define different climatic conditions. Different combinations of the values of indoor climatic elements define different indoor climates.

Variation ranges of the values of the climate elements which are considered acceptable (or satisfying) from the thermal comfort stand point, are limited. In other words, human body requires to be maintained within a limited range of climate conditions. This particular range of climate conditions define the state of comfort. Indoor thermal comfort conditions are the optimal inputs or impacts for the human body to be maintained in health and comfortable conditions.

Acceptable variation ranges for the climatic elements or conditions and state of climatic comfort can be explained by comfort charts, practically.

2.1.3 Comfort zone and comfort charts

According to Panchyk [6], thermal comfort in an interior space can be considered as the sum-total of heat or cold sensations experienced by occupants. Further, if the interior space has neither excessive heat nor cold conditions, it is then considered to be thermally comfortable. This reveals that the space is within an occupant's comfort zone. Thus, the comfort zone may be defined as a thermal condition in which little or no effort is required by occupants to adjust their bodies to surrounding environmental conditions.

The range of conditions in which thermal comfort is experienced is called comfort zone which differs according to individuals preferences and is affected by environment conditions. Although the comfort zone is defined as a subjective assessment of the environmental conditions, the limits of the zone do have a physiological basis; the range of conditions under which the thermo-regulatory mechanisms of the body are in a state of minimal activity.

ASHRAE Comfort Zone as important comfort zone is defined as the range of indoor climatic conditions (i.e., temperature, humidity, airspeed) within which the majority of persons experience thermal comfort. The ASHRAE comfort zone is usually drawn on a conventional psychrometric chart. The comfort zone defines the indoor air temperature and humidity for a sedentary person. The comfort zones are intended to provide acceptable thermal environment for occupants wearing typical indoor clothing and at a near sedentary activity. According to the Standard Effective Temperature lines on a psychrometric chart and the ASHRAE comfort zones, acceptable thermal environment is an environment that at least 80% of the occupants would find thermally acceptable (Figure 2.2).

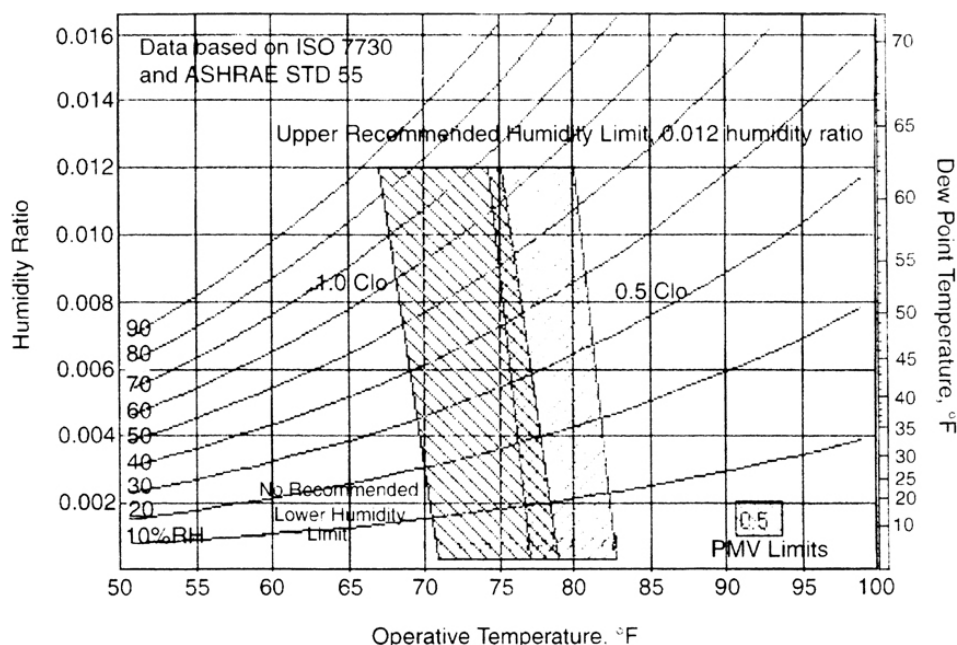


Figure 2.2:ASHRAE comfort zone [7]

Figure 2.3 gives the bioclimatic chart. This Bioclimatic Chart is based on the assumptions that subjects (persons) clothed normally for indoor living

(thermal resistance of clothing is 0.8 clo) and subjects engaged in no more than light activity-reading, office work, occasional walking about the room and activity level is 1.3 met.

All the points which take place in the comfort zone define various sets of comfortable thermal conditions under the still air conditions (air movement velocity less than 0.25 m/s). The zone which lays in between the upper boundary of the comfort zone and 0.8 m/s wind velocity line is “the comfort zone under moving air conditions”. In case of the air temperature and relative humidity combination take place under the shading line, mechanical heating or solar radiation gain becomes necessary to achieve the climatic comfort. In case of the air temperature and relative humidity combination take place over the 0.8 m/s wind velocity line, mechanical cooling or air conditioning becomes necessary for the achievement of climatic comfort [8].

Factors other than climatic ones also influence the wellbeing of the inhabitants, for example, psycho-social condition, age and health, air quality and acoustical and optical influences. Although these factors cannot be changed by climatically adapted construction, they should not be forgotten, because they may considerably reduce the tolerance.

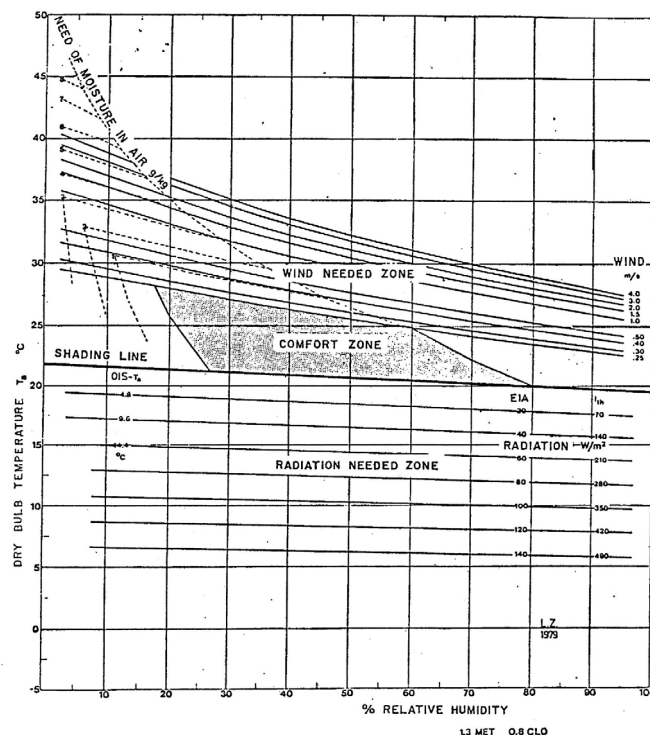


Figure 2.3:The Bioclimatic Chart [9]

2.2 Visual Comfort

Visual comfort relates to the field of vision. Adequate visibility so that tasks can be performed with required speed and accuracy should be provided. In a comfortable visual environment users' physiological and psychological needs should be achieved. The needs for visual comfort are given as recommended values for illumination level, luminance and colour. Visual function parameters are used to determine whether a given lighting condition permits sight or visibility and are directly related to the physiology of the eye. Generally, good visibility is defined by an adequate quantity of light for the expected visual task, uniform distribution of illuminance and luminance, sufficient directionality to model three-dimensional objects and surfaces (direction of incident light from the side or from above), the absence of glare, and sufficient spectral content to render colours accurately when required [10]. Lighting requirements for various functions of interiors are explained in EN 12464 and a summary of the "Schedule of lighting requirements" is given [11].

Visual comfort is one important aspect of building indoor environment. Daylight design and analysis is one of the two parts of the indoor visual comfort. It is important to realize great significant of visual comfort for human comfort, zero energy cost, energy consumption of the built environment, the indoor lighting and visual environment of the building and satisfaction in the field of building science and technology.

In visual comfort, which is a state of mind that expresses satisfaction with indoor and the built environment, there are many factors and influences that affect on both visual efficiency and comfort. Sufficient light and elimination of disturbing effects connected to the lighting are the major influencing factors of visual comfort. Maintaining visual comfort means ensuring that people have enough light for their activities, enough light affects visual quality which consists of visual efficiency combined with visual comfort. Visual efficiency is a measure of a person's ability to perform tasks involving vision. Elimination of disturbing effects in visual comfort depends on the intensity of illumination on the area of interest,

the uniformity of illumination, the formation of shadows, background lighting, glare from the light source, veiling reflections, and color rendering.

2.2.1 Daylighting and architecture

Daylighting an important element of sustainable design and an important technique for illuminating interior spaces affects the characteristic of the architecture. Daylight is a primary source of lighting in buildings and consideration of desired daylight strategies is the most important factor to achieve energy-saving and human comfort.

Although renewable energy in the form of daylighting has been widely used in built environment for reducing energy consumption and energy-saving but it is difficult to predict under local conditions daylight availability inside building with specific window configurations and portion of lighting energy saving.

Daylighting is an effective sustainable development strategy to alleviating the problems in energy and environment, and improving the qualities for visual comfort and health. The architectural trends of glazed envelope represent more daylighting and transparency into buildings, although with large glazed areas come a large amount of solar radiation which can be wisely utilized for better environmental building design. This is mainly related to areas connected to the energy consumption and indoor environmental comfort and visual comfort. According to Moore [12], the use of daylight has changed over time from an opening at the spot where light is needed to the use of abundant glazed areas. This modern usage, resulting from new materials and structural development, adds heat gains to the interior space. Moreover, for areas far from the building perimeter, electric light must be used, increasing the energy consumption of a building. Most elements of the outdoor environment in architecture, such as neighbouring buildings, site topography and local climate, are largely out of the control reach of the individual designer. It is possible to control the consequences these elements hold for daylight availability and solar access and because energy crisis and sustainable development is an important consideration in architectural design, daylight is once again seen as an important technique to help

obtain energy savings.

Appropriate design of outdoor environments can have a beneficial effect on the indoor building and for indoor air quality control should achieve an optimal balance between indoor and outdoor. Controlling the consequences of outdoor environmental elements includes the following as:

- The elaboration of building plan and section.
- The orientation of the various envelope surfaces, including daylight apertures, in response to site conditions.
- The choice of ground cover and vegetation surrounding the building.
- The detailed design of interior finishing, furnishing and fixtures.

Building plan and section determine the amount of indoor surface area that is connected to the building envelope and outdoor environment, and thus allows for daylight apertures; in general, the more compact building plan and section are, the less indoor area can be daylight.

2.2.2 Benefits of daylighting

Daylight has many benefits and many articles have discussed the advantages of integrating daylight into design. The benefits of daylighting are discussed in the following section.

The quality of daylight is superior to that of electric lights. Robbins [13] stated that daylight has a high quality, because it is the one light source that is full-spectrum and that closely matches human visual perception [13]. It is also considered the best light source for its color rendering quality, which is also superior to electric light. It can be said that daylight helps create a visually comfortable space and enhances the visual quality of that space.

The luminous efficacy of daylight is higher than that of electric light. The luminous efficacy of a light source is the ratio between light output to heat produced (in lumen/watt). The efficacy of various light sources is compared in different studies. For example, daylight introduces heat 6 times less than incandescent light with the same light level mentioned in a study by Lechnor [14].

Another benefit of daylighting, mentioned by Robbins, is that it connects occupants with the exterior environment. Building with daylight aperture provides occupants with views, creating visual connections between the interior and exterior, and satisfying the human need for contact with the outdoor environment.

Daylight has shown to help increase sales rates, occupant productivity, and student attention in classes, because people prefer daylight. In a study by the Heschong Mahone Group on daylight and retail sales [15], it was found that the increased rate of retail sales is strongly associated with increased daylight during the day. Another study from this group suggests that daylight can increase worker performance in the areas of mental function and memory recall by 10-25% [15]. When applied in schools, daylighting increases student attention by 21% when compared with classrooms with less access to daylight [15]. One of the most pronounced benefits of daylight is that it helps save energy by reducing the use of electric lighting. Since energy crisis of the early 1970's, people have begun to realize the significance of energy savings found in the use of renewable energy resources.

According to the Illuminating Engineering Society of North America (IESNA), the use of daylight can reduce by 30% the amount of electricity used for interior lighting [16]. In addition to its physiological and psychological benefits, daylight has a green issue factor. By using daylight, the use of electric lighting is reduced. According to the IESNA Handbook, the use of daylight can reduce the amount of electricity used for interior lighting by 30% thus lowering the emission of CO₂ and in turn the green house effect [17,18].

Given these benefits, it is apparent that daylight should be utilized to its full potential to help create a visually pleasant environment and a sustainable architecture.

2.2.3 Evaluation of Daylighting

The measurement, prediction, and simulation of daylight require just as much creativity and technical skill as the design of the systems themselves. Although readily measurable in real life, natural light is subtle and constantly changing, which makes providing a temporally unspecific daylighting analysis of any space challenging. It is important, therefore, to discuss the way in which we quantify daylighting levels and decide what “appropriate” daylighting is. It helps to characterize the daylight entering a space by its origin sun or sky and the path by which it has arrived directly from the source or by reflection (Figure 2.4). For evaluation daylighting, there are many techniques and accuracies.

Daylight simulation for interior spaces can be divided into two modes of evaluation:

- Quantitative, or numerical
- Qualitative, or visual

Quantitative data are usually presented in the form of line graphs, surface plots, or false-color maps, for example, of the distribution of illuminance across a plane.

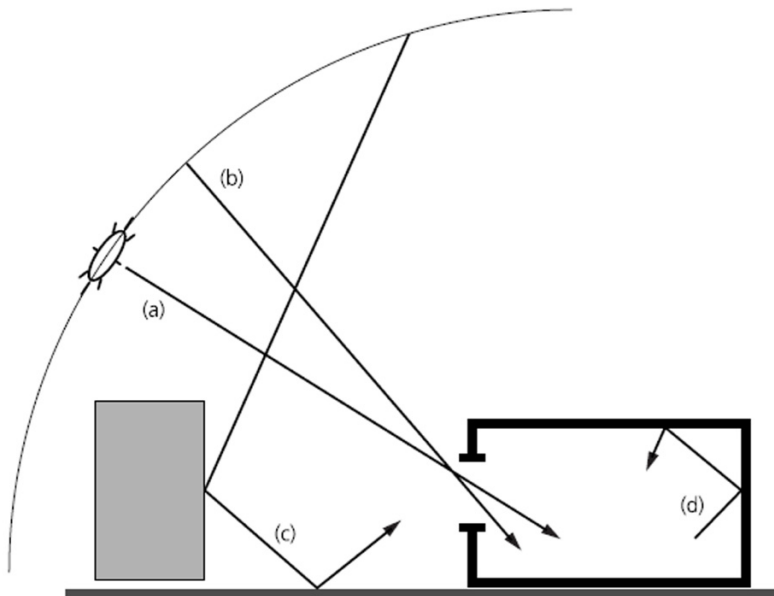


Figure 2.4:Components of daylight: (a) direct sun, (b) direct sky, (c) externally reflected and (d) internally reflected [19]

For daylight calculation procedures, it is sufficient to establish different basic sky conditions. These are explained as follows:

- **CIE Standard overcast sky conditions (daylight factor prediction):** Sky completely covered by clouds with no sun visible.
- **CIE Standard clear sky:** luminance distribution of a cloudless sky is developed by Krutler in 1967 and published by CIE. CIE standard clear sky is a reference cloudless sky condition, having the greatest luminance near the sun and least luminance 90 degrees from the sun.
- **Average sky model:** Average sky model is a model which considers the effect of orientation and partly cloudy sky.

Daylight factor as evaluation factor which, is a ratio between internal illuminance on the working plane 850 mm over the floor level and external illuminance on non-shaded horizontal plane was determined under overcast sky conditions [20] .

There are recommended daylight factor (ranging from 1-5%) for different room types and requirements.

The daylight factor at any point is the ratio of the interior illuminance at that point to the global horizontal illuminance under CIE standard overcast sky conditions. The daylight factor (DF) is normally expressed as a percentage as shown in Equation (2.1).

$$DF = \frac{E_{in}}{E_{out}} \cdot 100 \quad (2.1)$$

Daylight Factor is a measurement of the subjective quality of daylight within a room. The Daylight Factor measures the interior light levels as they compare to exterior light levels on an overcast day. For reference, a room that has a DF of less than 2% is considered poorly lit. Rooms with DF between 2% and 5% are considered ideal for activities that commonly occur indoors.

For the 1995 Building Regulations BRE carried out calculations of window area and daylight provision for a range of representative house types. The aim was

to calculate the minimum window area which would be enough to meet the minimum daylight recommendations in BS 8206 Part 2. The BS requires an average daylight factor of 1% in bedrooms, 1.5% in living rooms and 2% in kitchens [21].

The interior illuminance is usually evaluated at workplane height (Figure 2.5).

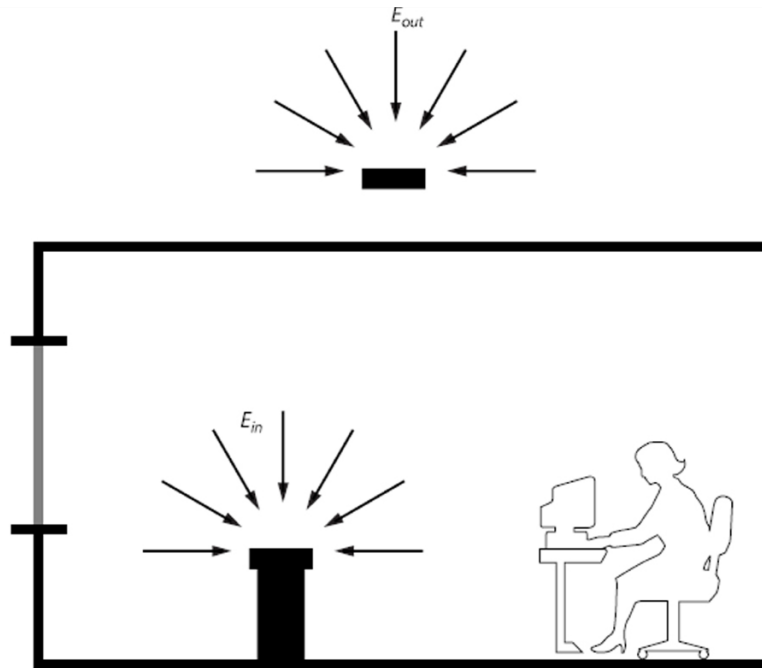


Figure 2.5:Internal and external horizontal illuminance [19]

2.3 Acoustic Comfort

Acoustics is defined as “the science of sound” and as an environmental variable significantly impacts the human impression of an interior environment. Productivity, speech intelligibility, privacy, safety, positive user attitude and response, and environmental “comfort” all depend on proper acoustic design. Acoustical comfort can be characterized as follows [22]:

- Absence of unwanted sound
- Desired sounds with the right level and quality
- Opportunities for activities without being heard by other people or annoying them.

To most people, acoustic comfort is a vague concept that becomes clear only when they are dissatisfied. The objectives of good acoustic design are to enhance wanted sounds and attenuate unwanted sounds (noise). The designer is concerned

with reducing unwanted noise and preserving desirable sound in a space. Enhancing the quality of communication through the use of reflective surfaces, and reducing undesirable noise through the use of absorptive surfaces is achieved by the specification of finishes, furnishings, equipment, and specially designed assemblies.

Noise from outside can be reduced in the following ways:

- a) by quietening or removing the source of noise;
- b) by attenuating the sound on its path to the receiver;
- c) by obstructing the sound path between source and receiver;
- d) improving the sound insulation of the building envelope.

The acoustic environment in an occupied space is the result of the sound arriving at the space from engineering services, adjacent zones, and external environment, and from sound generated within the occupied space such as voices, human activities, entertainment devices, and machinery. They all generate small rapid variations in pressure about the static atmospheric pressure and propagate through the air as sound waves.

Good acoustics involves the adaptation of the acoustics to the activities being carried on in a room. Acoustic comfort means providing an acoustic environment that is conducive to speech intelligibility, speech privacy, low distractions and annoyance, and concentration where appropriate. The issue of acoustic comfort may be not linked to just the value of the insulation of the partition between rooms. The perception total, partial or inexistent, of conversation in an adjacent dwelling also contributes to comfort levels which may range from unpleasant to ideal.

This might involve low noise levels; ease of hearing speech and, in music rooms, the acoustics must contribute to good sound reproduction.

Figure 2.6 shows main factors in design of acoustic environment.

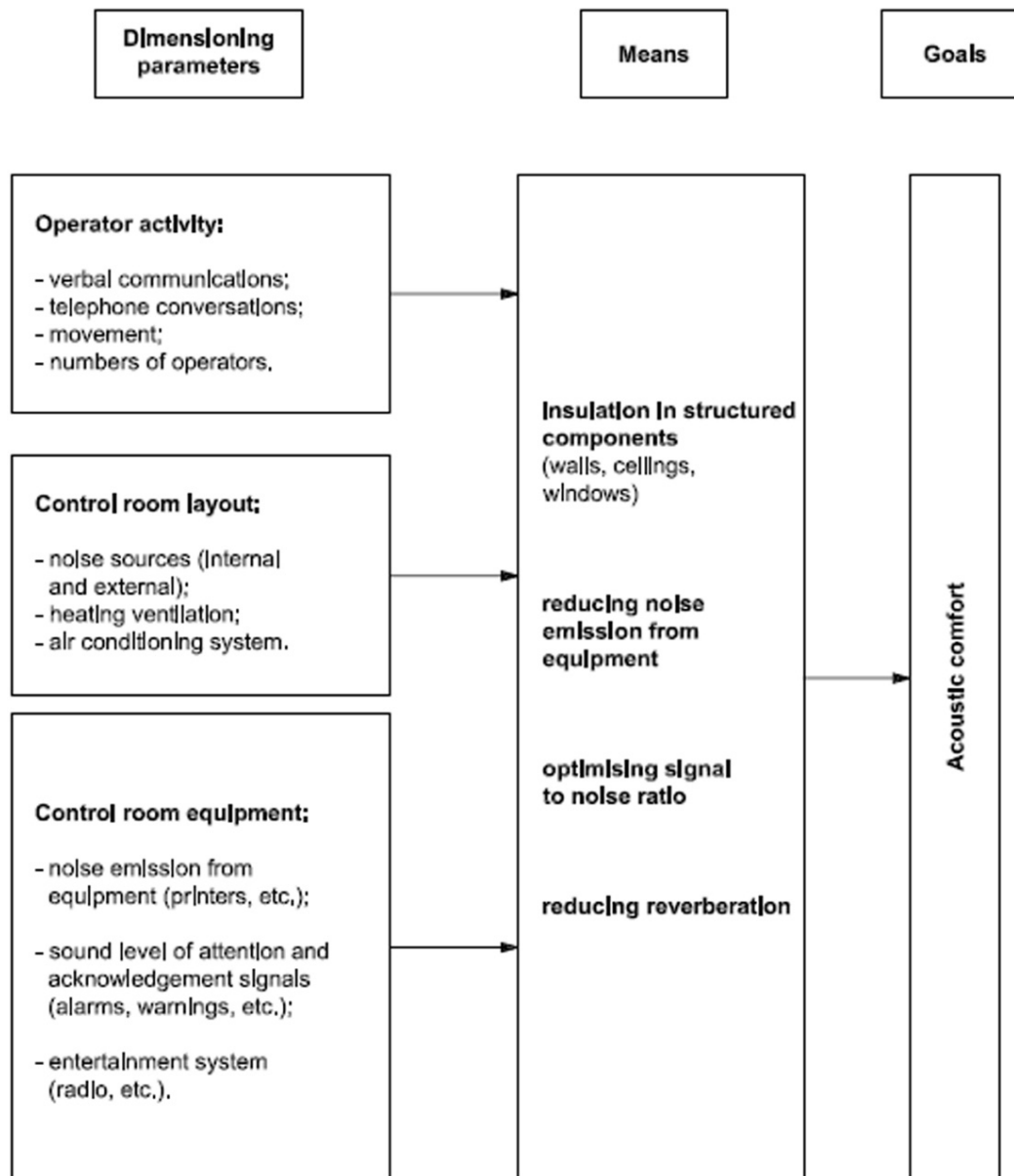


Figure 2.6:Main factors in design of acoustic environment [23]

2.3.1 Required Noise Reduction:

The required noise reduction (NR) is simply the difference between the outdoor sound level and the desired indoor sound level.

The required noise reduction standards achieved by any suitable combination of building design, choices of building materials, and execution of construction details in accordance with established architectural and acoustical principles. To satisfy user requirements the designer should select measurement quantities to match external noise quantities and then should choose criteria and appropriate noise levels for sensitive areas.

2.3.2 External noise levels

The main sources of noise are air, road and rail traffic, and industrial/commercial activities. The external noise level(s) is the value that would be observed near the outside surface of the building. This includes both sound energy coming directly from the noise source and sound energy reflected from the building. The levels of existing and future noise sources can be predicted if there is reliable information. Otherwise measurement will be necessary, either of the existing noise, or of a noise source similar to that proposed.

The noise source(s) should first be located and the designer should apply the following procedures:

- a) Select quantities to use for measuring or predicting noise levels (e.g. $L_{Aeq,T}$, or L_p in octave or third octave bands).
- b) Assess effects of topography and other features such as noise screens or reflecting surfaces.
- c) Measure or predict noise levels at strategic points. In some complex situations it may be worth drawing a contour map of external noise levels.
- d) If appropriate, assess noise levels due to user activities around the buildings and site.

Whether noise levels are measured or predicted, it should be borne in mind that wind gradients, temperature gradients and turbulence affect the level of received sound over short periods. The effects range from increasing the level by typically 2 dB downwind, to reducing it by typically 10 dB upwind or even more in extreme conditions (Table 2.1). It is not usually practicable to use this factor in design, but the prevailing wind direction should be considered when planning building orientation. For example, for a site with similar noise sources on two opposite sides, noise sensitive rooms should be oriented on the leeward side [24].

Table 2.1: Typical traffic noise levels measured about 1 m from the façade [24]

Situation	LAeq,16h dB
At 20 m from the edge of a busy motorway carrying many heavy vehicles; average traffic speed 100 km/h; intervening ground grassed	78
At 20 m from the edge of a busy main road through a residential area; average traffic speed 50 km/h; intervening ground paved	68
On a residential road parallel to a busy main road and screened by the houses from the main road traffic; free flowing traffic	58

- Design criteria and limits for intrusive external noise:

For dwellings, the main criteria are reasonable resting/sleeping conditions in bedrooms and desired listening conditions in other rooms. As well as protection for the building, barriers or bunds should be considered to protect the gardens. In Turkey, acceptable noise limits are described in the Regulation of Assessment and Management of Environmental Noise [25].

Occupants will usually tolerate higher levels of anonymous noise, such as that from road traffic, than noise from neighbours which may trigger complex emotional reactions that are disproportionate to the noise level. For simplicity, only road traffic noise is considered in Table 2.2.

Table 2.2: Limit values for Road Traffic Noise in Turkey [25]

Areas	New roads		Existing roads	
	L _{day} (dBA)	L _{night} (dBA)	L _{day} (dBA)	L _{night} (dBA)
Rural areas	55	45	60	50
Noise sensitive areas (Schools, hospitals, cultural centers)	60	50	65	55
Residential settlements	63	53	68	58
Working and residential areas	65	55	70	60
Industrial areas	67	57	72	62

To ensure a smooth passage through the planning system, even when a full environmental assessment is mandatory, proposals for developments on noisy sites, or sites which generate noise, should take account of noise and an assessment should be made of the possible effects of:

- a) Noise generated outside that enters the building
- b) Noise generated inside the building that may disturb people outside the building.

2.3.3 Indoor Ambient Noise

The substantial increase in sound level near an open window is a matter of common experience, but even with closed windows the sound levels vary noticeably within a typical room. Normally the average sound level in the room is used as the indoor sound level or indoor ambient noise level. In order to minimize disturbance from internally generated noise the following points should be considered.

- In houses and flats, services should be kept away from bedrooms.
- As footfall noise can be particularly disturbing, care should be taken to avoid locating stairs next to noise sensitive rooms, such as bedrooms, in adjacent dwellings. It should be noted that footfalls on concrete stairs produce less low frequency noise than on timber stairs.
- In flats, avoid locating bedrooms near the lift and circulation areas; less sensitive rooms may be used as buffers. Compatibility between rooms of adjacent dwellings can be ensured by handing and stacking identical dwelling plans.

Tables 2.3 and 2.4 gives the appropriate design range for various spaces.

Table 2.3: Indoor ambient noise levels in spaces when they are unoccupied [24]

Criterion	Typical situations	Design range $L_{Aeq,T}$ dB	
		Good	Reasonable
Reasonable industrial working conditions	Heavy engineering	70	80
	Light engineering	65	75
	Garages, warehouses	65	75
Reasonable speech or telephone communications	Department store	50	55
	Cafeteria, canteen, kitchen	50	55
	Wash-room, toilet,	45	55
	Corridor	45	55
Reasonable conditions for study and work requiring concentration	Library, cellular office, museum,	40	50
	Staff room	35	45
	Meeting room, executive	35	40
Reasonable listening conditions	Classroom	35	40
	Church, lecture theatre, cinema,	30	35
	Concert hall, theatre,	25	30
	Recording studio	20	25
Reasonable resting/sleeping conditions	Living rooms,	30	40
	Bedrooms	30	35

Table 2.4: Indoor ambient noise levels in spaces when they are unoccupied and privacy is also important [24]

Criterion	Typical situations	Design range $L_{Aeq,T}$ dB
Reasonable acoustic privacy in shared spaces	Restaurant	40-55
	Open plan office	45-50
	Night club, public house	40-45
	Ball room, banquet hall	35-40
	Reception room	35-40

According to Noise regulations in Turkey acceptable noise limits may vary depending on the building typology and window conditions (Table 2.5 and 2.6).

Table 2.5: Indoor noise limits in Turkey [25]

Typology	Indoor noise levels, L_{eq} , dBA
Dwellings	Living room: 45 Bedroom: 35
Offices	Office: 45 Meeting room: 35
Schools	Classroom: 35 Dining hall: 45 Sports hall: 45
Hotels	Room: 35 Restaurant: 35
Hospitals	Policlinic: 35 Physical examination: 25
Cinemas	Hall: 30

Table 2.6: Acceptable indoor ambient noise levels in Turkey [25]

Room function	Closed windows Leq, (dBA)	Open windows Leq, (dBA)
Bed room	35	45
Living room	45	55

The maximum acceptable indoor sound level depends on the use of the room, and slightly different criteria have been proposed and adopted by the accredited standards. Currently there are a number of indoor noise criteria used to quantify the level of background noise in rooms, including Noise Criteria (NC), Balanced Noise Criteria (NCB), Room Criteria(RC), and others. NC curves have been used to set or evaluate suitable indoor sound levels resulting from the operation of building mechanical equipment (Figure 2.7). Noise criteria give the highest acceptable noise levels inside the room.

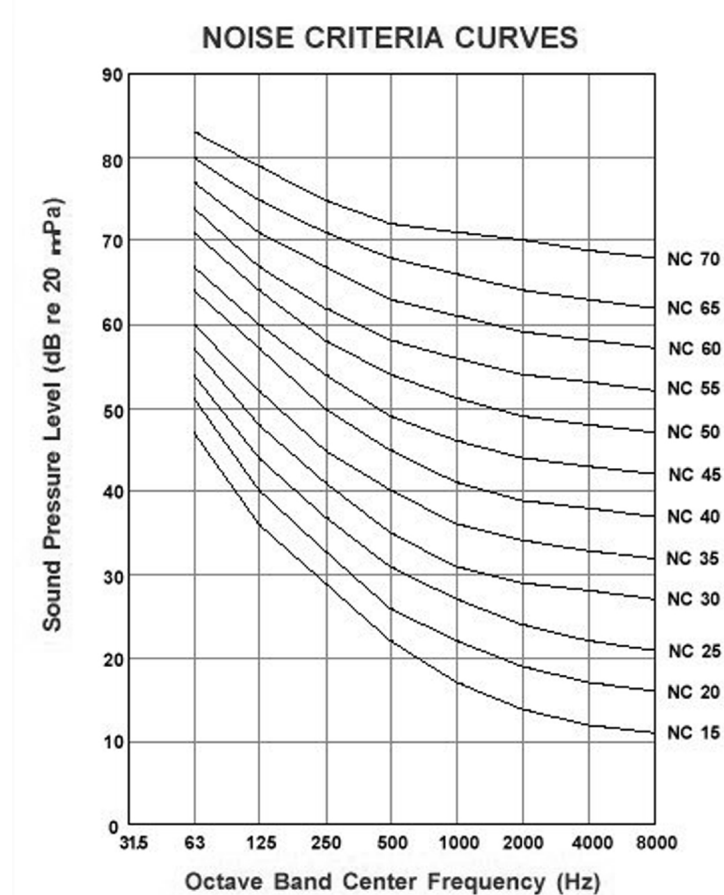


Figure 2.7:Noise criteria curves [26]

The NCB curves were derived by a different procedure from that used to define NC curves. RC curves are used for the specification of services noise limits. The range of values proposed for maximum acceptable indoor noise levels is given in Table 2.7 for a variety of residential and commercial uses. To ensure occupant satisfaction, use of the lowest value in each range is recommended.

Table 2.7: Recommended Criteria for Indoor Design RC or NC Range [27]

Type of area	Recommended criteria Type of area for RC or NC range
Private residence	25–30
Apartments	25–30
Hotels/motels	
Individual rooms or suites	30–35
Meeting/banquet rooms	25–30
Halls, corridors, lobbies	35–40
Service/support areas	40–45
Offices	
Executive	25–30
Conference	25–30
Private	30–35
Open-plan	30–35
Computer equipment rooms	40–45
Public circulation	40–45
Hospitals and clinics	
Private rooms	25–30
Wards	30–35
Operating rooms	35–40
Corridors	35–40
Public areas	35–40
Churches	25–30
Schools	
Lecture and classrooms	25–30
Open-plan classrooms	30–35
Libraries	35–40

3. ENERGY EFFICIENT SYSTEMS: PASSIVE SYSTEMS

Because of the growing scarceness of energy sources used for artificial heating and air conditioning purposes, resulting in an increase in cost of such resources, the threat to human health posed by pollutants emitted into the air in the course of artificial heating and air conditioning systems and the cost of the measures aimed at reducing environmental problems necessitate the reduction of energy consumption for artificial or active systems.

Using environmental feedback to enhance passive conditioning in buildings makes passive strategies more effective, and more viable for a broader range of people and promoted as a strategy for energy conservation. Therefore in this chapter passive systems have been explained.

3.1 Definition of The Passive System

Built environment consists of various sub-systems from the environmental control point of view, built environment sub-systems may be classified into two main groups such as:

- Passive systems
- Active systems

Active systems are the mechanical and electrical systems. External and internal components of building envelope mainly constitute the passive systems under consideration in other words, a building itself, excluding the active systems, works as a set of the passive systems in controlling physical environmental factors such as climate, light, sound. Active systems should be considered supplementary systems.

One of the functions assumed by the building or in a more general sense, by the artificial environment is that of passive heating and cooling. A building fulfilling passive heating and cooling function on an optimum level will show an optimum performance in terms of controlling the effects of climatic elements [5].

Environmental and energy problems necessitate the reduction of energy consumption for artificial heating and cooling purposes to a minimum level. In the light of this necessity, it is natural and cost effective energy sources will be preferred. Speaking of non-polluting and zero cost forms of energy, solar energy comes to mind. Passive solar method involves the exclusion of any kind of energy and to design buildings as passive heating and cooling systems by improving the design parameters.

Passive solar buildings range from those heated almost entirely by the sun to those with south-facing windows that provide some fraction of the heating load. The difference between a passive solar building and a conventional home is design. In general passive solar building includes five distinct elements: the aperture (or collector) the absorber, thermal mass, the distribution, and the control. But there are three basic types of passive solar design: direct gain, indirect gain, and isolated gain that differ in how these five elements are incorporated. Passive solar building systems are introduced in the following part.

• **Direct Gain**

Direct gain is the simplest passive design technique. Sunlight enters the house through the aperture (collector) usually south-facing windows with a glazing material made of transparent or translucent glass. The sunlight then strikes masonry floors or walls, which absorb and store the solar heat.

The surfaces of these masonry floors and walls are typically a dark color because dark colors usually absorb more heat than light colors. At night, as the room cools, the heat stored in the thermal mass convects and radiates into the room. The difference between a passive solar home and a conventional home is design. Figure 3.1 shows the five elements that constitute a complete passive solar design, using a direct gain design as an example. Each performs a separate function, but all five must work together for the system to be successful.

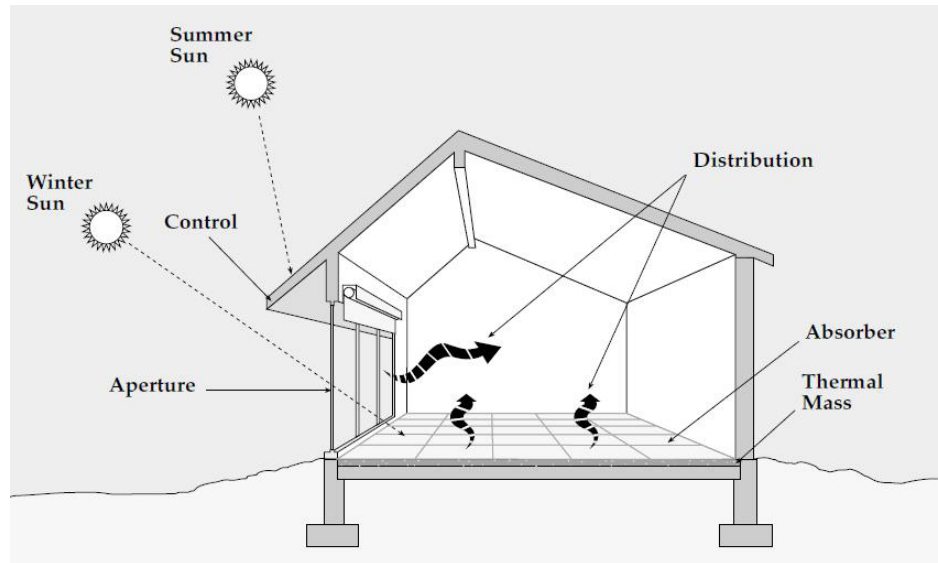


Figure 3.1: Five elements of passive solar design [28]

- **Aperture (Collector):** the large glass (window) area through which sunlight enters the building. Typically, the aperture(s) should face within 30 degrees of true south and should not be shaded by other buildings or trees during the heating season.
- **Absorber:** the hard, darkened surface of the storage element. This surface which could be that of a masonry wall, floor, or partition (phase change material), or that of a water container is placed in the direct path of sunlight. Sunlight hits the surface and is absorbed as heat.
- **Distribution:** the method by which solar heat circulates from the collection and storage points to different areas of the house. A strictly passive design will use the three natural heat transfer modes conduction, convection, and radiation exclusively. In some applications, however, fans, ducts, and blowers may help with the distribution of heat through the house.
- **Control:** roof overhangs can be used to shade the aperture area during summer months. Other elements that control under and/or overheating include: electronic sensing devices, such as a differential thermostat that signals a fan to turn on; operable vents and dampers that allow or restrict heat flow; low-emissivity blinds and awnings.

- **Indirect Gain – (Trombe Wall) :** An indirect-gain passive solar home has its thermal storage between the south-facing windows and the living spaces. Using a Trombe wall is the most common indirect-gain approach. The wall consists of a 10 to 20 cm thick masonry wall on the south side of a house. A single or double layer of glass is mounted about 2.5 cm or less in front of the wall's surface. Solar heat is absorbed by the wall's dark-colored outside surface and stored in the wall's mass, where it radiates into the living space.

The Trombe wall distributes or releases heat into the home over a period of several hours (Figure 3.2). Solar heat migrates through the wall, reaching its rear surface in the late afternoon or early evening. When the indoor temperature falls below that of the wall's surface, heat begins to radiate and transfer into the room.

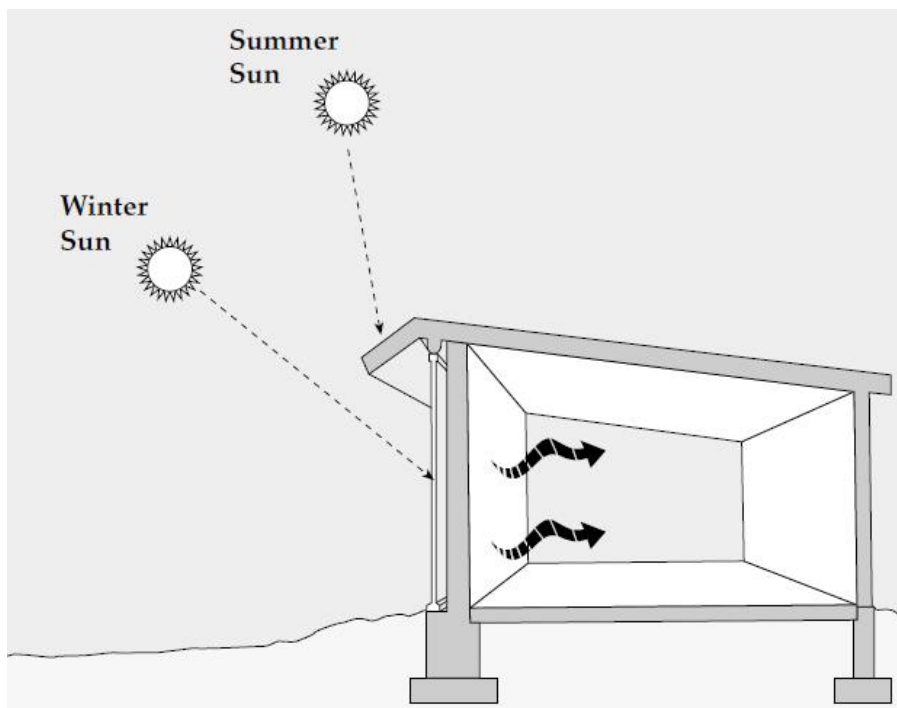


Figure 3.2:Trombe wall [28]

- **Isolated Gain – (Sunspace)**

A sunspace also known as a solar room or solarium is a versatile approach to passive solar heating. A sunspace can be built as part of a new home or as an addition to an existing one. The simplest and most reliable sunspace design is to install vertical windows with no overhead glazing (Figure 3.3). Sunspaces may experience high heat gain and high heat loss through their abundance of glazing. The temperature variations caused by the heat losses and gains can be moderated by thermal mass and low-emissivity windows. The thermal mass that can be used include a masonry floor, a masonry wall bordering the house, or water containers.

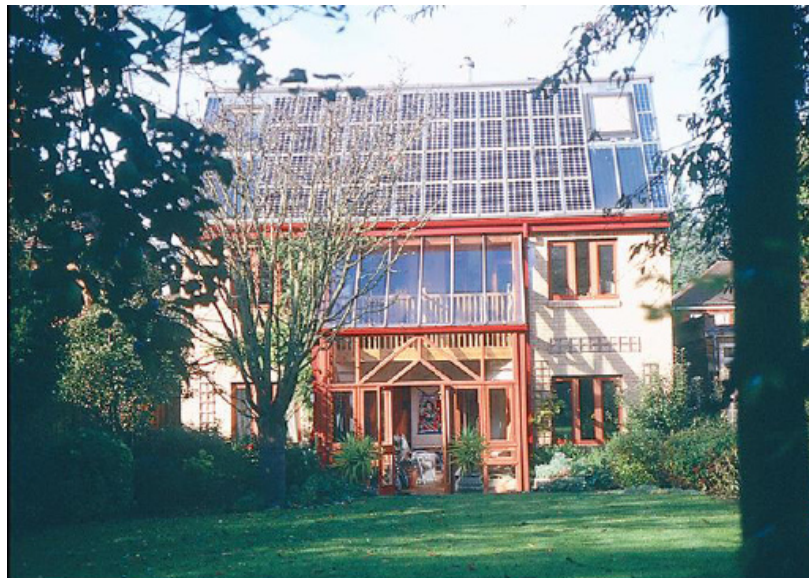


Figure 3.3:Example of sunspace in a building [29]

The distribution of heat to the house can be accomplished through ceiling and floor level vents, windows, doors, or fans. Most homeowners and builders also separate the sunspace from the home with doors or windows so that home comfort isn't overly affected by the sunspace's temperature variations. Sunspaces may often be called and look a lot like "green houses." However, a green house is designed to grow plants while a sunspace is designed to provide heat and aesthetics to a home.

Many elements of agreenhouse design, such as overhead and sloped glazing, which are optimized for growing plants, are counterproductive to an efficient sunspace. Moisture-related mold and mildew, insects, and dust inherent to gardening in a greenhouse are not especially compatible with a comfortable and healthy living space. Also, to avoid overheating, it is difficult to shade sloped glass, while vertical glass can be shaded by a properly sized overhang.

Figure 3.4 shows basics of passive strategies in the buildings.

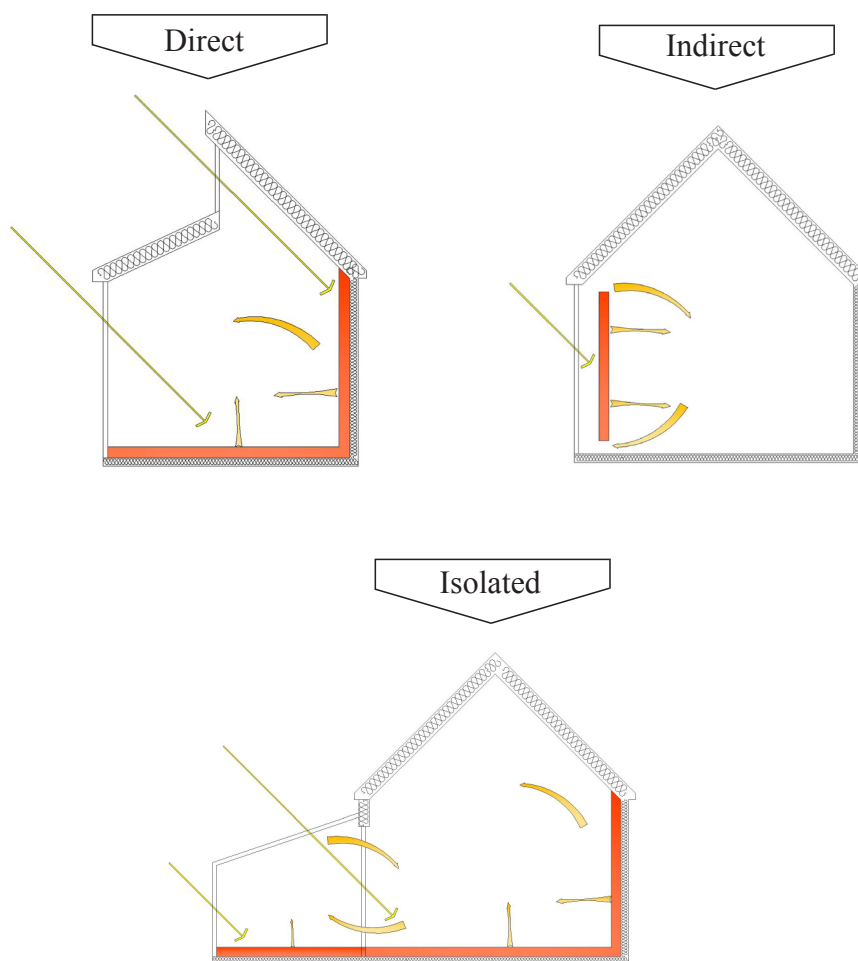


Figure 3.4: Passive strategies in the buildings

3.2 Design parameters effecting energy efficient building envelope

Envelope design, which aims at ensuring comfort conditions and energy conservation in the room, is possible with the determination of an appropriate set of values for the design parameters with an influence on the artificial environment as a function of the external conditions. The main design parameters when effecting buildings envelope as passive systems are explained in Table 3.1.

Table 3.1: Design parameters involved in design process of building envelope

Parameters related to user	Parameters related to the outdoor environment	Parameters related to the built environmet
User Characteristics age, gender, activity level, clothes type	Outdoor environment Outdoor air temperature Solar radiation Outdoor air humidity Wind outdoor illumination outdoor sound level	On the settlement unit scale On the building scale On the room scale On the element scale
Physiological Parameters Objective Subjective		

3.2.1 Parameters related to user: User parameters divided into user characteristics and physiological parameters. The human body by burning the food unit also referred to as the level of metabolism and the amount of energy produced is an important variable affecting. Physiological parameters can be considered as objective, subjective. Skin temperature, sweating are examples of objective parameters and thermal emotions can be defined as subjective parameters.

3.2.2 Parameters related to the outdoor environment: The parameters of this group of natural factors have a determining influence on the outdoor. In the design stage, must be considered with their given values. These parameters are:

- Outdoor air temperature
- Solar radiation

- Outdoor humidity
- Outdoor wind velocity
- Outdoor illumination level
- Outdoor sound level.

3.2.3 Parameters related to the built environment: The built environment is defined as an environment which designed and constructed by man, and can be considered under different criteria related to scale. The parameters in this group may be considered on the basis of a settlement unit, a building, a room or an element. The main design parameters related to the built environment with an influence on the control of heat, light and sound, as well as energy conservation are given below.

1) Design parameters on the settlement unit scale:

- Dimensions and orientation of external obstacles
- Solar radiation reflectivity of surrounding surfaces
- Light reflectivity of surrounding surfaces
- Soil cover, and nature of the ground (plant cover and groups of trees).

2) Design parameters on the building scale:

- Orientation of the building
- Position of the building relative to the noise source
- Position of the building according to the other buildings and to the noise source
- Building form.

3) Design parameters on the room scale:

- Position of the room within the building
- Dimensions of the room and its shape factor
- Orientation of the room
- Absorption coefficient of the room for solar radiation entering through the transparent component
- Sound absorption coefficients of the surfaces inside the room
- Total sound absorption coefficient of the room
- Light reflection coefficients of the surfaces

4) Design parameters on the element scale:

The design parameters related to be structural elements can be differentiated in two groups as opaque and transparent components and considered separately [1].

(a) Properties of the opaque components of the building envelope

- Thickness of the materials.
- Density of the materials.
- Specific heat of the materials.
- Heat conduction coefficients of the materials.
- Light absorption and reflection coefficients of the surfaces.
- Sound transmission coefficient.
- Porosity and roughness of the surface.
- Sound absorption coefficient of the surface.
- Construction of the surface (flat, with interstices, ribbed).
- Single or multilayer structure.
- Depth of the cavity between the layers.
- Thickness and sound absorption of the insulating material used inside the cavity.
- Kind of connection between layers of different materials, and their number.

(b) Properties of the transparent components of the building envelope

- Dimensions of the transparent component
- Number of layers of the glazing
- Heat transmission coefficient of the glazing
- Absorption, reflection and transmission coefficient of the glazing for solar radiation
- Transmission coefficient of the glazing for diffuse sunlight
- Transmission coefficient of the glazing for direct sunlight
- Transmission coefficient of the glazing for sound
- Type of frame used for the transparent component
- Maintenance factor of the glazing.

3.3 Passive Design Principles of Building Envelope

A sustainable building should rely on efficiency and passive design and provide thermal comfort. For the design, construction and operation of a facility, there is an especially important interface between the indoor and outdoor environments as the building envelope. The building envelope is comprised of the outer elements of a building-foundations, walls, roof, windows, doors and floors. The prime functions of the building envelope are to provide shelter, security, solar and thermal control, moisture control, indoor air quality control, access to daylight, and views to outside, fire resistance, acoustics, cost effectiveness and aesthetics. For this purpose in accordance with the steps of the passive design process are described below.

3.3.1 Meteorological data collection

The environmental parameters that meteorological data contains are hourly average air temperature (°C), wind speed (m/s) and relative humidity (%). These data are essential for the analysis of the effects weather parameters on the envelope design.

3.3.2 Design principles based on climatic regions

Compatible with the building location climatic regions is most important factor in the design principles. Koppen world climate classification is one of the most widely used climate classification systems in world and combines average annual and monthly temperatures and precipitation, and the seasonality of precipitation. There are five major climate regions according to Koppen classification (Figure 3.5):

- Tropical/mega thermal climates (A)
- Continental/microthermal climates (D)
- Dry (arid and semiarid) climates (B)
- Polar climates (E)
- Temperate/mesothermal climates (C)
- Alpine climates (F)

World map of Köppen-Geiger climate classification

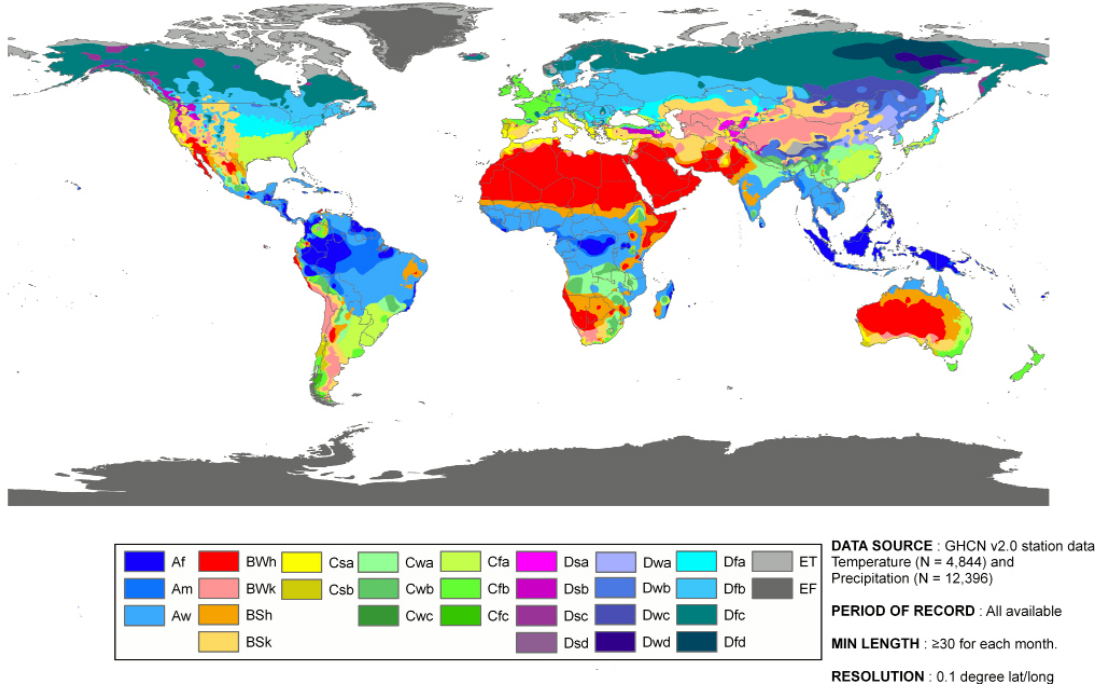


Figure 3.5: Climate regions according to Koppen classification [30]

Turkey climate classification has been divided into five groups (Figure 3.6). These climatic regions are based on the results of the previous scientific researches which had been carried out in Istanbul Technical University [Zeren 1962,1967]. The major climatic regions and priot cities of these regions are follows;

- 1) Cold climatic regions: Erzurum
- 2) Temperate - dry climatic regions: Ankara
- 3) Temperate - humid climatic regions: Istanbul
- 4) Hot - humid climatic regions: Antalya
- 5) Hot - dry climatic regions: Diyarbakır

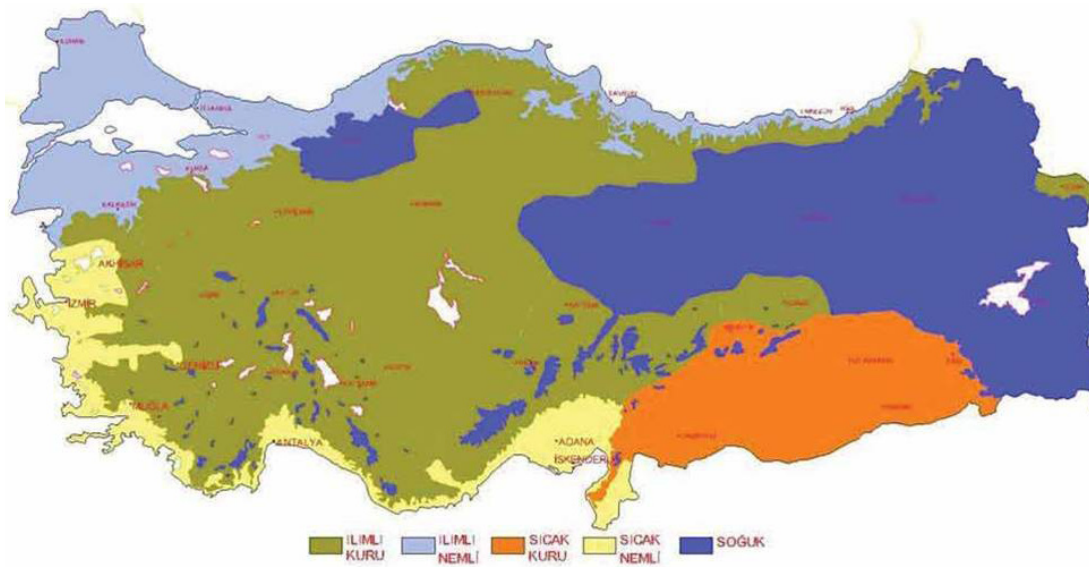


Figure 3.6: Climate regions of Turkey [9]

First step in design principle based on climatic regions is to achieve design principle that is compatible with the climate regions which, include pre-design principles. To ensure a sustainable environment, passive systems in the design of energy efficient buildings will be considered as a priority proposals. Building envelope that is affected by the climate of the environment such as climate elements, can be considered as important element in the process effective energy conservation of physical environmental factor.

Physical environmental factors include solar radiation, external air temperature, humidity, and wind. With available existing climatic conditions to provide desired internal climatic conditions should be controlled relating to design parameters. Firstly, to achieve comfort condition with climatic conditions the values of the external climate elements and climatic data collection should be required. Main passive strategies in building design should be taken into consideration in sustainable design, assessing the environmental impact of buildings.

• **Determination of the appropriate design parameters on the settlement scale**

Settlement, is effective as a design parameter in preventing environmental pollution and climate control. This design parameter include direction, slope, location and cover of area. Applies to appropriate values of parameters are determined by the

climatic conditions and human needs and region settlements are defined according to the most appropriate region. Firstly, suitable land parts should be determined from the human comfort and energy efficiency point of view. The selection of the location must be done according to the climatic characteristics of the region and people's climate-related needs [5].

It is essential to understand the climate characteristics of the building site for climate responsive building design. The climate data is useful not only for estimating heating- and cooling load of the building but also for creating passive design concepts. The environment potential discovered through survey and analysis of the climate information on sun, wind, humidity, air temperature provide necessary ideas to build a passive design strategy and demonstrate what kind of passive designs are effective at the specific site. They also demonstrate the capacity of renewable energy resources such as photovoltaics, wind generation, geothermal and others that can replace conventional energy [31].

- **Determination of the appropriate distances between buildings**

Buildings may serve as obstacles to solar irradiation and wind, depending on the spaces (distances) between them, their height and their arrangement with respect to one another.

Appropriate pattern of settlement depending on the distances between buildings and the height and position relative to each other, which is important role to optimum use of the impact of solar radiation or wind for each other. To the maximum benefit from solar radiation the distances between buildings must be greater than or equal to length of the longest shadow of adjacent buildings. In designing of the building ranges should be considered in terms of land slope, direction, and measuring relative settlement intensity and in terms of passive air-conditioning for comfort ventilation and thermal performance the distances between buildings should be checked local weather data for seasonal prevailing wind directions.

Distances between buildings change with climatic zones based on the principles of protection or getting benefit from the sun and wind. Buildings work as sun or wind obstructions for each other. Buildings create protected areas from wind around themselves. These areas are important for cold region. Conversely, in hot-humid regions distances between buildings should be determined to get benefit from the wind. Because in this zone wind has comfort restoring effect. In cold zones, distances between buildings should be determined to get benefit from the solar radiation. In determining distances between buildings the aim is to maximize solar heat gain [5]. Figure 3.7 shows an example of passive design strategies for cold zones.

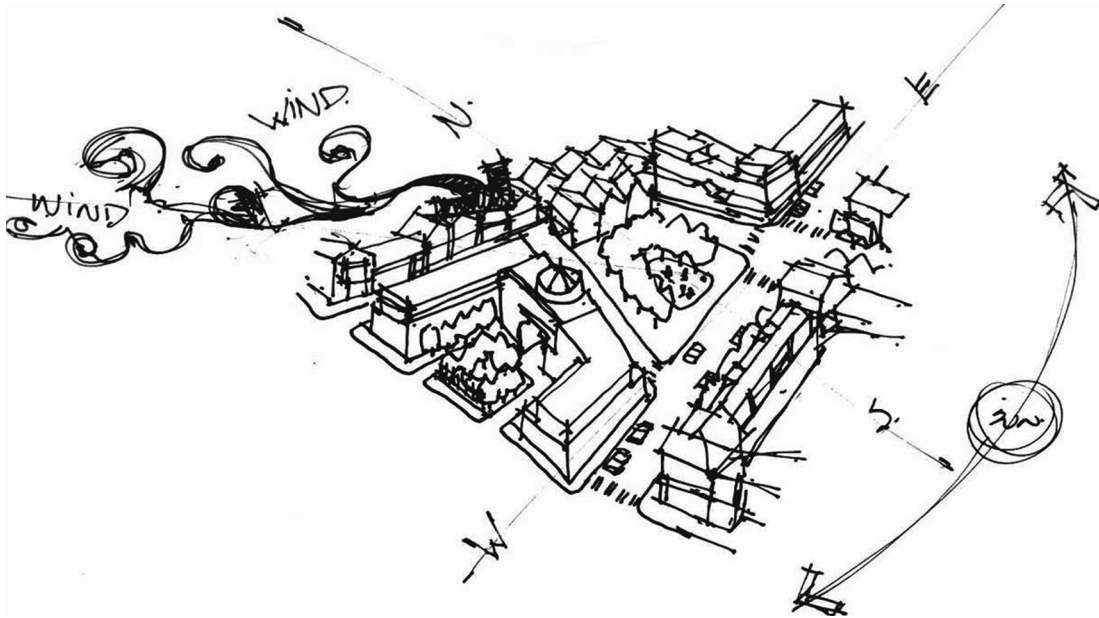


Figure 3.7: An example of cold climatic design strategies [32]

•Determination of appropriate orientation and form

Orientation is the direction of the building or building envelope relative to north and south, and to the sun and wind patterns.

Solar radiation intensity and wind velocity affecting the building surfaces change with the facade orientation. The solar radiation and wind velocity affect indoor climate. The solar radiation affects indoor air temperature and inner surface temperatures. In the northern hemisphere, the building's south side experiences increased heat gains from solar radiation and building's north side experiences lower heat gains.

In the southern hemisphere these relations are reversed. The effects of climatic factors can be controlled through the orientation of buildings and/or building envelope from the energy conservation point of view. To define the optimal orientation with regard to heat gain by solar radiation, it is useful to analyse the radiation intensity on differently oriented surfaces. During the heating period, the heat gain at the building façade must be maximized, and minimized during the time when no heating is required. The most suitable directions for the orientation of buildings are South and Southern directions, since they are the directions of maximum heat gain during the heating period. Building form can be defined as the combination of building height, building room, roof type and shape factor (ratio of building length to building depth).

In general, compact shapes with increased floor area and room in relation to surface area are the most energy efficient due to reduced heat losses. Wide and shallow forms can increase heat gains from solar radiation through a long south side at night and in cold weather.

Conversely narrow and deep forms in terraces can reduce exploitation of solar radiation. A trapezoidal form with a long south and short north side may increase heat gains and reduce heat losses. Complex forms may cause over-shadowing, reduce heat gains from solar radiation, and increase heat losses from infiltration. The suitable form of buildings differs very much amongst the main climate zones.

The appropriate building forms according to the climatic regions from the heating and cooling energy conservation are given in Figure 3.8. For example compact form is appropriate for cold zones while rectangular form is appropriate for hot humid zones. Atrium type, with openings into the interior should be preferred in hot dry zones. In temperate humid climatic regions, the type of construction for the period when no heating is required must be with a large surface to the wind, and a rectangular or irregular shape. In temperate dry climatic regions, the type of construction for the heating period must be compact and close to a square shape, providing shelter from the wind.

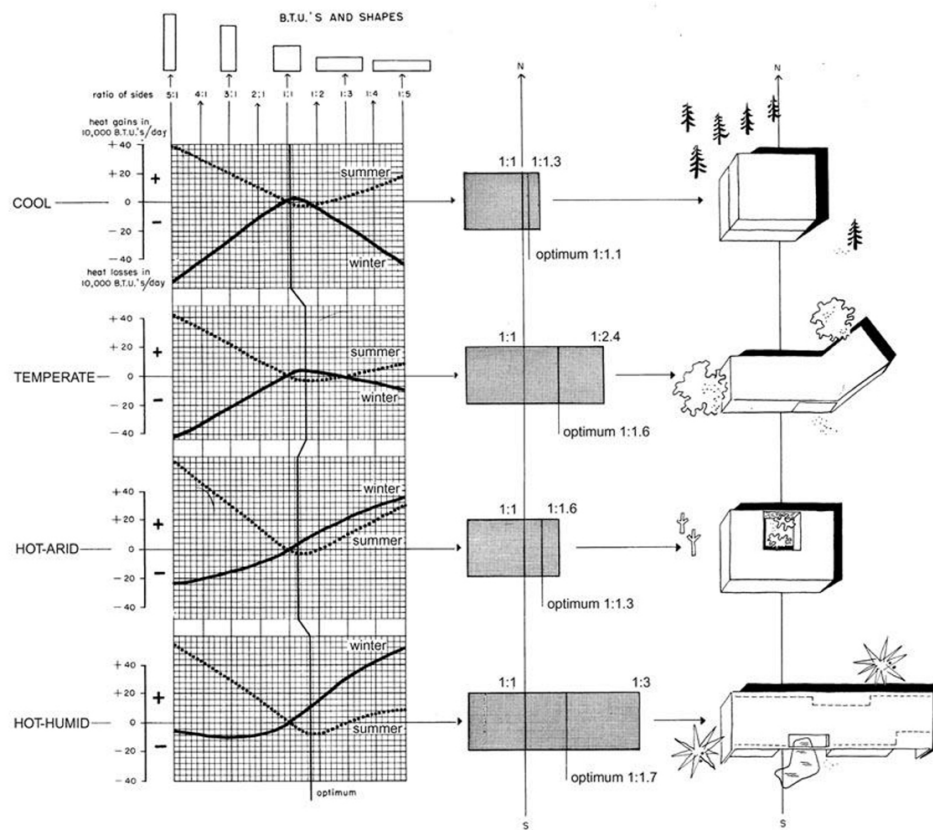


Figure 3.8: Building shapes in different climate regions [33]

- **Determination of the appropriate thermophysical and optical properties of building envelope**

The design parameters related to be structural elements can be differential in two groups as opaque and transparent components.

Depending on climatic condition of internal environment and air-conditioning energy loads the amount of total heat lost and gained may vary based on these conditions. Properties components of the building envelope relating to internal climatic conditions comfort, external climatic conditions, local data, indoor should be selected according to region condition. As a main determinant of the transmission of the physical factors, in opaque or transparent component should be designed appropriate value based on the type of property of a component.

Designing opaque building envelope components the appropriate combinations of the main parameters of the opaque components from the heat , light and sound point of view such as:

- Thickness of the materials, density of the materials, specific heat of the materials, heat conduction coefficients of the materials, light absorption and reflection coefficients of the surfaces, sound transmission coefficient, porosity and roughness of the surface, sound absorption coefficient of the surface, construction of the surface (flat, with interstices, ribbed), single or multilayer structure should be determined [1].

The optimal values of these parameters are the qualitative and quantitative framework for the building envelope design which ensures the comfort conditions with respect to heat, light and sound control, as well as the highest performance environmental control through design of the building envelope.

In determination of the transparent component properties, the transparent component of the envelope has certain objectives, like maximum daylight availability, controlling the direct sunlight, minimizing the heat gain during overheated period, providing glare control and view to the outdoor environment.

These objectives are sometimes contradictory and their importance depends on parameters like, region, latitude, season, function and occupation time. This complexity requires a specific solution for each project.

For example, window dimensions are generally given as transparency ratio, which equals to the ratio between the window area and the façade area. There are certain important things to be considered while selecting window for the transparent component that requires energy efficiency performance features or daylighting performance which, is providing glare control and view to the outdoor environment and an understanding of some basic energy concepts and basic sound insulation concepts that is essential to choosing appropriate windows and skylights.

• **Thermophysical and optical properties of building envelope**

The solar optical properties of a building envelope are:

- Absorbance
- Reflectance
- Transmittance.

Absorbance is the ratio of the amount of absorbed solar radiation by the surface, to the total solar radiation on the surface. Reflectance is the ratio of the amount of reflected solar radiation by the surface, to total solar radiation on the surface. Reflectance and absorbance change with colour of the external surface of building facade. Transmittance is a property which only belongs to the transparent parts of the building envelope such as windows and doors made of glass. Transmittance is the ratio of the amount of transmitted solar radiation through the glass to the solar radiation on the external surface of the glass.

For opaque building surfaces sum of the values of the absorbance and reflectance is equal to 1, for transparent components sum of the values of three solar optical properties (absorbance, reflectance, transmittance) is equal to 1.

Solar optical properties for transparent components change with:

- Thickness of the glass
- Any film or coating applied to its surface
- Incidence angle of the sun for the surface

For sun control coated with highly reflected films may be used. Those coated with highly reflected films have lower absorbance and transmittance.

The main thermophysical properties of building envelope are:

- U value (overall heat transfer coefficient)
- Transparency ratios

Transparency Ratio (%) is the ratio of window area to total surface area of the facade.

U value is the unit amount of heat transmitted in a unit time (1h) through a building component of a unit surface area (1 m²) when difference between the air temperatures is 1°C.

U values of a given component can be calculated by using the following formula.

$$U = \frac{1}{\frac{1}{h_o} + \frac{L_1}{k_1} + \frac{L_2}{k_2} + \frac{L_3}{k_3} + \frac{L_4}{k_4} + \frac{1}{h_i}} \quad (3.1)$$

U: overall heat transfer coefficient, W/m² °C

L₁, L₂, L₃, L₄ : thickness of the layers, m

k₁, k₂, k₃, k₄ : thermal conductivities of the materials, W/m °C

h_o, h_i : external and internal surface conductances, W/m² °C

Thermal conductivity (k) is the unit amount of heat transmitted in a unit time (1h) through a building material of a unit thickness (1 m²) and unit surface area (1m²) when the difference between the surface temperatures of opposite faces of the material is 1 °C.

Surface conductance (h) is the unit amount of heat transmitted in a unit time (1h) from the surface of a building component of unit area (1 m²) to the air, that is in contact with the surface, when the difference between the surface and air temperatures is 1 °C. U values of windows change with:

- Thickness and material of the window frames
- Ratio of window frame area to window are
- Thickness and quality of window glass
- Number of the glass sheets (single glass, double glass..) [5].

Table 3.2 gives the U values of different window types.

Table 3.2: U values of different window types [34]

		Aluminum Frame without thermal break (with conventional spacer)	
		Alum. Frame with thermal break (with conventional spacer)	
Wood or Vinyl Frame (with insulated spacer)			
GLAZING TYPE	U-FACTOR (Btu/hr-ft ² -°F)		
Single glass	-----	1.07	1.30
Double glass, 12 mm air space	0.48	0.62	0.81
Double glass, e = 0.20* 12 mm air space	0.39	0.52	0.70
Double glass, e = 0.10* 12 mm air space	0.37	0.49	0.67
Double glass, e = 0.10* 12 mm argon space	0.34	0.46	0.64
Triple glass, e = 0.10 on two panes*, 12 mm argon spaces	0.23	0.36	0.53
Quadruple glass, e = 0.10 on two panes*, 6mm krypton spaces	0.22	-----	-----

*e is the emittance of the
low-E coated surface.

•Heat Storage and Time Leg

Another important properties of building envelope are heat storage and time leg. The capacity of building components to store heat and to release it later has an important regulating effect on the indoor climate. A high internal mass reduces the indoor temperature swing. During the daytime it is thus cooler and at night warmer than outdoors.

The indoor temperature of a light structure is similar to the outdoor temperature with a slight time leg. Without proper reflection of the solar radiation this temperature can

also rise for above the outdoor temperature. The indoor temperature of a heavy structure remains near the average outdoor temperature, with a longer time lag. The temperature can be considerably lowered during the day by combining a heavy structure with proper night ventilation.

Time lag is defined as the time difference between the peak outer surface temperature and the peak inner surface temperature it is actually the time required for the heat to pass through a material. The time lag determines when maximum heat is emitted. This is important where internal heat gain is desired later in the evening. For example in cold regions bedrooms should be located on western side because its side will be warmer than outdoor in the evening because of the time lag of building envelope.

To improve the thermal performance of building envelope elements , there are many factors to consider when designing building elements which, include (external walls, roofing, windows, flooring, doors.).

•**Determination of the natural ventilation systems**

Natural ventilation in buildings relies on wind and thermal flotation as driving forces. Ventilation of occupied spaces in buildings through the building envelope has four the main objective.

- 1) To provide an acceptable indoor air quality, which essentially is based on the supply of fresh air and the removal or dilution of indoor pollution concentration.
- 2) To provide thermal comfort by providing a heat transport mechanism.
- 3) To cool the mass of the building envelope and inside during the night.
- 4) To warm the mass of the building envelope and inside during the day.

Natural ventilation can be defined as the event where stale, polluted air in a room is replaced by fresh air without any mechanical influence.

Elements of forming natural ventilation system may be explained as follows;

- Dimensions of the room
- Ventilation inlet and outlet openings
- Position of the openings according to each other and the wind.

Inlet openings must be located in areas of positive pressure, and the outlet openings in areas of negative pressure.

Under the aspect of human needs, there are 2 categories of natural ventilation:

1. Health Ventilation:

This is ventilation that is needed only for health purposes. It is the minimum ventilation required throughout the year.

2. Comfort Ventilation:

This is ventilation needed to feel oneself comfortable. In the winter months, we cannot speak of comfort ventilation. If a need for it is felt, then this is usually due to overheating (not an economic solution).

If comfort ventilation has been achieved in a room, this automatically means that health ventilation has also been accomplished.

For health ventilation, the amount of incoming fresh air is most important (the purpose is to prevent the air pollution in the room to pose a threat to human health).

For comfort ventilation, the speed of the incoming air movement is most important (comfort ventilation particularly gains importance in hot and humid areas).

• Opening size and shape

Opening size and shape are important factors that determine the airflow within buildings. For buildings with openings in opposite walls, improved ventilation rate can normally be achieved by an angular wind incidence to the inlet. In this situation, greater airflow rates are also usually achieved when the outlet is larger than the inlet opening. But whereas the reverse is also true, air speed is more evenly distributed around the space when the outlet is smaller than the inlet [35]. This is because part of the kinetic energy is converted to static pressure around the leeward opening [36].

When the inlet and outlet are of the same size, the internal air speed is related to the porosity of the building envelope irrespective of the angle of incidence of the wind. For instance, a building with 40% porosity causes an average indoor wind speed nearly twice that of a building with 15% porosity [36].

The interior wind velocity, the areas of the ventilation entrance and outlet openings and the wind velocity at the exterior design are directly proportional. If the wind velocity at the exterior design increased, the interior wind velocity will also increase. In other words, since the wind velocity at the exterior design varies with the pattern of settlement units, the wind velocity required in the interior can also be achieved in dependence of the settlement pattern [5].

A strategy relying on comfort ventilation, which is common mainly in warm, humid regions, calls for design details that will maximize the comfort achievable with natural ventilation. When dealing with ventilation in the context of its effect on comfort, it should be remembered that the important factor is the air speed over the human body [37].

As an energy efficient design strategy and a climate change mitigation measure, natural ventilation is being incorporated in buildings [38]. Air velocity affects both convective and evaporative heat losses from the skin and thus plays an important role in determining thermal comfort of occupants in a space. ASHRAE-55 (Figure 3.9) allows elevated air speeds to be used to increase the maximum temperature for acceptability in naturally ventilated buildings if the affected occupants are able to control the air speed.

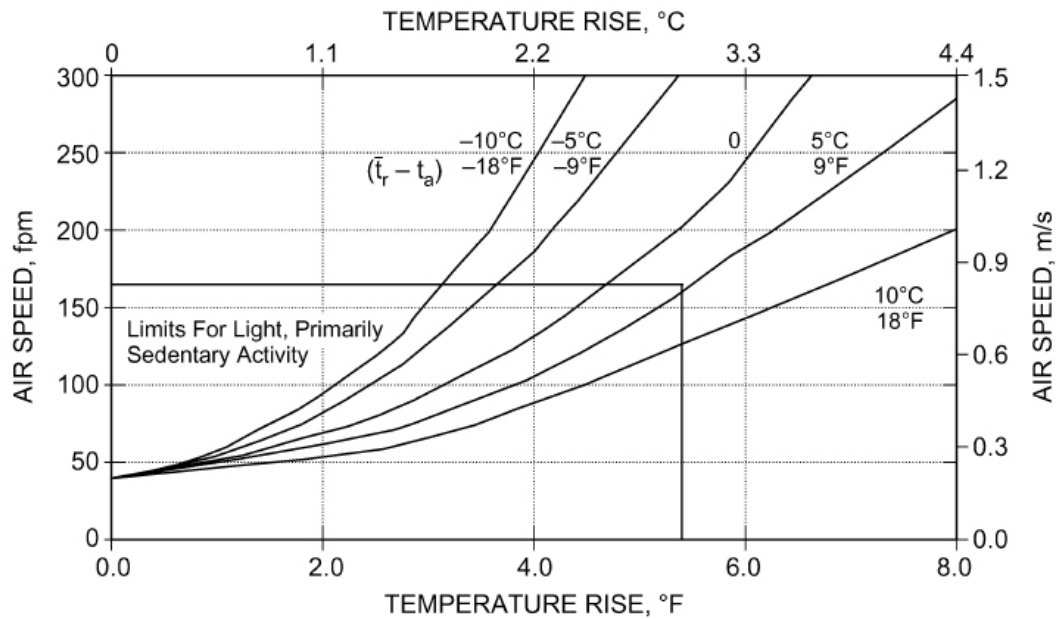


Figure 3.9: Air speed required to offset increased air and radiant temperature [39]

ASHRAE has proposed an adaptive comfort standard (ACS ASHRAE Standard 55), applicable for naturally ventilated buildings. Indoor comfort temperatures in NV buildings are strongly influenced by shifting thermal expectations resulting from both higher levels of perceived control, and a greater diversity of thermal experiences in the building [40].

3.3.3 Design principles of the solar control systems in the building envelope

Daylighting parameters are presented: illuminance and luminance. Illuminance and luminance are used for evaluation of daylighting performance of shading devices. Apertures should be designed to optimize solar heat gain. Therefore, solar control device should be employed to block solar irradiation when overheating or glare problems arise.

Depending on seasonal incident radiation angles, different shading device strategies and determinants should be considered. External shading devices, which obstacle sunlight before it passes through the glazing, are the most effective solar control strategy to avoid overheating. This can be achieved by trees, preferably deciduous trees or shrubs (natural shading), horizontal or vertical overhangs or other parts of a building, or fixed or movable shading devices. Internal devices like curtain, rollers

shades, panels and venetian blinds are less effective for overheating avoidance since radiation is not blocked or reduced until after having passed through the glazing element. At that point, some of the solar radiation will turn into heat, and the heat will be mixed with the indoor air.

To evaluate the performance of different solar shading devices there are many calculation methods and software. Traditionally, the performance of solar shading devices has been described by a simple fixed shading factor defined as the fraction of transmitted solar energy through a standard glazing including the shading device compared to the transmitted solar energy through a standard glazing alone. This measure can be useful for comparison of different solar shading devices, but it is not sufficient when evaluating their performance in a specific building, since the performance depends on the actual glazing and on the position of the sun. In order to take the varying performance of solar shading devices into consideration, the optical properties, transmittance and reflectance of the window system, consisting of the solar shading device and the actual glazing, must be given for specific positions of the sun. Some of the most common external shading devices are given in the Figure 3.10.

Shading devices have the potential to reduce peak cooling load and annual energy consumption because they can be used to control solar gain. Thus, the need to model shading devices in a glazing system analysis is important. Most shading device systems installed in the building envelope are used only for protection from overheating and glare, neglecting other possible functions, such as increasing the daylight level in the space or collecting solar energy.

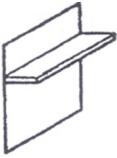
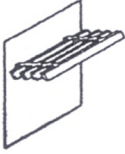
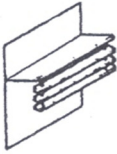
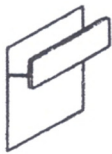
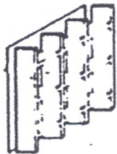
	Descriptive Name	Best Orientation	Comments
I	 Overhang Horizontal panel	South, East, West	Traps hot air Can be loaded by snow and wind
II	 Overhang Horizontal louvers in horizontal plane	South, East, West	Free air movement Snow or wind load is small
III	 Overhang Horizontal louvers in vertical plane	South, East, West	Reduces length of overhang View restricted Also available with miniature louvers
IV	 Overhang Vertical panel	South, East, West	Free air movement No snow load View restricted
V	 Vertical fin	East, West, North	Restricts view For north facades in hot climates only
VI	 Vertical fin slanted	East, West	Slant toward north restricts view sig- nificantly
VII	 Eggcrate	East, West	For very hot climates View very restricted Traps hot air
VIII	 Eggcrate with slanted fins	East, West	Slant toward North View very restricted Traps hot air For very hot climates

Figure 3.10: The most common external shading devices [14]

There is also a need for a specific guidance for the selection and design of shading device systems in the building envelope.

In order to design the solar control systems following areas should be examined:

- Performance of shading devices
- Standards, codes, and recommendations
- Available shading device systems.

The performance parameters are used as the criteria for the analysis of shading devices in the process of their selection or design for a particular building. After performance parameters are analyzed, standards, codes, and recommendations, which are related to daylighting and shading devices, are investigated. Standards are investigated to determine values for performance parameters that are used for evaluation of the shading device performance. At the end, the search on shading device systems is conducted to identify and classify both existing and the patented shading device systems. Performance of shading devices is studied because the main criteria in the decision-making framework are performance criteria, and particularly in the specific, daylighting performance of shading devices. The terms “performance parameter” and “variable” are defined because the structure of the decision-making framework includes performance parameters and variables related to a shading device.

Providing and controlling daylighting in buildings received special attention in a series of studies under design parameters on the solar control through the building envelope. The building envelope as an environmental filter and building element which, manipulates the admission and distribution of daylight inside, plays an important role in control of daylight transmission, visual comfort through enhanced daylighting and energy conservation.

The design of an indoor visual environment of the required quality need to meet the requirements of the user's visual comfort or providing specific performance characteristics or evaluate built environment and its impacts on energy savings from installation of solar control. For that reason it is imperative that the development

of new design guidelines for solar control considers not only solar design that must be considered early in the design process, but also solar control should be designed in the context of its prevailing climatic conditions.

Standards for shading

Both energy and lighting codes recommend application of shading devices to protect space from overheating and provide sufficient daylight and protection from glare. The International Energy Conservation Code 2000 in Chapter 4, which is related to the design of a building utilizing renewable energy sources, states: “Passive solar building designs shall provide documentation, acceptable to the code officials, that fixed external or other acceptable shading is provided to limit excessive summer cooling energy gains to the building interior [41].

This code also recommends that:

- “The windows are provided with operable insulated shutters or other devices which, when drawn or closed, shall cause the window area to reduce maximum outward heat flows.”
- “The window areas are shaded or otherwise protected from direct rays of the sun during periods when mechanical cooling is required.”

The International Energy Conservation Code 2000 recommends that the effect of any permanent exterior solar shading device should be included in the calculation of a combined solar heat gain coefficient (the area-weighted average) of all glazed fenestration products.

The section related to daylight in the International Standard ISO 8995, CIE S 008/E – Lighting of Indoor Work Places recommends: “Provide adequate sun control such as blinds or shades, so that direct sunlight does not hit workers and/or surfaces within their field of view”[42].

The code also recommends: “To reduce glare from windows, screening shall be provided.

In the IESNA Lighting Handbook, blinds and louvers are also recommended as a control technique to limit light that enters the space and to keep brightness balance in the space.

Recommended Practice of Daylighting - IESNA RP-5-99 suggests various methods of solar shade controls:

- Using fixed shades that will exclude sunlight for all sun positions during which the space is occupied (the problem with this method is that sunlight can be excluded when it is desired)
- Using adjustable shading devices
- Glare can be eliminated by using systems that diffuse the incident sunlight
- Occupants should choose workstations [43].

Performance parameters for the shading devices which are considered in design parameters on the solar control building envelope are as follows (including possible subparameters for each performance parameter): thermal, visual, acoustic and aesthetic performance, cost of the shading devices, and control strategy.

3.3.4 Design principles effecting the sound insulation in the building envelope

At the outset the designer should decide which of the following noise criteria are appropriate for all or different parts of the proposed building:

- Reasonable industrial working conditions;
- Reasonable speech and telephone communications;
- Reasonable acoustic privacy in shared spaces;
- Reasonable conditions for study and work requiring concentration;
- Reasonable listening conditions;
- Reasonable resting/sleeping conditions.

The designer should then establish limits for the noise levels that will meet the chosen criterion. For each design criterion a range of levels exist that are considered to meet it. The designer should use judgment to select a level appropriate for the particular circumstances. In noisy workshops etc., the activity noise will be dominant and

so the indoor ambient noise level will not be critical. In most other situations indoor ambient noise will be important.

Limits for desired conditions and reasonable conditions are given. Normally, only the upper noise limit will need to be decided. In some cases, such as open-plan offices and restaurants, a moderate noise level is required to ensure adequate privacy while not causing disturbance, so upper and lower limits should be considered.

Unless otherwise stated, the noise should be assumed to be steady, such as that due to road traffic, mechanical services, or continuously running plant, and should be the noise level in the space during normal hours of occupation but excluding any noise produced by the occupants and their activities. The time period should be appropriate for the activity involved (e.g. 23.00±07.00 for bedrooms). As the noise will be fairly steady, a short measuring period will usually be sufficient to establish the typical outdoor level.

• **Sound insulation in the building envelope**

Sound insulation is the principal method of controlling both airborne sound and impact sounds in buildings. The building envelope can play an effective part in controlling and absorbing sound energy by acting as a barrier to sound. The effective sound insulation of a building envelope component, such as a window, depends on its area and on its sound transmission loss (the attenuation of the transmitted sound energy measured in decibels). The effectiveness of the design of a complete building, however, depends on both the transmission loss, varying with frequency, and the areas of each component of the building envelope. Selecting components with high transmission loss values or with a small area improves the sound insulation.

Transmission loss is the reduction in the amount of sound energy passing through the building element or assembly roof- wall-floor. This is expressed in decibels (dB). Noise can be either impact sound or airborne.

Sound absorption and sound proofing are two very important characteristics which are used in sound insulation in the building envelope. With an aim of investigating

an effect of sound in the building envelope , it is necessary to know the properties of materials to be used for sound insulation improvement on which sound energy absorption depend.

Weighted Sound Reduction Index, is a single number value expressed in decibels (dB) which describes the overall sound insulation performance or sound reduction that the wall or floor provides. R_w represent sound reduction index in Europe, a similar single number rating, including weighted reduction index, R_w , over 100 Hz to 3150 Hz, according to ISO 717, which takes strong lower frequencies of music and machinery into account [44].

When designing a the built environment that will provide the desired acoustic comfort ,should be provided several alternative solutions for various design issues. Noise levels of some point sources or place of immission, depending on :

- The position and size of buildings and barriers surrounding,
- Types of vegetation in place,
- Noise source location relative to a the building envelope,
- The building envelope properties,
- Organization of space inside building,
- Types of the reinforcement in building,
- Dimensions of building elements,
- Materials and forms of transparent and opaque components.

In order to obtain the desired noise level in a room by using all alternative options listed above, it is required to find the most suitable combination method for each. The two types of sound that the building envelope must be able to insulate are:

- Airborne sound passing through gaps and openings,
- Structure-borne sound from impact or vibration.

Sound-attenuating walls, roofs, windows and doors can be used to block external sources of sound. For the purposes of attempting to improve the insulation properties of a the building envelope against external noise, the following prioritized list of treatments will generally apply as it is shown in Table 3.3 :

Table 3.3: The insulation properties of the building envelope against external noise

Windows:	• Provide airtight perimeter seals, • Reduce window size, • Locate larger windows on quiet side of house, • Use heavier glass and larger airspace between sheets of glass, • Add layer of heavy glass with large airspace to existing window (i.e., create a storm window), • If window must remain openable, consider using a solid screen or baffle to shield the opening from the noise source.
Doors:	• Use solid wood, solid core or insulated steel doors, • Provide airtight seals along top, bottom and sides, • Add a second “storm door” separated by an airspace 100 to 150 mm deep - seal perimeters of both doors, • Create an entrance vestibule (entryway or “mud room”).
Vents and Holes:	• Locate ventilation openings on quiet side of house, • Cover with hood and acoustically line ventilation ducts, • Caulk or otherwise seal all holes and cracks (airtight).
Walls:	• Increase mass of lightweight constructions with additional interior layers of gypsum board or heavy external materials such as cement stucco or brick, • Fully insulate cavities (with glass, mineral or cellulose fibre batts or loose- fill, blow-in insulation), • Attach interior gypsum board (one or two layers) to the framing using resilient channels, • Consider using staggered-stud or double-stud exterior walls.
Roofs (dealing with aircraft)	• Install 200 to 300 mm thermal/acoustical insulation in cavity between roof and ceiling, • Treat (attached duct section and acoustically line) attic ventilation openings, • Keep fireplace dampers closed when not in use, consider an enclosed fireplace (insert) or a wood stove, • Construct suspended ceiling using one or two layers of gypsum board mounted on resilient channels.

To compare various window, door and wall constructions and select the appropriate construction for the building envelope, it is necessary to determine the sound insulation values of each building envelope component.

The main factors which determine the sound insulation of a building element (wall, floor or façade) are mass, air tightness and the isolation between elements (e.g. between the leaves of a cavity wall) [24]. Other factors which influence the sound transmission through a building are the characteristics of materials used for construction, the standard of workmanship, and the layout and detailing of the building. The sound insulation between rooms in a building is not only influenced by the sound insulation of the separating element, but also by transmission via adjoining elements and air paths through or round the element, known as flanking transmission. In order to control flanking transmission careful design and high standards of site supervision and workmanship are essential. In addition to obvious air paths, hidden paths may be contained in materials themselves due to porosity and permeability: materials having a high permeability will provide sound insulation considerably lower than an impervious material of similar mass per unit area. Applying a sealing finish such as plaster or cementitious paint can make a substantial improvement to the performance of a permeable material.

The degree of flanking sound transmission depends on the overall design of a building and in some cases flanking transmission can exceed direct sound transmission. It is often a limiting factor where high performance is required. Some factors which should be considered are:

- a) Junction detail between the separating wall/floor and the flanking wall;
- b) Mass of flanking elements;
- c) Transmission through floor voids, loft spaces, service ducts and similar paths.

It is not practicable to consider the sound insulation of all possible combinations of the elements that might form a building. In the initial stages of a design, individual elements are often considered as though they behaved independently of each other, but later in the design process possible interactions between the elements should be considered and the design modified or refined as necessary [24].

Sound insulation characteristics of common building elements

• Single leaf masonry walls

The main parameter which determines sound insulation is mass, and a rough guide to performance can be obtained from the mass law. However, all materials have a characteristic reduction in sound insulation due to the coincidence effect at their critical frequency; the position of which is mainly dependent on the mass and stiffness of the wall. The reduction in sound insulation in this frequency region depends on the amount of damping present, and for common materials the insulation at the critical frequency is often 5 dB to 10 dB below the trend at lower frequencies and will remain low for an octave above the critical frequency. A typical 225 mm solid, dense masonry wall may show coincidence effects in the 125 Hz octave band, while 100 mm solid lightweight concrete may show the effects in the 500 Hz octave band.

• Double leaf masonry cavity wall

With masonry double leaf walls, sound energy is transmitted from one leaf to the other through the air in the cavity which separates them, and in the form of mechanical vibrations through any ties or structural links between the two leaves. A wide cavity will assist in providing good sound insulation.

A high degree of structural isolation between the two leaves also assists in reducing structure-borne sound transmission. To this end, ties between the two leaves should be as few as possible and be flexible whilst maintaining structural stability. Butterfly pattern ties are better in this respect than most other types which will degrade acoustic performance. Because of unavoidable structural links, masonry cavity walls seldom

attain their potential acoustic performance. Each leaf of double leaf walls is subject to coincidence effects, and in addition, double leaf constructions exhibit a mass-air-mass resonance.

• **Partition walls**

Lightweight partitions are often used to divide a large floor area into separate rooms, for example, in large office blocks. The needs of flexible room planning and of quick installation have resulted in the production of many proprietary systems of prefabricated lightweight demountable partitions that are easily assembled using dry methods. The mass of these partitions seldom exceeds about 40 kg/m². The majority employ room height units about 1 m wide, usually constructed with skins about 50 mm apart, and with mineral wool or other lightweight cavity filling materials. Various methods are used to fix the panels to the structure and to fasten them together. However, for maximum sound insulation the partition should be fitted to the soffit of the structural slab and sealed around all edges.

Particular care should be taken to avoid any significant loss of sound insulation through indirect sound transmission routes. For example, where a partition wall is butted to a suspended ceiling, a continuous barrier should be provided in the space above it. Because of their lightness, and the inevitable small gaps around them, the insulation of prefabricated office partitions usually lies in the range 30 dB Rw to 40 dB Rw, occasionally extending up to 45 dB Rw. Folding and sliding partitions generally provide about 30 dB Rw, but better performance can be achieved with careful design and installation [24].

• **Construction details**

The following recommendations should be closely followed in order to maximize sound insulation. They are particularly applicable to masonry separating walls between dwellings.

- a) Avoid forming recesses in the separating wall but, if it is necessary to recess electrical sockets in the wall, they should not be placed back to back to avoid the risk of complete penetration.
- b) Complete filling of mortar joints, particularly perpend, is good practice. In brick walls, if the bricks have frogs they should be laid frog up so that the frogs are filled with mortar.
- c) In the case of walls formed from permeable materials, the wall surface should be sealed with cementitious paint or render unless it is to have a plaster finish. Ideally, this sealing should include the wall surface where it passes through a suspended timber floor.
- d) The minimum number of connections between the leaves of masonry cavity separating walls consistent with structural stability should be used. Butterfly or similar low stiffness ties are recommended.
- e) Care should be taken to ensure that mortar droppings or other foreign matter does not bridge cavities.
- f) A cavity separating wall construction should continue right through the roof space.
- g) Air paths through or round a separating wall, even in the loft space, should be kept to the minimum possible by careful sealing around any necessary penetration of the wall. Joists should preferably run parallel to a separating wall, but if they are perpendicular joist hangers should be used, or if they are built in all air paths should be filled.
- h) The reveals of windows should be well sealed to prevent sound getting into the wall cavity. At the junction with the separating wall it is good practice to stop the external wall cavity with a flexible closer, such as mineral wool, to reduce sound transmission along the cavity. If the cavity is to be filled or partially filled for thermal insulation additional stopping is not necessary.
- i) Masonry separating walls should be rigidly bonded or tied to the inner leaf of a cavity wall or only leaf of a solid external masonry wall.

• Doors

The main factors determining the sound insulation of single doors are the mass of the door and the gaps around the edges; usually the latter are decisive. For good sound insulation, it is important to see that the door forms airtight joints with the frame when closed and that the joints between frame and wall are sealed. A threshold seal is essential, and even key hole covers should be fitted in critical situations.

Single doors providing a sound insulation greater than 35 dB R_w are specialist products and are supplied as complete door sets. High performance seals may make the door hard to open and close. The most effective solution, where space is available, is to use two well-sealed doors separated by a lobby lined with absorbent. Such sound lobbies are particularly useful where uninterrupted sound insulation is required (e.g. audiometric examination rooms) because one door can be closed before the other is opened. Well-constructed lobbies can be expected to provide sound insulation of 45 dB to 60 dB, although the higher figure will only be achieved if the whole construction is carefully designed. Where infrequent access to a space is required, a removable panel may be considered in place of a door.

• Windows

Table 3.4 gives guide values for the sound insulation of windows, as measured in the field.

Table 3.4: Sound insulation of typical windows [24]

Description	Weighted sound reduction index R_w dB
Any type of window in a façade when partially open	10 -15
Single glazed windows (4 mm glass)	22-30
Thermal insulating units (6-12-6)	33-35
Secondary glazed windows (6-100-6)	35-40
Secondary glazed windows (4-200-4)	40-45

Glass often shows a pronounced dip in insulation at its critical frequency. For 6 mm glass this is around 2 000 Hz. Laminated glass performs better because the increased damping reduces the effect.

When adjoining rooms have their windows open the sound reduction from one to the other will be limited to about 30 dB if there are other buildings close to the windows to reflect the sound back. When the window is closed in one of the rooms, a reduction of over 50 dB between the rooms should be obtainable, and with both windows closed, this flanking path should not limit the insulation provided by normal separating elements.

- **Double glazed thermal insulating glass units**

An insulating unit is unlikely to perform better than a single pane of mass equivalent to the thicker pane of the sealed unit and should be used in a frame with good seals to realize its full potential.

- **Secondary windows**

In addition to the need for good sealing, the following recommendations apply for double windows:

- a) The air space should be at least 100 mm, although for good performance over the main frequency range of interest a cavity of about 300 mm is desirable.
- b) The sides and top of the reveal should be lined with sound absorbent (the bottom should be left clear to avoid staining due to condensation).
- c) The best results are obtained if both windows are sealed, but this has obvious difficulties for cleaning (and means of escape where appropriate). When opening lights are used some loss of insulation will occur, but this can be minimized by good quality fittings and weather stripping.
- d) The outer pane can be an insulating glass unit to improve performance and reduce condensation.

•Non-uniform partitions

Figure 3.11 shows how to calculate the overall sound insulation of a partition consisting of two parts having different sound-insulating properties, e.g. a window in a wall. It may also be used to give an indication of the effect of gaps or holes in a partition by assigning a sound insulation value of 0 dB to the aperture.

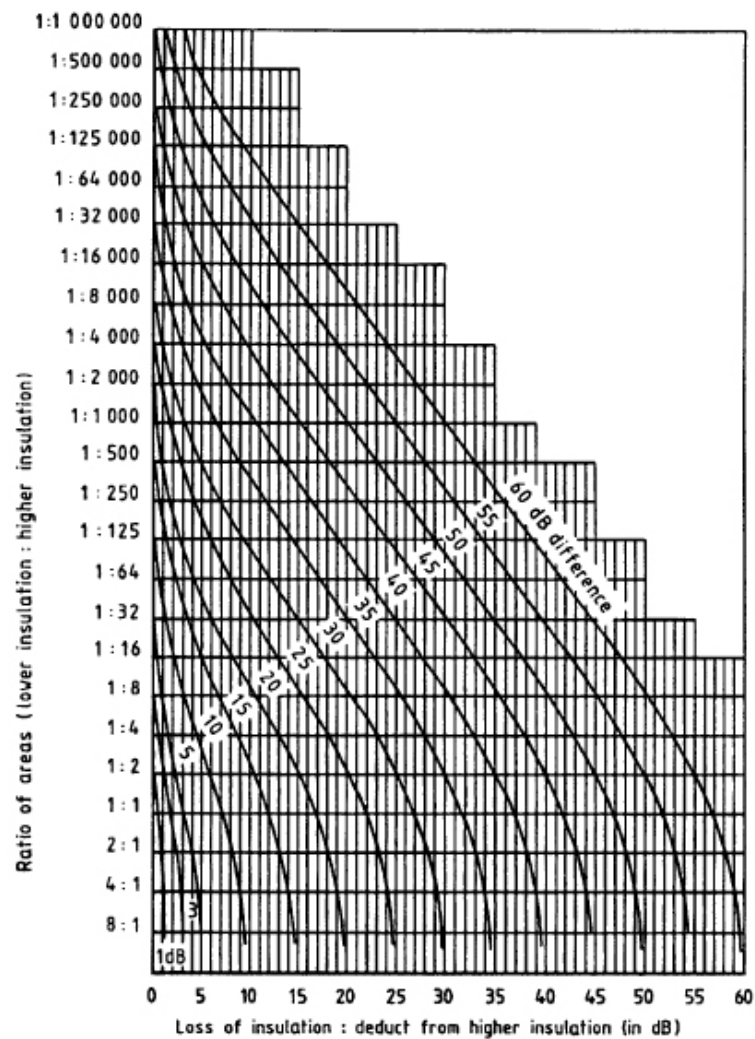


Figure 3.11: Sound insulation of non-uniform partitions [24]

4. AN APPLICATION FOR THE DETERMINATION OF DESIGN PARAMETERS AFFECTING BUILDING ENVELOPE IN TERMS OF HEAT, LIGHT, SOUND: EXAMPLE PROJECT URFA AGRICULTURAL VILLAGE

As it is known, the energy demand increases due to comfort requirements related to population increases in Turkey. South-eastern Anatolia is one of the rapidly developing region and now has a population growth rate that surpasses the Turkey average. Parallel to this population growth housing and energy problems are rising in this region. As energy problems play important role in the economic and social development of the region, designers should develop energy efficient solutions for this region. For this purpose, in this study an agricultural residential building which has been developed for Urfa in south-eastern Anatolia by TOKI (Housing Development Administration of Turkey) has been selected as the reference building. Different building envelope alternatives have been improved for the reference building and evaluated in terms of heat, light and sound and energy efficiency.

4.1 Methodology of study

This study develops building envelope alternatives for the reference building in order to performance of the building in terms of physical environmental parameters (heat, light and sound) and energy efficiency. For each alternative energy simulations have been executed and results have been compared. In order to compare the energy performance developed alternatives for the reference building, the heating, cooling energy and daylight analysis have been carried out by means of the ECOTECH energy simulation program and the results have been compared.

The comparison is performed with a simulation defining a thermal model with the software Ecotect v5.60 that applies a dynamic simulation method, the admittance method.

By means of ECOTECH with three-dimensional drawing environment, drawings

can be modified quickly and easily. ECOTECT is a complete building design and environmental analysis tool that covers the full range of simulation and analysis functions required to truly understand how a building design will operate and perform. It allows designers to work easily in 3D and apply all the tools necessary for an energy efficient and sustainable future. Another important feature, prior to the analysis by creating three-dimensional calculation rays on the model can provide visualization of the calculation. In this way, errors in the model can be seen and it is easier to correct.

ECOTECT building energy simulation program is considered as a priority the 3D model-building. As it is known traditional CAD drawings simply do not contain the kind of material, operational and spatial information required by building simulation and analysis tools. Whilst some of the information in a 3D CAD model may be suitable for lighting and shadow analysis (where colour and transparency are the critical properties), it is almost entirely unsuitable for detailed thermal and acoustic studies. Traditional CAD models have no real concept of 'spaces', they exist solely as a by-product of the layout of a series of disassociated geometry in the form of prisms and polygons. Without human interpretation, it is difficult if not impossible to automatically extract important information such as room volume, floor area or which windows affect which space. All of these are fundamental to any thermal analysis [45].

The thermal analysis routines in ECOTECT require a different perspective. Firstly, for modeling the all thermal zones created a three-dimensional prism without thickness. It is possible to create a zone for each base, also it is possible to create separate zones for each space. It will depend on the user what exactly user want for analysing. There are basically two-zone option and referred to as a "thermal zone" and "non-thermal zone".

ECOTECT itself imposes no limit on the number of zones and program can contain any number of zones but creating more zone during analysis, may be extend the duration of the calculation. The model should be created correctly and to check created model "Interzonal adjacency calculations" command is used, which

examine heating zones during these calculations. In order to control heating, cooling energy performance, daylight and acoustic performance through the building envelope and improve reference (existing) building from the energy efficiency point of view, different building envelope alternatives have been evaluated.

The main steps of the study are explained as follows:

- Description of the reference building data (existing building) (4.2.1)
- Gathering the regional climatic data (4.2.2)
- Gathering of external noise levels (4.2.3)
- Calculation and evaluation of annual energy loads for reference building (4.2.4)
- Prediction of daylight factors (daylight analysis) (4.2.5)
- Evaluation of the acoustic performance of the reference building (4.2.6)
- Development of the building envelope alternatives / scenarios (4.2.7)
- Calculation of the energy loads and comparison of the results (4.2.8)
- Prediction of daylight factors for the scenarios and comparison of the calculation results. (4.2.9)

4.2 Application of the methodology

This chapter covers the application of the methodology to selected reference building and the results of the application. The application study has been explained in the light of the main steps of the methodology as follows:

4.2.1 Description of the reference building data

In this study, the selected reference building was designed for lower income families by TOKI (Housing Development Administration of Turkey). The reference building is one of the agricultural-rural residential building in a settlement in the province of Şanlıurfa where, located in hot dry region. The settlement is under construction and still incomplete. Some of the duties of TOKI (Housing Development Administration of Turkey) can be summarized as follows:

- Establishing companies related with housing sector or participating in those that have already been established.

- Granting individual and mass housing credits; granting credits for projects intended for improvement of rural architecture, transformation of squatter areas, preservation and restoration of historical and regional architecture; and making interest subsidies for all such credits, where deemed necessary.
- Developing projects both in Turkey and abroad directly or through the agency its participations; carrying out or appointing others to carry out applications for housing, infrastructure and social facilities.
- Building, promoting and supporting construction of housing units as well as social facilities and infrastructures in locations where disasters take place, if considered necessary.
- Fulfilling duties imposed by laws and other legislation. In addition to the loans given to cooperatives, municipalities are also supported by TOKI loans - facilitating new housing projects on lands they own for the provision of low-cost owner-occupied housing. long range strategic plan is to create low and medium income social housing, facilities and infrastructure. TOKI will also revitalize blighted neighborhoods, restore and reconstruct buildings of historic importance and create the infrastructure for rural areas and provide housing, infrastructure and social facilities for the victims of disasters [46].

As it is known in Turkey most of the common types of projects of mass production residential buildings are being developed and constructed by TOKI (Housing Development Administration of Turkey) recently. These buildings in which energy efficient approach is being disregarded for years. In regards to national economics as it is essential to evaluate energy efficiency and to develop suggestions to decrease energy loads in residential buildings, it is also an up to date topic which should continually be researched and produced solutions on. Because the energy consumption of existing residential buildings drains a major part of Turkey's energy resources, it is obvious that the reduction of energy costs in residential buildings will also contribute to a cost reduction in other sectors. Therefore, in this study a simple residential house developed by TOKI has been selected as the reference building.

The reference building is one of the agricultural-rural residential building in a settlement in Halfeti (Şanlıurfa). Figure 4.1 gives the settlement plan. The plan of the reference building, 3D view of the building and facades are shown in the Figures 4.2, 4.3, 4.4 respectively.

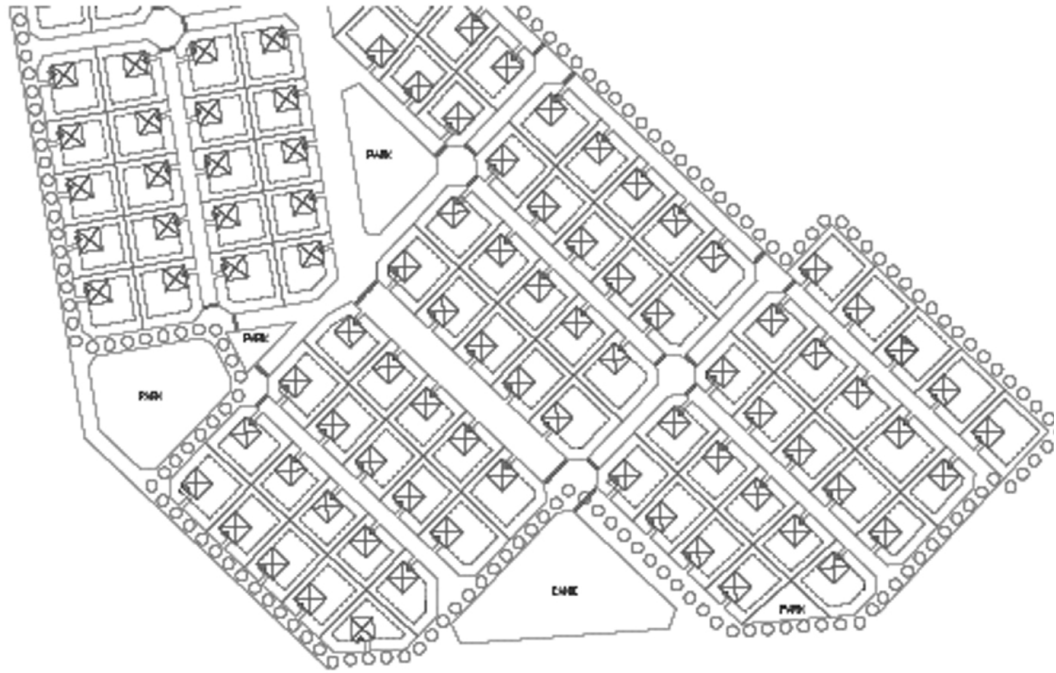
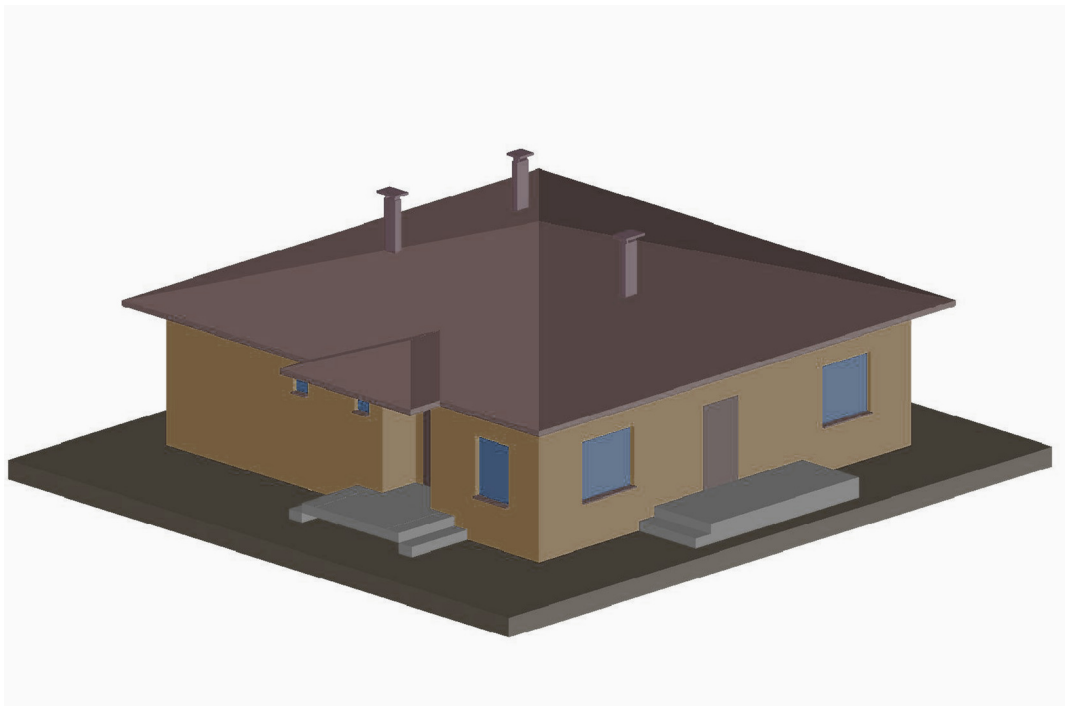
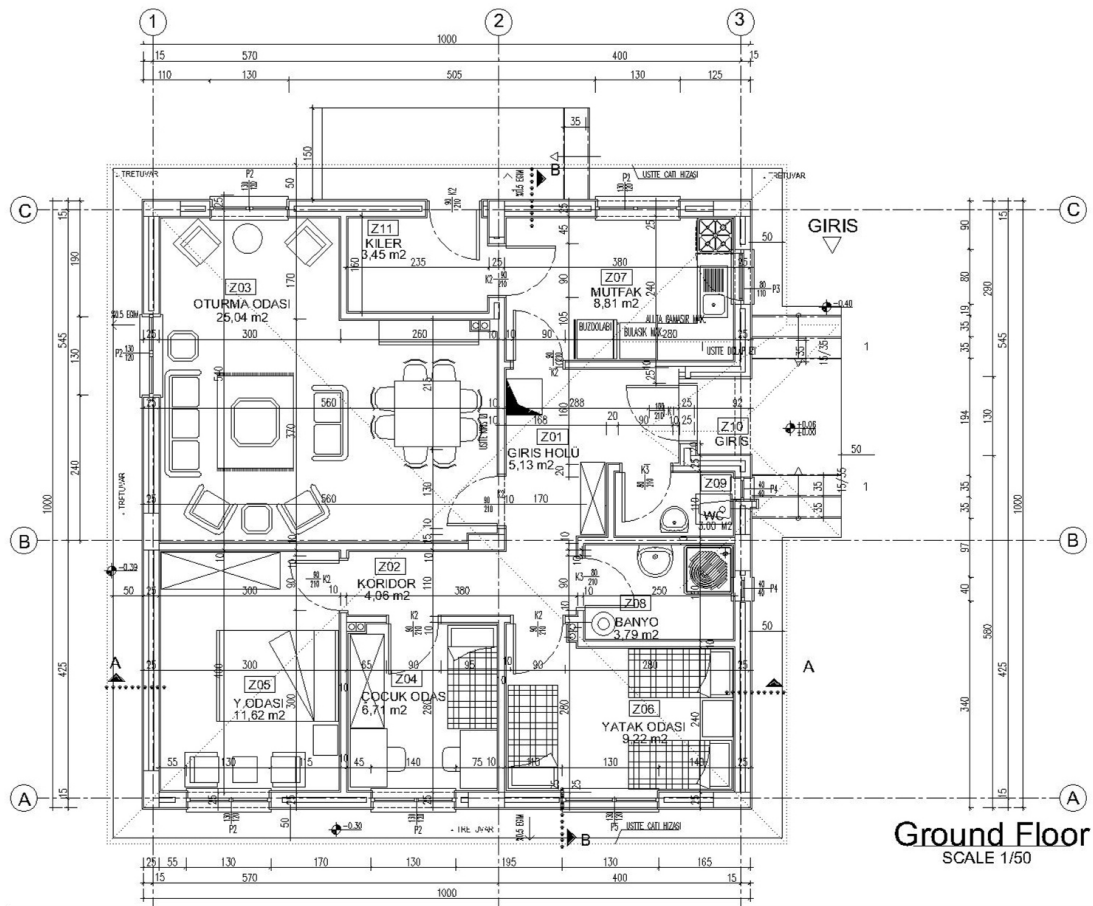


Figure 4.1: Settlement plan



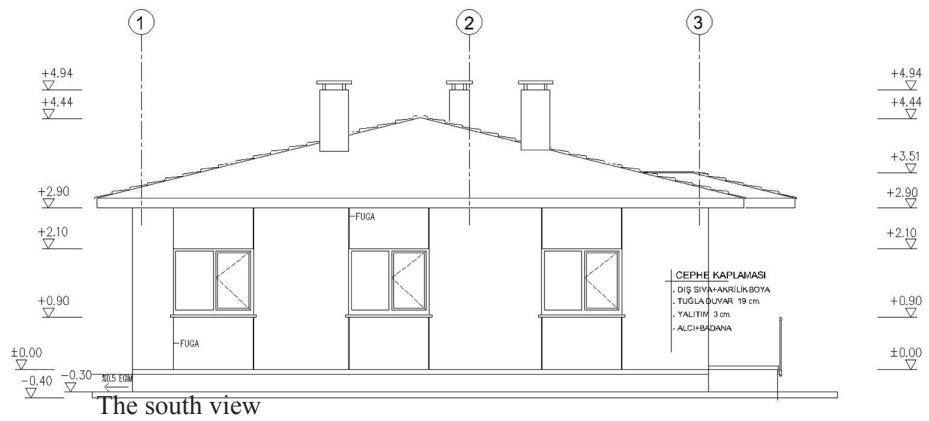
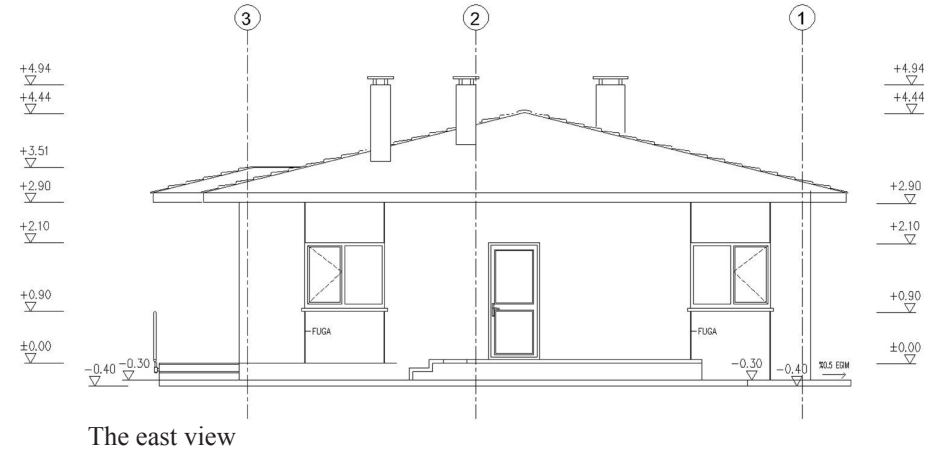
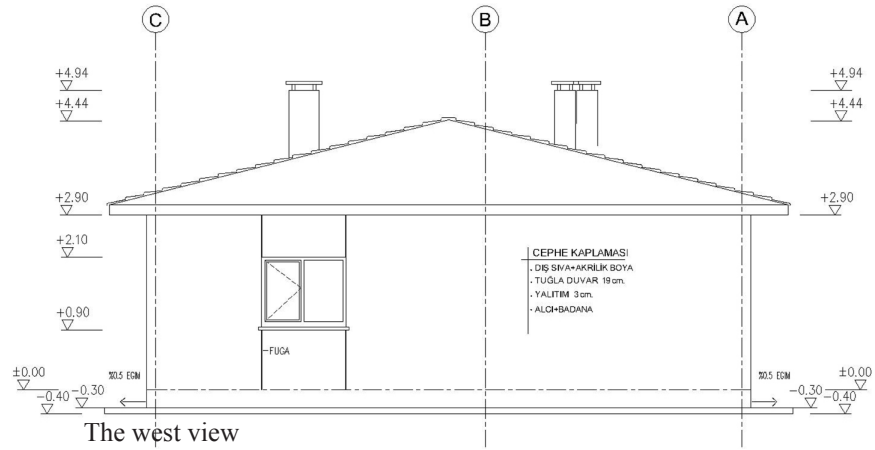
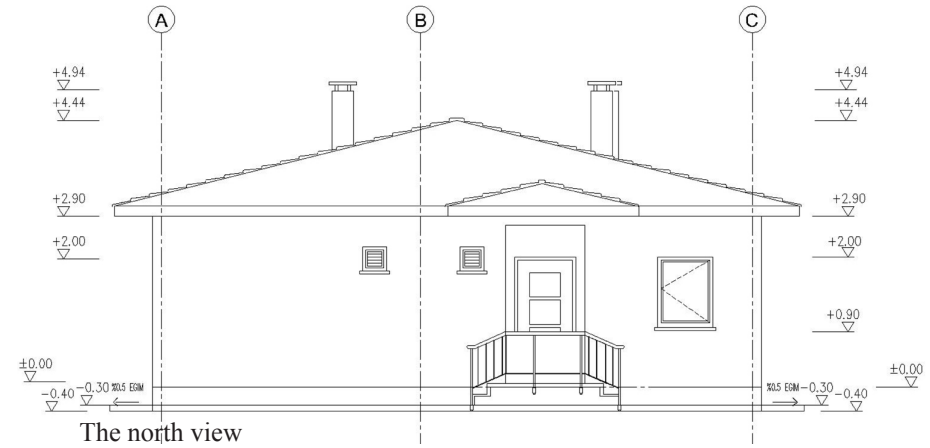
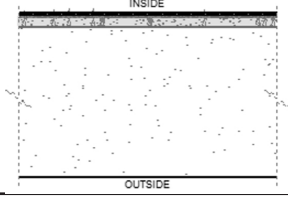


Figure 4.4: Views of the reference building

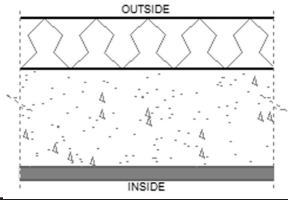
The building is one storey high. It has four external walls oriented towards the four main directions. A detailed description of the wall, floor and roof constructions is given in the Tables 4.1, 4.2, 4.3 respectively. Interior walls are made of brick. Thickness of the walls is 13 cm and U-value 1.97 W / m² K. Window type is single glazed aluminum frame, U value of the windows is 5 W / m² K.

Table 4.1: Thermal properties of the floor in the reference building

Flooring		
Material	Thickness cm	Thermal conductivity W/m°C
ceramic coating	3	1.75
concrete smoothing	2	1.40
concrete	10	1.75
blockage	15	1.75

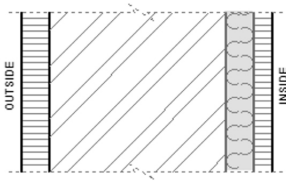
U-value= 0.89 W / m² K

Table 4.2: Thermal properties of roof covering in the reference building

Roof		
Material	Thickness cm	Thermal conductivity W/m°C
Glass wool	8	0.04
Reinforced concrete	15	2.1
Internal plaster	2	0.4

U-value = 0.44 W / m² K

Table 4.3: Thermal properties of exterior wall in the reference building

Exterior wall		
Material	Thickness cm	Thermal conductivity W/m°C
Internal plaster	2	0.4
Insulation XPS	3	0.04
Brick normal	19	1.8
External plaster	3	0.08

U-value = 0.930 W / m² K

4.2.2 Gathering the regional climatic data

According to research studies carried out by the Faculty of Architecture of Istanbul Technical University on meteorological data taken from Turkish State Meteorological Services that country Turkey has five different climatic zones: temperate humid, temperate dry, cold, hot humid, and hot dry. The reference building located in Şanlıurfa which represents the hot dry climate zone [9]. Şanlıurfa represents the hot and dry climate zone and has a great temperature difference between day and night. In the simulation ECOTECT weather tool has been used. Climatic data has been shown the very intense solar radiation and high air temperatures in summer lead to major sources of discomfort for Şanlıurfa's residents. Figure 4.5 gives the variation of outdoor air temperatures of Şanlıurfa as an example of weather tool from ECOTECT.

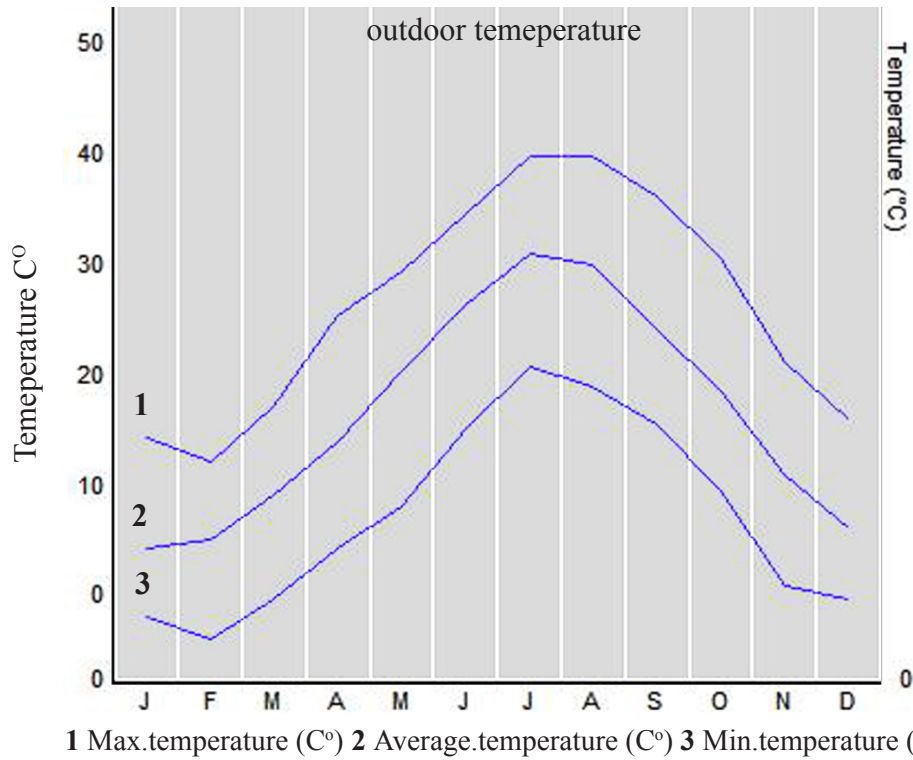


Figure 4.5: Climatic data for Şanlıurfa (Weather Tool ECOTECT)

4.2.3 Gathering of external noise levels

External noise levels (L_1) depend on the environmental noise sources in an area. Road traffic noise is a common source of noise which affects many buildings of all types in and around built up areas. For measurement external noise levels of the reference building accepted noise level measurement that is carried out in the near-field sound region in Istanbul. Because the reference building is under construction the city, which was approved for this study assumed to have the same noise levels. This measurements derived from Environmental and Building Acoustics 2007 (In Turkish) [45].

Table 4.4: L_1 (Exterior) data [45] .

	Frequencies					
	125	250	500	1000	2000	4000
L_1	73	75	79	74.3	72.7	71
L_2 (NC-30)	48	41	36	31	29	27

4.2.4 Calculation and evaluation of the annual energy loads for the reference building

In order to evaluate the performance of the reference building energy loads are calculated by using ECOTECT simulation program.

Material assignments all objects in the ECOTECT model can be assigned two different material, referred to as their primary and alternate materials. In ECOTECT the layers that make up architectural elements, such as thermal conductivity ($W / m^{\circ} K$), thickness (mm), density (kg / m^3) and the specific heat ($J / kg K$) are separately identified. In Tables 4.1, 4.2, 4.3 properties of objects and building elements of reference building shown and zone properties to each element is recognized. In order to determine heating, cooling and lighting loads and the total energy loads assumptions are as follows:

- The number of users is four that composed of four-person family with two children and parents and is accepted as a standard.
- Solar control elements is not defined in the building envelope.
- The thermal comfort range, initially set to 20-26°C was also varied to analyse its effect on predictions. For the building reference should be provided initial model settings according to optional of ECOTECT program.
- In the passive gains analysis, it was assumed that reference building initially using the natural ventilation setting to determine the expected thermal comfort levels without the use of a heating and or cooling system.
- In the evaluation of under mixed mode it was assumed that heating and cooling appliances would only be used from 5pm to 11pm Monday to Friday and from 8am to 11pm on weekends. It was assumed that a mixed mode system would be used with an efficiency of 95%.

•Passive gain analysis

For the passive gain analysis in this study, calculations has been carried from 1st January until 31st December. The passive gains breakdown graph shows gains and losses that occur via the various heat transfer mechanisms that occur within a zone. These mechanisms include conduction, sol-air, direct solar, ventilation, internal and inter-zonal gains and losses.

Assuming that the reference building was designed according to a passive house principles, for selected region zone calculated the passive gains breakdown analysis through each zone in the reference building and shown results. In the passive gains breakdown analysis, it is assumed that active systems were not operated. Natural ventilation has been taken into consideration.

The natural ventilation scenario assumes that the user will open and close windows and doors when the external temperature conditions are comfortable than internal condition, whilst the mixed mode setting combines the use of natural ventilation with mechanical heating and cooling devices. In other words, the model assumes that when internal conditions fall outside the specified thermal comfort range the occupants will firstly open the windows and doors if beneficial, or else use mechanical means. The model will only calculate the energy use for appliances between user specified on and off times. Passive analysis is consisted as following:

-Fabric: loses include all loses through the building envelope; walls, windows, roof, etc.

-Sol-Air: gains due to indirect solar exposure.

-Direct solar: heat gains occur through transparent surfaces such as windows and skylights.

-Ventilation: represents gains and losses that occur due to ventilation and infiltration (affected by wind data. Terrain type also affects the wind exposure).

-Internal: internal gains due to artificial lighting, occupancy by people and equipment.

-Interzonal: gains and losses that occur between adjacent zones (heat flow from one zone to another). This calculation only includes zones marked as thermal. Figure 4.6 shows passive gain analysis for the reference building in Şanlıurfa.

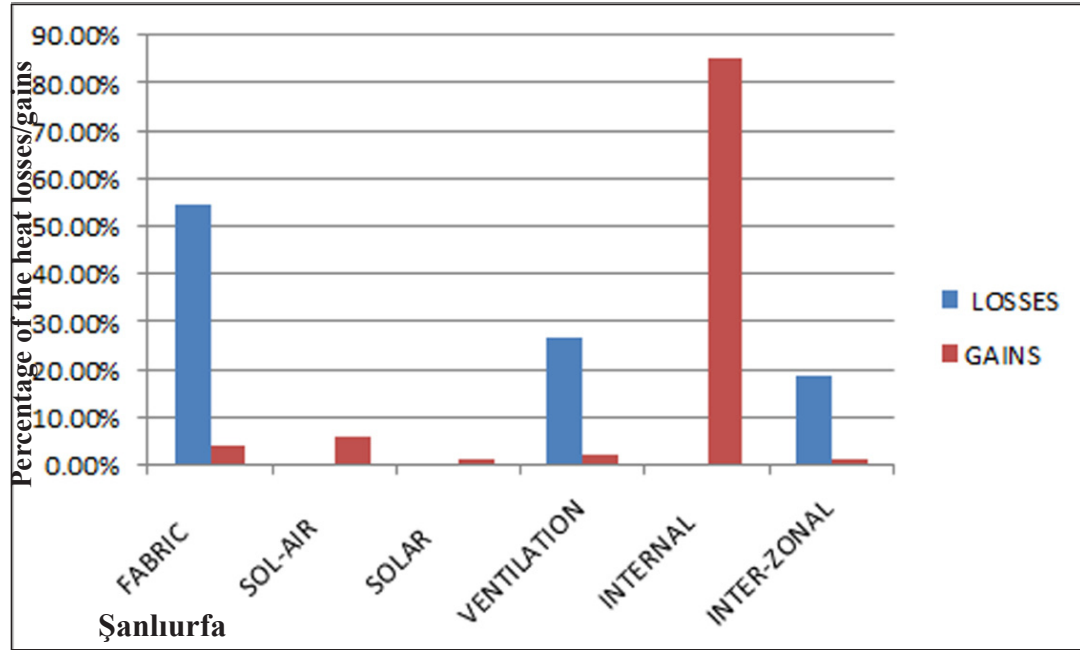


Figure 4.6:Passive gain analysis for the reference building in Şanlıurfa

•Diurnal variation of the indoor air temperature from the thermal comfort point of view

The variation of indoor air temperature is one of the most important factor for thermal comfort. On the other hand, as it is known in residential buildings the rooms of major activities or primary function are the living rooms. For this reason in this study indoor air temperature variation depending on the outdoor air temperature variation is given for the living room. Figure 4.7 gives the variation of indoor air temperature for the living room. Zone A gives the zone in which indoor air temperatures are between 20 °C and 26 °C.

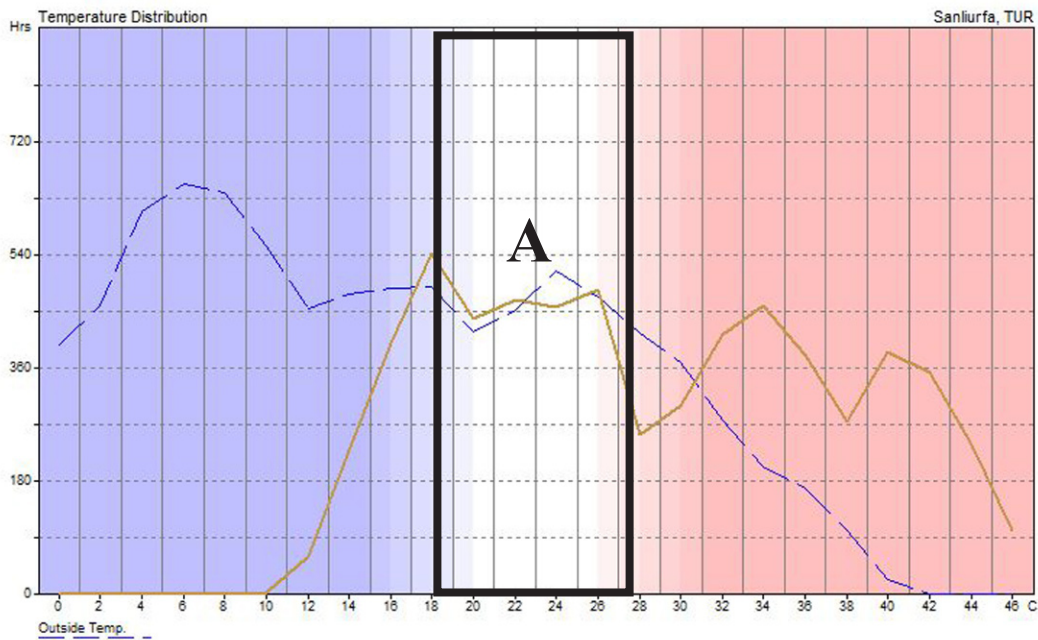


Figure 4.7: The temperature variation for living room for reference building

Figure 4.8 gives the total hours at each given temperature under natural ventilation conditions for the living room. In case comfort band is between 20 °C and 26 °C. Comfort conditions has been provided during 1847 hours in other words percentage of comfort hours is 29.6%.

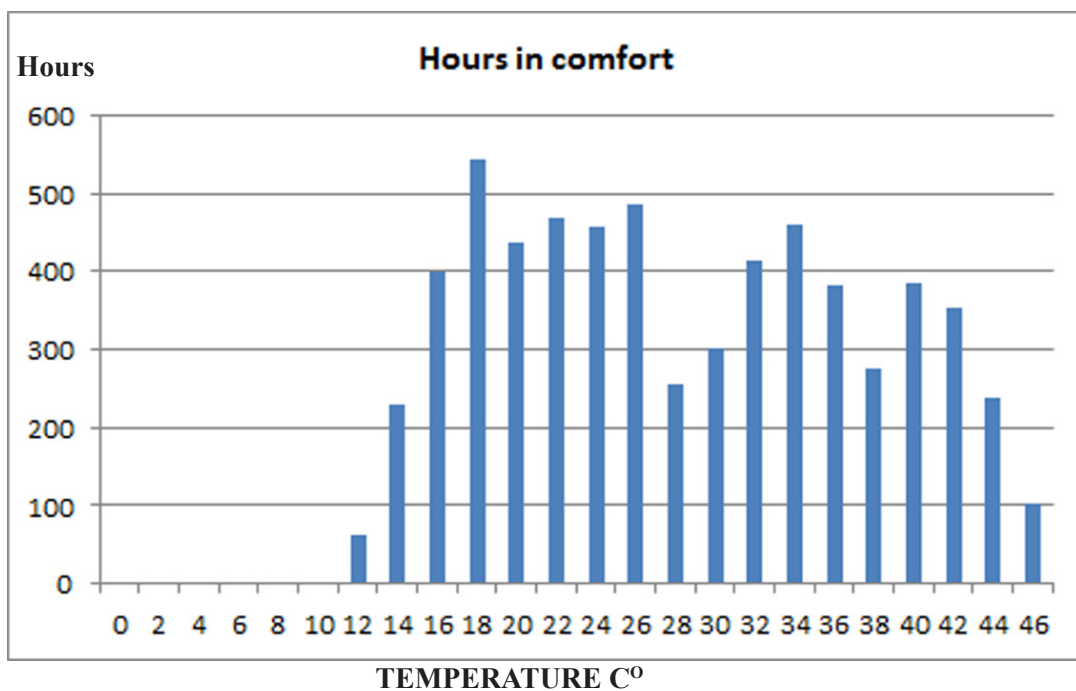


Figure 4.8:The total hours at each given temperature under natural ventilation in living zone

Thermal comfort parameters set points have significant impact on heating and cooling load, the average mean minimum and the average mean maximum inside air temperature obtained from the field monitoring were 20 -26 C°. This air temperature range was used as a set point temperature in the simulation software.

In study 21 July is selected as the design day of the cooling period and 21 January as the design day of the heating period. Figure 4.9 and 4.10 gives the variation of the hourly temperatures of the living room in the reference building with natural ventilation conditions for 21 July and 21 January respectively.

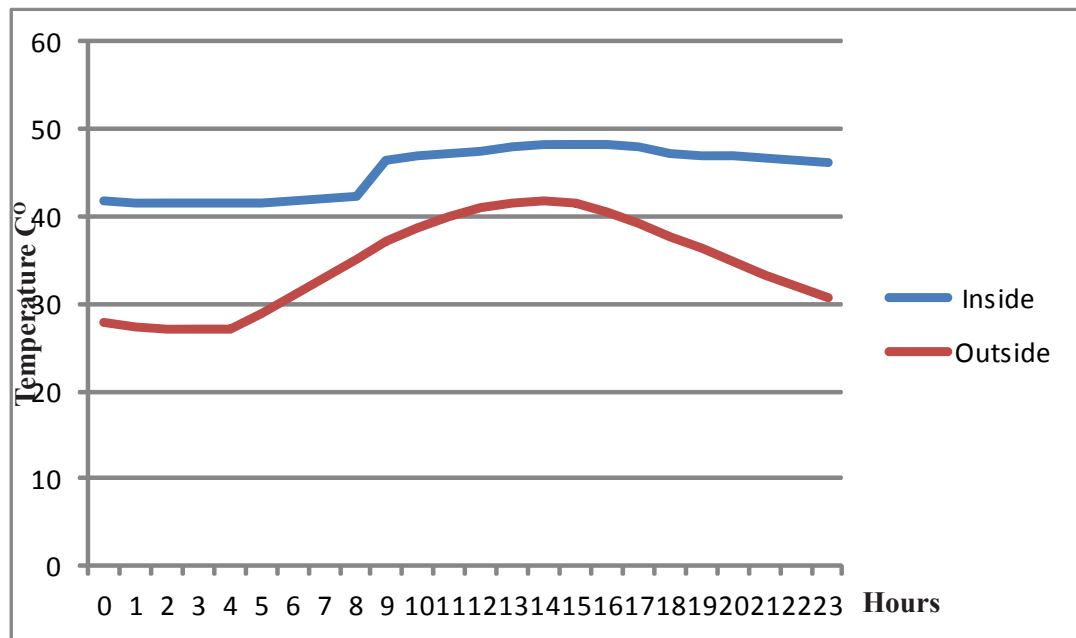


Figure 4.9: Hourly temperatures of the living room in 21 July in the reference building with natural ventilation conditions

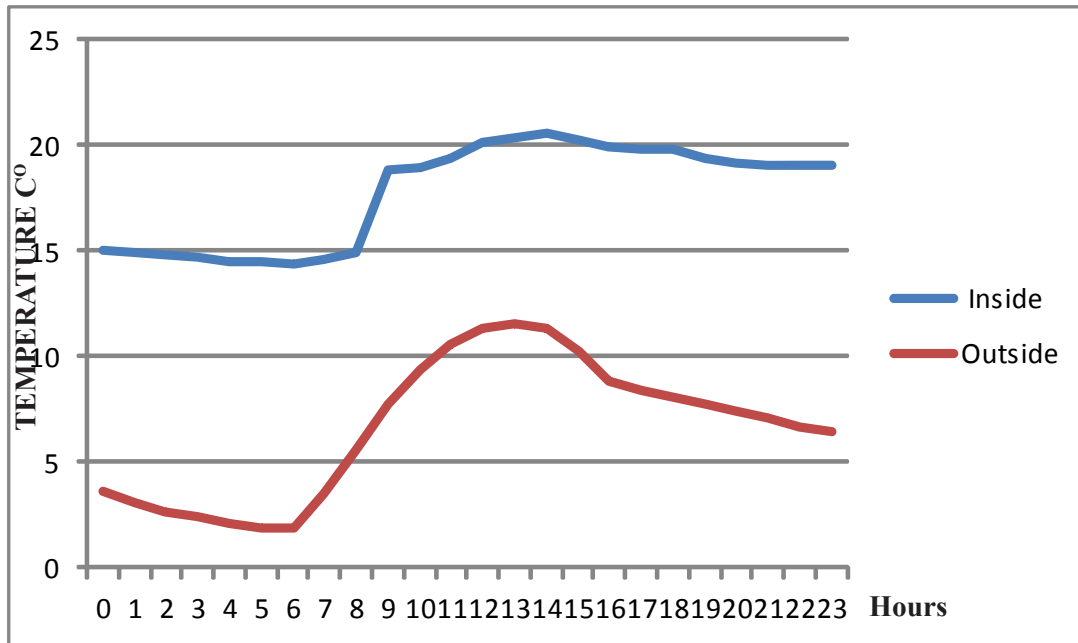


Figure 4.10: Hourly temperatures of the living room in 21 January in the reference building with natural ventilation performance

•Building performance under active mode

To monitor the air conditioning runtime of the reference building, mixed mode systems was installed in the air supply duct. Under the active mode, simulation for reference building was also executed for 12 months . Figure 4.11 gives monthly heating and cooling loads for living room in case of using mixed mode.

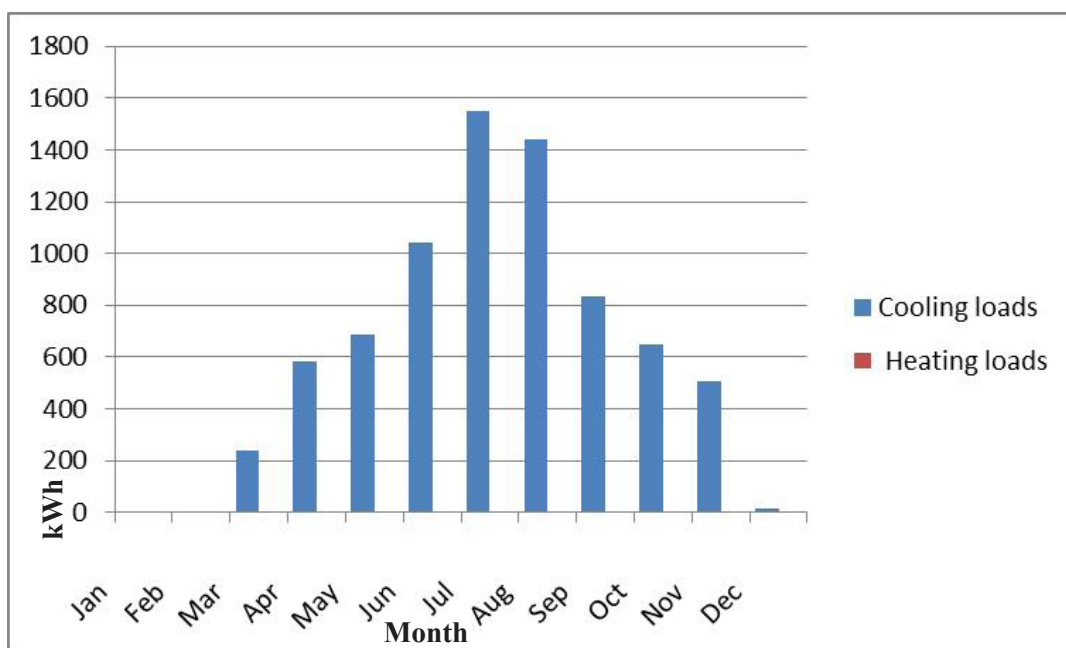


Figure 4.11: Monthly heating and cooling loads with a mixed mode system for the living room

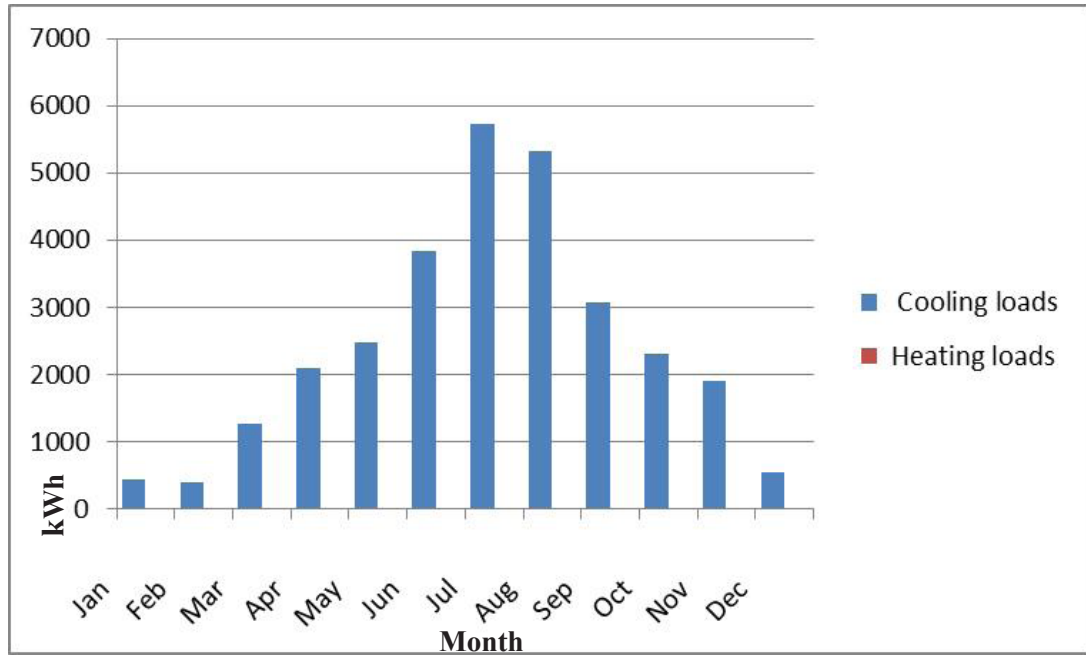


Figure 4.12: Monthly heating and cooling loads with a mixed mode system for the reference building

The reference building energy performance simulation showed that cooling load is higher than the heating load. Maximum heating load is 0.196 kWh at 06:00 on 15th January and maximum cooling load is 4.099 kWh at 12:00 on 29th July for living room. Maximum heating load 1.035 kWh at 06:00 on 15th January and maximum cooling load is 16.133 kWh at 12:00 on 29th July for the reference building.

4.2.5 Prediction of daylight factors (daylight analysis) for the reference building

Daylight analysis is based on analysis to work out the daylight factor or daylight illumination levels for the evaluation of the reference building at the platform of Ecotect, which is the main analysis tool.

For the calculation of daylight factor, Split Flux Method in Ecotect is used. The Split-Flux Method regards the scene as consisting of only two surfaces: the floor with the part of the vertical walls below the center of the window and the ceiling and the part of the vertical walls above the center of the window. It is then assumed that the light from the sky is distributed over the lower part, and the externally reflected light over the upper part.

In Split Flux Method in Ecotect, with UK Building Research Establishment (BRE) daylight factor consist of direct (sky) component (SC), externally reflected component (ERC) and internally reflected component (IRC).

An externally component is modified by luminance of the sky it would have hit, reflectance of the material assigned to the external object and relative surface angle and glazing transmittance.

An internally reflected component is modified by store internal surface reflectance of the object and altitude angle of the ray. BRE daylight factor method uses a relatively simple formula for the effect of internal reflections. To be fully compliant with this method, Ecotect cannot consider multiple reflections. Therefore, Ecotect under estimates indirect daylight solutions that rely on the reflection of light off multiple surfaces to illuminate a space. Limitations of the sky model (Ecotect does not use annual climate file data for daylighting).

The average daylight factor value of the reference building and the minimum value of daylight factor according to BS 8206 Part 2 depicted in Table 4.5.

Table 4.5: Value of daylight factor and standard value

Room type	The value average daylight factor of the reference building	Standard value of daylight factor of residential building	
Bedroom 1	1.48 %	Bedrooms	1 %
Bedroom 2	1.99 %		
Children Bedroom	2.42 %		
Living room	1.56 %	Living rooms	1.5 %
Kitchen	3.05 %	Kitchens	2 %

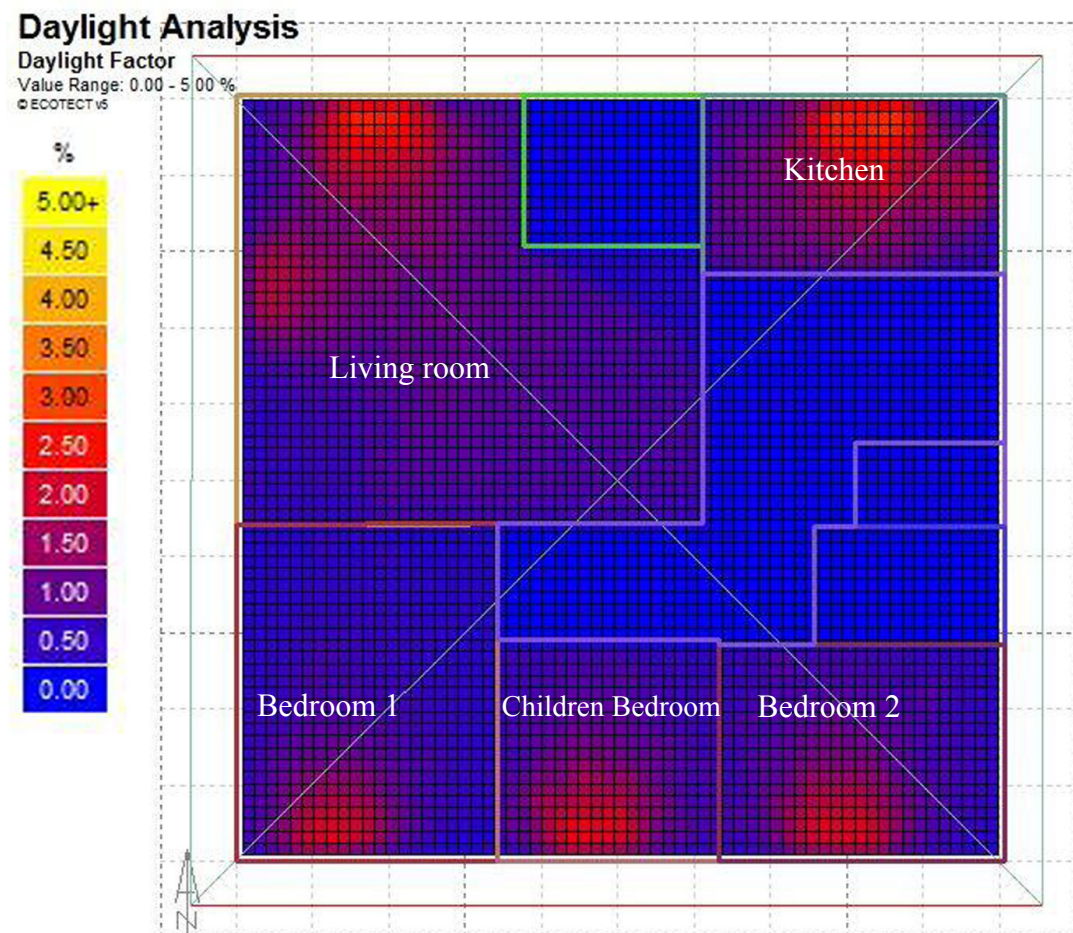


Figure 4.13: Daylight factor analysis in the reference building

•Comparison of the reference building results and the recommended values:

The ECOTECT simulations in Figure 4.13 shows the results from the reference building. According to lighting for buildings BS 8206; bedrooms, living room and kitchen of the reference building have the required value of daylight factor and the comparison is shown as follows:

Bedroom (1) 1.48 % > 1 %

Bedroom (2) 1.99 % > 1 %

Children Bedroom 2.42 % > 1 %

Living room 1.56 % > 1.5 %

Kitchen 3.05 % > 2 %

•Discussion

The most significant result that can be drawn from the data in Figure 4.13 the daylight inside the reference building has sufficient value in the bedrooms, living room, kitchen. It is concluded that by software simulation and results analysis, the design result is proved that the daylight factor values in the reference building higher are than the recommended values.

4.2.6 Evaluation of the acoustic performance of the reference building

The acoustic properties of building envelope predetermine the sound penetration through building constructions. The sound insulation performance of a wall or floor is a measure of its ability to reduce the amount of sound that is transmitted from one side to the other. The required sound insulation is determined by guidelines and design requirements or regulations. In this section the sound insulation performance of building envelope of the reference building is calculated in order to check if transmission loss of the façade is enough to provide required isolation.

- **Methodology objectives:**

For determining sound insulation performance in the reference building the living room envelope selected for this purpose. The main steps of the methodology are explained as follows:

- a) Gathering of external noise data (4.2.3)
- b) Calculation of required sound insulation (R_{req})
- c) Calculation of existing sound insulation of reference building (R_{field})
- d) Comparison of R_{req} and R_{field}

- **General description about project:**

Project is located outside of Şanlıurfa and predicted to be a small town. Figure 4.1 shows the layout of the proposed site plan of the reference building. The living room selected for this study has the following properties:

The room is 25, 74 m² and in 1 floor of the building (Figure 4.14). The height of the room is 2, 90 m and the volume is 74, 64 m³. All the walls are made of brick and window is ordinary glazing and the door is solid wood panel. The floor is vinyl on concrete and ceiling is poured concrete painted. The plan and section of selected room (living room) and components input data's are seen in Figure 4.14, 4.15 and Table 4.6.

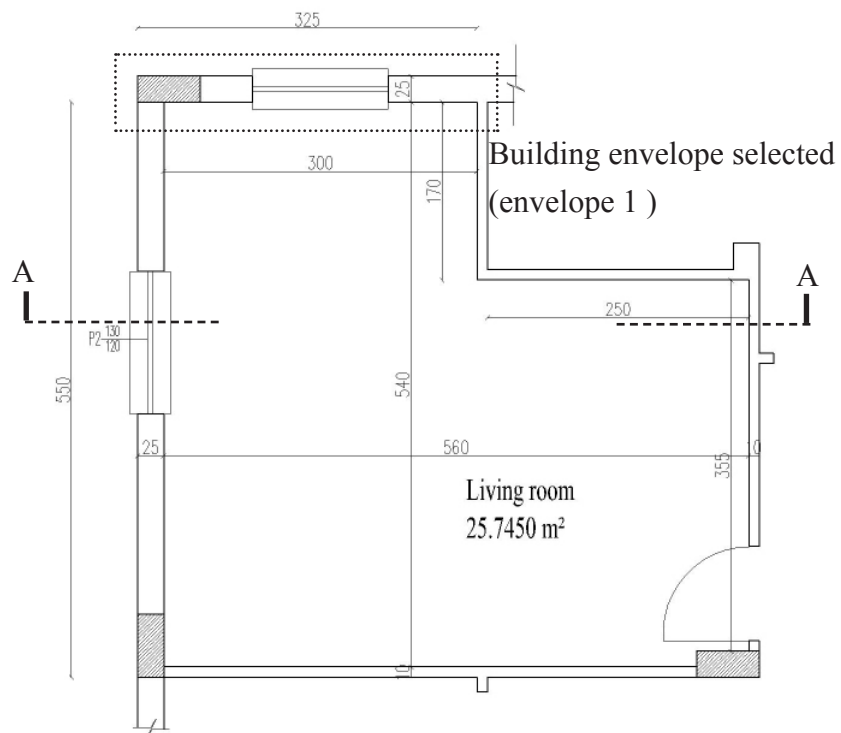


Figure 4.14: Plan of selected room for sound insulation project

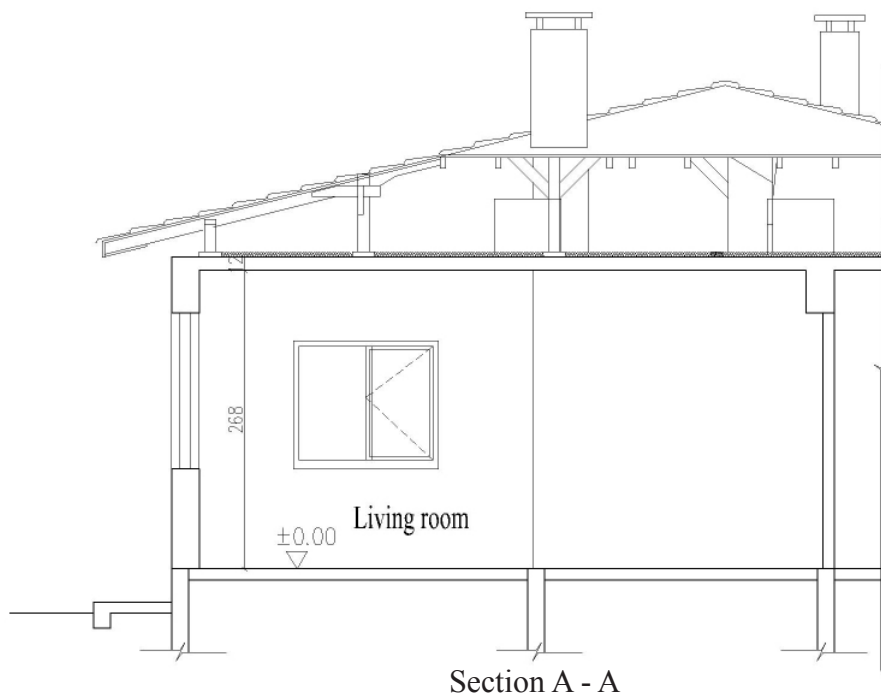


Figure 4.15: Section of selected room for sound insulation project

Table 4.6: Component data's of reference envelope [46]

Component	Wide (m)	Length (m)	Height (m)	Area (m ²)	Thickness (m)	C _L	η	M _s f _c
Wall (envelope1)	3,25	-	2,90	7,86	0,20	3800	0,015	31250
Wall (envelope2)	5,50	-	2,90	14,39	0,20	3800	0,015	31250
Wall (interior)	5,60	-	2,90	16,24	0,10	3800	0,015	31250
Wall (interior)	1,70	-	2,90	4,93	0,10	3800	0,015	31250
Wall (interior)	2,50	-	2,90	7,25	0,10	3800	0,015	31250
Wall (interior)	3,55	-	2,90	8,40	0,10	3800	0,015	31250
Floor	3,00	5,40	-	16,20	0,15	-	-	-
Ceiling	3,00	5,40	-	16,20	0,15	-	-	-
Window	1,30	-	1,20	1,56	0,07	-	-	-
Door	0,90	-	2,10	1,89	0,10	-	-	-

b) Calculation of required sound insulation (R_{req})

For determination of sound insulation, first step is to calculate the existing sound reduction index of the wall (envelope 1).

Transmission loss or Sound Reduction Index, R (dB), is a measure of the effectiveness of a wall, floor, door or other barrier in restricting the passage of sound. The sound reduction index is usually determined in octave or third-octave frequency bands, in the range of 100 - 3150 Hz.

The required sound reduction index is found from the equations (4.1), (4.2), given below:

$$R_{req} = L_1 - L_2 + 10 \log_{10} \left(\frac{S}{A} \right) \quad (4.1)$$

L₁: Average sound pressure level in the source room

L₂: Average sound pressure level in the receiving room

S: Façade wall area (m²)

A: Equivalent sound absorption area in the receiving room (m²)

$$A = \sum S \alpha \quad (4.2)$$

α: absorption coefficient

For calculating the equivalent sound absorption area, the absorption coefficient of each material must be known. Table 4.7 gives the absorption coefficient of the materials used in the room.

Table 4.7: Absorption coefficient of materials [46]

Component	Material	Frequency(Hz)					
		125	250	500	1000	2000	4000
Wall	Brick unglazed & painted	0.01	0.01	0.02	0.02	0.02	0.03
Floor	Ceramic tiles	0.01	0.01	0.01	0.02	0.02	0.02
Ceiling	Poured concrete painted	0.01	0.01	0.01	0.02	0.02	0.02
Window	Ordinary glazing	0.35	0.25	0.18	0.12	0.07	0.04
Door	Solid wood panel	0.1	0.07	0.05	0.04	0.04	0.04

One procedure for noise control is to provide an acoustic barrier or wall to reduce the transmission of sound. For design purposes, one must be able to predict the transmission loss for the wall over a wide range of frequencies [47].

The general variation of the transmission loss with frequency for a homogeneous wall is shown in Figure 4.16 . There are three general regions of behavior for the wall or panel.

- (a) Region I: stiffness-controlled region
- (b) Region II: mass-controlled region
- (c) Region III: wave-coincidence region (damping-controlled region)

sampling techniques and formulas for prediction of the transmission loss for each of these regions are given in Figure 4.17.

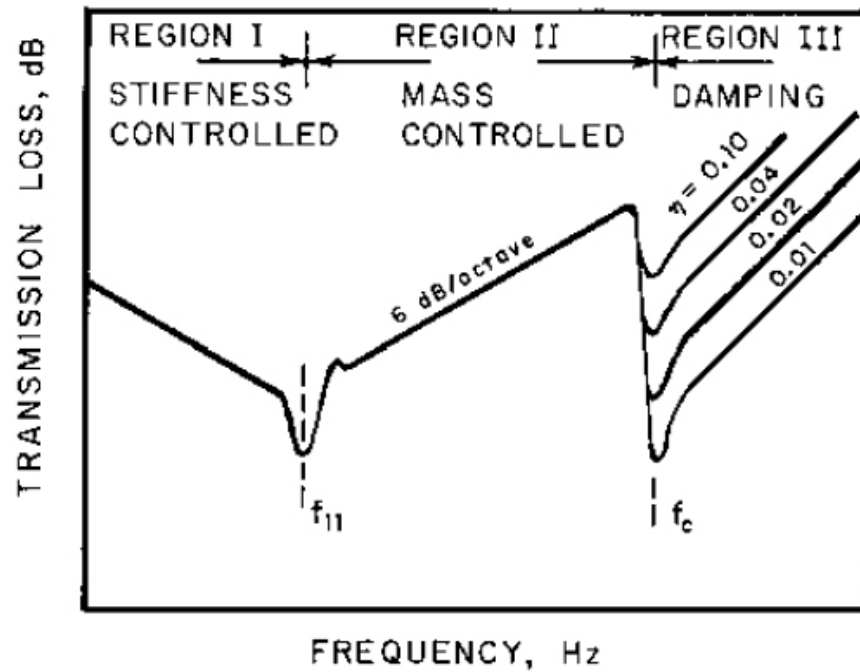


Figure 4.16: General variation of the transmission loss with frequency for a homogeneous wall or panel [47]

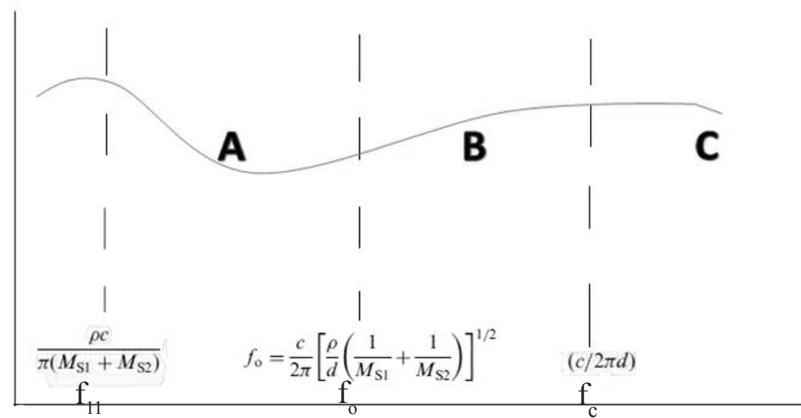


Figure 4.17: sampling techniques and formulas for general regions frequency

A = If $f_{11} < f < f_0$ f_{11} : resonant frequency

B = If $f_0 < f < f_c$ f_c : the critical frequency

C = If $f < f_c$

To calculate sound reduction index, region of wall should be known. the values of the resonant frequency (f_{11}) and the critical frequency (f_c) should be indicated. For application of technique to the calculation of sound insulation in some frequency ranges used Figure 4.17 formula to calculate sound insulation. This figure consisting of three regions of each section and calculated with the designated formulas. Standard methods for calculation sound reduction index are determined from one-third octave band range 125 Hz to 4000 Hz. In the following equation calculated sound reduction index from 125 Hz to 4000 Hz.

125 Hz:

$$A = \sum S \alpha = S_{\text{wall}} \alpha_{\text{wall}} + S_{\text{floor}} \alpha_{\text{floor}} + S_{\text{ceiling}} \alpha_{\text{ceiling}} + S_{\text{window}} \alpha_{\text{window}} + S_{\text{door}} \alpha_{\text{ceiling}} =$$

$$A = 7,14 \times 0,01 + 14,39 \times 0,01 + 16,24 \times 0,01 + 4,93 \times 0,01 + 7,25 \times 0,01 + 16,20 \times 0,01 + 16,20 \times 0,01 + 1,56 \times 0,35 + 1,89 \times 0,1 =$$

$$A = \sum S \alpha = 1,6388$$

$$R_{\text{req}} = L_1 - L_2 + 10 \log_{10} \left(\frac{S}{A} \right) = 73 - 48 + 10 \log_{10} \left(\frac{7.86}{1.63} \right) = 25 + 6.80 = 31.80 \text{ dB}$$

$$R_{\text{req}} = \mathbf{31.80 \text{ dB}}$$

c) Calculation of existing sound insulation of reference building (R_{field}):

$$R_{\text{field}} = 10 \log_{10} (1 / \tau_{\text{avg}}) \quad (4.3)$$

$$\tau_{\text{avg}} = \frac{\tau_{\text{avg}} \cdot S_{\text{wall}} + \tau_{\text{window}} \cdot S_{\text{window}}}{\sum S} \quad (4.4)$$

$$TL_{\text{wall}} = R_{\text{wall}} = -10 \log_{10} (\tau_{\text{wall}}) \quad (4.5)$$

In this section the resonance and the critical frequencies need to known. The resonance (f_{11}) and critical frequencies (f_c) are as follows:

$$f_{11} = (\pi/4\sqrt{3}) c_L h(1/a^2 + 1/b^2) = (\pi/4\sqrt{3}) 3800 \cdot 0,20(1/2,70^2 + 1/2,90^2) = \quad (4.6)$$

$$f_c = (\sqrt{3} c^2) / (\pi c_L h) = f_c = \frac{(\sqrt{3} \cdot 346^2)}{\pi \cdot 3800 \cdot 0,20} = 86.846 \text{ dB}$$

$$f_{11} > f_c$$

So, that all the frequencies are in the region III (C region). This region is damping-controlled region. The sound reduction index of this region is follows:

$$TL_{wall}=R_{wall}=TL_n(f_c)+10 \log(\eta)+33,22 \log(f/f_c)-5,7=$$

$$TL_n(f_c)=10 \log [1+((\pi M_s f_c)/(\rho_1 c_1))^2]=10 \log[1+(\pi \cdot 31250/413,3)^2]=$$

$$TL_n(f_c)=47.51477$$

$$TL_{wall}=R_{wall}=TL_n(f_c)+10 \log(\eta)+33,22 \log(125/86)-5,7=$$

$$R_{wall}=29 \text{ dB}$$

$$TL_{wall}=R_{wall}=-10\log_{10}(\tau_{wall}) \quad \tau_{wall}=0.0001269$$

The sound reduction index of window should be taken from the literature. Sound reduction index of window is given in Table 4.9.

Table 4.8: Sound reduction of the reference building `s window [45]

	Frequencies					
	125	250	500	1000	2000	4000
R_{Window}	25	31	41	45	49	39

$$TL_{window}=R_{window}=-10\log_{10}(\tau_{window})$$

$$TL_{window}=25=-10\log_{10}(\tau_{window}) \rightarrow \tau_{window}=0.003162278$$

$$\tau_{avg} = \frac{\tau_{avg} \cdot S_{wall} + \tau_{window} \cdot S_{window}}{\sum S} \rightarrow \tau_{avg} = \frac{0,001269 \times 7,86 + 0,003162 \times 1,56}{9.42} =$$

$$\tau_{avg} = 0,001667308$$

$$R_{field} = 10 \log_{10}(1/\tau_{avg}) =$$

$$R_{field}=28.0295 \text{ dB}$$

d) Comparison of R_{req} and R_{field}

The required sound reduction index is 30 dB and the field (existing) sound reduction index is 28 dB for frequency 125 Hz. As can be seen from Figure 4.18, the field reduction index of wall at 125, 250, 500 and 4000 Hz are lower than required (R_{req}) values. Therefore, it is necessary to increase the insulation performance of wall.

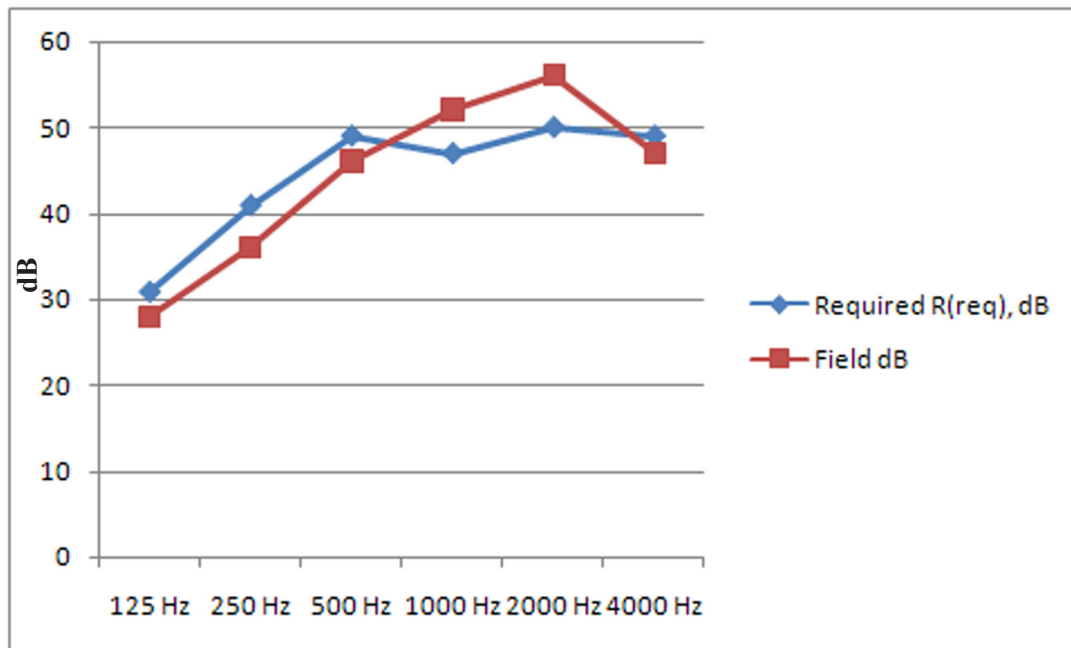


Figure 4.18: Required and field values of the selected envelope

-In order to determine the optimum values between 125-4000 Hz frequencies , only 1000, 2000 Hz Frequencies are sufficient to meet required the values for sound insulation in the reference building.

As a first step, it is recommended to replace the transparent existing windows with double glazed windows.

For that purpose to use insulating glass for windows instead of using ordinary solid (or monolithic) window glass has been selected. For this project, Pilkington Laminated Safety Glass which has double glazed windows has been selected (10/200/60). Table 4.9 shows technical details about the recommended glass.

Table 4.9: Recommended double windows [48]

Third octave band Centre Frequency (Hz)	Sound Insulation (dB) for Glass Thickness (mm)					
	6/100/4		6/150/4		10/200/6	
100	25		27		32	
125	27	26	30	29	37	35
160	27		30		39	
200	33		34		45	
250	33	34	34	35	46	46
315	37		39		46	
400	41		42		47	
500	46	44	46	45	45	46
630	50		50		45	
800	54		54		44	
1000	57	56	57	56	45	46
1250	59		58		50	
1600	58		58		53	
2000	52	53	52	52	58	56
2500	51		49		58	
3150	48		47		64	
4000	57	52	52	50	64	65
R_m (dB)	44		44		47	
R_w (dB)	46		47		49	
R_{TRA} (dBA)	37		39		45	

•**New calculations with the new glass:**

As a result, for sound evaluation in this section, the required sound reduction and the field sound reduction compared with the new window, required values are provided.

Figure 4.19 shows the improved sound reduction values of new envelope.

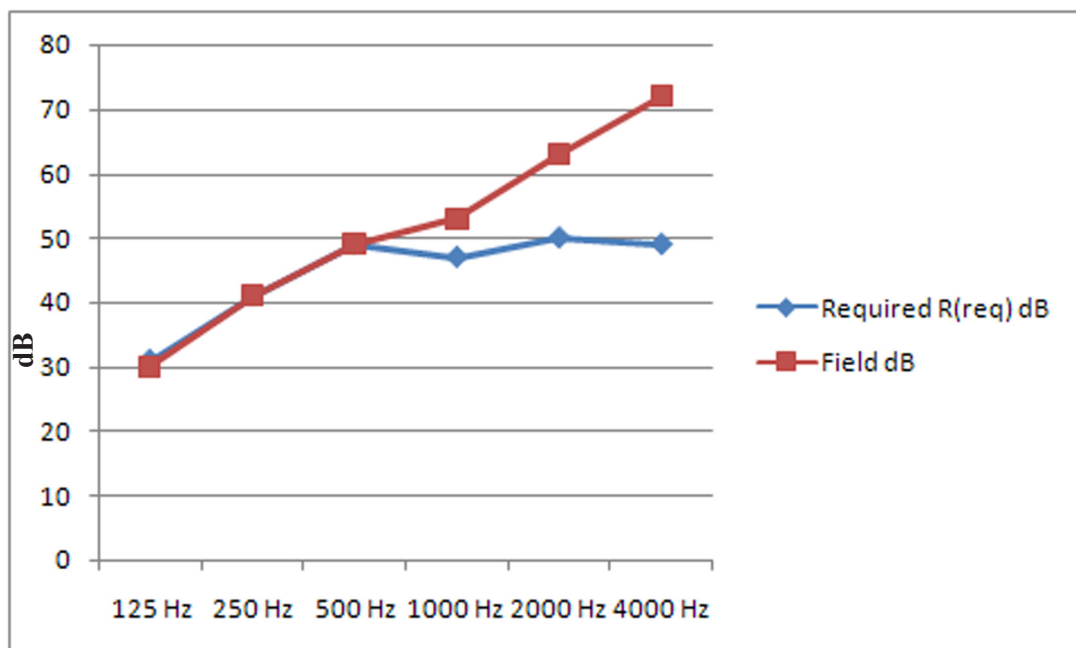


Figure 4.19: Requirement and field dB for the building envelope

4.2.7 Development of the building envelope alternatives

In this step, new building envelope alternatives have been developed. Developing alternatives for the building envelope to assess energy efficiency include scenarios can improve energy efficiency. In each scenario one parameter was changed whilst holding others constant and the thermal performance of the reference building under the mixed mode settings was investigated. The modelling scenarios used to quantify their savings has been explained in Table 4.10.

Table 4.10: Scenarios developed for the reference building

Scenario 1 (SC1)	The changing transparent component which is appropriate from sound control insulation point of view
Scenario 2 (SC2)	Recommending new component alternative
Scenario 3 (SC3)	Adding shading device on south and west façades
Scenario 4 (SC4)	Final combinations (By applying of the previous alternatives (Sc1+ Sc2+ Sc3))

4.2.8 Calculation of the energy loads and comparison of the results

For each scenario, energy simulations have been executed to calculate energy loads. The simulation results have been explained for each scenario.

1) Scenario 1:

The new transparent component alternative in Scenario 1 has been improved by changing the existing window in order to achieve required sound insulation. The new window type is double glazed with PVC frame and recommended technical data for window. Overall heat transfer coefficient of the transparent component (U_w) is 2,410 W/m²K.

For each scenario calculated monthly heating and cooling loads with a mixed mode ventilation system of the living room and the whole building are explained by graphics.

For scenario 1 (SC1) monthly heating and cooling loads with a mixed mode system of the living room and the whole building are given in the Figure 4.20 and 4.21 respectively.

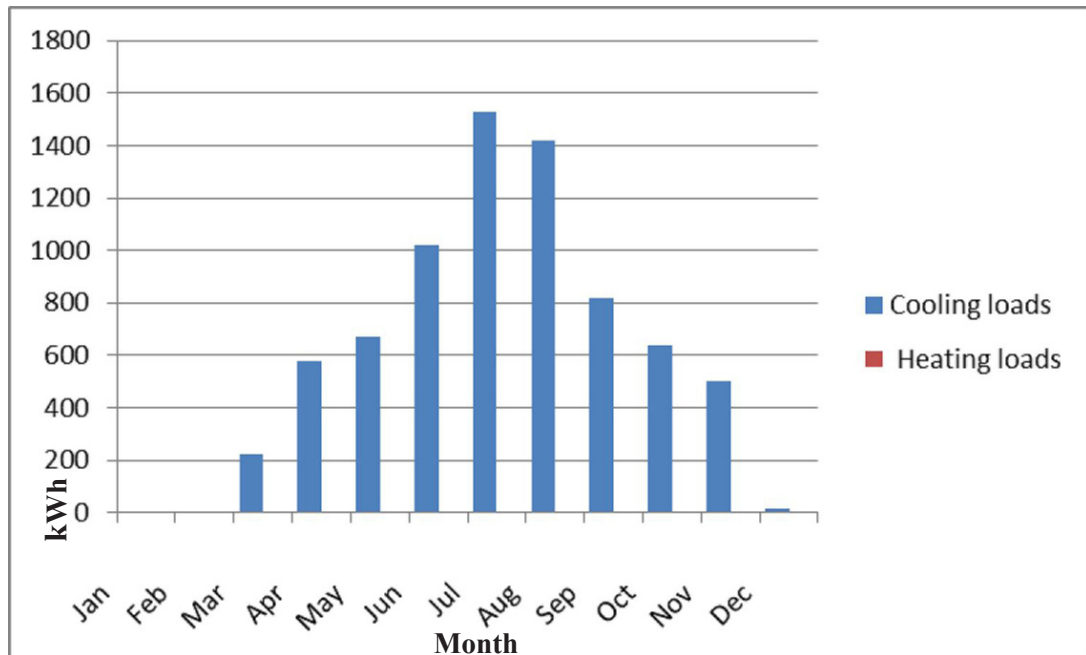


Figure 4.20: Monthly monthly heating and cooling loads with a mixed mode system of the living room for SC1

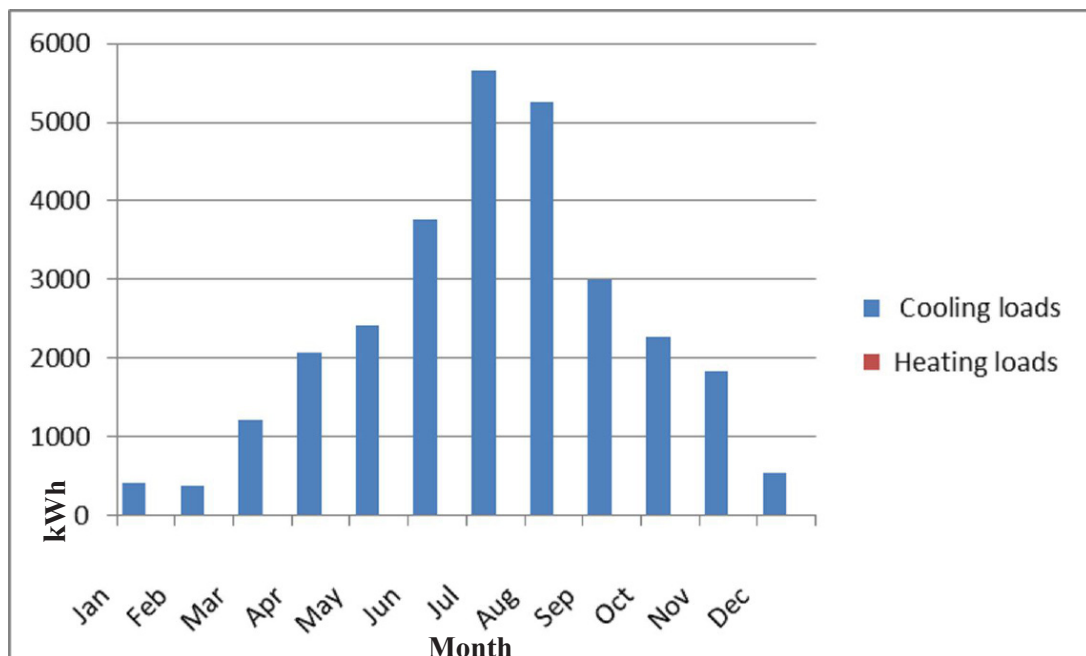


Figure 4.22: Monthly monthly heating and cooling loads with a mixed mode system of the whole building for SC1

2) Scenario2:

The opaque component alternative in SC2 have been derived for Şanlıurfa based on the limit U values which have been given in Turkish Standard TS 825 Rules of Heat Insulation in Building for these region. In TS 825 Turkey has divided into four different climatic regions. Şanlıurfa is located in 2 th region and upper limit U values of wall, floor, roof (U_{wall} , U_{floor} , U_{roof}) which have been recommended in TS 825 shown in Table 4.11 and Table 4.12 shows the limit U values of wall, floor, roof (U_{wall} , U_{floor} , U_{roof} W/m²K) which have been developed in SC2.

Table 4.11 : U values of the reference building component and recommended U-value

Component	Exisiting U-value(W/m ² K)	Recommended U-value (according to TS 825)
Wall	0.930 (W/m ² K)	0.60 (W/m ² K)
Floor	0.89 (W/m ² K)	0.60 (W/m ² K)
Roof	0.44 (W/m ² K)	0.4 (W/m ² K)

Table 4.12: U values for developed SC2

Component	developed U value
Wall	0.59 (W/m ² K)
Floor	0.50 (W/m ² K)
Roof	0.34 (W/m ² K)

For developing scenario 2 straw insulation has been added to exterior walls, roofs. The primary benefit of straw insulation over more common methods is the low embodied energy of the material. It is sourced from an agricultural waste product and thus is often not harvested directly for any other purpose and straw is a rapidly renewable resource which, can be useful to access to sustainable design. Straw bale material also benefits human health. Unlike many modern building products there are no manufactured chemicals in straw bale walls. Various chemicals from building products have been related to human ailments and Sick Building Syndrome.

Another great benefit of straw material is its insulating value. The benefit of higher insulating values is reduced heating and cooling loads on the building that will result in lower energy consumption for space conditioning and smaller heating and cooling equipment.

Thermal properties of straw materials has been measured in Österreichischen Strohballen-Netzwerk (2000) Danish institute (TeknologiskInstitut) [49].

Recommended detail for the reference building is shown in Figure 4.22.



Figure 4.22: Example of recommended detail for the reference building plaster with straw behind [50]

Monthly heating and cooling loads with a mixed mode system of the living room and the whole building are given in the Figure 4.26 and 4.27 respectively.

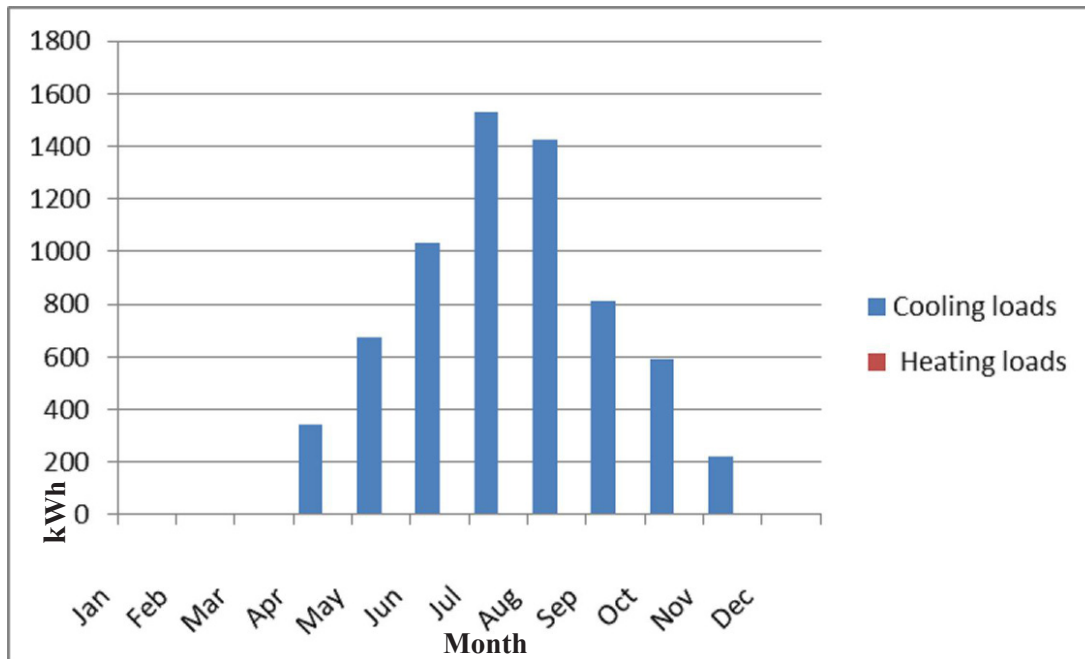


Figure 4.23: Monthly heating and cooling loads with a mixed mode system of the living room for SC2

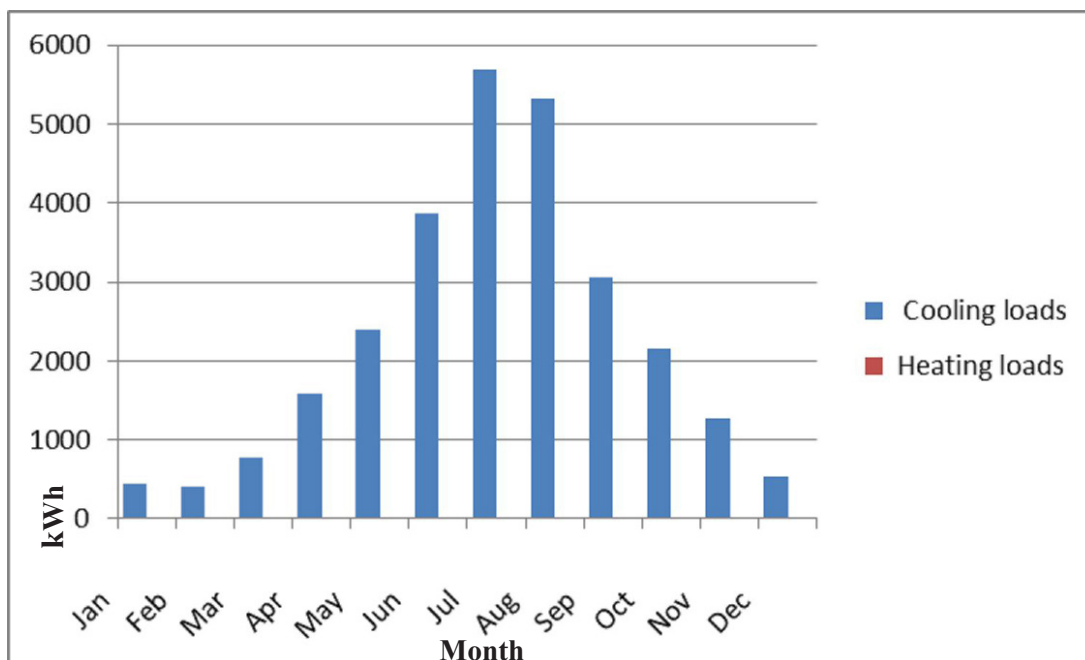


Figure 4.24: Monthly heating and cooling loads with a mixed mode system of the whole building for SC2

3)Scenario 3:

In order to reduce cooling loads shading devices have been added on the south and west façades. By adding these shading devices (For scenario 3/ SC3). Monthly heating and cooling loads with a mixed mode system of the living room and the whole building are given in the Figure 4.25 and 4.26 respectively.

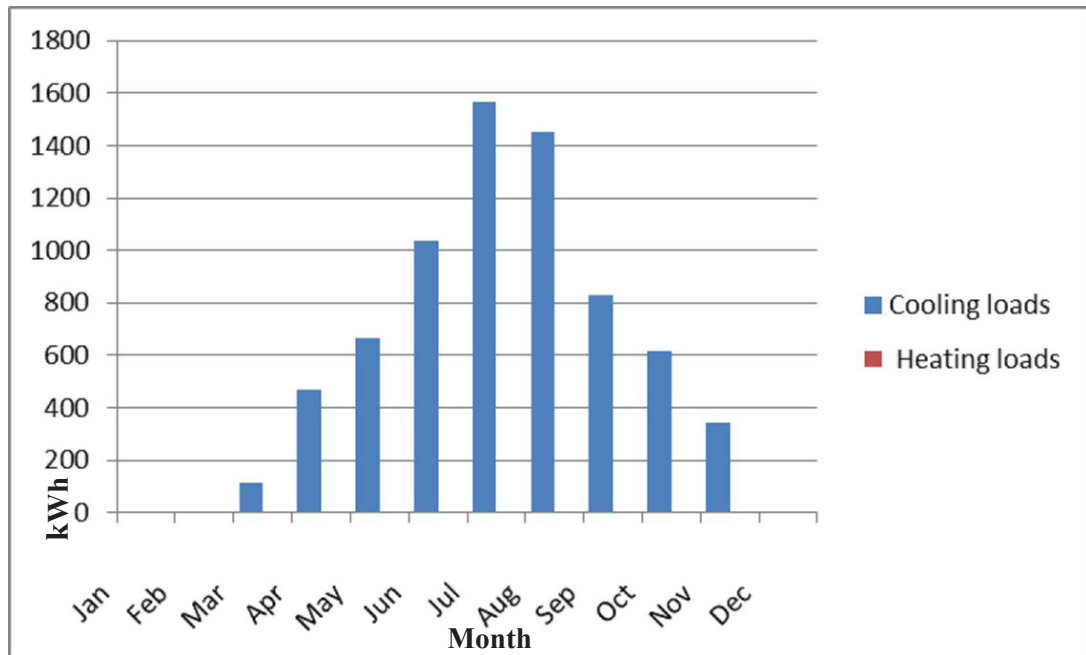


Figure 4.25: Monthly heating and cooling loads with a mixed mode system of the living room for SC3

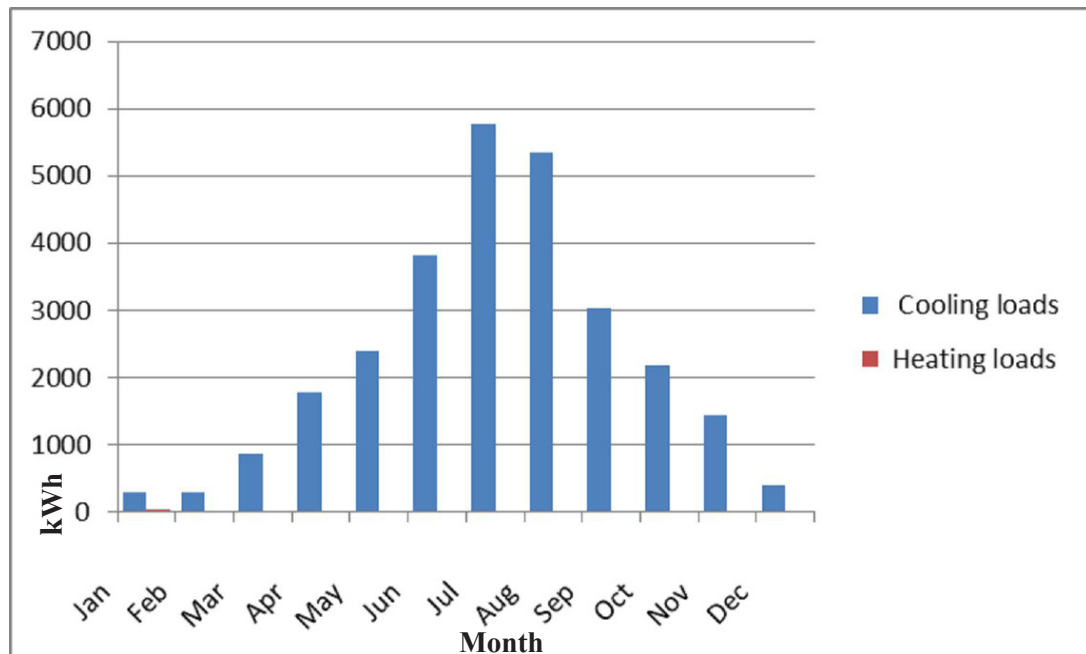


Figure 4.26: Monthly heating and cooling loads with a mixed mode system of the whole building for SC3

4)Scenario 4 :The fourth scenario (SC4) is a proposal of combination of the previous scenarios alternatives (SC1+ SC2+ SC3). Monthly heating and cooling loads with a mixed mode system of the living room and the whole building are given in the Figure 4.27and 4.28 respectively.

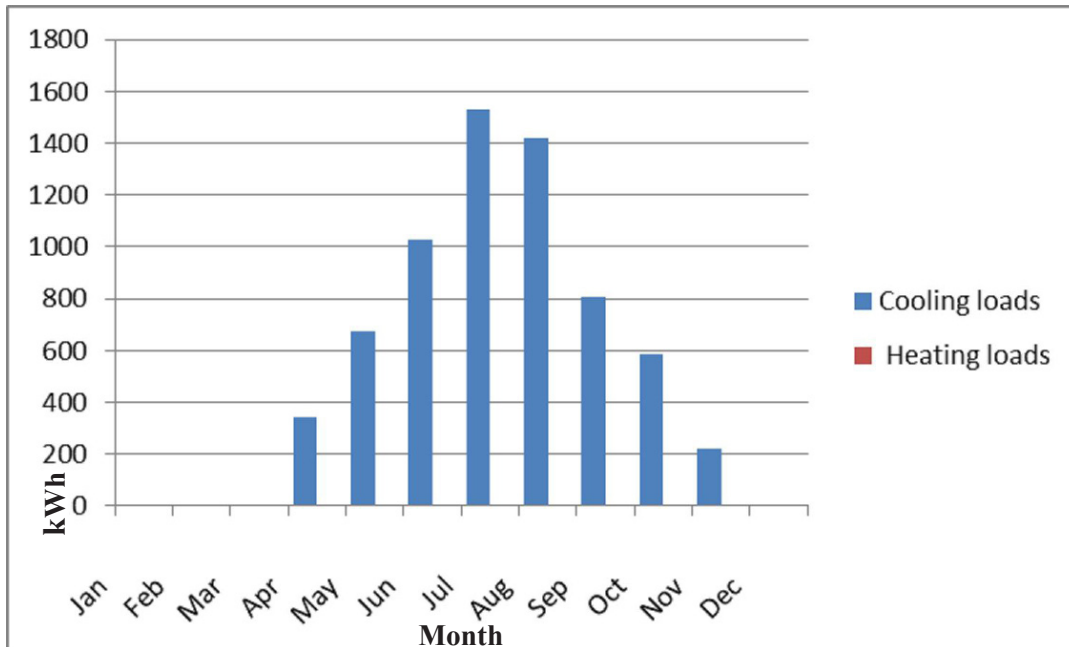


Figure 4.27: Monthly heating and cooling loads with a mixed mode system of the living room for SC4

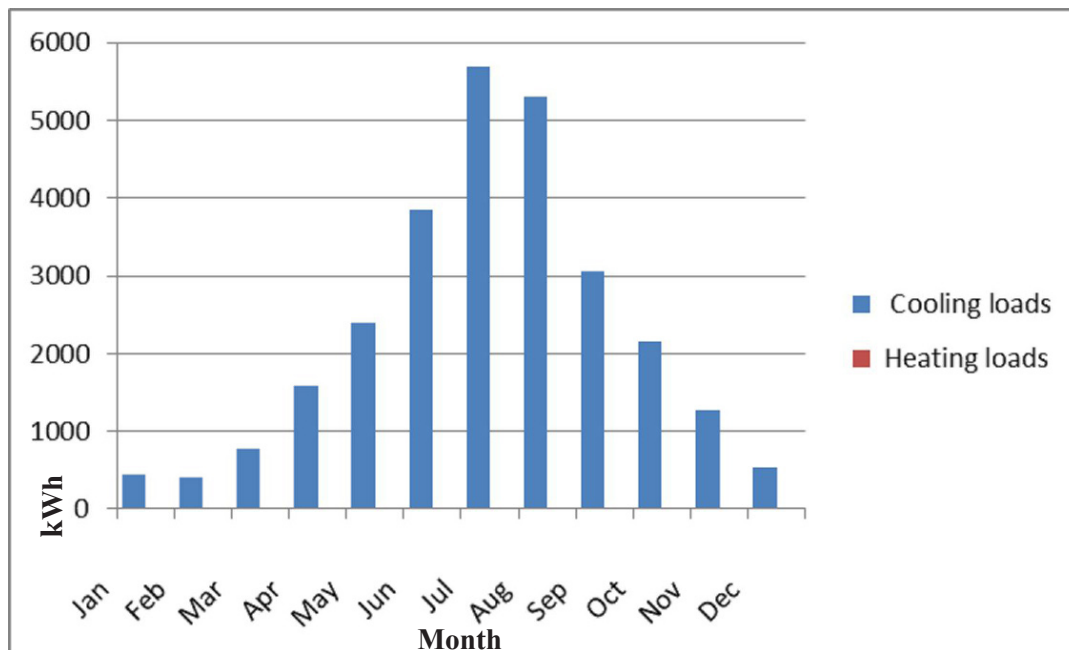


Figure 4.28: Monthly heating and cooling loads with a mixed mode system of the whole building for SC4

Comparison of the heating and cooling loads

In this step first calculated heating and cooling loads for developed scenarios have been compared with the heating and cooling loads of the reference building.

In the previous step, for each scenario monthly heating and cooling loads with a mixed mode system of the living room and the whole building are explained by graphics.

In this step in order to compare the calculated results depending on the reference (existing) building annual heating, cooling and total (heating+cooling) loads have been calculated for the living room and whole building for the reference building and each scenario and evaluated by means of graphics.

The comparison graphics are given in the following graphics:

- For the scenario 1, the Figures 4.29 and 4.30.
- For the scenario 2, the Figures 4.31 and 4.32.
- For the scenario 3, the Figures 4.33 and 4.34.
- For the scenario 4, the Figures 4.35 and 4.36.

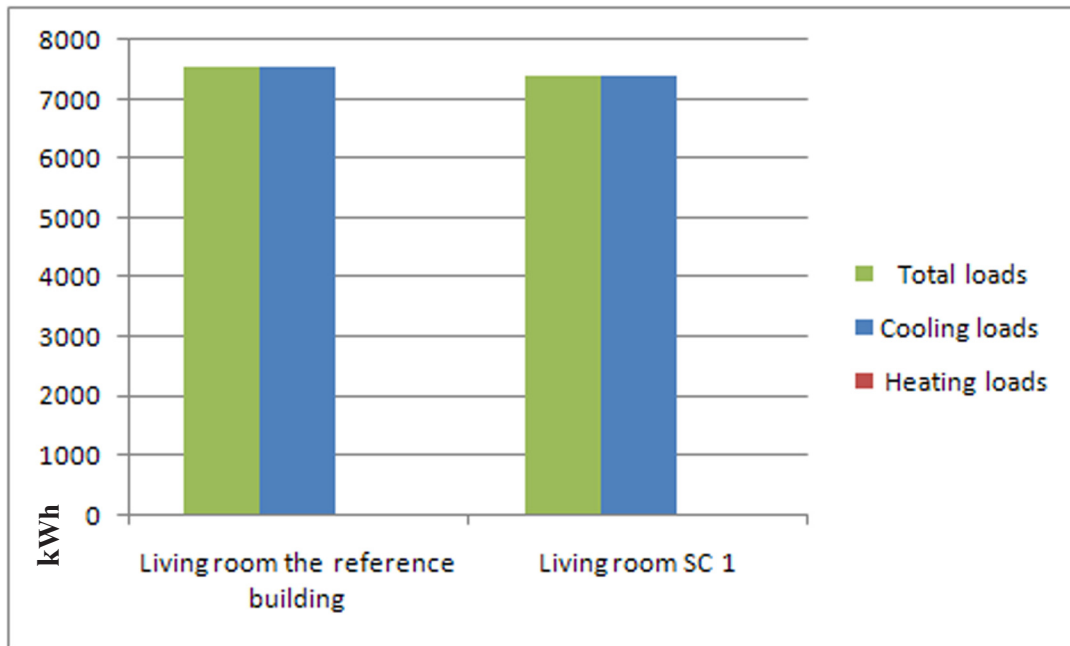


Figure 4.29: Comparison of the annual cooling, heating and total loads of the living room for the reference building and SC1

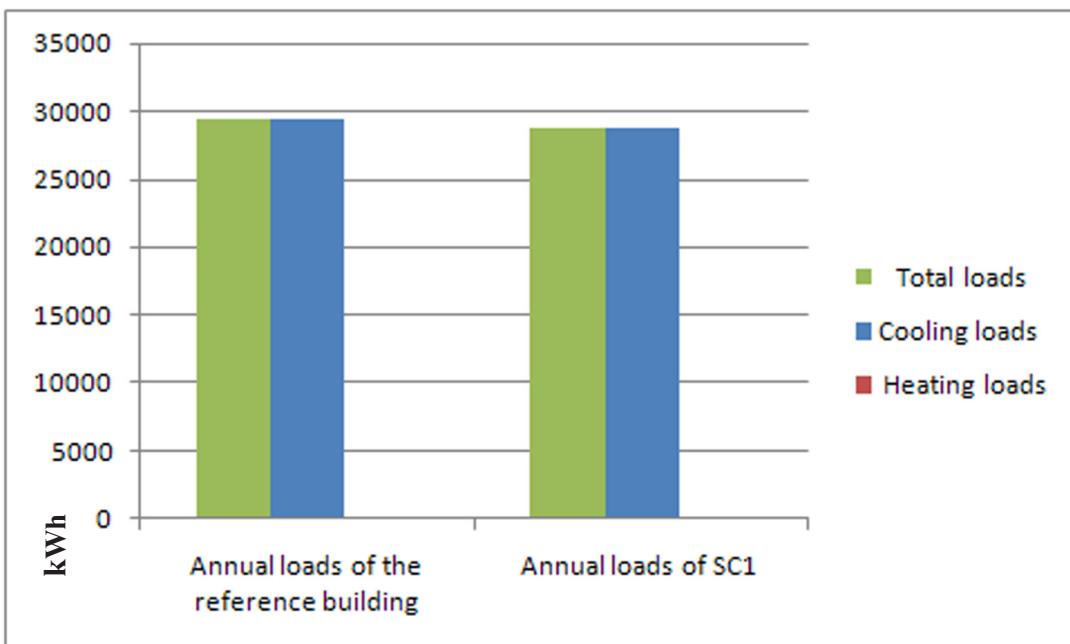


Figure 4.30: Comparison of the annual cooling, heating and total loads of the whole building for the reference building and SC1

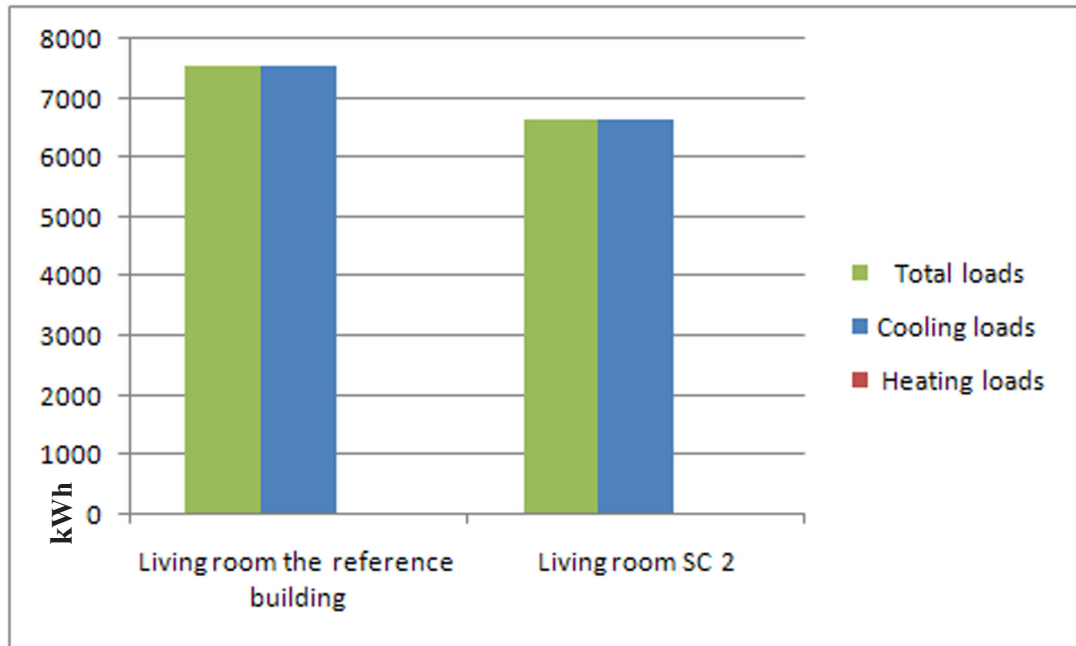


Figure 4.31: Comparison of the annual cooling, heating and total loads of the living room for the reference building and SC2

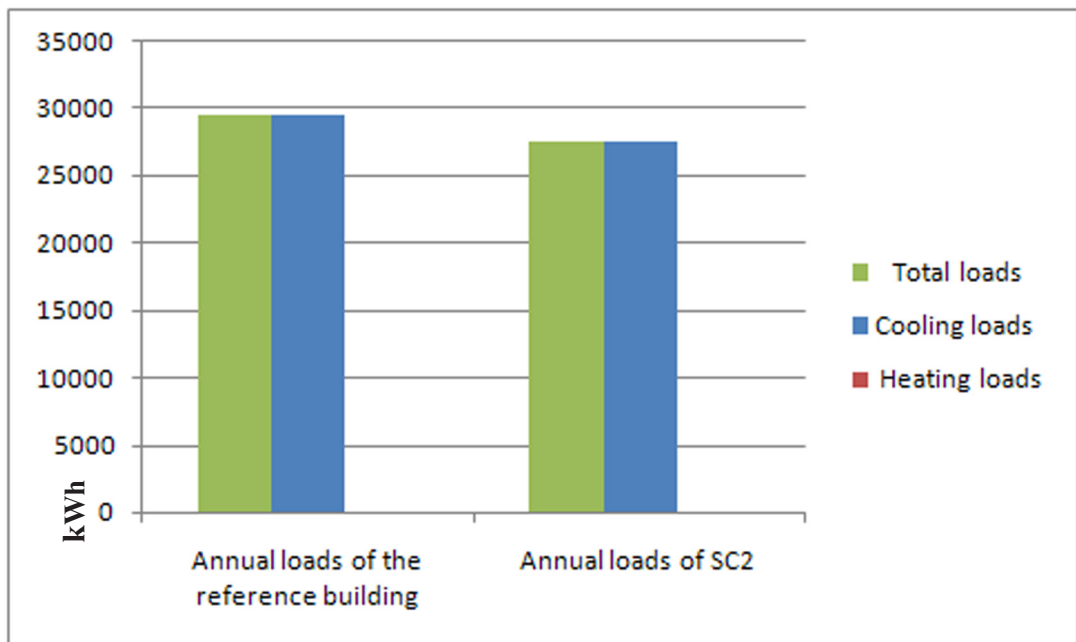


Figure 4.32: Comparison of the annual cooling, heating and total loads of the whole building for the reference building and SC2

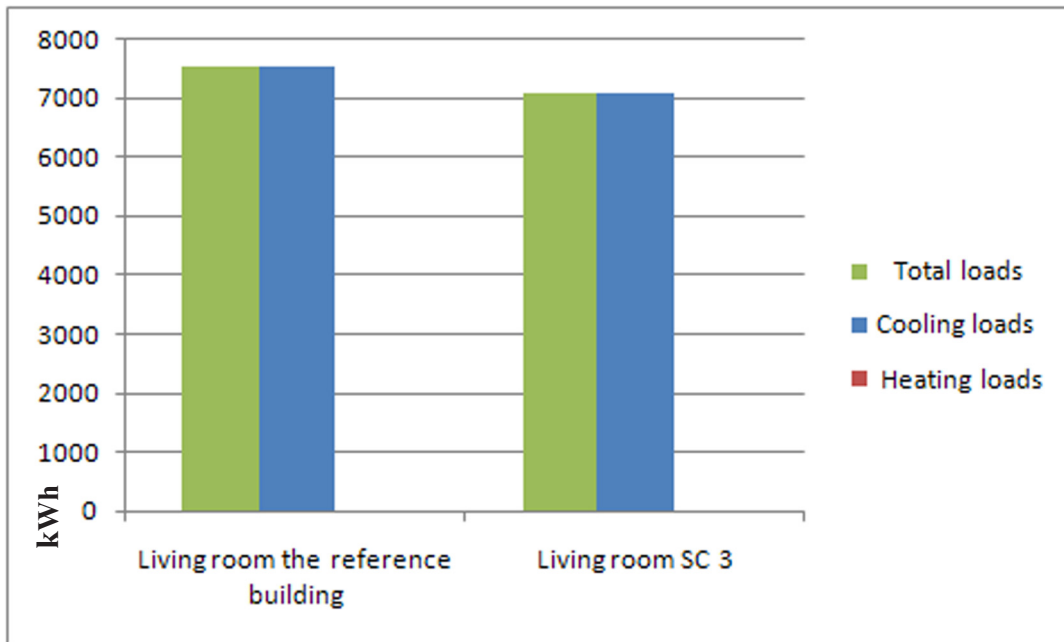


Figure 4.33: Comparison of the annual cooling, heating and total loads of the living room for the reference building and SC3

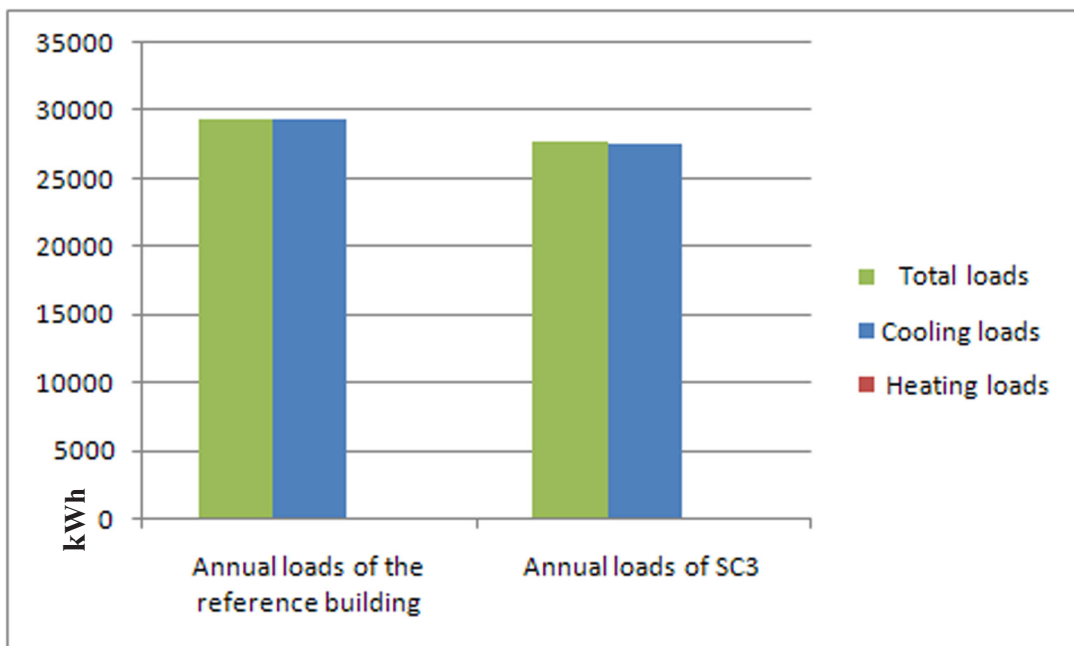


Figure 4.34: Comparison of the annual cooling, heating and total loads of the whole building for the reference building and SC3

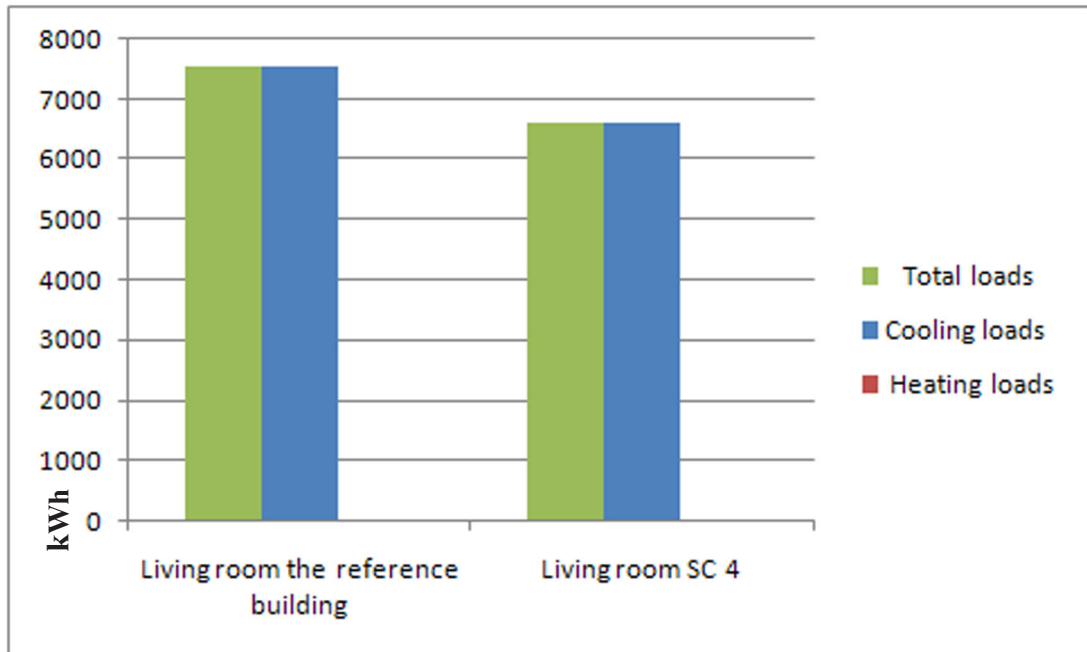


Figure 4.35: Comparison of the annual cooling, heating and total loads of the living room for the reference building and SC4

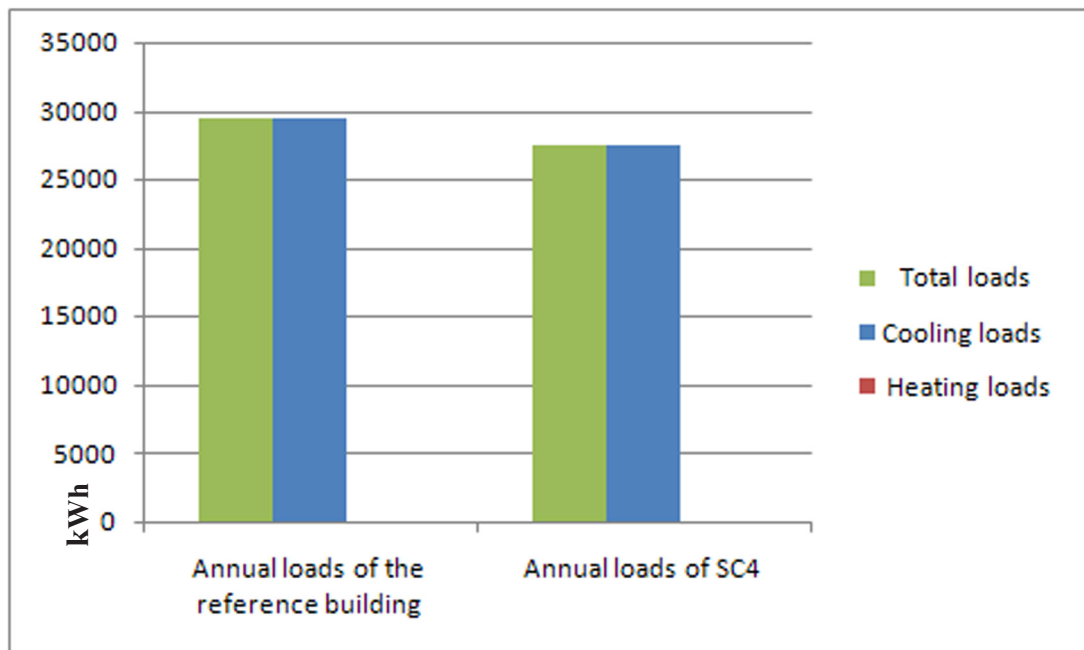


Figure 4.36: Comparison of the annual cooling, heating and total loads of the whole building for the reference building and SC4

By comparison of the graphic the results have been explained as follows:

- In the Figure 4.29 and 4.30 scenario 1 presents lower annual cooling and total energy loads compare to the reference building while heating loads are being a small increase.
- In the Figure 4.31 and 4.32 scenario 2 presents lower annual cooling heating and total energy loads compare to the reference building.
- In the Figure 4.33 and 4.34 scenario 3 presents lower annual cooling and total energy loads but higher heating loads compare to the reference building.
- In the Figure 4.35 and 4.36 scenario 4 presents lower annual cooling and heating and total energy loads compare to the reference building.

Table 4.17 gives the annual cooling, heating, and total energy loads of the living room for the reference building and the scenarios. Table 4.13 gives the annual heating and cooling and total loads of the whole building for the reference building and the scenarios.

Table 4.13: The annual cooling, heating and total loads of the living room for the reference building and the scenarios

	Cooling load, kWh	Heating load, kWh	Total load, kWh
Reference building (living room)	7551.22	0.616	7551.84
Scenario 1	7400.83	0.633	7401.463
Scenario 2	6630.01	0.275	6630.28
Scenario 3	7082.66	4.343	7087
Scenario 4	6608.858	0.279	6609.137

Table 4.14: The annual cooling, heating and total loads of the whole building for the reference building and the scenarios.

	Cooling load, kWh	Heating load, kWh	Total load, kWh
Reference building (whole building)	29388.8	34.405	29423.2
Scenario 1	28761.5	35.078	28796.6
Scenario 2	27490.7	4.934	27495.6
Scenario 3	27600.8	57.608	27658.4
Scenario 4	27445.8	4.941	27450.8

As becomes apparent from the table 4.13 and 4.14 scenario 4 (final combination) provides the lowest cooling, heating and total energy loads.

For scenario 4 variation of hourly air temperatures have been calculated and the calculation results have been given in Figure 4.37 and 4.38 for 21 July and 21 January. It can be accepted that 21 July is the design day of the cooling period and 21 January is the design day of the heating period.

As it can be seen from the Figure 4.37 and 4.38:

- In 21 July, during the day hours inside air temperatures are lower than the outdoor air temperatures.
- In 21 January, during the day hours it is possible to achieve the comfort value of inside air temperatures as 20° C.

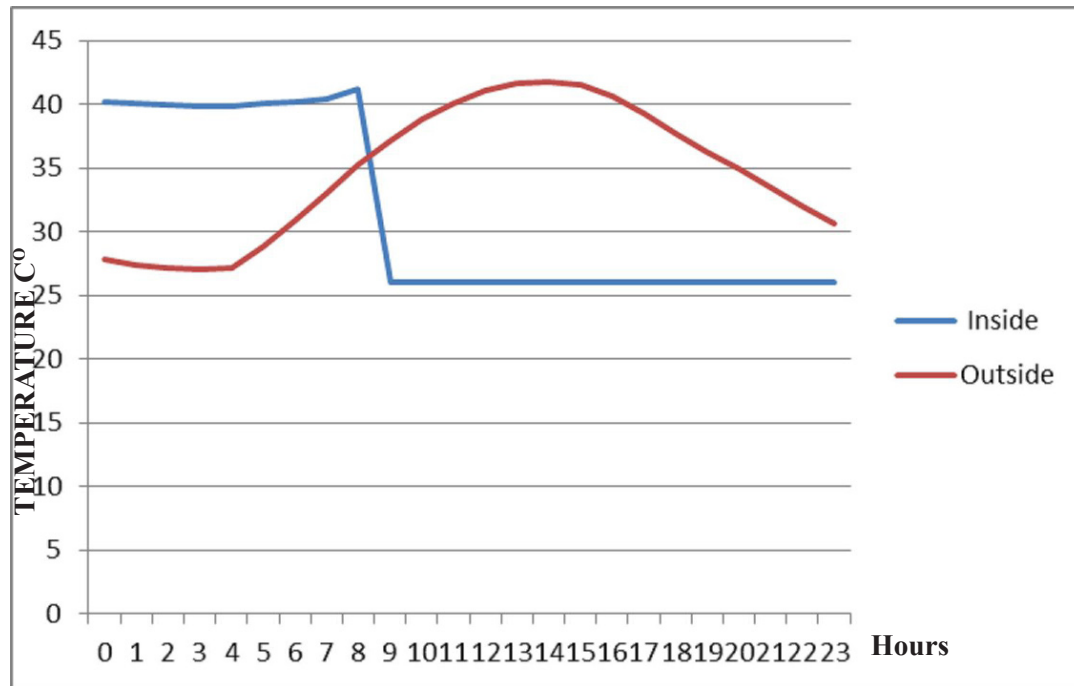


Figure 4.37: Hourly temperatures of the living room in 21 July with mixed mode performance in Sc4.

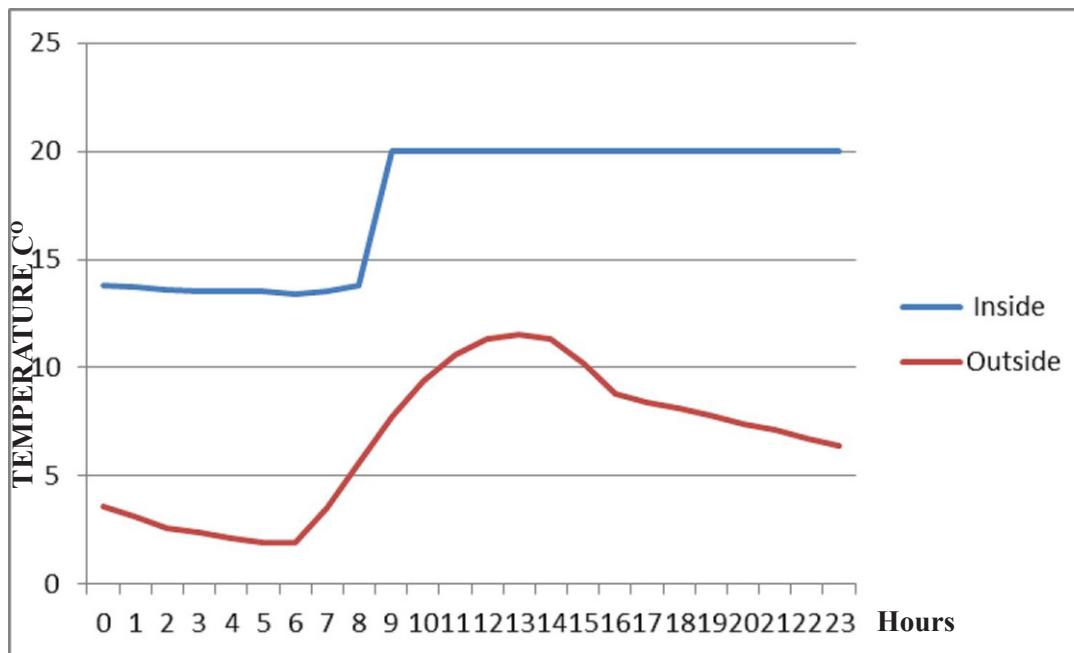


Figure 4.38: Hourly temperatures of the living room in 21 January with mixed mode performance in Sc4.

4.2.9 Prediction of daylight factors for the scenarios and comparison of the calculation results

The primary goal of daylighting analysis in SC1 is the reliable evaluation of the potential of the reference building to provide useful levels of natural illumination. By changing transmittance of optical single glass 0.9 in the reference building to 0.73 in SC1, results of daylight factors of SC1 have been changed to under the international standard. Because main purposes of SC1 is to provide acoustic and thermal comfort properties of glass of SC1 approved this purposes. The predicted daylight factors of the building for SC1 has been explained in the Table 4.15.

Table 4.15:The predicted daylight factors of the reference building for scenerio 1 (SC1)

Room type	The average daylight factor value	Standard value of daylight factor of residential building	
Bedroom 1	0.59 %	Bedrooms	1 %
Bedroom 2	1.03 %		
Children Bedroom	1.09 %		
Living room	0.98 %	Living rooms	1.5 %
Kitchen	1.77 %	Kitchens	2 %

• **Comparison of daylight factors (daylight analysis) in SC2 with standard:**

In SC2 by developing the opaque component, not change in transparent components therefore, the daylight factor does not change with SC2.

• **Comparison of daylight factors (daylight analysis) in SC3 with standard:**

The shading devices are designed to prevent direct sun from entering the interior spaces at average hours which is from 5:00 am – 19:00 pm in SC3. The results of SC3 show that daylight factors do not comply with the requirements of the international standard for residential. Table 4.16 shows the predicted daylight factor of the reference building for scenario 3 (SC3).

Table 4.16: The predicted daylight factors of the reference building for scenerio 3 (SC3)

Room type	The average daylight factor value	Standard value of daylight factor of residential building	
Bedroom 1	0.47 %	Bedrooms	1 %
Bedroom 2	0.76 %		
Children Bedroom	0.83 %		
Living room	1.04 %	Living rooms	1.5 %
Kitchen	2 %	Kitchens	2 %

From the results of analysis, it could be concluded that, when all the developed SC3 have performed in terms of the thermal, visual, acoustic performance by having amounts of energy load, shading device has proved to be very significant for reduce energy load in a climate like that of Şanlıurfa therefore, while comfort is of critical concern, energy efficiency is the primary concern and there are some tips for accepting value of daylight factor of the reference building in SC3 as flowing:

- Shading device can be used as a daylighting system that redirect daylight to spaces where daylight is needed and adjusted either manually or automatically to maintain a design illuminance level in the space.
- The reference building located in hot dry region climate and all scenarios are focused on the reduction of cooling loads in buildings and this issue can be a primary target.
- The reference building is small house and workplace can occur at any point.

5.CONCLUSION

As the environmental and energy problems that have arisen in residential buildings in Turkey, to ensure conditions of thermal, visual and acoustic comfort in buildings with a minimum energy consumption is of great importance for the health of user and the energy conservation. One of the most important functions of the building envelope is, therefore to control physical environmental factors such as heat, light and sound in order to realise defined comfort conditions for the user with a minimum energy conservation. For this purpose, in this study different building envelopes alternatives have been developed for a selected building.

As the reference building an agricultural residential building which has been developed for Urfa in south-eastern Anatolia by TOKI. Four scenarios which have been in the study evaluated for controlling physical environmental factors in order to reduce energy conservation. Sound insulation performance have been evaluated and suggestions introduced. The energy loads have been calculated by the help of simulation program ECOTECT 5.6 v.

The evaluation of simulation results can be summarized as follows:

As it can be seen in Table 4.13, 4.14, SC1, SC2, SC3, SC4 present lower cooling load compared to the reference building. By applying this scenarios, cooling loads are reduced by %2 for SC1, %12.5 for SC2, %6.5 for SC3, %12.7 for SC4 in the living room cooling loads and %2.2 for SC1, %6.5 for SC2, %6.1 for SC3, %6.6 for SC4 in annual loads in the reference building.

The evaluation of heating and cooling and sound reduction requirements and visual comfort can be reduced by developing from the energy efficiency point of view. At the same time, as it can be seen from the figures heating and cooling loads and internal temperature vary significantly according to scenarios. For that reason, when designing an energy efficient building envelope thermal comfort and visual comfort and acoustic comfort should be taken into consideration.

Evaluation of scenarios include limited to four scenarios, however more retrofitting improvements are still possible. In order to reach general results and provide optimum alternatives ensuring energy saving, human comfort many scenarios should be improved and analyzed. Appropriate design strategies in energy efficiency need to determined heating and cooling energy requirement and human comfort and environment control in different climatic regions.

The application presented in the study is a sample study that aims to emphasis importance of the design of building envelope with optimal performance in ensuring thermal, visual and acoustic comfort conditions as well as energy conservation. This study did not include a cost analysis. In order to choose appropriate alternative provides minimum energy conservation cost analysis will be crucial. On the other hand effective codes and regulations are also needed to evaluate building envelope alternatives.

In this context, to creat comfort conditions in buildings with minimum energy cost, appropriate new evaluation methods which can be used at the design stage should be developed in the future investigation.

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