The Effect of Shading Device and Natural Ventilation on Thermal Comfort in Office Buildings

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Submitted to the
Institute of Graduate Studies and Research
in the partial fulfillment of the requirements for the degree of

Master of Science
in
Architecture

Eastern Mediterranean University
June, 2017
Gazimağusa, North Cyprus

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ABSTRACT

Window opening ratios have bigger role on thermal comfort conditions of buildings than size and type of fixed external shading devices. In this study, author analyzed an office with standard envelope, by using EDSL Tas software with PMV and PPD results according to thermal sensations of ASHRAE, ISO 7730: 2005 and EN 15251: 2007 for generating the effect by window opening ratio and size of horizontal shading device which affect thermal comfort in Mediterranean climate conditions of Famagusta region. The building which dynamic thermal simulations have been done for it, is oriented on east to west because of the best wind availability.

PMV and PPD results showed that thermal comfort is affected by window opening ratios. Annual averaged PMV performance of the simulated office is based on the office hours, this paper shows; 30 cm long with or without any horizontal shading device, when the window is 0% (closed) open PMV is -0.34. When window is 25% open, PMV is -0.25. When window is 50% open (half), PMV is -0.21. When window is 75% open, PMV is -0.2 and when window is 100% (full) open PMV is -0.19. Moreover, according to category A, when PMV is -0.2 to 0.2, averaged yearly thermal comfort based on office hours obtained is approximately 326 hours of all year, according to category B, when PMV is -0.5 to 0.5, averaged yearly thermal comfort obtained is approximately 742 hours of all year and according to category C, when PMV is -0.7 to 0.7, averaged yearly thermal comfort obtained is 915 hours of all year.

Keywords: Fixed shading devices, Mediterranean climate, PMV and PPD, ISO, EDSL Tas Software, Thermal comfort.

ÖZ

Pencere açma oranları, binalardaki termal konfor koşullarında, sabit dış gölgeleme cihazlarının boyut ve tiplerine göre daha önemli bir role sahiptir. Bu çalışmada, yazar, pencere açma oranı ve yatay boyut ile efekti elde etmek için, ASHRAE, ISO 7730: 2005 ve EN 15251: 2007 tarihli termik sansasyonlara göre PMV ve PPD sonuçları olan EDSL Tas programı kullanarak standart bir ofisiö Gazimağusa bölgesi ve Akdeniz iklim koşullarında termal konforu etkileyen gölgelendirme cihazı analiz etmiştir. Bunun için dinamik termik simülasyonlar yapılan bina, en iyi rüzgar verimi nedeniyle doğudan batıya doğru yönlendirilir.

PMV ve PPD sonuçları, termal konforun pencere açma oranlarından etkilendiğini ortaya koymuştur. Bu araştırma, simülasyon bürosunun yıllık ortalama PMV performansını mesai saatlerine dayanmaktadır; 30 cm uzunluğunda veya yatay bir gölgeleme aygıtı olsun veya olmasın, pencere % 0 olduğunda (kapalı) açık PMV -0.34'tür. Pencere % 25 açık olduğunda, PMV -0.25'tir. Pencere % 50 açık (yarısı) olduğunda, PMV -0.21'dir. Pencere % 75 açık olduğunda, PMV -0.2 ve pencere % 100 (tam) olduğunda PMV -0.19'dur. Ayrıca, kategori A'ya göre, PMV -0,2 ile 0,2 arasında olduğunda, elde edilen çalışma saatlerine dayalı yıllık ortalama ısıl konfor, yılın yaklaşık 326 saati, kategori B'ye göre, PMV -0,5 ila 0,5 olduğunda ortalama yıllık ısıl konfor elde edilmiştir Tüm yılın yaklaşık 742 saati ve kategori C'ye göre, PMV -0.7 ila 0.7 olduğunda, elde edilen yıllık termal konfor, tüm yılın 915 saatidir.

Anahtar Kelimeler: Sabit gölgelendirme elemanları, Akdeniz iklimi, PMV ve PPD, ISO, EDSL Tas programı, Termal konfor.

To My Lovely Family

ACKNOWLEDGMENT

First I would like to express my deepest gratitude to my supervisor, Assoc. Prof. Dr. Halil Zafer Alibaba, who has supported me throughout my thesis with his patience and knowledge.

Furthermore, I would like to give my effort to my family for their constant help while my education and especially to my parents who encouraged and supported me.

Finally, many thanks to my dear friend, Ali Mehrazin for contribution towards me during writing my thesis.

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LIST OF SYMBOLS AND ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and Air Conditioning Engineer
HVAC	Heating, Ventilation and Air-Conditioning
(m^2)	Meter Square
(Max)	Maximum
(Min)	Minimum
(%)	Percent
(Kg/s)	Kilogram/ Second
(M/s)	Meter/ Second
(l\s)	Liters/ Second
(W)	Watt
(°C)	Centigrade

Chapter 1

INTRODUCTION

1.1 Introduction

In today`s world, because of fast populations growth, working hours have become longer in office buildings, this issue has given a big importance to the energy efficiency. That is why natural ways of energy supporting for indoors gain great importance by provision of thermal comfort issues. The sizes of the opening and glazing on facades has a complete impact on the indoor thermal comfort in hot and humid climates (AbuGrain and Alibaba, 2017).

Not only buildings need thermal comfort standards in order to satisfy their users, but also low energy consumption as stated by Kirimtat et al. (2016) will influence the thermal comfort and the sustainability will be obtained by using the international standards such as ASHRAE (2001), ISO 7730:2005 and EN 15251:2007. Therefore, EDSL Tas Software is one of the best options to test the buildings by dynamic thermal simulations. EDSL Tas software has a 3D modeler that allows creating zones, energy analysis module that also allows finding infiltration, ventilation rates and building material patterns as the last step of results, the viewer can read outputs for each hour on the screen (EDSL Tas, 2016).

In addition it can calculate air flows, the effect of shading, heat flows, thermal comfort as PMV and PPD. EDSL Tas software uses a responsive factor method, which is more accurate and ten times quicker in computational speed than different limited methods (EDSL Tas, 2016; Alibaba and Ozdeniz, 2016).

A ventilation system that is needed to ventilate the buildings naturally has to create a good air quality. Moreover, providing extra ventilation may cause energy losing (Daghigh, 2015). Hence, clear understanding of shading devices is fundamental, for example by opening a shading device in winter time sun radiation will heat up the indoor space, so as a result it will help to create energy efficient buildings (Saelens, Parys, Roofthooft, de la Torre, 2013).

For sustainable buildings of Taiwan where climate is hot and humid between May till October, shading and natural ventilation are very important (Cheng, Liao, Chou, 2013). Nowadays, living standards of industrialized countries are high, so it should be noted that increasing of energy conservation seems very important (Ralegaonkar and Gupta, 2010).

Buildings Energy Data Book of USA in 2006 points out that building sector uses 38.9% and space heating, ventilation and air conditioning take 34.8% of the energy (Kwok and Rajkovich, 2010).

Construction sector takes the largest consumption of energy. Moreover, changes in weather, forces the architects towards sustainable construction strategies (Lotfabadi et al. 2016). It is greatly important for sustainability that suitable building elements must be selected (Alibaba and Ozdeniz, 2004).

Mandalaki, Zervas, Tsoutsos and Vazakas (2012) worked on fixed shading devices that might reduce daylighting which it not only will increase the usage of artificial lighting but also it will blockage beneficial winter sun radiation as well. Comparatively thermal simulations studied for balancing the south facade of single occupant office in Athens, Chania and Crete. Results showed that integrated PV on all shading devices can produce electricity efficiently but only surrounding types, Brise-Soleil full facade and Canopy type shading device are beneficial against thermal, cooling and controlling daylight effectively.

In hot-dry climate, electrochromic glazing or exterior shading devices provide the best performance in reducing solar heat (Aldawoud, 2013). In Tropical climate, natural ventilation can improve thermal comfort between 9% and 49% in April. In subtropical climate, improvement is 3% to 14%. In temperate climate, improvement is between 8% and 56%. Therefore, it is clear that natural ventilation is beneficial in tropical and temperate climates but not in subtropical climate (Haase and Amato, 2009), (Tantasavasdi, Srebric, and Chen, 2001).

In hot and humid climate regions natural ventilation has great importance due to high air speed over body for sweating evaporation; therefore, it reduces discomfort of moist and wet skin conditions. Furthermore, in hot-dry climate, natural ventilation during night times will increase cooling rate; therefore, it improves thermal comfort of residents of the buildings. In wide buildings where natural ventilation is impossible or it is very hard, fans may be used (Givoni, 2011).

Also, ventilation in the night may cool down the absorbed heat of the building that it is gained during day time and night ventilation may be achieved via small fans and temperature differences of day and night time (Santamouris and Kolokotsa, 2013).

Exterior shading devices will increase energy saving, especially residential buildings of warm climates with direct sunlight conditions. Furthermore, wood and PVC is the most suitable and environmental friendly construction materials (Babaizadeh et al. 2015).

Usage of external moveable shading devices will affect entrance of solar radiation and daylighting performance of the building (Lee et al. 2016). Also, using shading devices has a risk of reducing daylight and increasing artificial lighting as well. For hot and humid climates, an external shading design is the best option (Ossen et al. 2005).

Environmental friendly buildings are very popular due to being energy efficient by providing good daylighting. Shading devices can be energy efficient, provide good daylighting, and protect buildings from excessive solar radiation, thus it will decrease the cooling load of the building in the summer.

If external and internal shading devices are compared with the same geometry, external ones will perform better but in point of view of energy performance, adjustment of solar transmittance, solar reflectivity, distance between shading device and window, internal shading device may provide good performance as well (Ye et al. 2016).

1.2 Statement of the Problem

Normally buildings are considered as a shelter for human to keep them safe and secure especially against climatically changes such as rain, wind or etc. Meanwhile architects have tried to create more comfortable interior environment for users according to their senses. When the climate is considered as hot and humid, the effects of temperature changes play an important role on sense of comfort for the residents. As there is no sufficient consideration to the building façade and shading devices, the primary aim of this study is going to analysis indoor thermal comfort and energy efficiency which can be mentioned that indoor thermal comfort is the most effective factor among all related factors (size and kind of shading elements and also openings which produce thermal comfort, in Famagusta climate).

For having a convenient interior space, it is quite evident that percentage of opening and type of shading devices are crucial system to affect the indoor thermal comfort. In hot and humid climates, the sense of comfortable indoor is affected by temperature changes in office buildings.

Nowadays, it is believed that by controlling the air circulation inside the building, the percentage of openings and the type of shading devices, more energy efficient indoors can be created.

1.3 Aim and Objectives of the Research

This study will address the effects of window opening sizes with fixed horizontal shading devices on thermal comfort, with the help of EDSL Tas Software (EDSL Tas, 2016).

In this research, categories defined in ISO 7730: 2005 and EN 15251: 2007 standards will be used for analysis of yearly performance obtained in standard office natural ventilation. PMV and PPD results will determine local comfort and discomfort obtained in each category. The defined categories are A that defines PMV -0.20 to 0.20 (PPD <6%), B which defines PMV -0.50 to 0.50 (PPD <10%) and C that defines -0.70 to 0.70 (PPD <15%). In addition category D that exceeds category C is not included in this study. Furthermore, this research also aims to guide designers for thermal comfort issues in Mediterranean climate offices.

1.4 Research Scope and Limitation

All available data on the energy efficiency of facade demonstrated that a gap existing in the designing of the building's facade system in various orientation that it directly affects the indoors thermal comfort.

As already mentioned some factors cause energy losing, for realizing the amount, it is required to offer some evidences that designers can understand easily and use them in an appropriate way accordingly to create new improvements and more energy efficient buildings. Also in the selected case it is impossible to offer any optimized shading element.

1.5 Methodology of Research

For literature review part all fundamental data have gathered from various sources such as books, articles, and online reliable sources in order to provide a basement to put the analysis of this enquiry.

This study is from quantitative family that software simulation would support and make the exact influence of each variable size and direction of the shading devices, understandable to compare three levels including plan drawings and 3D designing simulation of building with the stuffs that are available to elevate the office building, the research result and finally the conclusion.

Thermal Simulation is the highest emphasis for the method according to the instruments which are used to measure distance of shading by TAS program. 3D models of the construction would be designed by TAS software. The program evaluates the building by analyzing the materials and the environment.

1.6 Organization of the Thesis

The existing research includes four chapters; introduction is the first part, also it describes the problem, purpose of the research, limitation of the research, methodology and optimum collection of the thesis.

In the second chapter the connected information that are connected to the selected subject, are collected, energy efficiency in building, office building definition, and thermal comfort and energy efficiency simulation.

In the third chapter, the case study, it means the office building was analyzed concerning its interior space for thermal comfort by using TAS program. The simulation compared each several opening percentage and the type of shading device for office building. In conclusion, final chapter describes results, brief contents of findings in the simulated results and also suggestions for further researches.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

As a very important global warning and by limiting the usage of fossil fuels which harms human being, the amount of fossil fuels usage should be controlled and containment. Providing a practical solution for solving all problems actually is impossible however there are some useful methods which they are reducing the speed and harm of these factors. One method is, energy efficiency passage should be followed, in other word, the maximum advantage of minimum creates energy.

So that appropriate building design can cover the most important energy efficiency factor. Each element plays its own role and none of them should be omitted. The size of optimized shading elements plus their directions as sub-elements have hundred present communication by environment.

In contents, energy efficiency is calculated. In the office building, façade designer does not consider the shading as the element to be more effective part for inside. This thesis recommend horizontal shading for office facade.

2.2 Energy Efficiency in Building

There is a belief that energy has an important role due to absorption and exothermic. Adaptive reuse needs to reduce energy consumption in historical buildings. The energy and heat in the inner buildings is directly transmitted through the transparent surfaces in addition the secondary emission of the inner skin and energy gain, if there is ventilation of the air (Infield D, Mei L, & Eicker U, Solar Energy 2004), depends strictly on the radiation absorbed by the inner system. In the period of summer season, in some countries with warm climate, the skin of facade could easily bring some gap of overheating, with the slight increasing of cooling loads (Gratia E & De Herde A, 2004).

The material for reuse of ruin part is an important part of the function for energy consumption. One of the crucial issue for saving energy is the thickness of the materials. Thickness and glazing of glass for façade is a useful approach for saving energy, but it needs to be calculated. This type of material helps to use the natural light for indoor, so lights in the inside of the historical buildings are useful for energy efficiency. The standards of glazing and materials as a thermal break material for any opening including windows and doors have a really important role which are needed to be calculated for saving energy.

According to the historical building, adaptation is believed as an important common. Historical building that performs in terms of energy efficiency, comfort conditions or environmental impact is a potential candidate for adaptation (Energy Research Group, 1999).

Energy Efficiency (EE) means decreasing of relevant costs to the necessary energy. Developing of efficient energy and related movements are very important for building industry (Tirado Herrero, Tirado, 2012). Although the applying efficient technology can cost too much, but the energy can be saved and balance any extra charges (Ghatikar, Granderson, Piette, 2011).

In other word, energy efficiency definition is, decreasing of energy consumption which is necessary for usage in a construction by outputting or quality measuring of energy in each per unit for energy input. Also this can be created by product's output which increased in quantity and quality however energy usage in total should be kept constant.

According to International Energy Agency (IEA) a lot of developments have been done until now in direction of having more efficient constructions and energy consumption and this amount is going to be by one third on 2050 (Gustavsson, Joelsson, 2010). Nowadays all around the world there are a lot of attempt to follow energy efficiency approaches in different countries. For example in the most of Asian governments, for example China tries to obey the latest rules to have more energy efficient construction by considering standards so all construction materials have been improved. In addition in Japan some buildings have commenced to be appeared in traditional and vernacular design and every day the number of them are increasing. Also usage of solar cells in their constructions is very popular in Japan.

Furthermore, in Thailand, the government has made both owners and builders to take some useful classes about using of vernacular architecture in order to understand the importance of energy saving potential in construction industry. (Wu, Ren, tang, 2009).

European commission gives an energy efficient certificate to a building which is qualified for this title and all owners have to get that by considering many traditional architecture principles. (Doukas, Nychtis, Psarras, 2009). Also recently changing of some basic materials in Californian's construction system has led to save 30-40 percent energy in the United States (Zehner, 2012).

Paying much more attention to the mechanisms of material usage after designing proses and using of natural energy in order to save more energy in a building helps having more energy efficient buildings. Building modeling is a technique to apply efficiency to the building by simulating materials in order to decrease indoor heat consumption (Ries, Jenkins, Wise, 2009).

In addition building modeling gives an opportunity to the designer to have an appropriate deal with the environment and fit his plan to it in the best natural condition by providing more energy efficiency (Zhou, Levine, Price, 2010).

2.3 Thermal Comfort

The reaction of human to heat and coldness in an environment is called thermal comfort (via ASHRAE standard). The issues which influence the thermal comfort are four physical variables (the speed of the air, the temperature of the air, radiant temperature, and comparative moisture), and three individual variables (clothing isolation, the level of body activities and the rate of metabolism) also several other issues which influence the thermal comfort can be, sex, season and daily rhythms, day-to-day variations, adaption and age.

Thermal comfort is the most important issue to be considered when human wants to have convenient condition in terms of temperature (Fanger, 1970).

Certainly different countries have different climate zones so these different climate zones have fluctuation in humidity, temperature, global temperature and air velocity, so that various values can be evaluated for comfort zone. ASHRAE (2009) says during summer and winter thermal comfort are equal between indoor conditions. However, the preferable of a residential building for thermal comfort may alter during the day.

The temperature rhythm of human body is lower in the early morning and in the late afternoon is higher. Some particular thermal comfort standards are used in Air-conditioned buildings. Atmosphere with comparative moisture and speed provide thermal comfort (Fanger, 1970).

The temperature of human's body decreases in the winter and in the summer it increases. So these issues influence the quality of thermal comfort for the residents.

It is impossible to have real definition for human thermal comfort standard, although, some standards are being used which they are 4-6 air changes in one hour to heat or cool of machine-driven system while outdoor air freshening for one person minimum for all types of environments, is 8 l\s.

On the other hand the numbers of air changing can be less if the room is empty. (Krewinkel, 1998).

Use of 10% window size on external walls will provide thermal comfort in May, September and October for hot and humid climates with naturally ventilated office environments (Alibaba, 2016). Proper use of shading devices will improve thermal comfort of interior spaces and reduce cooling energy load effectively (Cho et al. 2014).

Solar radiation affects energy consumption of buildings due to usage of air conditioning and lighting systems. Therefore, usage of shading devices will provide appropriate level of natural lighting and solar energy (Maestre et al. 2015). In contemporary architecture, usage of large windows and highly glazed facades allow to access daylighting, solar gain and external gain. Sun rays passing through non-shaded windows will increase internal air temperature in hot climate of Jordan. Increasing internal air temperature will negatively affect the thermal comfort, increase the cooling load and become the source of glare (Freewan, 2014).

Usage of extensive glass in Mediterranean climates like Italy will cause high cooling loads due to solar irradiance. National codes of Italy require using external shading elements or low solar gain coatings (Manzan, 2014).

In today's buildings, energy consumption may be reduced by applying energy efficient strategies like Trombe walls, ventilated walls (double skin facades), glazed wall applications, aerogel, vacuum glazing, frames, green roofs, photovoltaic roofs, radiant-transitive barrier and evaporative roof cooling systems (Sadineni et al. 2011).

Integration of site features for naturally ventilated buildings during hot seasons is important for thermal comfort because natural ventilation will replace necessity of mechanical cooling systems (Stephan et al. 2009).

Siew et al (2011) reported that air wells (courtyards), facade designs, ventilation openings, corridors and shadings with blockage and partitions are physical passive designs for natural ventilation in order to reduce energy use of buildings. Bastide et al. (2006) stated, for hot and humid tropical areas, to reduce the usage period of air-conditioners, natural ventilation is the answer by application of bioclimatic approach via design of building envelope and airflow optimization.

Ralegaonkar and Gupta (2010) found that, in order to reduce artificial energy requirements for achieving indoor thermal comfort, intelligent building construction with approach of passive solar architecture is needed.

Zingre et al. (2015) stated that cool roof construction technique is being popular nowadays in Singapore which has tropical climate due to being passive energy saving. This roof type may perform peak roof temperature of 14.1 °C, 2.4 °C as indoor air temperature and 0.66 kWh/m² (or 54%) as daily heat gain when it is sunny day with a cool coating (solar reflectance of 0.74).

Liping et al. (2007) reported that, for residential buildings in Singapore, U value for facade materials of north and south orientations should be less than 2.5 W/m² K and the optimum window to wall ratio should be 0.24.

Optimal fixed horizontal external shading devices in Milan can cut off 70% of summer time sun gain, whereas they may cut off only 40% in winter time (Datta, 2001).

In the hot-Dry climate of Malaysia, analysis of external fixed shading devices on window showed that egg-crate shading elements provided the best performance in decreasing discomfort hours among all other types of shading devices (Al-Tamimi and Fadzil, 2011).

Arifin and Denan (2015) stated that egg crate type shading device showed significant impact on decreasing indoor temperature with discomfort hours when compared to other types of shading devices.

Kim et al. (2012) tested external shading device that saves 11% of cooling energy with 60° of slat by using IES_VE dynamic simulation software for apartment buildings in South Korea.

Bellia et al. (2013) stated that suitable use of shading devices may give energy efficiency in Italian climates; for example, 8% in Milan (coldest climate) and 20% in Palermo (warmest climate) as global annual energy saving for common air-conditioned office buildings.

El-Monteleb and Ahmed (2012) studied buildings in hot desert areas by thermal simulations and recommended that, for all seasons, 38 cm of vertical louvers will decrease the indoor temperature by 2 °C in all orientations.

Liping and Hien (2007) stated that in Singapore, north and south facing facades can provide more thermally comfortable spaces than east and west facing facades. Moreover, it was found that, 600 mm horizontal shading device is needed for all orientations for better thermal comfort.

Raeissi and Taheri (1998) stated that in Shiraz in Iran, summer cooling loads may be reduced 12.7% with proper window shading with an increase of 0.6% winter heating loads.

Developments in technology creates a lot of opportunities for thermal comfort calculation with the help of developed computer software and new simulation methods of energy. Nowadays all designers can estimate, analyze and compare all simulation data for a building by using computer modeling programs which serves them actual parameters of design.

By using these simulation applications the best design alternatives can be selected which meets all the needs for energy saving by reducing energy consumption in the indoor of the building that led to creation of thermal comfort for inhabitants. This purpose can be possible when the building model is created by the program with all the material details.

Many computer programs for thermal comfort simulation give more opportunities for constructors to have ability for evaluating the project in many different ways.

So TAS software is the most accurate and exact simulation program among all these computer programs which the building data can be modeled in a very correct way and thermal performance can be calculated by considering environmental conditions and specific characteristics of the structure, also designer is able to evaluate the building with the standards of ASHARE definition for comfort zone.

2.3.1 Thermal Comfort Problems in Hot- Humid Climates

One of the main characters of hot climate is losing high amount of heat during winter and gaining high amount of heat during summer which can influence thermal comfort rate; therefore, creating cool indoor environment requires paying much more attention to this issue as the most important matter because it increases indoor air movement and provides more thermal comfort conditions for users (Yilmaz, 2007).

Three main parameters of thermal comfort principles that buildings deal with in hot and humid climate region are:

- Gaining of heat in summer extremely
- Losing of heat in winter extremely
- Great range of humidity

In hot and humid climate regions a lot of financial costs are spent in the residential buildings for energy consumption for producing thermal comfort for users (Nicol, Humphreys, & Roaf, 2012). Plus, another important parametere for air ventilation is moisture control for the excessive loss and gain of the heat (Fanger, 1970).

As it is mentioned previously the main purpose of this research is controlling of performance in thermal comfort and sustainability by considering the structure orientation and enveloping some details such as (opening, solar control, shape, insulation) which designers should evaluate these aspects when they start to design (Baker & Steemers, 2000).

2.3.2 Factors Which Influence Thermal Comfort in Hot- Humid Climates

Generally wind flow happens when heated air goes up and replaced with cooler air; so this can be a very useful method for creation of air quality which decreases usage of energy and also creates acceptable indoor thermal comfort.

Wind and flexibility are two ways of natural ventilation. One of them is wind pressure and the other is temperature which can be different between inside and outside atmosphere of the building envelope, both of them lead to creation of air exchange naturally between these two spaces.

Energy of air flow from the outdoor, cools the air and ventilate it to the indoor of building which is called passive natural cooling so no fan or other mechanical power is used to produce air ventilation by consuming energy.

Normally new buildings are designed according to passive cooling systems although some of existing structures have the same principles. Not only wind flow can provide convenient situation but also blowing of dry-bulb temperature let the body temperature has pleasant cooling.

Just in opposite side when the weather is too cold or humidity is less on the air the human body starts to lose high amount of heat and this ventilation is too much suffering; or even though this dry-bulb temperature stays over the skin temperature, an unpleasant and disturbance situation will cause by the circulation of the air.

In hot-humid and high temperature-humid climates, while the temperature is used to be high and effective, all struggle should be consumed to receive winds indoor and around the envelope of the building (Schulze, Eicker, 2013).

The other important issue in causing of local discomfort is windows, because they deliver the cold radiations to indoor in winter, or storage of solar during summer. In technology of today, ventilation inside the building can be controlled by opening or closing adjusted windows which gives air circulation in hot weathers or stop the circulation completely in cold weather.

Position of the window should be well-designed because it needs to permit exact ventilation in hot or windy weathers (Alloccaa, Chenb, & Glicksma, 2003).

Natural ventilation creates the thermal comfort indoors for users of the building and it has been considered as the main challenges for hot and humid climate. Another benefit of natural ventilation is the amount of energy that is conserved in this way because natural ventilation removes the heat storage in the structure’s thermal mass which decreases cooling loads.

Humidity evaporates and cause to cool environment fleeing, so when natural ventilation and wind is used in structure design, the flooded air is detached and fresh air is provided to the space and unhealthy air is removed because natural ventilation increases the amount of evaporation. This is very popular in hot and humid climates to decrease heat and humidity.

2.4 Shading Device in Literature Review

Through the architecture history and related cultures from classical to unrefined vernacular structures, shading has had various advantages that can be found in its applications to history (Sadler, 2005).

Furthermore large shading elements have been used for two aims, for shading of indoor and also outside living place (Lechner, 2009).

As matter of fact, vast wide windows should be equal to the most natural ventilation in hot and humid weather, but it is also obvious that the amount of sunlight that can pass through these big openings at the same time will cause to feel unpleasant atmosphere inside the building.

When there is a sensible design, different areas of the building can be multifunctional. Greek porch preserves the building against rain and it is undeniable and at the same time controls solar. In this way it gives more value to a porch in hot and humid climate, where commonly rains and sunlight is extremely curl (Lechner, 2009).

The key point is shading which creates thermal comfort during summer easily. As there are there-level design approach for cooling a building, shading is one of them to escape from heat (Figure 1).

Passive cooling is considered as the second level and third level is using of mechanical facilities which make indoor environment cool that two previous levels could not did (Lechner, 2009).

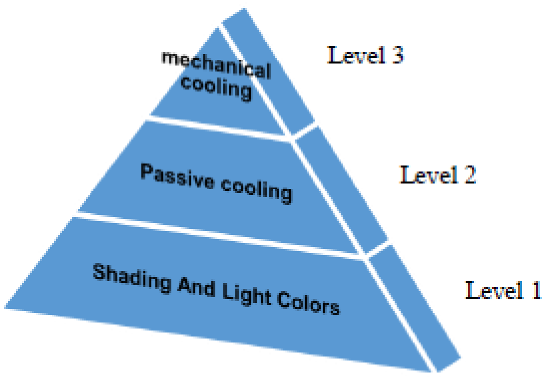


Figure 1: Logical and sustainable method for achieving thermal comfort in summer.

As figure 2 demonstrates, on 21st of June, an opening (horizontal glazing) attracts solar radiation five times more than window on south side. Mainly, it is better skylights avoided to be considered as an effective shading element.

In addition figure 2 illustrates that east or west glazing gathers solar radiation almost three times more than south side windows. Therefore, east and west windows has more effective shading elements than south side windows (Duffie, 2013).

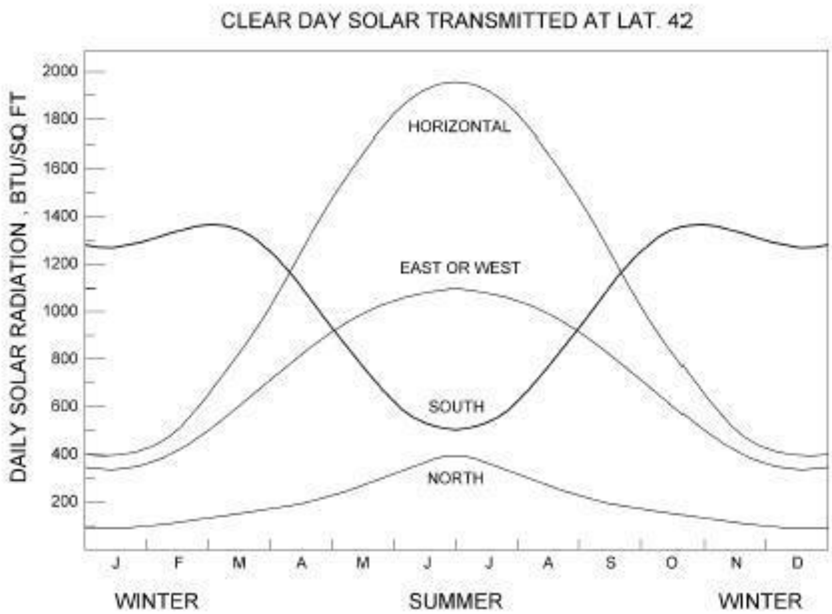


Figure 2: Amount of solar radiation in season (Duffie, 2013).

The whole solar load includes three mechanisms: direct, diffuse, and reflected radiation. In order to prevent passive solar heating, the windows must have shading element in the direction of solar or reflected radiation or diffuse sky.

In regions with sharp sun shine and humid climate the diffuse-sky radiation plays an important role. Also in these areas when dust and air pollution is added absolutely it causes diffuse radiation (Figure 3).

In addition in these areas reflected radiation is considered a big problem as it is in Southwest, where there are strong sunlight and reflection on surfaces are high. In urban regions there is another problem where these surfaces reflect more sunlight. For example Concrete paving, white walls, and reflective glazing all have a powerful reflection of solar into windows. In some cases it is obvious that north façade of the structure influenced south orientation solar load when the structure is built towards north direction with reflective glazing (Figure 4) (Lechner, 2009).

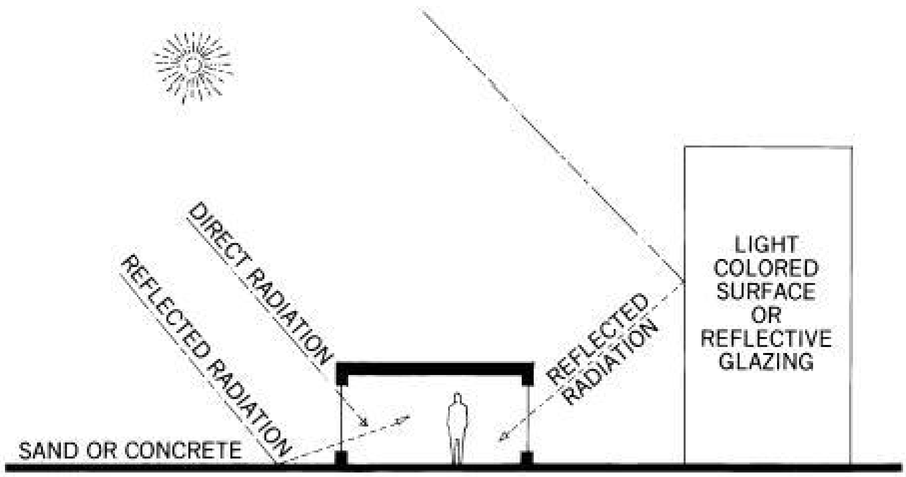


Figure 3: In humid and dusty regions, the diffusesky component is a large part of the total solar load (Lechner, 2009).

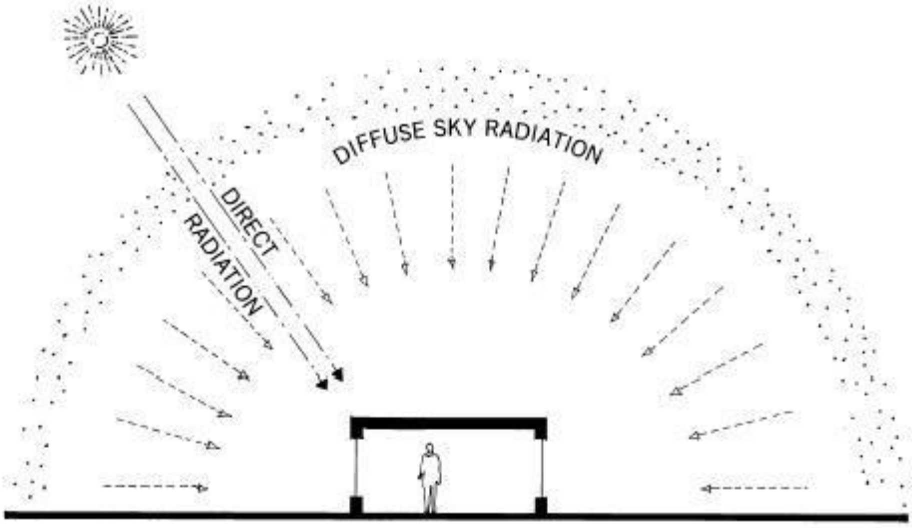


Figure 4: In dry regions, the solar load consists mainly on the direct and reflected components. (Lechner, 2009).

The factors which are important for making decision about size, location and type of shading element all depend on the size of the direction, diffusion, and reflection of whole solar load.

Reflection on surfaces can be controlled when solar reflection reduced on offended surfaces.

Normally it is possible when there are some undergrowth like trees. The problem is a little bit bigger when it comes to diffuse-sky section that it related to the angle of radiation which it usually can be controlled by adding shading element inside or creation of shading for glazing. In contrast direct solar can be controlled by outside shading elements in an effective way (Lechner, 2009).

Providentially, solar energy should be taken in to the building in a calculated way because in this way sunlight will have very high quality and at the same time the heat that enters into the building will decrease as much as possible. In this manner proficiently there will be no need for artificial lightening as already it is allowed to entrance of adequate light into the space.

Also it is possible to prevent solar radiation to enter during extreme heated duration of a year when daylight has no use for users. These periods are totally different for northern resident and southern resident of a big office building as overheated period is just a few months for northern side and it will be two or three times longer for southern side of the building so that the necessity of shading according to the overheated period totally depends on weather conditions and the structure nature (Armaroli, 2011).

According to orientation of shading devices, when the shading device horizontally over hanged from the southern facade it will have more effective influence on windows in this direction against the sun altitude. Although the same over hanged horizontal shading device has low effect when it is installed on the southwest, west, east, southeast and the same orientations.

In hot and humid regions all northern windows must be shaded because in the summer period the sun will rise from north of east and will set in the north of west.

In addition because of sun location in the sky which is lower, so it is better to have fins work vertically by considering that having just horizontal shading devices will not meet the required shading in the north façade. (Figure 5) (Lechner, 2009).

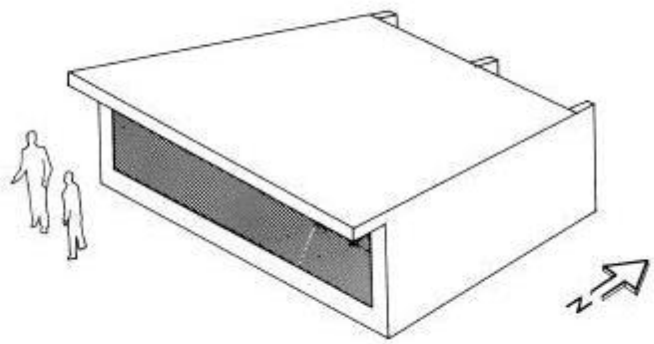


Figure 5: Each orientation requires a different shading strategy (Lechner, 2009).

As the sun altitude has lower angel on the morning and afternoons there is a problem in east and west facing windows. So it will be beneficial if it is avoided using of windows on eastern and western side of the building as much as possible. Using of windows in east and west side can be a good solution if these window represented in south or north part (Figure 6).

If there is no possible action for doing this the other solution can be using of over hanged fins vertically and/or horizontally, however it should be noticed that although they can be very effective solution, but at the same time they will limit the view (Schittich, 2003).

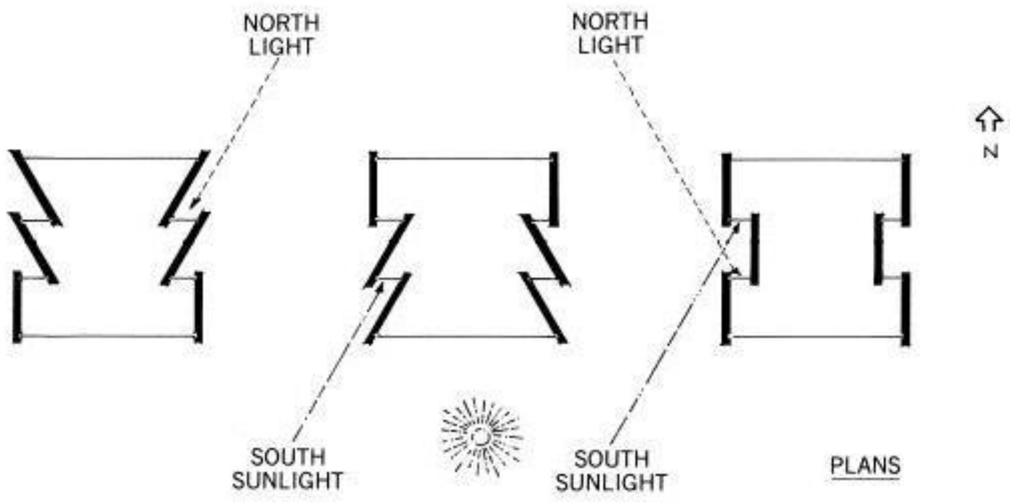


Figure 6: Window orientation (Lechner, 2009).

As the figure 7 demonstrates, when horizontal and vertical shading devices are used together in a mixed way they will perform in a more efficient way. When the distance between horizontal and vertical parts are close to each other the final shape will be look like an egg which this device on the east and west side is very appropriate for southwest and southeast facades in extremely warm weathers (Loutzenhiser, 2007).

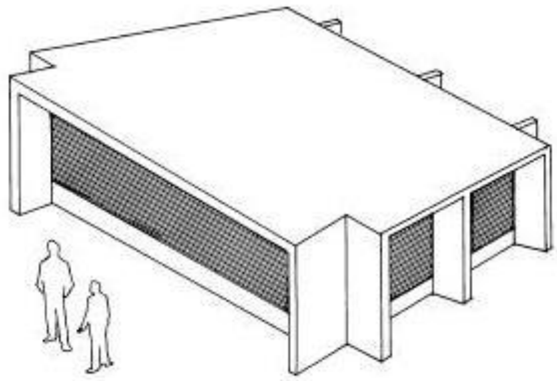


Figure 7: Combination of vertical and horizontal shading elements is used (Loutzenhiser, 2007).

As figure 8 illustrates shading devices block the sun radiation in different angles, both small and massive shading devices have very useful effect constantly. In all cases the quantity of length to vertical portion of shaded window is constant. In some other cases there are screens for windows which contains tiny louvers that not only they block sun lighting but also they are transparent (Kotey, 2009).

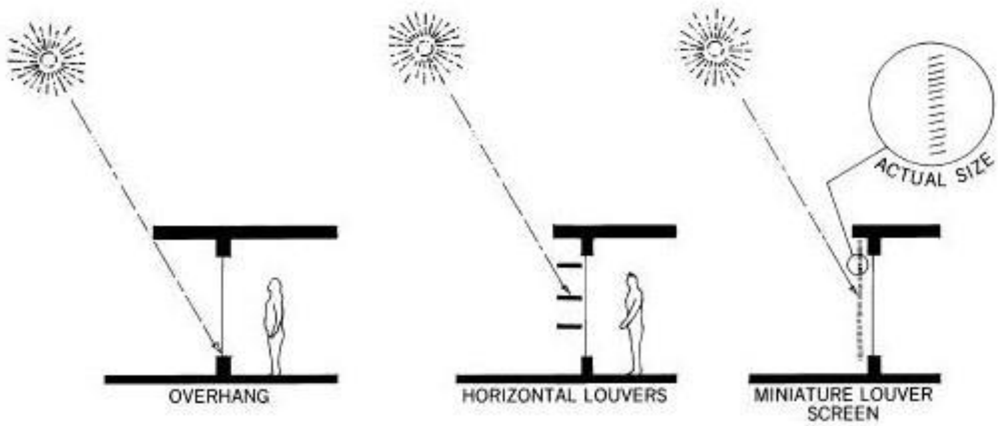


Figure 8: Shading effect with many small elements (Sun, 2012).

Exterior shading devices for instance over hanged fins which integrated to the building facade, reduced the amount of heat which is caused by solar radiation. Advantages that exterior shading devices have, is giving a lot of sustainable characteristic to the building. The primary effect of exterior shading devices is energy saving because they prevent the interior space gains a lot of direct solar power through the windows.

When exterior shading devices are used on the building façade with cheaper price for glazing, sometimes the result will be the same when the window is unshaded and it is necessary to use glazing with better performance.

The second advantage of exterior shading devices is less demand for electricity charges while mechanical devices are being used for cooling the space which saves money in this way.

The last advantage is exterior shading devices omit the glare on the windows for indoors and there is no need for lowering shades or closing the screens of window, in other word day lightening and vision will not decrease by dark colored glazing or block by indoor shagging. By using of exterior shading devices, glare will not be connected to the usage set-up (Figure 9), (Carmody, 2007).

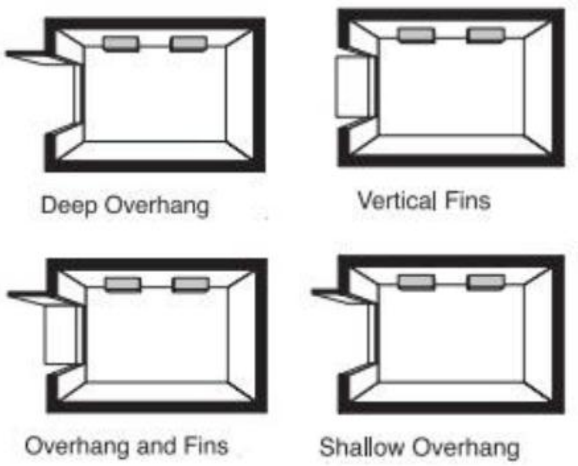


Figure 9: Example of Exterior Shading Device (Grondzik et al., 2011).

According to internal shading devices, when the rejection of energy is considered, the exterior shading devices play very efficient role, but also for some useful reasons interior elements are very efficient as well (Figure 10). Interior devices are most of the time cheaper than exterior shading devices, as they are not considered as a resistant elements and they can be easily adjusted or moved, which also gives them ability to be changeable according to requirements.

Addition to their role as shading device they have so many other advantages, As well, they block the "black hole" consequence which open windows create during night time (Galloway, 2004).

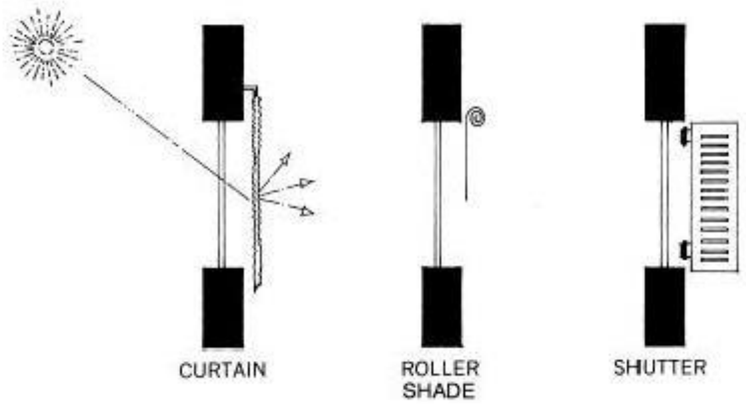


Figure 10: Interior Shading Devices for Solar Control (Lechner, 2009).

As internal elements are usually used with exterior shading devises, so they have advantage in their usage, for example they should be used to prevent solar radiation when exterior shading devices cannot be useful.

Also they works in benefits of external shading when they are not used as Venetian blinds or light defers in some hot days during hot weather of the year (Figure 11) (Grondzik et al., 2011).

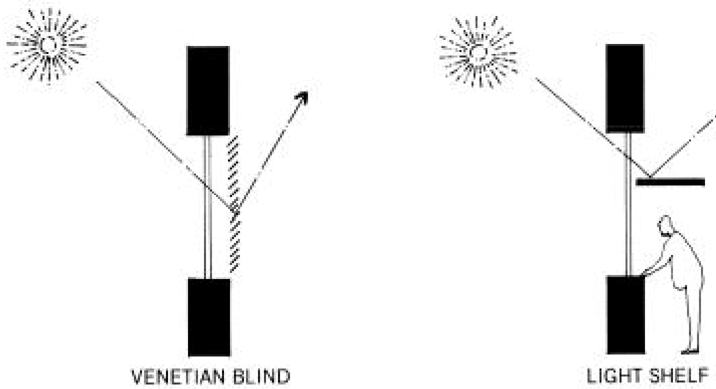


Figure 11: Interior Shading Devices (Grondzik et al., 2011).

The only problem that interior devices have, is they are not constantly effective. They are not able to prevent the solar radiation by admitting the view at the same time, when they prevent sun light to enter the indoor area by glazing, high amount of hot air stays indoors as well.

The side of the shading device which faces the window has to be in very light color (white) because sun light doesn't come back to indoor.

Every device for shading is made of either flippers vertically, over hangings horizontally, or mixtures of two of them. It is very appropriate to use horizontal over hanged shadings on the south façade. As a matter of fact according to the window direction they can be selected, in winters they prevent sunlight comes into the indoors and on the other hand they make shade for hot summer day's sun light, also they don't have any limitation in vision of the view through the window.

Also they can be best alternatives for east, southeast, southwest, and west orientations. In comparison of solid shading over hanged with horizontal louvers, horizontal louvers' advantages, such as decreasing of structural loads, because snow and wind passes through them, outweighed the solid ones. Horizontal louvers don't let heated air remain under the overhang (Figure 12) (Galloway, 2004).

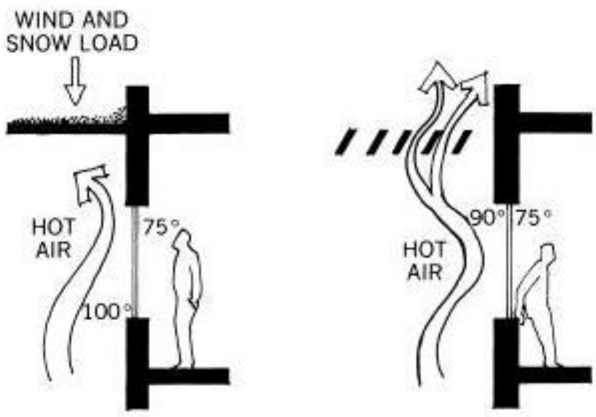


Figure 12: Horizontal louvered overhangs both vent hot air and minimize snow and wind loads (Galloway, 2004).

When the distance between the wall and the window is limited, it will be appropriate to have horizontal louvers vertically. This is more understandable if the structure situated close to the boundaries. Also louvers are very useful when the design includes tiny-scale workings and high numbers of texture.

When shading over hanged elements are designed it should be absolutely considered than sun rises from south east until noon and on the afternoon it will be on the south west.

Therefore, sun radiation moves around, an over hanged shading elements as wide as the window is. So narrow windows requires wide over hanged shading device or vertical fins rather than over hanged shading device. (Figure 13). As it is obvious in figure 14 extensive strip windows are influenced less by this problem (Maurya, 2011).

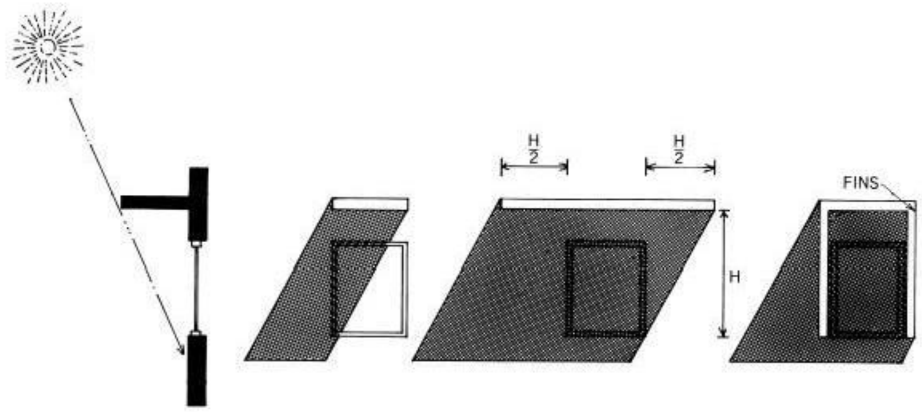


Figure 13: Use a wider overhang or vertical fins on each side of the window. (Maurya, 2011).

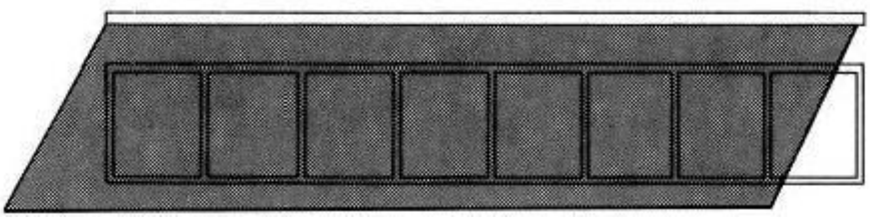
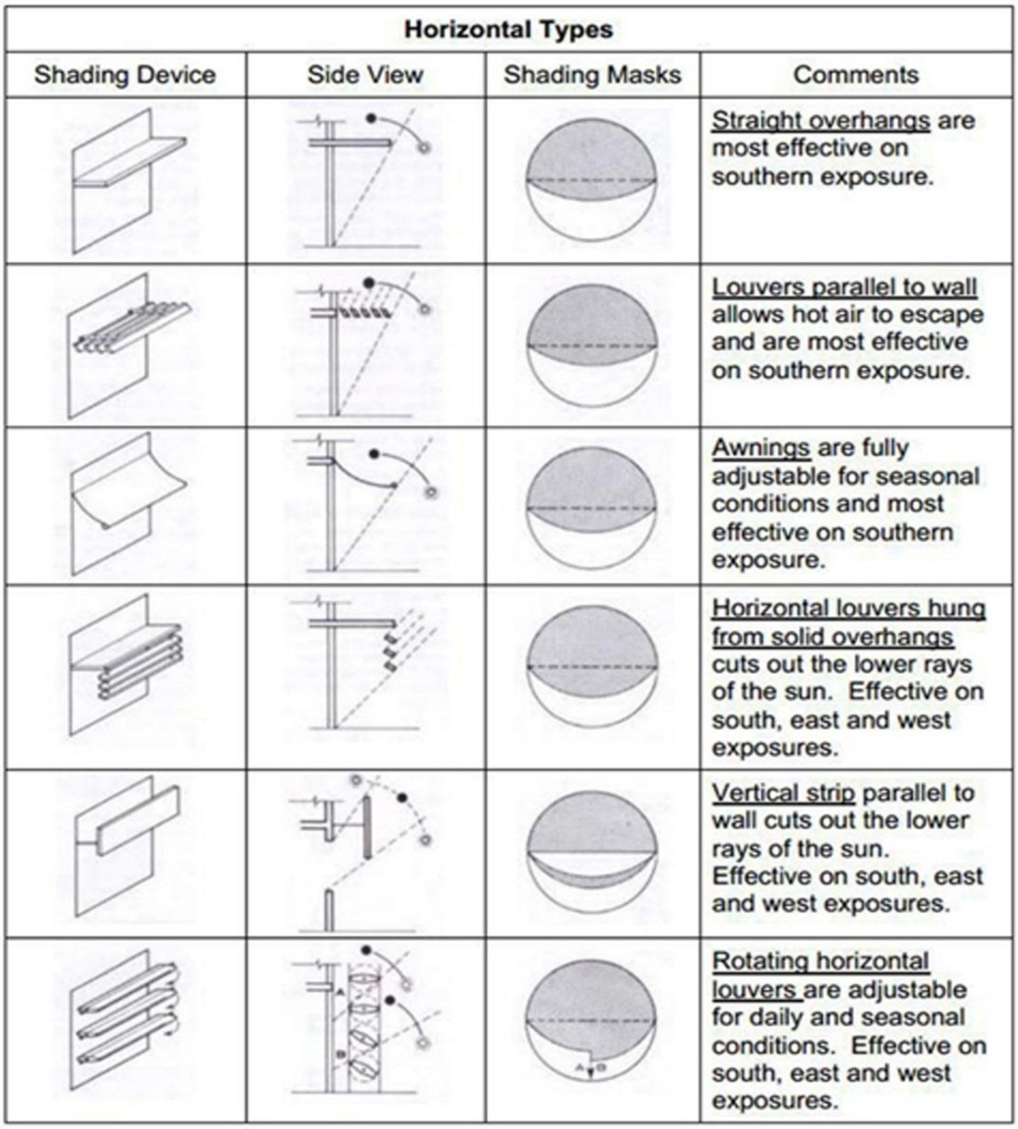


Figure 14: Long strip windows make efficient use of the horizontal overhang (Maurya, 2011).

The following pictures demonstrate various shading devices of basic ones, categorized as horizontal. (Figure 15).

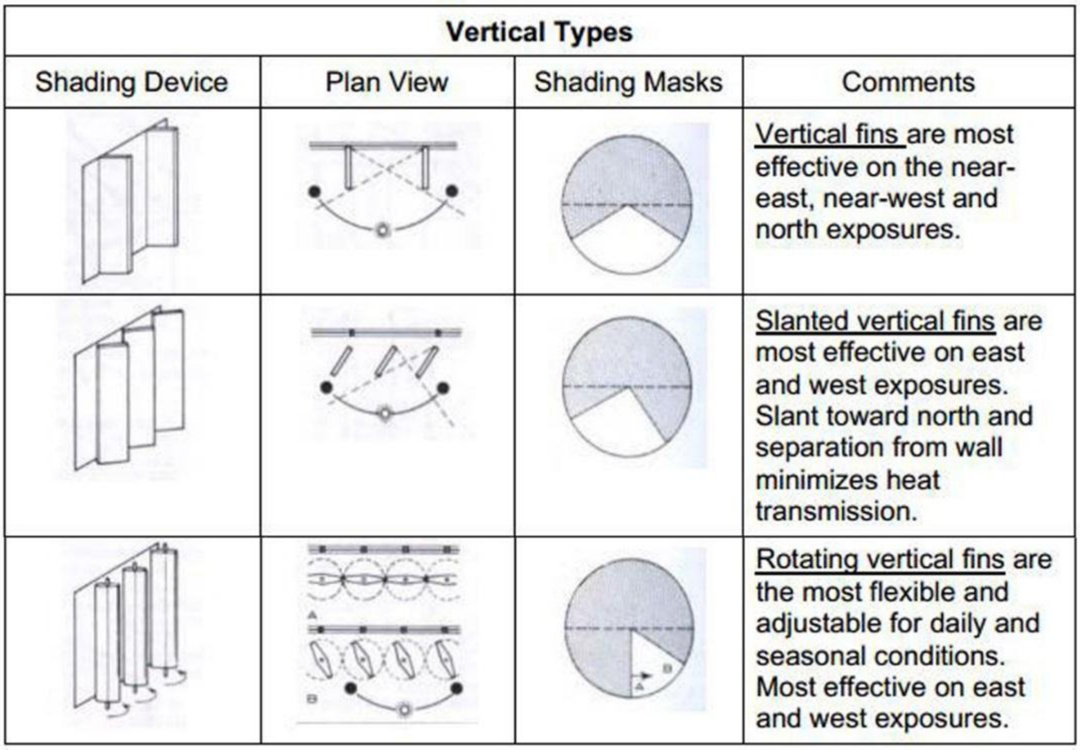


Horizontal Types			
Shading Device	Side View	Shading Masks	Comments
			Straight overhangs are most effective on southern exposure.
			Louvers parallel to wall allows hot air to escape and are most effective on southern exposure.
			Awnings are fully adjustable for seasonal conditions and most effective on southern exposure.
			Horizontal louvers hung from solid overhangs cuts out the lower rays of the sun. Effective on south, east and west exposures.
			Vertical strip parallel to wall cuts out the lower rays of the sun. Effective on south, east and west exposures.
			Rotating horizontal louvers are adjustable for daily and seasonal conditions. Effective on south, east and west exposures.

Figure 15: Horizontal Shading Devices (Galloway, 2004).

At the first step, the vertical shading devices, are appropriate for west and east orientations. In addition vertical shading devices increase the assessment of insulation during the winter months by shelterbelt performance. Plus, vertical shading can be designed for various angles depends on the sun's position (Brown & DeKay, 2001).

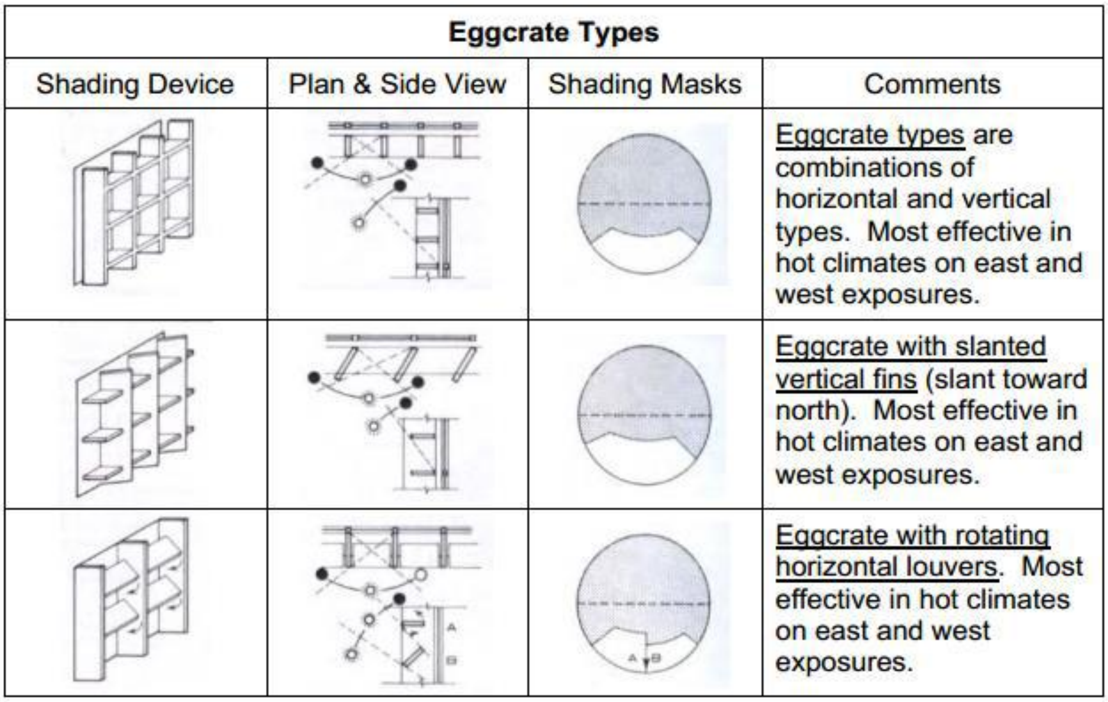
The following pictures demonstrate many different types of basic shading devices, categorized as vertical: (Figure 16)



Vertical Types			
Shading Device	Plan View	Shading Masks	Comments
			Vertical fins are most effective on the near-east, near-west and north exposures.
			Slanted vertical fins are most effective on east and west exposures. Slant toward north and separation from wall minimizes heat transmission.
			Rotating vertical fins are the most flexible and adjustable for daily and seasonal conditions. Most effective on east and west exposures.

Figure 16: Vertical Shading Devices (Brown & DeKay, 2001).

Egg crate shading elements are useful mainly for windows on west and east sides in sunny weather. An egg crate is a mixture of flippers vertically and over hangs horizontally (louvers). As the sun is in center and its radiation in both angels (azimuth and altitude) this kind of shading is very effective shading for windows. The next pictures shows different kinds of basic shading elements, categorized as egg crate. (Figure 17).



Eggcrate Types			
Shading Device	Plan & Side View	Shading Masks	Comments
			Eggcrate types are combinations of horizontal and vertical types. Most effective in hot climates on east and west exposures.
			Eggcrate with slanted vertical fins (slant toward north). Most effective in hot climates on east and west exposures.
			Eggcrate with rotating horizontal louvers. Most effective in hot climates on east and west exposures.

Figure 17: Egg Crate Shading Devices (Brown & DeKay, 2001).

For better outer view of glazing fixed shading elements are normally installed because they minor the direction of radiation that reaches to the indoor ambient and stops the solar radiation. In table one famous fixed external shading elements have been illustrated. All of them are the changed shape of either egg crate or the vertical fin, or the horizontal overhang in a combined way.

The angel of these fins and louvers can be changed for controlling of extra solar radiation (Van Moeseke, 2007).

As can be seen in movable shading devices, without doubt dynamic devices have better performance than static ones especially for this dynamic nature of weather condition in hot and humid climate, so movable shading elements are more popular for using. As it is needed to have shad in hot weather period of a year and in opposite way also solar radiation is needed in cold weather period of a year, the shading elements should be in cooperation with the thermal environments of the building.

When the shading element is in a fixed format, duration of sun radiation to the window and sun position is not the main matter, but the most important issue which should be considered is the temperature (Figure 18). Unluckily, the radiation angles of sun is not totally match with the temperature. For example for one day the weather condition can be completely different, like spring or autumn daily weather is very changeable, one day is very hot and one day is so cold.

A wide constant shading element that can block sun radiation at the end of April is not useful for a cold April day. Another reason for this can be the differences between thermal year and solar year which is not balanced.

According to statistics, the weather condition always starts to change in spring time by getting warm gradually until it reaches to the pick point in summer solstice temperature (21 June). In the same situation, one or two months break time exist in winter cooling cycle time all around the world. 21 of December is the date that exactly sun heat comes to the lowest amount so during a year January and February are two coldest months. The most important advantage of a fixed shading element is its usage before and after 21 of June because it has useful shade in both periods. For instance, the same shade will be created by fixed shade device on 21 of August and 21 of April although always August is considered much hotter than the other months (Crawley, 2004). (Figure 18)

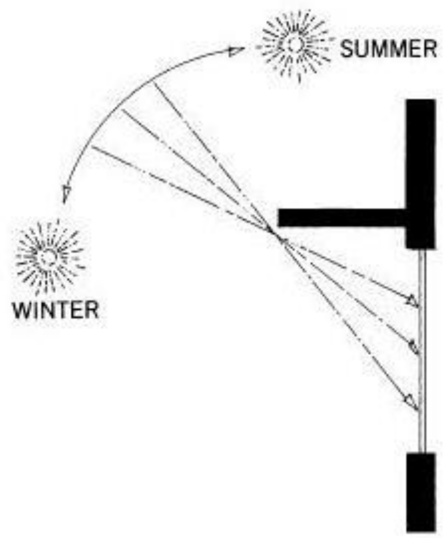


Figure 18: Function of the time of year and not of the temperature (Crawley, 2004).

Shading devices can easily move so it’s a very prominent advantage for them. Not only the system is very simple but also two small changes during a year can meet all the need. At the end of spring when the overheated period commence, the shading element should be extended which most of the time it is done manually. When the overheated period finishes, it means at the end of fall, for full solar elimination the shading element should be extended back (Figure 19) (Wen, Steller Chiang, Shapiro, & Clifford).

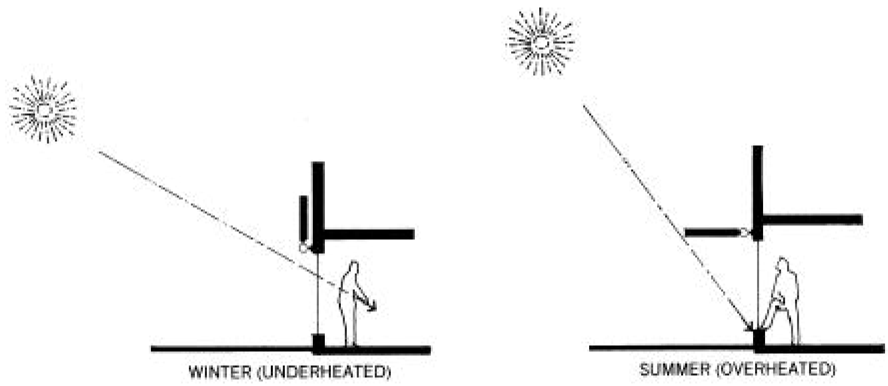


Figure 19: Movable shading device with just two simple adjustments per year (Wen et al.).

In the time that air conditioning wasn’t epidemic, for shading the windows in summer awnings were utilized. Commonly luxury buildings used to have awnings, just like hotel buildings (Figure 20).

When winter commenced for having more sun light these awnings uninstalled from the building. Now modern awnings are fabulous shading elements.

By adjusting shading devices, more attraction can be created and with durability that it has daily and even hourly needs can be met. When there is a desire for adjusting a movable shading device daily in sunny days, often automatic one is used, while when this desire is reduced for two times a year manual one is operated. (Wienold, 2007).

Figure 20: Awnings element on many buildings during the first half of the twentieth century (Wienold, 2007).

It is possible to have these shading devices with the help of some plants, which they are connected to the thermal performance of the building by growing the leaves or missing them according to temperature changes.

Some plants with different treatment also have a prominent advantage which is proved by fact that although these plants don't have leaf but still they can create some shades not very far from the others (Figure 21).

Also, it can be mention that they have disadvantages for example there is limitation in their height, they grow slowly and also there is some possibility for their illness which destroys the plant. Though, growth of vines on a light frame made of bars of wood or metal crossed over each other, fixed to a wall for plants to grow up (Figure 22).

Exterior roller shade is another useful form of movable shading element. For west and east exposures the appropriate shading element is principally the exterior roller shade devices. Especially it is better they are used where half of day is sunny and shading is essential and the other half of day no shading is required (Baldinelli, 2009)

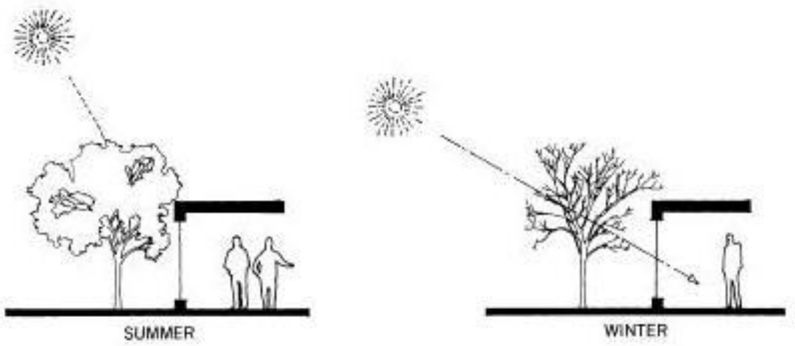


Figure 21: The shading from trees (Baldinelli, 2009).

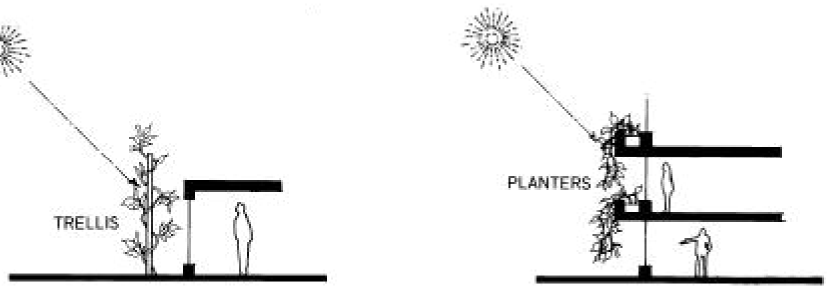


Figure 22: Vines as effective sun shading element (Lechner, 2009).

2.5 Literature Review about Thermal Comfort for Office Buildings

According to Benya in 2003, to provide day lighting of office space and make it brighter, it should be controlled for responding to the existing work and task work in the surrounding area. The works that require more accurate concentration are called task works and the works that paying exact attention is not important in them like casual daily works are called ambient works. (Benya, 2003).

Using day lighting in office buildings will create many profits which some important ones can be named: productivity can be increased, employees will have more motivation, environment will be affected less, electric lighting will be reduced and demand for cooling will be decreased which all in all contains 30-40% of the entire energy consumption in an office building (Connor, 1997).

ISO 7730 uses PMV and PPD directories that is an International Standard. Thermal senses of human can be predicted by these directories that also they can illustrate reasonable thermal environments, in addition these directories can show the feeling of comfortable environment in specific situation which is acceptable. (ISO 7730, 2005)

The creation of thermal comfort in the building depends on four environmental conditions which cause to loss of heat rather than the heat dissipation mechanisms of human body, these four circumstances are:

2.7.1. Mean radiant temperature (MRT)

2.7.2. The speed of air (cm/min)

2.7.3. Comparative Moisture (%)

2.7.4. Air temperature (°C)

These four circumstances influence the human body simultaneously.

When the differences between MRT and air temperature is huge, the result can be thought. For instance when someone sits at the side of window in south direction during the winter she probably feels too much heat, just opposite of the fact that contented air temperature is 24°C. It is obvious that sun's rays increase the MRT which is higher that comfortable level for human. When the sun sets, though she can feel cold just opposite the fact that the room inside temperature is still 24°C because the cold window glass reduces the MRT and the person inside the room will feel radiant lost.

The important case here is being aware about average clothing and skin temperature approximately is 30°C so the temperature and radiant will substitute by space. Normally, the main target is to sustain the temperature (Huizenga, 2006).

Moving of air influence the heat-loss level by each evaporation and convection. Accordingly, one of the main reasons for heat losing is the velocity of the air. During the summer it is perfect quality and during the winter it is risk. From 20 to about 60 cm/min is a contented level for air velocity (Huizenga, 2006).

The humidity of the air directly affects the amount of evaporation of skin dampness. The moisture of the skin can be absorbed by dry air also this swift evaporation can make the body cold efficiently.

In addition, with the 100 percent comparative humidity, water vapor air holds by air so it would be cold by stopping the evaporation. The comfortable level of the RH should be over 20% during the whole year, under 80% during the winter and less than 60 % during the summer.

These limitations are not very accurate, it should be considered that when the humidity range is very low noses, skin, eyes, and mouths will be dry so metabolic developed illnesses will increase (Krishan, 2001).

In contrast the high rate of humidity not only reductions the evaporative cooling rate, but also inspires the creation of skin moisture (sweat), which is very uncomfortable sense for human body.

Convection causes to heat loss by speed because it depends on air temperature. Over 37°C, the hot movement cause the body to gain heat from the air. The range that human feel comfortable for many (80 %) starts between degrees 20°C in winter and 25.5°C in summer (Fiala, 2007).

Chapter 3

RESULTS AND ANALYSIS OF THERMAL COMFORT IN OFFICE BUILDING

3.1 Introduction

The office building is located at the EMU Campus, in the architecture department, the area is 15 m². There are interior walls, interior cell, and interior floor which all of them have different materials to be suitable for the thermal comfort and energy saving. It is quite obvious that openings are a crucial system for office buildings to use natural energy and environmental sources (Figure 23).

Figure 23: Picture of Office building/ EMU University/ Architectural Office Building/Cyprus.

The office working hours during the day is from 8:00 am to 17:00 pm. Furthermore, it is highly believed that interior atmosphere plays an important role in office buildings. Also windows as a lightning source and as an element to save energy, are important as well. TAS simulation defines the material of façade skin, floor, celling, and interior walls which the thickness of them is 20 cm.

3.2 Analysis of TAS Simulation for Office Building

The range of comfort is defined by the kind of cloth, activities, health, and body metabolism level. There are lots of differences among humans and the heath of their bodies plus their activities are totally various especially those which are related to the thermal comfort.

It is essential for human to feel comfortable during winter and summer so Thermal mass, windows, interior walls, and applicable shading devices should provide it (Bainbridge 2011). The prominent function of shading elements is reducing of overheating to prevent from thermal discomfort (Lechner 2009).

Moreover, shading elements creates visual comfort by minimizing the amount of glare. As solar shading elements reduce the necessity of cooling in hot seasons, green buildings require a better rate of solar radiation conservation. Shading methods are considered for saving energy of an office building and also for development of interior thermal comfort (Lin, 2010).

3.2.1 Famagusta, North Cyprus Climate

Cyprus is one of the three large islands in the Mediterranean Sea, it is situated at the north-eastern of the sea. The location of Cyprus is at 34° E longitude and 35° N latitude and after Sardinia and Sicily, Cyprus is the third large island in the Mediterranean Sea (Figure 24).

Also, the distance between Cyprus and Turkey is 65 km, 750km from Greece, 350 km from Egypt, and 95 km from Syria. According to the Geography of the island, Besparmark and Trodos are the two main mountains that lay down on the northern and in the center of the island separately. On the other hand, the city of Famagusta which is a shoreline town is situated at the eastern side of Cyprus and its elevation level is 7m above the sea level (Ozay, 2005).

Figure 24: Map of Cyprus (en.wikipedia.org).

Famagusta, the city which is known for its fast growth and considered as a benefit in North Cyprus growth with a harbor and also historic old city. (Figure 25).

In fact, as the University of EMU established at 1979 the growth of the city has been increased swiftly, therefore Famagusta has changed to a destination for immigrants such as students and their families.

Medieval architecture samples are prominent in Famagusta. Through summer, the temperatures level is from 37°C to 40°C. Through winter, it is also between 9°C to 12°C (Alibaba, 2013). Also, according to 2004 census, the number of people who live in Famagusta city is 42,526 (Pasaogullari & Doratli, 2004)

Figure 25: Location of Famagusta in North Cyprus (www.iansmithestate.com).

3.2.2 TAS Simulation

TAS is a simulation software for 3D building modeling and its thermal analysis. In this software some factors are analyzed, including wind speed (m/s), wind direction (°), global radiation (W), air temperature (°C), and humidity (%). This software evaluates the buildings with some features including materials, environment, and energy.

Data of TAS software show the influence of orientation and effect of horizontal and vertical shading devices on Façades. Also, this software is one of the complete program for analyzing thermal situation expected at optimization of buildings environmentally, and energy efficiency. Furthermore, this software program is available to use in Famagusta weather file was bought from meteorological station of TRNC.

3.3 Methodology

3.3.1 Predicted Mean Vote (PMV) Method

Dynamic thermal simulations via EDSL Tas Software version 9.3.3 (EDSL Tas, 2016) were used for natural ventilation of a standard constructed office building. Famagusta weather data were used for the simulations.

In Figures 26-42, the plan and simulation results of the tested shading device with Predicted Mean Vote (PMV) and Percentage of People Dissatisfied (PPD) are given with all window opening percentages.

The office was deigned to be 3.0 m x 5.0 m in size with a 3.0 m ceiling height. In this office, only one zone with two inlet and outlet windows on east and west walls were placed for testing.

Table 1 gives information on the category for thermal state of the body and local discomfort.

The opaque and glass construction layer properties with U-values are given in Tables 2 and 3 respectively.

In Table 4, ASHARE thermal sensation scale is given. Dynamic simulation results with categories A, B and C with results of PMV were analyzed according to ISO 7730: 2005 and EN 15251: 2007 as shown in Tables 5 and 6 respectively.

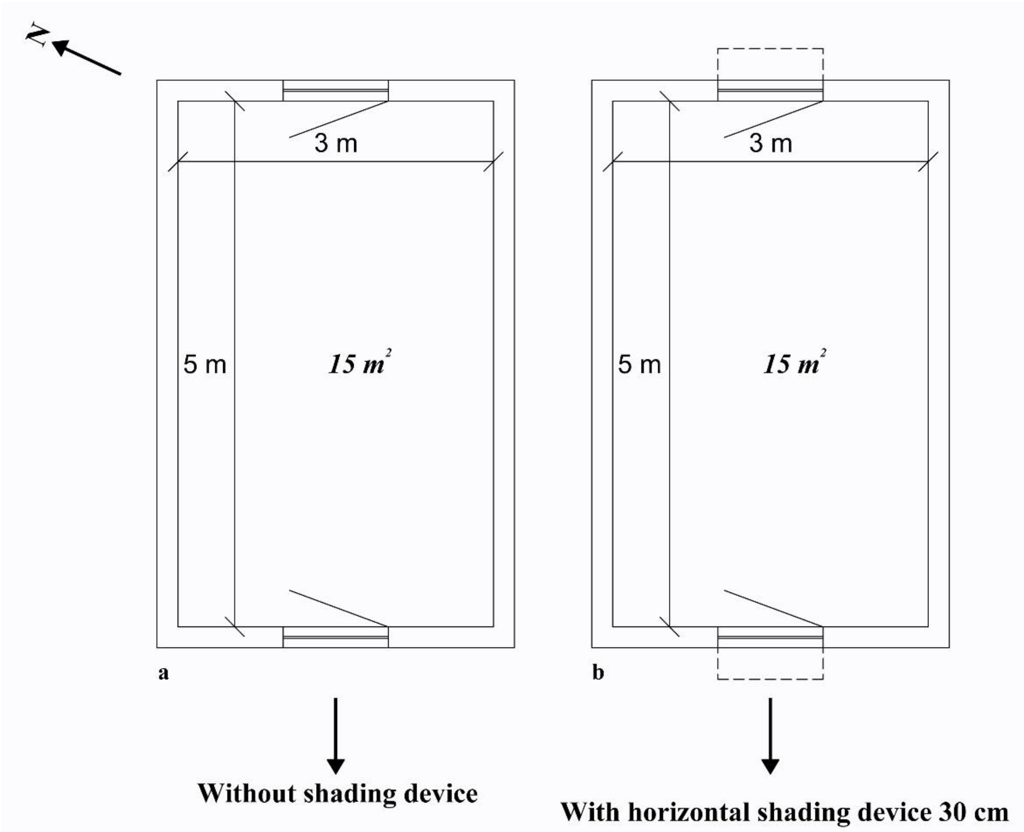


Figure 26: Plan of the Office. Naturally ventilated office dimensions are 3.0 m * 5.0 m * 3.0 m.

Table 1: Classification of thermal environments proposed by ISO 7730: 2005 and EN 15251: 2007.

Category Thermal State of The Body as a Whole			**Local Discomfort**			
	Predicted Percentage of Dissatisfied (%)	Predicted Mean Vote Range	Percentage of Dissatisfied (PD) Due to Draught (%)	PD Due to Vertical Air Temperature Difference (%)	PD Due to Cool of Warm Floor (%)	PD Due to Radiant Temperature Asymmetry (%)
1 (A)	< 6	-0.20 to 0.20	< 10	< 3	< 10	< 5
2 (B)	< 10	-0.50 to 0.50	< 20	< 5	< 10	< 5
3 (C)	< 15	-0.70 to 0.70	< 30	< 10	< 15	< 10
4 (D) (EN 15251)	> 15	< -0.70 or >0.70				

Table 2: Shows used properties of opaque construction layers with U-values for the simulated office.

	U-Value (W/m^2, K)	**Solar Absorptance**		**Emissivity**		**Conductance (W/m^2, °C)**	**Time Constant**
		Ext. Surface	**Int. Surface**	**External**	**Internal**		
Ground floor	0.283	0.760	0.500	0.910	0.900	0.297	127.999
Walls	1.135	0.400	0.400	0.900	0.900	1.407	4.920
Ceiling	1.01	0.700	0.500	0.900	0.900	1.251	13.749

Table 3: Properties of glass construction layers with U-values for the simulated office.

	U-Value (W/m², K)	Solar Transmittance	External Solar Absorptance		Internal Solar Absorptance		Light Transmittance	Time Constant
			Ext. Surf.	Int. Surf.	Ext. Surf.	Int. Surf.		
Windows (clear 6-12-6 double glazing low E)	1.803	0.498	0.173	0.135	0.227	0.097	0.760	0

PMV and PPD results from EDSL Tas Software with its macros part for thermal comfort prediction. The simulated office had one zone with PMV parameters as the following; metabolic rate of 1.2 met, air speed of between 0.15 m/s as the lower limit and 0.3 m/s as the upper limit.

The clothing value was 0.6 clo as the lower value and 0.95 clo as the upper value. The schedule for the office was created for full year (365 days and 24 hours).

Table 4: ASHRAE (2001) scale for thermal sensation.

+3	Hot
+2	Warm
+1	Slightly warm
0	Neutral
-1	Slightly cool
-2	Cool
-3	Cold

3.3.2 Dynamic Simulation of Tas Software with Results

In this research EDSL Tas Software was used with its macros section in order to generate PMV-PPD results for different window opening ratios 0% (closed), 25%, 50% (half open), 75% and 100% (fully open) with fixed shading device sizes of 30 cm for averaged monthly and yearly performances based on office hours which it means between 8:00 am till 17:00 pm.

Three categories (A, B and C) of ISO 7730: 2005 and EN 15251: 2007 were used in order to generate thermal comfort performance of the office during the whole year (8760 h) and office hours (3285 h) as shown in Tables 5, 6, and Figures 27-42.

For horizontal or without shading device with dimensions of 30 cm, in Figure 27 the PMV results in month are shown, in Figure 28 the PMV results of office hours performance in month are shown, in Figure 29 PMV as yearly average for different window opening ratios are shown and Figure 30 shows PMV results of office hours performance for different window opening ratios and Figure 31 shows results regarding category A (-0.20 to 0.20).

Figure 32 shows results of office hours performance regarding to category A (-0.20 to 0.20). Figure 33 shows results PMV and MRT regarding to category A (-0.20 to 0.20), B (-0.50 to 0.50), C (-0.70 to 0.70). Figure 34 shows results PMV and MRT regarding to category A (-0.20 to 0.20), B (-0.50 to 0.50), C (-0.70 to 0.70) based on office hour's performance.

Figure 35 shows results of PPD horizontal shading device by 30 cm, percentage of dissatisfied due to draught % regarding to category A (-0.20 to 0.20), B (-0.50 to 0.50), C (-0.70 to 0.70). Figure 36 shows results of PPD horizontal shading device by 30 cm, percentage of dissatisfied due to draught %, based on office hour's performance regarding to category A (-0.20 to 0.20), B (-0.50 to 0.50), C (-0.70 to 0.70).

Figure 37 shows results of PPD horizontal shading device by 30 cm, percentage of dissatisfied due to vertical air temperature difference % regarding to category A (-0.20 to 0.20), B (-0.50 to 0.50), C (-0.70 to 0.70).

Figure 38 shows results of PPD horizontal shading device by 30 cm, percentage of dissatisfied due to vertical air temperature difference %, based on office hour's performance regarding to category A (-0.20 to 0.20), B (-0.50 to 0.50), C (-0.70 to 0.70).

Figure 39 shows results of PPD horizontal shading device by 30 cm, percentage of dissatisfied due to cool or warm floor % regarding to category A (-0.20 to 0.20), B (-0.50 to 0.50), C (-0.70 to 0.70). Figure 40 shows results of PPD horizontal shading device by 30 cm, percentage of dissatisfied due to cool or warm floor %, based on office hour's performance regarding to category A (-0.20 to 0.20), B (-0.50 to 0.50), C (-0.70 to 0.70).

Figure 41 shows results of PPD horizontal shading device by 30 cm, percentage of dissatisfied due to radiant temperature asymmetry % regarding to category A (-0.20 to 0.20), B (-0.50 to 0.50), C (-0.70 to 0.70).

Figure 42 shows results of PPD horizontal shading device by 30 cm, percentage of dissatisfied due to radiant temperature asymmetry %, based on office hour's performance regarding to category A (-0.20 to 0.20), B (-0.50 to 0.50), C (-0.70 to 0.70).

In May, PMV based on office hour's performance was 0.04 when window was 0% (closed), and 25%, whereas it was 0.06, 0.07, and 0.07 when window was 50% (half) open, 75% and 100% (fully) open. In October, PMV was 0.16, 0.19, and 0.2 when window was 0%, 25% and 50% open, also it was 0.21 when window was 75% and 100% open.

According to category B, PMV performance is (-0.50 to 0.50); PMV based on office hour's performance was 0.04 when window was 0% (closed), and 25%, however it was 0.06, 0.07, and 0.07 when window was 50% (half) open, 75% and 100% (fully) open. In October, PMV performance according to office hours was 0.16, 0.19, and 0.2 when window was 0%, 25% and 50% open, also it was 0.21 when window was 75% and 100% open.

According to category C, PMV performance is (-0.70 to 0.70); apart from May, the months October, and November may also be added, whereas in November, PMV is -0.7, -0.68, and -0.66 when window was 50%, 75%, and 100% open.

The yearly average PMV was -0.41 when window was 0% open (closed), -0.42 when window was 0.25% open, -0.43 when window was 0.50% open, -0.44 when window was 0.75% open and -0.45 when window was 100% (fully) open as given in Figure 27.

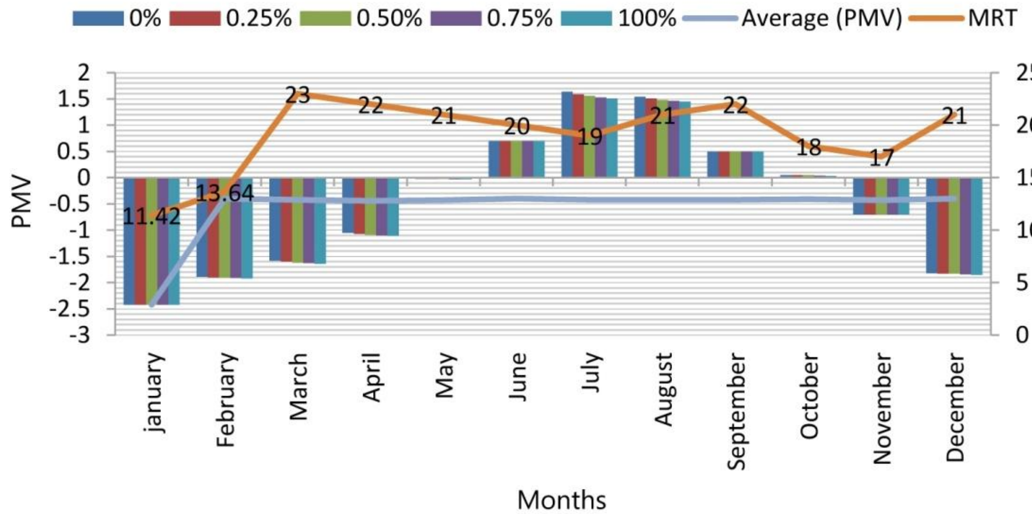


Figure 27: According to 24 hours performance/ Predicted Mean Vote (PMV) and Mean Radiant Temperature (MRT) results of each month with different window opening percentages for whole (8760 hr.) year with M: 1.2 met, air speed of 0.15-0.3 m/s, clothing value of 0.6-0.95 clo.

The yearly average PMV performance based on office hours was -0.34 when window was 0% open (closed), -0.25 when window was 25% open, -0.21 when window was 50% open, -0.2 when window was 75% open and -0.19 when window was 100% (fully) open as given in Figure 28.

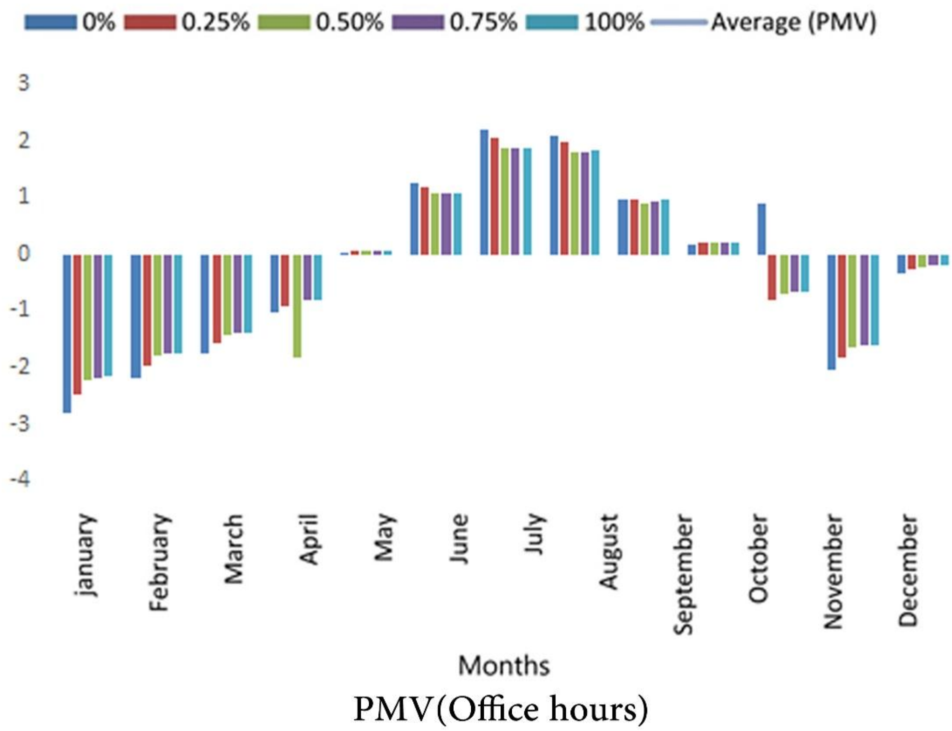


Figure 28: According to office hour's performance/ Predicted Mean Vote (PMV) results of each month with different window opening percentages for whole (3285 hr.) year with M: 1.2 met, air speed of 0.15-0.3 m/s, clothing value of 0.6-0.95 clo.

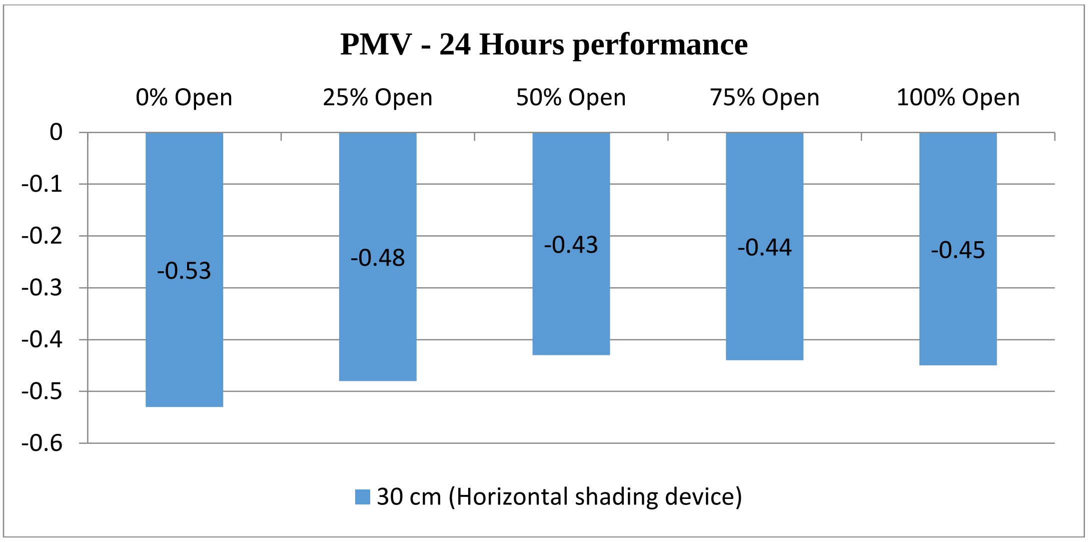


Figure 29: According to 24 hours performance/ Predicted Mean Vote (PMV) performance of different window opening ratios during a whole year.

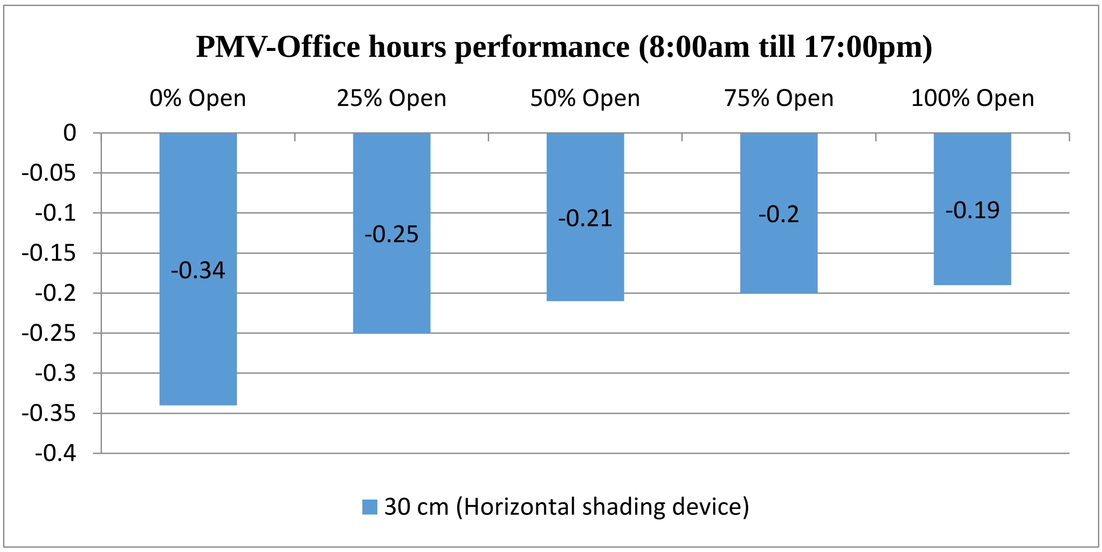


Figure 30: According to office hour's performance/Predicted Mean Vote (PMV) performance of different window opening ratios during a whole year.

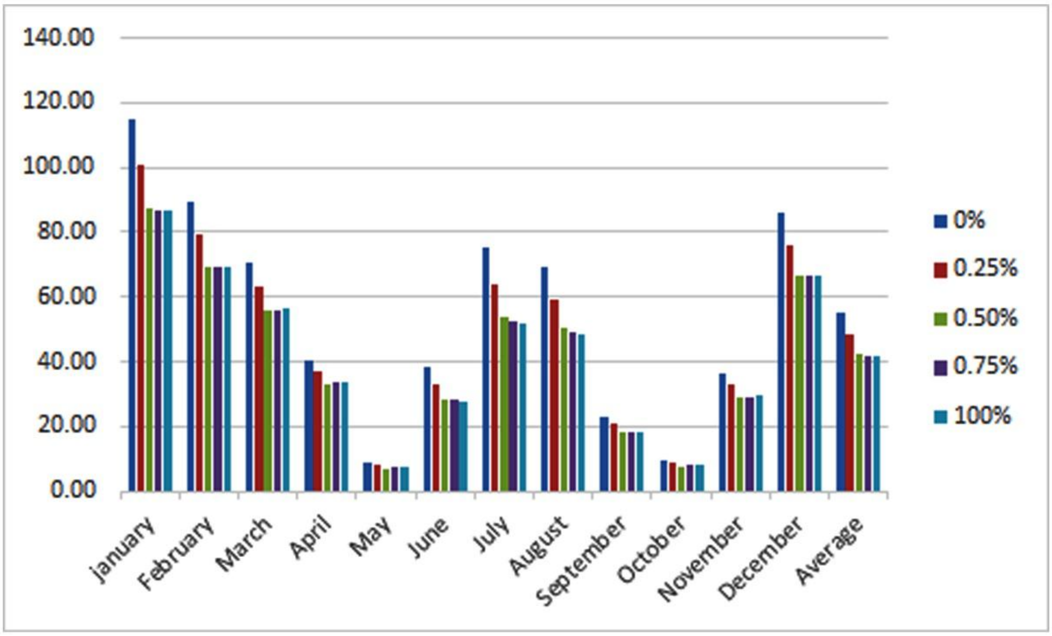


Figure 31: According to 24 hours performance/ Predicted Mean Vote (PMV) as monthly categorization according to (A) -0.2 to 0.2, (B) -0.5 to 0.5 and (C) -0.7 to 0.7.

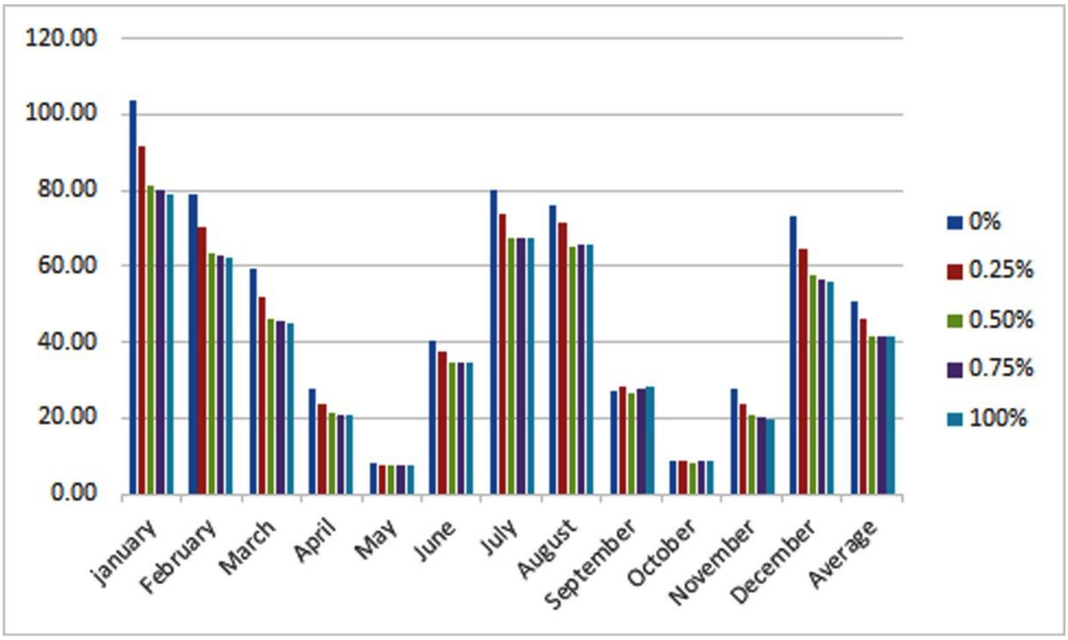


Figure 32: According to office hour's performance/Predicted Mean Vote (PMV) as monthly categorization according to (A) -0.2 to 0.2, (B) -0.5 to 0.5 and (C) -0.7 to 0.7.

Table 5: Predicted Percentage of Dissatisfied People (PPD) and Predicted Mean Vote (PMV) results for a whole (8760 hr.) year for categories A, B and C with M: 1.2met, air speed of 0.15-0.3 m/s, and clothing value of 0.6-0.95 clo.

PPD (%)		PMV							
(A) <6		(A) -0.2 to 0.2	PMV-30cm- Horizontal Shading Devices- 24 hours performance						
(B) <10		(B) -0.5 to 0.5	Win. Opening (%)	0%	0.25%	0.50%	0.75%	100%	PPD (%) (A) <6 and PMV (A) -0.2 to 0.2 \ PPD (%) (B) <10 and PMV (B) -0.5 to 0.5 \ PPD (%) (C) <15 and PMV (A) -0.7 to 0.7
(C) <15		(C) -0.7 to 0.7	Months (~)	~Hrs.	~Hrs.	~Hrs.	~Hrs.	~Hrs.	
Winter	Under-heated (cool) period	A (-0.2 to 0.2)	January (~ Hrs.)						
		B (-0.5 to 0.5)							
		C (-0.7 to 0.7)							
		A (-0.2 to 0.2)	February (~ Hrs.)			0 Hr.			
		B (-0.5 to 0.5)							
		C (-0.7 to 0.7)							
Spring		A (-0.2 to 0.2)	March (~ Hrs.)						
		B (-0.5 to 0.5)							
		C (-0.7 to 0.7)		0 Hr.			1 Hr.		
		A (-0.2 to 0.2)	April (~ Hrs.)	5 Hrs.	9 Hrs.		10 Hrs.		
		B (-0.5 to 0.5)		58 Hrs.	60 Hrs.	62 Hrs.	61 Hrs.		
		C (-0.7 to 0.7)		126 Hrs.	139 Hrs.	138 Hrs.	142 Hrs.		
	Over-heated (warm) period	A (-0.2 to 0.2)	May (~ Hrs.)	**320 Hrs.**	**314 Hrs.**	**313 Hrs.**	**315 Hrs.**	**320 Hrs.**	
		B (-0.5 to 0.5)		**704 Hrs.**	**698 Hrs.**	**679 Hrs.**	**676 Hrs.**	**672 Hrs.**	
		C (-0.7 to 0.7)		**728 Hrs.**	**724 Hrs.**	**713 Hrs.**	**711 Hrs.**	**709 Hrs.**	
Summer		A (-0.2 to 0.2)	June (~ Hrs.)	113 Hrs.	110 Hrs.	123 Hrs.	127 Hrs.	130 Hrs.	
		B (-0.5 to 0.5)		294 Hrs.	308 Hrs.	317 Hrs.	318 Hrs.	322 Hrs.	
		C (-0.7 to 0.7)		**460 Hrs.**	**455 Hrs.**	**456 Hrs.**	**458 Hrs.**	**464 Hrs.**	
		A (-0.2 to 0.2)	July (~ Hrs.)	1 Hrs.	5 Hrs.	8 Hrs.	8 Hrs.		
		B (-0.5 to 0.5)		8 Hrs.	17 Hrs.	27 Hrs.	36 Hrs.	44 Hrs.	
		C (-0.7 to 0.7)		29 Hrs.	45 Hrs.	55 Hrs.	61 Hrs.	73 Hrs.	
		A (-0.2 to 0.2)	August (~ Hrs.)			0 Hr.		1 Hrs.	
		B (-0.5 to 0.5)		1 Hrs.	2 Hrs.	5 Hrs.	11 Hrs.	15 Hrs.	
		C (-0.7 to 0.7)		4 Hrs.	15 Hrs.	32 Hrs.	43 Hrs.	50 Hrs.	
Autumn		A (-0.2 to 0.2)	September (~ Hrs.)	132 Hrs.	119 Hrs.	132 Hrs.	134 Hrs.	135 Hrs.	
		B (-0.5 to 0.5)		345 Hrs.	355 Hrs.	365 Hrs.	371 Hrs.	380 Hrs.	
		C (-0.7 to 0.7)		452 Hrs.	445 Hrs.	447 Hrs.	459 Hrs.	466 Hrs.	
		A (-0.2 to 0.2)	October (~ Hrs.)	**324 Hrs.**	**305 Hrs.**	**295 Hrs.**	**291 Hrs.**	**296 Hrs.**	
		B (-0.5 to 0.5)		**671 Hrs.**	**654 Hrs.**	**643 Hrs.**	**634 Hrs.**	**632 Hrs.**	
		C (-0.7 to 0.7)		**717 Hrs.**	**703 Hrs.**	**697 Hrs.**	**692 Hrs.**	**693 Hrs.**	
	Un.-he.(cool) period	A (-0.2 to 0.2)	November (~ Hrs.)	80 Hrs.	78 Hrs.	77 Hrs.	78 Hrs.		
		B (-0.5 to 0.5)		193 Hrs.	207 Hrs.	211 Hrs.		208 Hrs.	
		C (-0.7 to 0.7)		**265 Hrs.**	**266 Hrs.**	**271 Hrs.**	**273 Hrs.**	**267 Hrs.**	
Winter		A (-0.2 to 0.2)	December (~ Hrs.)						
		B (-0.5 to 0.5)				0 Hr.			
		C (-0.7 to 0.7)			0 Hr.		3 Hrs.	1 Hr.	~ Total
All Year-8760 Hrs.	Non Com	A (-0.2 to 0.2)	All Year ~ Hrs.	~975 Hrs.	~940 Hrs.	~957 Hrs.	~963 Hrs.	~978 Hrs.	~ 963 Hrs.
		A (-0.43)	All Year Average-%	0.11%	0.10%	0.10%	0.10%	0.11%	~ 0.10%
	Comfort	**B (-0.5 to 0.5)**	**All Year ~ Hrs.**	**~2274 Hrs.**	**~2301 Hrs.**	**~2309 Hrs.**	**~2318 Hrs.**	**2334 Hrs**	**2307 Hrs.**
		B (-0.43)	**All Year Average-%**	**0.25%**	**0.26%**	**0.26%**	**0.26%**	**0.26%**	**~ 0.26%**
	Comfort	**C (-0.7 to 0.7)**	**All Year ~ Hrs.**	**~2781 Hrs.**	**~2792 Hrs.**	**~2810 Hrs.**	**~2840 Hrs.**	**2866 Hrs**	**2818 Hrs.**
		C (-0.43)	**All Year Average-%**	**0.31%**	**0.31%**	**0.32%**	**0.32%**	**0.32%**	**~ 0.32%**

PMV (A) Thermal Comfort Conditions	PMV (A-B-C) Non Thermal Comfort Conditions
PMV (B) Thermal Comfort Conditions	~ Average
PMV (C) Thermal Comfort Conditions	

Table 6: Predicted Percentage of Dissatisfied People (PPD) and Predicted Mean Vote (PMV) results based on office hour's performance for a whole (8760 hr.) year for categories A, B and C with M: 1.2met, air speed of 0.15-0.3 m/s, and clothing value of 0.6-0.95 clo

PPD (%)	PMV								
(A) <6	(A) -0.2 to 0.2	PMV-30cm- Horizontal Shading Devices- Office hours performance (8:00am till 17:00pm)							
(B) <10	(B) -0.5 to 0.5	Win. Opening (%)		0%	0.25%	0.50%	0.75%	100%	PPD (%) (A) <6 and PMV (A) -0.2 to 0.2 \ PPD (%) (B) <10 and PMV (B) -0.5 to 0.5 \ PPD (%) (C) <15 and PMV (A) -0.7 to 0.7
(C) <15	(C) -0.7 to 0.7	Months (~)		~Hrs.	~Hrs.	~Hrs.	~Hrs.	~Hrs.	
Winter	Under-heated (cool) period	A (-0.2 to 0.2)	January (~ Hrs.)	0 Hr					
		B (-0.5 to 0.5)							
		C (-0.7 to 0.7)							
		A (-0.2 to 0.2)	February (~ Hrs.)						
		B (-0.5 to 0.5)							
		C (-0.7 to 0.7)							
Spring		A (-0.2 to 0.2)	March (~ Hrs.)						
		B (-0.5 to 0.5)							
		C (-0.7 to 0.7)		0 Hr			1 Hr.		
		A (-0.2 to 0.2)	April (~ Hrs.)	4 Hrs.	8 Hrs.	9 Hrs.	10 Hrs.		
		B (-0.5 to 0.5)		35 Hrs.	44 Hrs.	47 Hrs.	10 Hrs.	11 Hrs.	
		C (-0.7 to 0.7)		72 Hrs.	96 Hrs.	99 Hrs.	13 Hrs.	14 Hrs.	
	Over-heated (warm) period	A (-0.2 to 0.2)	May (~ Hrs.)	119 Hrs.	115 Hrs.	112 Hrs.	115 Hrs.	118 Hrs.	
		B (-0.5 to 0.5)		265 Hrs.	267 Hrs.	262 Hrs.	262 Hrs.	262 Hrs.	
		C (-0.7 to 0.7)		272 Hrs.	277 Hrs.	276 Hrs.	274 Hrs.	274 Hrs.	
Summer		A (-0.2 to 0.2)	June (~ Hrs.)	33 Hrs.	30 Hrs.	29 Hrs.	29 Hrs.	30 Hrs.	
		B (-0.5 to 0.5)		69 Hrs.	58 Hrs.	56 Hrs.	50 Hrs.	52 Hrs.	
		C (-0.7 to 0.7)		131 Hrs.	95 Hrs.	91 Hrs.	90 Hrs.	85 Hrs.	
		A (-0.2 to 0.2)	July (~ Hrs.)	0 Hr					
		B (-0.5 to 0.5)							
		C (-0.7 to 0.7)							
		A (-0.2 to 0.2)	August (~ Hrs.)						
		B (-0.5 to 0.5)							
		C (-0.7 to 0.7)							
Autumn		A (-0.2 to 0.2)	September (~ Hrs.)	34 Hrs.	28Hrs.	25 Hrs.	22 Hrs.	22 Hrs.	
		B (-0.5 to 0.5)		76 Hrs.	63 Hrs.	58Hrs.	58 Hrs.	57 Hrs.	
		C (-0.7 to 0.7)		123 Hrs.	99 Hrs.	95 Hrs.	89 Hrs.	88 Hrs.	
		A (-0.2 to 0.2)	October (~ Hrs.)	130 Hrs.	112Hrs.	110 Hrs.	106 Hrs.	100 Hrs.	
		B (-0.5 to 0.5)		242 Hrs.	229 Hrs.	225 Hrs.	224 Hrs.	222 Hrs.	
		C (-0.7 to 0.7)		264 Hrs.	254 Hrs.	251 Hrs.	244 Hrs.	243 Hrs.	
	Un.-he.(cool) period	A (-0.2 to 0.2)	November (~ Hrs.)	32 Hrs.	34 Hrs.	34 Hrs.	35 Hrs.	37 Hrs.	
		B (-0.5 to 0.5)		86 Hrs.	99 Hrs.	104Hrs.	107Hrs.	108 Hrs.	
		C (-0.7 to 0.7)		126 Hrs.	135 Hrs.	141 Hrs.	140 Hrs.	140Hrs.	
Winter		A (-0.2 to 0.2)	December (~ Hrs.)	0 Hr					
		B (-0.5 to 0.5)							
		C (-0.7 to 0.7)							~ Total
All Year-8760 Hrs.	Non Com	A (-0.2 to 0.2)	All Year ~ Hrs.	~352 Hrs.	~327 Hrs.	~319 Hrs.	~317 Hrs.	~317 Hrs.	~ 327 Hrs.
		A (-0.43)	All Year Average-%	0.04%	0.03%	0.03%	0.03%	0.03%	~0.03%
	Comfort	B (-0.5 to 0.5)	All Year ~ Hrs.	~773 Hrs.	~760 Hrs.	~752 Hrs.	~711 Hrs.	~712 Hrs	~ 742 Hrs.
		B (-0.43)	All Year Average-%	0.08%	0.08%	0.08%	0.08%	0.08%	~0.08%
	Comfort	C (-0.7 to 0.7)	All Year ~ Hrs.	~988 Hrs.	~966 Hrs.	~954 Hrs.	~852 Hrs.	~847 Hrs	~ 921 Hrs.
		C (-0.43)	All Year Average-%	0.11%	0.11%	0.10%	0.09%	0.09%	~ 0.10%
		PMV (A) Thermal Comfort Conditions				PMV (A-B-C) Non Thermal Comfort Conditions			
		PMV (B) Thermal Comfort Conditions			~ Average				
			PMV (C) Thermal Comfort Conditions						

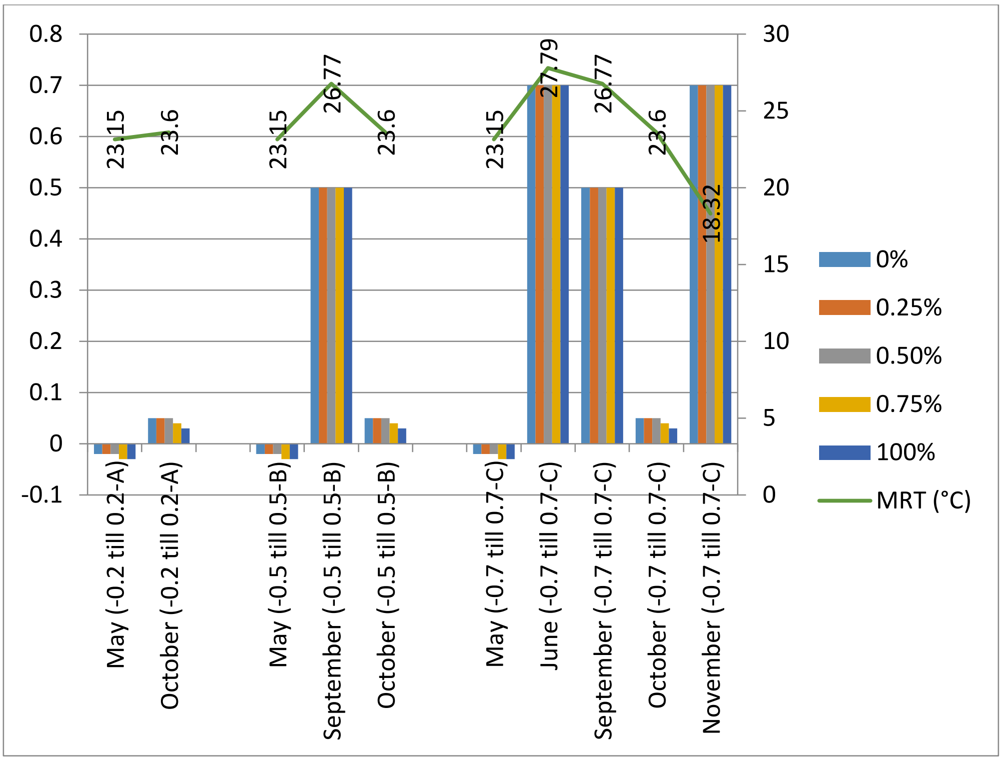


Figure 33: According to 24 hours performance/ Predicted Mean Vote (PMV) as monthly categorization according to (A) -0.2 to 0.2, (B) -0.5 to 0.5 and (C) -0.7 to 0.7 and MRT.

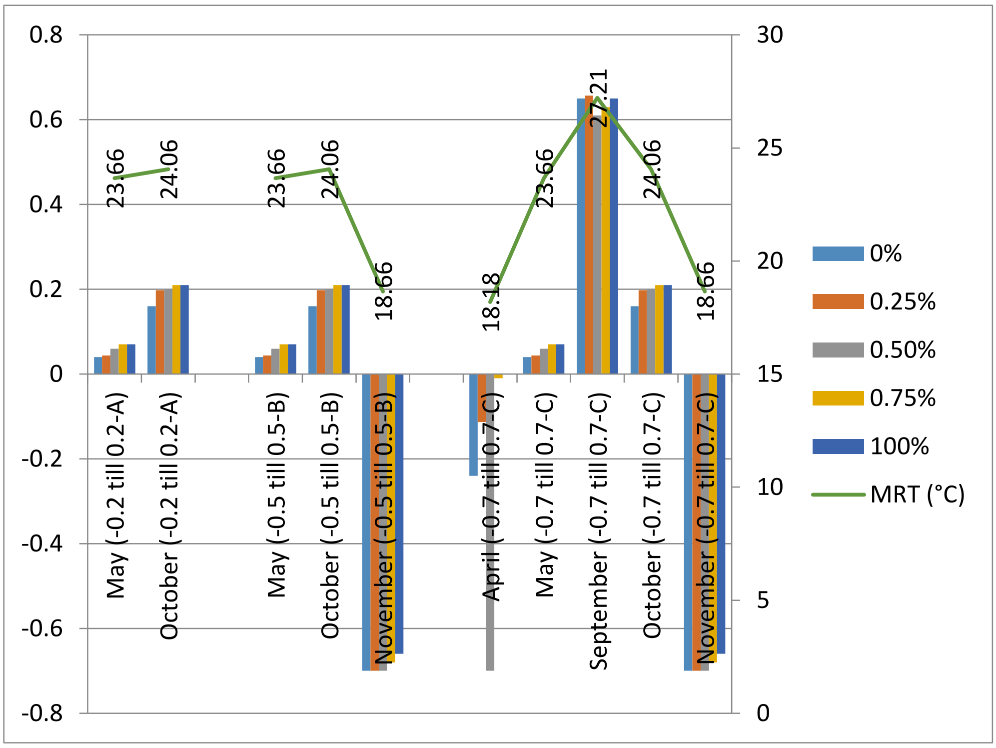


Figure 34: According to Office hour's performance/ Predicted Mean Vote (PMV) as monthly categorization according to (A) -0.2 to 0.2, (B) -0.5 to 0.5 and (C) -0.7 to 0.7 and MRT.

According to the office hours with all the window openings (0% to 100%), PPD hours according to categories A, B and C that were in thermal comfort are shown in red, green and blue colors and dotted parts show non-thermal comfort times.

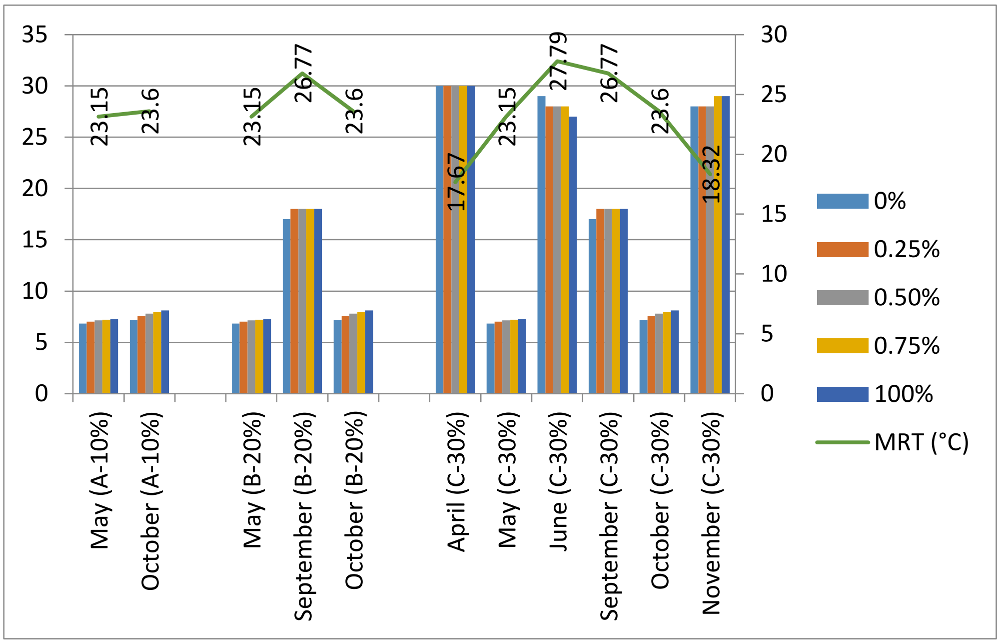


Figure 35: According to 24 hours performance/Percentage of Dissatisfied People (PPD) for Draught performance where (A) up to 10%, (B) up to 20% and (C) up to 30%.

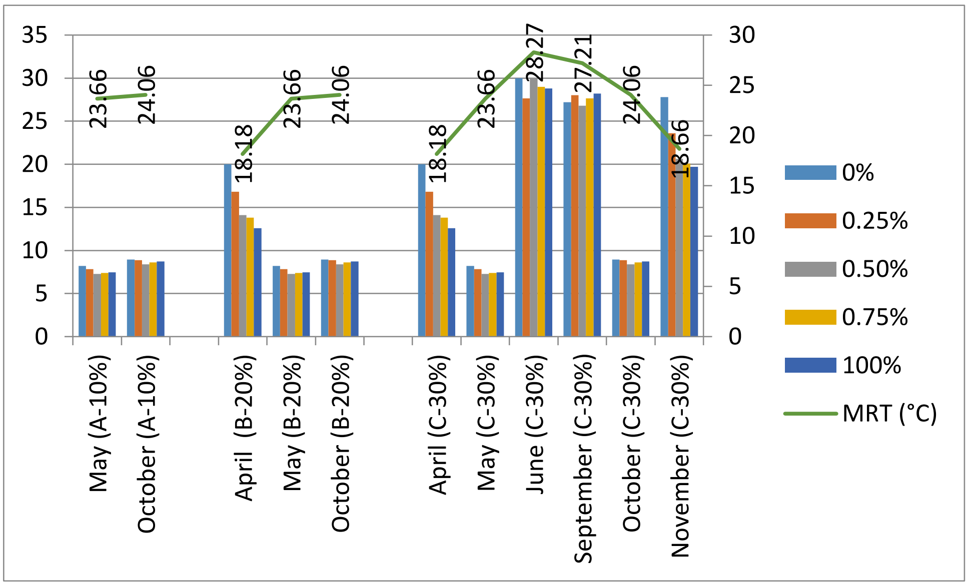


Figure 36: According to Office hour’s performance/Percentage of Dissatisfied People (PPD) for Draught performance where (A) up to 10%, (B) up to 20% and (C) up to 30%.

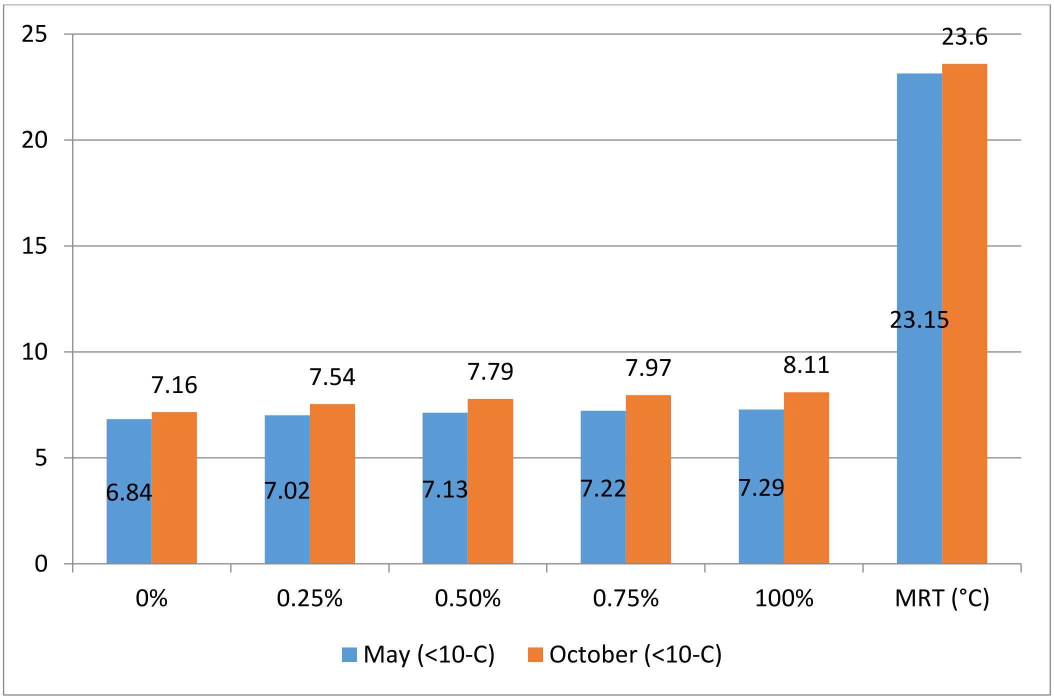


Figure 37: According to 24 hours performance/Percentage of Dissatisfied People (PPD) due to Vertical Air Temperature Difference performance where (A) up to 3%-no performance existing, (B) up to 5%-no performance existing and (C) up to 10%.

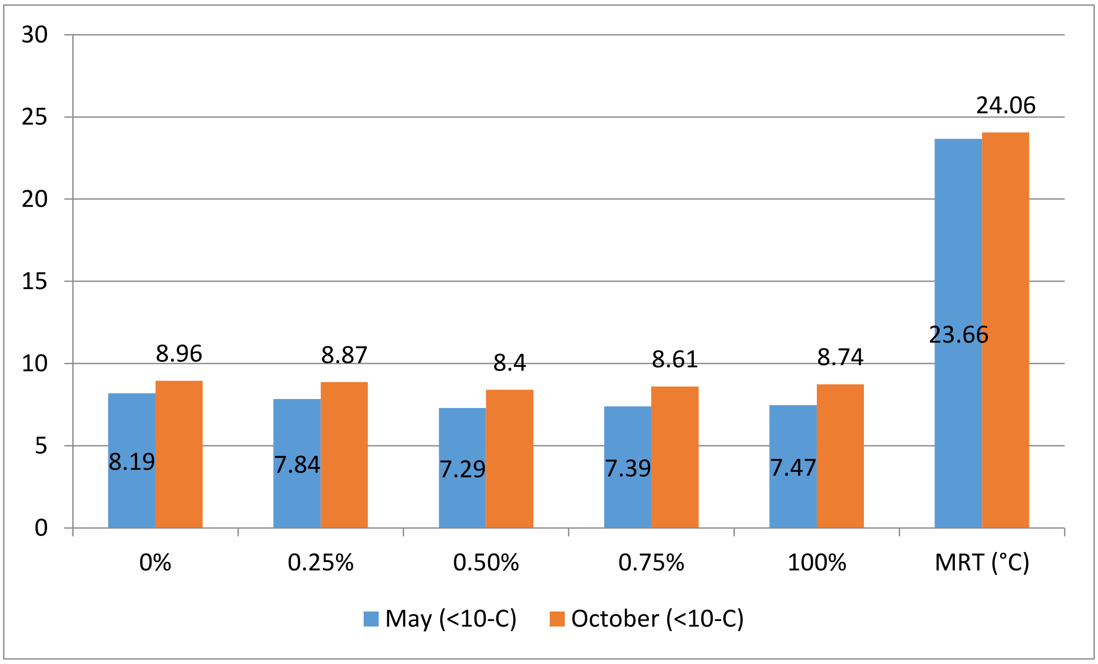


Figure 38: According to Office hour's performance/Percentage of Dissatisfied People (PPD) due to Vertical Air Temperature Difference performance where (A) up to 3%-no performance existing, (B) up to 5%-no performance existing and (C) up to 10%.

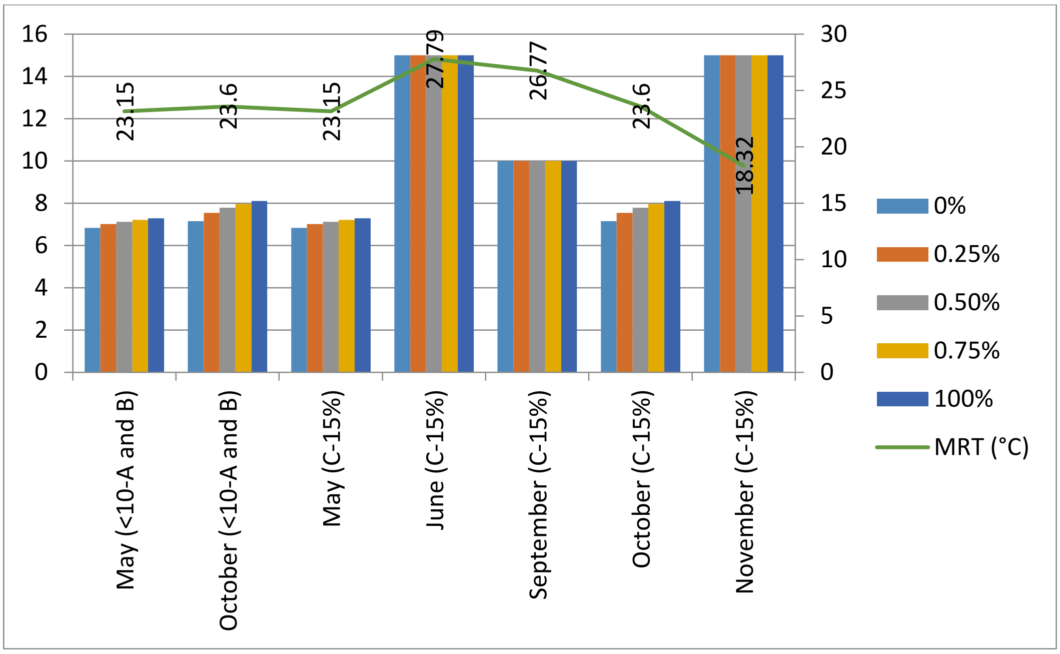


Figure 39: According to 24 hour's performance/Percentage of Dissatisfied People (PPD) due to Cool of Warm Floor where (A) and (B) up to 10% and (C) up to 15%.

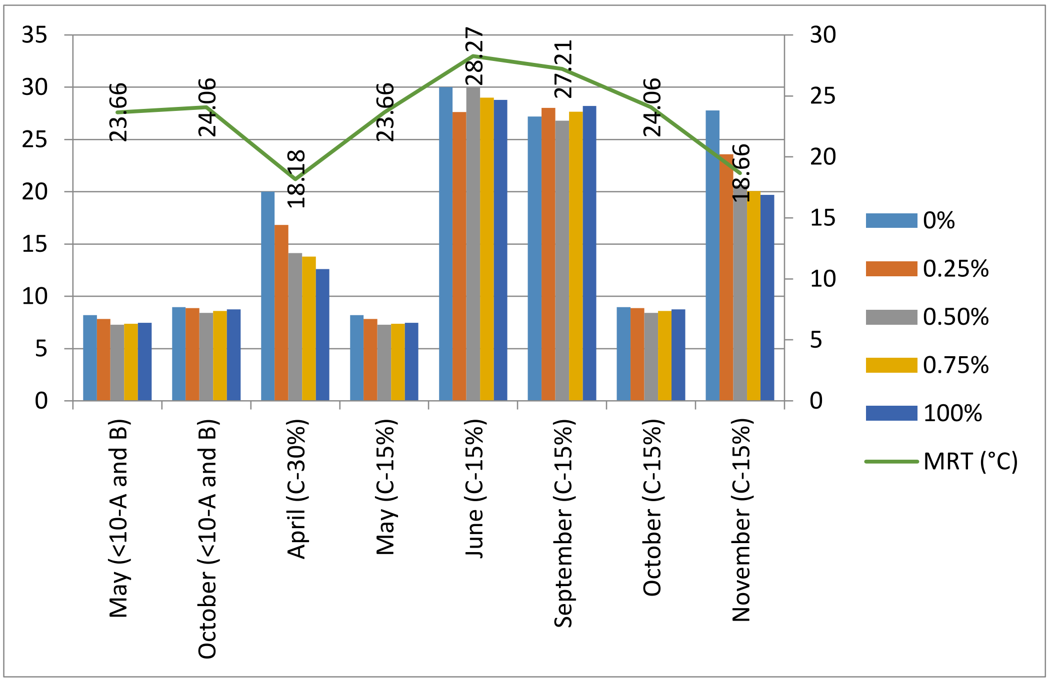


Figure 40: According to Office hour's performance/Percentage of Dissatisfied People (PPD) due to Cool of Warm Floor where (A) and (B) up to 10% and (C) up to 15%.

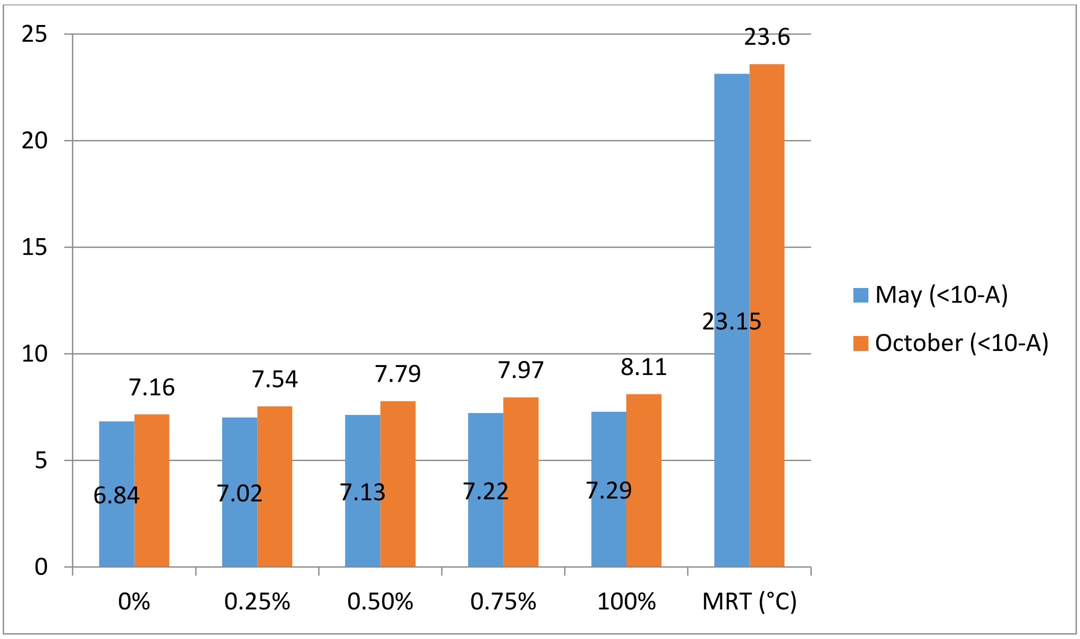


Figure 41: According to 24 hour's performance/Percentage of Dissatisfied People (PPD) due to Radiant Temperature Asymmetry where (A) and (B) up to 5%- no performance existing and (C) up to 10%.

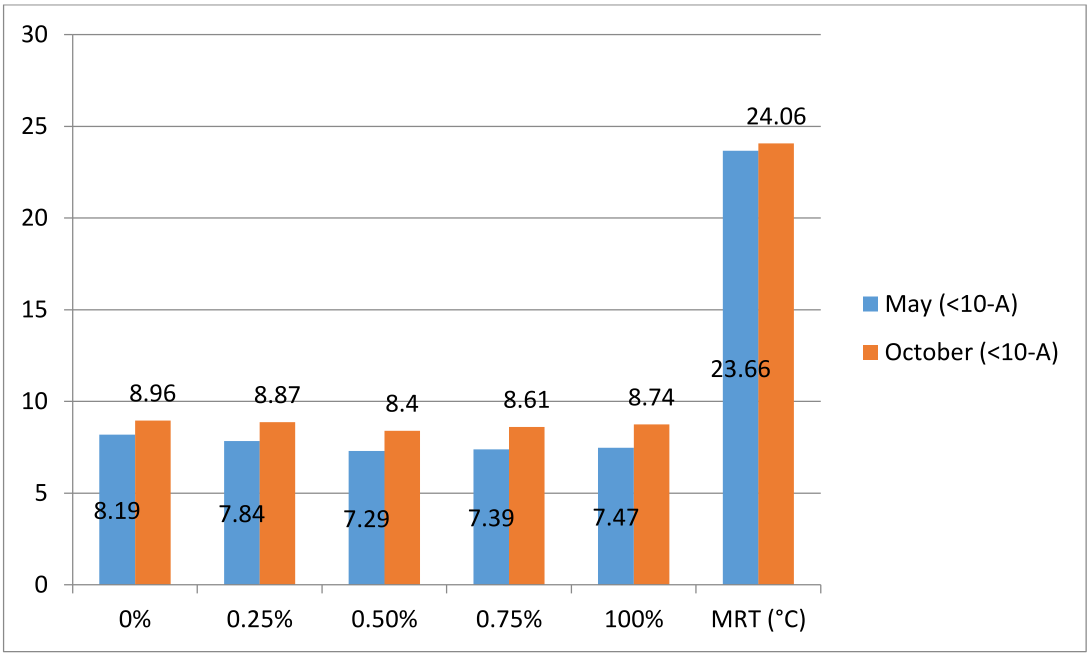


Figure 42: According to Office hour's performance/Percentage of Dissatisfied People (PPD) due to Radiant Temperature Asymmetry where (A) and (B) up to 5%- no performance existing and (C) up to 10%.

In this research analysis by EDSL Tas Software illustrates the data which can be seen in these below tables;

Table 7 illustrates the PMV-Horizontal shading devices by distance of 30 cm. Table 8 illustrates the PPD-Horizontal shading devices by distance of 30 cm.

Table 9 till and table 12 illustrate the PPD-Horizontal shading devices by distance of 30 cm according to Percentage of Dissatisfied Due to Draught %, PD Due to Vertical Air Temperature Difference %, PD Due to Cool or Warm Floor %, and PD Due to Radiant Temperature Asymmetry %, respectively.

Table 13 illustrates the MRT-Horizontal shading devices, and without shading device by distance of 30 cm.

Table 7: PMV-Horizontal Shading Device-30 cm

		PMV-Horizontal Shading Device-30 cm										
Seasons		Window Opening Ratio	0%-closed-24 HOURS	0%-closed- 8AM Till 5 PM	25%-24 HOURS	25%- 8AM Till 5 PM	50%-half-24 HOURS	50%-half- 8AM Till 5 PM	75%-24 HOURS	75%- 8AM Till 5 PM	100%-full-24 HOURS	100%-full- 8AM Till 5 PM
Under-heated (cool) period	Winter	**Jan. (montly average (PMV)**	-2.42	-2.34	-2.42	-2.25	-2.42	-2.21	-2.42	-2.18	-2.42	-2.15
		(-0.2 to 0.2)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(-0.5 to 0.5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(-0.7 to 0.7)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		Feb. (montly average (PMV)	-1.89	-1.82	-1.9	-1.79	-1.9	-1.77	-1.91	-1.76	-1.92	-1.75
		(-0.2 to 0.2)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(-0.5 to 0.5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(-0.7 to 0.7)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
	Spring	**Mar. (montly average (PMV)**	-1.58	-1.47	-1.6	-1.43	-1.62	-1.41	-1.63	-1.4	-1.64	-1.39
		(-0.2 to 0.2)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(-0.5 to 0.5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(-0.7 to 0.7)	0 hr.	0 hr.	0 hr.	0 hr.	1 hr.	1 hr.	1 hr.	1 hr.	1 hr.	0 hr.
		Apr. (montly average (PMV)	-1.05	-0.87	-1.07	-0.83	-1.09	-1.82	-1.1	-0.81	-1.11	-0.8
		(-0.2 to 0.2)	5 hr.	4 hr.	9 hr.	8 hr.	9 hr.	9 hr.	10 hr.	10 hr.	10 hr.	10 hr.
		(-0.5 to 0.5)	58 hr.	35 hr.	60 hr.	44 hr.	62 hr.	47 hr.	61 hr.	10 hr.	61 hr.	11 hr.
		(-0.7 to 0.7)	126 hr.	72 hr.	139 hr.	96 hr.	138 hr.	99 hr.	142 hr.	13 hr.	142 hr.	14 hr.
Over-heated (warm) period		**May. (montly average (PMV)**	-0.02	0.03	-0.02	0.04	-0.02	0.06	-0.03	0.07	-0.03	0.07
		(-0.2 to 0.2)	320 hr.	119 hr.	314 hr.	115 hr.	313 hr.	112 hr.	315 hr.	115 hr.	320 hr.	118 hr.
		(-0.5 to 0.5)	704 hr.	265 hr.	698 hr.	267 hr.	679 hr.	262 hr.	676 hr.	262 hr.	672 hr.	262 hr.
		(-0.7 to 0.7)	728 hr.	272 hr.	724 hr.	277 hr.	713 hr.	276 hr.	711 hr.	274 hr.	709 hr.	274 hr.
	Summer	**Jun. (montly average (PMV)**	0.85	1.03	0.83	1.06	0.82	1.08	0.81	1.08	0.81	1.09
		(-0.2 to 0.2)	113 hr.	33 hr.	110 hr.	30 hr.	123 hr.	29 hr.	127 hr.	29 hr.	130 hr.	30 hr.
		(-0.5 to 0.5)	294 hr.	69 hr.	308 hr.	58 hr.	317 hr.	56 hr.	318 hr.	50 hr.	322 hr.	52 hr.
		(-0.7 to 0.7)	377 hr.	109 hr.	376 hr.	95 hr.	375 hr.	91 hr.	376 hr.	90 hr.	379 hr.	85 hr.
		Jul. (montly average (PMV)	1.64	1.84	1.59	1.87	1.56	1.87	1.53	1.88	1.51	1.88
		(-0.2 to 0.2)	1 hr.	0 hr.	5 hr.	0 hr.	8 hr.	0 hr.	8 hr.	0 hr.	8 hr.	0 hr.
		(-0.5 to 0.5)	8 hr.	0 hr.	17 hr.	0 hr.	27 hr.	0 hr.	36 hr.	0 hr.	44 hr.	0 hr.
		(-0.7 to 0.7)	29 hr.	0 hr.	45 hr.	0 hr.	55 hr.	0 hr.	61 hr.	0 hr.	73 hr.	0 hr.
		Aug. (montly average (PMV)	1.54	1.75	1.51	1.79	1.48	1.8	1.46	1.81	1.45	1.82
		(-0.2 to 0.2)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	1 hr.	0 hr.
		(-0.5 to 0.5)	1 hr.	0 hr.	2 hr.	0 hr.	5 hr.	0 hr.	11 hr.	0 hr.	15 hr.	0 hr.
		(-0.7 to 0.7)	4 hr.	0 hr.	15 hr.	0 hr.	32 hr.	0 hr.	43 hr.	0 hr.	50 hr.	0 hr.
	Autumn	**Sep. (montly average (PMV)**	0.56	0.79	0.57	0.87	0.58	0.91	0.58	0.93	0.58	0.95
		(-0.2 to 0.2)	132 hr.	34 hr.	119 hr.	28 hr.	132 hr.	25 hr.	134 hr.	22 hr.	135 hr.	22 hr.
		(-0.5 to 0.5)	345 hr.	76 hr.	355 hr.	63 hr.	365 hr.	58 hr.	371 hr.	58 hr.	380 hr.	57 hr.
		(-0.7 to 0.7)	452 hr.	123 hr.	445 hr.	99 hr.	447 hr.	95 hr.	459 hr.	89 hr.	466 hr.	88 hr.
		Oct. (montly average (PMV)	0.05	0.13	0.05	0.18	0.05	0.2	0.04	0.21	0.03	0.21
		(-0.2 to 0.2)	324 hr.	130 hr.	305 hr.	112 hr.	295 hr.	110 hr.	291 hr.	106 hr.	296 hr.	100 hr.
		(-0.5 to 0.5)	671 hr.	242 hr.	654 hr.	229 hr.	643 hr.	225 hr.	634 hr.	224 hr.	632 hr.	222 hr.
		(-0.7 to 0.7)	717 hr.	264 hr.	703 hr.	254 hr.	697 hr.	251 hr.	692 hr.	244 hr.	693 hr.	243 hr.
Under-heated (cool) prd.		**Nov. (montly average (PMV)**	-0.88	-0.76	-0.89	-0.72	-0.9	-0.7	-0.91	-0.68	-0.91	-0.66
		(-0.2 to 0.2)	80 hr.	32 hr.	78 hr.	34 hr.	77 hr.	34 hr.	78 hr.	35 hr.	78 hr.	37 hr.
		(-0.5 to 0.5)	193 hr.	86 hr.	207 hr.	99 hr.	211 hr.	104 hr.	211 hr.	107 hr.	208 hr.	108 hr.
		(-0.7 to 0.7)	265 hr.	126 hr.	266 hr.	135 hr.	271 hr.	141 hr.	273 hr.	140 hr.	267 hr.	140 hr.
	Winter	**Dec. (montly average (PMV)**	-1.82	-1.70	-1.83	-1.65	-1.83	-1.63	-1.84	-1.61	-1.85	-1.6
		(-0.2 to 0.2)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(-0.5 to 0.5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(-0.7 to 0.7)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	1 hr.	0 hr.	3 hr.	0 hr.
		Average of All Year (PMV)	-0.41	-0.28	-0.42	-0.23	-0.43	-0.21	-0.44	-0.2	-0.45	-0.19
		Average of All Year (-0.2 to 0.2)	975 hr.	352 hr.	940 hr.	327 hr.	957 hr.	319 hr.	963 hr.	317 hr.	978 hr.	317 hr.
		Average of All Year (-0.5 to 0.5)	2274 hr.	773 hr.	2301 hr.	760 hr.	2309 hr.	752 hr.	2318 hr.	711 hr.	2334 hr.	712 hr.
		Average of All Year (-0.7 to 0.7)	2698 hr.	966 hr.	2713 hr.	956 hr.	2729 hr.	954 hr.	2759 hr.	852 hr.	2783 hr.	847 hr.

Table 8: PPD-Horizontal Shading Device-30 cm

		PPD-Horizontal Shading Device -30cm										
Seasons		Opening	0%-closed-24 HOURS	0%-closed- 8AM Till 5 PM	25%-24 HOURS	25%- 8AM Till 5 PM	50%-half-24 HOURS	50%-half- 8AM Till 5 PM	75%-24 HOURS	75%- 8AM Till 5 PM	100%-full-24 HOURS	100%-full- 8AM Till 5 PM
Under-heated (cool) period	Winter	**Jan. (montly average (PPD)**	88.45	86.28	87.75	83.16	87.31	81.37	87	80.12	86.76	79.18
		(<6)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<15)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		Feb. (montly average (PPD)	68.59	65.62	68.69	63.9	68.91	63.1	69.11	62.59	69.27	62.22
		(<6)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<15)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
	Spring	**Mar. (montly average (PPD)**	54.09	49.24	54.95	47.25	55.6	46.3	56.08	45.69	56.43	45.24
		(<6)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<15)	0 hr.	0	0 hr.	0	0 hr.	0	2 hr.	2	2 hr.	2
		Apr. (montly average (PPD)	31	23.08	31.98	21.66	32.8	21.12	33.44	20.81	33.94	20.6
		(<6)	10 hr.	9	12 hr.	11	12 hr.	11	10 hr.	10	10 hr.	10
		(<10)	56 hr.	34	59 hr.	42	59 hr.	44	59 hr.	47	58 hr.	47
		(<15)	124 hr.	79	130 hr.	91	134 hr.	98	137 hr.	100	132 hr.	96
Over-heated (warm) period		**May. (montly average (PPD)**	6.84	6.83	7.02	7.13	7.13	7.29	7.22	7.39	7.29	7.47
		(<6)	345 hr.	130	340 hr.	120	342 hr.	125	341 hr.	125	335 hr.	124
		(<10)	701 hr.	263	695 hr.	262	689 hr.	257	681 hr.	256	676 hr.	255
		(<15)	726 hr.	270	723 hr.	268	723 hr.	268	719 hr.	266	718 hr.	266
	Summer	**Jun. (montly average (PPD)**	29.69	33.55	28.91	34.21	28.41	34.5	28.06	34.67	27.8	34.78
		(<6)	124 hr.	35	118 hr.	30	136 hr.	30	133 hr.	31	142 hr.	31
		(<10)	290 hr.	68	305 hr.	58	312 hr.	54	314 hr.	50	318 hr.	49
		(<15)	373 hr.	104	372 hr.	93	374 hr.	90	372 hr.	86	372 hr.	83
		Jul. (montly average (PPD)	57.71	66.55	55.4	67.19	53.82	67.33	52.7	67.37	51.85	67.38
		(<6)	1 hr.	0 hr.	5 hr.	0 hr.	8 hr.	0 hr.	8 hr.	0 hr.	6 hr.	0 hr.
		(<10)	8 hr.	0	15 hr.	0	27 hr.	0	34 hr.	0	44 hr.	0
		(<15)	27 hr.	0	44 hr.	0	55 hr.	0	62 hr.	0	72 hr.	0
		Aug. (montly average (PPD)	53.17	63.24	51.46	64.78	50.18	65.33	49.24	65.62	48.52	65.8
		(<6)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	1 hr.	0 hr.
		(<10)	1 hr.	0	2 hr.	0	4 hr.	0	9 hr.	0	12 hr.	0
		(<15)	4 hr.	0	13 hr.	0	29 hr.	0	40 hr.	0	48 hr.	0
	Autumn	**Sep. (montly average (PPD)**	17.51	22.66	18.02	25.48	18.15	26.81	18.19	27.64	18.21	28.22
		(<6)	148 hr.	37	132 hr.	29	136 hr.	25	145 hr.	24	153 hr.	22
		(<10)	338 hr.	73	352 hr.	60	362 hr.	58	366 hr.	58	374 hr.	55
		(<15)	445 hr.	119	435 hr.	96	438 hr.	90	446 hr.	89	448 hr.	86
		Oct. (montly average (PPD)	7.16	7.47	7.54	8.07	7.79	8.4	7.97	8.61	8.11	8.74
		(<6)	351 hr.	140	335 hr.	124	317 hr.	117	319 hr.	115	308 hr.	113
		(<10)	671 hr.	241	651 hr.	230	637 hr.	224	629 hr.	225	623 hr.	223
		(<15)	716 hr.	263	701 hr.	253	692 hr.	250	686 hr.	245	682 hr.	243
Under-heated (cool) prd.		**Nov. (montly average (PPD)**	28.11	23.15	28.48	21.45	28.9	20.63	29.23	20.08	29.5	19.69
		(<6)	83 hr.	32	85 hr.	35	87 hr.	37	86 hr.	40	87 hr.	42
		(<10)	191 hr.	84	203 hr.	95	207 hr.	101	211 hr.	107	212 hr.	109
		(<15)	262 hr.	125	264 hr.	133	269 hr.	139	269 hr.	141	268 hr.	142
	Winter	**Dec. (montly average (PPD)**	66.22	60.77	66.19	58.56	66.32	57.38	66.43	56.56	66.51	55.95
		(<6)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		(<10)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		(<15)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	1 hr.	1
		Average of All Year (PPD)	42.39	42.42	42.2	41.96	42.11	41.68	42.05	41.48	42	41.32
		Average of All Year (<6)	1062 hr.	383	1027 hr.	349	1038 hr.	345	1042 hr.	345	1042 hr.	342
		Average of All Year (<10)	2256 hr.	763	2282 hr.	747	2297 hr.	738	2303 hr.	743	2317 hr.	738
		Average of All Year (<15)	2677 hr.	960	2682 hr.	934	2714 hr.	935	2733 hr.	929	2743 hr.	919

Table 9: PPD-Horizontal Shading Device-30 cm- Percentage of Dissatisfied Due to Draught %

PPD-Horizontal Shading Device -30cm			Percentage of Dissatisfied Due to Draught%									
Seasons		Opening	0%-closed-24 HOURS	0%-closed- 8AM Till 5 PM	25%-24 HOURS	25%- 8AM Till 5 PM	50%-half-24 HOURS	50%-half- 8AM Till 5 PM	75%-24 HOURS	75%- 8AM Till 5 PM	100%-full-24 HOURS	100%-full- 8AM Till 5 PM
Under-heated (cool) period	Winter	**Jan. (montly average (PPD)**	88.45	86.28	87.75	83.16	87.31	81.37	87	80.12	86.76	79.18
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<20)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		(<30)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		Feb. (montly average (PPD)	68.59	65.62	68.69	63.9	68.91	63.1	69.11	62.59	69.27	62.22
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<20)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		(<30)	0 hr.	0	1 hr.	1	1 hr.	1	1 hr.	1	2 hr.	2
	Spring	**Mar. (montly average (PPD)**	54.09	49.24	54.95	47.25	55.6	46.3	56.08	45.69	56.43	45.24
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<20)	6 hr.	5	10 hr.	9	11 hr.	10	14 hr.	13	15 hr.	14
		(<30)	99 hr.	51	104 hr.	62	111 hr.	70	111 hr.	71	113 hr.	74
		Apr. (montly average (PPD)	31	23.08	31.98	21.66	32.8	21.12	33.44	20.81	33.94	20.6
		(<10)	56 hr.	34	59 hr.	42	59 hr.	44	59 hr.	47	58 hr.	47
		(<20)	230 hr.	128	225 hr.	138	225 hr.	143	222 hr.	145	219 hr.	147
		(<30)	389 hr.	198	378 hr.	209	376 hr.	213	369 hr.	218	365 hr.	218
Over-heated (warm) period		**May. (montly average (PPD)**	6.84	6.83	7.02	7.13	7.13	7.29	7.22	7.39	7.29	7.47
		(<6)	701 hr.	263	695 hr.	262	689 hr.	257	681 hr.	256	676 hr.	255
		(<10)	735 hr.	277	733 hr.	274	733 hr.	274	731 hr.	273	729 hr.	271
		(<15)	744 hr.	279	741 hr.	277	739 hr.	276	738 hr.	275	737 hr.	274
	Summer	**Jun. (montly average (PPD)**	29.69	33.55	28.91	34.21	28.41	34.5	28.06	34.67	27.8	34.78
		(<10)	290 hr.	68	305 hr.	58	312 hr.	54	314 hr.	50	318 hr.	49
		(<20)	424 hr.	140	430 hr.	139	425 hr.	127	414 hr.	116	415 hr.	114
		(<30)	470 hr.	162	470 hr.	155	474 hr.	154	478 hr.	154	484 hr.	155
		Jul. (montly average (PPD)	57.71	66.55	55.4	67.19	53.82	67.33	52.7	67.37	51.85	67.38
		(<10)	8 hr.	0	15 hr.	0	27 hr.	0	34 hr.	0	44 hr.	0
		(<20)	57 hr.	3	72 hr.	3	84 hr.	3	93 hr.	5	101 hr.	5
		(<30)	100 hr.	12	116 hr.	11	140 hr.	12	156 hr.	13	162 hr.	14
		Aug. (montly average (PPD)	53.17	63.24	51.46	64.78	50.18	65.33	49.24	65.62	48.52	65.8
		(<10)	1 hr.	0	2 hr.	0	4 hr.	0	9 hr.	0	12 hr.	0
		(<20)	24 hr.	0	47 hr.	0	59 hr.	0	72 hr.	0	84 hr.	0
		(<30)	105 hr.	8	129 hr.	9	151 hr.	9	172 hr.	11	179 hr.	11
	Autumn	**Sep. (montly average (PPD)**	17.51	22.66	18.02	25.48	18.15	26.81	18.19	27.64	18.21	28.22
		(<10)	338 hr.	73	352 hr.	60	362 hr.	58	366 hr.	58	374 hr.	55
		(<20)	524 hr.	160	514 hr.	144	513 hr.	135	509 hr.	127	503 hr.	120
		(<30)	606 hr.	210	600 hr.	197	599 hr.	189	597 hr.	185	595 hr.	181
		Oct. (montly average (PPD)	7.16	7.47	7.54	8.07	7.79	8.4	7.97	8.61	8.11	8.74
		(<10)	671 hr.	241	651 hr.	230	637 hr.	224	629 hr.	225	623 hr.	223
		(<20)	733 hr.	274	726 hr.	270	721 hr.	265	715 hr.	261	712 hr.	260
		(<30)	744 hr.	280	743 hr.	280	741 hr.	280	740 hr.	280	736 hr.	276
Under-heated (cool) prd.		**Nov. (montly average (PPD)**	28.11	23.15	28.48	21.45	28.9	20.63	29.23	20.08	29.5	19.69
		(<10)	191 hr.	84	203 hr.	95	207 hr.	101	211 hr.	107	212 hr.	109
		(<20)	318 hr.	147	319 hr.	155	330 hr.	163	329 hr.	163	313 hr.	166
		(<30)	455 hr.	190	446 hr.	196	446 hr.	200	441 hr.	203	446 hr.	208
	Winter	**Dec. (montly average (PPD)**	66.22	60.77	66.19	58.56	66.32	57.38	66.43	56.56	66.51	55.95
		(<10)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		(<20)	0 hr.	0	2 hr.	2	5 hr.	5	10 hr.	10	12 hr.	12
		(<30)	23 hr.	16	29 hr.	23	32 hr.	27	34 hr.	28	36 hr.	30
		Average of All Year (PPD)	42.39	42.42	42.2	41.96	42.11	41.68	42.05	41.48	42	41.32
		Average of All Year (<10)	2256 hr.	763	2282 hr.	747	2297 hr.	738	2303 hr.	743	2317 hr.	738
		Average of All Year (<20)	3051 hr.	1134	3078 hr.	1134	3106 hr.	1125	3109 hr.	1113	3121 hr.	1109
		Average of All Year (<30)	3735 hr.	1406	3757 hr.	1420	3810 hr.	1431	3837 hr.	1439	3855 hr.	1443

Table 10: PPD-Horizontal Shading Device-30 cm- PD Due to Vertical Air Temperature Difference %

PPD-Horizontal Shading Device -30cm			PD Due to Vertical Air Temprature Difference %									
Seasons		Opening	0%-closed-24 HOURS	0%-closed- 8AM Till 5 PM	25%-24 HOURS	25%- 8AM Till 5 PM	50%-half-24 HOURS	50%-half- 8AM Till 5 PM	75%-24 HOURS	75%- 8AM Till 5 PM	100%-full-24 HOURS	100%-full- 8AM Till 5 PM
Under-heated (cool) period	Winter	**Jan. (montly average (PPD)**	88.45	86.28	87.75	83.16	87.31	81.37	87	80.12	86.76	79.18
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		Feb. (montly average (PPD)	68.59	65.62	68.69	63.9	68.91	63.1	69.11	62.59	69.27	62.22
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
	Spring	**Mar. (montly average (PPD)**	54.09	49.24	54.95	47.25	55.6	46.3	56.08	45.69	56.43	45.24
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		Apr. (montly average (PPD)	31	23.08	31.98	21.66	32.8	21.12	33.44	20.81	33.94	20.6
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	56 hr.	34	59 hr.	42	59 hr.	44	59 hr.	47	58 hr.	47
Over-heated (warm) period		**May. (montly average (PPD)**	6.84	6.83	7.02	7.13	7.13	7.29	7.22	7.39	7.29	7.47
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	701 hr.	263	695 hr.	262	689 hr.	257	681 hr.	256	676 hr.	255
	Summer	**Jun. (montly average (PPD)**	29.69	33.55	28.91	34.21	28.41	34.5	28.06	34.67	27.8	34.78
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	290 hr.	68	305 hr.	58	312 hr.	54	314 hr.	50	318 hr.	49
		Jul. (montly average (PPD)	57.71	66.55	55.4	67.19	53.82	67.33	52.7	67.37	51.85	67.38
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	8 hr.	0	15 hr.	0	27 hr.	0	34 hr.	0	44 hr.	0
		Aug. (montly average (PPD)	53.17	63.24	51.46	64.78	50.18	65.33	49.24	65.62	48.52	65.8
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	1 hr.	0	2 hr.	0	4 hr.	0	9 hr.	0	12 hr.	0
	Autumn	**Sep. (montly average (PPD)**	17.51	22.66	18.02	25.48	18.15	26.81	18.19	27.64	18.21	28.22
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	338 hr.	73	352 hr.	60	362 hr.	58	366 hr.	58	374 hr.	55
		Oct. (montly average (PPD)	7.16	7.47	7.54	8.07	7.79	8.4	7.97	8.61	8.11	8.74
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	671 hr.	241	651 hr.	230	637 hr.	224	629 hr.	225	623 hr.	223
Under-heated (cool) prd.		**Nov. (montly average (PPD)**	28.11	23.15	28.48	21.45	28.9	20.63	29.23	20.08	29.5	19.69
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	191 hr.	84	203 hr.	95	207 hr.	101	211 hr.	107	212 hr.	109
	Winter	**Dec. (montly average (PPD)**	66.22	60.77	66.19	58.56	66.32	57.38	66.43	56.56	66.51	55.95
		(<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		Average of All Year (PPD)	42.39	42.42	42.2	41.96	42.11	41.68	42.05	41.48	42	41.32
		Average of All Year (<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		Average of All Year (<3)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		Average of All Year (<10)	2256 hr.	763	2282 hr.	747	2297 hr.	738	2303 hr.	743	2317 hr.	738

Table 11: PPD-Horizontal Shading Device-30 cm- 30cm- PD Due to Cool or Warm Floor %

PPD-Horizontal Shading Device -30cm			PD Due to Cool or Warm Floor%									
Seasons		Opening	0%-closed-24 HOURS	0%-closed- 8AM Till 5 PM	25%-24 HOURS	25%- 8AM Till 5 PM	50%-half-24 HOURS	50%-half- 8AM Till 5 PM	75%-24 HOURS	75%- 8AM Till 5 PM	100%-full-24 HOURS	100%-full- 8AM Till 5 PM
Under-heated (cool) period	Winter	**Jan. (montly average (PPD)**	88.45	86.28	87.75	83.16	87.31	81.37	87	80.12	86.76	79.18
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<15)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		Feb. (montly average (PPD)	68.59	65.62	68.69	63.9	68.91	63.1	69.11	62.59	69.27	62.22
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<15)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
	Spring	**Mar. (montly average (PPD)**	54.09	49.24	54.95	47.25	55.6	46.3	56.08	45.69	56.43	45.24
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<15)	0 hr.	0	0 hr.	0	0 hr.	0	2 hr.	2	2 hr.	2
		Apr. (montly average (PPD)	31	23.08	31.98	21.66	32.8	21.12	33.44	20.81	33.94	20.6
		(<10)	56 hr.	34	59 hr.	42	59 hr.	44	59 hr.	47	58 hr.	47
		(<10)	56 hr.	34	59 hr.	42	59 hr.	44	59 hr.	47	58 hr.	47
		(<15)	124 hr.	79	130 hr.	91	134 hr.	98	137 hr.	100	132 hr.	96
Over-heated (warm) period		**May. (montly average (PPD)**	6.84	6.83	7.02	7.13	7.13	7.29	7.22	7.39	7.29	7.47
		(<10)	701 hr.	263	695 hr.	262	689 hr.	257	681 hr.	256	676 hr.	255
		(<10)	701 hr.	263	695 hr.	262	689 hr.	257	681 hr.	256	676 hr.	255
		(<15)	726 hr.	270	723 hr.	268	723 hr.	268	719 hr.	266	718 hr.	266
	Summer	**Jun. (montly average (PPD)**	29.69	33.55	28.91	34.21	28.41	34.5	28.06	34.67	27.8	34.78
		(<10)	290 hr.	68	305 hr.	58	312 hr.	54	314 hr.	50	318 hr.	49
		(<10)	290 hr.	68	305 hr.	58	312 hr.	54	314 hr.	50	318 hr.	49
		(<15)	373 hr.	104	372 hr.	93	374 hr.	90	372 hr.	86	372 hr.	83
		Jul. (montly average (PPD)	57.71	66.55	55.4	67.19	53.82	67.33	52.7	67.37	51.85	67.38
		(<10)	8 hr.	0	15 hr.	0	27 hr.	0	34 hr.	0	44 hr.	0
		(<10)	8 hr.	0	15 hr.	0	27 hr.	0	34 hr.	0	44 hr.	0
		(<15)	27 hr.	0	44 hr.	0	55 hr.	0	62 hr.	0	72 hr.	0
		Aug. (montly average (PPD)	53.17	63.24	51.46	64.78	50.18	65.33	49.24	65.62	48.52	65.8
		(<10)	1 hr.	0	2 hr.	0	4 hr.	0	9 hr.	0	12 hr.	0
		(<10)	1 hr.	0	2 hr.	0	4 hr.	0	9 hr.	0	12 hr.	0
		(<15)	4 hr.	0	13 hr.	0	29 hr.	0	40 hr.	0	48 hr.	0
	Autumn	**Sep. (montly average (PPD)**	17.51	22.66	18.02	25.48	18.15	26.81	18.19	27.64	18.21	28.22
		(<10)	338 hr.	73	352 hr.	60	362 hr.	58	366 hr.	58	374 hr.	55
		(<10)	338 hr.	73	352 hr.	60	362 hr.	58	366 hr.	58	374 hr.	55
		(<15)	445 hr.	119	435 hr.	96	438 hr.	90	446 hr.	89	448 hr.	86
		Oct. (montly average (PPD)	7.16	7.47	7.54	8.07	7.79	8.4	7.97	8.61	8.11	8.74
		(<10)	671 hr.	241	651 hr.	230	637 hr.	224	629 hr.	225	623 hr.	223
		(<10)	671 hr.	241	651 hr.	230	637 hr.	224	629 hr.	225	623 hr.	223
		(<15)	716 hr.	263	701 hr.	253	692 hr.	250	686 hr.	245	682 hr.	243
Under-heated (cool) prd.		**Nov. (montly average (PPD)**	28.11	23.15	28.48	21.45	28.9	20.63	29.23	20.08	29.5	19.69
		(<10)	191 hr.	84	203 hr.	95	207 hr.	101	211 hr.	107	212 hr.	109
		(<10)	191 hr.	84	203 hr.	95	207 hr.	101	211 hr.	107	212 hr.	109
		(<15)	262 hr.	125	264 hr.	133	269 hr.	139	269 hr.	141	268 hr.	142
	Winter	**Dec. (montly average (PPD)**	66.22	60.77	66.19	58.56	66.32	57.38	66.43	56.56	66.51	55.95
		(<10)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		(<10)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		(<15)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	1 hr.	1
		Average of All Year (PPD)	42.39	42.42	42.2	41.96	42.11	41.68	42.05	41.48	42	41.32
		Average of All Year (<10)	2256 hr.	763	2282 hr.	747	2297 hr.	738	2303 hr.	743	2317 hr.	738
		Average of All Year (<10)	2256 hr.	763	2282 hr.	747	2297 hr.	738	2303 hr.	743	2317 hr.	738
		Average of All Year (<15)	2677 hr.	960	2682 hr.	934	2714 hr.	935	2733 hr.	929	2743 hr.	919

Table 12: PPD-Horizontal Shading Device-30 cm- PD Due to Radiant Temperature Asymmetry %

PPD-Horizontal Shading Device -30cm			PD Due to Radiant Temperature Asymmetry%									
Seasons		Opening	0%-closed-24 HOURS	0%-closed- 8AM Till 5 PM	25%-24 HOURS	25%- 8AM Till 5 PM	50%-half-24 HOURS	50%-half- 8AM Till 5 PM	75%-24 HOURS	75%- 8AM Till 5 PM	100%-full-24 HOURS	100%-full- 8AM Till 5 PM
Under-heated (cool) period	Winter	**Jan. (montly average (PPD)**	88.45	86.28	87.75	83.16	87.31	81.37	87	80.12	86.76	79.18
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		Feb. (montly average (PPD)	68.59	65.62	68.69	63.9	68.91	63.1	69.11	62.59	69.27	62.22
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
	Spring	**Mar. (montly average (PPD)**	54.09	49.24	54.95	47.25	55.6	46.3	56.08	45.69	56.43	45.24
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		Apr. (montly average (PPD)	31	23.08	31.98	21.66	32.8	21.12	33.44	20.81	33.94	20.6
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	56 hr.	34	59 hr.	42	59 hr.	44	59 hr.	47	58 hr.	47
Over-heated (warm) period		**May. (montly average (PPD)**	6.84	6.83	7.02	7.13	7.13	7.29	7.22	7.39	7.29	7.47
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	701 hr.	263	695 hr.	262	689 hr.	257	681 hr.	256	676 hr.	255
	Summer	**Jun. (montly average (PPD)**	29.69	33.55	28.91	34.21	28.41	34.5	28.06	34.67	27.8	34.78
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	290 hr.	68	305 hr.	58	312 hr.	54	314 hr.	50	318 hr.	49
		Jul. (montly average (PPD)	57.71	66.55	55.4	67.19	53.82	67.33	52.7	67.37	51.85	67.38
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	8 hr.	0	15 hr.	0	27 hr.	0	34 hr.	0	44 hr.	0
		Aug. (montly average (PPD)	53.17	63.24	51.46	64.78	50.18	65.33	49.24	65.62	48.52	65.8
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	1 hr.	0	2 hr.	0	4 hr.	0	9 hr.	0	12 hr.	0
	Autumn	**Sep. (montly average (PPD)**	17.51	22.66	18.02	25.48	18.15	26.81	18.19	27.64	18.21	28.22
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	338 hr.	73	352 hr.	60	362 hr.	58	366 hr.	58	374 hr.	55
		Oct. (montly average (PPD)	7.16	7.47	7.54	8.07	7.79	8.4	7.97	8.61	8.11	8.74
		(<5)	0 hr.	0 hr.	0 hr.	0	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0
		(<10)	671 hr.	241	651 hr.	230	637 hr.	224	629 hr.	225	623 hr.	223
Under-heated (cool) prd.		**Nov. (montly average (PPD)**	28.11	23.15	28.48	21.45	28.9	20.63	29.23	20.08	29.5	19.69
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	191 hr.	84	203 hr.	95	207 hr.	101	211 hr.	107	212 hr.	109
	Winter	**Dec. (montly average (PPD)**	66.22	60.77	66.19	58.56	66.32	57.38	66.43	56.56	66.51	55.95
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		(<10)	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0	0 hr.	0
		Average of All Year (PPD)	42.39	42.42	42.2	41.96	42.11	41.68	42.05	41.48	42	41.32
		Average of All Year (<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		Average of All Year (<5)	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.	0 hr.
		Average of All Year (<10)	2256 hr.	763	2282 hr.	747	2297 hr.	738	2303 hr.	743	2317 hr.	738

Table 13: MRT-Horizontal Shading Device-30 cm

			MRT-Horizontal Shading Device -30cm									
Seasons		Opening	0%-closed-24 HOURS	0%-closed- 8AM Till 5 PM	25%-24 HOURS	25%- 8AM Till 5 PM	50%-half-24 HOURS	50%-half- 8AM Till 5 PM	75%-24 HOURS	75%- 8AM Till 5 PM	100%-full-24 HOURS	100%-full- 8AM Till 5 PM
Under-heated (cool) period	Winter	**Jan. (montly average (MRT)**	11.48	11.29	11.44	11.34	11.41	11.37	11.39	11.39	11.38	11.4
		Feb. (montly average (MRT)	13.72	13.71	13.68	13.71	13.64	13.7	13.61	13.69	13.59	13.69
	Spring	**Mar. (montly average (MRT)**	15.27	15.37	15.19	15.36	15.14	15.34	15.09	15.33	15.06	15.32
		Apr. (montly average (MRT)	17.67	18.18	17.6	18.19	17.54	18.18	17.5	18.17	17.47	18.16
Over-heated (warm) period		**May. (montly average (MRT)**	23.15	23.7	23.08	23.67	23.03	23.65	22.99	23.64	22.96	23.63
	Summer	**Jun. (montly average (MRT)**	27.79	28.3	27.71	28.29	27.65	28.27	27.61	28.25	27.57	28.24
		Jul. (montly average (MRT)	30.26	30.71	30.16	30.67	30.1	30.64	30.04	30.61	30	30.59
		Aug. (montly average (MRT)	29.88	30.34	29.8	30.32	29.75	30.31	29.71	30.29	29.68	30.28
	Autumn	**Sep. (montly average (MRT)**	26.77	27.18	26.72	27.22	26.68	27.22	26.64	27.22	26.61	27.22
		Oct. (montly average (MRT)	23.6	24.01	23.57	24.05	23.53	24.07	23.5	24.07	23.48	24.08
Under-heated (cool) prd.		**Nov. (montly average (MRT)**	18.32	18.6	18.3	18.65	18.28	18.68	18.26	18.69	18.24	18.7
	Winter	**Dec. (montly average (MRT)**	14.07	14.27	14.04	14.3	14.01	14.32	13.98	14.32	13.97	14.33
		Average of All Year (MRT)	21.03	21.34	20.98	21.35	20.93	21.35	20.9	21.34	20.87	21.34

3.3.3 Dynamic Simulation of Tas Software with Discussions

Thermal comfort times of the whole year (8760 h) regarding category A were as the following; 30 cm horizontal shading device provided thermal comfort conditions of 975 hours (0.11% of the whole year) when window was 0% open, 940 hours (0.10% of the whole year) when window was 25% open, 957 hours (0.10% of the whole year) when window was 50% (half) open, 963 hours (0.10% of the whole year) when window was 75% open and 978 hours (0.11% of the whole year) when window was 100% (fully) open.

Thermal comfort times of the whole year based on office hours, regarding category A were as the following; 30 cm horizontal shading device provided thermal comfort conditions of 352 hours (0.04% of the whole year) when window was 0% open, 327 hours (0.03% of the whole year) when window was 25% open, 319 hours (0.03% of the whole year) when window was 50% (half) open, 317 hours (0.03% of the whole year) when window was 75% open and 317 hours (0.03% of the whole year) when window was 100% (fully) open.

According to category A, as the average of full year with all the window openings (0% to 100%), 963 hours with 0.10% thermal comfort was provided as shown in red color in Table 5.

According to category A, as the average of full year based on office hours, with all the window openings (0% to 100%), 327 hours with 0.03% thermal comfort was provided as shown in red color in Table 6.

The thermal comfort times of the whole year (8760 h), according to category B were as the following; 30 cm horizontal shading device provided thermal comfort conditions of 2274 hours (0.25% of the whole year) when window was 0% open, 2301 hours (0.26% of the whole year) when window was 25% open, 2309 hours (0.26% of the whole year) when window was 50% (half) open, 2318 hours (0.26% of the whole year) when window was 75% open and 2334 hours (0.26% of the whole year) when window was 100% (fully) open.

The thermal comfort times of the whole year based on office hours, according to category B were as the following; 30 cm horizontal shading device provided thermal comfort conditions of 773 hours (0.08% of the whole year) when window was 0% open, 760 hours (0.08% of the whole year) when window was 25% open, 752 hours (0.08% of the whole year) when window was 50% (half) open, 711 hours (0.08% of the whole year) when window was 75% open and 712 hours (0.08% of the whole year) when window was 100% (fully) open.

According to category B, as average of the full year with all the window openings (0% to 100%) 2307 hours with 0.26% thermal comfort was provided as shown in red and green colors of Table 5.

According to category B, as average of the full year based on office hours, with all the window openings (0% to 100%) 742 hours with 0.08% thermal comfort was provided as shown in red and green colors of Table 6.

The thermal comfort times of the whole year (8760 h), according to category C were as the following; 30 cm horizontal shading device provided thermal comfort conditions of 2781 hours (0.31% of the whole year) when window was 0% open, 2792 hours (0.31% of the whole year) when window was 25% open, 2810 hours (0.32% of the whole year) when window was 50% (half) open, 2840 hours (0.32% of the whole year) when window was 75% open and 2866 hours (0.32% of the whole year) when window was 100% (fully) open.

The thermal comfort times of the whole year based on office hours, according to category C were as the following; 30 cm horizontal shading device provided thermal comfort conditions of 988 hours (0.11% of the whole year) when window was 0% open, 966 hours (0.11% of the whole year) when window was 25% open, 954 hours (0.10% of the whole year) when window was 50% (half) open, 852 hours (0.09% of the whole year) when window was 75% open and 847 hours (0.09% of the whole year) when window was 100% (fully) open.

According to category C, as average of the full year with all the window openings (0% to 100%), 2818 hours with 0.32% thermal comfort was provided as shown in red, green and blue colors of Table 5.

According to category C, as average of the full year based on office hours, with all the window openings (0% to 100%), 921 hours with 0.10% thermal comfort was provided as shown in red, green and blue colors of Table 6.

According to office hour's performance, non-thermal comfort times of the year that are under-heated periods can be stated as in January, where PMV was -2.81 (cold) with 30 cm horizontal or without any shading devices.

February was -2.18 when window was 0% (closed), -1.97 when window was 25%, -1.77 when window was 50% (half) open, -1.76 when window was 75% open and -1.75 when window was 100% (fully) open.

In March PMV was -1.76 when window was 0% open, -1.57 when window was 25% open, -1.41 when window was 50% open, -1.4 when window was 75% open and -1.39 when window was 100% (fully) open.

In April PMV was -1.04 when window was 0% (closed), -0.91 when window was 25% open, -1.82 when window was 50% (half) open, -0.81 when the window was 75%, -0.8 when the window was 100% (fully) open.

In December, PMV was -2.04 when window was 0% (closed), -1.81 when window was 25%, -1.63 when window was 50% (half) open, -1.61 when window was 75% open, -1.6 when window was 100% (fully) open as shown in dotted parts of Tables 7.

Non-thermal comfort times of the year that are over-heated periods (warm) are in July, where PMV was 2.21 (warm) when window was 0% (closed), 2.06 when window was 25% open, 1.87 when window was 50% (half) open, 1.88 when window was 75% open, 1.88 when window was 100% (fully) open.

In August PMV was 2.10 when window was 0% (closed), 1.97 when window was 25% open, 1.80 when window was 50% (half) open, 1.81 when window was 75% open, 1.82 when window was 100% (fully) open.

In category A where PPD was <6%, draught was in thermal comfort up to 10%, therefore draught had 746 hours based on office hours performance.

In category B where PPD was <10%, draught was in thermal comfort up to 20%, therefore draught had 1123 hours based on office hours performance.

In category C where PPD was <15 %, draught was in thermal comfort of up to 30%, therefore draught had 1428 hours based on office hours performance.

In category A where PPD was <6%, due to horizontal shading device by 30 cm, was 353 hours based on office hour's performance.

In category B where PPD was <10%, due to horizontal shading device by 30 cm, was 746 hours based on office hour's performance.

In category C where PPD was <15%, due to horizontal shading device by 30 cm, was 953 hours based on office hour's performance.

Chapter 4

CONCLUSION

4.1 Conclusion

The building which is selected for this study investigates the research and analysis of the office building of architecture department in EMU in Famagusta, North Cyprus. The study calculates thermal comfort and energy consumption of the interior space of this office building.

This inquiry has been concluded to understand new methods to solve the safety supplement of energy and creation of the environment which is healthier. All findings are related to increase the quality of life. These days the subject of thermal comfort for buildings has great value to investigate according to international standards such as heating, cooling, lighting and so on.

Four basic factors which influence human thermal environmentally are radiation temperature, air temperature, air movement and humidity. As already it is mentioned, the more natural sources are used, the more cooling and heading will be cheaper and more efficient.

Lately architects have paid too much consideration on the association between both architecture and climate to deliver inhabitants' comfortable situation. By accomplishment of several stratagems like office coordination, wind in hot and humid climates can be appealed.

Openings are very important and fundamental in buildings by considering this importance according to the last simulations, the size and position of the windows were altered. These changes cause to absorb more air into the building and increase the amount of the air circulation in each part of the building.

The aim of this research is development of thermal performance in interior of office building, by rising the quality of the building environment for human thermal comfort and reducing of energy consumption for cooling and heating.

As a result, natural resources are limited and the country has to import raw materials, energy and goods, recently the government of Cyprus for this island has planned to use more renewable energy sources like solar and wind energy.

This solution by using of natural and renewable energy resources like the light of sun, the power of water and wind can provide the highest degree of thermal comfort which this issue will reduce the amount of energy consumption on the buildings.

This office building that is situated in hot and humid climate is drawn in TAS software and after getting the existing materials from inside and outside of this building, they are analyzed by TAS software in three categories.

These are category A, category B, and category C. Furthermore, horizontal shading devices with 30 cm distance are analyzed to be known which direction of shading elements has thermal comfort, and the window doesn't have shading device.

In analyses, the dimension of shading element is 30 Cm.

At first, the opening of window is started by 0%, 25%, 50%, 75%, and 100% in this place. Results of these categories were explained in bellow part:

In the result of these categories, category A is analyzed in one year based on office hour's performance, it means between January and December in hot and humid climate of Famagusta in North Cyprus, which they approached to some conditions about indoor thermal comfort:

PMV as category A (-0.20 to 0.20) in May and October was in thermal comfort conditions with all 0% (closed) to 100% (fully open) window opening percentages.

In addition to this results, category B analyzed by TAS software in one year in the same climate:

PMV as category B (-0.50 to 0.50) in May, October and November was in thermal comfort conditions with all 0% (closed) to 100% (fully open) window opening percentages.

As can be realized from the results of TAS software in category C, thermally comfort of interior space of this office building analyzed:

PMV as category C (-0.70 to0.70) in April, May, September, October and November was in thermal comfort conditions with all 0% (closed) to 100% (fully open) window opening percentages.

When dynamic modelling was created by TAS software, the energy consuming of the office building by this window was calculated.

The usage of computer simulation software had too much advantage, because it was very difficult to make the real environment and produce the exact weather condition for each simulation.

By overviewing on all the represented simulations briefly, it can be concluded that in simulation category A:

Where PMV was between -0.2 and 0.2 and window openings were between 0% and 100%, average of the hours based on office hour's performance was 327 hours in category A.

By overviewing on all the represented simulations briefly, it can be concluded that in simulation category B:

Where PMV was between -0.5 and 0.5 and window openings were between 0% and 100%, average of the hours based on office hour's performance was 742 hours in category B.

By overviewing on all the represented simulations briefly, it can be concluded that in simulation category C:

Where PMV was between -0.7 and 0.7 and window openings were between 0% and 100%, average of the hours based on office hour's performance was 915 hours in category C.

Moreover, the building lost heat load in winter period and gained extra heat in summer.

The non-thermally comfort periods of the office in under-heated (cold) seasons were January (cold), February (cool), March (cool), and December (cool).

In addition to these, as over-heated (warm) seasons were July (warm) and August (warm), during these seasons, this office could never be in thermal comfort conditions of any category with natural ventilation strategies.

When the results of simulation is monitored, the all data which are reached from analysis by TAS software completely are among three categories, category A, category B, and category C.

The analyzed simulation and collected data on the site showed that an office building with selective materials analyzed as a suitable and efficient for hot and humid climates which placed in North Cyprus.

Moreover, the important reason to select the office building in Famagusta climates reached the effect of window opening between 0% (closed), 25%, 50% (half open), 75%, 100% (full open) in the simulation. Hence, this simulation calculates the solar radiation with natural ventilation which keeps inside zone of office. This is based on 24 hours in one years and also based on office hour's performance (8:00 am till 17:00 pm).

4.2 Further Suggestions for Research

More than a few areas of research have been considered for further research, which are reached by analyzing the recent research. This research has achieved the basic calculation and information which is going to consider the shading element on window openings as a further studies. Therefore, the first step to prepare the optimum situation of office is the using of results. In general, the climate is related to Famagusta's weather and calculated by simulation, although there are many problematic areas which need to work on.

The analyzes of this research has presented the influence of horizontal shading element by 30 cm size on office building space for saving energy so as further study the optimum atmosphere of indoor can be searched to save energy consumption. Hence, the useful data for extending this research should be prepared by this simulation software. Office buildings in the climate of Famagusta are one of the crucial subjects to realize the optimum results of them. Also, it would develop the quality of the office atmosphere for inhabitants.

Generally, a point of view in the new chapter about energy efficiency will explain the environment, atmosphere, and location of the office building. So, results of this analyzing will be useful for building designers and civil engineers. The standard method will be accepted by engineers.

Briefly, this research, the effect of window openings between 0%, 25%, 50%, 75%, 100% means, from closed to open completely analyzed and defines the best situation in each month of the year in the hot and humid climate as a thermally comfort in office buildings.

Moreover, as further study the movable type of shading devices can be analyzed in hot and humid climate through TAS simulation so consideration of the analyzed amounts may reduce the energy consumption of office buildings as well. In addition finding out the standards of relation between movable type of shading devices and thermal comfort in details can be a good research topic for further study.

Additionally, a simulation software must be used to calculate the influence of opening and shading device in office building's thermal performance.

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