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OPTIMAZE NATURAL VENTILATION AND THERMAL MASS IN RESIDENTIAL BUILDINGS TO ACHIEVE THERMAL COMFORT AND REDUCTION OF ENERGY CONSUMPTION IN HOT DRY CLIMATE

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ABSTRACT

Using natural phenomena to reach indoor comfort has been known since early time and the oldest heritage architecture's and engineering of Middle East region, which has responded with such phenomena as well very good solutions special for hot-dry region (height temperature and radiation at summer the longest period reverses at winter period. Big swing between day temperature and night also between the hot summer and cool winter). It realized easily inside its houses the optimum comfortable Temperature throughout nearly all the days of the yearlong .That was through equating with the volume adopting and the space taming with the different natural elements forces of the sun, atmosphere, biosphere . . . and climate as all which is common in these days as passive design strategies and reducing energy consumption .

As consequences for all these prefaces and looking at the native engineering civilization seemed obviously that no separation is there between architecture ,engineering , environment's planning and the adopted human behavior as they are in the old Damascus city especially inside the old historic fence (wall)| as a real example . There, the quarters take almost similar engineering and architectural style in an alive coherence body and homogenous harmony. It receives generally the impacts of the climatic currents and absorbs particularly the heating's surplus throughout the creation of the integrated texture (thermal mass combine with natural ventilation). If the old city Damascus were as detached in smaller masses as it is now, the outer surfaces were too much increased and exposed to the disturbances of cold- and hot strikes waves either in winter or in summer. That means, each building needs an artificial ventilator at the peak of the hot or /and the lowest cool period. Therefore, the Damascene architects substitute it by generating natural ventilation ways through the nature itself inside house lung (the closed courtyard and cross, stack ventilation related to windows distributions, orientations and areas) instead of the opening outside windows to the streets' sides in the downstairs.

However the Family inside the rooms can feel with almost sustainable comfortable temperature with the help of social behavior discipline of reducing occupant metabolic of the day mix with the cooling air movement of the normal outdoor atmosphere in the summer nights when the buildings emits the absorbed day heat.

This research investigate the thermal mass and natural ventilation for traditional house(at hot-dry region) that gives high energy efficiency in providing cool indoor air through ventilation (single sided , cross ventilation) and envelope behavior, with the procedures of measurements combination with simulation program model , to improve Middle East new residential buildings through utilize combination of passive cooling and heating techniques , such as natural ventilation in traditional building couple with effects of massive construction and design assemble to provide thermal comfort (temperature control) over interior condition this strategies are utilized to conserve energy in a hot-dry climate [middle east region as Damascus and other cities which have comfort traditional houses] .

Measuring make up as ASHRAE standard way for temperature and relative humidity to be recorded every 5 minutes to get good indicators, measurements are made parallel with survey (ASHRAE way). Air velocity collected manual corresponded with experiment measurements and survey. The most collected Data is recorded during the hottest summer period of JULY /AUGUST

2014th and the hottest case of the year 2015th for typical summer performance likewise during the coldest period at December/ January 2015th .

The modern template applied by simulation program for traditional heating and cooling technique to achieves thermal comfort related to occupant behavior and reduce energy consumption for new apartment about 30-45% reduction of energy loading at Damascus cities and for other cities as Cairo from 20-35% also at very hot dry climate as Riyadh cities from 15-30% better than the codes applied at the current late period.

DEDICATION

This thesis dedicated to my country Syria.

My parents,

For their endless love, support and encouragement.

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CHAPTER 1

RESEARCH OVERVIEW

1.1 Introduction.

The optimization of building design for getting nearly zero energy, which is the one step of passive building, in narrow form of sustainability, this procedure have multivariable problem, which can accept different sets of solutions. The purpose of architect and engineer designer is integrated design to guarantee a comfortable indoor environment and hence to minimize and reduce energy needed for space conditioning. Especially in USA and EU after May 2010, European Union recast the Directive 2010/31/EU on the energy performance of buildings (rEPBD), which states that the new buildings shall be nearly zero energy buildings respectively after December 31, 2018 and after December 31, 2020. After that day all countries try to follow that directive also Middle East countries (Mediterranean area) with varying steps. The optimization aim to minimizing two long-terms seasons (summer and winter) is one of potential paths toward passive and reduction of energy building consumption, starts with design and optimizing the building envelope materials and passive technologies as natural ventilation in free-floating mode. This method is also suggested by USA community ASHRAE Stander Fundamental, 55-2013 and Adaptive comfort model through the Particle swarm optimization algorithm.

The Middle East –Arab countries (Mediterranean area) which is classified hot-dry/humid climate toward that purpose are depending on latest standards and European standard EN 15251:2007.

The oldest heritage housing in hot-dry (arid, semi-arid) climate region represents good engineering solutions to the external climatic conditions, high temperature and solar radiation in summer (which is the longest period respect to winter period) big thermal excursion between day and night (summer and winter), also occupant adaptive and comfort through social behavior.

From previous point of view this research is an effort to revive the traditional housing passive performance (structure materials and natural ventilation) in a modern context, which were traditionally known for their distinctive passive cooling Performance and thermal comfort to achieve thermal comfort and reduction of energy consumption at new residential building for hot-dry regions which one of those regions are SYRIA, EGYPT also very hot climate Saudi Arabia.

One of the typical Syrian houses is at old Damascus city which have courtyard at outside and inside the ancient walls of old Damascus city, consist of two levels: the first represents the ground floor with heavy solid mass (stone), and the second is built over ground floor with light mass (timber structure). This house has different room's orientation, size, windows distribution and different kinds of natural ventilation. Several monitoring data (air temperature, humidity and air velocity) were acquired during the coldest period in winter 2014/2015th and hottest period in summer 2014th and exceptional very hot summer 2015th, in parallel with occupancy survey The survey results were processed, correlations between thermal sensations and physical parameters, with the help of dynamic computer simulations Design Builder and Energy Plus Simulation program to collect other parameters and optimization process.

The Exceptional circumstances for Arab- Middle East region make this research more important for new residential building and rebuilding from sustainability view, at the same time these circumstances make experimental research so difficult caused by situation.

That gives energy modeling priority in this research to collect and analysis all data to achieve comfort and reduction energy for residential building.

1.2 Problem Definition.

Due to the significance consumption of non-renewable power resources in construction and building sector growing in our countries on large scale, and its increased emissions of SH2, NO2, CO and CO2, with the associated vapors. The decision makers in middle East (Mediterranean area) have associated as other countries, which take into consideration the limitation of non-renewable power resources consumption, in an attempt to develop the construction quality and technologies with its materials and adopt sustainable renewable power construction concepts special for hot-dry climate region which need more cooling load energy for long hot summer period and heating load energy for winter period.

Those countries which have huge rate of urban development and change in building construction sector occurred[in culture the heating or cooling system if it exist they are not continusly), and this led to huge changes on construction style with had negative impacts mostly in terms of the building interrelation with the surrounding atmosphere because of the various negative concentration of most executors on profits in the cheap buildings architecture special for residential building sector , these made the buildings in most cases far from the environmental interaction known in the traditional degraded houses , which was a successful example on achieve occupant comfort parallel with reduction energy consumption principally by structural materials and natural ventilation kind(cross ventilation , single side stack ventilation). Up to the previous aspects got the new design its importance to solve the late problems.

Another issue is the adaptive comfort model implemented in the ASHRAE standard 55-2013 is a relation between mean outdoor air temperature and the corresponding acceptable indoor air temperatures. The effect of the standard is limited to the prevailing mean outdoor temperatures ranging from 10 °C to 33 °C, while the mean outdoor temperatures is higher in hot dry climates in summer period. The study of the relation between mean outdoor temperatures and accepted indoor temperatures in hot dry climates may give a wider range than that incorporated in the existing standard .on other hand natural ventilation may expand the range of acceptable temperatures which gives the opportunity for more energy conservation.

1.3 Research Scope.

The research mainly based on residential building in semi and hot/very hot- dry climate at Damascus city in Syria and also as procedure at Cairo in EGYPT and Riyadh in SAUDIA ARABIA for optimization level, at summer hot and very hot dry climate also winter period at the peak of energy consumption over heating and cooling, the outcome of the experimental and simulation evaluation levels represented the traditional houses at two condition with natural ventilation and no natural ventilation in each condition there is no cooling or heating system only depend on passive traditional cooling and heating also the effect on thermal occupancy .

On other hand, optimization and new residential building reduction of energy consumption calculate the outcome and represents two types of building; the first mixed mode(natural ventilation and mechanical system) the other only mechanical HVAC system made for summer period. For winter period the best performance of mechanical HVAC system beside envelope optimization (materials and performance) applied to reach occupancy comfort.

The calibration for temperature and relative humidity step has forced done getting more parameter during exceptional circumstances at study region.

This research focus on only two point from passive design forward to sustainability: thermal mass and natural ventilation to achieve occupancy comfort and reduction energy consumption.

1.4 Research Aim and Purpose.

The aim of this research is to help the promote of energy efficient architectural design for residential building at hot-dry climates for Middle East region to reduction energy consumption by reviving the use of natural ventilation process [summer period] and positive envelope properties as traditional houses in a modern context and urban housing clusters at cities for new and rebuilding. Such houses were traditionally renowned for their distinctive thermal comfort.

The purpose is to develop an accurate thermal simulation methodology for the generated within courtyards that can be combined with building energy simulation software (Energy plus, Design Builder) modeling by comparing it and merge it with measured data from monitoring case studied on some typical Syrian courtyard houses to evaluate the influence of thermal performance of building structures and natural ventilation (cross ventilation, single side ventilation) on the indoor thermal comfort for traditional houses in Damascus old city then investigate other hot dry climate region in Cairo and Riyadh.

1.5 Research Methodology.

The research is divided into five steps **Figure 1-1**:

The first step is also divided into three steps: 1-Select an indigenous cases studies courtyard houses: Four traditional houses in the old city of Damascus, inside and outside the ancient historical walls, they could be divided into two building types: big houses (two or three courtyards) and small houses (one courtyard).They present two typical floor levels: the first which is the ground floor with heavy mass (stone), and the second with light mass (timber structure).Those houses have different rooms size, windows distribution and different kinds of natural ventilation beside different rehabilitation interventions . Several monitoring data (air temperature, humidity and air velocity) were acquired during a summer and winter period 2014th, in parallel with occupancy survey for the evaluation of comfort conditions to evaluate materials and orientation beside natural ventilation influence on thermal comfort by using Adaptive comfort model, PMV scale and psychometric-chart.

2- Select one case for deep investigation on natural ventilation effect (cross ventilation, single side stack ventilation) at summer period 2015th by several monitoring data (air temperature, humidity and air velocity) parallel with survey to evaluate occupant comfort.

3- This step extend to the latest one, on other hand it is forced step that related to specialty of the year 2015th (as a very hot summer) the advantage of this step is to evaluate the influence of natural ventilation at high temperature.

The second step: Complementary to the previous step for more parameters data and evaluation , caused by the Exceptional situation for the studied region and the difficulty in instruments availability and monitoring data by time. This step is energy modeling and calibration: generate model of courtyard house using Design Builder thermal simulation software, use weather data for 2014th and 2015th to calibrate measurements data (air temperature, humidity). This is important step to collect many other parameters and effective factor by merge between measurements and Modeling to complete evaluation of the case study and thermal comfort beside thermal mass.

The Third step is deep investigation in influence of natural ventilation types: cross ventilation, single side stack ventilation through effective opening area position, orientation combine with envelope thermal behavior also influence on thermal comfort.

The fourth step is applied all the recommendations and results (strategies) from previous tasks as modern context for new dwelling and residential building by orientation , envelope materials and thermal mass, windows and shading device integration with ventilation (cross ventilation, single side stack ventilation), final aspect reduction and energy consumption.

The fifth part is the conclusion: Dissemination of results at other hot dry climate region Egypt also very hot dry climate region Saudi Arabia from energy view and set of parameters to act as guiding for the future thermal investigation.

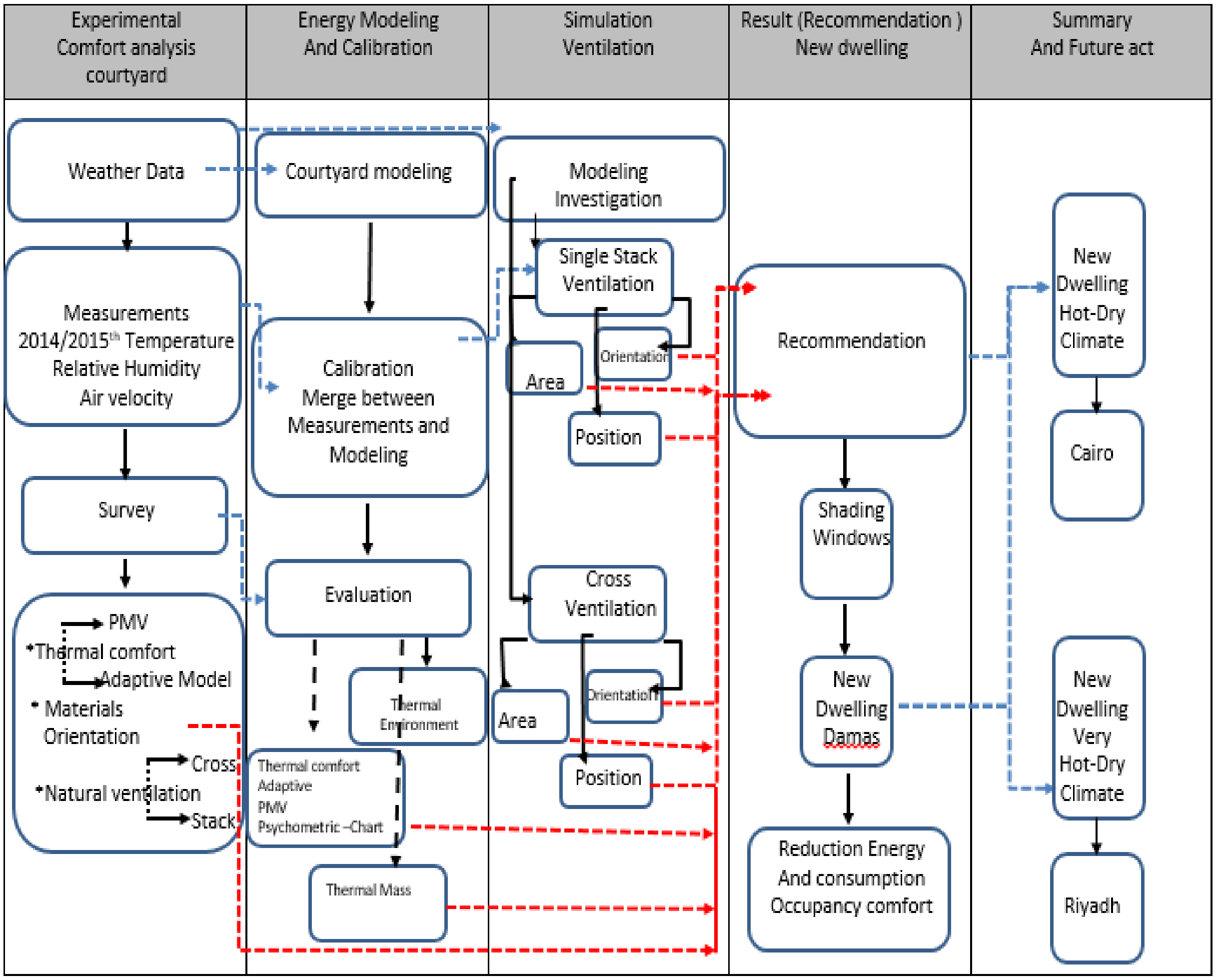


Figure 1-1: Research methodology steps.

CHAPTER 2

LITERATURE REVIEW

This literature review covers five basic aspects related to energy performance of residential houses, and courtyards. Previous studies include field of building envelope(energy balance , thermal mass) correlated to passive design and materials choice completed with studies regional codes utilized in the Middle east (Mediterranean area).Furthermore studies concerned of thermal comfort of occupant and field of measurements and surveys about the passive cooling and heating method of residential courtyards integrate with thermal simulation programs to predict thermal performance of courtyard buildings by calibration procedures for thermal simulations were reviewed. Latest studies about natural ventilation and performance of houses through simulation modeling.

2.1 Energy Balance and envelope (thermal comfort).

General approach and methodology for energy analysis of building envelope is the Energy Balance Equation. In order to analyses energy performances of building for optimizing the building envelope **Figure 2-1** the general energy balance equation can be defined [1992, U.S. Department of Energy]:

$$E = Q_{TRANS} + Q_{VENT} \pm Q_{RAD}$$

Where: E : energy balance , $Q\left(W\right)$

Q_{TRANS} is the energy transferred by transmission through the building envelope.
ϱ VENT is the energy transferred by ventilation
ϱRAD is the energy transferred by radiation (solar radiation from windows and transferred from different opaque surfaces)

2.1.1 <u>Thermal transmission</u>

Two bodies A and B at different temperatures exchange energy in the form of heat until complete disappearance of their difference in temperature(Thermal transmittance (Heat transfer coefficient) **Figure 2-2**). This exchange can be done according to three fundamental modes of transmission: conduction, radiation, convection. Actually, any heat exchange is carried out simultaneously under the three modes of transfers (for plate in steady-state condition):

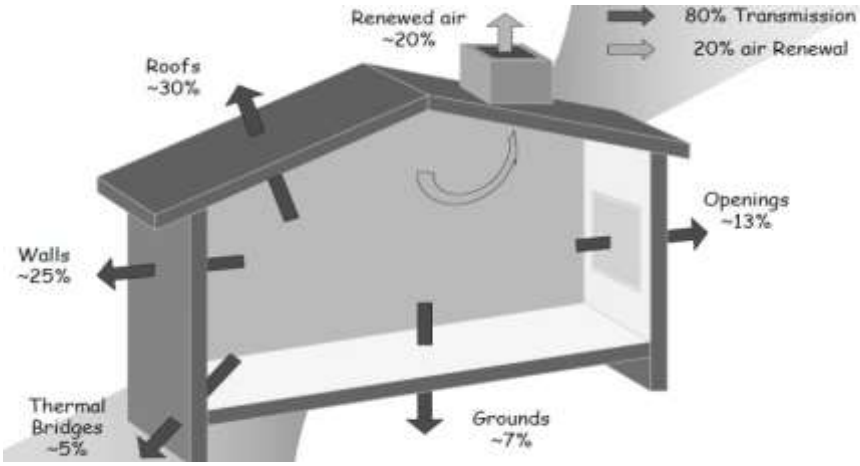


Figure 2-1: Thermal losses through the envelope.

Conduction:

$$Q = k\,\frac{(t_{s1} - t_{s2})A}{\Delta x} = \frac{(t_{s1} - t_{s2})}{\Delta x\,/\,(kA\ )}$$

Where: *k* thermal conductivity [W/(m·K)]

R conduction resistance R= L/(kAc)=Δx/kA. [K/W]

Q = *heat transfer rate [W]*

Δx = thickness (m)

A = surface area (m2).

,t_{s1} ,t_{s2} surface temperature for side 1 and 2 °C

Convection:

$$Q = h_c A\,(t_s - t_\infty) = \frac{(t_s - t_\infty)}{1/(h_c A\ )}$$

where: h_C convection heat transfer coefficient [W/(m^2·K].

R convection resistance R= 1/(*hc*A) .[K/W].

Q *heat transfer rate (W)*

A surface area (m2).

t_s surface temperature °C

t∞ temperature fluid

Radiation:

$$Q = h_r A\,(t_s - t_{surr})/(1/h_r A\ )$$
$$h_r = \sigma\varepsilon\,(t_s^2 + t_{surr}^2)(t_s - t_{surr})$$

Where: h_r radiation heat transfer coefficient W/m^2.K

σ = 5.67 × 10–8 W/(m2·K4) is the Stefan-Boltzmann constant.

ε is emissivity, where 0 ≤ ε ≤ 1. For a black surface, ε = 1.

R radiation resistance R= 1/(*hr* A) .(K/W).

Q *heat transfer rate (W)*

A surface area (m^2).

t_s surface temperature °C

$$Q = \frac{\Delta t}{R_1 + R_2 + R_3} \text{ Where: } R_1 = 1/h_c A \;,\; R_2 = \Delta x / kA \;,\; R_3 = \frac{(1/h_c A)(1/h_r A)}{(1/h_c A)(1/h_r A)}$$

$$Q = UA\Delta t$$

Where ***U*** is the overall thermal transmittance: $U = \frac{1}{A(R_1 + R_2 + R_3)}$ (W/m^{2}K) .

Optimizing of energy performances of building envelope can be obtained through increasing thermal resistance by using added insulation layers in winter and thermal capacity that give more shift time in summer **Figure 2-3**.Moreover, using new materials and technologies as *pcm*(phase change materials)to integrate the thermal mass .

$Q = m^{\cdot} c_p \Delta T$ — Q heat exchangers (Thermal Inertia)W

$m^{\cdot} c_p \Delta T = q^{''} A$ — *Cp* specific heat capacity J/kg.K

q'' heat flux W/m^2.

m mass of solid kg/m^2

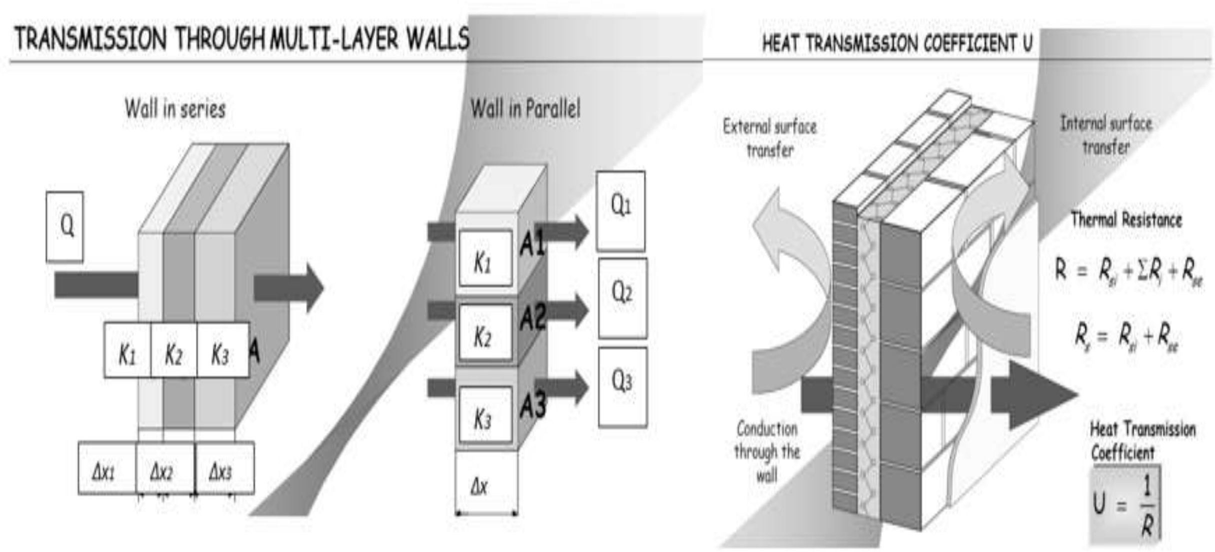


Figure 2-2: Thermal transmittance (integrate building envelope).

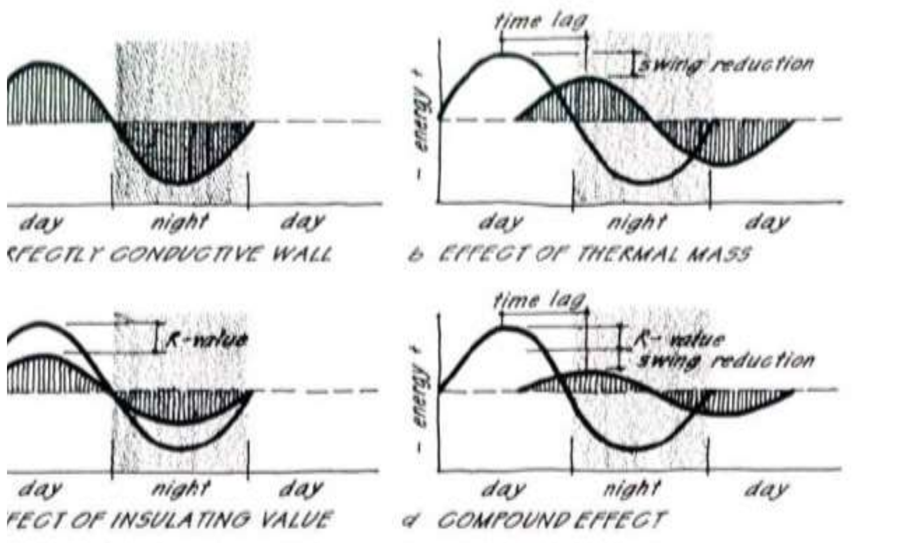


Figure 2-3: Thermal mass (integrate building envelope).

<u>Solar radiation.</u>

Solar radiation must be optimist through reducing it in summer and increasing it in winter by generating shading elements(materials , trees)depending on solar radiation angle for every season and sun path and fenestration (materials :kind of glass , solar heat gain coefficient (SHGC) and shading devices **Figure 2-4**.

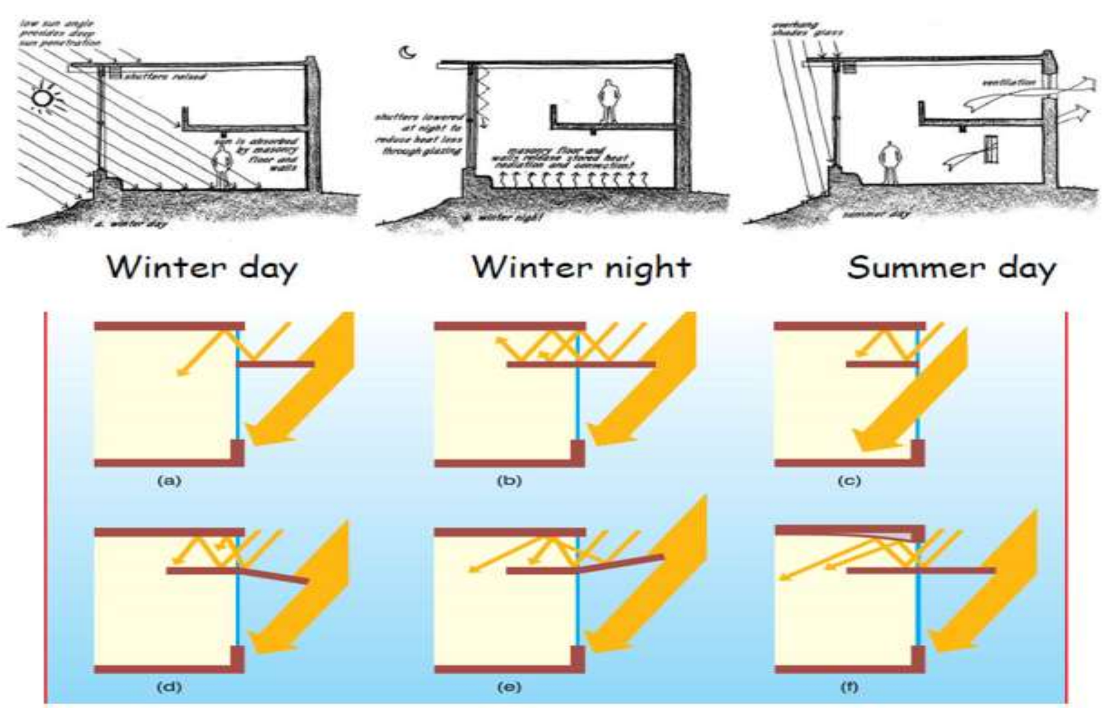


Figure 2-4: different position for radiation angle form one season to another and different kind of shading devices for summer radiation.

Solar heat gain coefficient:

$$SHGC = T^{sol} + A^{sol} N$$

$$SHGC_{opq} = A^{sol}_{opq} N_{opq} = A^{sol}_{opq} U_{opq} / h_{co}$$

T^{sol} is solar transmittance

A^{sol} is solar absorptance

N is flowing fraction for opaque U_{opq}

h_{co} is the convective heat transfer coefficient.

$C_s = SHGC / 0.86$ Shading coefficient .

The building envelope functions as an environmental filter; it forms a skin around the building and controls the influence of the outdoor on the indoor environment. In tall buildings, walls cover more than 90% of the shell and highly influence the indoor environment. Many researches made up optimize building envelope related to insulation and materials for Middle East countries and hot climate region by experimental or simulation method. Below a few examples of those studies. **Develop envelope**: (Hong Kong . M. Bojic , F. Yik, K. Wan, J. Burnett.2002) The study includes the model of the base-line characteristics of walls and doors of two typical apartments. The moiled walls have an additional 50 mm thick of thermal insulation and=or a thickness of up to 400 mm of concrete. Modeled doors have an additional 38 mm thickness of thermal insulation. The simulation predictions indicate that the highest reduction in the yearly cooling load could be obtained when the moiled walls and doors were used at suitable locations. In addition, from the predicted results, it was found that providing thermal insulation to external walls of residential buildings in very hot-humid climate regions, which would be air-conditioned primarily in the evening, would not lead to significant cooling load reductions. When the wall is thin, adding thermal insulation could even lead to a small increase in the cooling load. Increasing the thickness of the concrete external walls could also lead to an increase in the cooling load, but a small reduction in load could be achieved when the walls are also insulated **Figure 2-5**.

(Gulf. Monna, S. Masera, G. 2014) The study focus on the optimizing of thermal, visual comfort and energy efficiency through the application of different technologies and design strategies for office building envelope in hot arid climate. Building simulation were used to evaluate the effects of different technologies and design strategies on the comfort and energy consumption. The technologies included: glazing performance, shading and solar control, insulation, thermal mass, and daylight systems. In addition, the design strategies included the optimization of: opaque to transparent ratio, orientation, and natural day and night ventilation. The results show the potential for a significant decrease in energy consumption for cooling and lighting. On the other hand, thermal and visual comfort can be increased. Reducing the energy consumption for cooling and lighting as well as improving the indoor comfort are of great importance towards sustainable and climate responsive buildings(this studied in general procedure) .

Optimize materials: (Iran. Moulaii , Mahdavinejad , Gheisar,2011) The purpose of this research is to evaluate the potential usage of a particular, renewable energy options: Smart Materials in hot dry climate. Such exploitation could alleviate, at least in some part, the future environmental burdens. A large-scale assessment has been undertaken with the aim of examining the application of Smart Materials in connection with sustainability and energy efficiency and assesses the optimization of proposed Smart Materials and their products in favor of this region. Experimental research findings are presented, and then analyzed with the purpose of determining the present capability of a significant development of Smart Materials in the hot and dry climatic regions.

Suggestions are then provided to help the improvement of appropriate application and the wider introduction of viable Smart Materials in these regions.

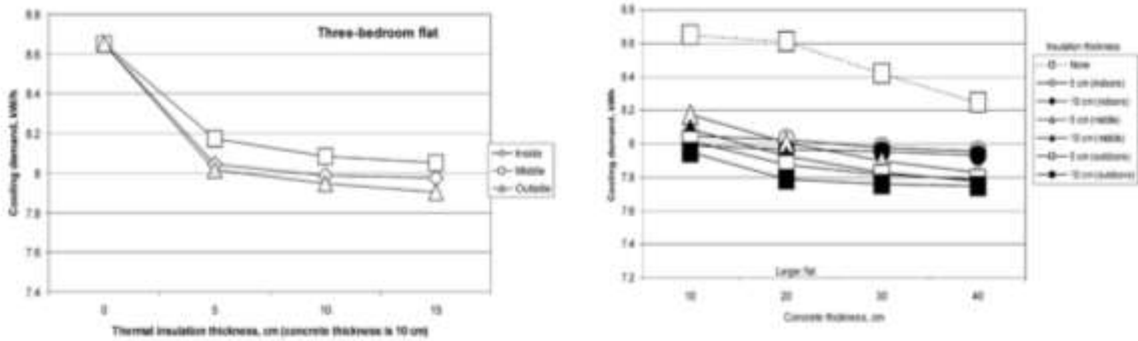


Figure 2-5: maximum cooling demand for three bedroom as functional of thickness and position of thermal insulation layer A 10cm concrete. B variable concrete thickness..

(Riyadh. A. Eben Saleh 2012)studied the thermal performance of buildings using four different building techniques of hollow clay blocks for building external walls were studied, evaluated and compared with similar building techniques of hollow cement blocks, in the hot dry climate of Saudi Arabia.
(Bortugal. N. Soares, J.J. Costa, A.R. Gaspar, P. Santos .2013) This study investigates how and where phase change materials (PCMs) are used in passive latent heat thermal energy storage (LHTES) systems, and how are these construction solutions related to the building's energy performance. Studies about the dynamic simulation of energy in buildings (DSEB) incorporating PCMs are reviewed, mainly those supported by EnergyPlus, ESP-r and TRNSYS software tools. The investigation shows that PCM passive LHTES systems can contribute to (i) increase indoor thermal comfort (air temperature peak reduction, decrease of daily temperature swing, changing in the surface temperature); (ii) improve buildings envelope performance and to increase systems efficiency (insulation capacity, change in heat flow through them, enhancing the thermal capacity); (iii) decrease the conditioning power needed (reduction of the heating and cooling peak loads); (iv) reduce energy consumption; (v) take advantage of off-peak energy savings; (vi) take advantage of renewable sources like solar thermal energy; (vii) save money during the operational phase; and (viii) contribute for the reduction of CO2 emissions associated to heating and cooling **Figure 2-6**.

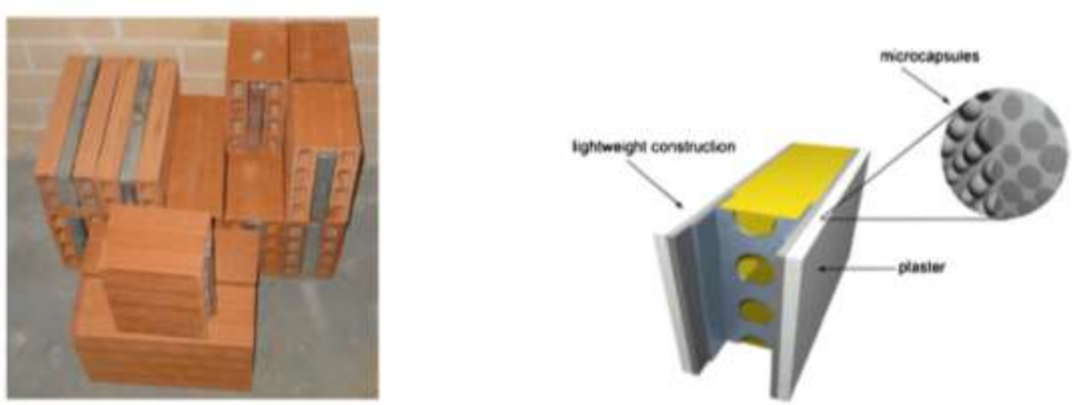


Figure 2-6: Clay bricks with PCM macro capsules and Schematic representation of a concrete roof with frustum holes filled with PCM.

Develop insulation: gulf .(Elsarrag and Alhorr 2012) investigate the Dynamic facade, using Dynamic Insulation (DI) system. This is an energy-efficient method of supplying pre-tempered, filtered ventilation air to a building through an air-permeable, dynamically insulated envelope or facade. DI system was used in a building facade for zone local insulation and ventilation. The energy saving and CO2 reduction are quantified against existing standards in the Gulf Region. The results show that DI can provide tempered fresh air, raise energy efficiency and reduce air conditioning energy demand without compromising Indoor Air Quality (IAQ) or thermal comfort level. Complete of previous investigation utilize simulation model to calculate the heat-transfer coefficient of the dynamically insulated walls, validated experimentally and then coupled with the energy models. The discrepancies in the predicted annual cooling demand between the simplified and detailed models did not exceed 15% for both static and dynamic operations of the Passive-House. This innovate technologies by using breathing process (as natural materials) reduce the cooling demand at hot-humid climate depend on QASA standard for calculation method and ISO **Figure 2-7**.

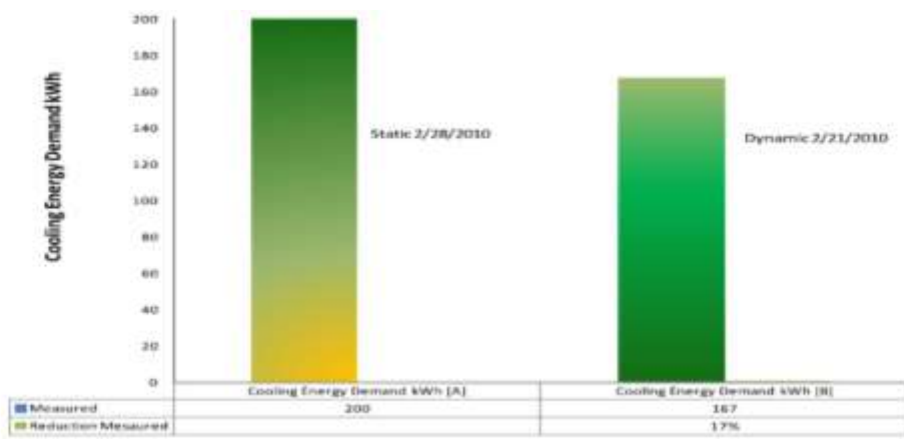


Figure 2-7: comparison of the cooling demand for the typical outdoor air temperature day.

2.2 Hot dry climate region (Middle East) characteristic.

2.2.1 Introduction

The basic climate of the Middle East is hot and dry, although winters are mild with a little rain. To the north of the desert are the great steppes. This area has extremes of temperature and rain in winter and spring. Rest of the area has rainfall between March and November and sometimes floods from March to May. Summers are long and hot and winters mild and wet along the Mediterranean coast. The coastal areas are humid but have a steady breeze to compensate.

The climate of hot-dry zones is in general characterized by high temperatures (40 - 50°C in summer), with sharp variations in both diurnal (day / night) and seasonal (summer-/ winter) temperatures Summer temperatures are usually around 29.5°C, but often rise above 37.5°C. In Baghdad, the record high is 48°C; in Basra, 53°C, the highest temperatures recorded in any major Middle Eastern city. In the Saudi desert, however, temperatures over 48°C are common (climateof. 2015), but may nevertheless cause severe floods. The solar radiation intensity is high and enhanced by the radiation reflected from the ground. The air humidity is low and this climate is generally healthier than those of warm-humid lands. Different climatic zones can be distinguished within desert regions according to their specific geographical characteristics. Particular conditions in maritime desert regions mean that the high humidity causes definite discomfort in summer. On the other hand, the humidity tends to reduce diurnal variations and moderate temperatures [Climate Responsive Building - Appropriate Building Construction in Tropical and Subtropical Regions (SKAT; 1993)].

The new study about Climate change 2015 Jeremy S. Pal of Loyola Marymount University in Los Angeles and(Elfaith A. B. Eltahir,2010) of the Massachusetts Institute of Technology authored the climate change could ultimately make parts of the Middle East too hot for human beings (since.co.2015).

The map below **Figure 2-8** shows the mean annual precipitation for the whole Earth. As can be seen on the map the yellow and brown colored regions mark the driest regions in the Sahara Desert (< 100mm) in North Africa and the Middle East located east of Sahara.

The climate change has already become a major global challenge for the 21st century. Based on the information derived from the IPCC (2007), the Arab region experienced an uneven increase in surface air temperature ranging from 0.2ºC to 2.0ºC that occurred from 1970 to 2004. And over 4°C for the end of the 21th century. Giorgi (2006) identifies North Africa and the Mediterranean among the most physically sensitive regions to climate change UNDP (2010). Climate models are projecting hotter, drier and less predictable climate, resulting in a drop in water run-off by 20% to 30% in most of MENA by 2050, mainly due to rising temperature and lower precipitation (Milly et al., 2005).

Moreover, the events occurred in a region (Syrian situation) that has serious resource imbalances. The summer of 2015 was dramatic both as a result of the events in Syria and also because of climatic conditions. At the end of July, in the Iranian city of Bandar Mahshahr on the Persian Gulf, the temperature reached 46ºC with a dew point of 90, yielding a heat index – a measure of what the air felt like – of 47ºC! In August, it was reported that temperatures had reached 51ºC in the Iraqi city of Basra and the government ordered a four-day holiday to help people deal with the heat. In Lebanon residents lacking electricity took to sleeping on bare floor tiles during extended power cuts that prevented them from using air conditioning(Paul Rivlin 2015).

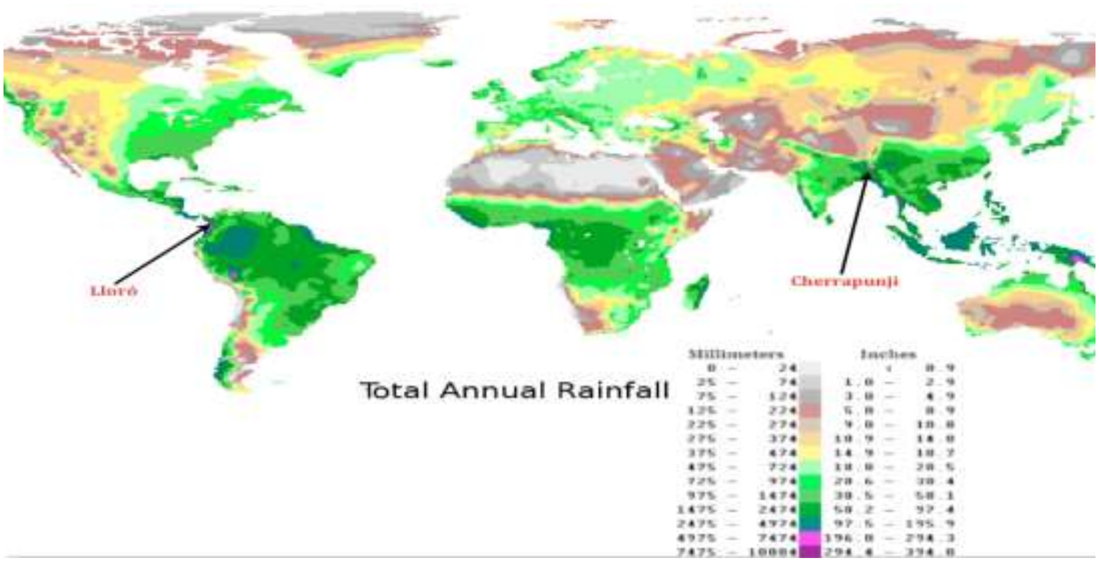
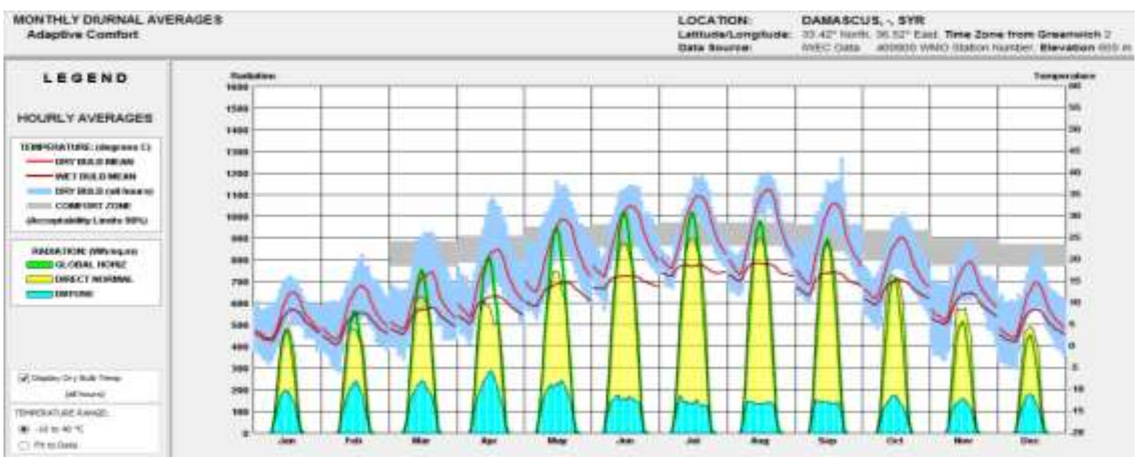


Figure 2-8: The mean annual precipitation for the whole Earth.

Middle East Climate:

Syria: The most striking feature of the climate is the contrast in different areas of this region. Between the humid Mediterranean coast and the arid desert regions, Damascus, becomes part of the semiarid climatic zone of the steppe, with precipitation averaging less than 250 millimeters a year and with temperatures from 4 °C in January to 37 °C in July and August. The vicinity of the capital is, nevertheless, verdant and cultivable because of irrigation from the Barada River by aqueducts built during Roman times.
In the south east, the humidity decreases, and annual precipitation falls below 100 millimeters. The scanty amounts of rain, moreover, are highly variable from year to year, causing periodic droughts. In the semi desert at the Iraqian and Jordanian's borders, temperatures in July often exceed 40 °C. Sandstorms, common during February and May, damage vegetation and prevent grazing.

Damascus City (Syria) Climate Its Global location coordinates are: longitude 36°30'E, Altitude 33°24'N. The hot dry climate summer relay on different climate features as follows:
-According to the Holdridge life zones system of bioclimatic classification Damascus is situated in or near the subtropical desert scrub biome.
-Damascus has a mid-latitude in a local cool steppe climate. or / semi-arid cool climate (Köppen-Geiger classification: BSk) due to the rain shadow effect of the Anti-Lebanon mountains] and the prevailing Mediterranean currents. Summers are dry and hot with less humidity. Winters are cool and somewhat rainy; snowfall is infrequent. Annual rainfall is around 130 mm occurring from October to May
(**Figure 2-9**a,b) CDD about 705 during the period from May till October/ HDD about 731 during period from November till April(CDD explanation at 2.2.2) .



a

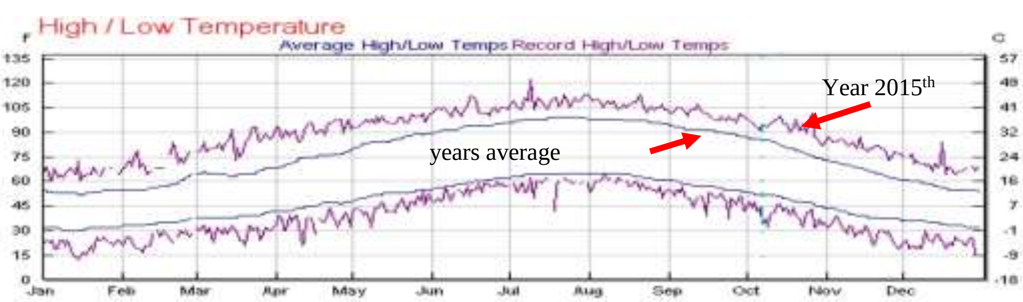


Figure 2-9: a. Damascus weather data climate consultant 5.5 program ASHRAE(average for 10 years started from 2002),b .year average temperature 2015th compare with average of last ten years .

Cairo: Egypt lies in a hot dry climate; it extends between the northern latitudes of 23º and 32º and eastern longitudes of 25º and 36º. According to the Köppen Climate Classification System, Egypt is located within the hot dry climate. Bioclimatic classifications that were carried out, based on temperatures, humidity and solar heat gains, for Egypt shows main six regional climates (Egyptian Climatic Authorities 1997). High temperatures in winter range from 19 to 29 °C ,while night-time lows drop to below 11 °C often to 5 °C In summer, the highs rarely surpass 40 °C and lows drop to about 20 °C .Rainfall is sparse and only happens in the colder months, but sudden showers do cause harsh flooding **Figure 2-10**.CDD about 809 during the period from May to October/HDD about 635 during the period from November to April .

Riyadh(Saudi Arabia): very hot dry climate, Classified as having a hot desert climate (Köppen: BWh), temperatures during the summer months are extremely hot. The average high temperature in August is 43.6 °C. Winters are warm with cool, windy nights. The city experiences very little rainfall, especially in summer, but receives a fair amount of rain in March and April. It is also known to have many dust storms **Figure2-11a**. CDD about 2045 during period from April to the end of October/.HDD about 551 during period from December to March.

Figure2-11b, .present comparison between cities (Damascus , Cairo, Riyadh)air temperature for cooling load season. Big swing between day /night specially in Damascus city (the different average about 25 degrees).The max temperature for Cairo and Damascus roughly equal. The hottest city (very hot-dry climate)Riyadh.

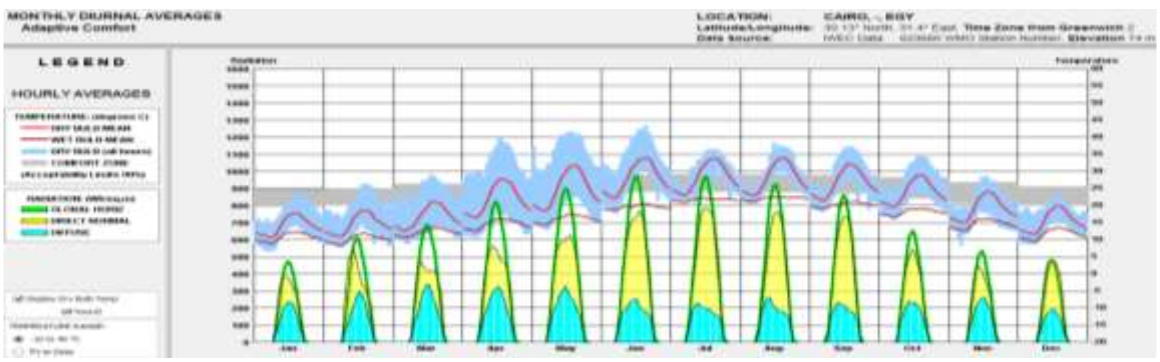
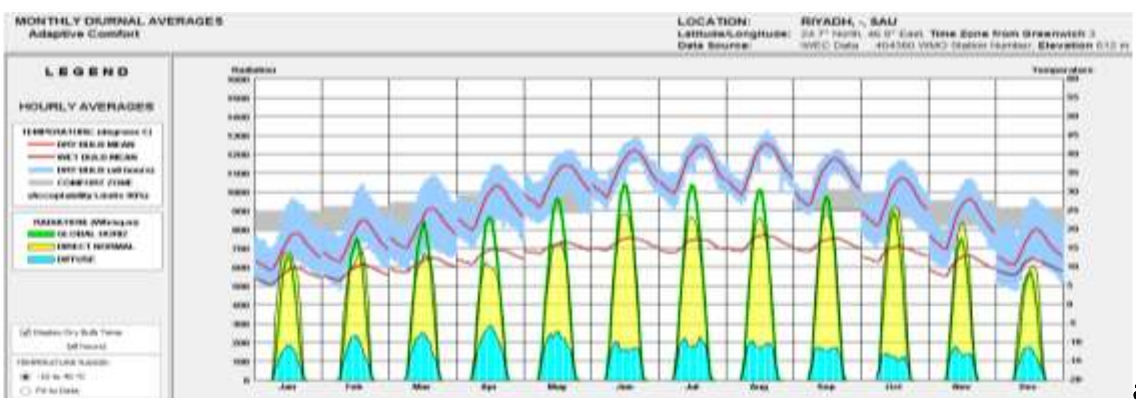


Figure 2-10: Cairo weather data climate consultant 5.5 program (ASHRAE).



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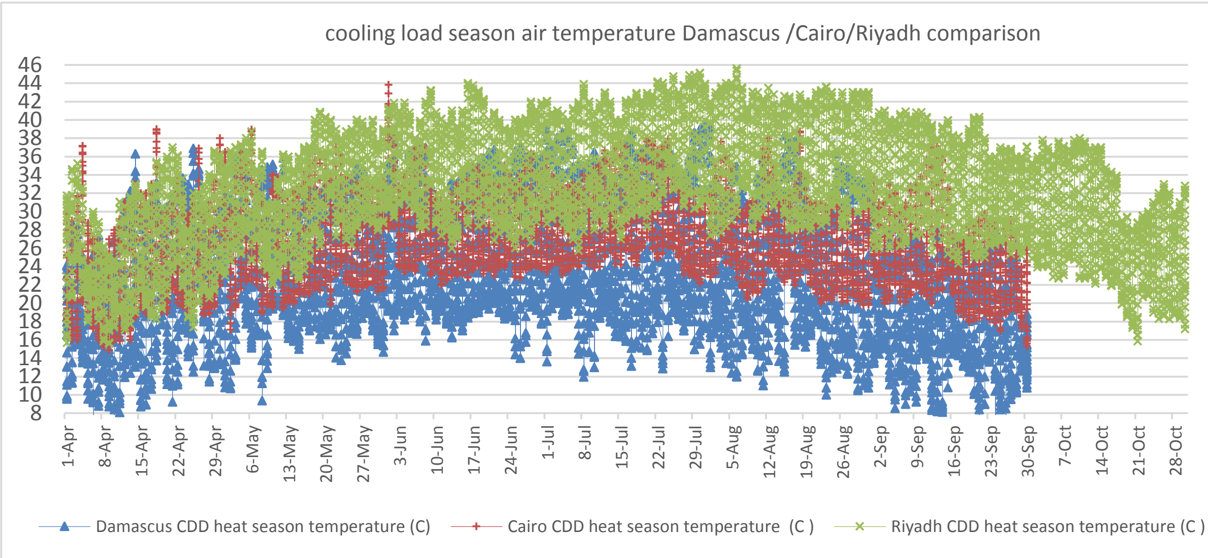

b

Figure 2-11:a. Riyadh weather data climate consultant 5.5 program (ASHRAE).b. temperature comparison CDD

2.2.2 Codes utilized in Middle East region.

The purpose of architect and engineer designer is to create on integrated building design to guarantee a comfortable indoor environment and hence to minimize the energy needs for space conditioning. Especially in USA and EU many standard codes are developed in order to increase new sustainable building. In EU Union recast the Directive 2010/31/EU on the energy performance of buildings (rEPBD), which states that the new buildings shall be nearly zero energy for public buildings and residential building respectively after December 31, 2018 and after December 31, 2020. After that day all countries try to follow that directive also middle east and Arab country (Syria, Egypt, Saudi Arabia, Jordan..) with varying steps . Residential buildings consume more than 50% of the total electricity consumption at Middle East and Arab countries. Artificial lighting is estimated to account about 40% of the electricity used in the residential sector and 35% of the electricity used for HVAC system. A significant increase in electricity demand is expected over the next few years. To improve the energy efficiency in residential buildings (based on the ASHRAE Stander, EN 15251:2007) through the Particle swarm optimization algorithm. One initial path toward passive and net zero energy buildings (NZEB), starts with design and optimizing the building envelope and passive technologies in free-floating mode with respect to an Adaptive comfort model. In spite of standard requirements variety but it is take same strategies with some different at recommended limits ,classification of building and elements specially residential building . **Figure 2-12** shows the energy codes utilized in Arabian middle east countries [ASHRAE 90.1 (2010) , ASHRAE 189.1 (2009) , IECC (2012) international energy conservation code, IGCC international green construction building (2012) , Kuwait Code ASHRAE 90.2 , United Arabian Code , Syrian insulation code , QSAS , ISO] .

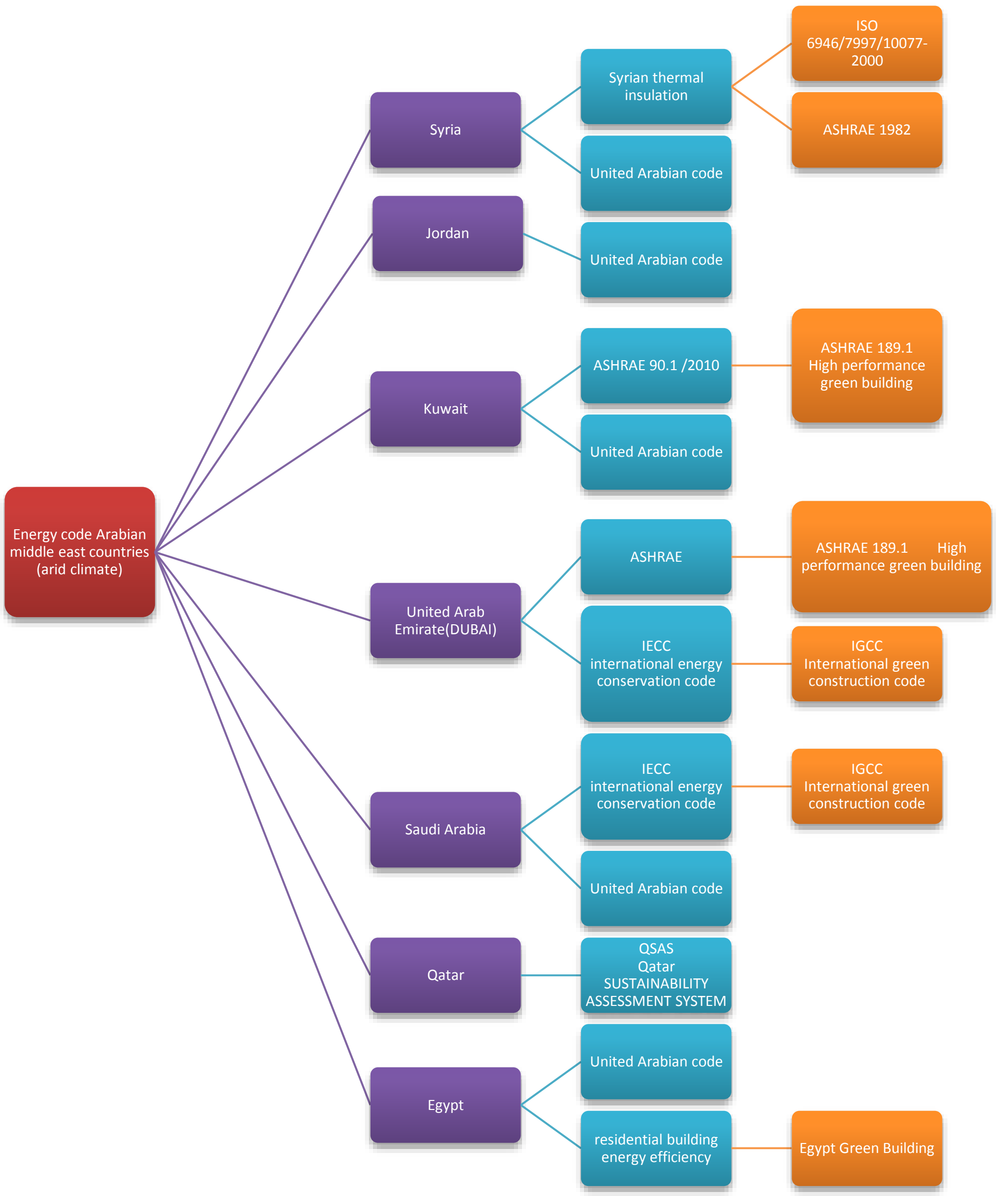

Figure 2-12: the energy codes utilized at Arabian Middle East countries.

From the 1970s many countries throughout the world introduced building regulations aimed at reducing energy consumption in residential and commercial buildings, see **Table 2-1**a,b show the crude oil and natural gas consumption during 2007 at Arab country (George B. HANNA 2010). The New Arab energy Building Code developed for new residential buildings [1. Energy Efficiency Residential Building Draft Code (2010), Final Draft the Arab Countries by the Ministry of Housing, HBRC, Egypt.] is determine the most cost-effective energy efficiency measures suitable for Mediterranean Arabian regions. The optimization of thermal performance of building envelope and fenestration components are considered one of the fundamental design features of energy efficient buildings. The Final Draft of the New Arab Building Energy Codes was approved by the League of Arab States (2010).

Table 2-1: a. Electricity Consumption for Selected Middle East Arabian Countries, b. Arabian Energy Consumption 2007

Arab Countries	Residential	Industry	Commercial
Egypt	37.1%	33.3%	2.5%
Tunis	25.0%	47.0%	--
Lebanon	5.0%	2.5%	2.2%
Jordon	33.0%	31.0%	15.0%
Bahrain	54.4%	17.4%	27.7%
Saudi Arabi	51.1%	22.1%	10.2%
Morocco	17.0%	34.0%	8.0%
Tunis	16.0%	35.5%	9.0%
Jordon	33.0%	31.0%	15.0%
Algeria	36.8%	37.6%	6.2%
Syria	49%	8%	31%

a

Region	Petroleum Consumption	Dry Natural Gas Consumption
Country	(Thousand Barrels /Day)	Billion Cubic feet
Egypt	680.00	999
Libya	261.00	--
Morocco	184.00	--
Tunisia	88.50	--
Algeria	267.00	--
Sudan	85.70	--
Iraq	596.00	--
Jordan	106.00	79
Kuwait	325.00	441
Lebanon	94.00	0
Qatar	115.00	693
Saudi Arabia	2,210.00	2,594
Syria	269.00	221
United Arab Emirates	441.00	1,522
Yemen	141.00	--
Bahrain	36.00	400

b

The different between requirement of Mediterranean Arabian countries for energy efficiency [building envelope the U, R value ……] applied at **Table 2-2** shows over view for index1 the total difference. And the classification related to 2009 ASHRAE Handbook—Fundamentals [Chapter 14, Climatic Design Information, and other data developed specifically for this standard from ASHRAE 1453-RP] this standard provides recognized climatic data for use in building-design and related equipment standards. The climate zone classification **Figure 2-13** related to degree-day: the difference in temperature between the outdoor mean temperature over a 24- hour period .

Temperatures, Degree-Days, and Degree-Hours. Monthly: average temperatures and standard deviation of daily average temperatures are calculated using the averages of the minimum and maximum temperatures for each complete day within the period analyzed. They are used to estimate heating and cooling degree-days to any base, as explained in the section on Calculating Degree-Days.

Heating and cooling degree-days (base 10 or 18.3°C) are calculated as the sum of the differences between daily average temperatures and the base temperature. For example the number of heating degree-days (HDD) in the month is calculated as

$$HDD = \sum_{i=1}^{N} (T_{base} - \overline{T_i})^{+}$$

where N is the number of days in the month, T_{base} is the reference temperature to which the degree-days are calculated, and $\overline{T_i}$ is the mean daily temperature calculated by adding the maximum and minimum temperatures for the day, then dividing by 2. The + superscript indicates that only positive values of the bracketed quantity are taken into account in the sum.

Heating degree-day base 18°C, HDD18: for any one day, when the mean temperature is less than 18°C, there are as many degree-days as degrees Fahrenheit or Celsius temperature difference between 18°C and the mean temperature for the day (18°C minus the mean temperature). Annual heating degree-days (HDDs) are the sum of the degree-days over a calendar year.

Monthly cooling degree-days (CDD) are calculated as:

$$CDD = \sum_{i=1}^{N} (\overline{T_i} - T_{base})^{+}$$

Cooling degree-day base 10°C, CDD10: for any one day, when the mean temperature is more than 10°C, there are as many degree-days as degrees Celsius temperature difference between the mean temperature for the day and 10°C (mean temperature minus 10°C). Annual cooling degree-days (CDDs) are the sum of the degree-days over a calendar year.

Degree-days are used in energy estimating methods, and to classify stations into climate zones for ASHRAE Standard 169.

Comparison between Arab Middle east energy code, **Table 2-2** (a,b,c) :

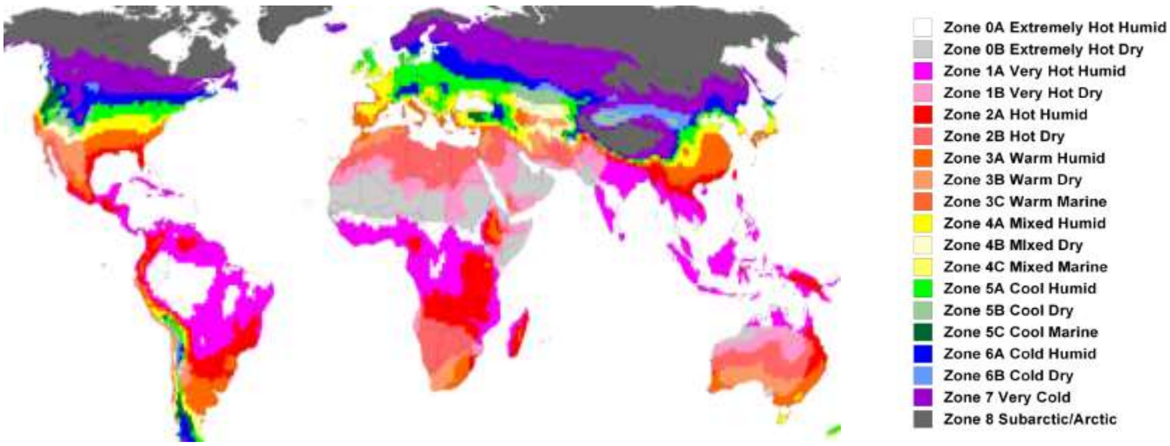

Figure 2-13: ASHRAE international climate zone map.

Table 2-2: .different at residential building classification (low high building three or four level).

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comparison between arabian middle east energy codes

	ASHRAE 90.1(2010)	ASHRAE 189.1(2009)	IECC International energy	IGCC International green	Kuwait code ashrae 90.2	United Arabian Code	Syrian thermal isolation code (2010)	ISO 6946	QSAS	caparative [illegible]
intent	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
residential	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
existing buildings	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Climate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mixed occupancy	—	—	[illegible]	[illegible]	—	—	—	[illegible]	—	
building envelope										
	[illegible]		[illegible]						[illegible]	

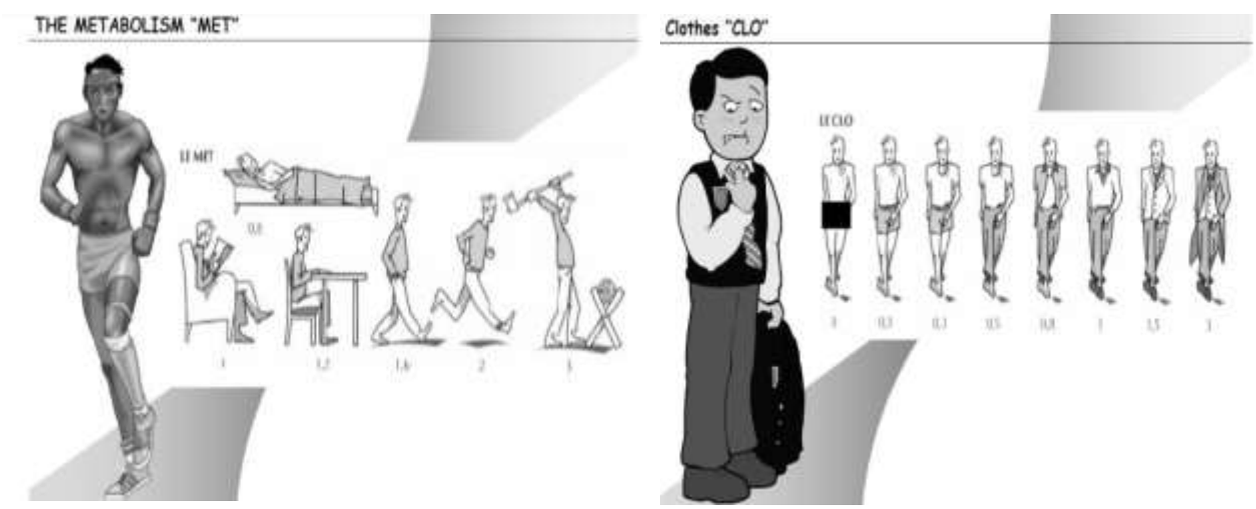
2.3 Thermal comfort.

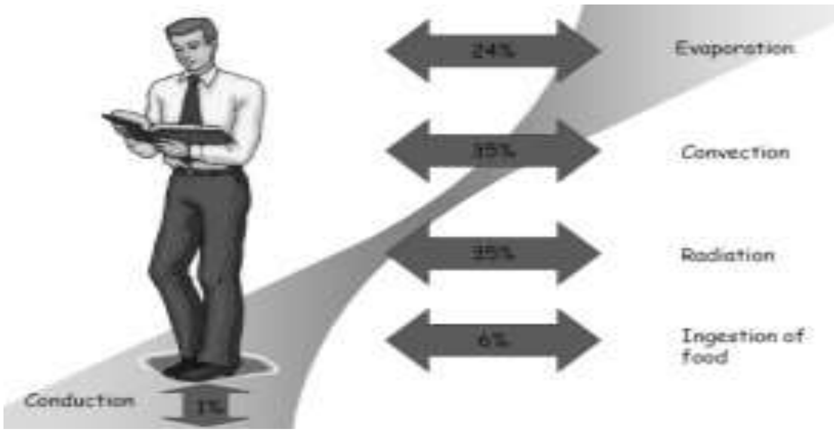
2.3.1 Introduction.

Thermal comfort is very difficult to define because of the need to take into account a range of environmental and personal factors when deciding what will make people feel comfortable. Comfort conditions from the physiological point of view can be obtained when a person maintains a normal balance between production and loss of heat at normal body temperature and without sweating (Yaglou 1949). Other concepts, which are of interest to many of the comfort community, are based on three main assumptions as pointed out by (Auliciems 1981). The first assumption the relation between thermoregulatory activity and subjective acceptability, the second the relation between thermal sensation and levels of discomfort implying that both are synonymous. The third the perception of warmth is exclusively the function of thermal stimuli. In the 1980s there was a great progress in the air conditioning industry. The former progresses lead to the extension of the definition of thermal comfort to include the environmental and expectations from memory. (Brager and de Dear 2003[1, 2, 3]).Thermal comfort is influenced by behaviour (clothing and activity) and environment. Today, Thermal comfort is commonly defined in EU Standard EN ISO 7730 as ―that condition of mind which expresses satisfaction with the thermal environment in ASHRAE(55-1992/2013) which proposed a definition of the suitable quality level for an indoor environment. A lot of studies were carried out in recent decades aiming at determining the comfortable thermal conditions within different types of buildings regarding the methods of heating and cooling used in each. In these studies, two main methodical approaches were used. The first was laboratory experiments using a climate chamber as an environment for the study. The second method was running field studies in real life context using real buildings as an environment of the study(Amgad A 2011).

2.3.2 Comfort Model:

Thermal comfort is basically a subjective concept. The criteria of thermal comfort are not identical for everyone: they depend on the age, the sex, the individual characteristics, carried out(met) and there are six primary factors that must be addressed when defining conditions for thermal comfort.**Figure2-14**.a,b





b

Figure 2-14: a,The index for metabolism(met)and clothes insulation (clo),b heat exchange

The basic equation for energy balance is:

$$M - W = q_{sk} + q_{res} + S$$

$$M - W = (C + R + E_{sk}) + (C_{res} + E_{res}) + (S_{sk} + S_{cr})$$

Where:
M = rate of metabolic heat production, W/m^2
W = rate of mechanical work accomplished, W/m^2
q_{sk} = total rate of heat loss from skin, W/m2
q_{res} = total rate of heat loss through respiration, W/m^2
C + R = sensible heat loss from skin, W/m^2
E_{sk} = total rate of evaporative heat loss from skin, W/m^2
C_{res} = rate of convective heat loss from respiration, W/m^2
E_{res} = rate of evaporative heat loss from respiration, W/m^2
S_{sk} = rate of heat storage in skin compartment, W/m^2
S_{cr} = rate of heat storage in core compartment, W/m^2
S= deficit stored

$$S_{cr} = \frac{(1-\alpha)mc_{p.d}}{A_D} * \frac{dt_{cr}}{d\theta}$$

$$S_{sk} = \frac{\alpha_{sk}mc_{p.d}}{A_D} * \frac{dt_{sk}}{d\theta}$$

Where:
α_{sk} = fraction of body mass concentrated in skin compartment
m = body mass, kg
$c_{p,b}$ = specific heat capacity of body = 3490 J/(kg·K)
A_D = DuBois surface area, m^2
t_{cr} = temperature of core compartment, °C
t_{sk} = temperature of skin compartment, °C
θ = time, s

Sensible heat loss from skin:

$$C + R = f_{cl}h(t_{cl} - t_o)$$

Where:
f_{cl} correction factor $f_{cl} = A_{ci}/A_D -$ A_D body surface area m2
$h = h_c + h_r$ coefficient clothing surface .
t_o operative temperature
t_{ch} mean temperature of the outer surface of clothed body

Evaporation heat loss from skin:

$C_{res} = 0.0014M(34 - t_a)$

$E_{res} = 0.0173M(5.87 - p_a)$

Where:
M = metabolic rate, W/m^2
Ta = ambient temperature C.
pa is expressed in kPa and ta is in °C.

$E_{sk} = \frac{W(p_{sk.s} - p_a)}{R_{e,cl} + 1/(f_{cl} h_c)}$

Where:
w = skin wettedness, dimensionless
$p_{sk,s}$ = water vapor pressure at skin, normally assumed to be that of saturated water vapor at tsk, kPa
p_a = water vapor pressure in ambient air, kPa
$R_{e,cl}$ = evaporative heat transfer resistance of clothing layer (analogous to Rcl), (m^2·kPa)/W
h_e = evaporative heat transfer coefficient (analogous to hc), W/(m^2·kPa)

Two important environmental indices can be intreduceed: humid operative temperature(t_{oh})and effective temperature(TE) **Figure 2-15**

The humid operative temperature is that temperature which at 100% rh yields the same total heat loss as for the actual environment:

$t_{oh} = t_o + wi_m LR(P_a - P_{oh.s})$

Where:
t_{oh} humidity operative temperature°C
t_o operative temperature °C
w = skin wettedness, dimensionless
LR = Lewis ratio, K/kPa
P_a pressure air kPa
$P_{oh,s}$ saturated vapor pressure .kPa
im = total vapor permeation efficiency: ratio of actual evaporative ,heat flow capability between skin and environment to sensible ,heat flow capability as compared to Lewis ratio.

The effective temperature is the temperature at 50% rh that yields the same total heat loss from the skin as for the actual environment:

$ET^* = t_o + wi_m LR(P_a - 0.5P_{ET*.s})$

Where ET is saturated vapor pressure, in kPa, at ET. The psychometric chart in **Figure 2-15** shows a constant total heat loss line and the relationship between these indices.

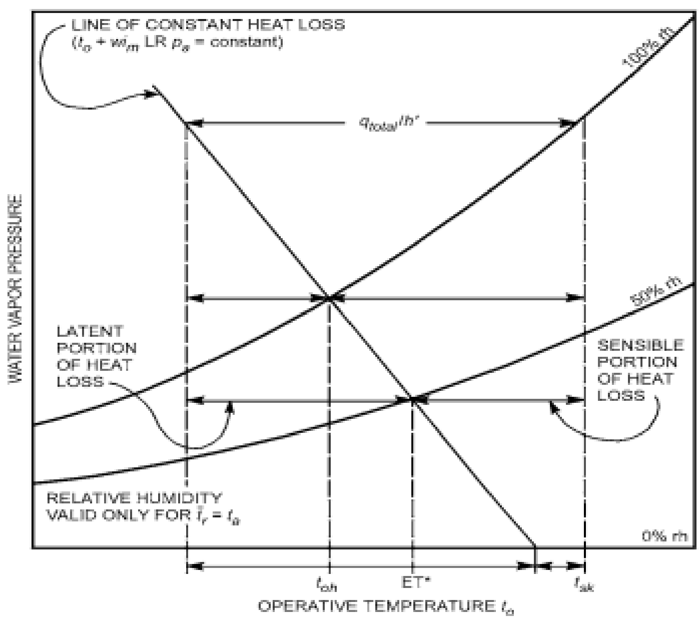


Figure 2-15: Constant Skin Heat Loss Line and Its Relationship to toh and ET*.ASHRAE fundamental chapter 9.

2.3.2.1 *Environment parameters:*

Directly Measured Parameters. Seven psychometric parameters used to describe the thermal environment are (1) air temperature ta, (2) wet-bulb temperature t_{wb}, (3) dew-point temperature tdp, (4) water vapor pressure pa, (5) total atmospheric pressure pt, (6) relative humidity (rh), and (7) humidity ratio Wa. Two other important parameters include air velocity V and mean radiant temperature **Figure 2-16** .

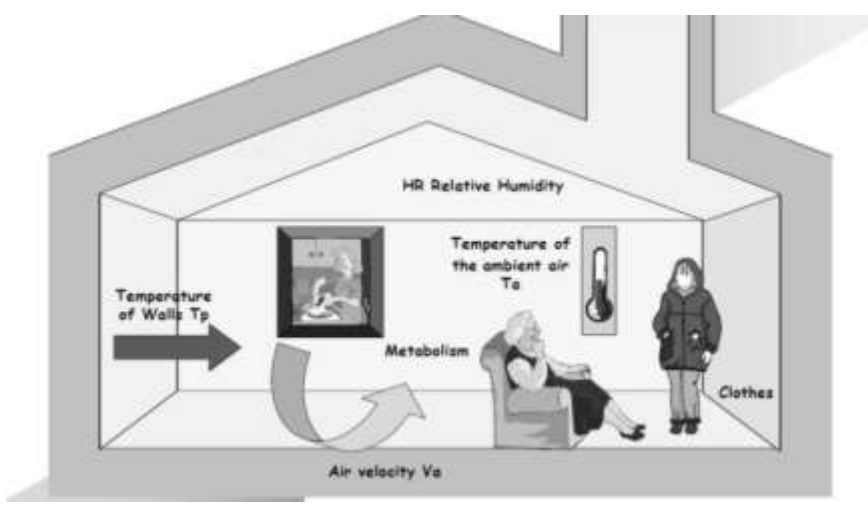


Figure 2-16: the parameters influence comfort.

2.3.2.2 *Condition for thermal comfort:*

There are six primary factors that must be addressed when defining conditions for thermal comfort.

1. Metabolic rate
2. Clothing insulation
3. Air temperature
4. Radiant temperature
5. Air speed
6. Humidity

The mean radiant temperature tr is a key variable in thermal calculations for the human body.

Mean radiant temperature can also be calculated from the measured temperature of surrounding walls and surfaces and their positions with respect to the person. Most building materials have a high emittance, so all surfaces in the room can be assumed to be black. The following equation is then used:

$$\bar{T}_r^4 = T_1^4 F_{p-1} + T_2^4 F_{p-2} + \cdots + T_N^4 F_{p-N}$$

Where
T_r^4mean radiant temperature, K
T_N = surface temperature of surface N, K
F_{p-N} = angle factor between a person and surface N **Figure 2-17**

This equation could be simplified to a linear form:

$$\bar{t}_r = t_1 F_{p-1} + t_2 F_{p-2} + \cdots + t_N F_{p-N}$$

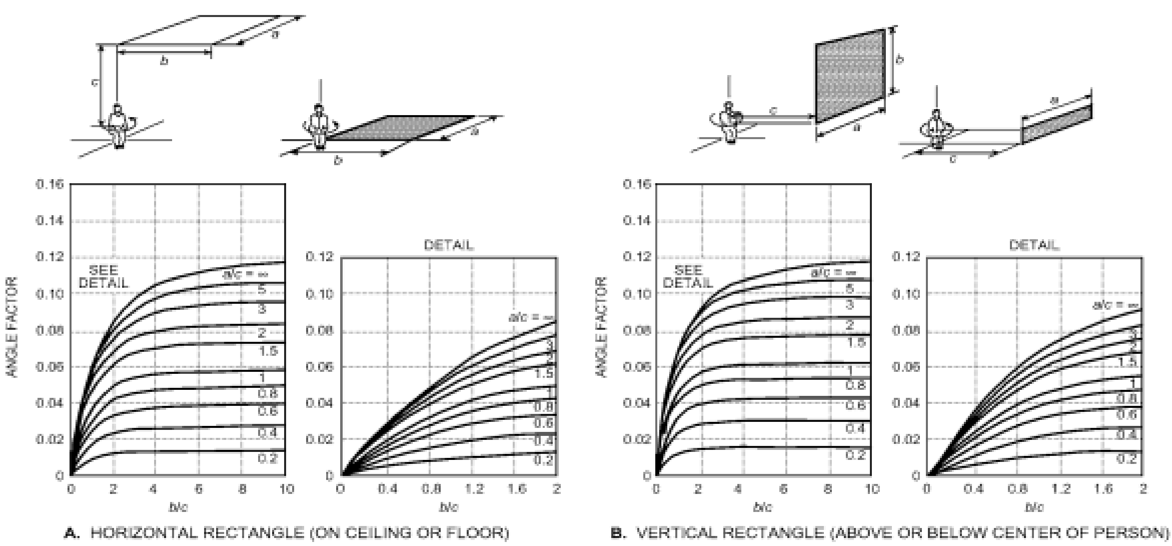


Figure 2-17: Mean Value of Angle Factor Between Seated Person and Horizontal or Vertical Rectangle when Person Is Rotated Around Vertical Axis (Fanger 1982)chapter 9 ASHRAE handbook fundamental .

Mean radiant temperature may also be calculated from the plane radiant temperature t_{pr} in six directions Thermal Sensation (up, down, right, left, front, back).

The ASHRAE thermal sensation scale, which was developed for use in quantifying people's thermal sensation, is defined as follows:

+3 hot
+2 warm
+1 slightly warm
0 neutral.
–1 slightly cool.
–2 cool.
–3 cold.

2.3.2.3 *Predication of thermal comfort:*

More numerical and rigorous predictions are possible by using the PMV-PPD and two-node models described in this section. Another way is the psychometric chart which are evaluate by steady state energy balance.

The following linear regression equations, based on data from Rohles and Nevins (1971), indicate values of t_{sk} and E_{rs} what provide thermal comfort **Figure 2-18** a,b:

$$t_{sk,req} = 35.7 - 0.0275(M - W)$$
$$E\_(rsw, req) = 0.42(M - W - 58.15)$$

Where
$t_{sk,req}$ meam skin temperature .
E_{rsw} sweat rate.
M = metabolic heat production, W/m2
W = external work accomplished, W/m2, or humidity ratio of air, kg (water vapor)/kg (dry air)

At higher activity levels, sweat loss increases and mean skin temperature decreases, both of which increase heat loss from the body core to the environment. The combination of environmental and personal variables that produces a neutral sensation may be expressed as follows:

$$M - W = 3.96 \times 10^{-8} f_{cl}[(t_{cl} + 273)^4 - (t_{\bar{r}} + 273)^4] + f_{cl} h_c (t_{cl} - t_a) + 3.05[5.73 - 0.007(M - W) - P_a] + 0.42(M - W) - 58.15] + 0.0173M(5.87 - P_a) + 0.0014M(34 - t_a)$$

Where
t r = mean temperature c.
f_{cl} = clothing area factor, Acl /AD, dimensionless
t a = air temperature c.
W = external work accomplished, W/m2, or humidity ratio of air, kg (water vapor)/kg (dry air)
M = metabolic heat production, W/m2
h_r= The radiant heat Exchange Stefan-Boltzmann law.

where

$$t_{cl} = 35.7 - 0.0275(M - W) - R_{cl}\{(M - W) - 3.05[5.73 - 0.007(M - W) - p_a] - 0.42[(M - W) - 58.15] - 0.0173M(5.87 - p_a) - 0.0014M(34 - t_a)\}$$

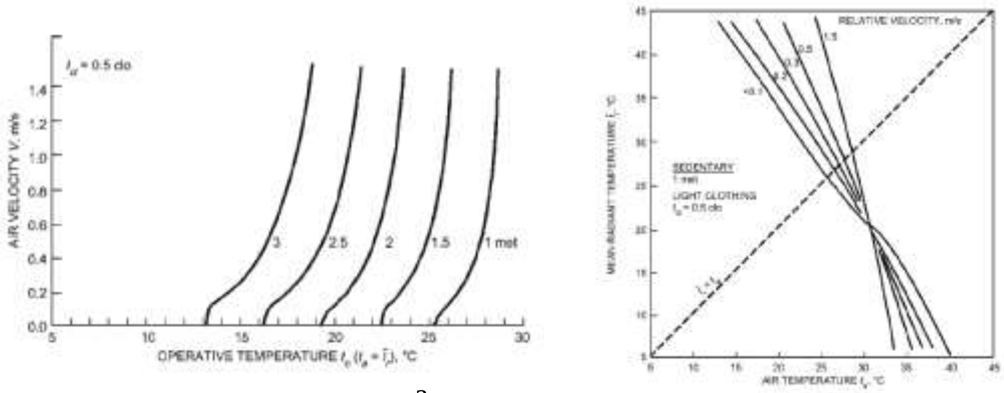
The values of h_c and f_{cl} can be estimated from tables and equations given in the section on Engineering Data and Measurements. Fanger used the following relationships:

$$h_c = \begin{cases} 2.38(t_{cl} - t_a)^{0.25} & 2.38(t_{cl} - t_a)^{0.25} > 12.1\sqrt{V} \\ 12.1\sqrt{V} & 2.38(t_{cl} - t_a)^{0.25} < 12.1\sqrt{V} \end{cases}$$

$$f_{cl} = \begin{cases} 1.0 + 0.2 I_{cl} & I_{cl} < 0.5 \text{ clo} \\ 1.05 + 0.1 I_{cl} & I_{cl} > 0.5 \text{ clo} \end{cases}$$

NOTE 1 metabolic unit = 1 met = 58,2 W/m2; 1 clothing unit = 1 clo = 0,155 m2 °C/W.

Expanded to include a range of thermal sensations by using a predicted mean vote (PMV) index. The PMV index predicts the mean response of a large group of people according to the ASHRAE thermal sensation scale.



a b

Figure 2-18: a.Air Velocities and Operative Temperatures at 50% rh Necessary for Comfort (PMV = 0) of Persons in Summer Clothing at Various Levels of Activity(Chapter9 ASHRAE handbook fundamental) .b. Air Temperatures and Mean Radiant Temperatures Necessary for Comfort (PMV = 0) of Sedentary Persons in Summer Clothing at 50% rh(Chapter9 ASHRAE handbook fundamental) .

Fanger (1970) related PMV to the imbalance between actual heat flow from the body in a given environment and the heat flow required for optimum comfort at the specified activity by the following equation:

$$PMV = [0.303exp(-0.036M) + 0.028]L$$

Where L is the thermal load on the body.

After estimating the PMV with the latest Equation or another method, the predicted percent dissatisfied (PPD) with a condition can also be estimated. Fanger (1982) related the PPD to the PMV as follows:

$$PPD = 100 - 95exp[-(0.03353PMV^4 + 0.2179PMV^2)]$$

Where dissatisfied is defined as anybody not voting -1, +1, or 0. This relationship is shown in **Figure 2-19**. A PPD of 10% corresponds to the PMV range of ±0.5, and even with PMV = 0, about 5% of the people are dissatisfied.

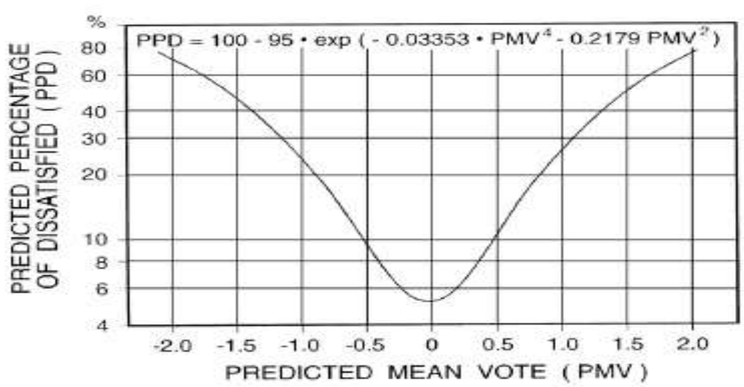


Figure 2-19: Predicted Percentage of Dissatisfied (PPD) as function of Predicted Mean Vote (PMV)ASHRAE standard 55-2010 for thermal environmental condition for human occupancy.

2.3.2.4 *ASHRAE STANDARD 55: Graphic comfort zone (psychometric-char):*

ASHRAE Standard 55-2010 defines comfort zones **Figure 2-20** for 0.5 and 1.0 clo [0.078 and 0.155 (m2·K)/W] metabolic rate between 1.0-1.3 met, average air speed not greater than 0.2 m/s require the use of increase air speed above 0.3 m/s in following section (The air speeds necessary to compensate for a temperature increase above the warm-temperature border are shown in **Figure 2-21** the corves .
The curves of **Figure 2-21** are for different levels of t_r– t_a. That is, when the mean radiant temperature is low and the air temperature is high, elevated air speed is less effective at increasing heat loss and a higher air speed is needed for a given temperature increase. Conversely, the air speed more effects when the t_r higher than t_a which applies to lightly clothed individuals [clothing insulation between 0.5 and 0.7 clo] who are engaged in near-sedentary physical activity.).
With constant ET*.The comfort zone's temperature boundaries (T_{min}, T_{max}) can be adjusted by interpolation for clothing insulation levels (I_{cl}) between those in Figure 16 by using the following equations for relationship :

$$T_{min,I_{cl}} = \frac{(I_{cl} - 0.5\text{ clo})T_{min,1.0\text{ clo}} + (1.0\text{ clo} - I_{cl})T_{min,0.5\text{ clo}}}{0.5\text{ clo}}$$

$$T_{max,I_{cl}} = \frac{(I_{cl} - 0.5\text{ clo})T_{max,1.0\text{ clo}} + (1.0\text{ clo} - I_{cl})T_{max,0.5\text{ clo}}}{0.5\text{ clo}}$$

At ASHRAE the relative humidity not exceed 60% and the low-humidity environments (dew point < 2°C) The Graphic Comfort Zone is limited to a humidity ratio at or below 0.012 kg H2O/kg dry air (0.012 lb H2O/lb dry air), which corresponds to a water vapor pressure of 1.910 kPa(0.277 psi) at standard pressure or a dew-point temperature of 16.8°C .

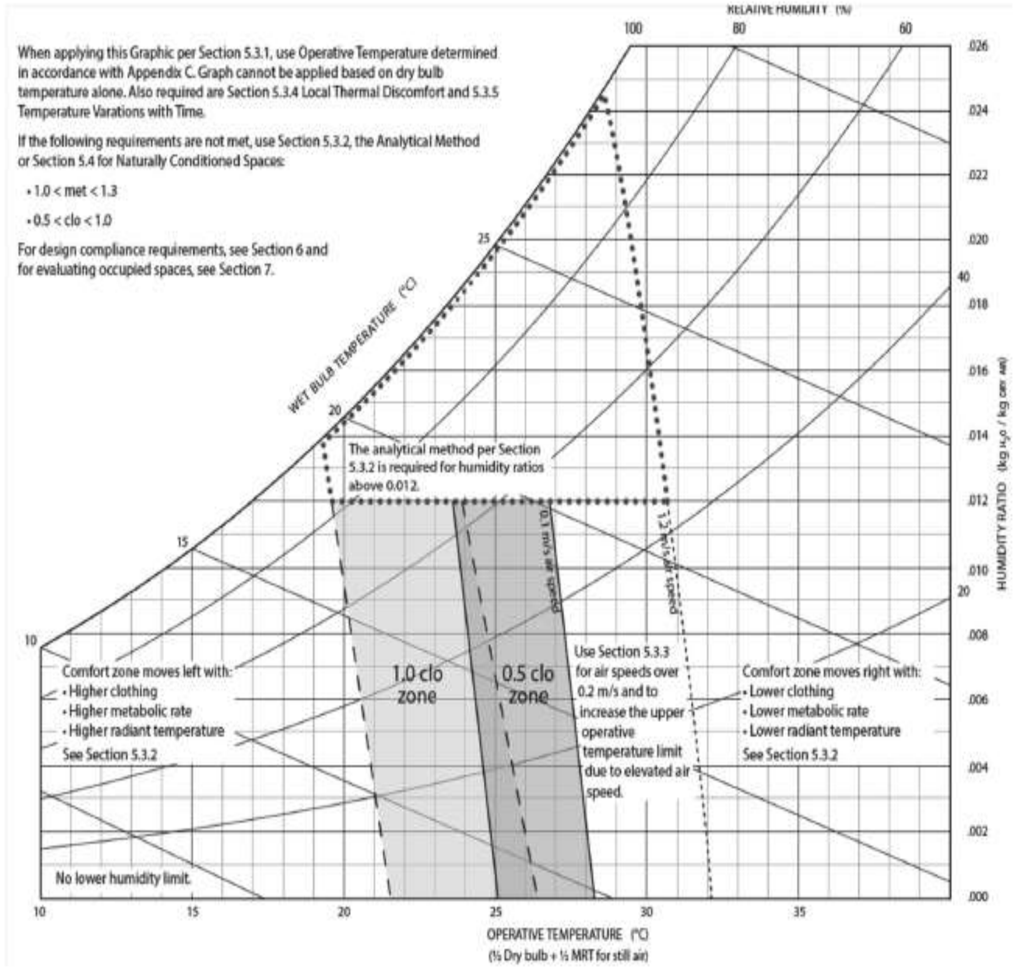


Figure 2-20: ASHRAE Graphic Comfort Zone Method: Acceptable range of operative temperature and humidity for spaces that meet the criteria specified in Section .ASHRAE standard 55-2010 for thermal environmental condition for human occupancy.

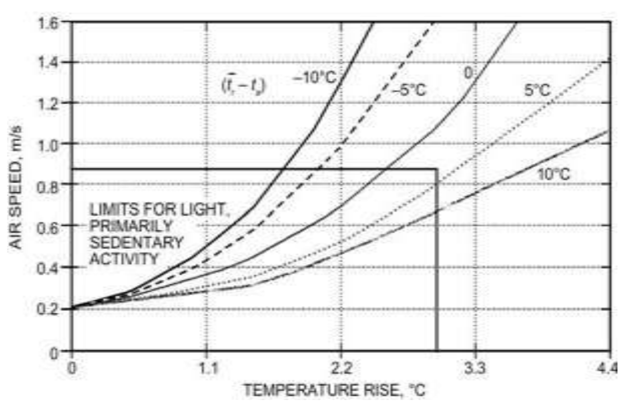


Figure 2-21: Air Speed to Offset Temperatures Above Warm- Temperature Boundaries of Figure16 (Air speed required to offset increased air and radiant temperatures**).**chapter 9 ASHRAE handbook fundamental

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2.3.2.5 *Thermal non uniform conditions and local discomfort:*

A person maybe feel thermally neutral but still discomfort when on part of his body too warm or cold than the others.

There are many factors cussed this feeling of discomfort. Asymmetric thermal radiation in space may be caused by window uninsulated walls, cold or warm product or machine.

Draft : is an undesired local cooling of human body caused by air movement .This problem is common not only in building but also in train ,bus ,car **Table 2-3**.

Fanger and Christensen (1986) aimed to establish the percentage of the population feeling draft when exposed to a given mean velocity. **Figure 2-22**.a (wearing normal indoor clothes).Fanger et al. (1989) investigated the effect of turbulence intensity on sensation of draft. This model can be used to quantify draft risk in spaces and to develop air distribution systems with a low draft risk.

$$PD = (34 - t_a)(V - 0.05)^{0.62}(0.37VT_U + 3.14)$$

Where

PD is percent dissatisfied and T_u is the turbulence intensity in % defined by $T_U = 100\frac{V_{sd}}{V}$

Ta air temperature C.

For $V < 0.05$ m/s, insert $V = 0.05$, and for PD > 100%, insert PD = 100%. V_{sd} is the standard deviation of the velocity measured with an omnidirectional anemometer having a 0.2 s time constant.

The effects of V for the experimental data to which the model is fitted are $20 < t_a < 26$°C, $0.05 < V < 0.5$ m/s, and $0 < T_u < 70$%. **Figure 2-22**.b gives more precisely the curves that result from intersections between planes of constant T_u and the surfaces of PD = 15%.

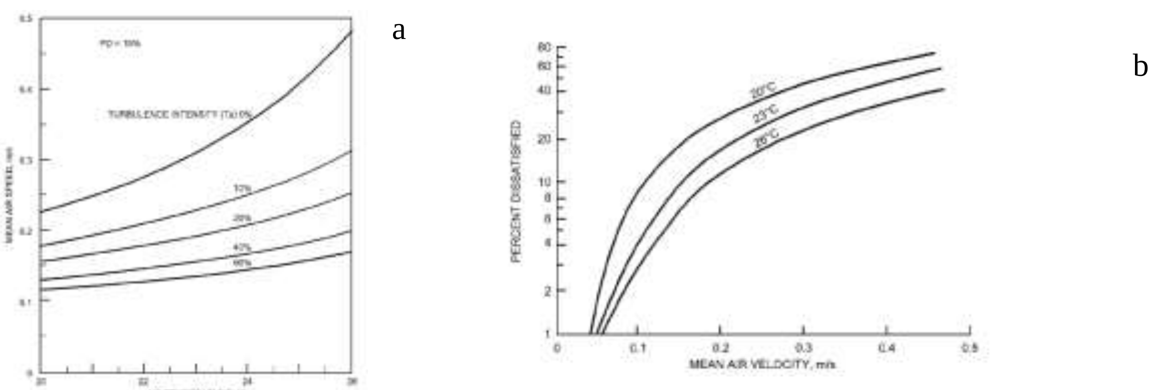


Figure 2-22: a. Percentage of People Dissatisfied as Function of Mean Air Velocity Chapter9 ASHRAE handbook fundamental , b. Draft Conditions Dissatisfying 15% of Population (PD = 15%)Chapter9 ASHRAE handbook fundamental

Another factor that caused human discomfort is the vertical temperature difference as the warm air increase with height above the floor , local warm discomfort occur at the head or cold discomfort can occur at feet.

Also warm or cold floor can occur discomfort feeling.

All those factors on one side the another one is depend on the personal (age , adaptive , sex, seasonal , day to day variation temperature).

Warm or Cold Floors

Because of direct contact between the feet and the floor, local discomfort of the feet can often be caused by a too-high or too-low floor temperature. Also, floor temperature significantly influences a room's mean radiant temperature. Floor temperature is greatly affected by building construction (e.g., insulation of the floor, above a basement, directly on the ground, above another room, use of floor heating, floors in radiant-heated areas). If a floor is too cold and the occupants feel cold discomfort in their feet, a common reaction is to increase the temperature level in the room; in the heating season, this also increases energy consumption. At the optimal Temperature, 6% of occupants felt warm or cold discomfort in the feet. **Figure 2-23** shows the relationship between floor temperature and percent dissatisfied, combining data from experiments with seated and standing subjects. **Table 2-3**.room or that ventilation systems be stopped.

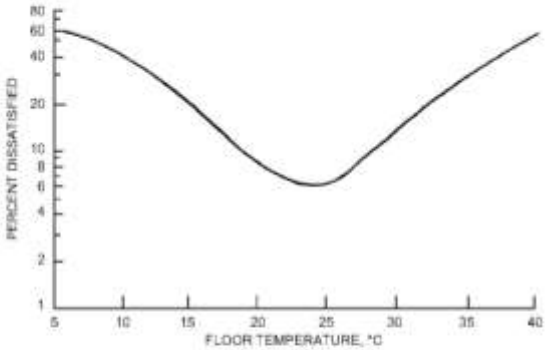


Figure 2-23: Percentage of People Dissatisfied as Function of Floor Temperature.

Table 2-3: Percantage dissatisfied PD due to local discomfort from draft/ASHRAE55.

PD Due to Draft	PD Due to Vertical Air Temperature Difference	PD Due to Warm or Cool Floors	PD Due to Radiant Asymmetry
<20%	<5%	<10%	<5%

2.3.2.6 *Two-Node Model:*

The PMV model is useful only for predicting steady-state comfort responses. The two-node model can be used to predict physiological responses or responses to transient situations, at least for low and moderate activity levels in cool to very hot environments (Gagge et al. 1971a, 1986) The Pierce model based on thermally lumps consider the human body as two isothermal mean concentric compartments, one representing the internal section or core (where all the metabolic heat is assumed to be generated) and the skin.

This allows the passive heat conduction from the core compartment to the skin to be accounted for. The boundary line between two compartments changes with respect to skin blood flow rate per unit skin surface area (SKBF in L/h•m2) and is described by alpha – the fraction of total body mass attributed to the skin compartment.

All the heat is assumed to be generated in the core compartment. In the cold, shivering and muscle tension may generate additional metabolic heat. This increase is related to skin and core temperature depressions from their set point values, or

$$M_{shiv} = [156(37 - t_a) + 47(33 - t_{sk}) - 1.57(33 - t_{sk})^2]/BF^{0.5}$$

Where:
t_a ambient temperature.
t_{sk} skin temperature.
shiv= shivering
BF is percentage body fat and the temperature difference terms are set to zero if they become negative (Tikusis and Giesbrecht1999).

In addition, the flow heat is conducted passively from the core to the skin. This is modeled as a massless thermal conductor [K = 5.28 W/(m^2·K)]. A controllable heat loss path from the core consists of pumping variable amounts of warm blood to the skin for cooling. This peripheral blood flow Q_{bl} in L/(h·m2) depends on skin and core temperature deviations from their respective set points:

$$Q_{bl} = \frac{\mathrm{BFN} + c_{dil}(t_{cr} - 37)}{1 + S_{tr}(34 - t_{sk})}$$

The temperature terms can only be > 0. If the deviation is negative, the term is set to zero. For average persons, the coefficients BFN, c_{dil} , and S_{tr} are 6.3, 50, and 0.5. Further, skin blood flow Q_{bl} is limited to a maximum of 90 L/(h·m2). A very fit and well-trained athlete could expect to have c_{dil}= 175.

Dry (sensible) heat loss from the skin and Evaporative heat note follows a similar path of PMV, flowing Maximum evaporation E_{max} occurs if the skin is completely covered with sweat. The actual evaporation rate E_{sw} depends on the size w of the sweat film:

$E_{sw} = WE_{max}$

Where $W = E_{rsw}/E_{max}$

$E_{rsw} = C_{sw}(t_{b-}t_{bset})exp[-(t_{sk} - 34)/10.7]$

Where:

$t_b = (1 - \alpha)t_{cr} + \alpha_{sk}t_{sk}$

$C_{sw} = 170\ W/(m^2.k)$

α_{sk} the fraction of the total body mass considered to be thermally in the skin compartment

$$\alpha_{sk} = 0.0418 + \frac{0.745}{Q_{bl} - 0.585}$$

Regulatory sweating Q_{rsw} in the model is limited to 1 L/(h·m2) or 670 W/m2. E_{rsw} evaporates from the skin, but if E_{rsw} is greater than E_{max}, the excess drips off. An energy balance on the core yields

$$M + M_{shiv} = W + q_{res} + (K + \mathrm{SkBF}c_{p,bl})(t_{cr} - t_{sk}) + m_{cr}c_{cr}\frac{\mathrm{d}t_{cr}}{\mathrm{d}\theta}$$

And for the skin

$$(K + \mathrm{SkBF}c_{p,bl})(t_{cr} - t_{sk}) = q_{dry} + q_{evap} + m_{sk}c_{sk}\frac{\mathrm{d}t_{sk}}{\mathrm{d}\theta}$$

Where c_{cr}, c_{sk} , and $c_{p,bl}$ are specific heats of core, skin, and blood [3500, 3500, and 4190 J/(kg·K), respectively]

SkBF is $\rho blQbl$,,

Where Q_{bl} is density of blood (12.9 kg/L).

The model uses empirical expressions to predict thermal sensation (TSENS) and thermal discomfort (DISC).

These indices are based on 11-point numerical scales, where positive values represent the warm side of neutral sensation or comfort, and negative values represent the cool side. TSENS is based on the same scale as PMV, but with extra terms for ±4 (very hot/cold) and ±5 (intolerably hot/cold).

The same positive/negative convention for warm/cold discomfort, DISC:

5 intolerable

4 limited tolerance

3 very uncomfortable

2 uncomfortable and unpleasant

1 slightly uncomfortable but acceptable

0 comfortable

TSENS is defined in terms of deviations of mean body temperature t_b from cold and hot set points representing the lower and upper limits for the zone of evaporative regulation: $t_{b,c}$ and $t_{b,h}$, respectively.

$$t_{b,c} = \frac{0.194}{58.15}(M - W) + 36.301$$

$$t_{b,h} = \frac{0.347}{58.15}(M - W) + 36.699$$

TSENS=
$$\begin{cases} 0.4685(t_b - t_{b,c}) & t_b < t_{b,c} \\ 4.7\eta_{ev}(t_b - t_{b,c})/(t_{b,h} - t_{b,c}) & t_{b,c} \le t_b \le t_{b,h} \\ 4.7\eta_{ev} + 0.4685(t_b - t_{b,h}) & t_{b,h} < t_b \end{cases}$$

Where η_{ev} is the evaporative efficiency (assumed to be 0.85).

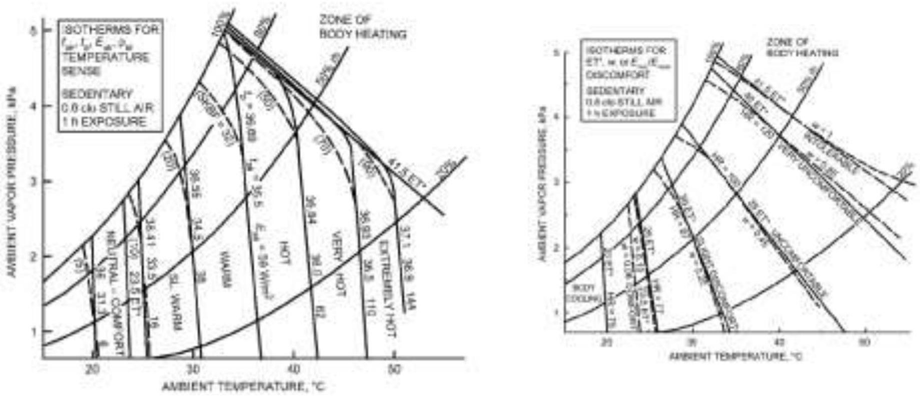
DISC is numerically equal to TSENS when t_b is below its cold set point $t_{b,c}$ and it is related to skin wittedness when body temperature is regulated by sweating:

DISC=
$$\begin{cases} 0.4685(t_b - t_{b,c}) & t_b < t_{b,c} \\ \dfrac{4.7(E_{rsw} - E_{rsw,req})}{E_{max} - E_{rsw,req} - E_{dif}} & t_{b,c} \le t_b \end{cases}$$

Where $E_{rsw,req}$ is calculated as in Fanger's model,

From Two Node Model combination with thermal sensation can distinguish two

Figure 2-24 depending on ET effective temperature functions of ambient temperature and are relatively independent of vapor pressure. All exceptions occur at relative humidity above 80% and as the isotherms reach the ET* = 41.5°C line, where regulation by evaporation fails.Fig23shows that lines of constant ET*.



a b

Figure 2-24: a. Effect of Environmental Conditions on Physiological Variables) Human respond only to heat stress from the environment, ASHRAE handbook fundamental , b. Effect of Thermal Environment on Discomfort Human respond to both heat stress from the environment and the resultant heat strain (Stolwijk et al. 1968). ASHRAE handbook fundamental.

2.3.2.7 *The Environment indices:*

By combination of microclimate parameters (air temperature, mean radiant temperature, humidity, air velocity),other indoor indices can be defined .

Effective temperature ET:

It combines temperature and humidity into a single index. It is a common and effective parameters so that two indoor environment with the same ET and air velocity have same thermal responds even though they have different temperature and humidity .ET is combination of three parameters (t_r,t_a and Pa) . Skin wittedness w and the permeability index im must be specified and are constant for a given ET line for particular situation. A standard set of conditions representative of typical indoor applications is used to define a standard effective temperature SET, defined as the equivalent air temperature of an isothermal environment at 50% rh.

Humid operative temperature:

It is analogous to ET corresponding to the temperature of a uniform environment at 100% rh.

The other parameters heat street index, index of skin wittedness, wet-bulb global temperature: that combines dry-bulb temperature t_{db}, a naturally ventilated (not aspirated) wet-bulb temperature t_{nwb}, and black globe temperature t_g, according to the relation (Dukes-Dobos and Henschel 1971, 1973):

$$WBGT = 0.7t_{nwb} + 0.2t_g + 0.1t_a$$

When the equation use the naturally ventilated wet-bulb thermometer is left exposed to sunlight, but the air temperature ta sensor is shaded. In enclosed environments, ISO Standard 7243 also uses the WBGT **Figure 2-25**.

WGT, wet-global temperature: introduced by Botsford (1971), is a simpler approach to measuring environmental heat stress than the WBGT, Onkaram et al. (1980) showed that WBGT can be predicted with reasonable accuracy from WGT for temperate to warm environments with medium to high humidities. With air temperatures between 20 and 35°C, dew points from 7 to 25°C (relative humilities above 30%), and wind speeds of 7 m/s or less, the experimental regression equation (r = 0.98) in °C for an outdoor environment is

$$WBGT = 1.044(WGT) - 0.187$$

This equation at very low humidity and high wind, WGT approaches the psychrometric wet bulb

Temperature, which is greatly depressed below ta. However, in the WBGT, t_{nwb} accounts for only 70% of the index value, with the remaining 30% at or above t_a.

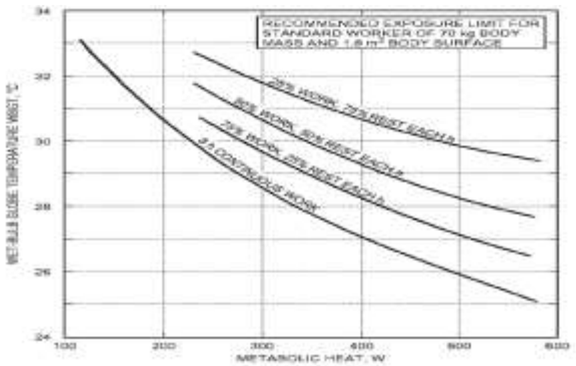


Figure 2-25: Recommended Heat Stress Exposure Limits for Heat Acclimatized Workers [Adapted from NIOSH (1986)]). ASHRAE handbook fundamental..

2.3.2.8 *Adaptive models:*

Adaptive models do not actually predict comfort responses but rather the almost constant conditions under which people are likely to be comfortable in buildings. An acceptable °C degree of
Comfort in residences and offices is possible over a range of air temperatures from about 17 to 31°C (Humphreys and Nicol 1998). Adaptive adjustments are typically conscious actions such as altering clothing, posture, activity schedules or levels, rate of working, diet, ventilation, air movement, and local temperature. This model predict comfort temperatures tc or ranges of tc from monthly mean outdoor temperatures. Humphreys and Nicol's (1998) model is based on data from a wide range of buildings, climates, and cultures:

$$t_c = 24.2 + 0.43(t_{out} - 22)exp - \left[\frac{t_{out} - 22}{24\sqrt{2}}\right]^2$$

Adaptive model could used usefully as guide design and energy consumption. The last adaptive model developed for buildings whose the cooling and heating central system is not required :

$$t_{oc} = 17.8 - 0.31t_{out}$$

Where t_{oc} is the operative comfort temperature. The adaptive model Boundary temperatures for 90% thermal acceptability are approximately t_{oc}+ 2.5°C and toc – 2.2°C according to ASHRAE Standard 55-2010.

<u>Method for determining operative temperature:</u>

Case 1: Average air temperature is permitted to use in place of operative temperature .in these conditions:

1. There is no radiant and/or radiant panel heating or radiant panel cooling system.

2. The area weighted average U-factor of the outside window/wall satisfies the following.

$$U_W < \frac{50}{t_{d,i} - t_{d,e}}$$

Where
U_W= area weighted average U-factor of window/wall, W/m²·K .
$t_{d,i}$= internal design temperature, °C .
$t_{d,e}$= external design temperature, °C .

3. Window solar heat gain coefficients (SHGC) are less than 0.48.

Case 2: calculate operative temperature based on air and mean radiation temperature.

$t_{op} = At_a + (1 - A)t_{\bar{r}}$

where

t_{op} = operative temperature,

t_a = air temperature,

$t_{\bar{r}}$ = mean radiant temperature

A can be found selected from the values below in **Table 2-4:** relative air speed .ASHRAE standard 55-2010 for thermal environmental condition for human

Table 2-4: relative air speed .ASHRAE standard 55-2010 for thermal environmental condition for human occupancy.

v_r	< 0.2 m/s (<40 fpm)	0.2 to 0.6 m/s (40 to 120 fpm)	0.6 to 1.0 m/s (120 to 200 fpm)
A	0.5	0.6	0.7

Case 3: For representative occupants with metabolic rates between 1.0 and 1.3 met, not in direct sunlight, when the average air speed is < 0.2 m/s and where the difference between mean radiant temperature and average air temperature is < 4°C , the operative temperature is permitted to be calculated as the mean of the average air temperature and mean radiant temperature.

Optional Method for Determining Acceptable Thermal Conditions in Naturally Conditioned Spaces: For space whose the ventilation is controlled by opening/ closing windows of occupants ,T_e indoor operative temperature can be evaluated from the value of the mean outdoor temperature regulated by occupants through opening or closing of opening, to determine the indoor operative temperature using the prevailing mean Outdoor air temperature determined in accordance with all of the following:

-It shall be based on no fewer than 7 and no more than 30 sequential days prior to the day in question.

- It shall be a simple arithmetic mean of all of the mean daily outdoor air temperatures of all the sequential days.

The equations corresponding to the acceptable operative temperature ranges in Figure 28 are:

Upper 80% acceptability limit (°C) = 0.31 (*prevailing mean outdoor air temperature*) +21.3

Upper 90% acceptability limit (°C) = 0.31 (*prevailing mean outdoor air temperature*) +20.3

Lower 80% acceptability limit (°C) = 0.31 (*prevailing mean outdoor air temperature*) +14.3

Lower 90% acceptability limit (°C) = 0.31 (*prevailing mean outdoor air temperature*) +15.3

This is shown in **Figure 2-26** includes the effects of people's indoor air speed adaptation in warm climates, up to 0.3 m/s, in operative temperatures warmer than 25°C,the acceptability temperature increased by the corresponding Δt_0 in **Table 2-5**, which is based on equal SET values.

Table 2-5: the acceptability temperature increased by the corresponding Δt_0.ASHRAE

Air Speed 0.6 m/s (118 fpm)	Air Speed 0.9 m/s (177 fpm)	Air Speed 1.2 m/s (236 fpm)
1.2°C (2.2°F)	1.8°C (3.2°F)	2.2°C (4.0°F)

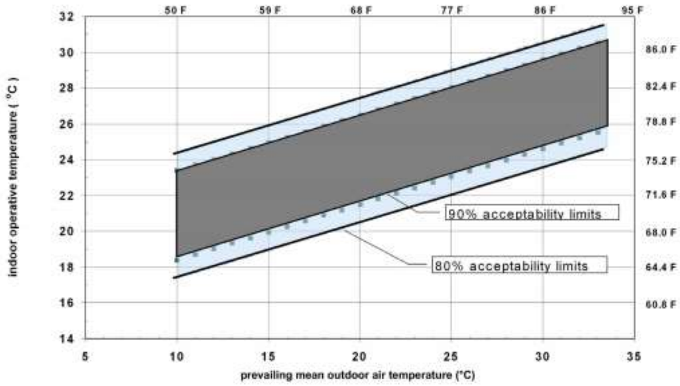


Figure 2-26: Acceptable operative temperature ranges for naturally conditioned spaces (80% bounds are normative, 90% bounds are informative)..ASHRAE standard 55-2010 for thermal environmental condition for human occupancy

2.3.2.9 *ASHRAE scale sensation (model method):*

The thermal sensation scale developed personal variables influencing thermal response and comfort also other factor **Table 2-6:**Equation for pridecating thermal sensation *Y*.of men ,women.present the equation for predicating thermal sensation of men and women.

Table 2-6: Equation for pridecating thermal sensation *Y*.of men ,women.

Exposure Period, h	Subjects	Regression Equations[a, b] t = dry-bulb temperature, °C p = vapor pressure, kPa
1.0	Men	$Y = 0.220\,t + 0.233\,p - 5.673$
	Women	$Y = 0.272\,t + 0.248\,p - 7.245$
	Both	$Y = 0.245\,t + 0.248\,p - 6.475$
2.0	Men	$Y = 0.221\,t + 0.270\,p - 6.024$
	Women	$Y = 0.283\,t + 0.210\,p - 7.694$
	Both	$Y = 0.252\,t + 0.240\,p - 6.859$
3.0	Men	$Y = 0.212\,t + 0.293\,p - 5.949$
	Women	$Y = 0.275\,t + 0.255\,p - 8.622$
	Both	$Y = 0.243\,t + 0.278\,p - 6.802$

[a] Y values refer to the ASHRAE thermal sensation scale.
[b] For young adult subjects with sedentary activity and wearing clothing with a thermal resistance of approximately 0.5 clo, $\bar{t}_r = \bar{t}_a$ and air velocities < 0.2 m/s.

Where Y range from +3 to -3.
+3 hot
+2 warm
+1 slightly warm
0 neutral
-1 slightly cool
-2 cool
-3 cold

This method applies to space when metabolic rates (1.0-2.0) met, and clothes 1.5 or lees clo. And air speed less than 0.2 m/s. and humidity ratio at or below 0.012. **Table 2-7** shows the combination between PMV .PPD.

Table 2-7: Acceptable thermal environment for general comfort ASHRAE 55.

PPD	PMV Range
<10	–0.5 < PMV < +0.5

2.3.2.10 *Graphic Elevated air speed method:*

This part is permitted to be used to increase the maximum allowable operative temperature and maximum allowable average air speed determined before. **Figure 2-28**.The reference point for these curves is the upper air-speed limit of the PMV- at or less 0.2m/s. this figure is combination between air speed and temperature the result in equal levels of heat loss from the skin (with clothing insulation between 0.5 clo and 0.7 clo).
The indicated increase in temperature pertains to both the mean radiant temperature and the air temperature. The benefit is Due to increases in skin wittedness, the effect of increased air speed is greater with elevated activity than with sedentary activity.
The Graphical Method, the required air speed for light, primarily sedentary activities may not be higher than 0.8 m/s (160 ft/min)—although it may be higher when using the SET Method.

SET Method for evaluating cooling effect of evaluated air speed, is calculated by a thermos physiological simulation of the human body.
The SET model reduces any combination of real environmental and personal variables into the temperature of the imaginary standard environment. The flowchart in **Figure 2-28** describes the steps for determining comfort under elevated air speed. The **Figure 2-27** for represents two particular cases of equal skin heat loss contours computed by the SET model[ASHRAE standard 55 addenda 2010]

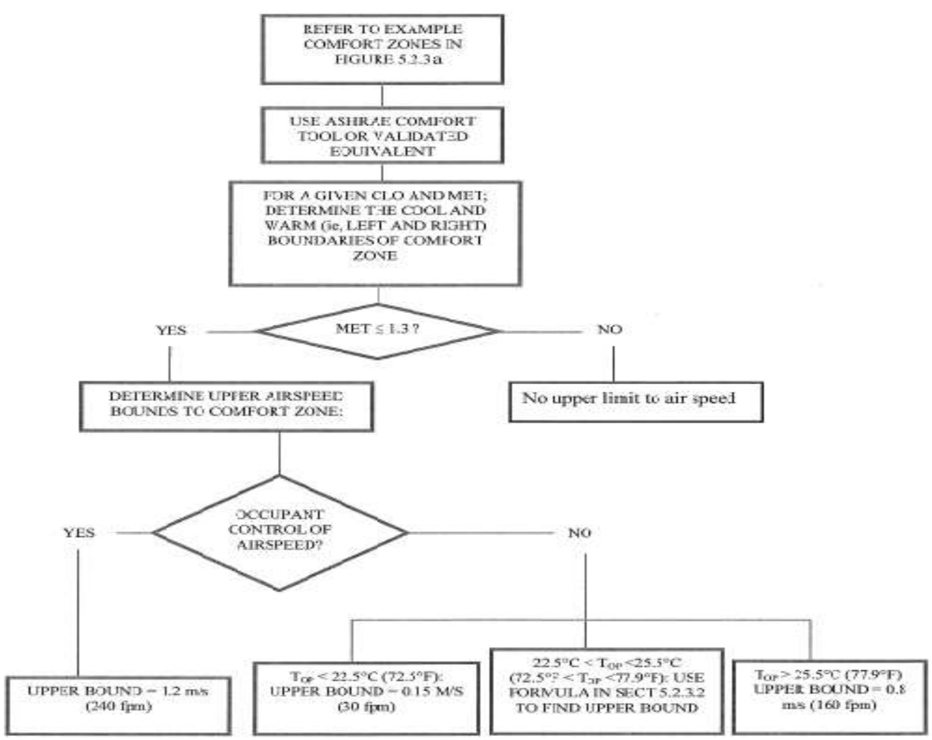


Figure 2-27: ASHRAE standard 55-2010 Flowchart for Determining Comfort Zone under Elevated Air Speed..

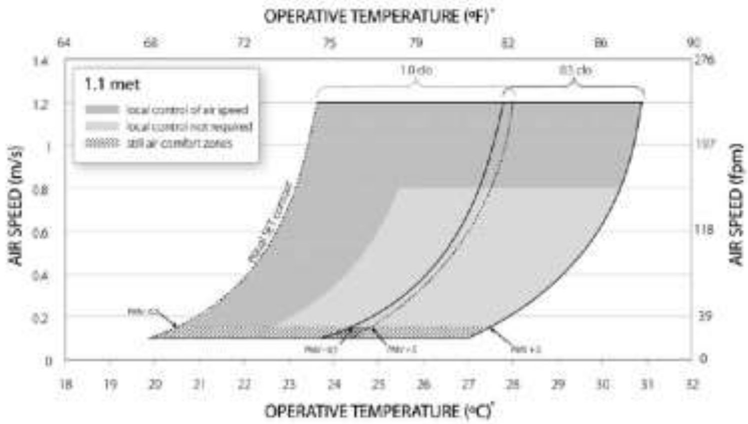


Figure 2-28: Acceptable range of operative temperature and air speeds for the comfort zone at humidity ratio 0.010.used SET.ASHRAE standard 55-2010 for thermal environmental condition for human occupancy.

2.3.3 Evaluation of thermal condition .

The subjective sensation of warmth, or thermal comfort, of the subjects is traditionally measured using the seven point scale. Using a descriptive scale as the ASHRAE scale or Bedford scale may cause the danger of overlapping with the cultural use of words. The most commonly used is the three point preference scale, where respondents are asked about what they prefer, and the answer is sorted in three categories (F. Nicol 1993[14]). Two other personal parameters affect the thermal sensation, determining the clo value, the metabolic rate varies according to the physical activity of the respondent.

There are three kind to evaluating thermal comfort (occupant survey, environment measurement, using building automation system)predicative simulation.

Environmental measurement:

For determined occupant metabolic and clothes use PMV then adjust the comfort zone boundaries for elevated air movement.

Measurement parameters and recorded:

• Occupant metabolic rate (met) and clothing (clo) observations.

• Air temperature (*ta*) and humidity.

• Mean radiant temperature (t_r), unless it can be otherwise demonstrated that, within the space, t_r is within 1°C of *ta*. The mean radiation temperature calculate from:

$$\bar{t}_r = \left[(t_g+273)^4 + \frac{1.10\times 10^8 V_a^{0.6}}{\varepsilon D^{0.4}}(t_g - t_a)\right]^{1/4} - 273$$

where
t_r *= mean radiant temperature, °C*
tg = globe temperature, °C
V_a *= air velocity, m/s*
t_a *= air temperature, °C*
D = globe diameter, m
ε *= emissivity (0.95 for black globe)*

• Air speed, unless it can be otherwise demonstrated that, within the space, average air.

For naturally condition space (adaptive model) .The parameters to measures in this case:

• Indoor air temperature and mean radiant temperature.

• Outdoor air temperature.

2.3.3.1 *Measurement method:*

In most cases of thermal comfort field studies and often for simplicity, only the air temperature is measured. If the measuring device is not protected from the effect of radiation, so the readings are to some extent affected by the mean radiant temperature of the surrounding surfaces. the relative humidity and the air velocity are measured, allowing the calculation of any composite thermal index depending on these variables. In this part provides standardized measurement methods for the evaluation of comfort conditions in existing buildings. The intention is to assist users of the standard in understanding what is actually happening in buildings. Use of standardized methods allows better comparison among different buildings and in the same building under a variety of conditions(ASHRAE STANDARD 2010 addenda).

- Physical measurement position in building

The measurement location should include:
a. the center of the room or space.
b. 1.0 m inward from the center of each of the room's walls. In the case of exterior walls with windows, the measurement location shall be 1.0 m inward from the center of the largest window.
Also should be at the extreme thermal parameters observe (occupied area near window, cornier ….)
Measure the air temperature and average air speed most be at(0.1 ,0.6 ,1.1)m, above the floor for seated occupant , for standing occupant should be(0.1 ,1.1 , 1.7)m .
For operative temperature and PMV shall be at (0.6, 1.1) m for seated and standing occupant.
Floor temperature which could caused discomfort the measurement shall be at the surface.
For radiation temperature asymmetry, which can be caused discomfort ,the sensor should be oriented to capture the greatest surface temperature difference.

- Timing for measurement:

Total occupied hours for period to evaluating (season , year,…)The measurement for air temperature mean radiation temperature and humidity shall be made every five minutes(twelve time/hour) or less, for air temperature not more than 15minutes(four time/hour), but for air speed must be three minutes or less (twenty times /hours).

- Measurement device criteria:

Table 2-8 shows range and accuracy criteria for instruments (air temperature shall be shielded from radiation exchange with surrounding.

Table 2-8: international measurement range and accuracy-ASHRAE 55.

Quantity	Measurement Range	Accuracy
Air temperature	10°C to 40°C (50°F to 104°F)	±0.2°C (+/-0.4°F)
Mean radiant temperature	10°C to 40°C (50°F to 104 °F)	±1°C (+/-2°F)
Plane radiant temperature	0°C to 50°C (32°F to 122°F)	±0.5°C (+/-1°F)
Surface temperature	0°C to 50°C (32°F to 122°F)	±1°C (+/-2°F)
Humidity, relative	25%-95% rh	±5% rh
Air speed	0.05 to 2 m/s (10 to 400 fpm)	±0.05 m/s (±10 fpm)
Directional radiation	-35 W/m² to +35 W/m² (-11 Btu/h·ft² to +11 Btu/h·ft²)	±5 W/m² (±1.6 Btu/h·ft²)

- Analysis base on measurement:

There are two comfort model PMV, adaptive.
The range for PMV -0.5 to +0.5.expressed as a comfort zone on psychometric chart.

Adaptive model: dependent on a running mean of previous outdoor air temperatures, to which people continuously adapt over time. Measures:

• Air temperature indoors

• Running mean of outside air temperature.

Criteria metrics:

- predicted during occupied hours within any time interval.

- It is possible to account for the severity of exceedance at any time, using a metric analogous to the familiar degree-day. The Weighted Exceedance Hours WEH (equivalent to degree-of-discomfort hours) for the comfort zone the index WEH can be calculate as:

$$WEH = \sum (H_{disc} (|PMV| - 0.5)).\ H_{disc}\ \textit{discomfort hours}$$

- Temperature-weighted exceedance hours. It may be useful to convert PMV comfort zone WEHs to a temperature x hours scale using the conversion 0.3 (thermal sensation scale units)/°C (0.15 [thermal sensation scale units]). The unit for temperature weighted exceedance hours is temperature x hours.).

- The WEH for the adaptive model also uses a temperature x hours scale:

$$WEH = \sum (H{>}\ upper\ (T_{op} - T_{upper}) + H{<}\ lower\ (T_{lower} - T_{op})).$$

-Expected number of episodes of discomfort, rate of- change exceedances, local discomfort exceedances within a time period of interest.

- Measuring air flow rate for ventilation:

The air flow depends on the pressure difference across the opening , velocity and direction wind ,temperature difference between inside and outside the building, also turbulence .For both cross and single-sided ventilation the air change rate is a function of incidence angle of wind and wind velocity .For air velocity measurement to avoid the turbulence and eddy, the distance of the sensor from opening edge should be about 10-30cm ,which the important measure is through the opening inside(near the center at the edge) .

Temperature shall be outside and inside the building and in the opening in more than one level. In order to find the temperature difference driving the air through the opening (behind the opening). In case of necessity, for vertical measurement to find mixing in the room the sensor shall shielding to avoid the radiation effect from surrounding surface ,this way maybe caused increase the error .

Air flow note can be also evaluated from present measurements inside the building (at the floor) in the opening (edge) and at the façade (front the opening).

From velocity and pressure (differential pressure)transducer: it is possible to obtain air from the following equation:

$$V = \sqrt{\frac{2P_W}{\rho}}$$

Where
V = velocity, m/s
p_W = velocity pressure (pitot-tube manometer reading), Pa
ρ = density of air, kg/m3

The air flow rate could be evaluated from the equation:

$$Q = kA_2\sqrt{\frac{2(P_1 - P_2)}{\rho}}$$

Where
Q = discharge flow rate, m3/s
A_2 = orifice area, m2
$p_1 - p_2$ = pressure drop as obtained by pressure taps, Pa
Values of K(Constance) are shown in ASME Standard PTC 19.5.

2.3.4 Survey.

The field surveys are key to understanding people's interaction with their environment, and hence for the development of the adaptive approach to comfort and for evaluate building performance.

Two basic types of sampling techniques are used: the "transverse" and the "longitudinal" types. The first type allows a larger number of subjects to contribute to the study at the same time, as each respondent gives one assessment of the thermal environment. This type of analysis provides information on the extent of variation among individuals' responses, which gives a good estimation of the population. The inclusion of a large number of subjects (representing the whole or most of the population) results in avoiding any bias in the results. This also means that the intrusion of the privacy of the respondents will be kept to a minimum. The problem with such a method appears when conducting the survey for a short time (e.g. one day), then the variety of the environmental variables and conditions surrounding the subjects is limited, and may not represent the normal life conditions faced by the population beside culture behavior. To overcome this defect it is better to conduct the survey over a number of days or even weeks (F. Nicol 1993). The longitudinal sampling ends in a small number of observations, due to the number of instruments afforded or the number of mustered volunteers. One problem is that subjects are required to exert a certain amount of dedication, particularly if the survey is extended beyond the subjects' working hours. The small number of sampling may lead to a sampling bias in the results or the sample may not be typical of the whole. However, such a way of sampling allows insight into the effect of time series on comfort (F. Nicol 1993).

The common survey 'ASHRAE -55'. Survey time shouldn't has cooling or heating source.

Surveys shall be solicited from the entire occupancy or a representative sample, minimum number of survey should be 15 must respond.

Thermal environment surveys are invaluable tools for diagnostic purposes in existing buildings and facilities. As a diagnostic tool, the goal is not a broad-brush assessment of environmental quality, but rather a detailed insight into the building's day-to-day operation through occupant feedback. For such purposes, each response is valuable regardless of the size or response rate of the survey.

There are two types of thermal environment surveys. In either type of survey, the essential questions are relate to thermal comfort,

Right-now or point-in-time(short time ST) surveys are used to evaluate thermal sensations of occupants, this kind used to correlate thermal comfort with environmental factors, such as those included in the PMV model: metabolic rate, clothing insulation, air temperature, radiant temperature, air speed, and humidity. This is a thermal sensation survey that asks occupants to rate their sensation (from "hot" to "cold") on the ASHRAE seven point thermal sensation scale. The scale units are sometimes designated TSENS.

A second form of thermal environment survey—a satisfaction survey LT(long time)—is used to evaluate thermal comfort response of the building occupants in a certain span of time. Instead of evaluating thermal sensations and environmental variables indirectly to assess percentage dissatisfied, this type of survey directly asks occupants to provide satisfaction responses. The thermal satisfaction survey can be used by researchers, building operators, and facility managers to provide acceptability assessments of building systems' performance and operations in new buildings,

2.3.4.1 *Survey evaluation of comfort in operating buildings.*

The evaluation approach depends on the intended application. The list of possible evaluation applications is extensive. They require evaluation over varying time periods, from Short-term (ST) to long-term (LT).

• Real-time operation of a building using comfort metrics (ST)

• Building management decisions regarding upgrades, continuous commissioning, and rating the performance of operators and service providers (LT)

• Real-estate portfolio management: rating building quality and value (LT, ST)

• Validating compliance with LEED existing buildings requirements (ST, LT)

• Validating compliance with requirements of codes— energy, hospital, etc. (ST)

The main approaches of (ST) to directly determine occupant thermal sensations and satisfaction through the statistical evaluation of occupant surveys. The other is to use comfort models to estimate sensations and satisfaction of the occupancy from measured environmental variables.

Surveys and physical measurements may be used in combination with each other for the purpose of problem diagnosis and research.

- Analysis Based on Occupant Surveys

Short-T term Analyses (Using Instantaneous Comfort Determinations)

Measures from Right-Now or Point-in-Time Surveys

• Thermal acceptability votes.

• Thermal sensation (TSENS) votes. When averaged for a population, TSENS votes correspond directly to PMV votes.

• Temperature/and Air movement preference votes (“less”/“no change”/“more”).

Accepted value:

• –0.5 to +0.5 on the PMV scale, inclusive, is the criterion for passing in Standard 55.

• Field surveys usually consider TSENS values of –1 and +1 as representing “satisfied;” the break along the categorical seven-point thermal sensation scale is at –1.5 and +1.5, inclusive.

- Analysis Based on Measurements of Environmental Variables

Environmental measurements are correlate with occupant comfort through comfort models. There are two comfort models (PMV and adaptive) specific to different types of buildings.

1- PMV Model(ST):

Measures: PMV heat balance model prediction of thermal sensation and satisfaction from environmental measurements AS described at ASHRAE.

Accepted value:

–0.5 to +0.5 on the PMV scale, inclusive. Expressed as a comfort zone on a psychometric chart.

2- Local discomfort limits:

Based on ASHRAE standard, presence of local discomfort is estimated. Local discomfort is added to PMV-predicted discomfort.\

3- Adaptive Model:

The Adaptive Model is an empirical model of adaptive human responses to environments offering

Operable window control. The comfort zone on a given day is dependent on a running mean of previous outdoor air temperatures.

1- Measures**:**

• Air temperature indoors

•prevailing mean outdoor air temperature.

2- Accepted value:

As PMV calculations above.

There are many researches in this filed mixed between two kind surveys and measurements or measurements and calibrate by simulation program [chapter4 explain simulation and calibration method].(Libya. M.A. Ealiwaa, A.H. Takia, A.T. Howarthb, M.R. Sedena .2001) This paper reviews the results from a field survey of thermal comfort within two types of buildings; old (traditional) and new (contemporary), in Ghadames oasis in Libya. The survey was undertaken in the summer seasons 1997 and 1998, which were typical of the hot±dry climate of North Africa. The field study also investigated occupants' overall impression of the indoor thermal environments; the results suggest that people have an overall impression of higher standard of thermal comfort in old buildings than in new buildings. (Tunis. C. Bouden , N. Ghrab .2005) survey filed investigate occupant They have been asked in their houses and working places at their normal living conditions once each month during 1 year. The selected sample of buildings has been chosen among free running buildings. Only few office buildings were equipped with heating systems but not with air conditioning systems. The main results are discussed and compared with those of similar surveys conducted in different geographic locations (theoretical calculation).(UAE. Radhi, Eltrapolsi, Sharples .2009) studied the relationship between envelope components and indoor environment by using Design Builder simulation program to focuses on residential buildings and concludes that the envelope component regulations contribute positively to the internal thermal performance **Figure 2-29**. the result shows that the thermal insulation regulation makes a small impact on thermal comfort, whereas the window regulation, particularly glazing, is more influential and that for most window areas, solar impacts are generally large.

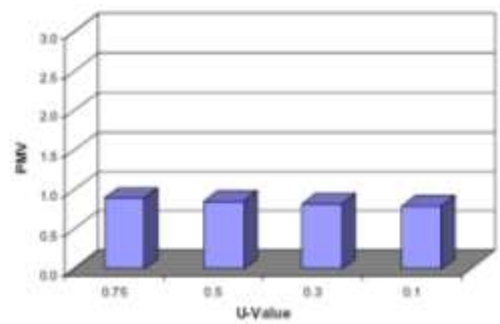


Figure 2-29: PMV as a function of envelope thermal insulation.

(Yemen. Abdulhak Mohammed [2009)] studied the effect of climatic factors on people in the Republic of Yemen, also analyzing bioclimatic conditions of some Yemeni cities, presenting contrasting differences in different regions: Sana'a (Cold in Winter), Adan (Hot-Humid) and Say'un (Hot-Dry) depend on Olgyay chart **Figure 2-30** shows constant behavior and temperature inside traditional Yemen houses that made from clay also thermal comfort the research put strategies for more comfort inside Yemen houses through winter period depend on clothes for heating and humidification in summer period which is the longer season and utilize shading device , natural ventilation and increase the envelope capacity beside decrease windows area .

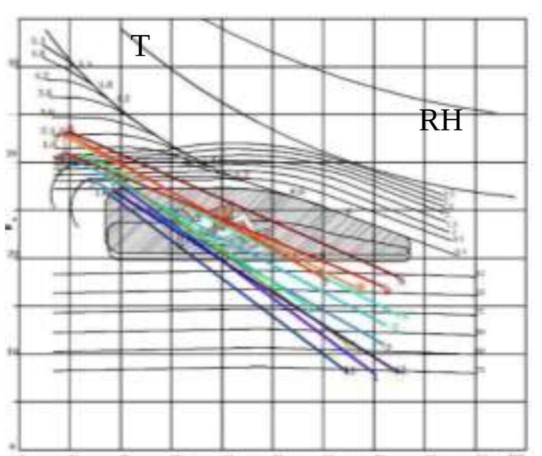


Figure 2-30: Calendar Albayoumnacha the city of Sanaa, based on comfort planned for the Olgyay.

(Egypt. Farghal 2011) combining of measurements and surveys , investigated the effects of individual factors on the comfort perception and the preference of occupants in three educational buildings in the Greater Cairo Region. The first two buildings are naturally ventilated and the third building is a mixed mode one. The buildings were analyzed in order to form a class thermal comfort field study. The study shows the difference between comfort perceptions according to the different size of examined spaces. The field studies were carried out during the autumn 2007, spring 2008, autumn 2008 and spring 2009. Data gathered represent physical measurements of air temperature and relative humidity in the examined spaces, together with the data from a paper based survey based on ASHRAE 55 , The survey results were processed, correlations between thermal sensations and physical parameters were found and the neutral temperatures were calculated for each season. The preferred temperature in both building types was below calculated the neutral temperature, the same as in ASHRAE RP884 project where preference was depressed below neutrality in warm climates. The outcome of the study showed the capability of the studied population to adapt to hotter conditions than that set by the adaptive comfort model implemented in the ASHRAE standard 55-2004 **Figure 2-31**. At the same time the analysis of the adaptive comfort model showed the need of revising the standards to be oriented towards different climatic zones, and to overcome the shortage of data gathered concerning the hot arid climates. The classification of the standard into different climate zones and setting a specific temperature range to each climate may expand the range of acceptable temperature.

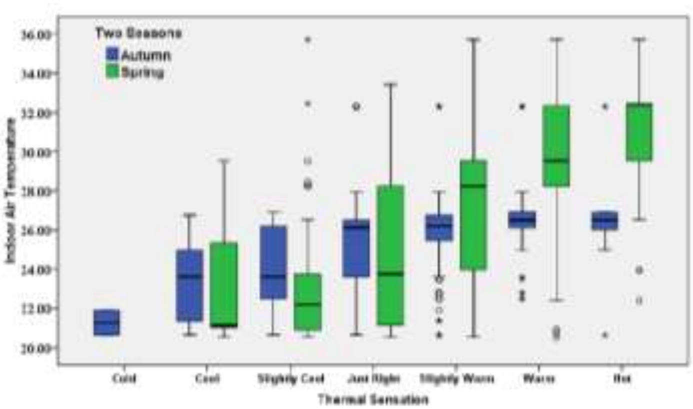


Figure 2-31: The thermal sensation categories subject to the range of indoor air temperature of each category in naturally ventilated buildings for both seasons of the study. The thick lines in the boxes represent the median values, the colored boxes cover the mean 50%of the values and the thin lines show the whole range of all values except for the small circles indicate outliers of each category.

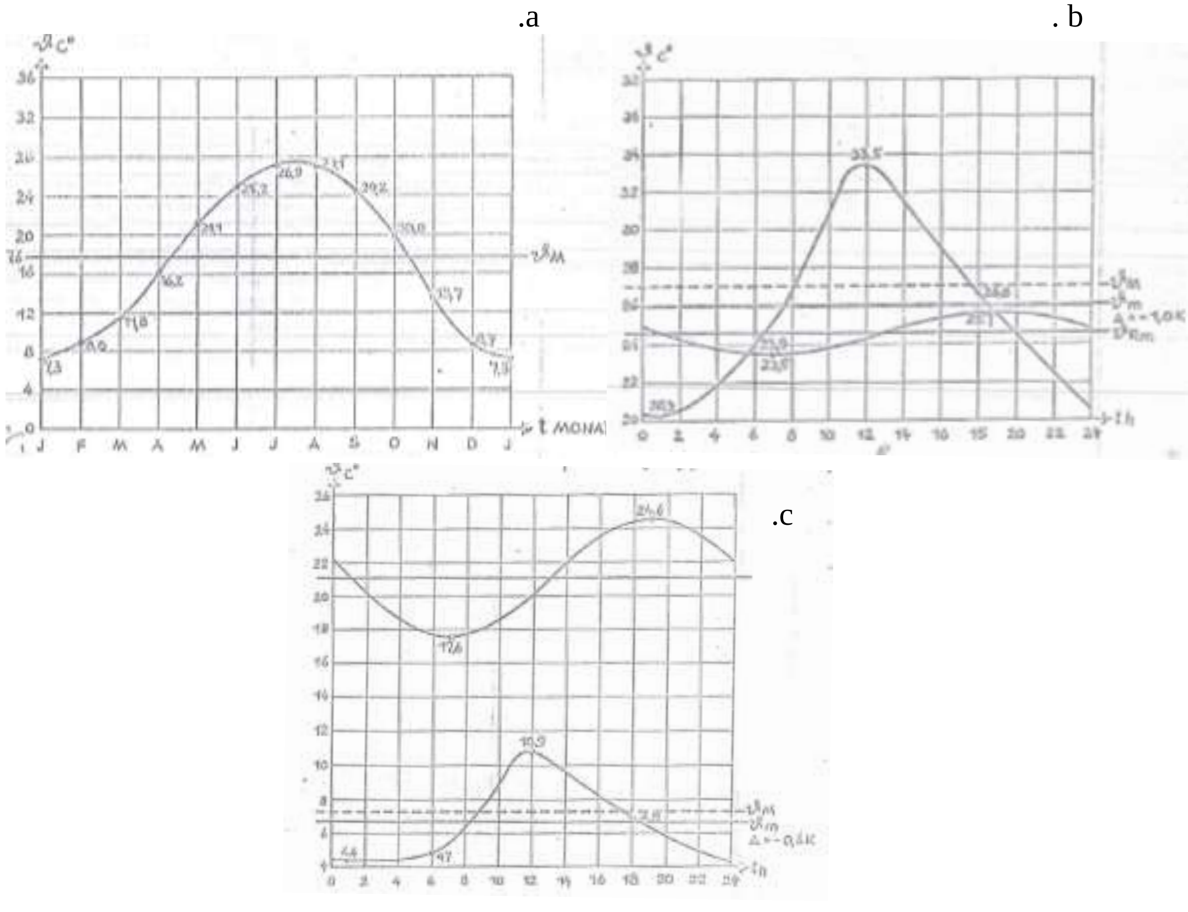
2.3.5 Courtyard .

Using natural phenomena to reach indoor comfort has been known since early time, especially for courtyard and its effect in providing cooling for hot season .These studies are divided between simulation and measurement. Courtyard buildings is mostly descriptive of the architectural features (MacIntosh, 1975). Some contains information about its measured thermal performance (Hyland, 1984). One study includes analyses on courtyard building design aspects including the presentation and analysis of the thermal monitoring of several courtyards in Mexico and Spain (Reynolds, 2002).

country for Halbouni Ghassan (1978) this research studied the indoor environment for Damascus traditional houses and new dwelling building , depend on Petzold ,K method in calculation for room temperature, three traditional houses with different architect configuration structures and one new building as cases study . the traditional investigate present the internal room air temperature average 26.8-23.5 °C at summer period and 17.5-24.6 °C at winter **Figure 2-32**a.b.c , there was trying to calculate the natural ventilation during night the night average temperature was 24.4 °C those calculation depend on average outdoor temperature for period between 1970-1974th

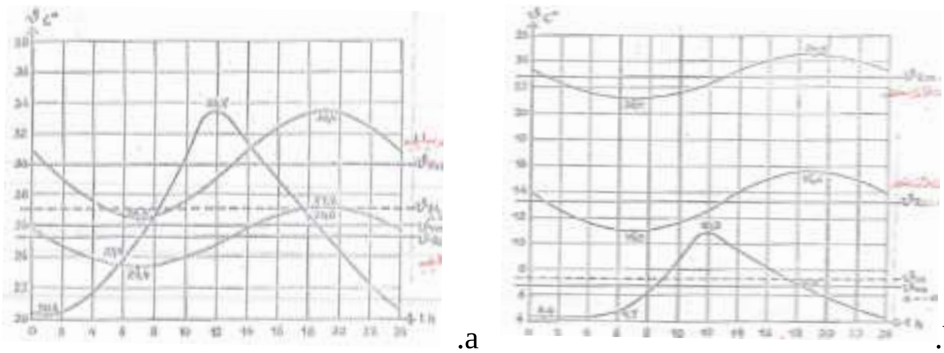
The night ventilation decrease the inside room air temperature about 4.7°C at new dwelling in Damascus city at high region (Mountain slope) **Figure 2-32** **Figure 2-33** a,b . This calculation result depend only on weather data for 1958th till 1974th as average temperature(observe the great change in weather till now the average temperature different between 5-7 °C degrees) , the result confirm about traditional house more comfort for occupant during year and the reflection on life way (seasonal immigration between floors). On other hand the effect of courtyard and trees. The best direction is south, north as traditional house.

.a . b



.c

Figure 2-32: a.Annual thermal average weather data for Damascus 1975 ,b. indoor room air temperature calculated for August ground floor ,c. Indoor room air temperature calculated for January first floor .



.a .b

Figure 2-33: a. calculated Indoor temperature with and without natural ventilation at summer, b. calculated indoor temperature with/without out blind at winter.

(Libya, Ahmad et al. (1985)) monitored a traditional courtyard house within a six centuries old indigenous urban cluster and compared it to a modern detached house within a new urban development under summer and winter climates of Ghadames, . Robitu et al. (2006) studied numerically (coupling of FLUENT and SOLENE models) and experimentally the thermal comfort in a courtyard in France. They found that trees and water pond reduce PMV (defined in Section 2) from 3.4 for the empty case to 0.54 for the actual case with trees and pond. A.S.Dili (2010) this study to An investigation was thus initiated by the authors to understand the passive environment control system of Kerala traditional architecture in providing better thermal comfort, by continuously monitoring thermal comfort parameters of a typical traditional residential building over a period of time. The investigation has revealed that, when the outside ambient temperature is below normal, the building system rise to maintain the indoor air temperature at a higher but comfort able level and when the outside temperature is above normal the indoor is kept at a lower but comfort able level. It is found that a continuous gentle wind flow is maintained inside the building irrespective of the wind outside. Sadafi et al. (2011) studied the interaction between inner and outer thermal comfort. The contribution of inner courtyards to the comfort of terrace housing in tropical climate was studied by model and measurements. (M Taleghani, M Tenpierik, A Dobbelsteen(2012)) investigate the effect of courtyards, atria and sunspaces on indoor thermal comfort and energy consumption for heating and cooling. One of the most important purposes is to understand if certain transitional spaces can reduce the energy consumption of and improve thermal comfort in houses. Method of Research- To conduct this research, 4 building types were modelled and simulated in three different climates with Design Builder. From these simulations, the energy consumption of the dwellings is determined. That a courtyard is the least efficient dwelling type for the Netherlands, while an atrium has better energy efficiency and indoor thermal comfort. Moreover, a sunspace is not recommended for the hotter climates of Cairo and Barcelona since there is a risk of overheating in summer. Hadi Ebadi (2014) provides an overview of Iranian traditional architecture, base on it and the important role of courtyards of houses in achieving the goals of this architecture. Then have concentrated on function of courtyards in various climates to enhance human comfort in the term of sustainability by describing and classifying different climates and geographical locations of Iran .a few studied about the effect using simulation and optimize model. The Preliminary studied for thermal comfort and mass from climate and architect design point at Arabic Middle East.

2.4 Natural ventilation.

Natural ventilation for cross ventilation and single side (stack) ventilation explain at chapter 5 also using simulation computer program at research at same chapter.

2.4.1 Cross and single side ’stack’ ventilation.

Natural ventilation has been studied till now by many researchers from different points views the cooling effect , thermal comfort and the important contribution to reduce energy consumption. The rang research on natural ventilation are related on simulation program or experimental. [Geros, M. Santamouris, A. Tsangrasoulis , G. Guarracino .1999] Investigate, in a systematic way and by using both experimental and theoretical tools, the potential of night ventilation techniques when applied to full scale buildings, under different structure, design, ventilation, and climatic characteristics. Also, the investigate the impact and the limitations of night ventilation techniques regarding the thermal behavior of various types of buildings. Real scale measurements in three buildings operating under free-floating and air conditioning conditions have been performed. The cooling potential of night ventilation techniques applied to buildings operating under different conditions and with variable air flow rates, has been experimentally and theoretically studied. Additionally, the night ventilation effective was between one and two °C degrees, To investigate the impact of various air flow rates of night ventilation on the building’s thermal performance, simulations considering 10, 20 and 30 ACH have been carried out for three set point temperatures and in particular 25, 27 and 29.8C. A summary of the obtained results is given in **Table 2-9**.

Table 2-9: mean indoor reducing of night time indoor air temperature related to ACH.

Mean reduction of the nighttime indoor air temperature when 10, 20 and 30 ACH are considered during the night period (‘Meletitiki’—Summer 1996)

Air flow supply (ACH)	Set point temperature 25°C		Set point Temperature 27°C		Set point temperature 29°C	
	AITR1[a]	AITR2[b]	AITR1[a]	AITR2[b]	AITR1[a]	AITR2[b]
10	0.85	0.71	1.57	1.31	2.43	2.13
20	1.01	0.82	1.84	1.51	2.80	2.41
30	1.08	0.87	1.96	1.61	2.93	2.50

[a]AITR1: Average indoor temperature reduction during the night period.
[b]AITR2: Average indoor temperature reduction at the early morning hours and prior to the operation of the air conditioning system.

‘Meletitiki’ building has an important thermal mass and the first set of experiments _ was made during1995.They has been performed during a period of very low internal gains, and without any operation of the air conditioning system. On the contrary, the ‘University’ building has a light structure and was monitored when internal gains were important and the air conditioning system was in use. It was found that the use of night ventilation techniques, permits to decrease the next day peak indoor temperature, under free-floating conditions, by up to 38C. Sensitivity analysis has shown that under the same conditions, the expected reduction of the overheating hours, varies between 39% and 96% for air flow rates between 10 and 30 ACH, In conclusion, night ventilation techniques can contribute to decrease significantly the cooling load.

More investigation for thermal mass and night ventilation for hot humidity climate was studied by [Al-Hemiddi and Al-Saud (2001)] studied experimentally the cooling in a building with an internal courtyard in a village house in Saudi Arabia. Changes in the courtyard ventilation were made by opening inner and/or outer windows in alternate ways during the day and night periods beside studied case cover and uncover courtyard , closing it at day time and open it at night time by tent and the effect of natural ventilation on energy efficiency .London [1993]. Typically, the energy cost of a naturally ventilated building is 40% less than that of an air-conditioned building. [A. Krishan - T. Willmert (2001)] contributes to a sustainable environment by reducing energy use in buildings. Natural ventilation has become a new trend in building design in architectural community. There are some studied completed between natural ventilation and survey, V .[Edna Shaviv ,Abraham Yezioro, Isaac G. Capeluto(2001)]studied the calculated influence of thermal mass and night ventilation on the maximum indoor temperature in summer. The results for different locations in hot humid climate, The maximum indoor temperature depends linearly on the temperature difference between day and night at the site , The exact reduction achieved depends on the amount of thermal mass , the rate of night ventilation **Figure 2-34**, and the temperature swing of the site between day and night. More studied and investigation for passive cooling : night ventilation by using simulation and measurement method .

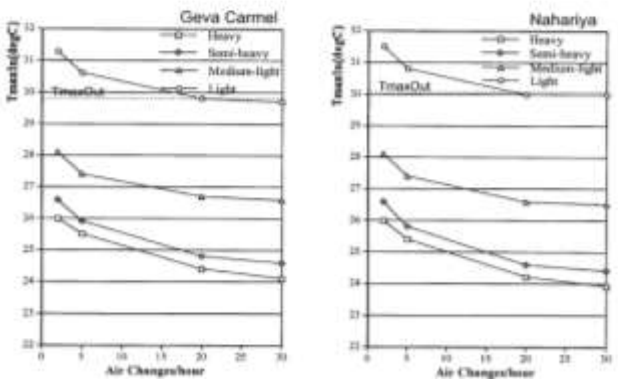


Figure 2-34: The prediction of the maximum indoor temperature (Tmax,In) in August in a residential building along the Mediterranean coastal plane, as a function of the thermal mass and night ventilation.

[Yi Jiang, Qingyan Chen (2002)] model has been used to study cross natural ventilation in buildings, which has experimental data available from on-site measurements and a wind tunnel There are discrepancies between the on-site and wind-tunnel cases for the wind-pressure difference across the buildings, the eddy size behind the buildings, and the wind speed distribution inside an apartment with cross ventilation. LES can successfully simulate both cases by changing or mixing incoming wind direction, and the simulated results agree reasonably with the corresponding experimental data.

[Camille Allocca, Qingyan Chen2, and Leon R. Glicksman.(2003)]. This investigation studied single-sided natural ventilation by using a computational fluid dynamics (CFD) model, together with analytical and empirical models. The CFD model was applied to determine the effects of buoyancy, wind, or their combination on ventilation rates and indoor conditions **Figure 2-35**. For buoyancy-driven flow, the CFD results are within a 10% difference from the semi-analytical results. For combined wind- and buoyancy-driven flow, CFD may have under predicted the empirical model results by approximately 25%. This investigation also studied the effects of opposing buoyancy and wind forces.

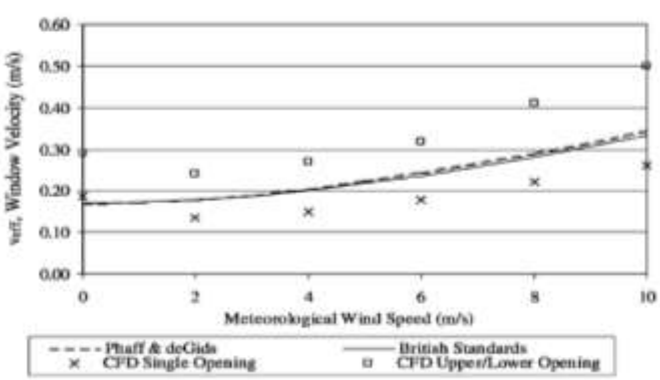


Figure 2-35: Combined wind and buoyancy-driven ventilation rates through an upper and lower opening or a single opening: CFD results vs. empirical models..

[Jens Pfafferott, Sebastian Herkel, Martina Jäschke(2003] in German at this study both mechanical and free night ventilation is used for passive cooling of the offices. The results from a long-term monitoring show, that room temperatures are comfortable even at high ambient air temperatures. In two offices, experiments were carried out in order to determine the efficiency of night ventilation dependent on air change rate, solar and internal heat gains. The experiments (one room with and one without night ventilation) are evaluated by using both a parametric model and the ESP-r building simulation programmer. Both models are merged in order to develop a method for data evaluation in office buildings with night ventilation and to provide a simple model for integration in a building management system.

[T Larsen (2006)] studied single side ventilation and cross ventilation depend on theoretical and experimental measurements, the results shows From the experiments cross-ventilation a clear dependence of the incidence angle of the wind was found on the measured air change rates and found that the air change rate was independent of the position, but the result will always depend on the shape of the building through the CP-values. The measured air change rates the discharge coefficient (CD) defined from the orifice equation was calculated in all cases studied. Here it was found that the assumptions concerning constant pressure and velocity distribution across the opening made in connection with the use of the orifice equation was not obtained in this work, since the CD-values were varying at different incidence angles. From the experiments made with single-sided ventilation in the wind tunnel it was seen that the air change rate also in this type of ventilation depends on the incidence angle. It was also shown that the airflow through an opening does not depend on the volume behind the opening, which makes a design expression independent of this parameter. The effect of increasing the wind velocity has different depending on the incidence angle. This shows that the dominating force (wind pressure or temperature difference) changes as function of incidence angle. It was also found that it depends on the level of either the temperature difference and the wind velocity. From the wind tunnel experiments a new design expression. The expression makes it possible to predict the airflow in single-sided ventilation. The deviation was in these cases found to be 14% which is considered satisfactory. The influence of natural ventilation clearly at hot climate has a lot of investigation for natural ventilation and the influence during day for hot humid climate made as[Malaysia (2009) Tetsu Kubota a, Doris Toe Hooi Chyee b, Supian Ahmad] for residential building .

2.4.2 Natural ventilation in courtyard.

Al-Hemiddi and Al-Saud (2001) studied experimentally the cooling in a building with an internal courtyard in a village house in Saudi Arabia. Changes in the courtyard ventilation were made by opening inner and/or outer windows in alternate ways during the day and night periods beside studied case cover and uncover courtyard , closing it on day time and open it at night time by tent . Nasser A. Al-Hemiddi (2001) this study describes an experiment to investigate the effect of a ventilated interior courtyard on the thermal performance of a house in a hot–arid region at Saudi Arabia. Statistical analysis of data recorded during the summer of 1997 was carried out. The results indicate that the courtyard gives high efficiency in providing cool indoor air through cross-ventilation. BAGNEID, AMR (2006) introduce a simplified thermal model that simulates the courtyard microclimate, which has been tested with actual field data from a case study house. The indoor air temperature, relative humidity, and floor surface temperature were measured using micro data-loggers. The case study house was an indigenous courtyard house in Cairo, Egypt. With heavy thermal mass. To accomplish this, a finite difference thermal network model was created for simulating the case study courtyard microclimate. The finite difference (FD) model showed validity as it calibrated very well against field data. The calibration periods winter (29th of December to 19th of January), summer (August 6-26). This model allowed running parametric sensitivity studies on the courtyard thermal simulation factors: air change rates, thermal mass (the result of the total house mass gave the best CV (RMSE) & NMBE calibration results), solar absorption, wall and floor emissivity, ground temperature, cloud cover, and ambient air temperature. The results of the parametric analysis showed that the model was sensitive to variations in the air change rates, solar absorptivity, and ambient air (rooftop) temperatures. The proposed combinations of the FD microclimate/DOE-2 simulation did not perform as well as the FD microclimate simulation. The FD courtyard microclimate simulation model with onsite data for calibration is advantageous in introducing for the first time the ability to perform computer simulations on any number of proposed courtyard design alternatives for reaching optimum thermal performance.

Sigalit Berkovic(2012)this study simulate courtyard to investigate The effect of wind, and shading by different means – galleries, horizontal shading or trees – has been examined. The effect of wind is evaluated by allowing cross-ventilation through openings at 3 and 5 m height above ground level, designed according to the prevalent wind direction. The study was conducted for the hours 11–17 LT during June assuming average climate conditions. The thermal comfort is evaluated by the Predicted Mean Vote (PMV) index. Sooleyon cho (2013) simulate the traditional IRAN courtyard and the effect of natural ventilation, improve energy plus model, the result emphasis that the courtyard has significant advantages on thermal performance of indoor space for dry climate and reduce cooling load by natural ventilation **Figure 2-36** .

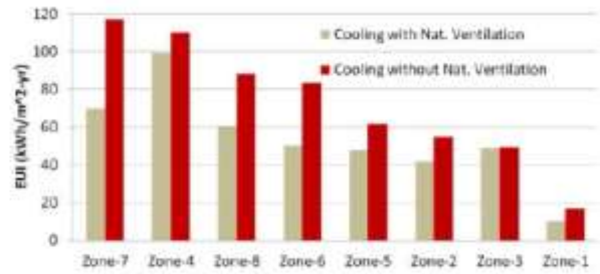


Figure 2-36: Cooling loads comparison.

2.5 Summary of literature review.

For thermal filed include measurement and survey, in most cases of field studies and often for simplicity, only the air temperature is measured. If the measuring device is not protected from the effect of radiation, so the readings are to some extent affected by the mean radiant temperature of the surrounding surfaces. While in some other studies, the air temperature, the mean radiant temperature, the relative humidity and the air velocity are measured, allowing the calculation of any composite thermal index depending on these variables.

Summary, Most of the existing literature focus only as general on optimize energy efficiency of new residential building or the influence of natural ventilation on occupant and reach comfort or night ventilation and thermal mass (better effect at big swing between day and night)or insulation layers . others studied passive design natural ventilation and thermal mass from viewer of energy not related to comfort or investigate the courtyard traditional houses from point view of passive cooling or occupant comfort, other studied natural ventilation of courtyard houses and the influence on thermal comfort (summer period, one study for spring and autumn) all previous studied methodology depend on two kind survey and measurement or simulation. other only calibration for many climatic regions a few of them dealt with hot dry climate ,but most of their investigation at very hot and humid climate, the purpose of this research is merging between traditional houses as passive cooling / heating by natural ventilation and envelope performance (thermal mass, materials)/ more specific for ventilation type (effective limit for cross and single side ventilation), beside thermal comfort (comfort range and extended caused by NV related to standard /survey)at hot dry climate region and the new cities houses facility through applied the positive passive deign of traditional houses also materials on Modern formulation adapted to modern life in new residential building to reach occupant comfort and reduction energy consumption with exceptional methodology integrate measurement and survey with calibration simulation to reach the aim (completed between all latest researches field to fill gaps for summer and winter periods). On other hand the complicated situation of the studied region also the weather changing during this period and crisis , which forced some more steps and complicated method to achieve the aim and for future rebuild destroyed building and cites for better performance[energy , comfort] and sustainability view.

On the other hand the specific characteristic of Damascus traditional house and life behavior give significant indicator for thermal mass cause by mix structures between heavy mass for ground floor and light mass for the first floor and social culture which reflected on seasonal occupants behavior and daily behavior in hot-dry summer: they usually take a long break after lunch (midday) with the family during the longest lighting sunny days. So can everybody stay laying in shadow far away from the direct hot lighting midday sunrays and relax to reduce the hot feeling and cooling load need it at afternoon to return to work when the hot waves decrease. This behavior of hot climate occupants considered in this research which neglected at all previous studied, these advantages gave more privacy and importance for this research.

CHAPTER 3
EXPERIMENTAL COMFORT ANALYSIS OF BUILDINGS WITH INTERNAL COURTYARD

3.1 The Courtyard Houses In Damascus.

3.1.1 Introduction

The use of passive house techniques and natural method to reach indoor comfort in residential building has been known since early time .The oldest heritage architecture of middle east region has responded with different climatic conditions with very good solutions special for hot-dry region :height temperature and radiation at summer(the longest period) wide spread between day and night temperature also in summer and winter. It realized easily outside its urban environment and inside its houses the optimum comfortable temperature throughout nearly all the days of the yearlong. That was realized by equating with the volume adopting and the space taming with the different natural forces of the sun, atmosphere, biosphere and climate which is common in these days as passive design strategies and reducing energy consumption .

As consequences for all these prefaces and looking at native engineering civilization seemed obviously that no separation in these between architecture ,engineering , environment's planning and the adopted human behavior as they are in the old Damascus city as real example through absorb heating's surplus throughout the creation of the integrated texture (thermal mass combine with natural ventilation).

3.1.2 The Cases Study

Four traditional houses in the old city of Damascus have been studied inside and outside ancient wall of old Damascus city **Figure 3-1**, **Figure 3-2**

The basic selection is two types of typical traditional houses; the first one is a large ones (with one or two courtyard), the second represents the smallest one (with one courtyard) as a part of the first one. Each one consists of two level compounds integrated houses with different orientation and different materials intervention.

First type represents each case behind the other, on the other hand, the second type is located in a different part of the old city shows the influence of old urban fabric special for wind tunnel

Figure 3-1: Old city of Damascus.

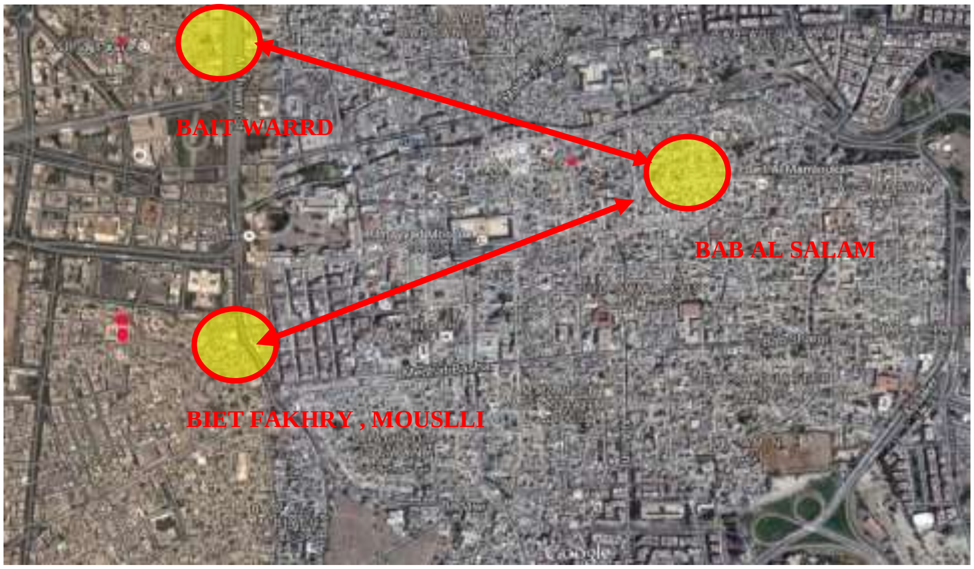


Figure 3-2:view of Damascus traditional houses cases study

3.1.2.1 *Case Courtyard Houses*

- BAIT FAKHRY AL BAROUDI

Expanded about 967m^2 in al QANAWAT quarter which is located in westen neighborhoods out of the old Damascus(antique wall) and recorded as one of archaeological slides in Damascus city, that appeared up the 11th century beside a south channel named Al Qanawat derived from Barada River.

FAKHRY's house is a typical Damascene large old house, return in its construction to the phase of the second half of 19th century. The old description consists three parts : ①Barrany(Outside), ②Wastani (middle) and ③Juw-wani (Inside).A bout its age is supposed to around 1915(**Figure 3-3**,a) The southern part has been sold to another family and it is exposed to many developing changes. Final configuration as it is now composed of two parts: 1 residential and service's parts, with two courtyards (**Figure 3-3** .b)

a. . b

Figure 3-3: FAKHRY house plan ,a the first period , b.current period ground floor .

The main courtyards: configuration is 1/3 of the hall’s area of the house.
FAKHRY’s house has two levels: the ground floor, entrance, five rooms and big main hall has small fountain (fisqey) made of Italian marble and dining room , bedroom, kitchen , three rooms for food storing , bath ,WC, two courtyards big one with fountain and trees , wooden stairs go up to the first floor,
The wall structure is made of Basalt ,White lime stone and loamy mud brick cladding with mud , lime plaster and lime wash .first slab structure of timber , timber board and lime mortar ,the finale slab covered with hemp and clay, roughly wall thickness between 45 cm to 70 cm[appendix c .

Second level has nine rooms with two main halls as entrances to others bigger than another with gabled roof and another smallest and wooden stairs goes up to the flat roof.
The first floor wall structure is made of timber structure fills up with mud block, covered with mud and lime wash roughly thickness 30cm Appendix C1.
Restoration works: lime and mud mortar replaced by concrete, also hemp and clay replaced by bitumen roll. Interior wall replaced with brick block cladding with cement plaster.

- BAIT AL MOSLLI

It expanded about 570 m^2 in Al QANAWAT quarter in the same ones quarter of BAYT FAKHRY AL BAROUDI, also built at the same period.

Al Mouslli house as a second type of Damascus traditional houses which is smaller than FHKRY’S type has only two courtyards; one for reception, second distribute to the other house parts.

Mouslli house has two levels , ground floor with two courtyards: the smallest ones has two rooms ,bath , small fountain at the entrance and stone stair goes up to the first floor , connect with the biggest courtyard by covered narrow path ,latest one has big fountain and two big trees ,IWAN (in the south has opened space from the north side , which used as shaded cool space in summer times), with two rooms behind it from each side (west, east), facing to IWAN there is the main north big hall , and kitchen with one food store room, and open wood stair goes up to first floor to small path opened to three rooms on north side and two at east side .

There were some interventions in the house design for reception part and adding some materials but without effecting on the structure of the main parts. On the other hand Mouslli house is still maintains old configuration and structure.

The wall structure is made of Basalt ,white lime stone and mud brick cladding with mud , lime plaster and lime wash .first slab structure of timber , timber board and lime mortar ,the finale slab covered with hemp and clay. roughly wall thickness between 45 cm to 70 cm .The structure of the first floor wall is made of timber structure fill up mud block covered with mud and lime wash roughly thickness 30cm Appendix C2 .

In this part there is a kind of restoration comparison in structure changes and design to investigate the impact of old structure and materials on the thermals beside the natural ventilation kinds for the same rooms orientation.

3.1.2.2 *One Courtyard Houses:*

- BAIT WARRD

It expands 90 m2 at SAROGA quarter which is one of the neighborhoods out of the old Damascus city wall. BAIT WARRD represents another type of old Damascus traditional houses with one courtyard.
Has two levels, ground floor with courtyard (with big tree shaded roughly all courtyard and estuary water) surrounded by two small rooms and main large room , IWAN opened typically towards the north side , stone stairs goes up to open space at first floor distribute to three rooms .
Configuration and structure as all traditional houses but there were a lot of interventions as FHAKRY AL BAROUDI structure for slab beside that all lime and mud plaster changed to cement plaster .On other hand the courtyard covered with sliding plastic roof plan and structure as figures at Appendix C3.

- BAB AL SALAM HOUSE

Expanded 120 m^2 at BAB AL SALAM region which is inside the old Damascus city fence and recorded as archaeological region in Damascus city.

Has two levels, ground floor with courtyard (with two trees and estuary water)opened to two small rooms, bath and big north hall and entrance opened to kitchen with two level MEZANIN (food store)and stone stair goes up to open space distribute to three rooms through covered path and bath.
Configuration and structure have a lot of interventions also in design; every room got here a bath that means a lot of brick block used and plaster although concrete slab structure like others present at Appendix C4.

3.1.3 Instruments

OMEGA USB : OM-EL-USB-2-LCD-PLUS HUMIDITY, TEMPERATURE AND DEW POINTDATA

Properties :**Table 3-1**

Table 3-1: Omega properties

cations		Minimum	Typical	Maximum	Unit
lumidity	Measurement range	0		100	%RH
	Repeatability (short term)		±0.1		%RH
	Accuracy (overall error)		±2.0*	±4	%RH
	Internal resolution		0.5		%RH
	Long term stability		0.5		%RH/Yr
ure	Measurement range	-35 (-31)		+80 (+176)	°C (°F)
	Repeatability		±0.1 (±0.2)		°C (°F)
	Accuracy (overall error)		±0.3 (±0.6)	±1.5 (±3)	°C (°F)
	Internal resolution		0.5 (1)		°C (°F)
t	Accuracy (overall error)		±1.1 (±2)**		°C (°F)
ate		every 10 s		every 12 hr	-
temperature range***		-35 (-31)		+80 (+176)	°C (°F)

TESTO 417 Vane anemometer:
Measuring instrument for measuring flow velocities and temperatures **Table 3-2**.
Measuring made as ASHRAE standard way for temperature and relative humidity to be recorded every 5minute to get good indicator, the measurement made parallel with survey (ASHRAE way).

Table 3-2: Testo properties.

Characteristic	Value
Parameters	Flow velocity (m/s), temperature (°C/°F)
Calculated variables	Volumetric flow rate (m³/h)
Measuring range	+0.1 ..+20 m/s 0...+50 °C/+32...+122 °F
Resolution	0.01 m/s 0.1 °C / 0.1 °F
Accuracy (± 1 Digit)	±0.1m/s+1.5% of reading ±0.5 °C/±0.9 °F
Probe	Vane probe 100 mm, NTC temperature probe (integrated)
Measuring rate	2/s
Operating temperature range	0...+50 °C / +32...+122 °F
Storage temperature	-40...+85 °C / -40...+185 °F

3.2 Measurements on Summer 2014

Outdoor weather Data is collected from the nearest weather station **Figure 3-4**to cases studied the weather station of faculty of agriculture at Damascus University. It provides many weather elements for every hour; (temperature , relative humidity , wind speed, dew point , pressure , wind direction).

Figure 3-4: weather station position related to cases studied

3.2.1 Instrument Position

Instruments position is based on three points;

- ASHRAY (2010) measurement standard for thermal comfort(ST) (60 ,110) cm, takes position at center or far away from walls at least 1m (position south wall means far 1m from wall), measurement intervals 5 minutes at least as explained at chapter2.
- Natural ventilation, opening windows position (one or two levels) and air circulation.
- Room orientation and level beside it protected from direct solar radiation.

Rooms are chose depending on natural ventilation way :cross ventilation (direct or adjacent windows), single side ventilation at one façade [single side with stack two levels of windows], on other hand rooms orientation.

Instruments in courtyard are located in order to avoided from direct solar radiation.

1. BAIT FAKHRY AL BAROUDI :

The instruments distribution depend on previous rules .

Ground floor :Courtyard: south west corner (shaded place); to avoid solar radiation at 60 cm high, for investigating the courtyard microclimate and the effect of it on the interior space.

Main south hall with high ceiling: at center hall at high 60,350cm .investigate the airflow behavior and natural ventilation impact at two levels of windows are opened in single side type.

West room: Middle West hall at 60cm high, investigate thermal comfort at new materials structure with high level of infiltration.

Study north hall: goes down stairs to level -23 cm [semi-underground]east part, study hall device position within its center at high 60cm, investigate thermal comfort for 20 students in stone structure hall with lower height and cross natural ventilation not facing’s windows.

First floor:

Large NORTH main hall entrance: has facing’s windows (at each directions) and high pitched ceiling, device fixed at 60,200cm, to investigate cross natural ventilation at high level.

Library east room: at 60 cm high **Figure 3-5**present the first measurements stage, other stages at appendix c.

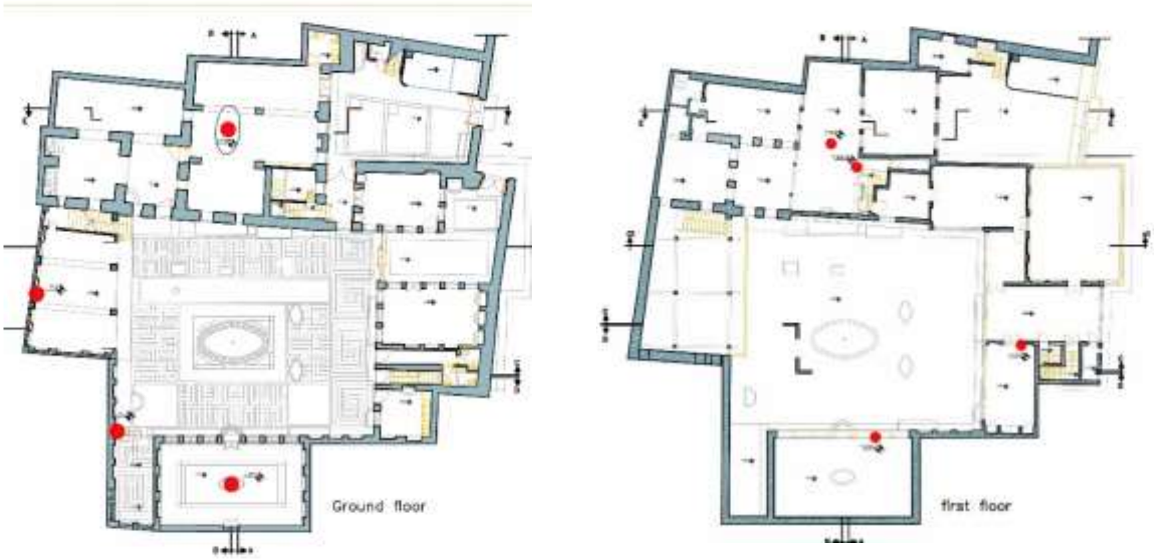


Figure 3-5: FAKHRY the first stage measurement , instruments positions.

2. BAIT AL MOUSLLI:

Follows the same previous strategies of FAKHRY AL BAROUDIs .and roughly the same rooms' orientations which have not interventions in structure and materials for comparisons.
The instruments have been distributed according to the following:
Ground floor: main north room: at the north, 60 cm high, with two windows level and high ceiling.
East and West room : south wall, at 60 cm high , cross ventilation of not facing window through two sides (north , west) and (north , east) with northern two windows level.
Courtyard (IWAN) to protect device from direct solar radiation.
First floor: east room: north at 60 cm high with single side ventilation Appendix C present the instruments plan positions .
The measurements followed parallel at the same time of FAKHRY AL BAROUDI period of natural ventilation (opening windows) stages to compare the difference kind of natural ventilation (normal , single side stack , cross ventilation)and structure behavior influence on the thermal.

3. BAIT WARRD.

Followed THE same previous strategies for instruments that have been distributed according to the following:
Ground floor: East and West room: at 60 cm high, two rooms have two windows opened.
Courtyard: at 60 cm high near the entrance and at 60 cm high at IWAN.
First floor: expanded to the courtyard volume fixed one instrument at open space on first floor north wall at 120 cm high. East room at 60 cm high with open window as plan at Appendix C3.
This case has other strategy with two stages to be compared with other orientations ,structure, natural ventilation and thermal comfort. The second aim courtyard impacted by open sliding roof and closed at specific time followed schedule table at Appendix C3.

4. BAB AL SALAM HOUSE.

As same strategies for instruments positions have been distributed according to the following:
Ground floor: Main north hall: near the center at 60 cm high, two levels of opened windows at the south elevation.
Courtyard: near the south east corner at 60 cm high, avoiding direct solar radiation.
Kitchen second level MEZANIN north side.

First floor: west room: north wall at 60 cm high with two windows opened to the stair space.
This case completes the second field investigation type with open courtyard and opened windows for natural ventilation (single side and stack with two windows level) and structure to get the effect on thermal comfort. The instruments plan position presented at AppendixC4.

3.2.2 Monitoring schedule

The most collected Data has recorded during the weeks of JULY 15 -22 and AUGUST 4-13, 2014th is considered as a represent of a typical summer performance although it was short period of time is actually involved. The weather during these weeks period was sunny, clear and hot. Maximum outside temperature (39-41) °C was typical during this period or little pit higher (less) about one or two °C degrees. The two weeks before this period were also hot and in general sunny , leading to reasonably stable thermal condition during first period , the second period was little pit higher . At the time these data were collected about 1250 measurement was made, the total result about 15 measurements for every house.

BAIT FAKHRY AL BAROUDI: measurements investigation followed three stages:
First one: all halls and rooms were closed without natural ventilation.
Second: natural ventilation through various numbers of opening windows at different time besides occupant thermal comfort through different surveying time.
Third : getting the impact of the courtyard fountain on the interior space thermal behavior and human comfort at specific day time for this case and investigate air flow behavior utilized three points in space analyzed air flow circulation as schedule presented at .

BAIT AL MOUSLLI : investigation follows the previous strategies as table in Appendix C2.
BAIT WARRD : investigation follows the previous strategies as table in Appendix C3.
BAB AL SALAM HOUSES : investigation follows the previous strategies as table in Appendix C4.

Table 3-3: summer 2014th measurements schedule.

FAKHRY AL BAROUDI										
USB N	floor	hall	position	high cm	day	time	window opened	window closed	up window opened	up window closed
7	ground floor	main hall	center	60	14/7/2014	12:00	0	all	0	all
9	ground floor	main hall	up north elevation	350	14/7/2014	12:00				
1	ground floor	west glass	west wall	60		12:00	0	all		
15	ground floor	courtyard	west wall	60	14/7/2014	12:00				
5	ground floor	north study	center	60		12:00	0	all		
2	first floor	east library	north wall	60		12:00	0	all		
14	first floor	center	center	60	14/7/2014	12:00	0	all	0	all
10	first floor	center	east wall	200	14/7/2014	12:00				
7	ground floor	main hall	center	60	15/7/2014		0	all	0	all
9	ground floor	main hall	up north elevation	350	15/7/2014	12:00				
1	ground floor	west glass	west wall	60	15/7/2014	12:00	0	all		
15	ground floor	courtyard	west wall	60	15/7/2014					
5	ground floor	north study	center	60	15/7/2014	12:00	0	all		
2	first floor	east library	north wall	60	15/7/2014	12:00	0	all		
14	first floor	center	center	60	15/7/2014		0	all	0	all
10	first floor	center	east wall	200	15/7/2014					
7	ground floor	main hall	center	60	16/7/2014	11:00	2 middle	4	0	all
9	ground floor	main hall	up north elevation	350	16/7/2014					
1	ground floor	west glass	west wall	60	16/7/2014		0	all		
15	ground floor	courtyard	west wall	60	16/7/2014					
5	ground floor	north study	center	60	16/7/2014		0	all		
2	first floor	east library	north wall	60	16/7/2014		0	all		
14	first floor	center	center	60	16/7/2014	11:00	0	0	1 south east	3
10	first floor	center	east wall	200	16/7/2014					
7	ground floor	main hall	center	60	17/7/2014	11:00	2 middle	4	0	all
9	ground floor	main hall	up north elevation	350	17/7/2014					
1	ground floor	west glass	west wall	60			0	all		
15	ground floor	courtyard	west wall	60						
5	ground floor	north study	center	60			0	all		
2	first floor	east library	north wall	60			0	all		
14	first floor	center	center	60		11:00	0	0	1 south east	3
10	first floor	center	east wall	200						
1	ground floor	courtyard	west wall	60	21/7/2014	10:30				
2	ground floor	main hall	up south elevation	350	21/7/2014	10:30	4 corner	2 middle	0	all
3	ground floor	main hall	center	60						
13	ground floor	north study	center	60		10:30:00 AM-13:30(student 18)	2 east	south 1	0	all
10	ground floor	north study	east center	60						
5	first floor	center	center	60		10:30	0	0	ıth east.1nortl	2
7	first floor	center	east wall	200						
1	ground floor	courtyard	west wall	60	22/7/2014					
2	ground floor	main hall	up south elevation	350		12:15	all	0	2center	4
3	ground floor	main hall	center	60						
13	ground floor	north study	center	60		12:15	1south	2	0	0
10	ground floor	north study	east center	60						
5	first floor	center	center	60		12:15	0	0	4north,south	0
7	first floor	center	east wall	200						
1	ground floor	courtyard	west wall	60	23/7/2014					
2	ground floor	main hall	up south elevation	350			all	0	2center	4
3	ground floor	main hall	center	60						
13	ground floor	north study	center	60			1south	2	0	0
10	ground floor	north study	east center	60						
5	first floor	center	center	60			0	0	4north,south	0
7	first floor	center	east wall	200						
1	ground floor	courtyard	tree east center	120	4/8/2014	11:00-12:00				
3	ground floor	courtyard	west wall	60		14:00-15:30fountain				
10	ground floor	main hall	west	60			2 middle	4 corner	0	all
13	ground floor	main hall	center	60						
15	ground floor	main hall	east	60						
1	ground floor	courtyard	tree east center	120	5/8/2014	9:00-11:00fountain,windows				
3	ground floor	courtyard	west wall/fountain	60						
10	ground floor	main hall	west	60		14:00-16:30fountain, windows	2 middle	4 corner	0	all
13	ground floor	main hall	center	60						
15	ground floor	main hall	east	60						

3.2.3 Data analysis.

All data measured were present in order to evaluate:

1-Daily trends:

The physical variable against time of day gives a lot of informations about conditions experienced.
There may be strong daily variation, particularly for temperature and often of air velocity.
Also some ideas of how data consistent are changes from subject to subject and from day to day .and how different conditions can be changed from environment to another that the subject encounter .Time can also suggest the motivations behind people's behavior.

2-Comparison of variables:

In most indoor condition the operative temperature and the air temperature are not different, in this case could shows how some variable close to other in particular survey. Also helpful in detecting outline.

3-Subjectve response to environment:

Two obvious variables plot against each other; the temperature and comfort vote. That because the human comfort vote is reflects to all environment changing in addition to the social circumstances (response to the environment), particularly where the votes are collected over an extended period. For more worthy result when physical theory would predict more complex relationship, is to plot comfort vote against two variables at the same time.

4-Proportion:

Another way to analyzing field study observation proportion of different comfort vote at different temperature over range of survey.
The proportion voting comfortable, comfortably warm and comfortably cool rise to maximum at the relevant time and then falls as the proportion of subject voting hot in the day or cool in the night increase. (The day characteristicsd swing between the cool condition in night and the hot condition during the day).
Diagrams provide a summary of temperature and relative humidity for each case steps compared with outdoor temperature for the same period [Fergus N, Michael H, Roaf S 2012]
These diagrams divided to:

- Closing/opening windows (with natural ventilation, without natural ventilation) schedule for each hall and houses.
- Rooms have equal orientation with different structure, size, opening percentage, kind of natural ventilation.
- Courtyards different size, structure.
- Comparison all.

3.2.3.1 *Thermal environment's characteristics.*

All collected measurements for all cases studied (air temperature and relative humidity) presented at Appendix C5.

Air temperature and relative humidity:

Comparison between all cases (traditional houses) studied depend on orientation and structure to investigate the natural ventilation behavior with structure (new, traditional sustainable materials) and its impact on temperature.
1-Ground Floor :

- NORTH HALL: **Figure 3-6**(a,b)shows difference between two type of halls without relation to the house type, FAKHRY hall lower high , cross ventilation , one level windows that makes it has more steady temperature day and night , the second type by two windows level have more gap between day and night . The most important in this case is the impact of the structure intervention and new materials especially concrete raised the temperature inside halls about 1 °C degree at least (MOUSLLI/ FAKHRY case).
- East And West HALL:

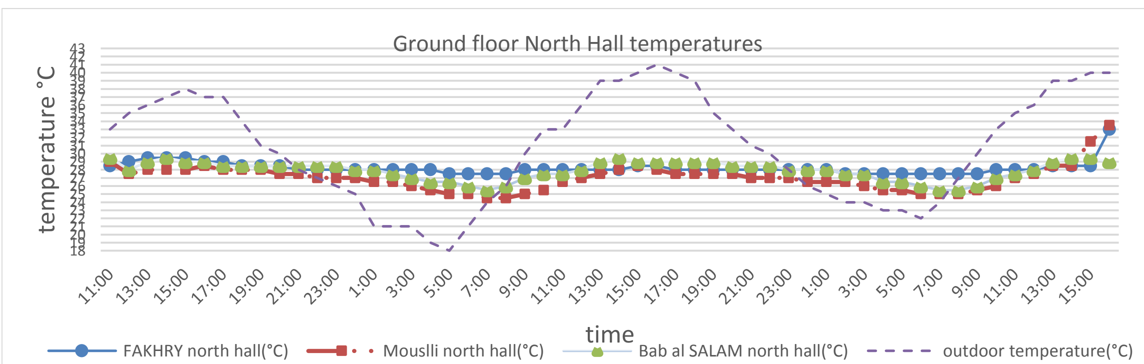
This case present structure impact on temperature in addition to stack single side nature ventilation for two levels which gives Mouslli halls best temperature behavior result at traditional houses studied. In other hand BAIT WARRD roughly close to MOUSLLI measurement during opening sliding plastic roof and beside big tree shaded courtyard all days. FAKHRY hall with lower height has increased temperature MIN 3 °C **Figure 3-6**(a,b)previous results

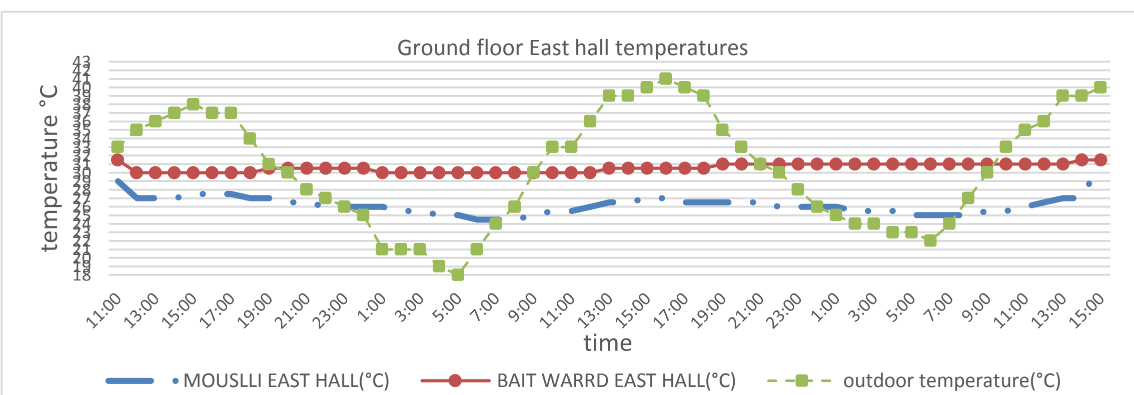
- Courtyard :

  Typical temperature trends inside courtyard are reported in **Figure 3-6**(a,b), the house that were with traditional structure gave better values for temperature and relative humidity (43%-63%) corresponding to courtyard size. The effect of a cover-up over the courtyard Bait Waard (two days closed) makes it as a greenhouse with high heat storage and a large thermal gradient: at ground level, with surrounding heavy mass with big tree effect[shadow], low stationary temperature were recorded, while at first floor very high values are measured due to greenhouse effect and to presence of light mass structure. The use of absorbing materials for wall plaster and roof covering (Fakhry) increase temperature, while the activation of fountain in the same courtyard decreased temperature (min 1°C).

2-first floor :

- North hall **Figure 3-6**(a,b,1.2) the effect of cross natural ventilation decrease the temperature of from 1°C to 3°C (at Fakhry hall due to high ceiling).
- East room: **Figure 3-6**(a,b,1.2) shows the effect of shaded room and small courtyard BAIT WARRD in comparison with big courtyard has got direct solar radiation in addition to intervention new materials FAKHRY, in spite of that the best temperature behavior for the room has traditional materials structure "MOUSLLI house".





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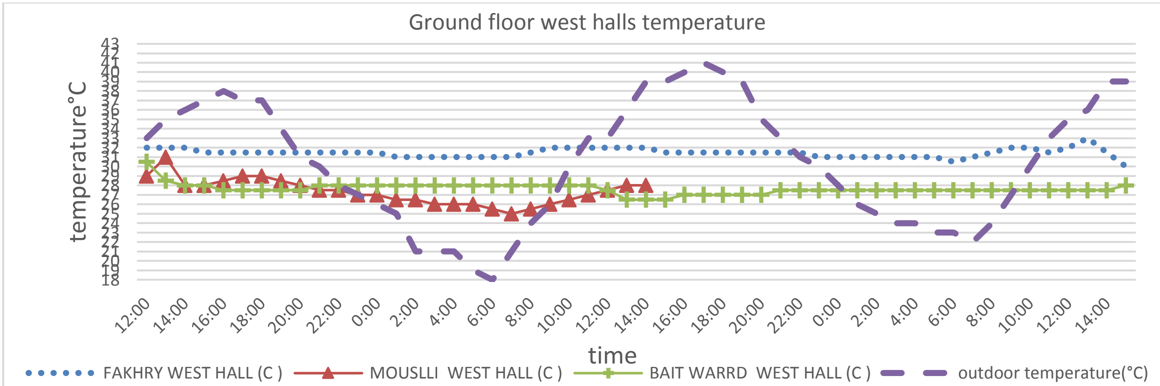
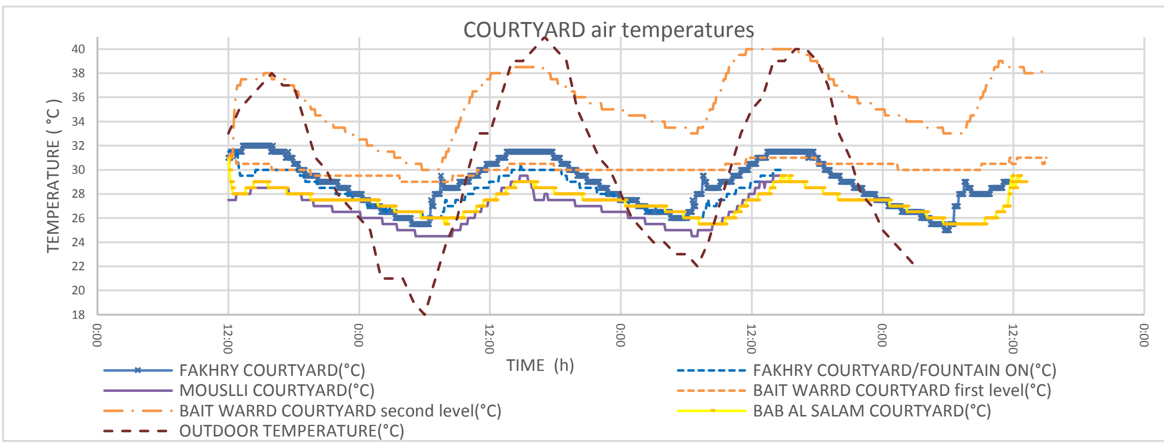
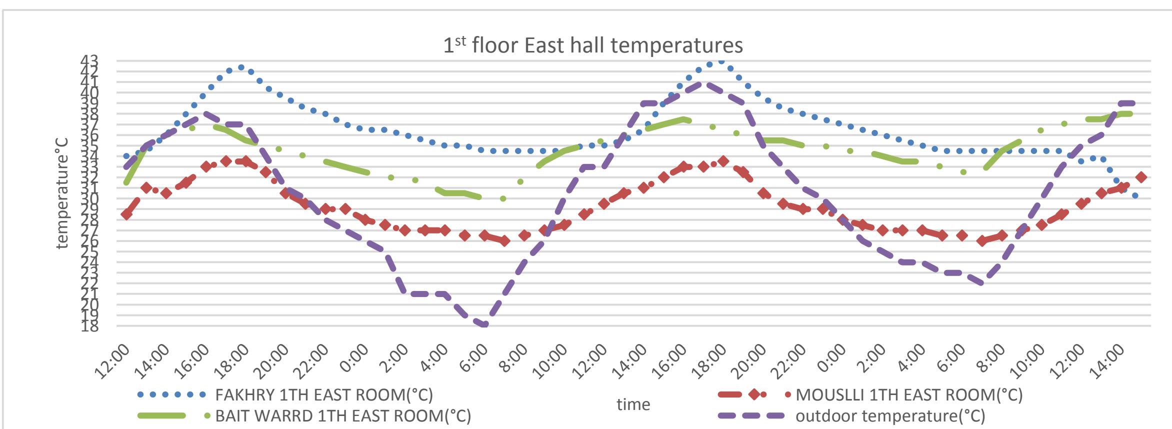
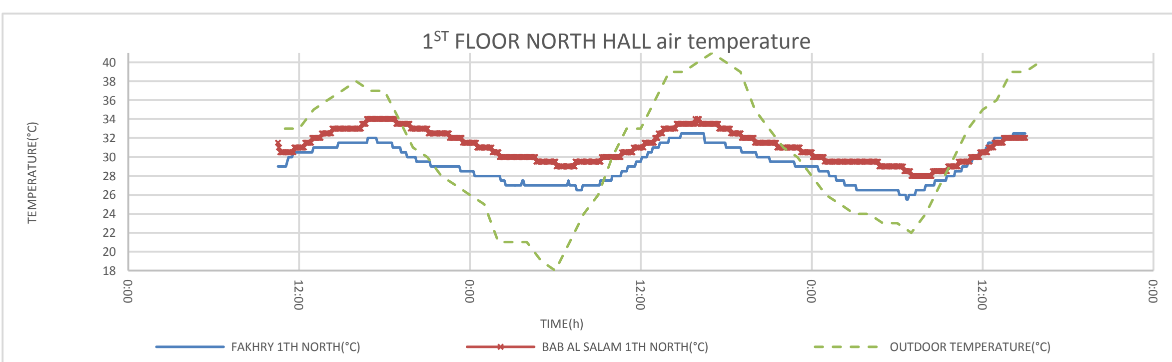
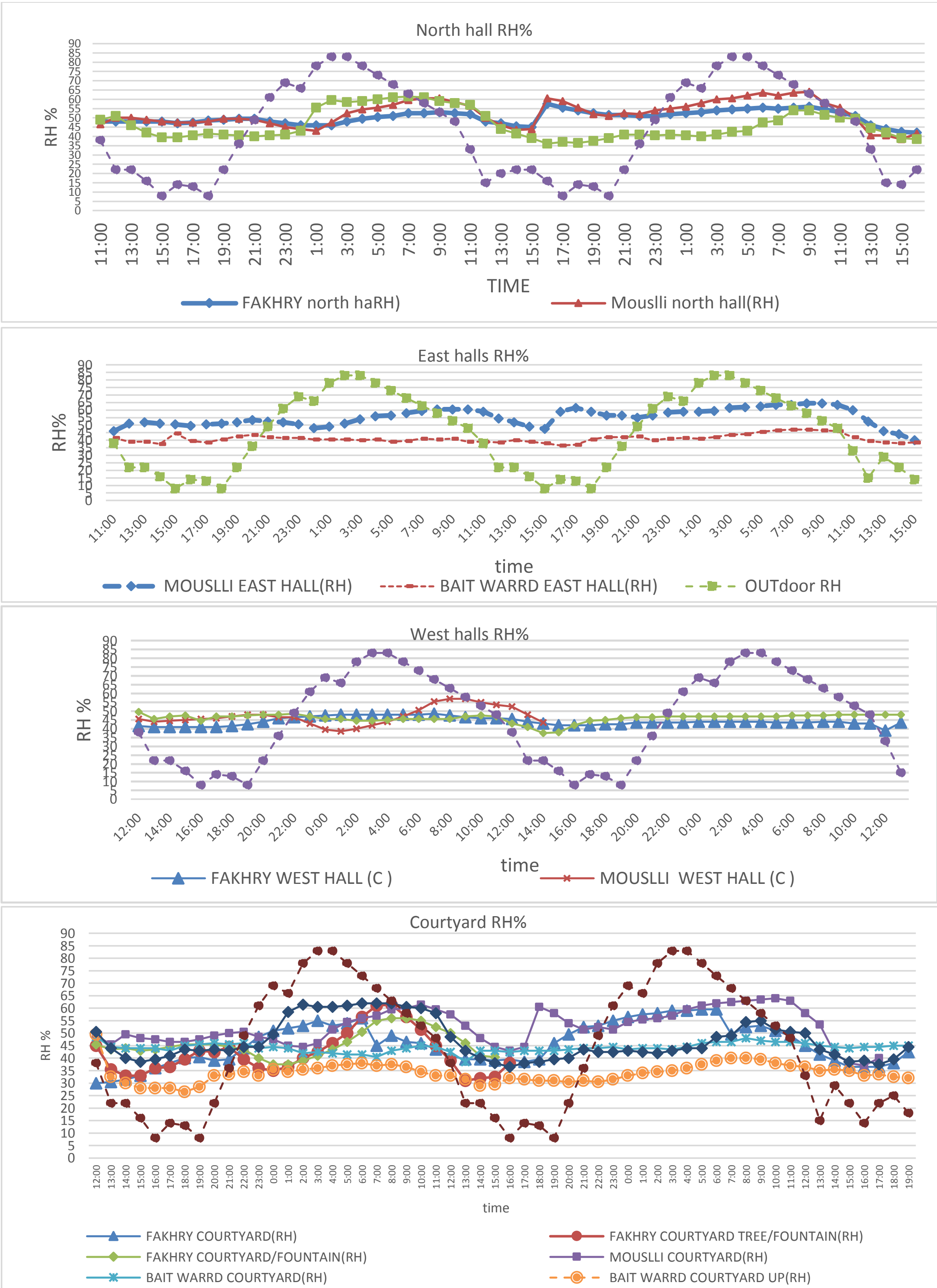




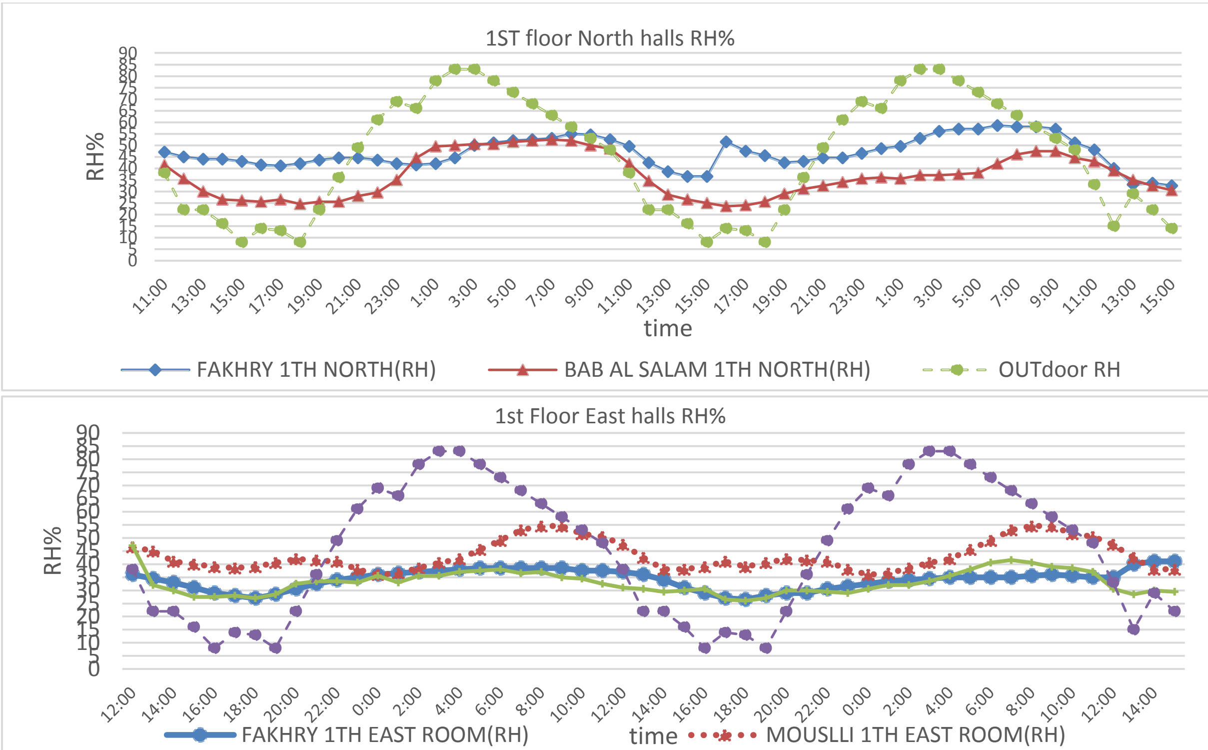




a2. cases halls air temperatures


North hall RH%
RH %
TIME
FAKHRY north haRH)
Mouslli north hall(RH)
East halls RH%
RH%
time
MOUSLLI EAST HALL(RH)
BAIT WARRD EAST HALL(RH)
OUTdoor RH
West halls RH%
RH %
time
FAKHRY WEST HALL (C)
MOUSLLI WEST HALL (C)
Courtyard RH%
RH %
time
FAKHRY COURTYARD(RH)
FAKHRY COURTYARD TREE/FOUNTAIN(RH)
FAKHRY COURTYARD/FOUNTAIN(RH)
MOUSLLI COURTYARD(RH)
BAIT WARRD COURTYARD(RH)
BAIT WARRD COURTYARD UP(RH)

b1



,b2. cases halls relative humidity.

Figure 3-6: a1,2. cases halls air temperatures. b.1,2 cases halls relative humidity.

3.2.3.2 *Thermal comfort .*

PMV/sensation scale and T_{op} is calculated at specific time using air velocity manual data corresponded with experimental measurements of physical parameters during analyzed period of study to calculate these parameters, which run parallel with survey, depended on ASHRAE standard way for all.

For personal activity: from survey set relaxing with reading 1.2 met.

For personal insulation clothes: average for all survey student (long trouser, short sleeve shirt, socks, shoes) 0.58-0.6 clo.

For this part the diagrams will divided to two kinds:

- PMV scale, Adaptive model as survey (point –in-time survey(ST)) (thermal sensations for occupancy):Short- term (evaluate building performance, occupant satisfaction) Comfort determination from occupant survey (ASHRAE standard) acceptability and satisfaction are directly determined from the response of occupants using the scales and comfort limits, survey numbers16 included seven- point sensation scale
- PMV/sensation scale, ADAPTIVE model, T_{op} calculated as ASHRAE way

PMV heat balance model prediction of thermal sensation and satisfaction from environmental measurements, The Adaptive Model is an empirical model of adaptive human responses to environments offering operable window control. The comfort zone on a given day is dependent on a running mean of previous outdoor air temperatures, to which people continuously adapt over time.

Criteria for Passing:

• –0.5 to +0.5 on the PMV scale, inclusive, is the criterion for passing in Standard 55.

• Field surveys usually consider sensation values of –1 and +1 as representing seven-point thermal sensation scale is at –1.5 and +1.5, inclusive

➢ FAKHRY AL BAROUDI

- Main south hall:

Survey submitted for every study steps (daily) for natural ventilation and thermal performance at south hall ,the surveys sensation also calculate PMV /sensation scale **Figure 3-7**,a shows result
The equations corresponding to the acceptable adaptive model are
Upper 80% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +21.3=29.73
Upper 90% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +20.3=28.73
Lower 80% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +14.3=22.73
Lower 90% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +15.3=23.73
All data made at the center of south hall at 60 cm high.
Observation diagram calculation way gives high result than survey and occupancy feeling and sensation for this result utilize adaptive model **Figure 3-7**,a .
The result at this model closer to occupant sensation than PMV scale specially for two level windows opened (single side stack ventilation) and fountain correlated to natural ventilation and its impact on human sensation.
All other detailed measurements and figures of FAKHRY halls studies are in the Appendix C5.

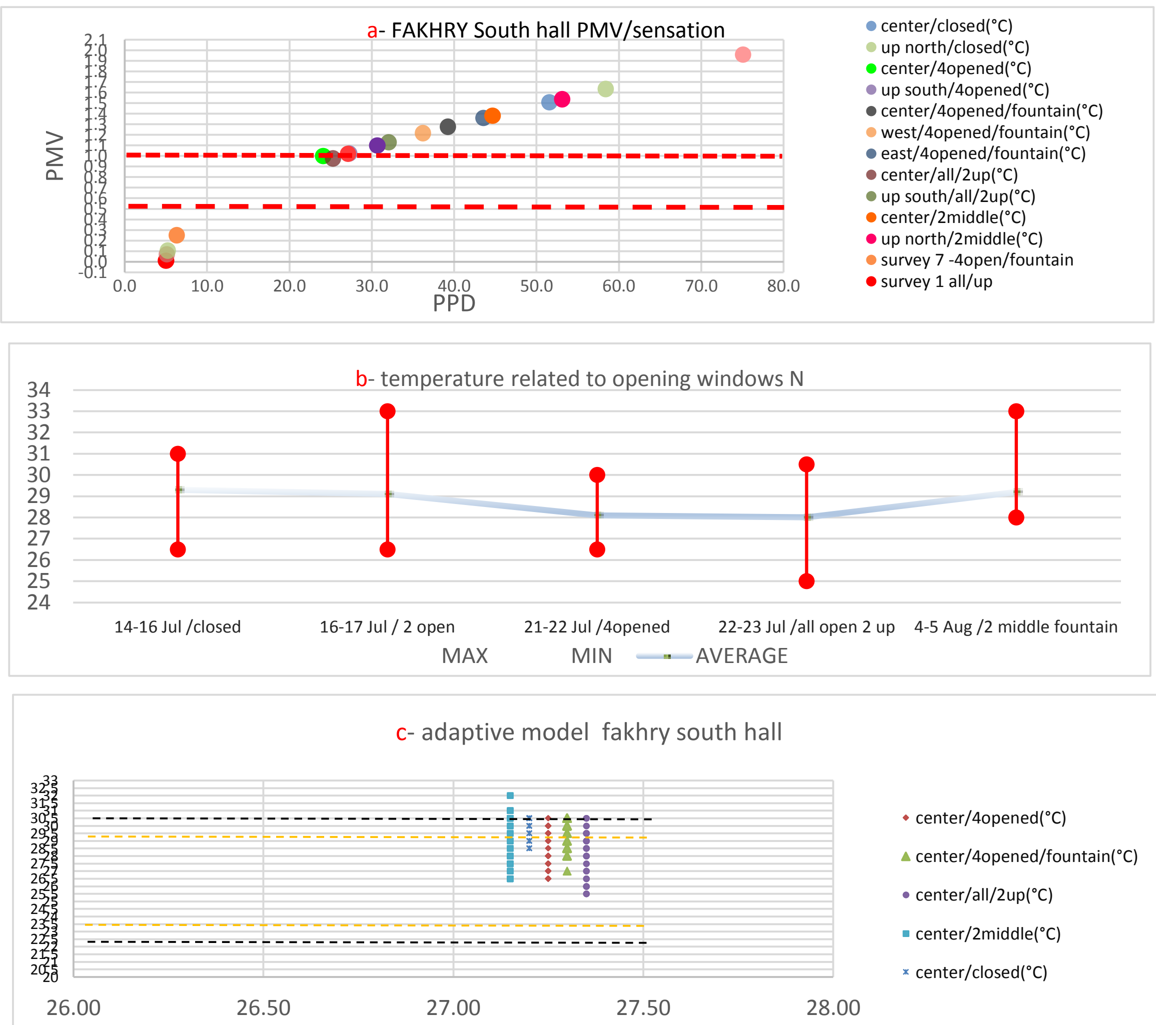


Figure 3-7: FAKHRY South hall ,a. PMV/ sensation)survey, b. ventilation effect ,c. Adaptive model part of °C degree.

- **Air flow behavior:**

Consequences acceptability limits 80% for all windows open (single side stack natural ventilation).
Close windows (without natural ventilation) case acceptability limits 90% was 0% for case two windows 30% for case four window 50% utilized fountain increase percentage for two windows15% to 45% comfort period.

At morning; time for cases two, four opening windows the air flow from inside to outside from all windows area and at every edge.
At midday; there are a circular motion, air flow comes in from west windows with air flow speed about 0.4 m/s and goes out from east windows part with lower velocity less than 0.2m/s with different temperature about 1°C different special in case turn on fountain at this case clearly impact at air velocity beside fountain (more higher) and around courtyard at least the different about 0.1m/s roughly at midday.
Case open door; the circular motion has proved two separate circles centration(middle of room) at door.
Case two level opened (stock)the clearly circular motion from down level to up level(from low temperature to high temperature).
Air motion studied by using smoking source. **Figure 3-8**

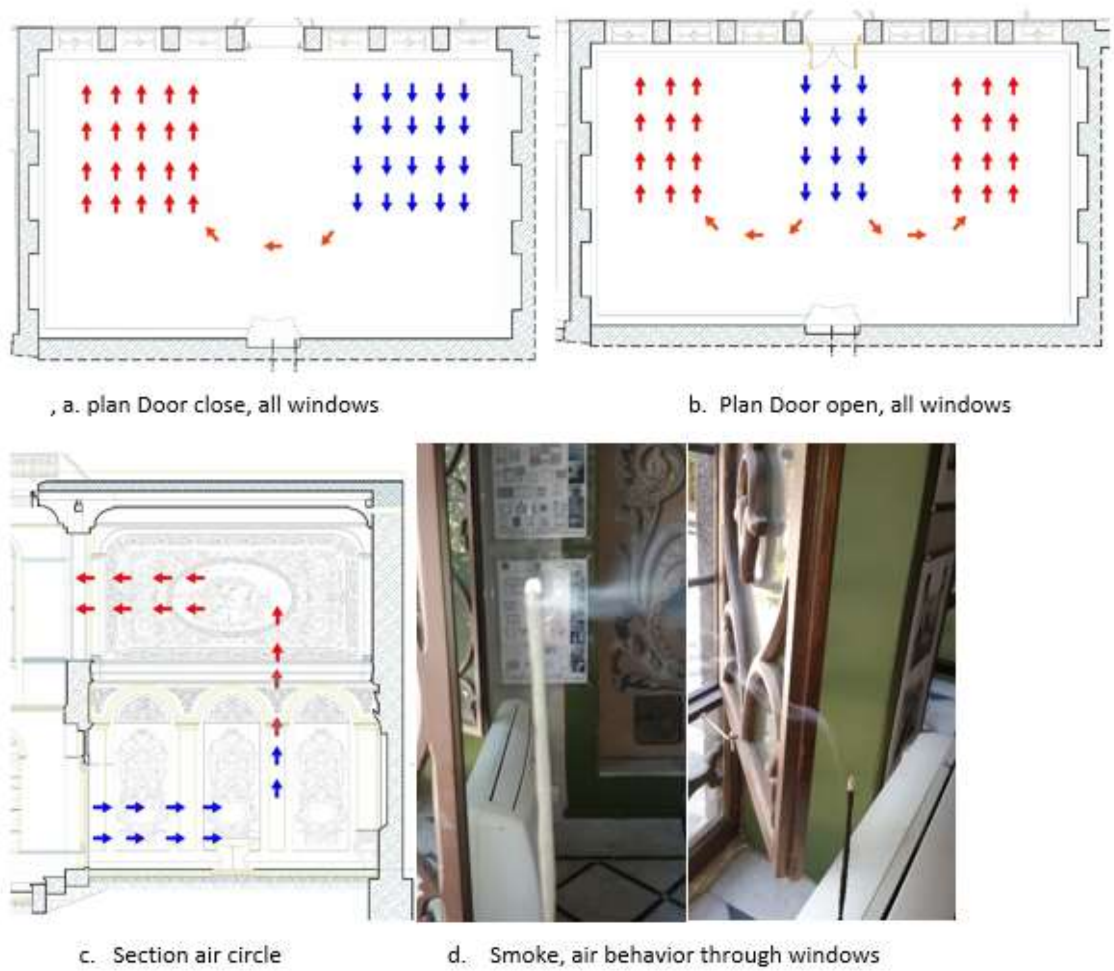


Figure 3-8: air flow behavior single side stack ventilation FAKHRY south hall.

3.2.3.2.1 PMV /sensation scale and survey.

Figure 3-9shows comfort sensation results from survey data compared to measured temperature, for all Fakhry halls, in two conditions: close and open windows(with and without natural ventilation). Significant differences were found between close windows condition (comfort values higher than 2), and open windows condition (values ranging from 0 to 1) due to the effect of kind of natural ventilation (cross “adjacent” ventilation; north hall, single side “stock” ventilation; south hall “two levels of windows”). Otherwise, the adaptive model are too closer to occupant sensation during natural ventilation effect. Natural ventilation has great effect on human sensation and microclimate of space: in summer period natural ventilation gives at least 2°C lower temperature respect to the closed window, depending on the kind of ventilation, orientation, structure, height, size and opening area.

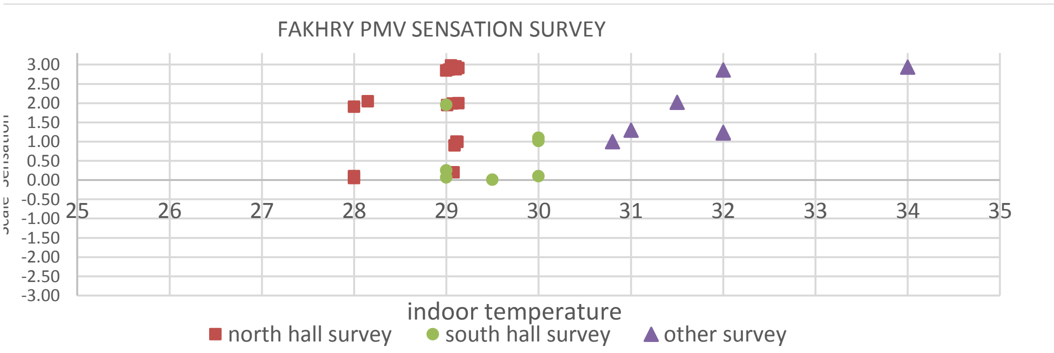


Figure 3-9: FAKHRY .PMV Sensation survey all halls.

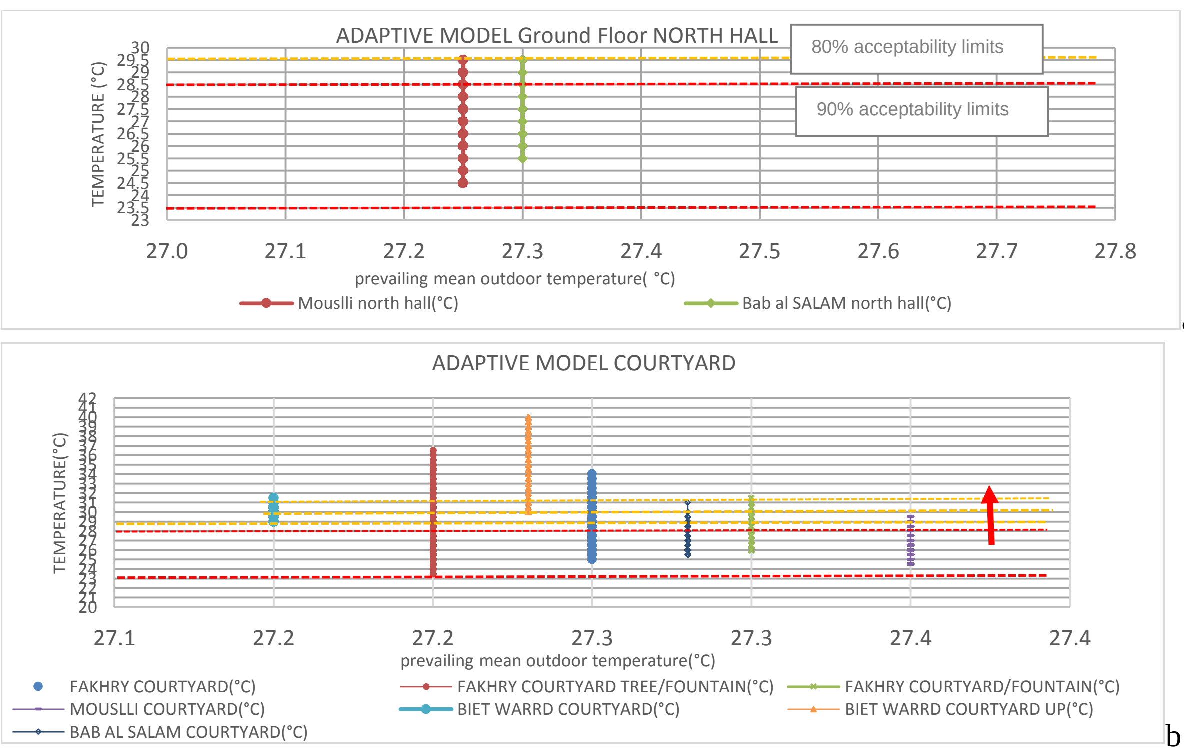
3.2.3.2.2 Adaptive Model.

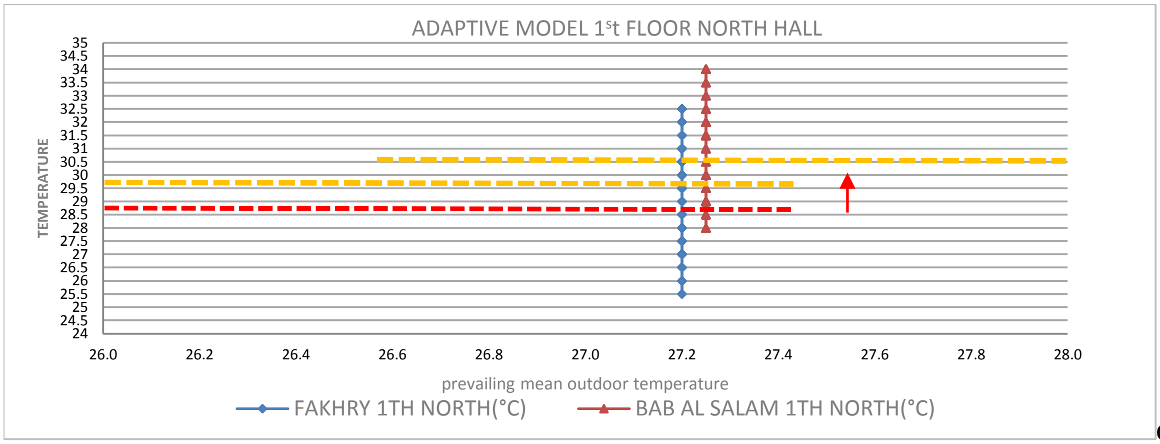
Depend on previous results **Figure 3-10**shows results of temperature measurements for different houses that fall within 90% limits of acceptability of the adaptive model of the adaptive model.

For North halls**Figure 3-10** (a) all cases fall within the acceptability limits of 90%, but Mouslli house presents better results, depending on structure and materials than Bab al Salam.

For Courtyard,**Figure 3-10** (b) the periods within the acceptability limits depend on the presence of trees, fountain, kind of building materials, structure (ground floor heavy mass, first floor light mass). The activation of a fountain increase the acceptability roughly of 20%, while the case of closed courtyard create a global worming at top level. Materials add more roughly 20% for acceptable period.

For First floor north hall **Figure 3-10**(,c) results confirm that cross ventilation increase acceptability limit roughly between 20% to 25% comfort period and in East hall the effect of natural ventilation increase 30% to 35% comfort period respect to closed space and also courtyard increase comfort period limits.





c

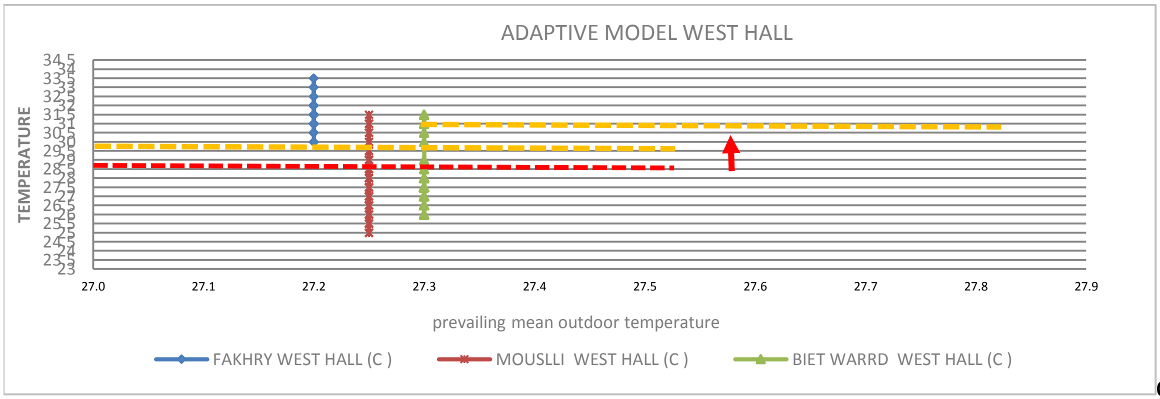


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Figure 3-10: a, b,c,d Adaptive Model ,North hall ,Courtyards , 1st floor north halls ,West halls.

3.2.3.3 *Summary of measurement 2014.*

Analysis inside courtyard shows the importance of the traditional structure materials (Mouslli) beside the size and shaded area (Bab Al Salam), the presence of another important factors as trees and fountain.. Building structure (heavy thermal mass at the ground floor) and ceiling height have main influence on thermal comfort. Opening area[air fow] and positions have significant influence on natural ventilation effective, that present in particular at stack effect (two level of windows in Fakhry south hall with elevation of about 8 m), cross ventilation (in west Mouslli hall with cross ventilation adjacent windows) better than single side ventilation (in west Fakhry hall). Using the adaptive model gets results closer to human sensation survey, which shows a great variability of subjective sensations, bringing to consider more relevant at adaptive model **Figure 3-11**present the effective percentage of each elements on thermal comfort.
Thermal mass (heavy mass) utilize natural sustainability materials gives more comfort for occupancy which increase by merging with natural ventilation as passive cooling strategies.
Effective factors on natural ventilation proportional and thermal comfort: volume [the rate between height and area (depth), WWR % (depend on façade) and it is the same for each kind of natural ventilation.
higher ceiling got lower indoor temperature in spite of high opening area correlate with structure Appendix C5 .

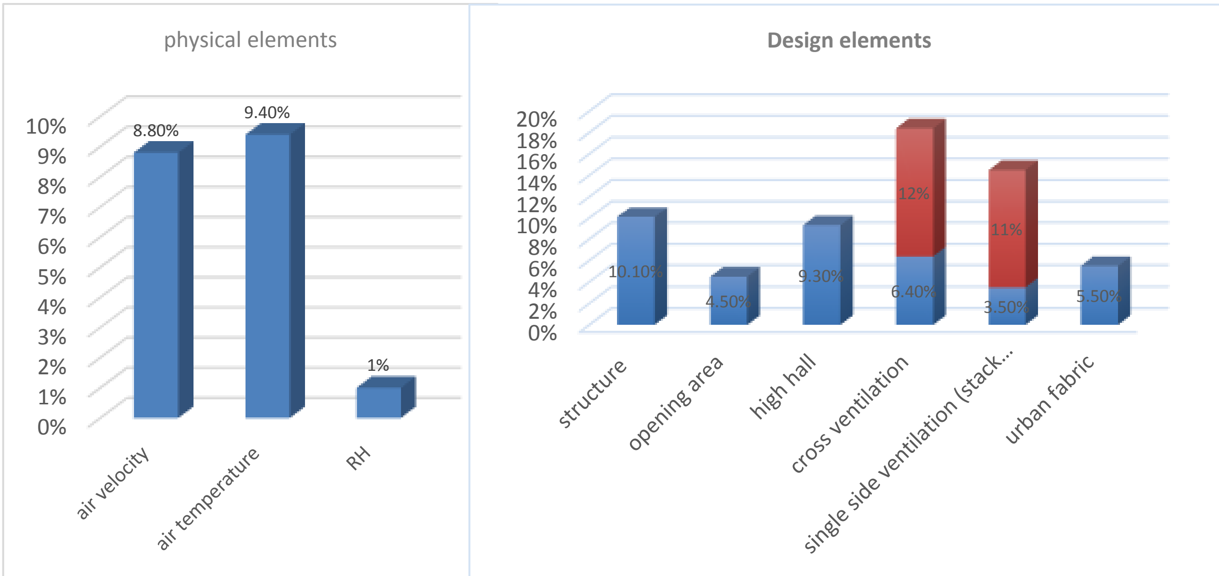


Figure 3-11: Elements effective on thermal comfort.

3.3 Measurement on winter 2014/2015.

Outdoor weather Data is collected from the nearest weather station to cases study. The weather station of faculty of agriculture at Damascus University(as summer 2014th measurements) had recorded many weather elements for every hour; (temperature , relative humidity , wind speed, dew point , pressure , wind direction).

The cases have been chosen for this investigation only two traditional houses, focus on envelope behavior and materials and their impact on thermal comfort and inside temperatures, the cases are BAIT FAKHRY AL BAROUDI , BAIT AL MOUSLLI. On other hand the rooms have been chosen releyed on summer investigation also .

3.3.1 Instruments

The used measuring instruments were the same and followed the same positions rules of summer Instruments followed same rules at summer 2014th as ASHRAE Standard.

1-BAIT FAKHRY AL BAROUDI:

The important aspect was to avoid the instruments from the direct solar radiation and the rains trops in opening spaces.

Ground floor: the instruments have been distributed according to the previous rules plus the followings:

Courtyard: south west corner (shaded place); avoided from solar radiation and rains at height 170 cm, to investigate the courtyard microclimate and the effect on the interior space.

Roof : at north with rain shelter and direct radiation at height 60 cm , for getting the region microclimate and to investigate the urban fabric effect on houses .

Main south hall with high ceiling: inside the hall center at 60 cm height . the second step at height 10,60,170 cm to investigate the comfort and dissatisfaction .

West room: West hall at 60cm high(1m far away from wall) , investigate thermal comfort at new materials structure with high level of infiltration.

Study north hall[semi-underground]: goes down stairs to level -23 cm east part, study hall device position within its center at high 60cm, investigate thermal comfort for students .second step as south hall 10,60,170cm for comfort investigation Appendix C1 present the instruments positions .
First floor:
Larg North main hall entrance: has facing's windows and high gabled ceiling, device fixed at 60 cm as first step, the second one as other room for comfort investigation.
Library east room: at height 60 cm

2-BAIT AL MOUSLLI.

Follow the same strategies of FAKHRY AL BAROUDIs .and roughly the same rooms' orientations which have no interventions in structure and materials for comparisons.
The instruments have been distributed according to the following:
Ground floor:
Main north room: at the north ,height 60 cm, with two windows level and high ceiling and open p windows , the second step at height (10,60,170) for comfort investigation .
East and West room : south wall, at 60 cm high , cross ventilation with adjacent windows through two sides (north , west) and (north , east) with northern two windows level.
Courtyard (IWAN) to protect device from direct solar radiation and rains position presente at Appendix C2.
The measurements followed parallel at the same time of FAKHRY AL BAROUDI period to investigate structure behavior influence on the thermal.

3.3.2 Monitoring schedule

The most collected Data have recorded during the 14 -31th of DECEMBER 2014th and 1-5/of JANUARY 2015th which have considered as a represent of a typical winter performance although it was short period of time is actually involved. The weather during these period was sunny and partly cloudy, cold. Maximum outside temperature was 18 °C was typical during this period or little pit lower but minimum outside temperature -2°C which is lower than typical temperature during this period about 4 to 5 °C degrees .The two weeks before this period were also cold and typically , leading to reasonably stable thermal condition during research period .
A bout 100 measurement was made for each hall. The total result 15 measurements for each case.

- BAIT FAKHRY AL BAROUDI: measurements investigation followed :

First one: all halls and rooms were closed .
Second : no heating inside rooms.
Third : getting the impact of the traditional materials and new intervention materials on the interior space, thermal behavior and human comfort(satisfied and dissatisfied) and utilized three vertical points in space to analyzed comfort schedule presented at Appendix C1.

- BAIT AL MOUSLLI: followed previous points . schedule present at Appendix C2.

3.3.3 Data analysis.

Analysis followed same strategies for summer 2014th results.

Thermal environment's characteristics.

Air temperature and relative humidity

- BAIT FAKHRY AL BAROUDI

Figure 3-12- a present changes in temperature depend on structure , orientation and level , height and solar direct gain as folowe :the best temperature for north hall with heavy mass caused through 25% of its size underground(srounded by balance environment/ temperature soil) that mean moderate temperature in addition to big facade on south , then 1st floor main north hall which has light mass and with high ceiling about 6m and small façade on south ,after this hall 1st floor east room with same structure as the last one with lower

ceiling 3.3m and west hall made from concrete , the latest hall in evaluate performance is main south with high ceiling 7.9m and big façade on north .
The important aspect the courtyard adjustment the microclimate and increase the temperature at least about 5°C degrees than surround ambient temperature.

- BAIT AL MOUSLLI:

Figure 3-12-b shows changes in temperature as same as FAKHRY AL BAROUDI also same result , the best result for main north room but in this case its on ground level not underground with high ceiling about 5.7m, then west and east hall also with high ceiling about 5m all those rooms has same structure heavy mass .
The effect of courtyard has same result of the latest house.
The important aspect for MOUSLLI case the high level of infiltration related to keep it without rehabitation and intervention .
MOUSLLI case has big swing between day and night related to high infiltrations comparing with FAKHRY with good rehabilitation which has more balance in behavior .on other hand the influence of courtyard to reduce and create microclimate more comfort and balance compare with outdoor environment **Figure 3-12-c** .

3.3.4 Thermal comfort.

Comparison between the two traditional houses studied types depend on orientation and structure to investigate the natural ventilation behavior with structure (new , traditional materials) and its impact on temperature comfort model-PMV /sensation survey, Adaptive model with same previous strategies.

3.3.4.1 *PMV Scale and survey*

All FAKHRY rooms were not comfort for occupant during the data collected period at PMV calculate way , by using surveys for assessment we found 50% of the result changed to be acceptable . **Figure 3-13** present this result. Survey submitted for every studies steps(each day during monitoring period).
Therefor utilized adaptive model for evaluate which was closer to survey result.

3.3.4.2 *Adaptive Model*

The equations corresponding to the acceptable operative temperature are : (7.5°c)
Upper 80% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +21.3=23.62
Upper 90% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +20.3=22.62
Lower 80% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +14.3=16.62
Lower 90% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +15.3=17.62.

- NORTH HALL:

Adaptive model (ST)measure : (fig12)shows the result more closer to occupant survey , Consequences acceptability limits 80% for FAKHRY cover about 70% as acceptable period for MOUSLLI only 20% this result because there are a big infiltration at MOUSLLI .

- West hall :

Acceptability limits 80% for FAKHRY cover only about 35% for MOUSLLI only 20% this result caused by utilized new structure for west FAKHRY room compare to north hall , for MOUSLLI the same reason for north and all rooms.

All other halls has equal result **Figure 3-14**present all results.

- People Dissatisfied as Function of Air Temperature Difference Between Head and Ankle:

For more comfort details another investigation made for vertical air temperature different inside the hall , In most halls, air temperature normally increases with height above the floor. If the gradient is sufficiently large, local warm discomfort can occur at the head and/or cold discomfort can occur at the feet, although the body as a whole is thermally neutral, the data collected many high (10, 60,170) as ASHRAE STANDERD way.

On other hand tha main porpuse of this investigation was to discover the infulence of structures(intervention materials, traditional sustainadl materials)

FAKHRY NORTH HALL:

Figure 3-14-a present the MAX difference for vertical air temperature only about 0.5 °C degree that means the north halls had been comfort sutisfied for occupant the floor consist of 6cm basalt stone as traditional structure .

MOUSLLI NORTH HALL:

Figure 3-14-b shows same result of FAKHRY north hall also for ankle (floor) temperature this caused by basalt stone thickness 7cm and other layers [without any intervention].

All other halls have same results caused by traditional structures .

3.3.5 Summary of winter measurement 2014/2015th .

Courtyard has great effect on traditional houses microclimate and halls period structure and materials which depend on orientation and levels, height and size , façade area , solar direct gain , beside physical elements .

The effect of mass and level so clearly through their relation with PMV /sensation scale and increase PMV ,Adaptive Model result increasing bout 25-30 % for light mass and solar direct gain for first floor in addition to underground impact .

Relation between summer and winter measurements results

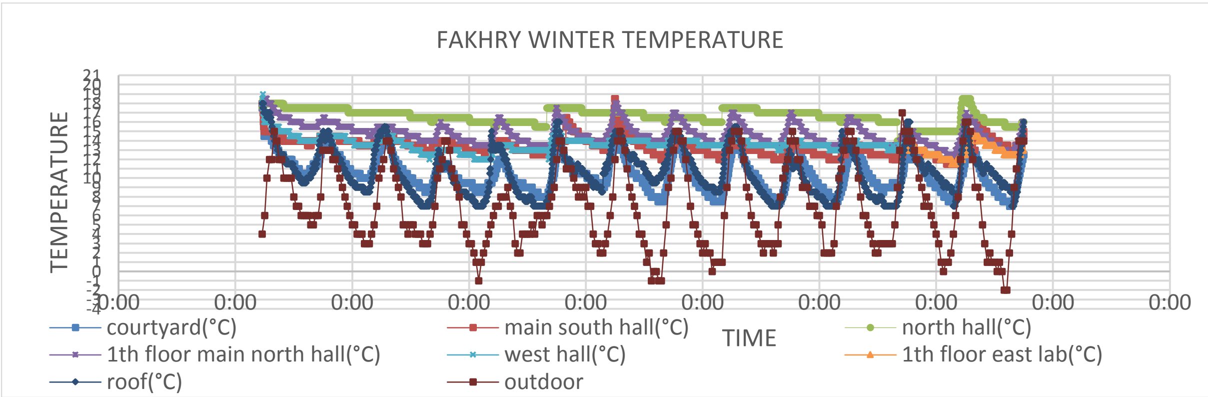
The highest parameters of relative humidity RH increase at value in winter period to amendment comfort scale , on other hand RH has inversely proportional with temperature , this relation between relative humidity and temperature proved for summer and winter period .

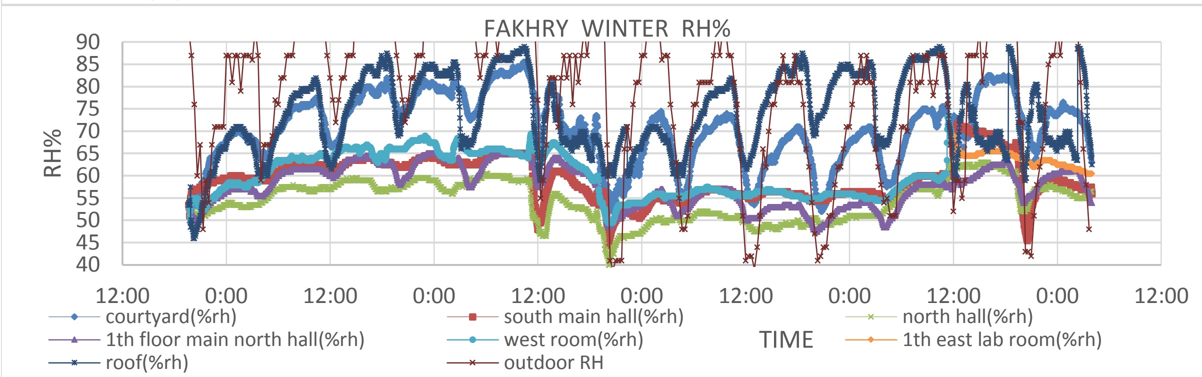
For winter period façade area parameter has more effect on comfort scale than height hall parameter. PMV /sensation scale/ Adaptive are proportional with façade area parameter.

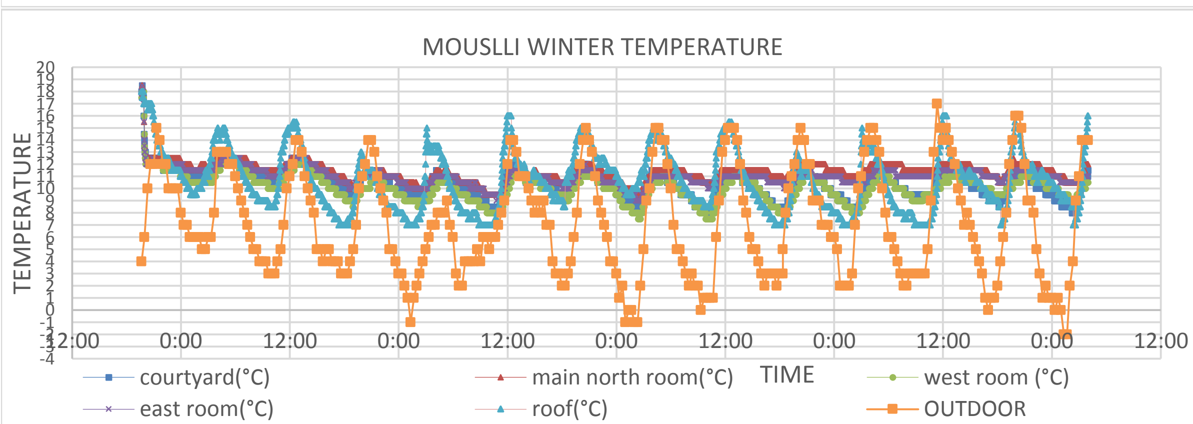
Infiltration has big effect on comfort scale especially in winter period has reverse effect.

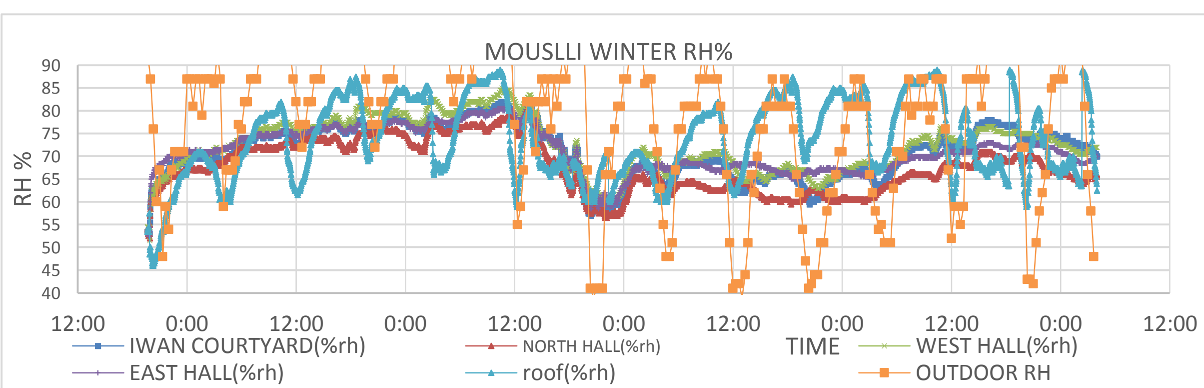
Semi-Underground position has good thermal behavior and comfort for summer and winter period **Figure 3-15**present late results.

The first floor has good comfort behavior for winter period which is revers with summer period, that could solve and amended by natural ventilation.

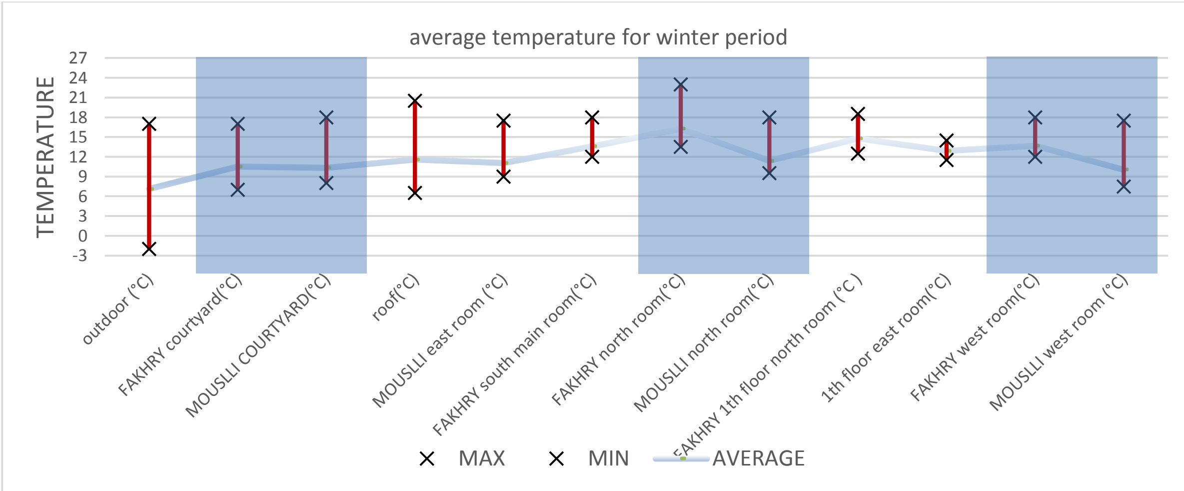






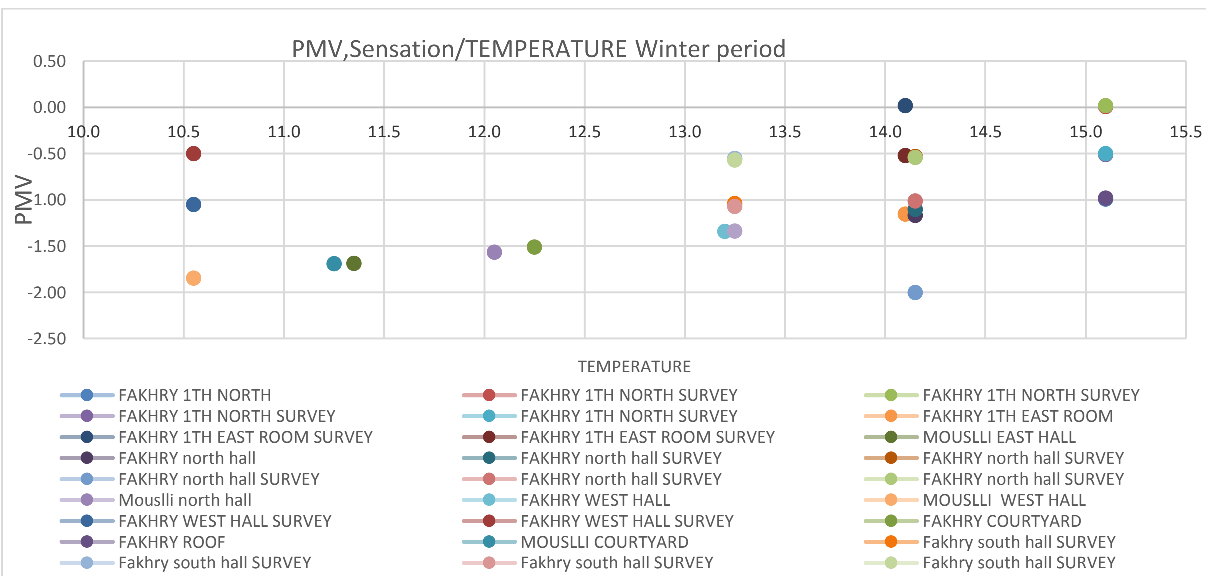


,a, air temperature,Relative humidity:a. FAKHRY ,b. MOUSLLI ,for winter period.



,b, air temperature, C average for winter period FAKHRY ,MOUSLLI

Figure 3-12: a,b air temperature.



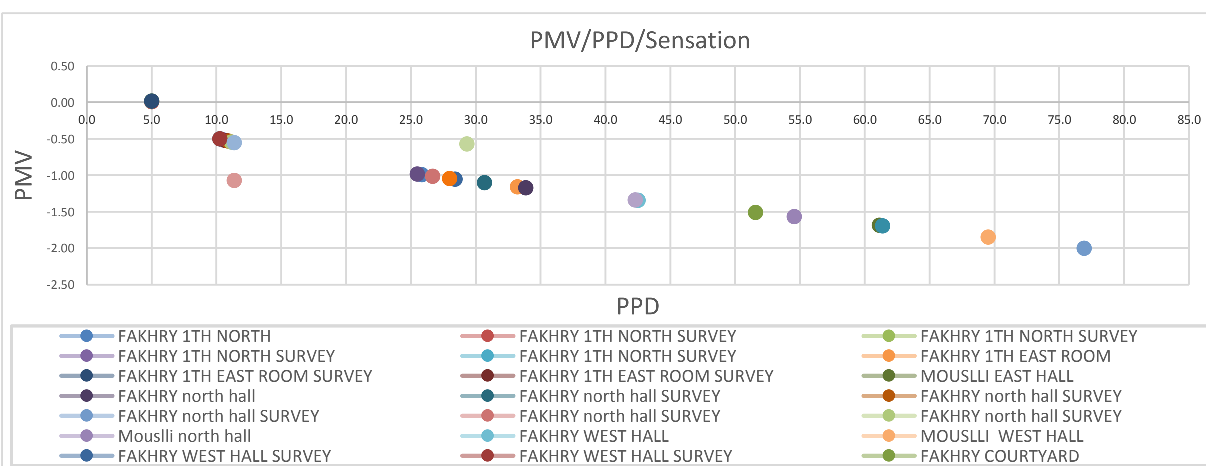


Figure 3-13: PMV sensation survey for winter period.

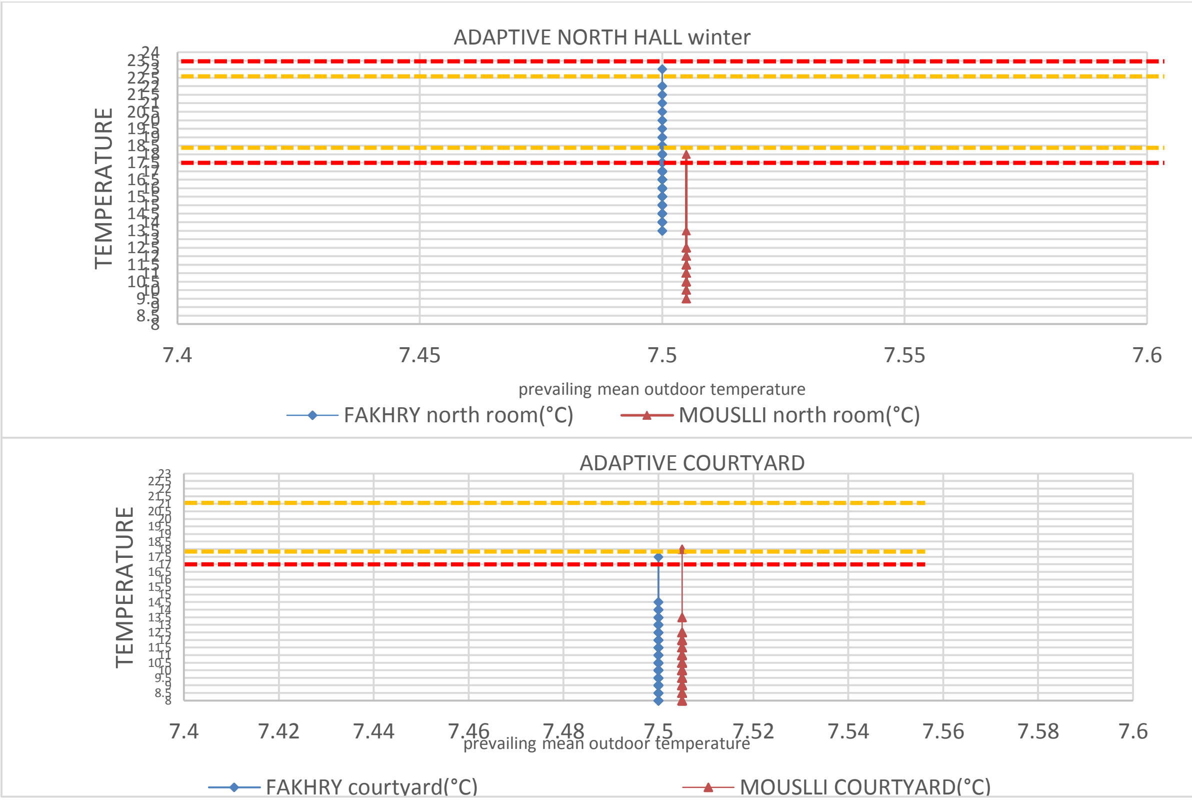


Figure 3-14: Adaptive Model for winter period.

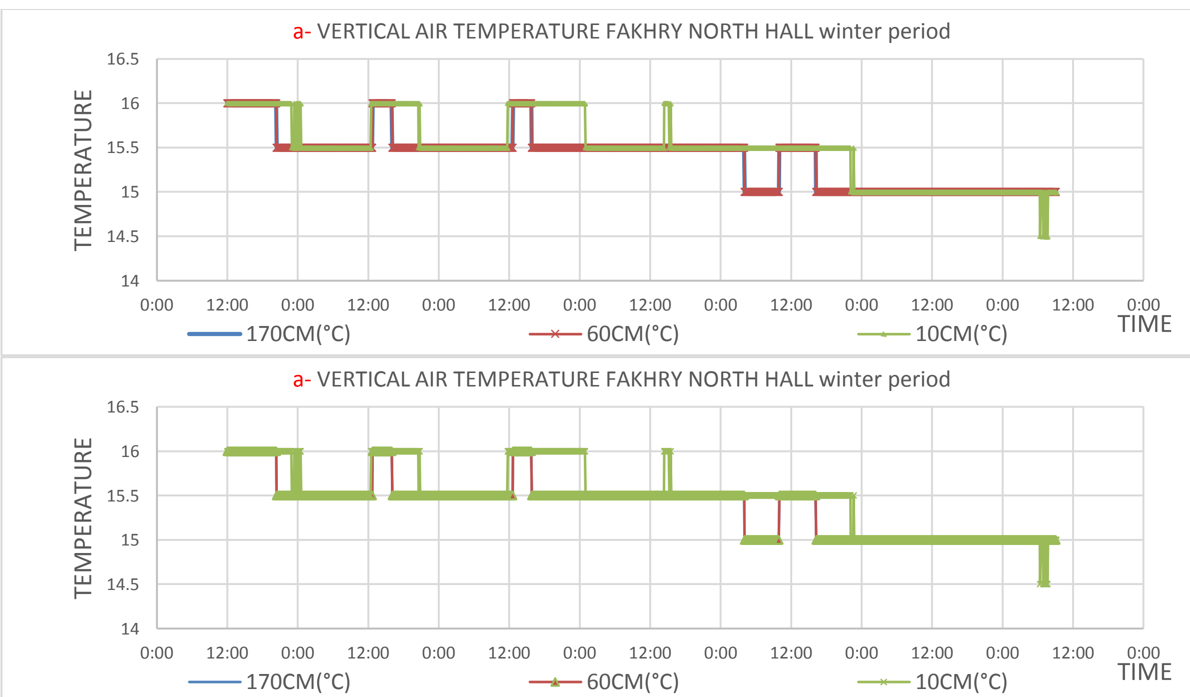


Figure 3-15: People Dissatisfied as Function of Air Temperature Difference Between Head and Ankle,winter.

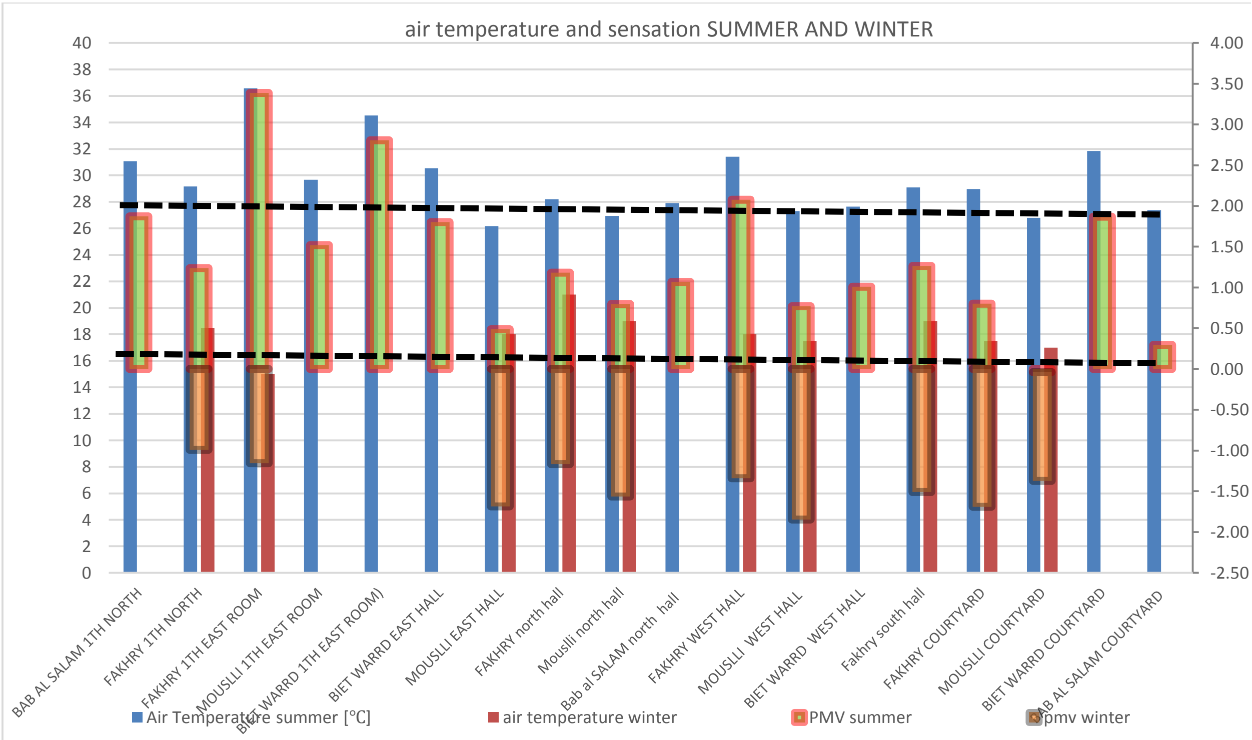


Figure 3-16: Thermal behavior and comfort for summer and winter period.

3.4 Measurement on summer 2015th on Natural ventilation.

Outdoor weather Data was collected from the nearest weather station to cases study the weather station of faculty of agriculture at Damascus University. It record many weather elements for every hour; (temperature, relative humidity, wind speed, dew point, pressure, wind direction) as all cases.

This part of investigation is to focus on natural ventilation and their effect on hall condition (temperature, relative humidity) beside concentrate on thermal mass and the main aim is their reflection on thermal comfort. The first investigation part was to evaluate natural ventilation beside materials and structure (traditional and sustainable materials, interventions) the investigation purpose was the effect on thermal comfort by chosen four cases study by use temperature / relative humidity diagram for data evaluation from measurements and surveys depend on ASHRAE way and Standard.
For more evaluation and get specific result used adaptive Model and sensation comparison with PMV scale.
As first step to generate a pre-design tool for summer cooling with natural ventilation as one of the low-coast passive cooling techniques that may contribute to reduce cooling load of buildings integration with thermal mass to improve thermal comfort of occupant.
Bait FAKHRY AL BAROUDI has been chosen for this step from four houses studied before to get more and specific results at natural ventilation (cross ventilation , single side stack ventilation).

3.4.1 Instruments

Followed same strategies for previous investigation step. Instruments have been distributed according to the following:
-Ground floor south hall (single side stack ventilation): the instruments distribute in three levels: 10 Cm, 60 cm, 110 cm height as ASHRAE STANDARD at four part: center, north, east and west.
North hall(cross adjacent ventilation): the instrument distribute in two parts: center, west at height 60 cm.

-1st floor :north hall(direct cross ventilation) : the instruments distribute in three levels: 60 cm ,110 cm , 220 cm height as ASHRAE STANDARD at five parts : center ,north, south , east and west .
Instruments position for summer 2015th present at Appendix C1.

3.4.2 Monitoring schedule

The most collect Data have recorded during July, August 2015th. These years has considered as exceptional year through the highest summer performance comparison with the few last years about 5 to 7 °C degrees above the typical temperature. The weather during these months was sunny, clear and very hot. Maximum outside temperature (46-47) °C .The two weeks before this period were also hot and in general sunny, leading to unstable thermal condition during these period. Data were collected a bout 1000 for each hall
0, the total result 20 measurements for each case.
South hall :The operation schedule as table is registered in Appendix C1 for opening and natural ventilation which divided to two period (two weeks at the last week of July and the first of August 2015) close all windows ,during the next period opening all two level windows (single side , stack ventilation) .
Air speed collected manual at specific time parallel with surveys at different time and cases: open, close windows(with and without natural ventilation).
North hall: The monitoring period divided into two periods (two weeks from August 2014th) close all windows, opening all adjacent windows as Appendix C1.
Also the same for the first floor north hall.

3.4.3 Data analysis

Analysis data and evaluation: Followed the same way of the first schedule.
The method for evaluation natural ventilation:
-Comparison of different strategies (design process):
-Comparison with and without natural ventilation during day for three main halls (south hall, north hall, 1st floor north hall)
-Comparison natural ventilation types: [1] cross ventilation: direct cross ventilation at 1st floor north hall, adjacent cross ventilation at north hall. [2] Single side ventilation (stack ventilation): two levels of opening at south hall.
-Comparison natural ventilation effectiveness complain with thermal mass: [1] heavy mass (stone structure at ground floor south hall), [2] light mass (timber structure with mud at first floor north hall).
Comparison the collected data between two years 2014 and 2015th.
Data evaluation (during initial operation):
Using temperature / relative humidity data.
Using evaluation surveys/ Adaptive Model, Psychometric-chart to determined thermal comfort of occupant.

Thermal environment’s characteristics

Air temperature and relative humidity

- South hall (single side stack ventilation):

Vertical temperature investigation: According to temperature stratification scale, the temperature at the floor was the lowest.
-Due to its little heat gain the temperature fluctuation at the partition walls (adjacent to other
Room consonant) is semi-steady and lower than at the center.
Furthermore, **Figure 3-16**a. Shows temperature profile before and during natural ventilation: during natural ventilation incoming, cold ambient air falls down to the floor.
The lower temperature near the floor, and the highest at the center of the hall while the temperature near west and east wall more steady that correlated to adjacent rooms.
These results realized by our predecessors through step at front of each room which they sat on the floor near the window in this case[the windows height begin from floor near to zero] (10 cm +40cm step) to get the effective of air flow and for winter period the colder air collected near the door by step space volume .

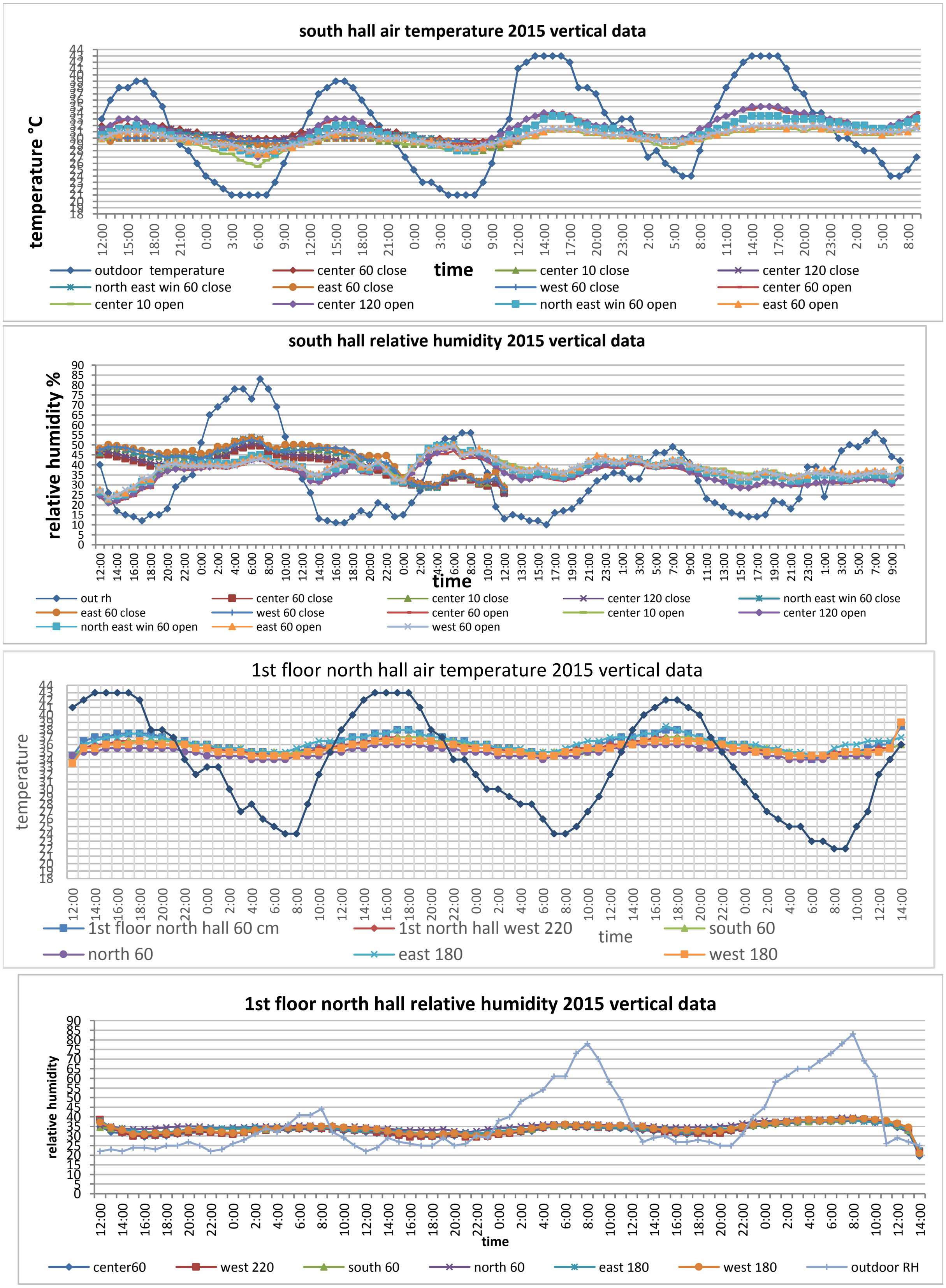
2015 exceptional year with high day temperature for this period night ventilation more effected than all day ventilation.
This result change with adaptive model and occupant thermal comfort correspond to the air flow and speed effective.
Relative vertical humidity data results reverse vertical air temperature data, the higher relative humidity near the floor that confirmed our predecessors habit.
Indoor Relative humidity influenced by outdoor climate that cleared at **Figure 3-16-a** when windows are closed the hall conserve humidity at the first day then start to lose it and the open windows case get higher relative humidity.

- First floor north hall (cross ventilation):

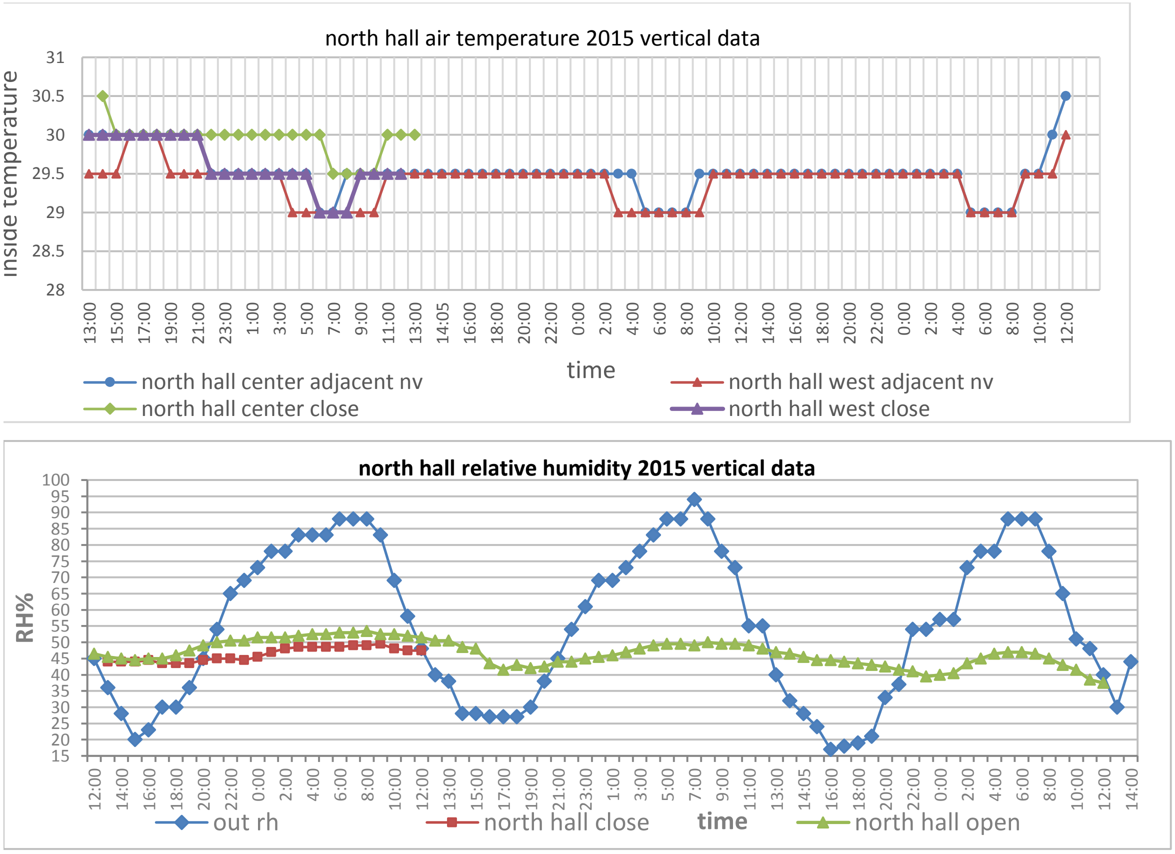
Vertical temperature investigation: **Figure 3-16–a** shows the temperature stratification the temperature at the lower level has lower value, except at the center of the hall.
The center temperature at 60 cm has the highest temperature equal at 180cm east part, that related to small heat gain temperature fluctuation at the partition walls (adjacent to other Room consonant) is semi-steady and lower than at the center also for north wall the lower solar gain, on other hand for south hall the temperature lower than center by high infiltration through windows and door allowed heat dissipation.
The highest temperature for the first floor related to thermal mass (light mass) and the important effect of natural ventilation and infiltration. In case no ventilation (close windows) the lower temperature achieve 34°C.
That demonstrate the old traditional immigration theory local season immigration live at ground floor in summer period and immigrate to first floor at winter period.
Relative humidity(comfort feeling) result proportion with temperature result in revers value the lower relative humidity value at the center of the hall **Figure 3-16-a** .

- North all (cross ventilation , adjacent opening):

Heavy mass and semi-underground (heat transfer between soil and envelope) give north hall Consonant thermal behavior at hot dry climate region by steady thermal transfer between soil (consonant temperature) and heavy mass, which explain the lower effect of natural ventilation in hot summer 2015th ,that related to steady temperature inside the hall closer to ground temperature **Figure 3-16-b** shows the semi-corresponded between no ventilation(close windows) case and ventilation all day (open windows) case[in different position] , the effect of natural ventilation limited on reduce temperature about half temperature and reduce high temperature period (by rapidly get rid of the hot air trapped in the room that entered during the daytime), The effect of natural ventilation more observation on relative humidity than air temperature, specially during night more than 5% increasing , this point gives night ventilation at very hot summer more comfort result to all day ventilation ,**Figure 3-16 -b** shows that result .



a air temperature ,relative humidity for south and 1st floor north hall summer 2015th.



,b. air temperature , relative humidity north hall summer 2015th.

Figure 3-17: . air temperature.

3.4.4 Summary summer 2015th.

- Natural ventilation for all day not effective at year's 2015 [as night ventilation]that during daytime the outdoor hot air entered the room, thus diurnal indoor air temperature followed that of the outdoors closely temperature.

-Moreover, indoor air temperature in close room maintained high value during the night as well This is not only due to the hot air trapped in the room, but also due to the heat stored in the building's structure that reradiated to the indoor spaces at night. In spite of hot month single side (stack) natural ventilation decrease temperature during night roughly 3 °C degree minimum.

-compares ventilation with no ventilation when the windows were closed all day (no ventilation), diurnal indoor air temperature was not increased largely because the outdoor air did not enter the room.

-for instance, argued that the daily air temperature range (swing day/night) about 10 °C degrees is required to obtain useful lowering of the indoor daytime air temperature by natural ventilation.

-2015th exceptional year with very hot summer, the influence of outside condition clearly through the increase inside temperature especially through light mass in 1st floor.

3.5 Summary of Measurement 2014th and 2015th natural ventilation.

Measured indoor air temperatures and corresponding to outdoor climatic conditions, that confirmed by the difference between measurements data for years 2015th and 2014th , the highest 2015th summer's reflected clearly on all measurements and results, though the rate of changing of indoor temperature related to outdoor temperature.

Thermal environment's characteristics

Air temperature and relative humidity:

- Courtyards:

The difference between similar courtyards temperatures depend on the outdoor ambient **Figure 3-17**present the effect of courtyard in reducing direct outdoor ambient impact on houses in addition to decrease swing between day / night and the air flow during the day specially at midday that reflected on the internal halls which keep their more comfort create more comfortable microclimate for occupant inside the house.

- South hall (single side stack ventilation):

The effective of natural ventilation for all day obviously at 2014th monitoring data and result present at **Figure 3-18**compare between 2014th ordinary climate and 2015th which has exceptional climate very hot summer season and cold winter .

Demonstrate the influence of outdoor climate on indoor thermal environment as shown on **Figure 3-19-a** for 2015th the indoor temperature is highly correlated to the corresponding outdoor temperature.

In this investigation concerned with using controls which do not involve using energy, when the building has free-monitoring.

The air temperature reflected on Relative humidity, **Figure 3-19, a** shown the effective years was 2014th for natural ventilation all day, which had the better value.

- The first floor north hall (cross ventilation):

Result corresponded to south hall result 2014th with normal climate, through wind and the effect of courtyard (microclimate) indoor comfort environment on surrounded halls.

The hottest summer for 2015th clearly at the high effect of high temperature and lower wind speed on light mass of 1st floor.

Figure 3-19,a shown the previous result through the relation and influence of outdoor climate to indoor thermal environment the different between two years about 3 °C degrees which highest for 2015th. The natural ventilation all day has clear influence which has reduced temperature about 4 °C .

Relative humidity result correlated to air temperature **Figure 3-19,a** present the comfort effect of natural ventilation at 2014th this result invers to 2015th .No ventilation (close windows) reduce the relative humidity so natural ventilation all day allowed humidity increase inside halls through the effect of airflow from outdoor to inside halls saturated with humidity.

- North hall(cross adjacent ventilation):

steady thermal behavior for north hall case and the similar as late result between no ventilation (close window) and with ventilation (open window) all day, specially at very hot summer 2015th, for 2014th the effect of natural ventilation more clearly at night about one degree but during day**Figure 3-19-b** present high temperature caused by twenty person stayed at the same time in north hall, other cases with normal number about two persons in hall. On other hand the reflection of outside temperature on north hall temperature, clearly through higher temperature of 2015th than 2014th.

On other hand, same effect on relative humidity **Figure 3-19-b** shows the impact of natural ventilation on RH and the effect of high person number inside the hall in increase RH.

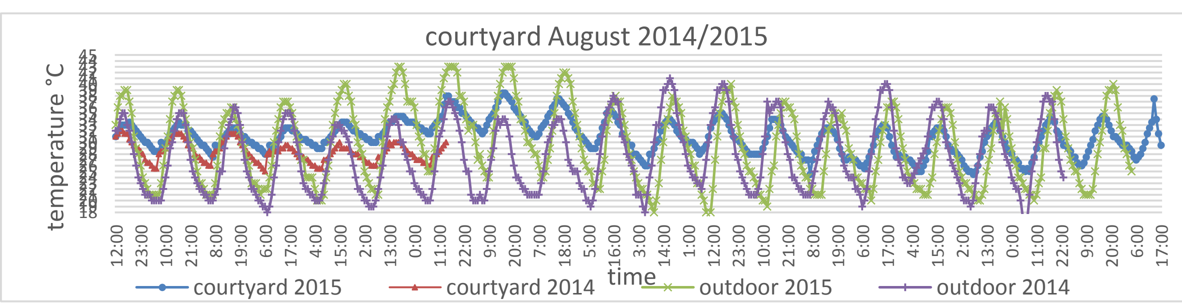
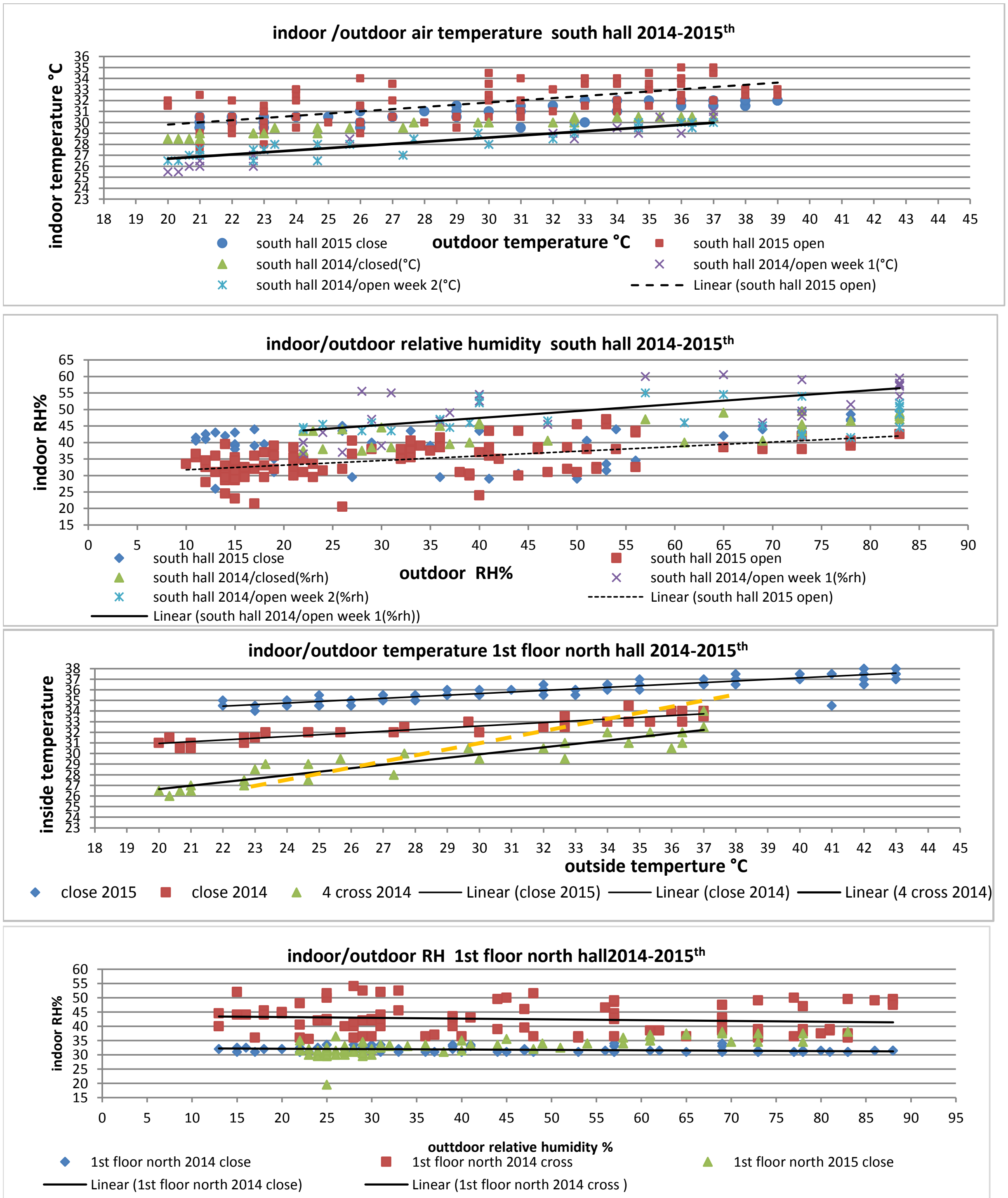
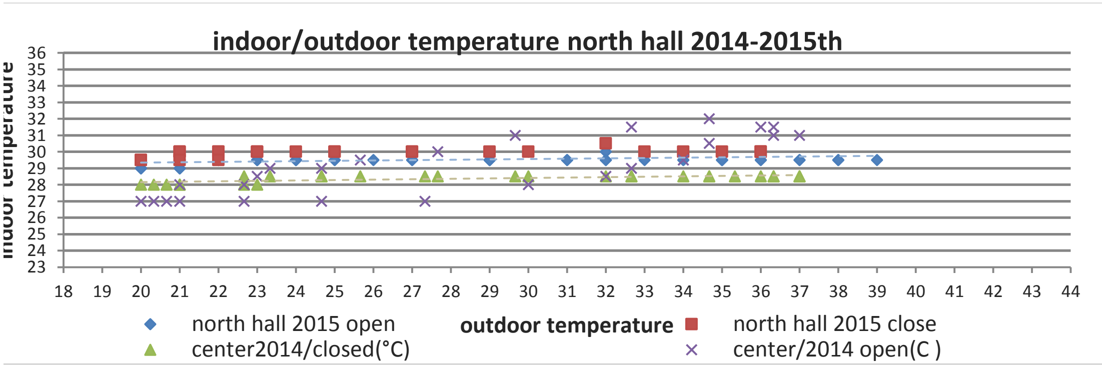
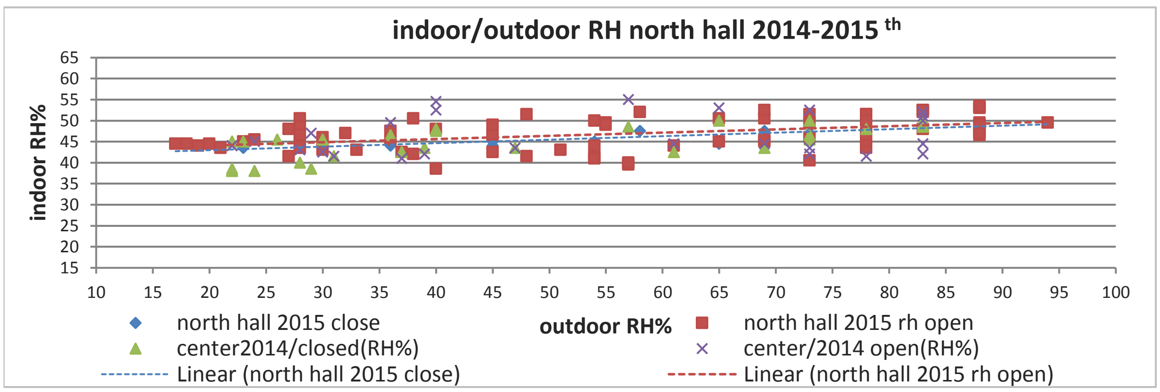


Figure 3-18: courtyard temperature 2014/2015th



a . air temperature, relative humidity 2014-2015th south hall, 1st floor north hall.





b. air temperature, relative humidity 2014-2015th north hall.

Figure 3-19: a,b. courtyard house halls air temperature /outdoor temperature.

3.5.1 Thermal comfort

- PMV scale and survey

- South hall:

Logical result correlated to air temperature and relative humidity also the air flow at surveys times, the PMV sensation survey result correlated with the previous parameters .
The different climate of 2014th and 2015th effected obviously on surveys and PMV scale calculation at (Fig18).
The survey average parallel with calculation average but with slope about 1 point scale.
Another important factor is fan air flow with 1m/s air speed at August 2015th get the same result of August 2014th(reduce the difference between air temperature value for the two years).

- 1st floor north hall:

2014th ,,2015th climate reflected survey result **Figure 3-20**shown the outdoor climate reflect on survey specially for hottest summer 2015th as south hall result.

- North hall:

Figure 3-20shows the PMV/sensation comfort survey result which correlated to previous results " attention to twenty person available period have difference results related to sex and edge " observe the air flow effect through fan gives more comfortable in spite of high temperature .

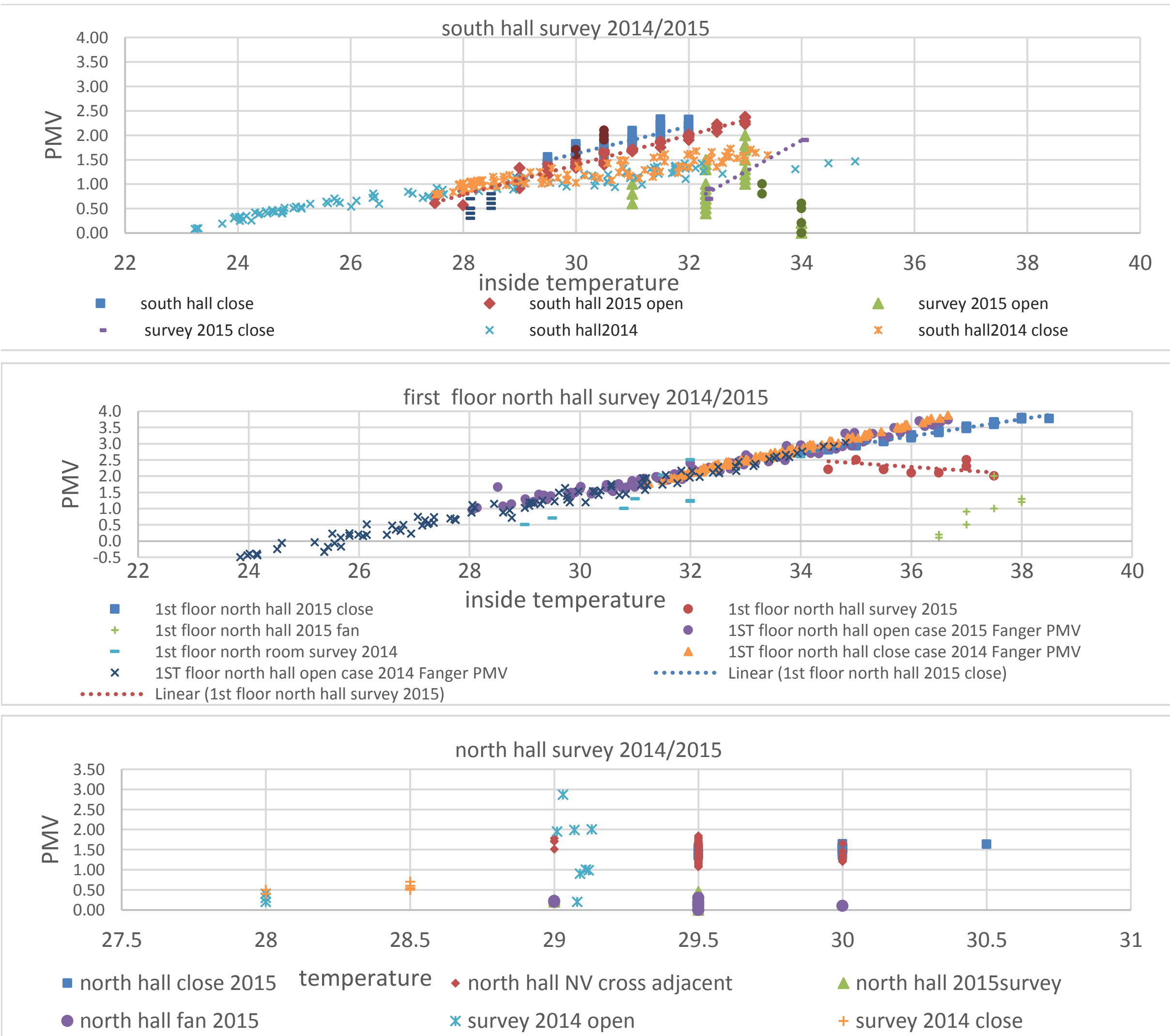


Figure 3-20: survey PMV scale 2014/2015th , south hall , 1st floor north hall and north hall.

➢ Adaptive Model

- South hall:

Adaptive model for short term demonstrate the difference between two years 2014th and 2015th also the natural ventilation case and no ventilation.

Adaptive model, ASHRAE Standard method over 0.3 to 0.6 m/s air velocity increase temperature T_o1.2°C.

Observation the wind showed more effective through day time than during night, that extend

acceptable range and comfort during day also for August 2015th **Figure 3-21-b**

2015th prevailing mean outdoor air temperature 29.6 °C higher than years 2014th about 2 °C degrees (27.25°C).

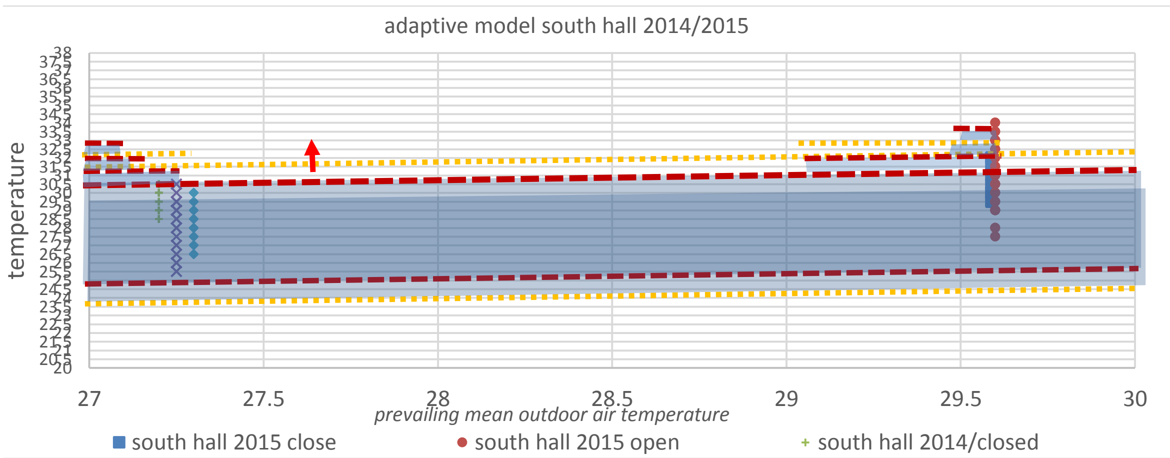
Upper 80% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +21.3=29.73
Upper 90% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +20.3=28.73
Lower 80% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +14.3=22.73
Lower 90% acceptability limit (°C) = 0.31 (prevailing mean outdoor air temperature) +15.3=23.73

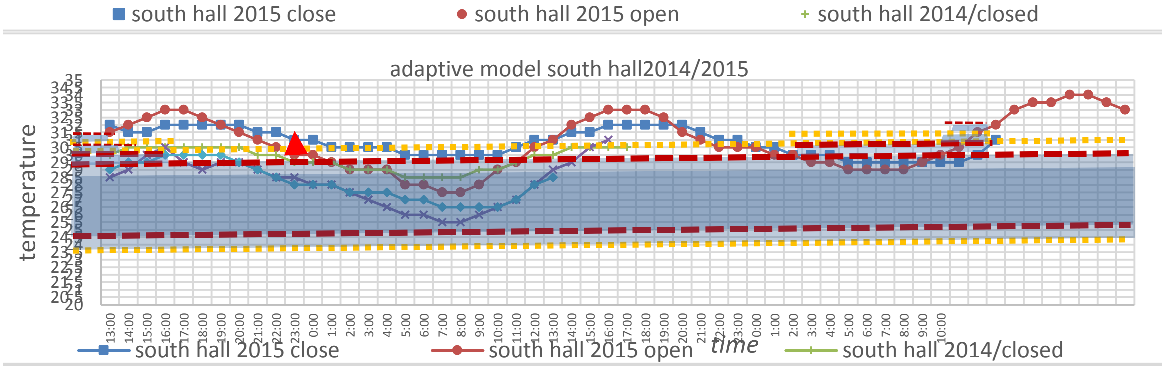
- The first floor north hall:

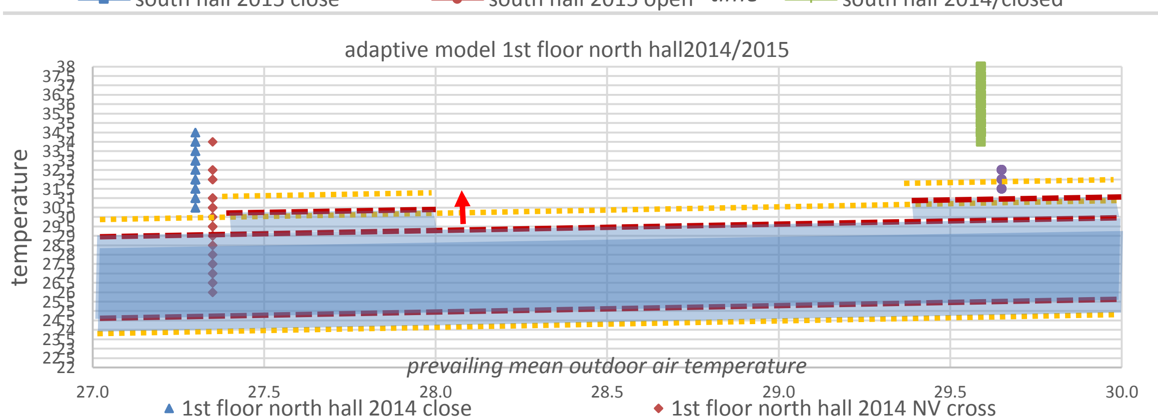
Figure 3-21presents adaptive comfort model the difference between two years about 4-5 °C degrees at no ventilation (close window)case , also natural ventilation for all day .on other hand the high effect of all day natural ventilation at 2014th at ordinary climate related to expand acceptable range over 0.3 to 0.6 m/s.

- North hall:

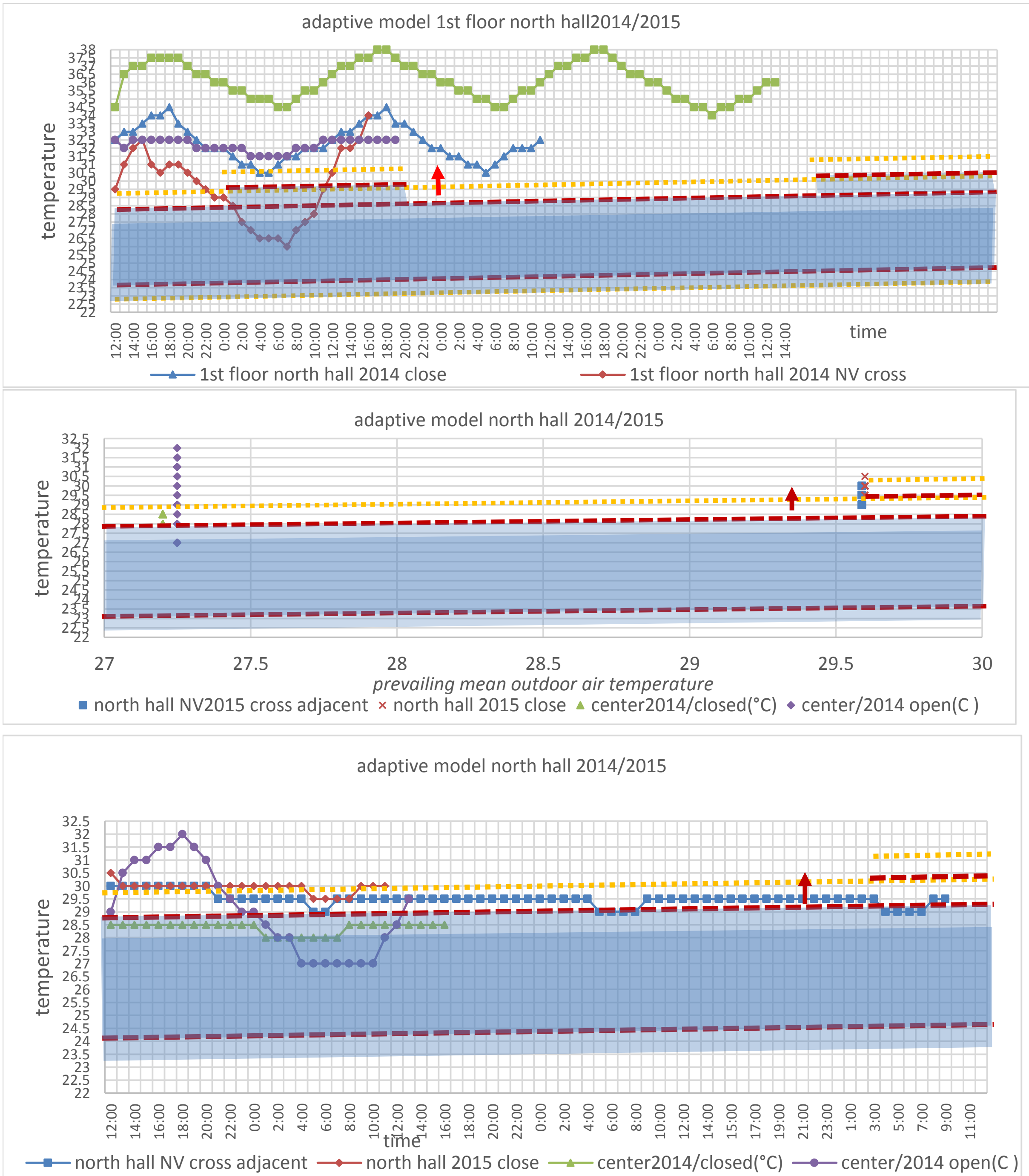
Adaptive model explain more previous comfortable cases. **Figure 3-21-b** shows 2014th more comfortable than 2015th.







a



b

Figure 3-21a,b: Adaptive model 2014/2015th, south hall, the first floor north hall and north hall.

There are many data from the experiments and the measurements but neither nor provides whole data for comparison of natural ventilation, because there are a lot of thermal influences, which effected on thermal comfort in addition to natural ventilation not collected.

CHAPTER 4

ENERGY MODELING AND CALIBRATION

4.1 Energy modeling

The second aim of the investigation is to create sophisticate building modeling simulation using Design Builder simulation program base calibrated with measurements and monitoring data .This model shows a good agreement between measurement and simulation.
The two procedures are merged in order to develop a method for evaluation of the thermal performance in residential building with natural ventilation ,by getting more parameters and factor it is possible to evaluate and to provide a simple model for integration strategies with residential building to reduce thermal loads.

4.1.1 Calibrated modeling simulation

The objective of this step is to develop an accurate methodology for the thermal simulation of courtyards that can be combined with building energy simulation software (E+,DB) calibration by comparing it with the measured data from a case study.
Calibrated simulations are energy simulations that are adjusted so that their simulated outputs match with monitored data obtained from the actual building. The purpose of calibrated simulations is to ensure that the thermal model can generate result close to the measured values.

Calibration Procedures
Three main types of calibrations were classified:
a) Calibrations based on manual, iterative and pragmatic intervention. This is the most common calibration approach to-date. It includes building data, use of onsite weather data, as-built drawings, and hourly monitored data for selected days, site visits and interviews.
b) Calibrations based on a suite of informative graphical comparative display: Along with manual, iterative and pragmatic approach to calibration described in the previous section.
c) Calibrations based on special tests and analytical procedures. These calibrations use controlled tests on lighting and HVAC systems for a few days (Blink-tests or on/off tests are used for snap-shots of end-use measurements of lighting, and motor control center electricity use.
During the entire building calibration, the nominal value for some parameters may change more than once. However, since the input file is adjusted by modifying its parameters on trial-and-error basis until the simulation output matched the measured data, this can reduce the credibility of the entire simulation.

4.1.1.1 *ASHRAE calibrate simulation (14-2002):*

There is still no broad consensus as to how to determine uncertainty or risk levels based on a calibrated simulation approach. Using utility bill data where the savings uncertainty can be estimated at the project proposal phase prior to implementation of the ECM (Energy Calibration Model). Though one does not have measured data at this stage, an analysis involving utility bill data along with the estimated savings fraction can provide an indication of what type of savings measurement approach to adopt later on.

In general one would like to select a modeling selection procedure that is simple to apply and produces consistent, repeatable results. Several procedures have been recommended to select the best regression model. In general these procedures calculate several regression models and select the best model depending on the goodness of fit as measured by the R2, coefficient of variation of the normalized annual consumption (i.e., CV(NAC)) or coefficient of variation of the root mean squared error (i.e., CV(RMSE).
-Models Based on Measured Indoor Temperature:
If thermostat set points change (e.g., weekend setback, seasonal set point changes, or other occupant/operator override) or the HVAC system does not maintain good temperature control, a change point model may not be adequate. If this is the case and energy use is strongly temperature dependent, it will be necessary to measure temperature (and possibly humidity as well) in the conditioned space(s). There may be other, more pressing reasons to monitor these conditions.

Statistical Indices and Calibration Accuracy:
While graphical methods are useful to assist in refining a simulation, the ultimate determination of acceptable calibration must use a statistical method. ASHRAE Guideline 14-2002 (ASHRAE, 2002) suggests for calibrated simulations the following two dimensionless indices to represent how well a mathematical model describes the variability in measured data:

- Mean Bias Error (MBE): is a dimensionless estimate of the bias of the prediction, which quantifies the percentage error of difference between the measured and simulated values summed over a period.
- Coefficient of Variation of the Root Mean Squared Error (CVRMSE)): is the square root of the average of the sum of the squared differences between the measured and simulated values, along with the coefficient of variation (CV) which is a dimensionless measure of the RMSE.

In general, the smaller these values are the better the prediction has performed. ASHRAE Guideline 14-2002 (ASHRAE, 2002) sets an uncertainty or tolerance limit for calibrated simulation as follows:
"The computer model shall have an MBE of 5% and a CVRMSE of 15% relative to monthly calibration data. If hourly calibration data are used, these requirements shall be 10% and 30%, respectively.". These tolerance values are based on the practical experience of the energy modelers who perform calibrated simulations.
Which defined as follows equations:

$$MBE = \frac{\sum_{i=1}^{N_s}(y_i - \hat{y}_i)}{\sum_{i=1}^{N_s} y_i} \times 100\%$$

$$\overline{Y_S} = \frac{\sum_{i=1}^{N_s} y_i}{N_s}$$

$$CVRMSE_{(S)} = \frac{\sqrt{\sum_{i=1}^{N_s}((y_i - \hat{y}_i)^2/N_s)}}{\overline{Y_S}} \times 100\%$$

Where, Y_i is the measured data; $\hat{Y}_1$ is the simulated data; Ns is the sample size; and $Y\overline{s}$ is the sample mean of measured data.
The calibration residual is defined as the difference between the modeled building performance and the measured one **Figure 4-1** presents ASHRAE calibration processing for simulation modeling. The MBE measures the mean of calibration residuals, showing how much a calibrated model over or under estimates building performance compared to the actual measurement. But MBE alone is not sufficient to measure the goodness of fit as a few overestimates and underestimates may cancel each other and result in a small MBE. The second statistic, CV (RMSE), is essentially the standard deviation of calibration residuals and shows how widely the variation of the residual is. Thus it is possible to have a perfect MBE and a less than desirable CV (RMSE) (Haberl and Bou-Saada 1998).

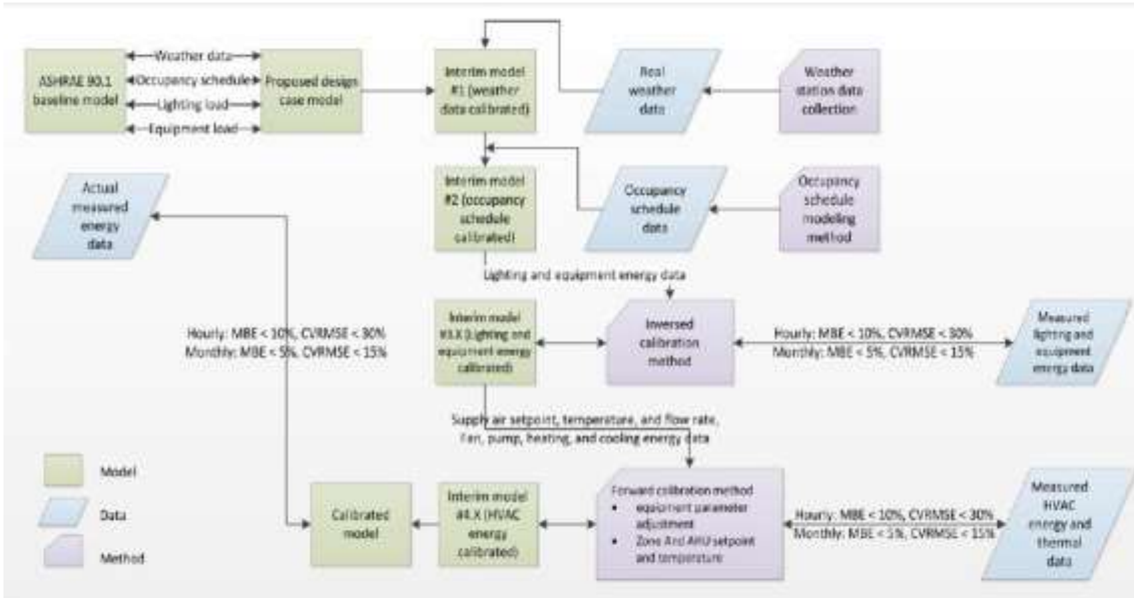


Figure 4-1: calibration ASHRAE processing for simulation modeling.

4.1.2 Modelling process

This step will monitor and analyze the thermal performance of a case study indigenous courtyard house in Damascus BAIT FAKHRY AL BAROUDI and traditional natural methods to achieving thermal comfort. An improved understanding on how this ancient building operate could point to effective methods that can be applied to modern houses.

This step seeks to introduce improvements to the current generation of building simulation software that will improve the modeling of the courtyard buildings to provide a more accurate assessment of their passive thermal performance.

Simulation with the DB runs includes a base case whose the calibration procedure is made with the ambient weather file detained from in T_o measurements. The weather data are collected with data from Damascus airport weather station, an ASHRAE International Weather for Energy Calculations (IWEC) weather file, and the case study rooftop records. An annual ambient weather file (EPW) was prepared based on IWEC data augmented with the case study rooftop temperature and humidity records as well as the Central Laboratory for Agricultural faculty weather station records during the monitored periods.

4.1.3 Measurements and Data Collection

4.1.3.1 *Damascus weather data:*

The ambient weather data collected for Damascus city during the summer of 2014th and winter 2015th were obtained from two sources:

a) The Central Laboratory for Agricultural faculty.

b) The Damascus International Airport.

The weather data obtained from the Central Laboratory for Agricultural faculty included: 1) dry-bulb temperature, 2) dew-point temperature, 3) Relative humidity. The weather data for Damascus International Airport were copied on daily basis from the National Weather Service NWS, National Oceanic and Atmospheric Administration (NOAA) website, published for each hour. These data included: 1) barometric pressure, 2) dry-bulb temperature, 3) dew-point temperature, 4) wind speed and direction.

4.1.3.2 *Microclimate measurements:*

Appendix C1 shows the placement of the sensors inside the courtyard house and sensors placed inside the halls.
The indoor air temperature, relative humidity was measured using OMEGA data-loggers.
The measurements included: 1) indoor air temperature and relative humidity inside the south main hall at the ground floor level, 2) indoor air temperature and relative humidity at the north main hall at the first floor level, 3) the air temperature and relative humidity at the heights 60cm. at the main courtyard besides with protection from direct radiation and rains Data-loggers were calibrated before being deployed at the site, and they were recalibrated after the measurements were completed.

4.1.4 Calibrated DB Model Simulations

The first step of the calibration is to replace the weather file (DOE 2013) with real weather information in accordance with the actual data collection period. The second step is to replace the design case occupancy schedules with the "real (or learned)" occupancy schedules generated from the data mining study.
This step is performed with Design Builder (DB) simulation program. The DB was chosen because of its ability to simulate the overall thermal performance of a building using specially prepared hourly weather files (EPW) that contained Damascus weather data during the monitoring periods for the case study courtyard house. The resulting simulated temperatures from the DB simulation for the "courtyard , south hall " at the ground floor were compared against monitored temperature data then calibrated to the measured data from the 21 days summer period, and the 21 days winter period. Then, The calibrated model was used to predict one year of hourly data for the courtyard using the energy plus weather file (EPW) to deduction the traditional natural ventilation process and its direct effect on thermal comfort . ASHRAE adaptive model is used for thermal comfort then CFD model is used to analyze airflow behavior .

4.1.4.1 *Thermal simulation:*

DB is an hourly thermal simulation program used to calculate multi-zone envelope, system, and plant heating and cooling loads and the global performance of building-plant system. This public-domain simulation program allows users to perform hourly building energy simulations for a one-year period using ASHRAE algorithms. The heat transfer by conduction and radiation through the walls, roofs, floors, windows, and doors are calculated separately using response factors.
Analyses of unconditioned zone:
DB was primarily designed to help building designers to perform annual calculations of energy consumed by various heating and cooling systems, mixed ventilation mode (mix between natural ventilation and cooling system HVAC). However, this step is concerned with the case study courtyard house that belongs to the set of heavy and light thermal mass buildings with no heating, ventilating system, or air-conditioning (HVAC) systems . Therefore, special procedures were used in modeling the case study courtyard house in DB

4.1.4.2 *Capability of Dynamic simulation software :*

Integrated, simultaneous solution: where the building response and the primary and secondary systems are tightly coupled (iteration performed when necessary)
Sub-hourly, user-definable time steps for the interaction between the thermal zones and the environment; variable time steps for interactions between the thermal zones simulation and measurements (automatically varied to ensure solution stability)
ASCII text based weather, input, and output files that include hourly or sub-hourly environmental conditions, and standard and user definable reports, respectively
Heat balance based solution technique for building thermal loads that allows for simultaneous calculation of radiant and convective effects at both in the interior and exterior surface during each time step (Appendix D1)

Transient heat conduction through building elements such as walls, roofs, floors, etc. using conduction transfer functions, • Time-dependent conduction – conduction through building surfaces calculated with conduction transfer functions – heat storage and time lags – finite difference, with variable properties to model phase-change materials(Appendix D1)
Thermal comfort models based on activity, inside dry bulb, humidity, etc.(ASHRAE)
Anisotropic sky model for improved calculation of diffuse solar on tilted surfaces
Advanced fenestration calculations including controllable window blinds, electro chromic glazing's, layer-by-layer heat balances that allow proper assignment of solar energy absorbed by window panes, and a performance library for numerous commercially available windows
Daylighting controls including interior illuminance calculations, glare simulation and control, luminaire controls, and the effect of reduced artificial lighting on heating and cooling.

4.2 Modeling Courtyard

Following are descripted different steps of modeling :

- Openings of the Case Study House and Their Modeling in DB.

The house is composed mainly of four wings around a main square courtyard. One of four wings include main big hall. The other includes the entry vestibule, terrace, rooms …etc. The smaller courtyard is located at the perimeter of the house. The largest window/wall ratios in the case study house are onto the main courtyard, which is the main outdoor space. The window/wall ratio for the south facing wing is 41 %(main south hall 37%), and for the north facing wing is 20 %(main north 1st floor hall about 50%).
The following is a summary of the simulation modeling concepts for the type of openings of the case study house:
- External Windows having an external wooden decoration with a single glass pane.
- Courtyard windows for big halls having an external wooden decoration with a single glass pane.
- Other openings: wooden doors (solid wood), wooden windows (solid wood), and windows of fixed glass panes with wooden frames.

- Structure modeling in DB:

Traditional house structure contain two kinds of thermal mass:
- Ground floor with heavy thermal mass consist of:

Façade courtyard from lime stone as structure core and basalt stone for cladding or lime wash with about 50cm total wall thickness.
Grilled mud block with lime mortar about 60cm thickness.
- First floor with light thermal mass consist of :

Timber structure filled with mud block:
- Single structure as partition.

Double structure for external wall.
To calculate U value for these kind of wall utilized THERM program(basalt wall U 2W/m^2.k).
Slab and roof consist of timber structure consist of two beams net over each other in opposite direction.
To calculate U value for these kind of slab utilized THERM program (U 0.113 W/m^2.k).

- Processing a DB Weather File Using the Damascus Weather Data

DB has same weather data file as Energy Plus ,the last has developed a generalized weather data format for use with two major simulation programs—ESP-r and EnergyPlus (Crawley et al. 1999). All the data are in SI units.

- Occupancy schedule data mining

The occupancy schedules are derived to equipment and occupancy schedule, the halls chosen haven't any kind of equipment but for lighting the schedule was decreased because of the situation and irregular electricity.
There are two possibilities to model courtyard by using DB simulation program:

- **Outside zone condition :**DB program designed special tools to create external spaces within building block perimeters as model courtyard 'Draw void perimeter' tools , in this case DB define courtyard as external space that means outside condition and data weather which is fare away from reality as microclimate

On other hand model courtyard as void not allowed studying courtyard and analyze thermal behavior within courtyard.

- **Inside zone** :model courtyard as zone with open roof as follow possibility :

1- Zone with big whole equal size of roof at it.
2- Zone with roof open windows.

4.2.1 Model Courtyard as outside zone condition:

Problem points at this model:

1- Simulation doesn't allow to study courtyard (outside zone) thermal behavior and its effect on surrounded halls through natural ventilation and reduce environment impact.
2- Traditional house halls have different height and to create void means surround zones have same height that obligated to study each hall separated.
3- The real microclimate of courtyard is not the same as outside climate, avoid tools consider courtyard condition as outside condition.

4.2.1.1 *Characteristics of the case study*

The dynamic simulation made it for traditional Damascus old house BAIT FAKHRY AL BAROUDI for main south hall has 63m^2 area and 7.9 m height the courtyard façade (south) has two levels of window the first on 6 windows at 60 cm high and 2.5 m^2 area the second level also has 7 windows at 340 cm high and 2.6m^2 for each window .**Figure 4-2** shows the placement of monitoring sensors and section

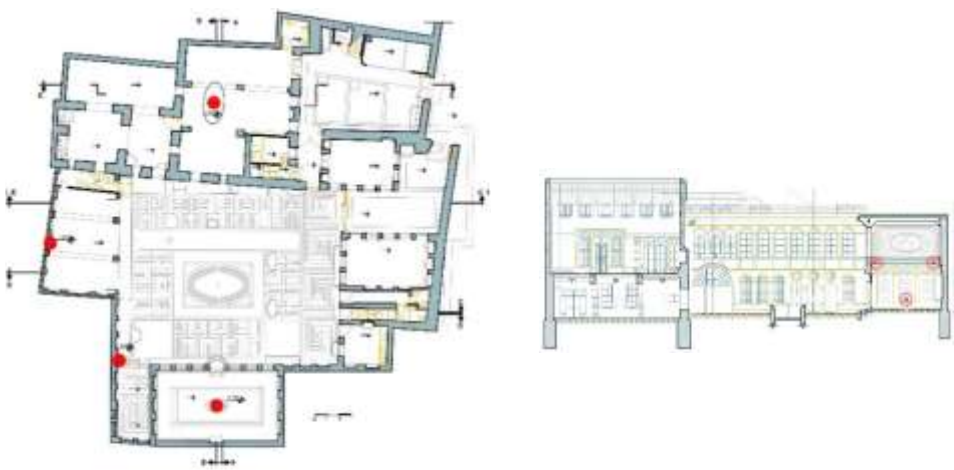


Figure 4-2: FAKHRY monitoring instruments position .plan, section.

Structure:
Wall structure mixed of three kinds of timber structure upper level (consist of wood net fixed, for these kind U value calculated by THERM program), basalt and grilled mud down level Appendix D2
Also roof consist of timber structure (consist of two beam wood nets fixed opposite each other, for these kinds U value calculated by THERM program).
Windows model is as the traditional house single about 6mm thickness in the first level the second level consist of double separate layers of windows .The distance between two windows 20 cm with same kind of glass
Calculate natural ventilation without heating or cooling.
Low infiltration as traditional houses case.
Time period: summer July third and fourth week; from 14 th of July.

Time set up 4.
Weather data:

Step 1: EPW file the data recorded from the Central Laboratory for Agricultural faculty weather station.
Step 2: EPW file the data recorded from courtyard.

4.2.1.2 *Case : main south hall*

Location template:
Damascus location, site display as sheltered exposed to wind to create ambient as city climate.
Occupancy schedule:
Schedule made as the occupant survey for Bait Fakhry occupant.
Equipment heat resource: there are no kind of these equipments at this hall so there are not any kind of energy resource except occupancy and structure load.
Program setup:
Natural ventilation setup for calculation, no cooling and heating system.
Calculations:
The ventilation rate (q) through each opening and crack in the model is calculated based on the pressure difference using wind and stack pressure effects:

$$q = C.(DP)^{n}$$

Where:
q Is the volumetric flow through the opening.
DP is the pressure difference across the opening/crack.
n is the flow exponent varying between 0.5 for fully turbulent flow and 1.0 for fully laminar flow.
C is the flow coefficient, related to the size of the opening/crack.
Wind-Driven Ventilation
When wind impinges on the surface of a rectangular building, a positive pressure is induced on the upwind face. The flow separates at the corners resulting in negative pressure regions on the side of the building and a negative pressure distribution on the leeward facade. The pressure distribution on the roof varies according to pitch - the pressure on the windward [upwind] face being negative for roof pitches of 30° and positive for steeper pitches.
The pressure on any point on the surface of a building facade can be represented by:

$$P_w = 0.5 .rho. C_p . v_z^2$$

Where:
P_w is the surface pressure due to wind,
rho is the density of air,
C_p is the wind pressure coefficient at a given position on the surface and
v_z is the mean wind velocity at height z.
The wind pressure coefficient, C_p, is a function of wind direction, position on the building surface and side exposure, which defined the building process exposure to wind.
Simulation argument:
Depend on the last problem point of outside zone condition for the courtyard as a void, the condition apply at courtyard is outside condition which is not realty for that reason simulation divided to two steps:
First one apply EPW weather data as the near climate station.
Second apply EPW as the data collected from the real courtyard in this step the program recognize courtyard condition as the realty, but the weak point of this step is the outside ambient effect (outside condition) will be changing to microclimate (Partial Climate) as inside condition specially for heat transfer, this step suggested within the old city Characteristic as a compact fabric so adiabatic surround heat transfer.

1- Calibration of the DB Simulation Models:
The hourly indoor measured temperatures for the south main hall in the ground floor during the monitoring periods of two weeks in July, 2014, and two weeks in December, 2014 - January, 2015 were used as an indicator of how well the base case DB simulation model represented the real building.

Similarly, the measured hourly courtyard microclimate temperatures at two heights (60cm. and 240cm.)

Once the simulated temperatures matched the measured data in a satisfied way, the DB simulation model was then declared calibrated.

The calibration process began by first running DB simulation for the case study courtyard house using the Damascus weather file The Central Laboratory for Agricultural faculty including the ambient weather data during the monitoring periods of two weeks in August third and fourth week(one closed windows , second open windows)plus two weeks in December, 2014. This was considered to be the base case. Then an annual courtyard microclimate weather file was obtained from the measurements data.

The calibration to investigate the summer period results of simulation at natural ventilation process during the second week of July 2015.

2- Result :

- **First step: summer period:**

1- Simulation with weather station data.

Temperature calibration :

Close case: Figure 4-3 presents result regarding to simulate courtyard climate as outside weather data for third and fourth week of July summer period from 14^{th} of July 2014^{th} , for these period the data collection for closed case(all windows close), for these kind of building the infiltration and crack templet set at lower scale.

Figure 4-3shows the different between measurements data and simulation result which difference has about 4 °C degrees during days for the same period.

Also present the difference between day and night (swing) inside hall about 2°C degrees at measurements data and simulation data.

The two ASHRAE indicators out of the acceptable range for hourly calibration data.

Open case (natural ventilation): For the fourth week case of open hall windows **Figure 4-3**shows decrease in measurements temperature especially at night and early morning time also simulation result temperature trend parallel with measurements with lower temperature about 3°C degrees ,corresponding with latest result .

The two ASHRAE indicators MBE out of the acceptable range for hourly calibration data but CVRMSE was accepted.

Relative humidity calibration:

Close case: Relative humidity calibration: **Figure 4-3**shows relative humidity regarding to simulate courtyard climate as outside weather data for third week of July summer period from 14th of July ,in this diagram the simulation result has upper value about 10% than measurements data , from observation these difference decrease to 1% afternoon. The different between day and night (swing) about 10% in both result.

ASHRAE indicator MBE out of range but CVRMSE has accepted.

Open case (natural ventilation):the fourth week of July **Figure 4-4** presents the period of opening windows, shows increase at RH about 5 % especially in early morning as effect of opening windows(natural ventilation) for measurements result same observed for simulation result with upper value about 15% as latest result .Same result for ASHRAE indicator .

2- Simulation with courtyard microclimate weather data:

Temperature calibration:

Close case: Figure 4-4present result regarding to simulate courtyard microclimate weather for third week of July summer period from 14th of July.

This Diagram present different simulation result data gives steady temperature during day as the average of measurement data which is far away from reality case and influence on occupant (thermal comfort, heat transfer).

For ASHRAE indicator MBE and CVRMSE accepted as value without influence.

Open case (natural ventilation): the fourth week case of open hall windows **Figure 4-4** observed the corresponded with measurement temperature at early morning, but as latest result for close case the

diagram similar to steady state the different between day and night(swing) less than one °C degree which is in realty the minimum difference about five °C degrees .
In This case the simulation result lower than measurements about 2 °C degrees.
For ASHRAE incident MBE and CVRMSE accepted as number error of calibration.
Relative humidity calibration:
Close case: Figure 4-4shows relative humidity regarding to simulate courtyard microclimate weather for third week of July summer period from 14th of July ,in this diagram the simulation result increase upper than measurements value about 10%,
ASHRAE indicator MBE out of range but CVRMSE has accepted.
Open case (natural ventilation): Figure 4-4present unsteady case and unexpected result anarchism that correlated to measurement RH which is reflection of opening windows especially at night, in addition to that result was far from realty state.
For ASHRAE indicator MBE out of range but CVRMSE accepted.

- **Second step: winter period:**

1- Simulation with the weather station data..

Temperature calibration:
Figure 4-5shows winter period observed more corresponded result between measurement temperature and simulation temperature results value.
For ASHRAE indicator MBE and CVRMSE are in accepted range.
Relative humidity calibration:
Figure 4-5present relative humidity regarding to simulate courtyard climate as outside weather data.
Winter case reverse to summer period, for winter period the measurement data higher than simulation relative humidity result about 5 % .This result caused depend on infiltration and cracks.
For ASHRAE indicator MBE has out of range but CVRMSE are in accepted range.

2- Simulation with courtyard microclimate weather data:

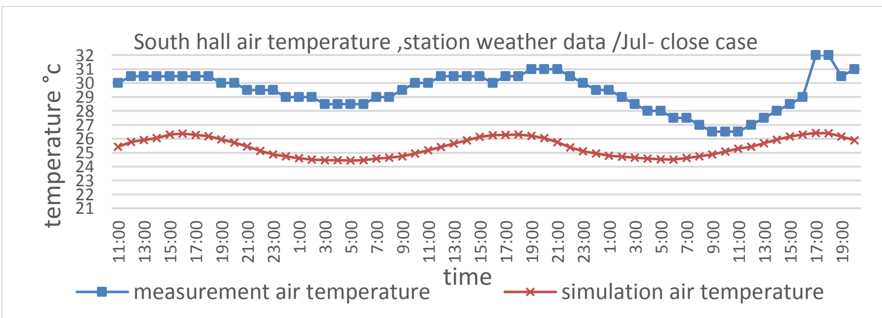
Temperature calibration:
Figure 4-5present result regarding to simulate courtyard microclimate weather for December, this case reverse to summer period which was steady and lower measurement data, in winter period the simulation result temperature was higher than measurement data about one °C degree, this result correlated to applied courtyard microclimate as weather data, these case neglect the real effect of wind and other environment effective.
For ASHRAE indicator MBE has out of range but CVRMSE has in accepted range.
Relative humidity calibration:
Figure 4-5present relative humidity regarding to simulate courtyard microclimate weather for December.
Winter case reverse to summer period, for winter period the measurement data higher than simulation relative humidity result about 5 %.
This result similar to latest result for simulate courtyard climate as outside weather data
For ASHRAE indicator MBE has out of range but CVRMSE has in accepted range.

- **Summary:**

- Previous results give reverse indicators, for summer period Simulation with weather station data was not accepted at ASHRAE indicator, but as thermal behavior it was closer to measurement data in two cases the opening windows and closed windows for both temperature and relative humidity.
- For winter period Simulation with weather station data was corresponded with measurement data for temperature but for relative humidity was different about 5% but as latest same behavior, so for ASHRAE indicator was accepted for temperature but for relative humidity MBE not accepted but CVRMSE accepted.
- On other hand, summer period of Simulation with courtyard microclimate weather data was accepted at ASHRAE indicator, but as thermal behavior it was stable which reflected to applied microclimate

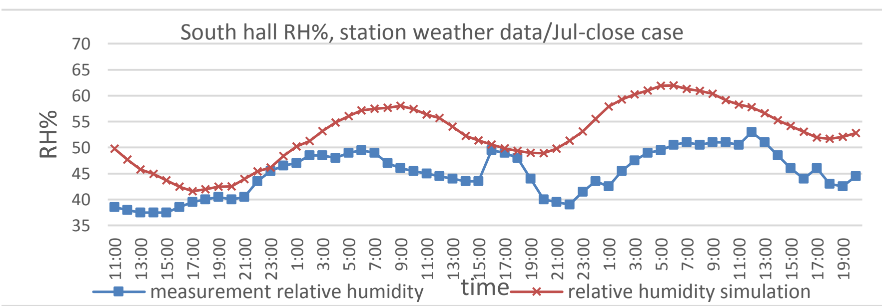
with no high gap between day and night (reducing at environmental influences), that given different data for occupant comfort and other data which reflected on ASHRAE indicator .

- For winter period, got high temperature as expected result but for relative humidity was reverse.
- The different in accepted range at ASHRAE indicator for relative humidity this related to instrument measure accuracy (5%).
- previously , simulate courtyard as void in DB simulation program has not been effective .on other hand using weather station data for courtyard it could be useful to give some indicators for temperature specially for winter period also for summer ,but those cases solution not the good and accurate solution .
- Also when make simulation during open windows(natural ventilation) period at the fourth week of July, the airflow behavior inconsequent for second case too low and the effect of natural ventilation closer to zero **Figure 4-6** airflow in hall through windows ACH calibration.



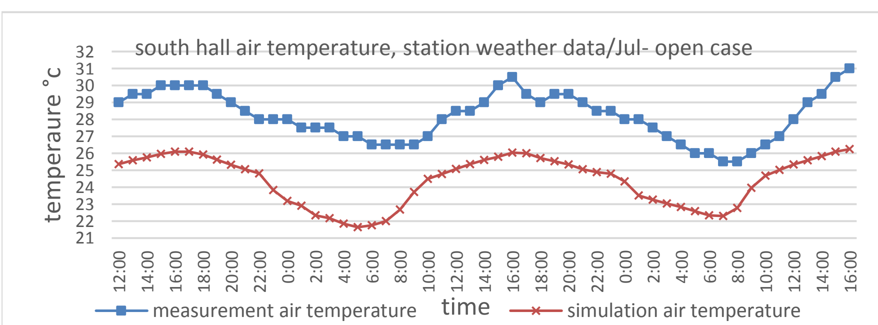
MBE = 14%

CVRMSE=41.9%



MBE = 17%

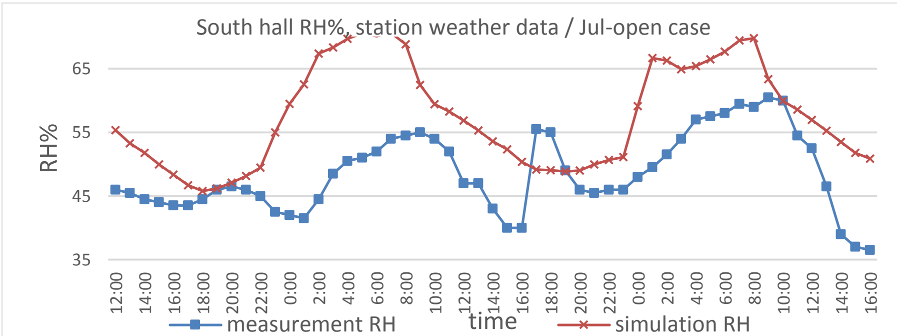
CVRMSE=18.7%



MBE = 13.4%

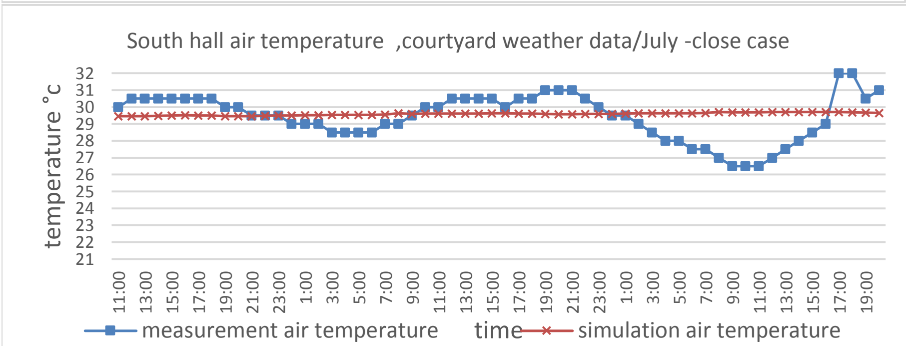
CVRMSE=12.9%

Figure 4-3: south hall .weather station data /July-Air temperature ,relative humidity /close and open case .



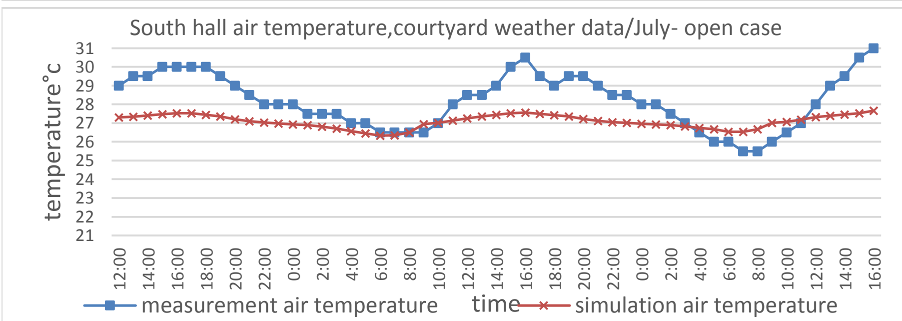
MBE = 18.2%

CVRMSE=22.4%



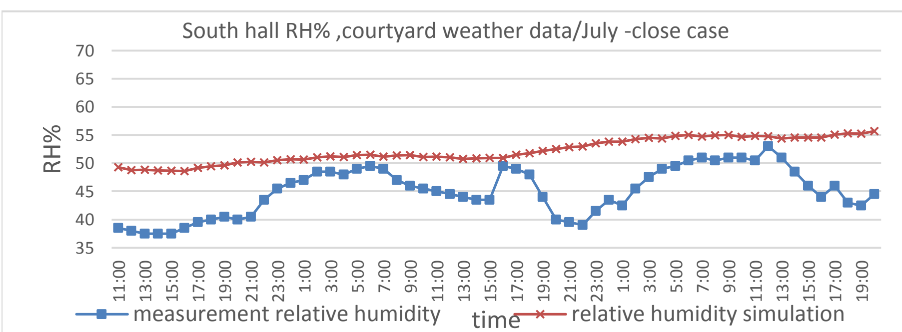
MBE = 0.5%

CVRMSE=4.6%



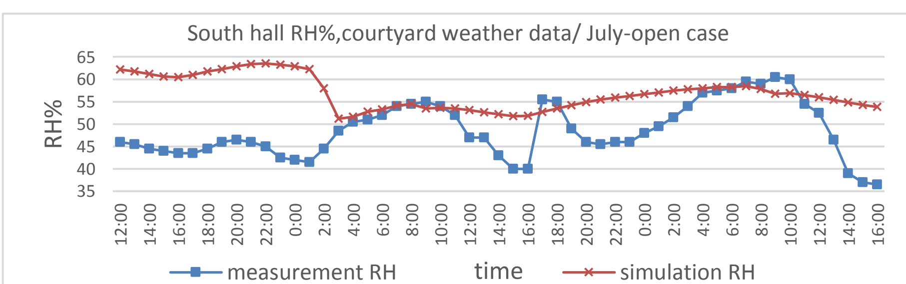
MBE = 3.9%

CVRMSE=5.5%



MBE = 15.8%

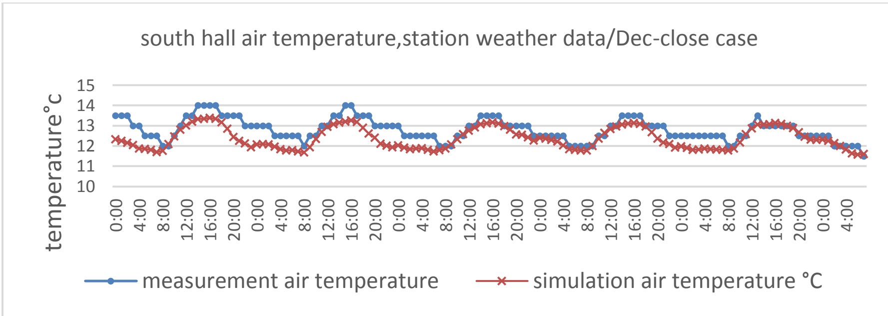
CVRMSE=17.4%



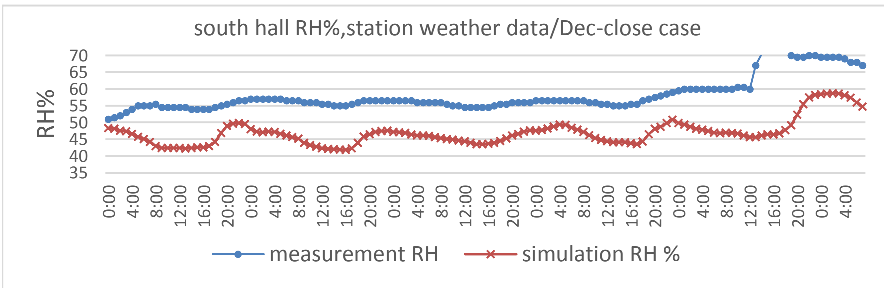
MBE = 16.9%

CVRMSE=22.7%

Figure 4-4: south hall .courtyard weather data /July(station)/-Air temperature ,relative humidity /close and open case.

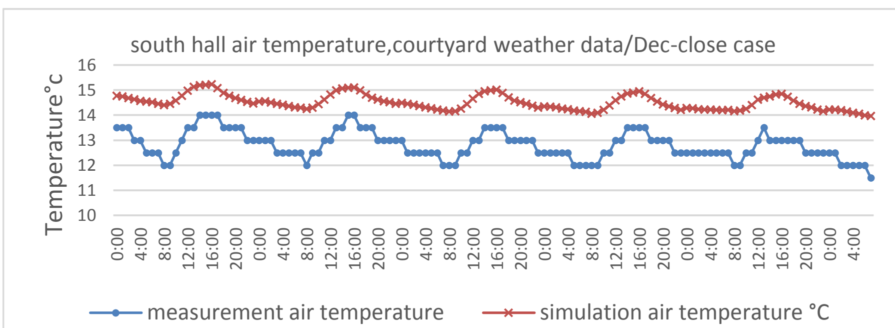


MBE = 3.35%
CVRMSE=4%



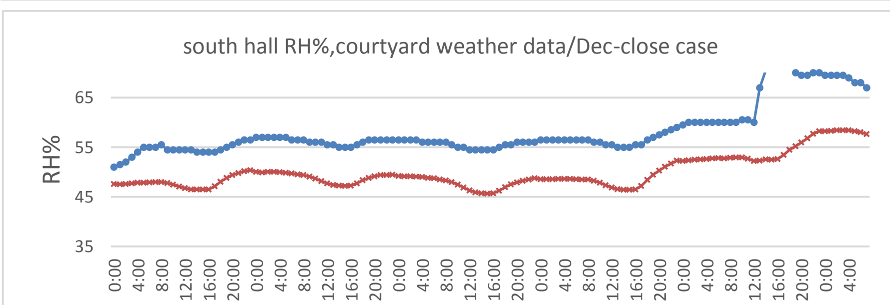
MBE = 19.2%

CVRMSE=20.0%



MBE = 13.2%

CVRMSE=13.3%



MBE = 14.2%

CVRMSE=14.8%

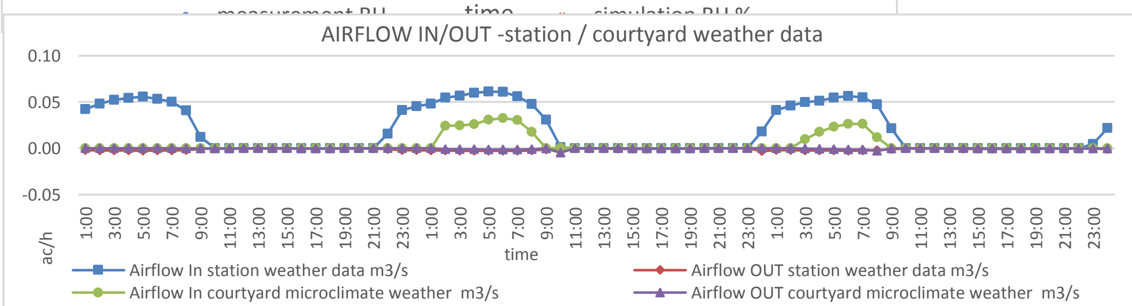


Figure 4-5: south hall .station/courtyard weather data /December- Air temperature ,relative humidity /close case/ airflow in/out windows south hall for open windows period.

4.2.2 Model Courtyard as inside zone :

1- Zone with big hole equal size of roof at it .
2- Zone with an open windows roof.

4.2.2.1 *Characteristics of the case study:*

This case studied four hall

- South main hall.
- Courtyard.
- North hall.
- 1st floor north hall.

Structure:

- **North hall:** located at the north part of BAIT FAKHRY. It is semi-ground floor, it is about 85m^2 area and 3.5m height, north hall has two façades; Ist represents the south façade open on the main courtyard, IInd east façade open to the small courtyard.
- Opening area at south façade 3m^2 and 9.1m2 at east façade.
- Walls: has the same structure for south hall basalt wall 53cm thickness, consists of basalt stone and lime stone as inside layer and lime mortar beside lime plaster as cladding.
- Floor :Appendix D2 define the floor layer same as courtyard floor consist of slab lime stone and cement mortar ,cast concrete and gravel(U1.435 W/m2.k).
- Ceiling: slab of 1st floor north Hall: Appendix D2 shows the layers consist of: timber slab and Cilicia board wood , of two beam wood net fixed opposite each other (double) as south hall
- **1st floor north hall:** located at the north part,this hall has pitched roof but under roof unoccupied only as attic , the hall area 50.3m^2 and 6m height under the attic , this hall has special Characteristic has south façade open to courtyard and part of the north façade to neighborhood and hall room over 4.5 m height has surrounded windows at every façade , the opening area 8m^2 at the south façade also for north and 10.8m^2 for each other façade east and west .

Wall: exterior walls: first floor wall structure is timber structure, double wood net, full with mud (U value calculated by using THERM program 0.586 W/m^2.k) Appendix D2.
Internal walls: timber structure consist of wood net full with mud single net (U 0.13W/m^2.k).
Roof (pitched): under pitched roof unoccupied space ,pitched roof consist of clay tile fixed on poplar wood net and insulation .The core timber roof structure two beam wood net fixed opposite each other (core structure U value calculate by THERM program)(U 0.2 W/m^2.k) for total pitched roof calculate by DB.
Under pitched roof: consist of Cilicia board wood cover with lime plaster.
For all other 1st floor room walls have the same previous structure, for roof consist of core timber roof structure and betwmeen insulation , concrete , upper insulation .
Slab same as roof structure but without insulation and the upper layer mad of concrete slab or marble (U 0.15 W/m^2.k).

Windows model:
As the traditional house single glass about 6mm thickness in the first levels the second level consist of double separate layers of windows, the distance between two windows in 20 cm with the same kind of glass .
Calculate natural ventilation without heating or cooling.

Time period:
Summer July third week and fourth from 14th of July .
Time set up 4.

Weather data:

Step 1: EPW file, the data recorded from the Central Laboratory for Agricultural faculty weather station.
Step 2: EPW file, the data recorded from courtyard.

Location template:

Damascus location has a site display as sheltered exposed to wind to create ambient city climate.

Occupancy schedule:

Schedule made as the occupant survey for Bait Fakhry Al Barodi.

Equipment heat resource: there are no kind of these equipment at this hall so there are not any kind of energy resource except occupancy and structure load.

Program setup:

Infiltration and stock model lower.

Simulation argument

This case modeled courtyard as zone and calibrated to reach the aim of investigation to analyze courtyard behavior and its microclimate effect on surrounded halls within types of natural ventilation (cross ventilation, single side stock ventilation) by thermal simulation.

4.2.2.2 *Calibration steps:*

First calibration: for courtyard as follows:

Modeled courtyard as closed zone has defined the roof opening DB allowed to open the roof zone by two ways **Figure 4-6**.

- First way is making a hole in all roof area: Holes are modeled using perfectly an airflow path. When the external walls holes positioned on only generate airflow in simulation calculations when the Natural ventilation building model option is set to be calculated (the hole energy plus doesn't allow the surface to be defined with hole surface to use a single set of vertical DB to generate two or more valid sub-polygons to represent the surface in energy plus)

- Second way; using glass roof perfectly clear glass plus with opening schedule: all round the time.

Defined Exposure to wind in location as normal (as suburb in energy plus) or sheltered (as city energy plus): The exposure to wind model data affects the pressure coefficients used when the 'Calculated' Natural ventilation option is set. It also affects the calculation of U-values but these are not used in Energy Plus simulations.

Apply Simulation with: EPW weather station data, EPW courtyard microclimate weather data.

This calibration simulations has three steps: 1- Roof zone modeling 2- Ambient position modeling/ defined exposure to wind.

- Third Applying the Weather data applied EPW (station, microclimate).

Second calibration: halls calibration (natural ventilation effect):

Wind factor: natural ventilation calibration. To exclude wind-driven airflow from the analysis altogether set.

The Wind factor to 0. For full treatment of wind effects set it to 1 and for intermediate treatment of wind set to a number between 0 and 1.

- **Calibration of the DB Simulation Models:**

The hourly measured indoor temperatures for each of south main hall, courtyard, north hall, 1st floor north hall in the ground floor during the monitoring periods of two weeks in July, and one week in August 2014th, and two weeks in December, 2014 - January, 2015 were used as an indicator of how well the base case DB simulation model represented the real building. Similarly, the hourly measured courtyard microclimate temperatures.

Once the simulated temperatures matched the measured data in a satisfactory way, the DB simulation model was then declared calibrated.

4.2.2.3 *Modeling steps results:*

1- First calibrated Modeling simulations: courtyard as closed zone.

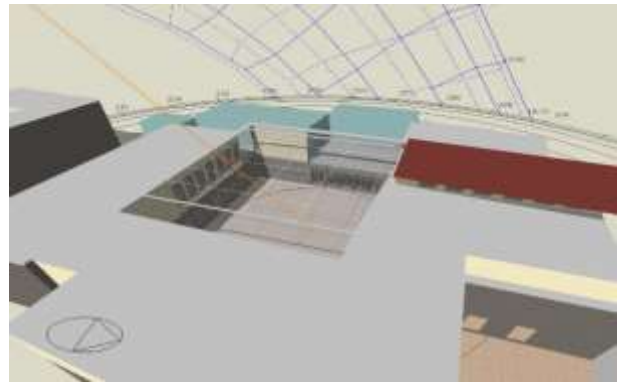



Figure 4-6: . Courtyard with hole in roof , Courtyard with glass roof.

- Courtyard roof modeling:

1- Summer period: wind factor (0.15)

Air temperature:
In this investigation many changes done at many factors to get the better result and to deduce best model, roughly two models have equal result but courtyard with hole roof has little difference in radiation effect , that depends on DB simulation program and hole define which give little higher direct radiation effect than courtyard with glass roof .

Figure 4-7present different air temperature and calibration percentage depend on ASHRAE indicator for hours , result present the two models has accepted value for courtyard hole roof MBE 3.1% , CVRMSE 17.2%.

For courtyard with glass roof roughly equal MBE 2%, CVRMSE 17.1%.

About half °C degree different between two models and about (3 – 5) °C degrees difference between models and courtyard measurement.

Relative humidity:

Figure 4-7shows the high difference between models and courtyard relative humidity measurements from 15 to 20 % day and night that also related to data logger sensor accuracy .

On other hand the model simulation result as equal about 2% difference only .

ASHRAE hourly calibration for courtyard with hole roof MBE 1.9%, CVRMSE 36.1%.

For courtyard with glass roof roughly equal MBE 0.5%, CVRMSE 35.6%.

This result get perfect MBE but underestimate CVRMSE that means the calibration has doubt.

Simulation runs to define the difference between two models to deduction the better one , radiation simulation **Figure 4-7**the result that equal with difference about (0.5 to 1) °C degree which make courtyard hole roof closer to measurements collected manual at specific time . The other parameters has equal results as air flow change per hour. Previous result for summer period for one week.

2- Winter period :

Air temperature:
For this period the result shows reverse value.

Figure 4-7presents the different between two models air temperature which about less than half °C degree. on other hand the high different between models simulations and courtyard measurements special at early morning time about 6 °C degrees , this result reflected on ASHRAE calibration values :
For courtyard with hole roof MBE 13.4 % , CVRMSE 29.7 %.
For courtyard with glass roof MBE 11 % , CVRMSE 28 %.
Those cases reverse values for relative humidity at summer period, the mean bias error out of accept average, on other hand CVRMSE still in range
Relative humidity:
Figure 4-7relative humidity of the winter period get better result than summer period in measurements and ASHRAE calibration value.
All results of the two models were similar and have equal results. The difference was less than one degree and less than 10% between the models(swing) result and courtyard relative humidity measurements .ASHRAE calibration value were all in average for courtyard with hole roof MBE 1.5 %, CVRMSE 12%. For courtyard with glass roof MBE 3.2 %, CVRMSE 11.9 %.
Conclusion:
Previously result indicate two models have similar performance, for ASHRAE calibration summer period more acceptable than winter period especially for air temperature modeling value. On other hand the relative humidity for summer period was more acceptable (depend on the lower accuracy of data logger (5%).
For radiation performance was the courtyard with hole roof closer to reality.

- Defined Exposure to wind in location normal and sheltered.

1- Summer period

Air temperature:
Appendix D3 ,the four models two for courtyard with hole roof the site correlated to wind exposure one of them set as normal position the second set as sheltered as center of city, same aspects for courtyard with glass roof.
Deduce the better result for courtyard with hole and sheltered set .On other hand the difference between models result not exceeded 4 °C degrees , but the difference between the simulation models result and courtyard air temperature measurements from 5°C degrees to 9°C degrees.
ASHRAE calibration value:
Courtyard hole roof (sheltered) MBE 3.1%, CVRMSE 17.2%.
Courtyard hole roof (normal) MBE 4.4%, CVRMSE 18.3%.
Courtyard with glass roof (sheltered) MBE 2%, CVRMSE 17.1%.
Courtyard with glass roof (normal) MBE 2.6%, CVRMSE 15.4%.all models have good value for air temperature.
Relative humidity:
Observed Appendix D3 the better result for normal set.
The difference between models from 5% to 13%. On other hand the difference between models and courtyard relative humidity measurements from 10% to 20%.
ASHRAE calibration value:
Courtyard with hole roof (sheltered) MBE 1.9%, CVRMSE 36.1%.
Courtyard with hole roof (normal) MBE 8.7%, CVRMSE 31.1%.
Courtyard with glass roof (sheltered) MBE 0.5%, CVRMSE 35.6%.
Courtyard with glass roof (normal) MBE 1.3%, CVRMSE 33.4%.
the result as the first calibration step for summer period MBE value accept but CVRMSE out of range but the closer one the courtyard with hole roof .for more details the simulation run for the four models to deduce the better models for radiation as the previous result the courtyard with hole roof . On other hand the normal models percent ACH more than 150 air change per hour which is not acceptable.
That makes normal set model illogical.

2- Winter period

Air temperature:
Appendix D3 , the same previous results of winter period for courtyard with hole roof and glass roof also for normal and sheltered set have roughly equal result.
ASHRAE calibration value:
Courtyard with hole roof (sheltered) MBE 13.4 % , CVRMSE 29.7 %.
Courtyard with hole roof (normal) MBE 15.9%, CVRMSE 31.1%.
Courtyard with glass roof (sheltered) MBE 11 % , CVRMSE 28 %.
Courtyard with glass roof (normal) MBE 13.6%, CVRMSE 29.8%.
These case revers values for relative humidity at summer period, the mean bias error out of accept average, on other hand CVRMSE still in range.
Relative humidity:
As latest result the same previous results of winter period for courtyard with hole roof and glass roof also for normal and sheltered set have roughly equal result Dig .
ASHRAE calibration value:
Courtyard with whole roof (sheltered) MBE1.5 %, CVRMSE 12 %.
Courtyard with hole roof (normal) MBE 0.2%, CVRMSE 13.9%.
Courtyard with glass roof (sheltered) MBE 3.2 %, CVRMSE 11.9 %.
Courtyard with glass roof (normal) MBE 2%, CVRMSE 13.7%.
The better performance for courtyard with hole roof in summer period the ACH illogical.
Conclusion:
Previous results for the second step calibration exposed wind site as normal get roughly equal sheltered. The problem of those models as normal site are the changing air flow per hour , the simulation result for this site illogical inside courtyard more than 150 ac/h .
The better performance for sheltered site and as first step calibration result for courtyard with hole roof.

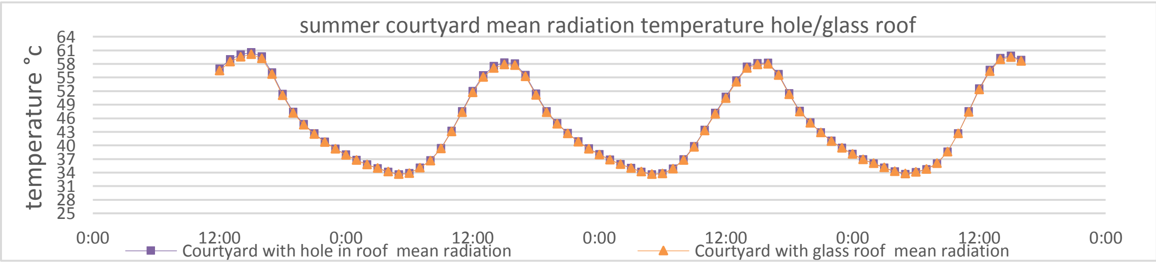
- Apply Simulation: EPW weather station data, courtyard microclimate.

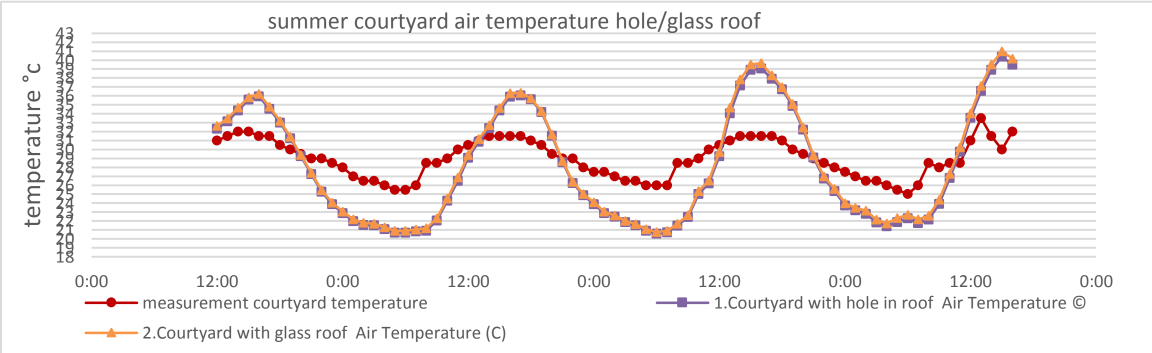
1- Summer period.

Air temperature:
Appendix D3 , the results to apply microclimate courtyard data for those was parallel with courtyard measurements with higher temperature(out of range) about 4°C degree.
The two models courtyard with hole or glass roof have equal result with applied microclimate data.
ASHRAE calibration value:
Courtyard hole roof MBE 3.1%, CVRMSE 17.2%.
Courtyard hole roof (microclimate data) MBE 12%, CVRMSE 11.9%.
Courtyard with glass roof MBE 2%, CVRMSE 17.1%.
Courtyard with glass roof (microclimate data l) MBE 12% , CVRMSE 11.9%.
At calibration with microclimate courtyard data EPW file has doubt result the mean bias error out of range that make calibration not accepted for air temperature for summer period .
Relative humidity:
Appendix D3, the temperature result, of two courtyard models with hole or glass roof have equal results with applied microclimate data.
The different between models result and courtyard relative humidity measurement not more than 10%.
ASHRAE calibration value:
Courtyard with hole roof MBE1.5 %, CVRMSE 12 %.
Courtyard with hole roof (microclimate data l) MBE 17%, CVRMSE 16.9%.
Courtyard with glass roof MBE 3.2 %, CVRMSE 11.9 %.
Courtyard with glass roof (microclimate data l) MBE 17%, CVRMSE 16.9%.
At calibration apply microclimate courtyard data EPW file has similar result of air temperature calibration. The mean bias error out of range.

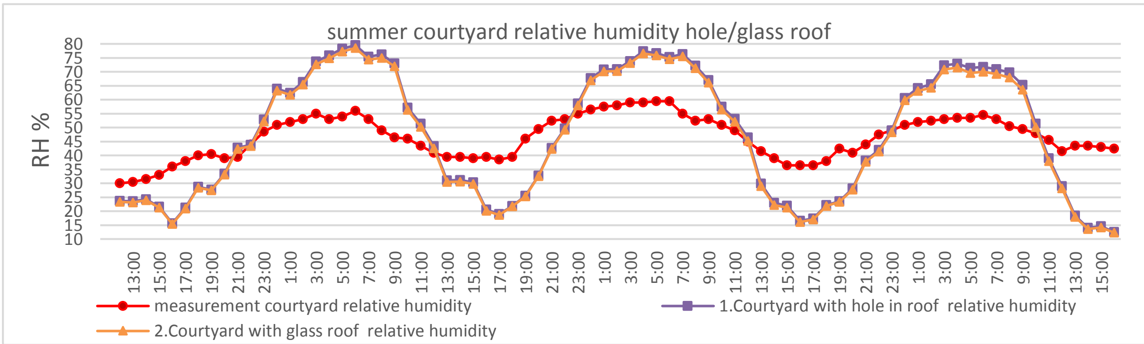
2- Winter period.

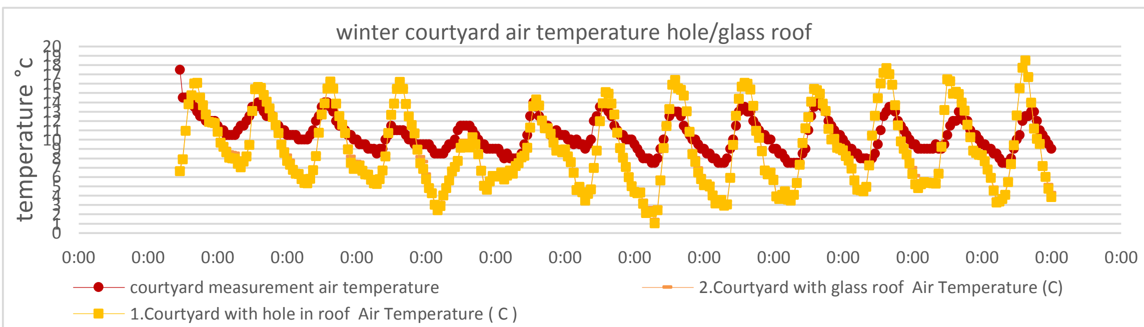
Air temperature:
Appendix D3 ,equal result for summer period, the microclimate diagram for courtyard with hole or glass roof parallel with air temperature courtyard measurements.
The different between microclimate data models and measurements less two °C degrees.
ASHRAE calibration value:
Courtyard with hole roof MBE 13.4 % , CVRMSE 29.7 %.
Courtyard with hole roof (microclimate data) MBE 19.3%, CVRMSE 20.2%.
Courtyard with glass roof MBE 11 % , CVRMSE 28 %.
Courtyard with glass roof (microclimate data) MBE 18.5%, CVRMSE 19.5%.
At calibration with microclimate courtyard data EPW file has doubt result the mean bias error out of range that make calibration not accepted for air temperature for winter period.
The air temperature calibration equal summer and winter period.
Relative humidity:
Observed Appendix D3 the relative humidity for models applied microclimate data lower than relative humidity for courtyard measurements less than 10%.
ASHRAE calibration value:
Courtyard with hole roof MBE1.5 %, CVRMSE 12 %.
Courtyard with hole roof (microclimate data) MBE 12.3%, CVRMSE 12.6%.
Courtyard with glass roof MBE 3.2 %, CVRMSE 11.9 %.
Courtyard with glass roof (microclimate data) MBE 11.8%, CVRMSE 12.1%.
similar all previous result for applying microclimate courtyard data result the mean bias error out of range that make calibration not accepted for air temperature for winter period .

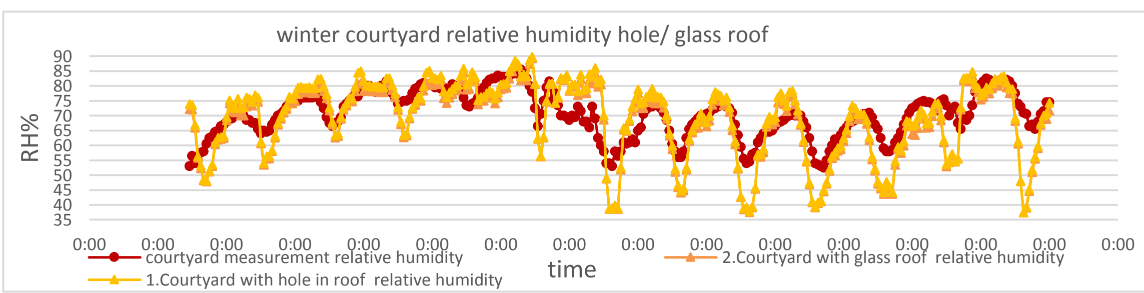




a.







b.

Figure 4-7:a,b. difference between two courtyard roof modeling hole/glass summer, winter period /temperature, RH, radiation for hole , glass roof cases.

- conclusion:

The all applying previous observed results of microclimate courtyard data get mean bias error values out of acceptable range. On other hand applying station climate data as EPW file get more logical results, in addition to the more close diagram to the courtyard measurements diagram.

From all previous data and results the best performance and calibration to sheltered courtyard modeling with hole roof , although it needs to change another factor to get better results .

Observe all diagrams show the huge difference between courtyard measurements and simulation results at after midday peak and the lowest temperature after midnight .Those differences occurred related to using data logger protection , which protect data logger from direct radiation and keep data logger colder than real climate under direct solar radiation within shading device.
To apply this case in simulation modeling, suggested light roof as shading device to protect small space limited by visual partition (not a real partition only to divide to divide only the big space) .This space(at the same data logger position) data logger protection shows at **Figure 4-8**.

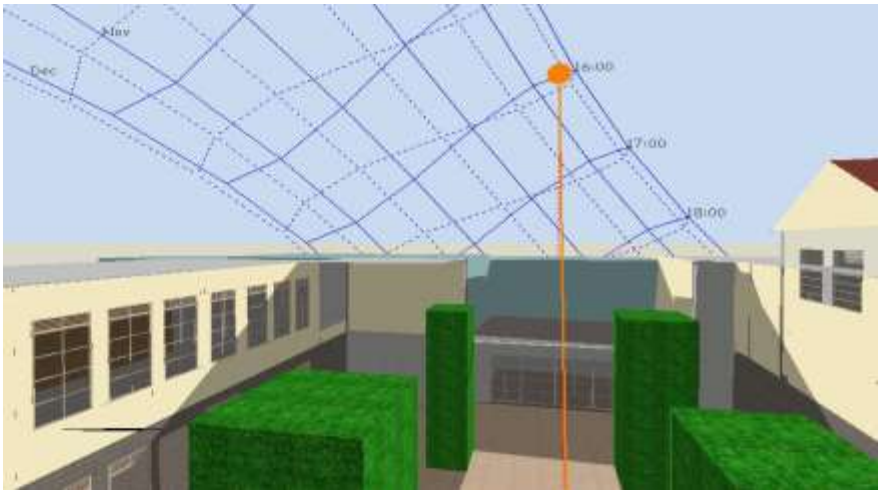


Figure 4-8: courtyard modeling with shaded space as data logger position and protection.

- **Summer period :Air temperature:**

Figure 4-9present better result for modeling calibration .The different between courtyard measurements and courtyard new modeling result are less than one °C degree.
For ASHRAE calibration value:
MBE 0.9%, CVRMSE 3.3% all value in range, this result the best one .
Relative humidity:
Calibration correlated to air temperature got best result.
For ASHRAE calibration value:
MBE 9 %, CVRMSE 24.03% all values in acceptable range. This result the best ones .
Indicating to the latest calibration result change depend on sensors place and case (with protection or shading place) that reflects direct on measurements , also on modeling and the way to get the result (within protection sensor consideration).
Specific position and condition sensor in simulation model get better calibrations.

- **Winter period :Air temperature:**

Figure 4-9presents results as well summer result (better calibration result) .
For ASHRAE calibration value:
MBE 9.9 % , CVRMSE 15.5 % the two values in range .

Relative humidity:
For ASHRAE calibration value:
MBE 0.1 % , CVRMSE 12.6 % the two values in range .

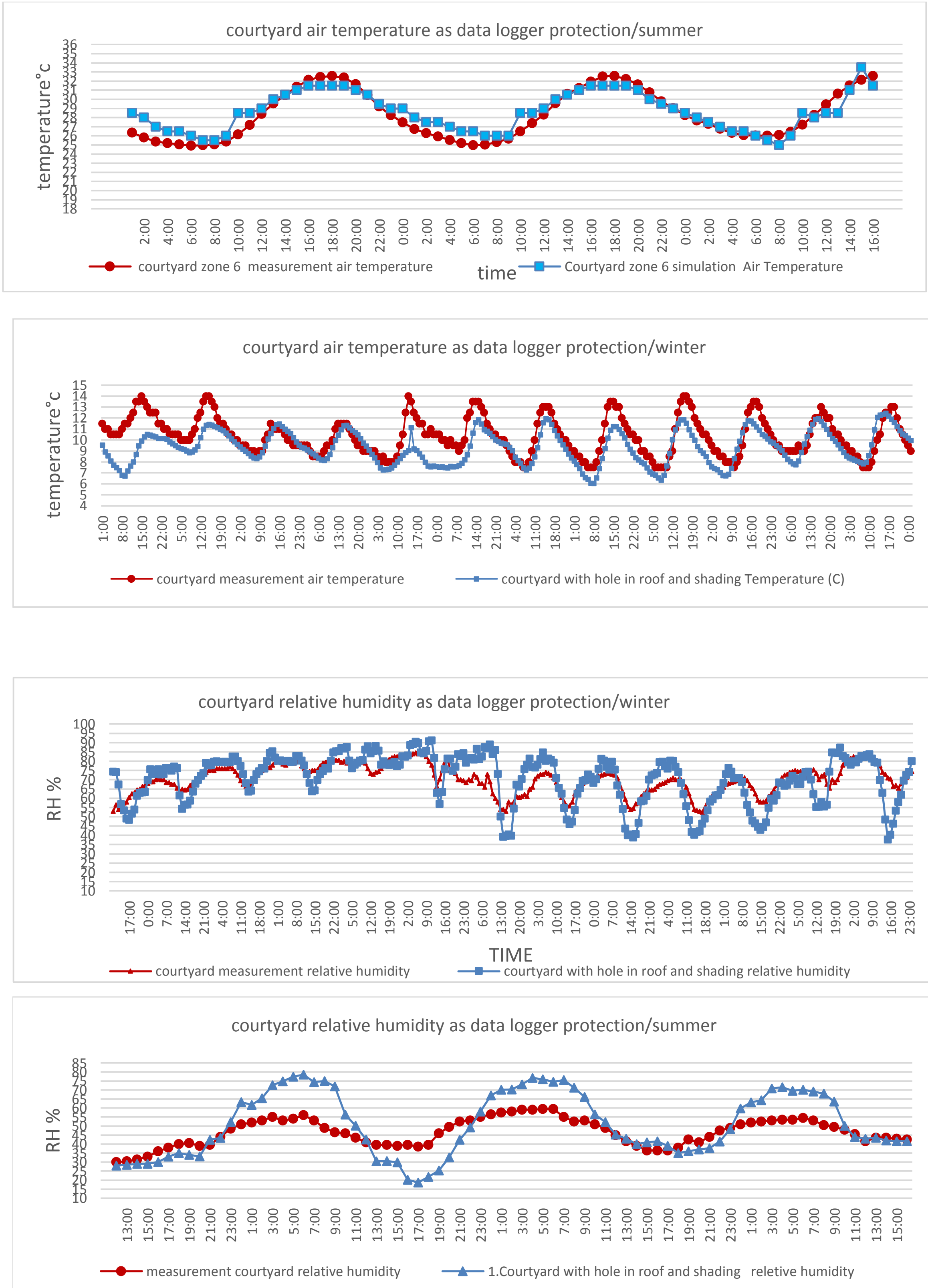


Figure 4-9: Courtyard modeling as data logger protection(shaded) for summer/winter – temperature,RH

2- Second calibration modeling : halls modeling(natural ventilation effect) :

- Wind factor

Natural ventilation calibration modeling: wind factor value has direct effect on natural ventilation zone.
Observe the influence through air temperature zone. For this calibration case of south main hall modeling during open windows period for the fourth week of July include wind-driven airflow from the analysis altogether set the Wind factor as[0, 0.15, 0.25, 1] that depend on house location within city center (windward, leeward) .

- **Simulation argument: summer period**

Model: courtyard with Shading and hole in roof: case study: **south main hall:** single side stack ventilation :the first windows level all windows opened beside four window within the second windows level through day and night to get the opening impact though the natural ventilation process at the fourth week of July .

North hall: cross ventilation (adjacent windows) south, east façade windows open through day and night to get the opening impact hypotheses as well natural ventilation process at the fourth week of July.
1st floor north hall: cross ventilation south, north façade windows open through day and night to get the opening impact thought natural ventilation process at the fourth week of July .

- **Result:**

Air temperature:

- South main hall :

Appendix D3 the simulation result. the closer temperature to measurements for wind factor 0 and 0.15, The other air temperature difference models result about 3 °C degrees at the natural ventilation effect period from later evening to early morning .
ASHRAE calibration value:
Main south hall with 0 wind factor: MBE 3.5 % , CVRMSE 4.2 %.
Main south hall with 1 wind factor: MBE 4 % , CVRMSE 7.9 %.
Main south hall with 0.25 wind factor: MBE 3 % , CVRMSE 5.9 %.
Main south hall with 0.15 wind factor: MBE 1 % , CVRMSE 4.8 %.
Calibration value for all models were in range and has better result for factor 0.15.

- North hall:

Appendix D3 the model with 0,1 wind factors has far results the closer results to north hall air temperature measurement with opening windows period for 0.15 ,0.25 wind factors.
ASHRAE calibration values:
North hall with 0 wind factor: MBE 5.3 % , CVRMSE 6.5%.
North hall with 1 wind factor: MBE 6 % , CVRMSE 6.5 %.
North hall with 0.25 wind factor: MBE 1 % , CVRMSE 4 %.
North hall with 0.15 wind factor: MBE 1 % , CVRMSE 4 %.
Calibration values for all models in range, the result correlated to diagram result the model of 0.15 wind factor has the better calibration result .

- 1st floor north hall:

Appendix D3 as previous result for north hall the better diagram for 0.15 wind factor model , on other hand the model of 0 wind factor has a high warm effect.
ASHRAE calibration value:
1st floor North hall with 0 wind factor : MBE 13.1 % , CVRMSE 13.4 %.
1st floor North hall with 1 wind factor : MBE 6 % , CVRMSE 8.6 %.
1st floor North hall with 0.25 wind factor : MBE 3 % , CVRMSE 5.5 %.
1st floor North hall with 0.15 wind factor : MBE 0.1 % , CVRMSE 4.1 %.
MBE value for 0 wind factor model out of accept calibration range correlated with diagram result , the best value for 0.15 wind factor model.

Relative Humidity:

Halls Relative humidity for 0.15 wind factor calibration :

Main south hall:

Appendix D3, few turbulence special for first simulation period , that depend on the influence of plants and trees at courtyard , green effect which is hard to included at modeling .

ASHRAE calibration value :

Main south hall with 0.15 wind factor : MBE 4.8 % , CVRMSE 16 %.

North hall:

Same result as south hall but at this hall has more differences, that also depend on the characteristics of the hall which has about 1m underground (semi-underground) soil effect.

ASHRAE calibration values :

North hall with 0.15 wind factor : MBE 10 % , CVRMSE 13 %.

1st floor north hall :

The result corresponded with other halls, on other hand the turbulence at 1st floor north hall relative humidity measurements that related to airflow behavior and the change in summer period.

ASHRAE calibration value :

North hall with 0.15wind factor : MBE 3.3 % , CVRMSE 21 %.

- **Simulation argument: winter period**

The hourly indoor temperatures had measurements for each of south main hall , courtyard , north hall , 1st floor north hall, during the monitoring periods of two weeks in December, 2014 - January, 2015 .

EPW weather data applied for 2014 weather data from the Central Laboratory for Agricultural faculty weather station and weather data collected near the case study.

Sky in winter roughly not clear , so there were no direct radiation that means no need for shading space for calibration [wind factor 0.15].

South hall :

Air temperature calibration: Appendix D3 the difference between south hall measurement air temperature Max two °C degrees.

ASHRAE calibration value: MBE 2.82% , CVRMSE 7.17%.

Relative humidity calibration : the difference between measurement and simulation was about 12%

ASHRAE calibration value: MBE 10.3% , CVRMSE 16.7%.

North hall:

Air temperature calibration : the difference between south hall measurement air temperature MAX three °C degrees .

ASHRAE calibration value :MBE 10.1% , CVRMSE 13.2%.

Relative humidity calibration : the difference between measurement and simulation about 14%

ASHRAE calibration value :MBE 2.77% , CVRMSE 9.02%.

1st floor north hall :

Air temperature calibration : the difference between south hall measurement air temperature MAX one °C degree .

ASHRAE calibration value :MBE 0.25% , CVRMSE 4.4%.

Relative humidity calibration : the difference between measurement and simulation about 10%

ASHRAE calibration value :MBE 8.93% , CVRMSE 10.55%.

4.2.3 Summary of modeling analysis

Natural ventilation calibration more complicated specially for relative humidity parameters , on other hand the green effects (trees) and airflow in the courtyard have more complicated effects to be modeled at simulation program.

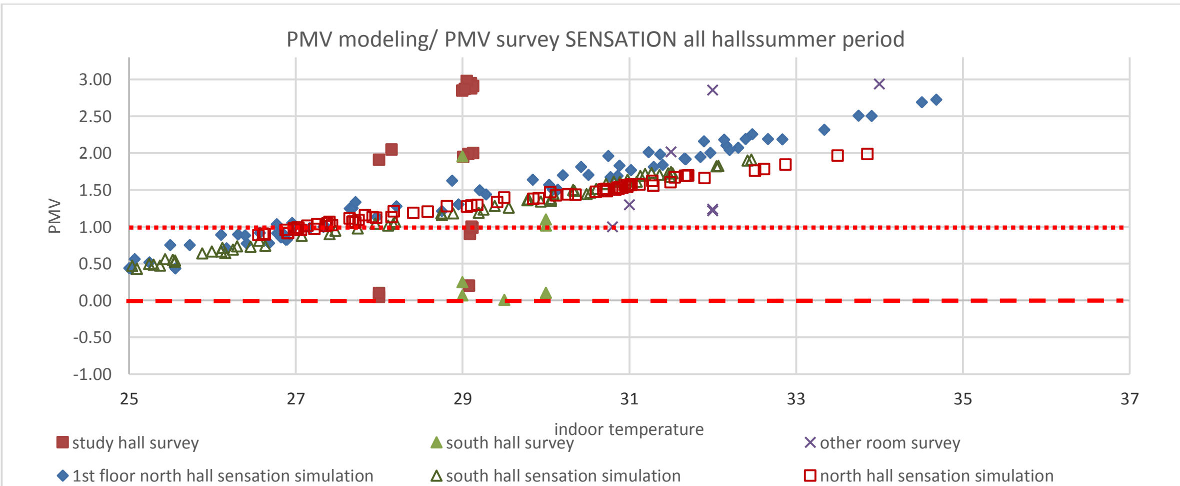
All previous results and integrate simulation model to reach best calibration for courtyard house, and to study the behavior and the effect of courtyard , modeling courtyard as a zone with hole on roof with sheltered location and 0.15 wind factor for natural ventilation period .

Summer Simulation PMV/ sensation scale achieve about 50 % of sensation survey **Figure 4-10**.

Winter simulation PMV/ sensation simulation achieves 70% of sensation survey.

The results of the building simulation match the measurements accurately at each time step. As the simulation program deals with many input parameters, an accurate parametric model can be deduced from a procedure in three steps:

1. Short-term measurements (weather, indoor air, surface And occupancy).
2. The thermal behavior is simulated by a sophisticated building simulation with the short-term measurements as input data and known material properties (g-value, U-value, thermal properties).
3. The main building characteristics are derived from the validated simulation model with standardised weather data, operation and user behavior.



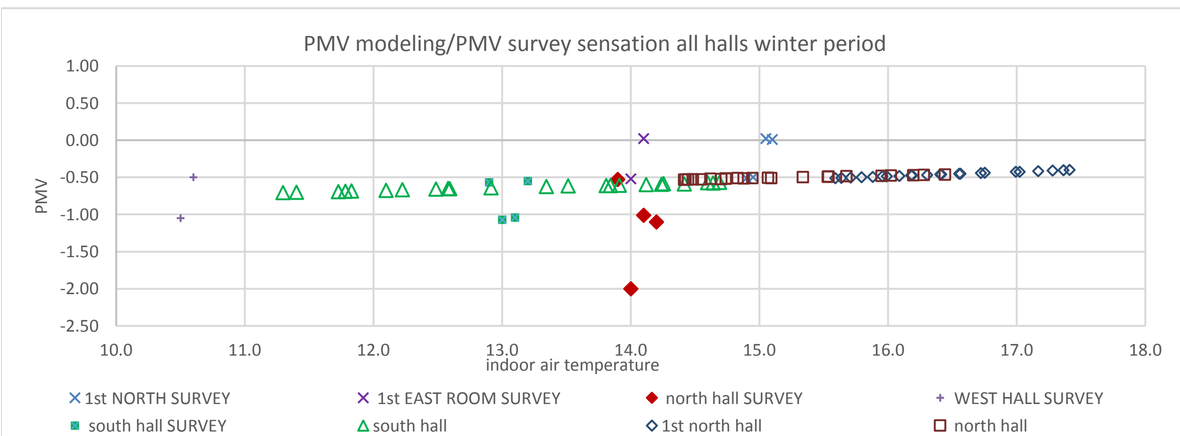


Figure 4-10: courtyard house PMV modeling /PMV survey sensation for all halls , summer/winter

4.3 Evaluation of Merge between Measurement and Modeling.

Simulation investigations are used to determine how the air change rates, the building construction and the climatic parameters affects the natural ventilation. The data evaluation deals with the nocturnal air change rates and the indoor air temperature,
In modeling the natural ventilation effect .here are some crucial points:
-Natural ventilation: As most ventilation concepts based on a free ventilation concept, the air change rates must be calculated. Due to the different driving forces (wind, buoyancy drived ventilation

(generate simple model for residential building), the design of free ventilation and inter-zonal air exchange are complicated.
- Heat transfer: As the natural ventilation cools down the building construction, an accurate modeling of the convective heat transfer coefficient is essential for the simulation of natural ventilation.
The effectiveness of mass and natural ventilation contribute in lowering the indoor daytime temperatures. The difference between natural ventilation all day and night ventilation as passive strategies focus on thermal comfort.
As a basic principle, results from experiments in buildings cannot be reproduced, as the heat storage of the building is a transient phenomenon. Using the building simulation, the measurements can be transferred into a harmonic oscillating model. With the parametric model, thermal building characteristics can be deduced from the simulation results. Thus, measured data are analysed by
1. Evaluation of measured data based on standardized graphs and indices.
2. Sophisticated building simulation using measured data and boundary conditions.
3. Data evaluation of the results from the building simulation with standardized boundary conditions using a parametric model.
The aim of the parameter identification is to set up an accurate simulation model: the building characteristics (i.e. heat transfer at internal walls, solar absorption at the external wall, SET-value) are known approximately and can be fitted to the measurements. Compares the operative room temperature from measurement and simulation for monitor period. The building simulation has been performed not only for the three periods, but also for the whole experiment. Additionally, the results from the parametric model. Thus, all boundary conditions and thermal interactions are taken accurately into account.
The simulation model is set up and validated with measurements, from two different periods (July and August and December 2014th,2015th) and can be used for data analysis. The assumptions, which are made in the parametric model, can be taken into account, if the heat fluxes are calculated accurately by the building simulation program.
On other hand, though the first section provides first evaluation of the thermal behavior of all day natural ventilation, the night ventilation effect cannot be quantified which could be better for hot summer as 2015th. In the following Sections, experiments and data evaluation based on a parametric model and building simulation are used to draw ACH and difference pressure also other parameters and to separate the natural ventilation effect from the other elements.
Using an accurate model for building simulation, the measurements from a real, transient experiment can be evaluated for artificial, regularly oscillating boundary conditions.

Night ventilation:
Natural ventilation techniques are based on the use of the cool ambient air as heat sink, to decrease the indoor air temperature as well as the temperature of the building's structure. The cooling efficiency of these techniques are mainly based on the air flow rate as well as the thermal mass. Ventilation by natural means, i.e., through the building's openings. In this case the air flow is variable and random and depends on the temperature and wind driven pressure differences between the indoor and outdoor environment (integrate with simulation model). Thus, the efficiency of this technique is affected by the interdependence of the environmental parameters. Outlines the principle of natural ventilation: dissipated heat storage **Figure 4-11** describes natural ventilation: energy balance .

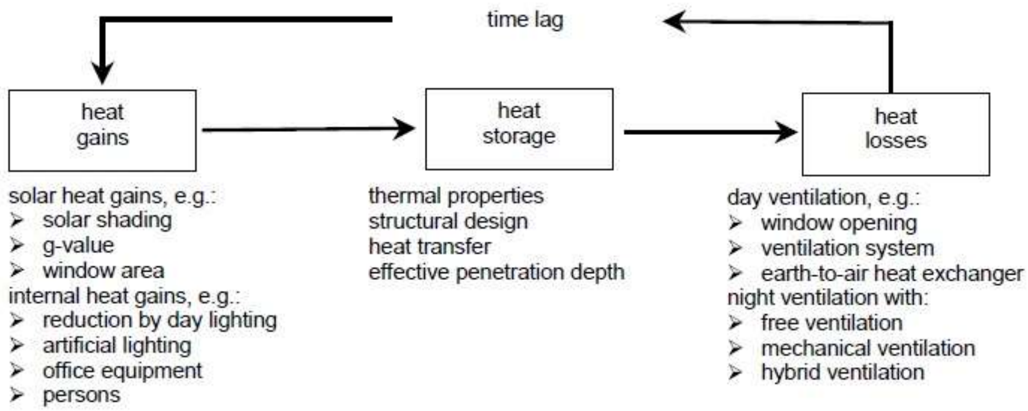


Figure 4-11: Principle of Natural ventilation: energy balance.

Buildings with night ventilation reach lower room temperatures than buildings without active or passive cooling.
Moreover, the maximum room temperature arrives later in the afternoon. Both effects are caused by the additional heat loss during the night and the heat dissipation from the fabric and the ceiling, respectively.
The night ventilation efficiency with
1. The reduction of the room temperature,
2. The heat dissipation by night ventilation.
The night ventilation was used only between 17 July and 23 August 2015 and 2014 during the summer period equal monitoring periods for two years.
Room temperatures can be classified by days with and without night ventilation.

Result:
Through the previous section all simulation modeling result are collected to compare, the 2014th and 2015th data integrated and generate night ventilation case for analysis.

4.3.1 <u>Thermal environment's characteristics</u>

4.3.1.1 *<u>Air temperature (indoor/outdoor)and relative humidity.</u>*

- **South hall:**

The relation between indoor and outdoor air temperature gives another indicator not only for the constant relation between indoor and outdoor but also for the effective outdoor temperature for natural ventilation correlated to indoor air temperature.
- the natural ventilation for all days is more effective than only night ventilation (with climatic data of year 2014th; for the year 2015th the night ventilation is a little bit effective than natural ventilation for all day with slope about 2h .This is because the building's structure was cooled by night-time ventilation and absorbed heat during the daytime.
Figure 4-12 show a similar dependence of halls indoor temperature on the outdoor temperature.
Figures show difference between ventilation (open windows all-round the day) and no ventilation (close windows) for each year, and the tender- line prove the natural ventilation influence on reduce indoor temperature compare with no ventilation and comfort [Through No ventilation case (close windows) the hall store heat quickly , on other hand the ventilation case (open windows) the effect of air flow from outside as a cooler for structure and inside air to refresh], also the difference between year 2014 and hottest summer for year 2015th on indoor temperature .

On other hand, the tinder-lines for ventilation and no ventilation cases cross at point related to outdoor specific temperature. cross point means two cases has equal effect at this point (outdoor temperature) and higher than this temperature .The no ventilation (close windows) case will be lower indoor temperature than with ventilation (open windows) and more comfortable .
On other hand the difference between halls temperature at certain outdoor temperature is caused by thermal mass (light, heavy) and kind of natural ventilation (single stack, cross ventilation). Cross ventilation has more effect than stack ventilation during day (by time).
, Figure 4-12 when the windows were closed during the daytime, relative humidity maintained same values compared with those of daytime and night time (all day) ventilation. Relative humidity was slightly reduced in the night ventilated room at night by opening windows,

- **1st floor north hall:**

Correlate to latest result for south hall and the relation between indoor and outdoor temperature.
(Fig15,Appendix D4)present the indicator temperature point (tinder-line for no ventilation and with ventilation) had higher value than south hall , related to higher temperature and thermal mass proprieties (store and lose heat gains, south hall) light mass specially for hot summer 2015th . Cross ventilation and light mass case the natural ventilation for all day roughly equal effect of night ventilation with little better effect for two years 2014th, 2015th with slope about 1h.
Cross ventilation influence by expand the value of indicator point more than single side stack ventilation. Figure shown natural ventilation effecte to reduce temperature max at night about 6 °C degrees, min during day about 3 °C degrees for 2014th this result decreased at 2015th in exceptional hot summer.
The difference between night and all day ventilation at light mass (first floor) and heavy mass (ground floor) related to heat transfer and capacity to trapped and heat gain in hall on other hand lose heat by ACH.
Relative humidity has equal result for south hall, natural ventilation all day and at night increase in relative humidity value. Relative humidity was slightly reduced in room at night by opening windows Appendix D4 explain this result.

- **North hall:**

Appendix D4 presents The relation between with natural ventilation (open windows)case and no ventilation (close windows) same as single side stack ventilation the tender-line cross at indicator outdoor temperature about 31 °C for normal summer 2014th . For 2015th the result; ventilation night change case more effective and equal to no ventilation during day which is more comfortable that related to heavy mass and the heat transfer with steady condition (soil) at almost surface(semi-underground) . **Figure 4-15** shows the relation between indoor and outdoor temperature.
Previous reflects on relative humidity result of the semi-underground hall that has lower relative humidity value at midday provides more effective night ventilation at very hot summer 2015th Appendix D4 .

4.3.1.2 *Inside Surface temperature.*

Explain natural ventilation effect through wall and loss heat gain , internal surface temperature give clear indicator for that incident .
The surface temperature is called the sol-air temperature and can be described as the equivalent outdoor temperature that will cause the same rate of heat flow at the surface and the same temperature distribution through the material as the current outdoor air temperature, the solar gains on the surface and the net radiation exchange between the surface and its environment.

$$Q=A\,U\,(T_{sa}\_T_i)$$

$$G\,.A.\alpha=A.h.(T_{sa}\_T_o)$$

$$T_{sa}=To+G_{\alpha}/h \quad \text{or} \quad T_{sa}=T_o+G\alpha R_{so}$$

$$T\,sa=T\,o\;+dT_e$$

Where: $dT_e = (G.\alpha.R_{so})$ = sol-air excess temperature (K); Q conduction heat flow rate (W), A area (m^2),Ti indoor temperature ,U thermal transmittance W/m^2 K , With T_{sa}= Sol-air temperature (C), T_o = Outside air temperature(C), Rso= outside air-film resistance. G = total incident solar radiation (W/m^2), aw = solar absorptance of wall (0–1)
The method used for estimating the potential of different passive strategies was taken from
shows the reflection of natural ventilation impact on decrease inside surface temperature, The effect of natural ventilation all day demonstrate at 2014th more than night ventilation roughly 1 °C degree different in compare with ordinary climate , for hot month 2015th ventilation all day roughly equal night ventilation .

- **1st floor north hall:** Thermal mass behavior with natural ventilation explain by Appendix D4 the relation between inside surface temperature and outside temperature . The roughly corresponding result between natural ventilation and night ventilation observed at**Figure 4-15**.
- **North hall:** This latest temperature result related to thermal mass behavior and surface temperature Appendix D4 inside surface temperature .
- **1st floor north hall:** Thermal mass behavior with natural ventilation explain by Appendix D4 the relation between inside surface temperature and outside temperature . The roughly corresponding result between natural ventilation and night ventilation observed at**Figure 4-15**.
- **North hall:** This latest temperature result related to thermal mass behavior and surface temperature Appendix D4 inside surface temperature .

4.3.1.3 *Pressure Difference*

Pressure result proportion with air temperature which gives indicator for natural ventilation effect through air flow, Equation used by the airflow network model: where

$$\Delta P = Pn - Pm + PS + PW$$

Pn, Pm = Total pressures at nodes n and m [Pa]
PS = Pressure difference due to density and height differences [Pa]
PW = Pressure difference due to wind [Pa]
The calculation depends on opening kind, vertical or horizontal details and stack (buoyancy) effect beside wind effect

- **South hall**: The previous result of the indicator temperature point(cross tinder-line) reflected the pressure difference, that means the equal pressure value(ventilation case) at inside and outside the hall .In this case, it has the same effect of no ventilation (close windows)case and it is not always a better solution but after a passing time **Figure 4-13**.

The different between temperature indicator point and the different indicator pressure point causes other air flow effects . The infiltration and stack within hall were not calculated with the surface pressure difference and views a slope of about 1 degree . Appendix D4) shows different pressure for windows where kinds of air always flow. The ventilation rate (q) through each opening and crack in the model is calculated based on the pressure difference using wind and stack pressure effects:

$$q = C.(DP)\ n$$

Where:
q is the volumetric flow through the opening.
DP is the pressure difference across the opening/crack.
n is the flow exponent varying between 0.5 for fully turbulent flow and 1.0 for fully laminar flow.
C is the flow coefficient, related to the size of the opening/crack.
The difference between air flow for 2014^{th}-2015^{th} depends on wind speed for year ,which was lower in the year 2015^{th} Appendix D4.

- **1st floor north hall:** Different pressure surface pressure is obviously shown at Appendix D4 and the climate reflection through the different effective pressure between 2014^{th} and 2015^{th} beside infiltration and ventilation kind.

Cross ventilation influence clearly specially for ordinary climate 2014th presents clear in.**Figure 4-15** the difference between single side stack ventilation (difference pressure surface) which has specific indicator point value reverse and the cross ventilation (difference pressure surface)which has infinity relation(parallel relation) between no ventilation (close windows)and with ventilation (open windows) cross ventilation has expended effect for normal climate 2014th .On other hand 2015th at hottest season the result change and cross ventilation has limited effect but with more comparative range to stack ventilation.
The difference between the temperature indicator and the pressure indicator related to other air flows effects .The infiltration and stack within the hall which is not calculated with the surface pressure difference, views about 1°C degree slope. **Figure 4-15** presents pressure difference for windows where always kind of air flow. The difference between air flow for 2014th-2015th depends on wind speed through the year which was lower at 2015th Appendix D4.

- **North hall:** The infiltration in traditional house has clear effect on inside hall thermal behavior specially at no ventilation (close windows) case .**Figure 4-15** shows difference pressure between inside and outside .On other hand reflects the relation of cross ventilation case and no ventilation (close windows) as temperature relation with slope about one °C degree related to surface pressure calculate without the airflow effect inside hall as south hall .
  Related to air flow in / out behavior shown at Appendix D4. The difference between airs flow for 2014-2015 depended on wind speed for year which was lower at 2015th but this effect was lower too than in the other hall related to lower opening area .

4.3.2 Thermal comfort.

4.3.2.1 *Psychometric-Chart.*

Thermal environment evaluation used adaptive comfort standard (ACS), Recently, ASHRAE recognized that the conditions required for thermal comfort in spaces that are naturally conditioned are not necessarily the same as those required for other indoor spaces.
Then, a new ACS for naturally ventilated buildings has been proposed to be integrated within ASHRAE Standard 55 though operative temperatures differs between cases due to the variation of outdoor climatic conditions .The night ventilated room provides better or equal thermal comfort with all day ventilation compared with the no ventilated at 2015th .
In 2014th the result was different from the previous one, that better thermal comfort for full day ventilation has.
The ASHRAE Standard 55 including ACS is intended primarily to apply to sedentary or near sedentary physical activity levels. Thus does not deal with sleeping or bed rest conditions. Therefore, it cannot be concluded from the above results alone that the ventilation technique would provide required thermal comfort. Nevertheless, the above results clearly indicate that there is a large potential in ventilation, which can be provided by either full-day ventilation or night ventilation, for eliminating the nocturnal use of air-conditioners in Damascus houses. The result depend on climate consultant program shows at **Figure 4-13**.

- **South hall:**

Figure 4-13 The ASHRAE Standard 55 includes the ventilation influence on thermal occupant comfort
ASHRAE Standard 55-2010: Thermal comfort is based on dry bulb temperature, clothing level (clo), metabolic activity (met), air velocity, humidity and mean radiant temperature. Indoors it is assumed that mean radiant temperature is close to dry bulb temperature. The zone in which most people are comfortable is calculated using the PMV/SET model. In residential settings people adapt clothing to match the season and feel comfortable in higher air velocities and so have wider comfort range than in buildings with centralized HVAC systems.
Adaptive comfort Model in ASHRAE 55-2010: In naturally ventilated spaces where occupants can open and close windows, their thermal response will depend in part on the outdoor climate, and may have a wider comfort range than in buildings with centralized HVAC systems. This model assumes occupants adapt their clothing to thermal conditions and are sedentary (1.0 to 1.3 met). There must be no mechanical

Cooling System, but this method does not apply if a Mechanical Heating System is in operation.[climate consultant] with added 1degree for 80% acceptable average and 1.2 °C degree for 0.6m/s air velocity . Finely the adaptive model had roughly equal ASHRAE Standard 55

Figure 4-13 presents comfort result depend on survey result, roughly adaptive model closer to survey result in small different with Standard 55.

The result confirm the night ventilation at very hot month equal to ventilation all day, for ordinary summer month natural ventilation all day more comfort.

- **1st floor north hall:**

Figure 4-16 presents thermal comfort for the first floor north hall depend on ASHRAE Standard 55-2010 psychometric-chart comparison between survey result and comfort model for measurement and simulation result .

As previous result for south hall adaptive comfort model more closer to survey at natural ventilation cases for no ventilation (close windows) ASHRAE 55 provides better result.

In summer 2014th it was more comfortable through the natural ventilation period specially the all day natural ventilation. It was more effective than only night ventilation.

- **North hall:**

Figure 4-16 shown standards comfort results for all cases , years and surveys.

For more explanation at **Figure 4-16**confirm the previous results the semi-underground hall with cross ventilation adjacent window also the equal result for no ventilation and with night ventilation some time at very hot summer 2015th . On other hand show all previous halls the adaptive comfort model result closer to survey sensation result than standard 55 , but for no ventilation psychometric-chart case provides standard 55 better result.

4.3.2.2 *PMV SET, Sensation.*

Those standards calculate RH as ASHRAE standard SET PMV.

Thermal environment evaluation using SET the ACS, is that the index does not take evaporative heat exchange between the occupants and the ambient environment into account. The effects of evaporative heat loss on thermal comfort increase considerably with the rise of ambient air temperature especially in warm conditions like in the tropics. Thus, this section attempts to evaluate the thermal conditions of the two rooms using standard effective temperature (SET) and compare the results with those obtained in the previous section. SET is considered to be one of the most comprehensive thermal comfort indices, which integrates the effects of air temperature, humidity, radiation, air velocity, clothing insulation and metabolic rate on human thermal comfort. SET is calculated by the program based on the human-body heat balance model. In contrast, it was found that when the evaporative heat loss of occupants is taken into account by using SET, the night ventilation would not be the superior technique to the others the SET more closer to sensation and survey.

Constraints and limitations:

The cooling effect of ventilation was found to be larger than no ventilation strategies. However, it should be noted the complete effect of relative humidity on all aspects of human comfort has not yet been established .ASHRAE Standard 55 proposed the upper limit of 12 g/kg in humidity ratio for systems designed to control humidity, but any humidity limits have not been set for the ACS. However, it is recognized that extremes of humidity are the most detrimental to human comfort, the effects of humidity on human health and comfort from various viewpoints, including biological contaminants, airborne pathogens and chemical interactions. As a result, the study proposed that the range between 40% and 60% RH would provide the best conditions for human occupancy. On the other hand, the full day ventilation could allowed to increase relative humidity during day.

- **South hall:**

SET result closer to adaptive model than standard. Survey result depend on sensation assessment present at **Figure 4-14** and Appendix D4.

- **1st floor north hall:**

For more comfort confirmation, PMV SET calculate comfort by simulation modeling and comparing with survey result related to sensation assessment, Appendix D4 present same result for south hall.

Depend on survey assessment adaptive model has the best result closer to survey also SET scale for 2014th and psychometric-chart as **Figure 4-17** .

- **North hall:**

As previous result the reflection on occupant more clear at SET scale, **Figure 4-17** shown the effect of natural ventilation

4.3.3 Thermal Mass.

Previous results of natural ventilation concentrate on temperature and air flow and reflected on thermal comfort but these results correlate to loss heat gain during day through the walls.

Which means the effectiveness of mass and natural ventilation in lowering the indoor daytime temperatures.

In addition, air exchange rates of the halls may not be large enough. According to the data of the on-site weather station, outdoor wind speed was found to be very lower especially at night in 2015th than 2014th The simulation changes per hour (ACH) during the day and night were estimated.

Figure 4-18 : courtyard house all halls, a. thermal mass (heavy/ground floor , light/ first floor)/ temperature /ACH effect ,b . north hall Min and Max temperature /ACH effect .

The different behavior in these cases and halls can be deduced from graphical analysis:

Different halls with different thermal mass , south hall : heavy mass(ground floor) , north hall : heavy mass (semi-udder ground) , 1st floor north hall : light mass .

Figure 4-18a presents comparison between each hall ACH value need to achieve specific air temperature to deduce the thermal mass effect on reduce air temperature beside the effect of natural ventilation all day and night ventilation.

The expected result the light mass need higher ACH value to decrease hall air temperature.

2015th exceptional year with hot month night ventilation little more effective or equal result.

2014th natural ventilation all day more effective.

South hall average air temperature reduced from 29.5°C to 23°C by 6.5 ac/h for stack ventilation.

North hall with heavy mass increase ACH 0.5ac/h decrease temperature between 1-1.5 °C degrees for cross ventilation adjacent windows.

1st floor north hall average air temperature reduce from 31°C to 26°C by 9.5 ac/h.

Each 1ACH decrease about 1°C air temperature for heavy mass hall

Each 2ACH decrease about 1.25°C air temperature for light mass hall **Figure 4-18-a**

Case night ventilation 2014th :

Heavy mass : south hall with min Temperature 23.7°C equal value of Light mass :1st floor north hall with higher max Temperature 2.5 °C degrees in spite of higher ACH about 1ac/h , light mass need more air flow than heavy mass to reduce air temperature .

North hall with heavy mass increase ACH 0.2ac/h decrease temperature about one °C degree for cross ventilation adjacent windows as **Figure 4-18-b.**

4.3.4 Summary.

Modeling result temperature T_{IN} / T_{OUT} diagram The use of controls is an important factor in explaining how thermal comfort indoors might be related to outdoor climate. Though the rate of change of indoor temperature with outdoor temperature is consistent among buildings, there is a noticeable difference in the mean indoor temperatures.
As expected, the night ventilation effect increases with the air flow change rate and decreases with the ambient temperature. (As swing day/night temperature differences are higher in summer, these measurements should not be extrapolated for higher summer ambient temperatures.
The study concluded that night ventilation is not as effective as full-day ventilation with low thermal conductance or little thermal inertia.

The good combination between ACH and thermal mass reduce the indoor temperature and gives more occupant comfort feeling.
Single side ‘stack’ ventilation has limit effect temperature, on other hand cross ventilation has more expend range than stack ventilation. the effective natural ventilation field between 25°C to 39/40°C out door temperatures above this range natural ventilation has reverse effect on indoor environment.

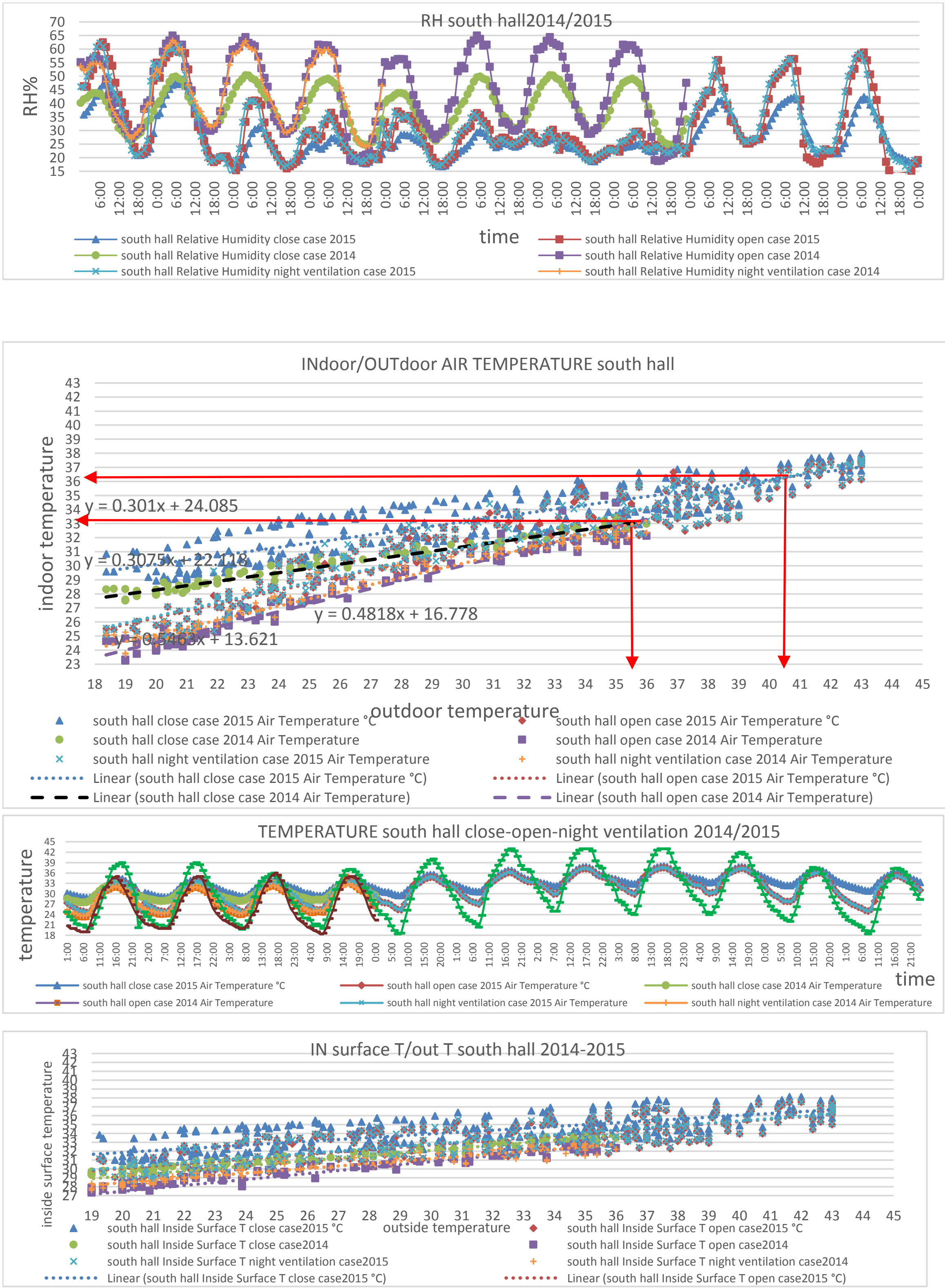
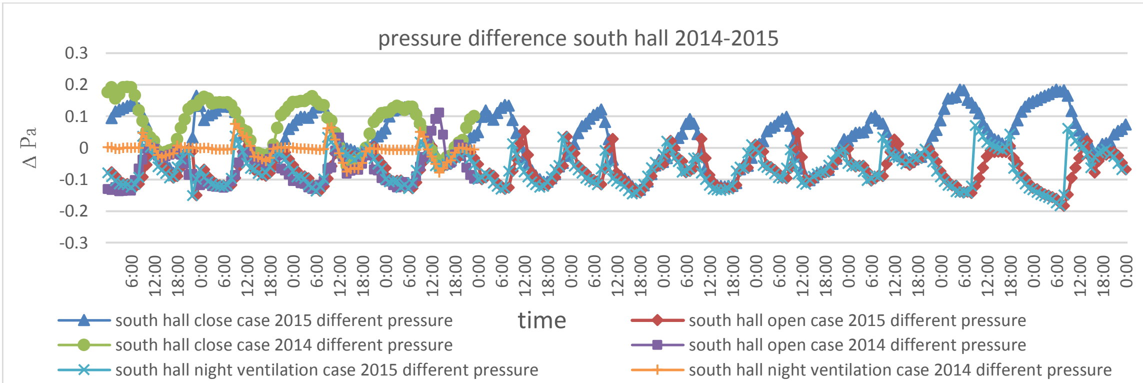
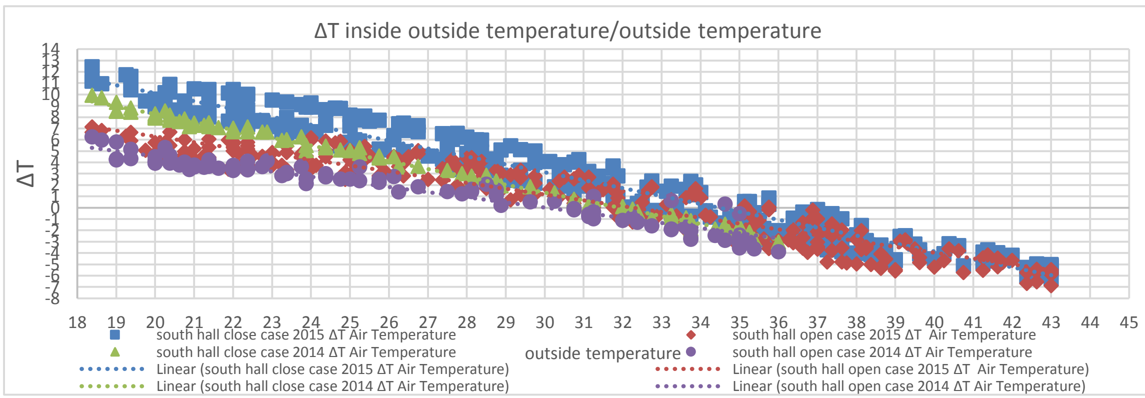
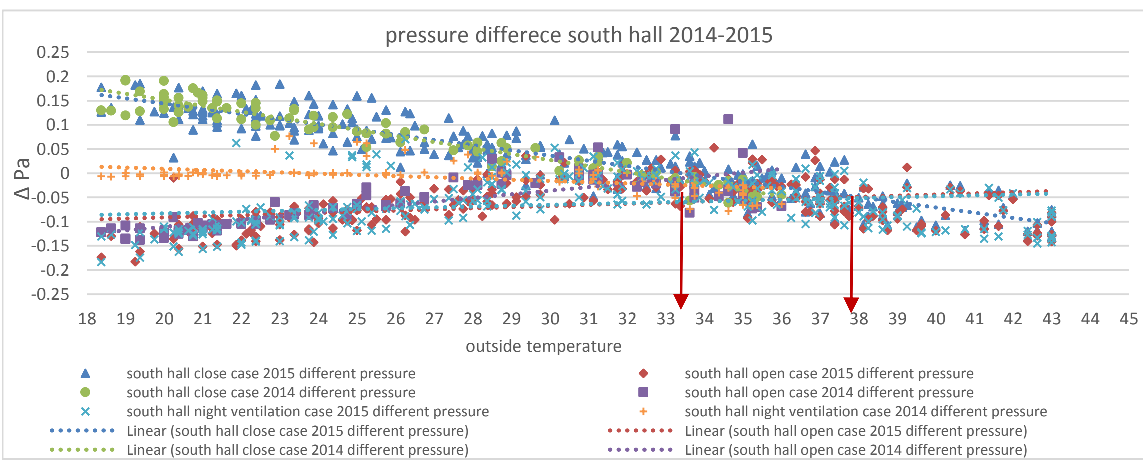


Figure 4-12: courtyard house ,south hall indoor/outdoor temperature ,RH,inside surface temperature/close ,open windows and night ventilation for years 2014/2015.







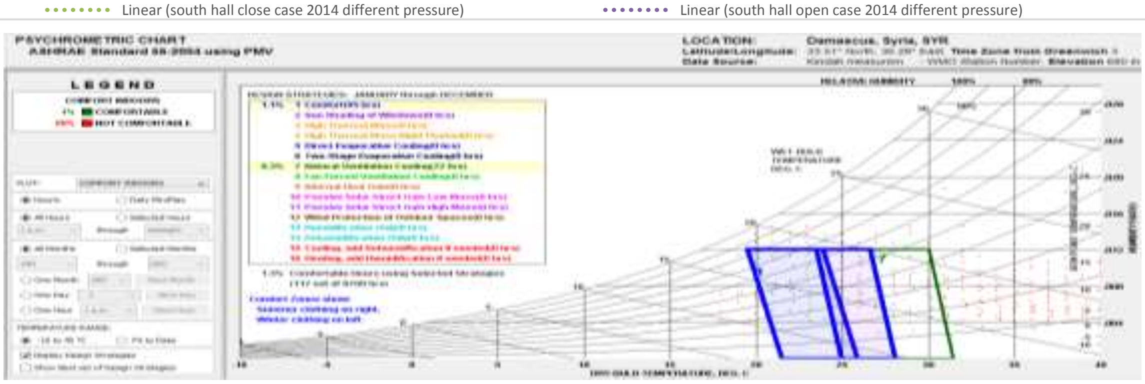


Figure 4-13: courtyard house ,south hall pressure difference indoor/outdoor for close ,open windows and night ventilation cases for years 2014/2015- climate consultant psychometric-chart.

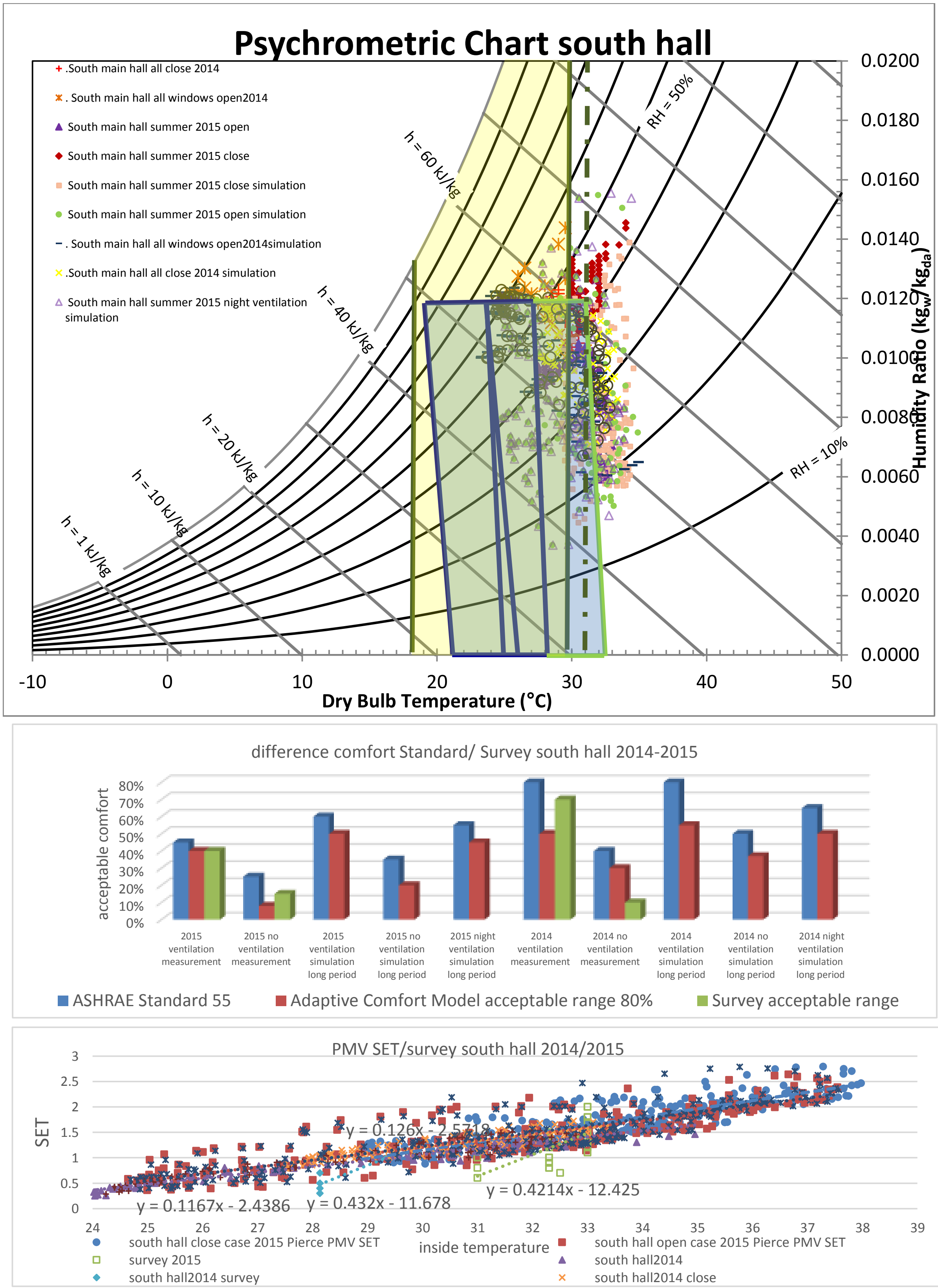


Figure 4-14: south hall thermal comfort by psychometric-chart ,adaptive ,survey,SET/open, close, windows and night ventilation for years 2014/2015.

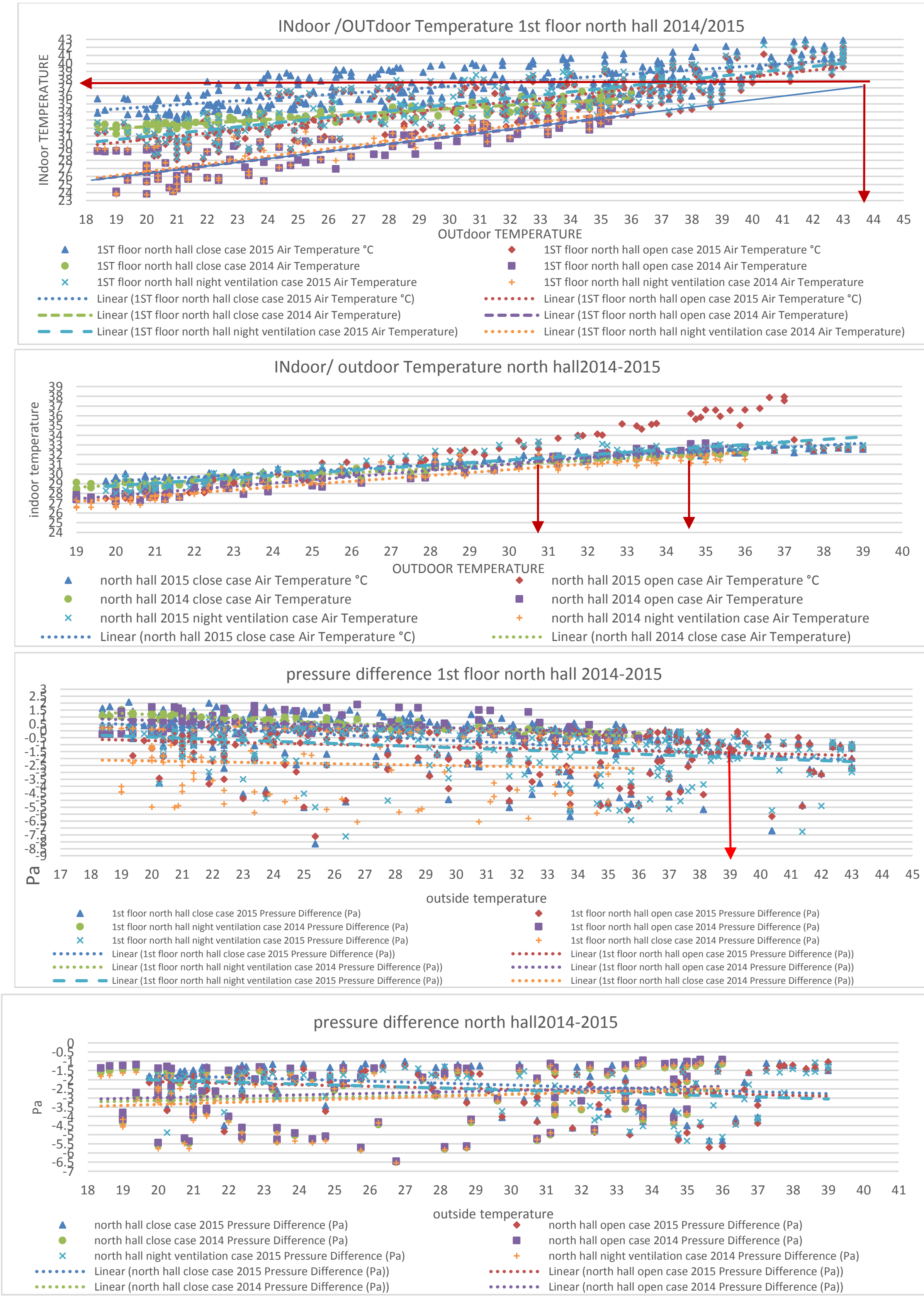
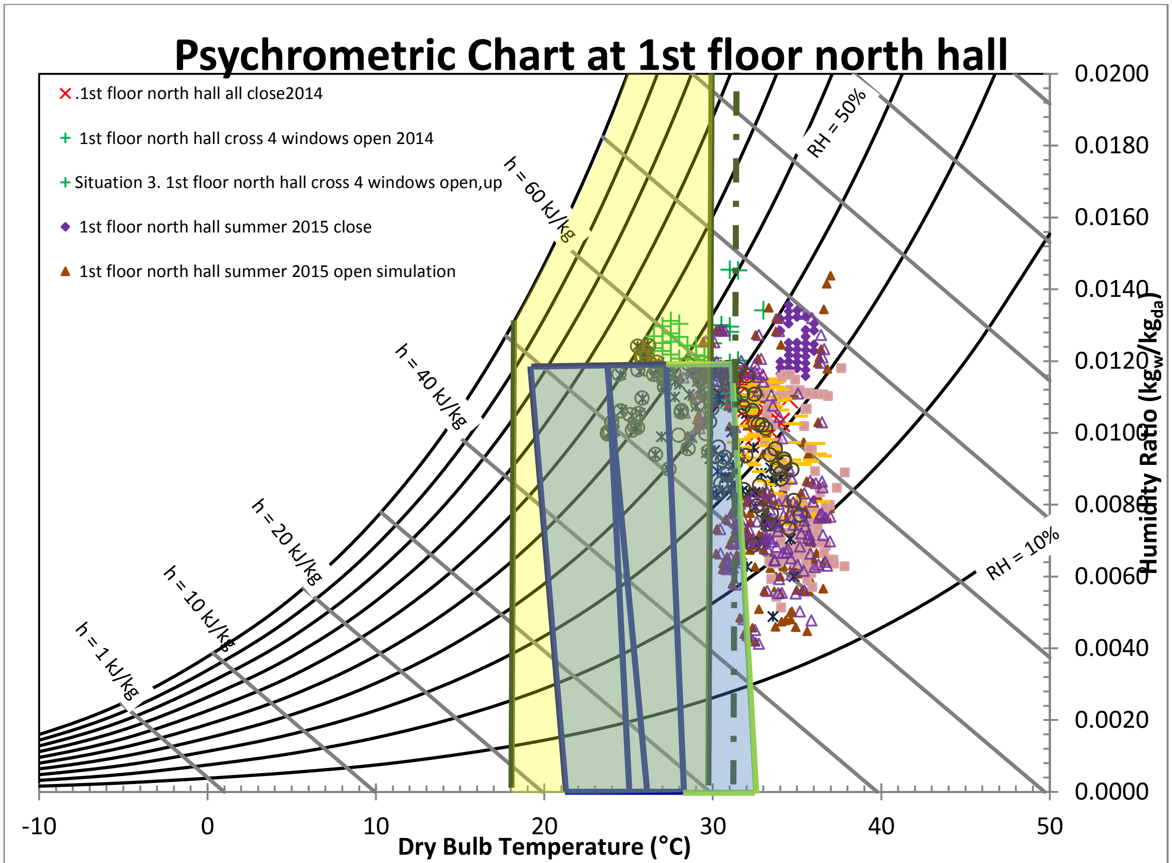


Figure 4-15: 1st floor north hall and north hall, pressure difference, indoor/ outdoor temperature.



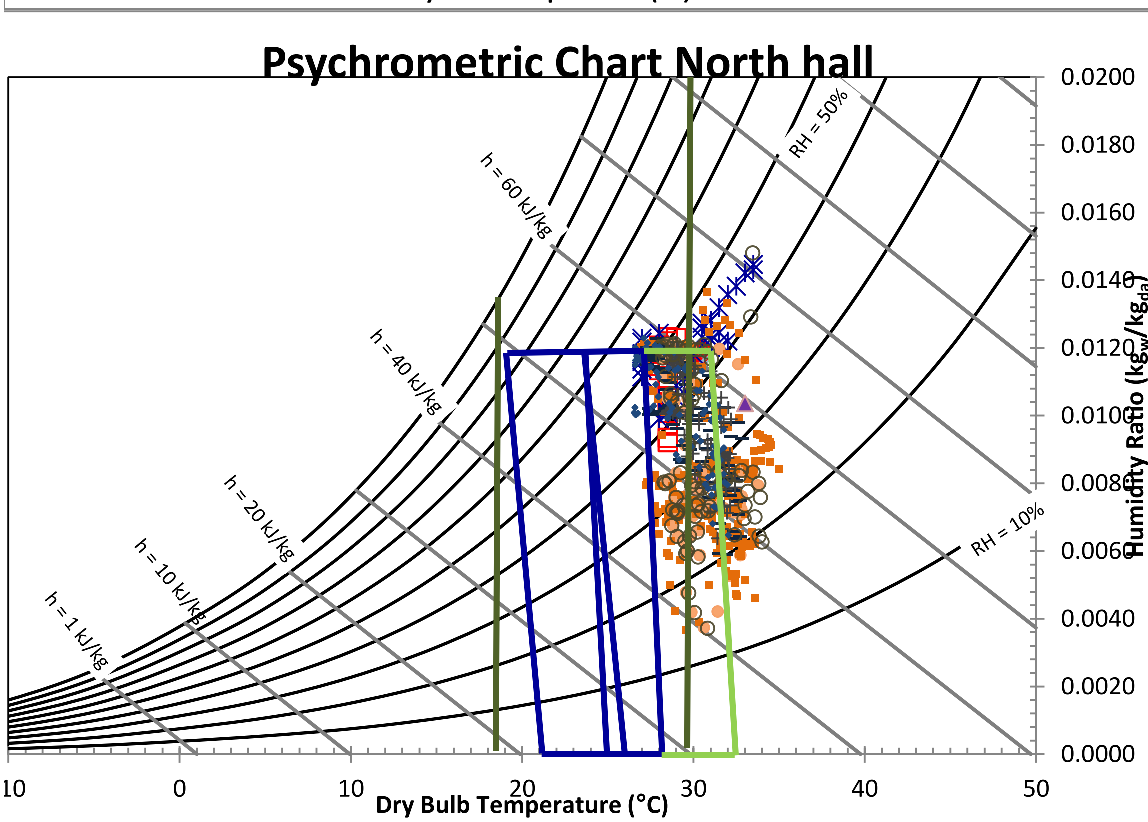


Figure 4-161st floor north hall, north hall comfort: psychometric-chart, Adaptive model ,ASHRAE55.

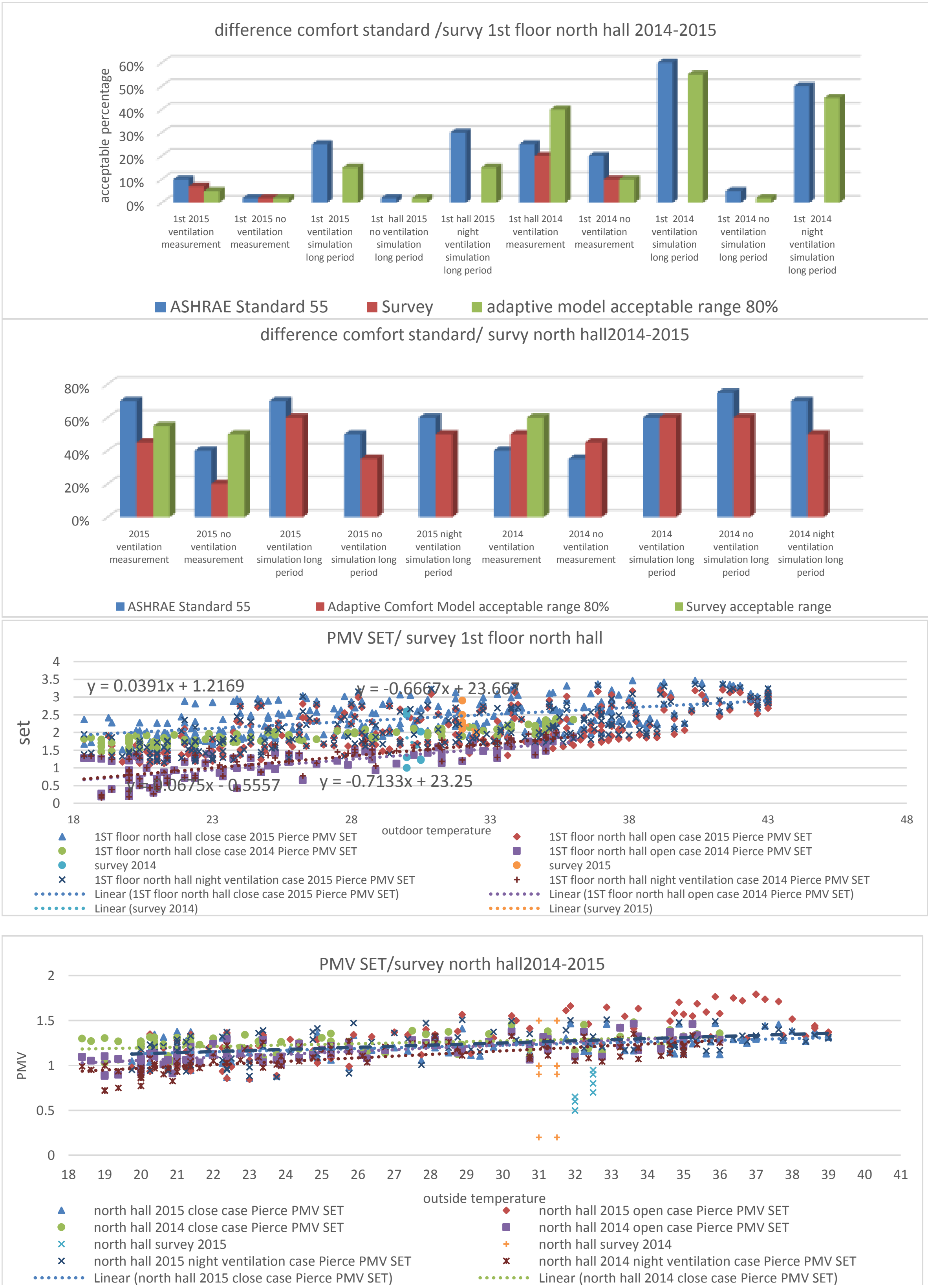
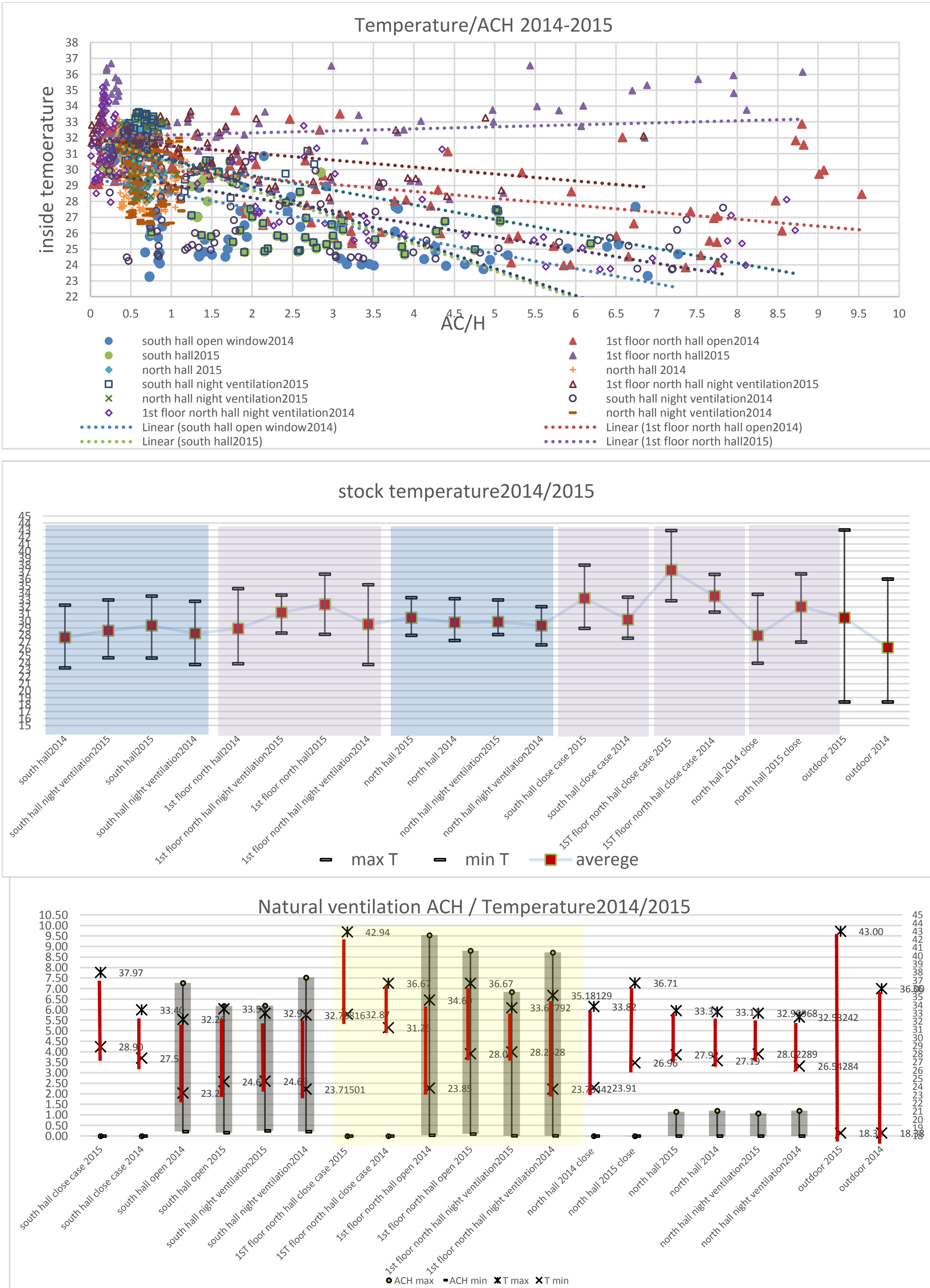
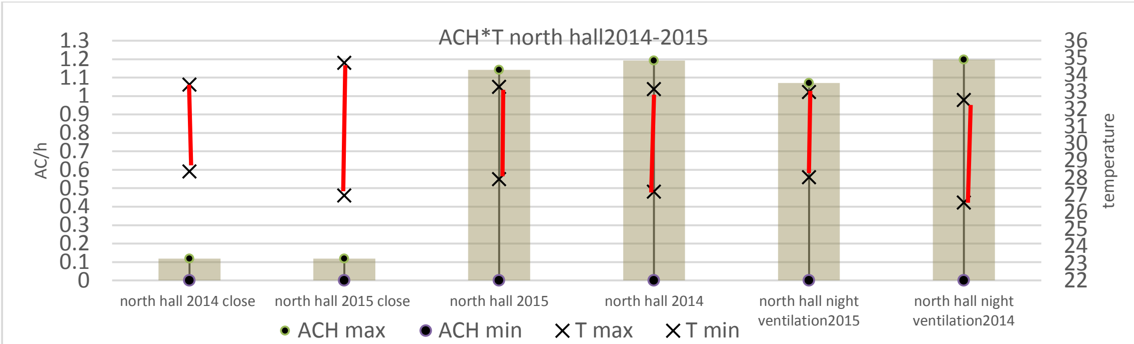


Figure 4-17: 1st floor north hall, north hall. Difference comfort standard ,and SET/survey open, close, windows and night ventilation for years 2014/2015.



,a. courtyard house all hall, thermal mass effect(inside surface temperature)/ minimum and maximum air temperature for years 2014/2015 and ACH effect to Max and Min T .



,b . north hall Min and Max temperature /ACH effect .

Figure 4-18 : courtyard house all halls, a. thermal mass (heavy/ground floor , light/ first floor)/ temperature /ACH effect ,b . north hall Min and Max temperature /ACH effect .

CHAPTER 5
VENTILATION: SIMULATION AND EFFECT ON COMFORT

5.1 Natural ventilation

An average normal person spends daily about 80% of his time indoors. Therefore, it is important to maintain focus on a good and healthy adapted indoor environment, in parallel with fossil energy saving and also increasing the use of the sustainable renewable energy technologies (such as wind and solar systems for natural ventilation). The local weather and climate conditions as well the houses' design and buildings materials play a very important role as natural variations in these technologies. On other hand the buildings requirements differs from an environment to another especially for the indoor qualities. In such case the architects in the ME countries had improved the use of natural delivered energies in their own homes since the beginnings of the history by the natural ventilation in their residential housings.
Natural ventilation include: 1) windows, doors, dormer (monitor) and skylights; 2) roof ventilators; 3) stacks; 4) inlet or outlet openings. This type of ventilation sets some requirements like room's depth, height and surroundings area of the fenestration.
Using only natural ventilation might be difficult to maintain constant and uniform comfortable indoor conditions, so long the outside weather conditions are often undesired changeable.
In the field of natural ventilation there are typically two types of ventilations: a) Cross Ventilation when openings and windows, located on different external walls, allowed the air to cross the room; b) Single Sided Ventilation when openings are only on one side of the façade of the building.

The driving forces in natural ventilation are caused by the differences of wind pressure and temperature (thermal buoyancy).

5.1.1 <u>Wind Pressure:</u>

The level of the velocity, air density and the direction of the wind, set the amount of air coming through the openings that create different pressure on the building. The wind make overpressure region (positive) at the windward side of the building and under pressure on the opposite part of the building at the leeward side (negative).

However, pressures on these side can be positive or negative depending on wind angle and building shape **Figure 5-1**.

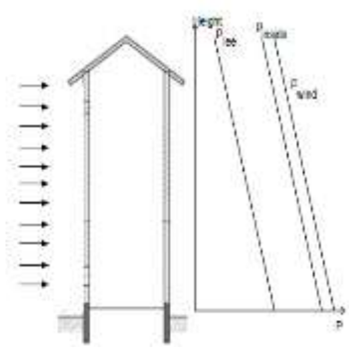


Figure 5-1: Wind pressure difference on building

$$P_w = C_P \rho \frac{U^2}{2}$$

Where
P_w= wind surface pressure relative to outdoor static pressure in undisturbed flow, Pa
$\rho =$ air density, kg/m3 (about 1.2 at or near sea level)
U = wind speed, m/s
C_P= wind surface pressure coefficient, dimensionless

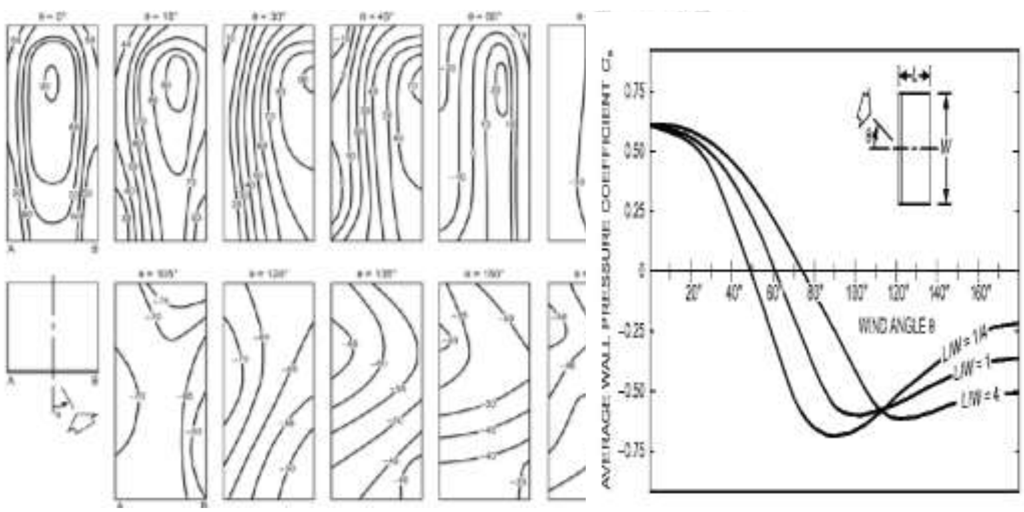
$$U = U_{mer}\left[\frac{\delta_{mer}}{H_{mer}}\right]^{\alpha_{mer}}\left[\frac{H}{\delta}\right]^{\alpha}$$

U wind speed at specific highest

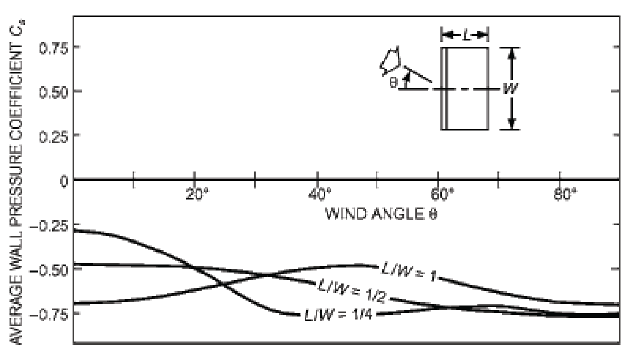
U_{met} is generally measured in flat, located at high H_{mer} and the other parameter (table 1)

C_P is a function of location, shapes and high of the building envelope, and wind direction. Many wind load codes (e.g., ASCE Standard ASCE/SEI 7-10, SA/SNZ Standard AS/NZS 1170.2) give mean pressure coefficients for common building shapes.

Figure 5-2 (a-b-c) shows pressure coefficients for walls of a tall rectangular cross section building (high-rise) sited in urban terrain (Davenport and Hui 1982).**Figure 5-3 (a-b)** shows pressure coefficients for walls of a low-rise building (Holmes 1986).

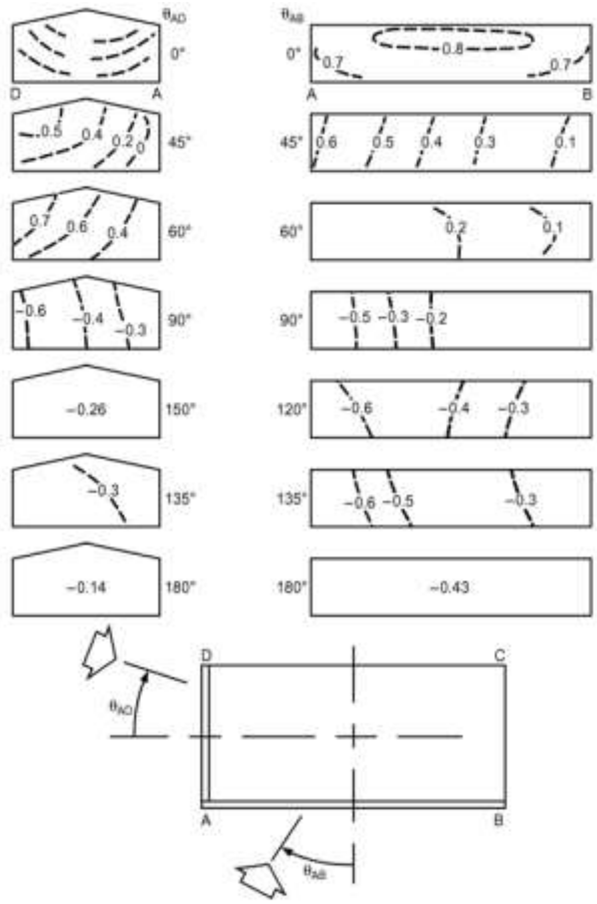


.a Local Pressure Coefficients (Cp* 100) for Tall Building with Varying Wind Direction
B. Surface-Averaged Wall Pressure Coefficients for Tall Buildings (Akins et al. 1979)



c. Surface-Averaged Roof Pressure Coefficients for Tall Buildings (Akins et al. 1979)

Figure 5-2: pressure coefficients .



A

Table 1 Atmospheric Boundary Layer Parameters

Terrain Category	Description	Exponent a	Layer Thickness δ, m
1	Large city centers, in which at least 50% of buildings are higher than 25 m, over a distance of at least 0.8 km or 10 times the height of the structure upwind, whichever is greater	0.33	460
2	Urban and suburban areas, wooded areas, or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger, over a distance of at least 460 m or 10 times the height of the structure upwind, whichever is greater	0.22	370
3	Open terrain with scattered obstructions having heights generally less than 9 m, including flat open country typical of meteorological station surroundings	0.14	270
4	Flat, unobstructed areas exposed to wind flowing over water for at least 1.6 km, over a distance of 460 m or 10 times the height of the structure inland, whichever is greater	0.10	210

b

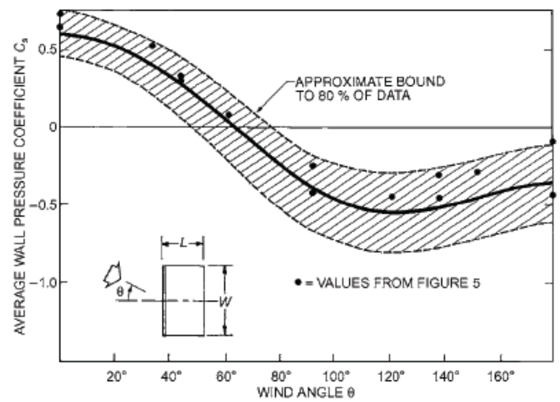


Figure 5-3: a. Local Pressure Coefficients for Walls of Low-Rise Building with Varying Wind Direction.

B. Variation of Surface-Averaged Wall Pressure Coefficients for Low-Rise Buildings Courtesy of Florida Solar Energy Center (Swami and Chandra 1987),**Table 5-1** atmosphere boundry.

The pressure difference between inside and outside of the building could calculate

$$\Delta P_w = C_P \rho \frac{U^2}{2} - P_i \quad P\text{i inside door pressure}$$

C degree	)	)0	80	70
Cp	.6	0.65	0.3	0.65

$$\Delta P_w = \Delta C_P \rho \frac{U^2}{2}$$

Table 5-1: Template for inserting tables

$$\Delta C_{P=} C_{P,out} - C_{p,in}$$

Where $C_{p,in}$ =-.02 (ASHRAE fundamental hand book).

5.1.2 Stack Pressure (thermal buoyancy):

The air pressure in this case depend on density and height of the interest point above a reference one. Air density is a function of local barometric pressure, temperature, and humidity ratio, as described

in psychometric charts (depending on thermodynamic equation) and of the relation between these parameters (pressure proportional with temperature and inversely with humidity).
The pressure difference is created by different densities in the warm and cold air, inside and outside a building through opening in wall. Either this pressure increased with the highest of the opening or between opening.
Assuming temperature and barometric pressure are constant over the height of the interest building, the stack pressure decreases linearly as the separation above the reference point increases. For a single column of air, the stack pressure can be calculated as

$$P_s = P_r - \rho g H$$

Where
Ps = stack pressure, Pa
Pr = stack pressure at reference height, Pa
g = gravitational acceleration, 9.81 m/s^2
ρ= indoor or outdoor air density, kg/m^3
H = height above reference plane, m

The building is characterised by an effective stack height and neutral pressure level (NPL) neutral pressure level (**Figure 5-4**). Neglecting vertical density gradients, the stack pressure difference for a horizontal leak at any vertical location is given by

$$\Delta P_s = (\rho_o - \rho_i) g (H_{NPL} - H)$$

$$\Delta P_s = \rho_o \left[\frac{T_i - T_o}{T_i}\right] g (H_{NPL} - H)$$

Where
To = outdoor temperature, K
Ti = indoor temperature, K
ρ o = outdoor air density, kg/m^3
ρ i = indoor air density, kg/m^3
*H*NPL = height of neutral pressure level above reference plane (without any other driving forces, m)

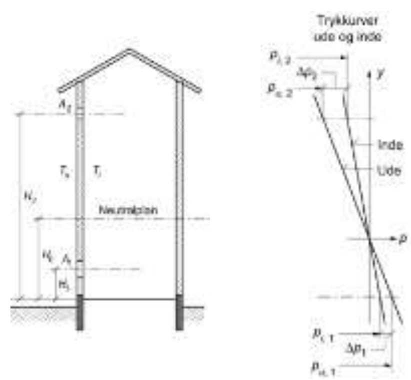


Figure 5-4: Pressure difference around the neutral plane in a building ventilated only by thermal buoyancy. /By og Byg 202/

Neutral Pressure Level:

The neutral pressure level (NPL) is that location in the building envelope where there is no indoor-to-outdoor pressure difference. **Figure 5-5**. qualitatively shows the addition of driving forces for a building with uniform openings above and below NPL and without significant internal resistance to airflow

Figure 5-5A, shows pressure differences caused by thermal forces (inside air warmer than outside) NPL is at mid high with inflow through the lower part of opening and outflow from the upper (flow direction from highest to lowest pressure region) .

Figure 5-5B, shows pressure differences due only by a wind, with opposing effects on windward and leeward side, so there is no NPL .

Figure 5-5C, shows combination of 5A and 5B with wind and thermal forces.

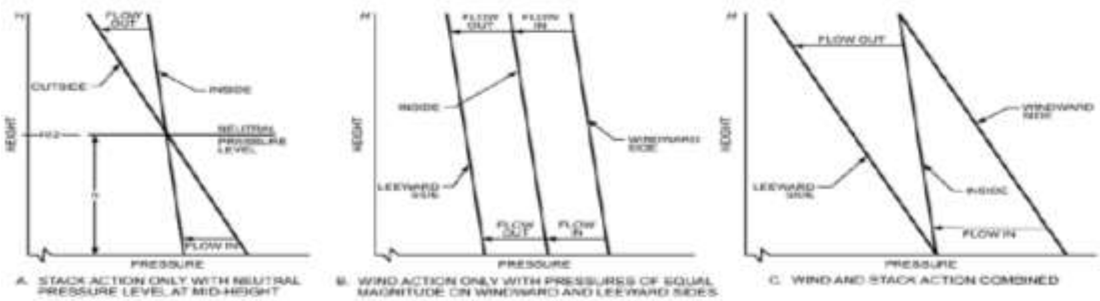


Figure 5-5: Distribution of Indoor and Outdoor Pressures over Height of Building

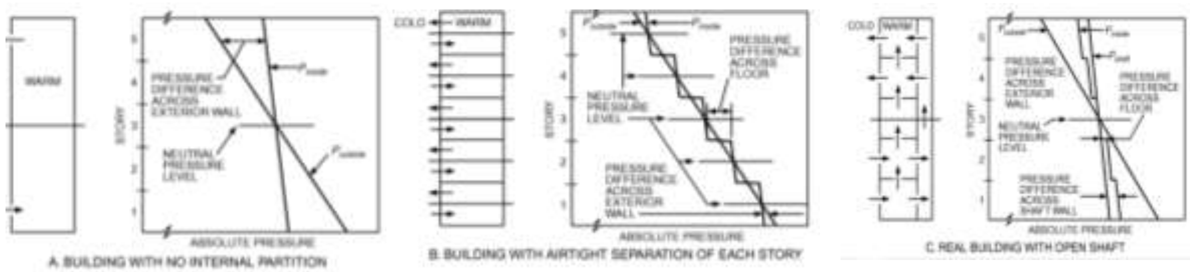


Figure 5-6: Compartmentation Effect in Buildings, Ashrae fundamental chapter16.

The relative importance of wind and stack pressures in a building depends on building height, internal resistance to vertical airflow, location and flow resistance characteristics of envelope openings, local terrain, and the immediate shielding of the building. The taller the building and the smaller its internal resistance to airflow, the stronger the stack effect.

Compartmentation of a building also affects the NPL location. The latest Equation provides a maximum stack pressure difference, given no internal airflow resistance. The sum of pressure differences across the exterior wall at the bottom and top of the building, The sum of actual top and bottom pressure differences, divided by the total theoretical draft pressure difference (**Figure 5-6**).

5.1.3 Combining wind and stack pressure effects:

Pressure differences caused by wind, stack effect, (and also effects of mechanical systems) are considered in combination by adding them together and then determining the resulting airflow rate through each building envelope.

For uniform indoor air temperatures, the total pressure difference across each leak can be written in terms of a reference wind parameter P_U and stack effect parameter P_T common to all leaks:

$P_U = P_0 \frac{U_H^2}{2}$

$P_T = gP_o[(T_i - T_o)/T_i]$

T is the temperature in K

The combined difference pressure into the building can be written as:

$\Delta P = s^2 C_P P_U + H P_T + \Delta P_i$

Where

s = shelter factor for the particular wind direction ϴ

ΔP_i =is the pressure that acts to balance inflows and outflows,

5.1.4 Air Flow caused by thermal forces (buoyancy):

The general form to calculate the air flow, that includes stack, wind pressure, across an opening (at different high, position or on one side wall) from the pressure difference, is:

$$Q = C_D A\sqrt{2\,\Delta P/\rho}$$

Where
Q = airflow rate, m^3/s
C_D = discharge coefficient for opening, dimensionless (0.6-0.75)
A = cross-sectional area of opening, m2
ρ = air density, kg/m^3
Δp = pressure difference across opening, Pa

If building internal resistance is not significant, flow caused by stack effect (thermal buoyancy) by single opening can be calculated as:

$$Q = C_D A\sqrt{2\,g\Delta H_{NPL}(T_i - T_o)/T_i}$$

Where
Q = airflow rate, m^3/s
C_D = discharge coefficient for opening
ΔH_{NPL} = height from midpoint of lower opening to NPL, m
T_i = indoor temperature, K
T_o = outdoor temperature, K

This equation applies when $Ti > To$. If $Ti < To$, reversed between T_i , T_o (T_o- T_i).
Estimation of ΔHNPL is difficult for naturally ventilated buildings. If one window or door represents a large fraction (approximately 90%) of the total opening area in the envelope, then the NPL is at the mid-height of that aperture, and HNPL equals one-half the height of the aperture. It could be also found from mass balance
$\sum ingoing\ air = \sum outgoing\ air.$

$$p_o Q_v = p_i Q_v$$

The coefficient C_D accounts for all viscous effects such as surface drag and interfacial mixing. The orifice coefficient can be calculated according to the following equation (Kiel and Wilson 1986):

$$C_D = 0.04 + 0.0045|T_i - T_o|$$

If enough other openings are available, airflow through the opening will be unidirectional, and mixing cannot occur. A discharge coefficient of C_D = 0.65 should then be used.

Greatest flow per unit area of opening occurred when inlet and outlet area are equal. Increasing the ratio between the two areas it will increases airflow but not in proportion to the add area: in this case, when the openings are not equal, the air flow Q is calculated from the latest equation using the smaller area and add the increases from **Figure 5-7**.

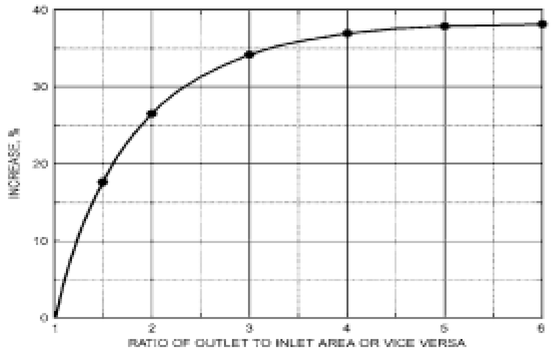


Figure 5-7: Increase in Flow Caused by Excess Area of One Opening over the other.

5.1.5 Air Flow Caused by Wind:

Aspects of wind that affect the ventilation rate include average speed, prevailing direction, seasonal and daily variation in speed and direction, and local obstructions such as nearby buildings, hills, trees. The rate of air forced through ventilation inlet openings by wind or in case to determine the proper size of openings to produce given airflow rates, can be calculated by the following equation:

$$Q = C_V A U$$

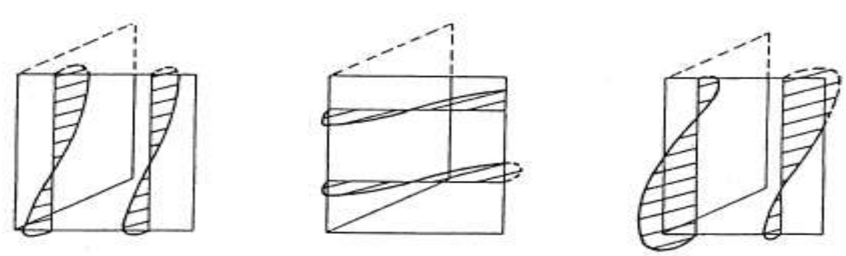
Where
Q = airflow rate, m^3/s
Cv = effectiveness of openings (Cv is assumed to be 0.5 to 0.6 for perpendicular winds and 0.25 to 0.35 for diagonal winds)
A = free area of inlet openings, m^2
U = wind speed, m/s

5.1.6 Air Flow Caused by Wind and Thermal forces (buoyancy):

The total ventilation rate calculated by this model is quadrature sum of the wind and thermal forces (stack) air flow component (as simulation program calculate in Figure 5.8):

$$Q = \sqrt{Q_W^2 + Q_S^2}$$

Q_W =air flow rate caused by wind m^3/s.
Q_s =air flow rate caused by thermal forces (stack) m^3/s.



Thermal forces wind combination

Figure 5-8: flow patterns through opening in single –sided ventilation

5.1.7 Air exchange Rate :

The air exchange rate / compares air flow to volume:

$I = Q/V$

Where
Q = volumetric flow rate of air into space, m^3/s
V = interior volume of space, m^3

The air exchange rate has units of 1/time, usually h–1. When the time unit is hours, the air exchange rate is also called air changes per hour (ACH). The air exchange rate may be defined for several different situations.

5.1.8 Energy transfer by ventilation:

Air exchange increasing the thermal load of building in several way. When the air flows into the building it must be heated or cooled from the outside temperature, the heating transfer can be calculated as:

$$Q_{VENT} = Q\rho C_p \Delta t$$

Where
Q_{VENT} = sensible energy transfer, W
Q = airflow rate, m^3/s
ρ = air density, kg/m^3 (about 1.2 at or near sea level)
c_p = specific heat of air, J/(kg·K) (about 1000)
ΔT = temperature difference between indoors and outdoors, K

With the air density near the sea, adjustment for typical room humidity it will be come:

$$Q_{VENT} = 1230 Q\Delta t$$

Air exchange also change the moisture of the building air, the energy consumption will be:

$$Q_{VENT} = Q\rho\Delta W(2501 + 1.805t)$$

Where
Q_{VENT} = latent energy transfer, W
Q = airflow rate, m3/s
ρ = air density, kg/m3 (about 1.2 at or near sea level)
c_p = specific heat of air, J/(kg·K) (about 1000)
ΔW =humidity rate difference between outdoor and indoor kg/kg
ΔT= temperature difference between indoors and outdoors, K

Conclusion:

There are many theoretical ways to calculate natural ventilation, with simplified models (as cited before) or detailed (CFD). In both cases , when the air flow is calculated, many parameters are needed to take in account: velocity, direction, pressure and turbulence of wind, temperature difference , opening area and position, shape of building and surrounding.

The problem is to determinate the coefficient C_p , C_D, C_v, since this parameters depend on the shape of the building and the orientation , shape of the opening ,and incidence angle of the wind that is not always possible to calculate them to get an accurate estimation .

5.1.9 Simulation of Natural Ventilation with Energy Plus:

The wind and stuck ventilation models in Energy Plus Software (and Design Builder) are based on equations defined at chapter 16 of ASHRAE 2009 handbook fundamental .

These two models could be used each one alone or in combination to determine the ventilation air for each zone of the building.

5.1.9.1 *Ventilation design flow rate:*

This model define the flow of the air from outdoor environment directly into the thermal zone.

The actual flow rate is calculated, according to schedule at each time step, as a function of temperature difference from inside to outside environment and the wind speed :

Ventilation Rate = $(V_{design})(F_{schedule})[A + B| T_{zone} - T_{odb} | + C(_{WindSpeed}) + D(_{WindSpeed2})]$

More advanced ventilation calculation could be made by using Air Flow Network Model

- One node displacement ventilation air model

Modeling the temperature near the floor surface (Mundt model). The slope of a linear temperature gradient can then be obtained by adding a second upper air temperature value that comes from the usual overall air system heat balance (**Figure 5-9**).

$$pC_pV(T_{air\ floor} - T_{supply}) = h_{Cfloor}A_{floor}(T_{floor} - T_{air\ floor}) + Q_{conv\ sourse\ floor} + Q_{infil\ floor}$$

Where

ρ is the air density

cp is the air specific heat at constant pressure

V is the air system Volume

T_{supply} is the air system's supply drybulb temperature

h_{cFloor} is the convection heat transfer coefficient for the floor

A_{floor} is the surface area of the floor

T_{floor} is the surface temperature of the floor

$Q_{convSourceFloor}$ is the convection heat transfer from internal sources near the floor (< 0.2 m)

$Q_{InfilFloor}$ is the heat gain (or loss) from infiltration or ventilation near the floor

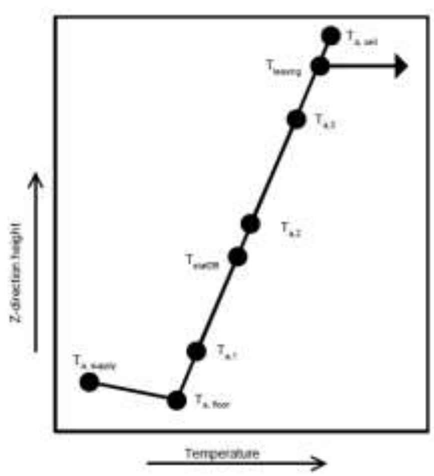


Figure 5-9: Height versus temperature schematic for Mundt model .The constant slope allows to obtain temperature values at any vertical location (Energy Plus engineering references).

- Three node displacement ventilation air model

The model is suitable for heat transfer and vertical temperature profile prediction in displacement ventilation.

The fully-mixed room air approximation that is currently used in most whole building analysis tools is extended to a three node approach, with the purpose of obtaining a first order precision model for vertical temperature profiles in displacement ventilation systems. The use of three nodes allows for greatly improved prediction of thermal comfort and overall building energy performance in low energy cooling strategies that make use of unmixed stratified ventilation flows.

This model predicts three temperatures that are characteristics of the three main levels in the stratification of the room:

1. a floor level temperature T_{floor} to account for the heat transfer from the floor into the air supply;
2. an occupied subzone temperature T_{oc} representing the temperature of the occupied region.
3. an upper level temperature T_{mx} representing the temperature of the upper, mixed region and the outflow temperature.

The supply air flow rate is obtained by summing all the air flows entering the zone: supply air, infiltration, ventilation, and inter-zone flow. The heat gain is estimated by summing all the convective internal gains. The last two models are useful to calculate the parameters for thermal comfort: SET, ET.

5.1.9.2 *<u>Ventilation by Wind and Stack:</u>*

In this model the ventilation air flow is function of wind speed and stack effect. The air flow rate could be controlled by schedule. The equations used to calculate ventilation driven by wind is given by chapter 16 ASHRAE hand book.

5.1.9.2.1 Air exchange:

The mixing air flow is only used for the energy and mass balance for the receiving zone.

5.1.9.2.2 Cross Ventilation Model:

The model distinguishes two regions in the room, the main jet region and the recirculation region, where it predicts characteristic airflow velocities and average air temperatures.

Cross ventilation always occur by wind driven with inflow through the operable opening.

As the ventilation cross the room, heat transfer between air flow and room surface, and internal lods causes the airflow temperature change between inlet and outlet (**Figure 5-10**).

The heat transfer between air flow and room surface is important not only for energy conservation but also for passive cooling design, specially for night cooling effect.

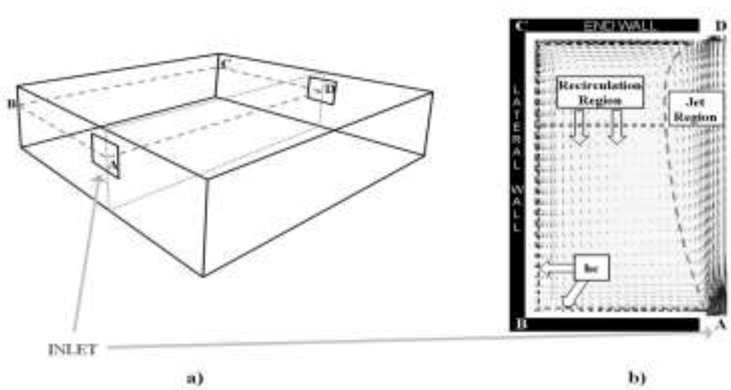


Figure 5-10: Schematic representation of room air geometry a) schematic representation of a room geometry that generates cross ventilation airflow. b) The proposed model distinguishes two

regions in the flow: jet and recirculation (shown here in a CFD simulation of one half of a symmetrical room).energy plus engineering references.

- Recirculating flow

Cross ventilation presents two possibility for airflow, with or without circulation (**Figure 5-11**).
Without circulation is a case that commonly occur at corridor and long space whose inlet opening area equal to the room cross -sectional area.
More complicated airflow occurs when the inlet opening area is smaller than the room cross sectional area. In this case the main cross ventilation region is at the core of the room, while the air from the adjacent regions forms recirculations that ensure mass conservation, with air moving in the opposite direction to the core jet flow.
The contact between the room surface and airflow occurs in the recirculation regions. So the air change his temperature due to convective heat transfer with different part of internal room surfaces (wall, floor, ceiling, furniture,..). **Figure 5-12** explains differences between flat plate heat transfer, and how the air temperature change along the flow (depending on the local ventilation rate in different part of the room volume).

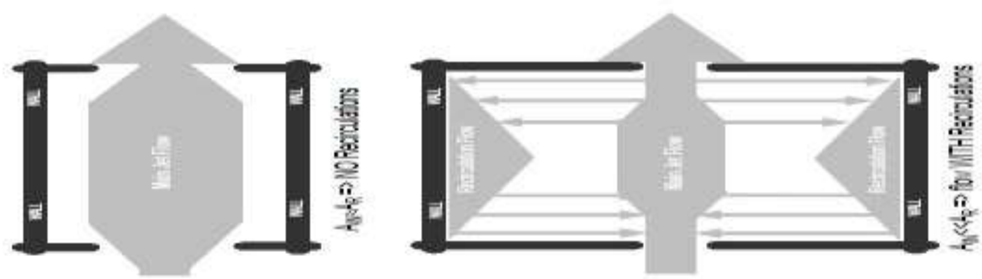


Figure 5-11: p View of the possible airflow patterns in cross-ventilation., energy plus engineering references.

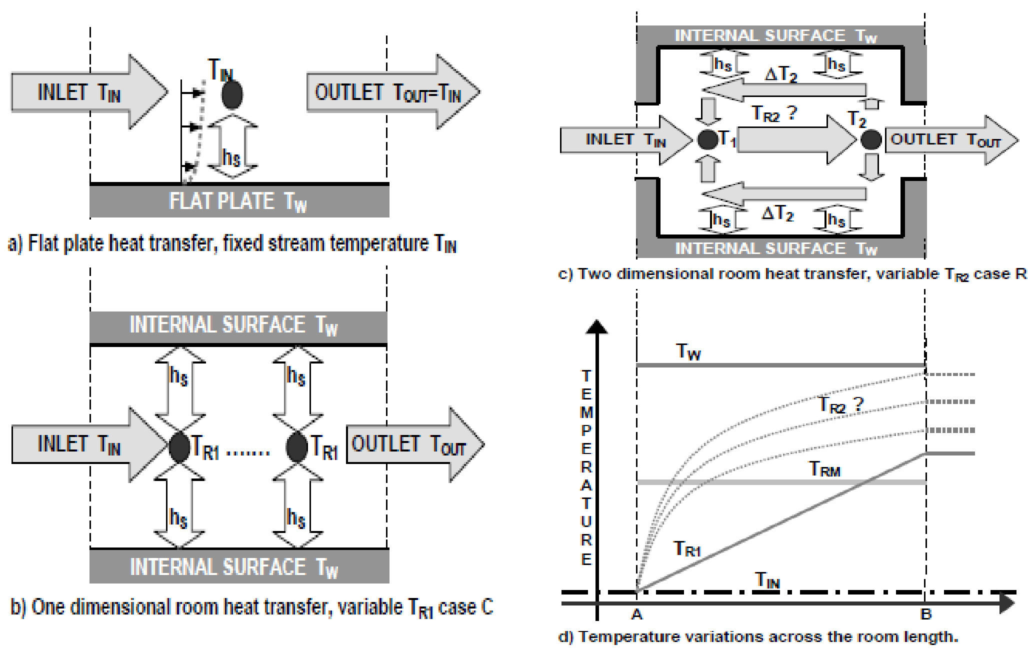


Figure 5-12: Differences between flat plate heat transfer and cross ventilation flow., energy plus engineering references.

In one–node model the room temperature is assumed constant, whenever fully mixing mod
3el is not perfect. The differences between CFD simulations of recirculating flows with a fixed heat source in the recirculation region and mixed model predictions can reach 1.5°C (Carrilho da Graça 2003). Confinement effects due to recirculation flow are also very influential in internal surface heat transfer predictions where using a perfectly mixed flow.

When designer have to analyses multi room ventilation, special for existing building and need to simulate using local measurements for several day or months, the use of CFD is impractical and simpler heat transfer models are needed. Zonal models simulate room heat transfer by numerically solving for mass and energy conservation in a set of fully mixed zones, which require the identification of the dominant airflow of the room. These features make these models complex to use and often imprecise.

5.1.9.2.3 Model:

The model used for calculation heat transfer and thermal comfort parameters, considers two components of the cross ventilation: the airflow pattern and the magnitude of the local heat transfer between room air and internal surfaces (partition elements, occupants, etc.).

- Airflow pattern

The cross ventilation flows to which the model applies are bounded by a stationary geometry and are dominated by horizontal momentum flux; all the velocities in the room are expected to scale linearly with the characteristic velocity of the inlet flow (Carrilho da Graça 2003)]:

$$U_R = C_n f\left(L, W, H, A_{IN,\ldots}\right) U_{IN}$$

Where:
U_R: averaged velocity in a given region of the room that is being modeled (m/s).
C_n: constant
f: correlation function. Depend on L,W, H, A.
L: room non-dimensional length ratio.
W: Room width (m).
H: high of room (m).
A_{IN}: inlet area (m^2).
U_{IN}: inlet average velocity (m/s)

The velocity scale (U_{IN}) of the inlet jet is defined using inflow momentum flux:

$$M = \int_{A_{IN}} p\left(U_{MAX} g(r)\right)^2 dA \quad , U_{IN} = \sqrt{M/\rho A_{IN}}$$

Where:
M: Momentum flux (N or J/m).
ρ: Air density (Kg/m3).
g gravity.
r: Non-dimensional recirculation flow ratio.
A_{IN}: Inlet area (m^2).
A: area (m^2).

From the scaling principle behind the correlations: the momentum flux through the inlet aperture is the dominant feature in the cross ventilation flow.

$$U_R = C_M \frac{\sqrt{A_{IN}}\, L}{A_R} U_{IN}^2$$

Where:
U_R: averaged velocity in a given region of the room that is being modeled (m/s).
A_{IN}: Inlet area (m2).
U in average velocity inlet
A_R: Room cross section area (m^2)
L: room non-dimensional length ratio.

The maximum airflow rate in the recirculation region defines the heat capacity of the recirculating airflow and the average airflow velocity near the internal partitions is correlated to the forced convection heat transfer.

The average recirculating flow velocity in the room cross section with maximum flow rate is predicted using the following expression ($1/3<C_L<11$):

$$U_R = C_M \sqrt{\frac{L}{A_R . A_{IN}^{3/2}}} F_{IN} . C_R = \left\{ \frac{0.298, 1/3 \leq C_L \leq 4}{0.162, 4 < C_L \leq 11} \right\}$$

Where:
U_R: averaged velocity in a given region of the room that is being modeled (m/s).
A_{IN}: inlet area (m2).
C_L: non-dimensional room aspect ratio (expression 1.18, chapter 1).
L: room non-dimensional length ratio.
F: ventilation airflow rate (m^3/s).
A_R: room cross section area (m^2)

Jet Region Average Velocity
Average volumetric velocity in the main jet region is given by ($1/3<C_L<11$):

$$U_J = 1.56 \frac{F_{IN}}{\sqrt{A_R . A_{IN}}}, 1/3 \leq C_L \leq 11$$

Where:
U_J: average velocity in the room volume occupied by inlet jet flow (m/s).
C_L: Non-dimensional room aspect ratio (expression 1.18, chapter 1).
F: Ventilation airflow rate (m^3/s).
A_R: Room cross section area (m2)
A_{IN}: Inlet area (m^2).

Total airflow rate in the recirculation regions:
The total volumetric flow rate of the recirculation region of the room airflow is given by ($1/3<C_L<11$)

$$F_R = C_F \sqrt{\frac{L \; A_R}{A_{IN}^{3/2}}} . F_{IN} \quad , \quad C_F = \begin{cases} 0.147 \, , \; 1/3 \leq C_L \leq 4 \\ 0.077 \, , \; 4 < C_L \leq 11 \end{cases}$$

Where:
U_J: average velocity in the room volume occupied by inlet jet flow (m/s).
C_L: Non-dimensional room aspect ratio (expression 1.18, chapter 1).
F_R: flow rate in the recirculation region (m^3/s).
Fin: Ventilation airflow rate inlet (m^3/s).
A_R: Room cross section area (m^2)
A_{IN}: Inlet area (m^2).

- Force convection

Through the cross ventilation the natural convection always occurs when there is a temperature difference between the air and a surface: room heat transfer always occurs through mixed convection.
Air enters the room in a developing jet composed of two shear layers that quickly become turbulent. Part of the air in the shear layers goes into the recirculation regions forming the wall jets, or wall currents that

exist in these regions. Colburn's analogy between heat and momentum transfers (Bejan 1994) is used to estimate the forced component of the convection heat transfer, resulting in:

$$h_F = \rho c_p U_\infty P_r^{-\frac{2}{3}} \tfrac{1}{2} C_{fx} = \rho c_p U_\infty^{\frac{4}{5}} P_r^{-\frac{2}{3}} 0.0296 \left(\frac{x}{\nu}\right)^{-\frac{1}{5}}$$

Where:
U: average velocity in the room volume occupied by inlet jet flow (m/s).
h_F: Surface averaged forced convection heat transfer coefficient.
ρ: Air density (Kg/m^3).
Cp: Heat capacity of the air at constant pressure (J/(Kg.K)).
x: Coordinate along the length of the boundary layer.
P_r :Prandtl number

- Heat transfer in recirculating flows

The mixing between recirculation and inflow jet is only partial (**Figure 5-13**). The flow is divided into three distinct streams with connected temperature variations:
-The main jet (labeled J in the figure).
-The part of the recirculation flow that exchanges heat with the jet (label R).
-The wall boundary layer part of the recirculation flow (label W).

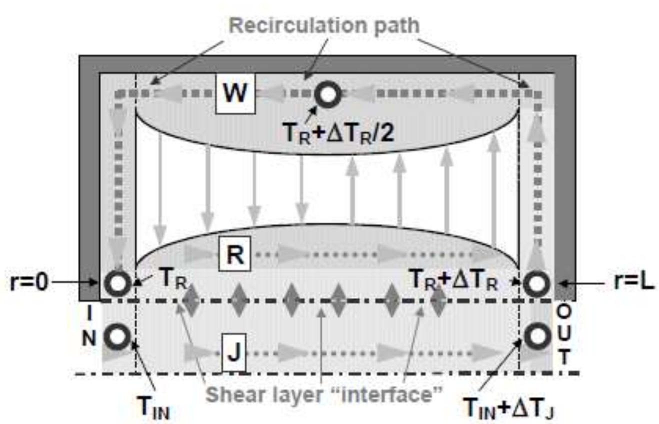


Figure 5-13: Top view of the flow structure in case R.. The light gray arrows show flow direction. The dark gray arrows show heat transfer in the shear layer. The recirculation region coordinate system is shown in the figure, with coordinate varying between 0 and L..

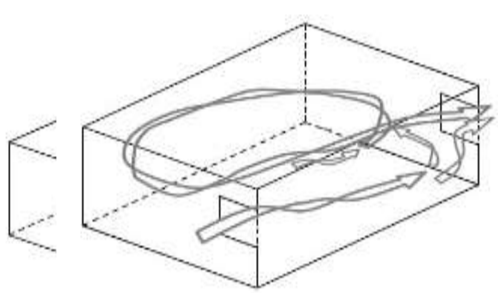


Figure 5-14: Left Schematic View - Room airflow dominated by jet. Right . Schematic - Room airflow -- a combination of jet and recirculation flow.

To predict the air temperature in the recirculating region air flow it depends on three point models heat transfer in the wall layer, the temperature variation of the portion of the recirculation flow that is in contact

with the jet region, the temperature variation recirculation region is symmetric to variation in temperature at jet region .
The temperature in the recirculation is inversely proportional to the recirculation flow ratio (R) (Combined effects of surface heat transfer and internal gains in the recirculation region). For The heat gain it is sum of two models the heat gain in jet region, the heat gain in the recirculation region (depend on temperature and heat transfer, internal gain)

Conclusion:
The model predicts representative air temperatures and airflow velocities in two regions of the flow: jet and recirculations. In addition a set of flow pattern related parameters are also predicted such as type of flow pattern (with or without recirculations), room length along the cross ventilation direction, inflow aperture area, and, for flow with recirculations the ratio between recirculation and inflow rate (**Figure 5-14**).

Structure:
The calculation routine follows the following steps sequentially in every time step:
1) Identify the dominant aperture and obtain its area, width and inflow velocity.
2) Calculate room length and cross sectional area.
3) Check whether recirculations are present in the flow, evaluate parameter.
4) Predict relevant flow characteristics.
5) If recirculations are present and all CV flow criteria are met, calculate recirculation flow temperature and surface mixed convection heat transfer coefficients.
6) Calculate jet region temperatures.

5.2 Integrate Investigation

Chapter 3,4 provides a first evaluation of the thermal behavior of all day natural ventilation and the night ventilation effects. In the following Sections experimental data are applied on the Energy model of courtyard building in order to investigate the effects of traditional natural ventilation (single side stack ventilation, cross ventilation). The method gives strategies (like passive cooling technique) to be applied in new contexts for new apartments.
Traditional house design created a microclimate environment through opening halls to inside part “courtyard“ and closed hall to outside part “outdoor condition“, through urban compact planning that protect and decrease outdoor environment direct effect and create indoor environment more steady (reduce swing).
Courtyard behaves like an environment filter by creating comfort indoor environment .

<u>Solar incident ;</u>

The solar incident has high value for west façade, then east the lower value for north façade as normal as shown at **Figure 5-15**

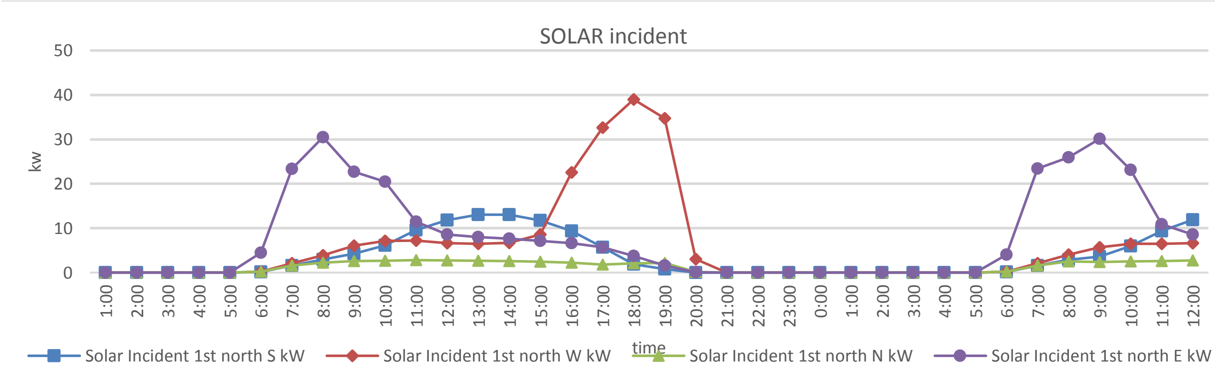


Figure 5-15: solar incident at all façade directions.

5.2.1 Single side Stack Ventilation

5.2.1.1 *Model case study*

South hall ventilation depend on single side' stack' ventilation , for more explanation about stack behavior, have done more simulation to deduce the effective area and percentage .

South hall has north façade consist of thirteen windows divided for two levels under level with six windows and upper levels with seven windows.

North façade divided for five vertical part start from opaque part then window by alternate configuration. Façade area divide to 40% window and 60% opaque. The vertical distribution as follow : 8% opaque , 25% window, 25% opaque ,25% window , 17% opaque .

The investigation depend on different distribution of opening area with different levels as specific table

The investigation include twenty-six different cases for different opening area and position, this investigation merge with measurements of summer 2014th.

The results from modeling simulation match the measurements accurately at each time step for July and August 2014th. As the simulation program which deals with many input parameters. This model presents a good agreement between measurement and simulation.

5.2.1.1.1 The first investigation:

This step to discover the air flow and reflection on temperature behavior in hall space as monitoring and sensor position depend on difference at opening area and position also orientation.

Original south hall: the investigation followed the **Table 5-2** cases. Started from 0% opening till 40% opening at north façade for two windows levels.

Table 5-2 present the opening area percentage for each levels and total opening area.

Result:

- Air temperature

Figure 5-16 presents expected behavior as the best result for thirteen windows open , the air temperature decreases at night about 4 °C degrees and at the hot peak of after midday about one °C degree .
The best result for ten windows opening cases: the opening area position four windows down level and six windows up level.
The best result for eight windows opening cases: the case of two windows down level and six windows up level also equal area divided between up and down.
The best result for six windows opening cases: the opening area position two windows down level and four windows up level.
There isn't any different behavior between opening area position at the same level. Comparison between opening area percentage and air temperature result observe from previous **Figure 5-16**
Ten windows case [six up level and four down level] air temperature result equal to the result of eight windows case [2 windows down level and 6 windows up level] .
That means 25% opening and 31% opening have given same result if they have same up level opening percentage roughly 19% .

Six windows case [six down level] air temperature result equal the result of 3 windows case their position [1 window down level and two windows up level].
Four windows case [four down level] air temperature result equal the result of two windows [1 window down level and 1 window up level].
Six windows case[four down level and 2 up level] air temperature result equal the result of 5 windows case [2 windows down level and 3 windows up level].
- Best natural ventilation influence for over 20% façade opening percentage: up level opening about 70% and down level opening about 30% of total opening area.
- Best natural ventilation influence for under 20% façade opening percentage: up level opening about 60-65% and down level opening percentage about 40-35% **Figure 5-16** presents latest result.

- Inside surface temperature

Natural ventilation influence appears clearly on the inside surface temperature **Figure 5-16** shows the big time shift beside the natural ventilation for all day influence on surface temperature specially for 13 opening windows during day and night , the effect about 4 °C degrees at night time and 1 °C degree at peak of midday.

- Air flow

previous result depend on air flow and air change which is the main factor to loss surface the heat gain get it during day Appendix E1 .
The relation between inside temperature and air change shown at **Figure 5-17**.
The highest ac/h for only one level opening[down level]caused by the air flow from outside [without stack effect calculate inside hall] .On other hand with high air change value the minimum average for air temperature value higher than other cases with equal opening percentage .
The influence of opening areas on air temperature present at **Figure 5-17**.all cases have roughly equal max air temperature except the high percentage of opening, the minimum air temperature proportion with opening percentage specially with high percentage for upper level opening . Deduced from previous **Figure 5-17** single stack ventilation achieve lower temperature with lower ACH than ordinary opening only down level.
Normal opening design (that has one level of windows has equal air temperature results for utilizing single side (stack) ventilation but with reducing opening about 50% [Single stack ventilation with 6.2% opening

(3.4% down level opening , 2.6% up level opening) : max Temperature 33°C , min Temperature 26 °C for ACH 7.4 ac/h.
Normal opening with 13.6% opening (all opening at down level) : max Temperature 33°C , min Temperature 26 °C for ACH 9.7ac/h].
On other hand, this result depend also on thermal mass and the behavior of heavy mass properties.
[Factor reduction (attenuation) 0.08, Delay factor reduction (offset) 10.26 h, Periodic thermal transmittance0.095 [W/m2K]].
This result related to different pressure surface between inside and outside [Appendix E1] present the positive value for down opening only but for stack ventilation the air flow out value higher than air flow in special at lower outside temperature , this result concern the high effect for stack ventilation air flow .
Specific case when up opening 75% from total opening and down opening 25% from total opening area.

- Thermal comfort

PMV/ SET scale result present the same result as all previous parameters **Figure 5-17** shows the reflect of air temperature and air flow on occupant comfort , the best result as all for all windows open for two levels.

5.2.1.1.2 The second investigation

Investigation for same south hall cases with another orientation west hall with east façade, followed the same previous step and opening percentage [table 1, appendix E1] the result roughly equal south hall.

- Air temperature

Figure 5-18 as latest result for south hall thirteen windows opening at two levels had best result decrease 4 °C degrees through night and one °C degree during day.
Different open percentage between two levels has equal south hall investigation result:
Six windows opening: two windows opening down level and four opening upper level got 24.8 °C.
Six windows opening: six opening upper level got 25.4 °C.
Six windows opening: six windows opening down level got 25.9 °C.
The best result for single side (stack) ventilation, especially for higher opening percentage upper level.
Six windows case [six down level] air temperature result equal the result of three windows case[1 window down level (3.6% opening)and two windows up level(6.8% opening) total opening percentage[33% down level opening , 66% upper level opening].
Four windows case [four down level] air temperature result equal the result of two windows [1 window down level (3.6% opening)and one windows up level(3.4% opening)].
The effective area opening percentage:
WWR > 20% the best single side ‘stack’ ventilation influence at total opening as follow [33% down level opening , 66% upper level opening].
WWR < 20% the best single side ‘stack’ ventilation influence at opening as follow [30% down level opening , 70 % upper level opening].

- Inside surface temperature

The natural ventilation influence observe at inside surface temperature **Figure 5-18** shows one case different between west and south hall the north surface more steady in no ventilation (close windows) case .
The other cases have roughly equal result.

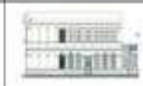
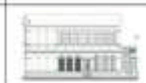
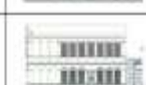
- Air flow

The previous result for air flow corresponding with west hall air flow in and out Appendix E1.

- Thermal comfort

Figure 5-18 shows same previous result for opening percentage on air temperature reflected on SET comfort.

Table 5-2: south hall opening percentage(single side stack ventilation) investigation schedule .

N	HALL	area M2	height	olume M	levation orientatio	levation area	EN POSITION leve	N open 1	a open level	POSITION	N open 2	a open level	open elevation position	N win	nt area leve	en area leve	open percentage
1	ain south h	63	7.9	497	N	82.1	0		0	0		0					0
2	ain south h	63	7.9	497	N	82.1	east 1	1	2.5	0		0		1	down3.4%	up0	3.40%
3	ain south h	63	7.9	497	N	82.1	west 1	1	2.5	0		0		1	down3.4%	up0	3.40%
4	ain south h	63	7.9	497	N	82.1	east 2	2	5	0		0		2	down6.8%	up0	6.80%
5	ain south h	63	7.9	497	N	82.1	1west/ 1east	2	5	0		0		2	down6.8%	up0	6.80%
6	1 st floor	50.3	6	301.8	N	31.9	1west	1	2.5	1east	1	2.6		2	down3.4%	up2.8%	6.20%
7	ain south h	63	7.9	497	N	82.1	1west	1	2.5	1middle	1	2.6		2	down3.4%	up2.8%	6.20%
8	ain south h	63	7.9	497	N	82.1	3east	3	7.5	0		0		3	down10.2%	up0	10.20%
9	ain south h	63	7.9	497	N	82.1	3east	1	2.5	least/1wes	2	5.2		3	down3.4%	up5.6%	9.00%
10	ain south h	63	7.9	497	N	82.1	1east /1west	2	5	1west	1	2.6		3	down6.8%	up2.8%	9.60%
11	ain south h	63	7.9	497	N	82.1	1east /1west	2	5	1middle	1	2.6		3	down6.8%	up2.8%	9.60%
12	ain south h	63	7.9	497	N	82.1	niddle 1east /1wes	2	5	1middle	2	5.2		4	down6.8%	up5.6%	12.43%
13	ain south h	63	7.9	497	N	82.1	1east /1west	2	5	east /1wes	2	5.2		4	down6.8%	up5.6%	12.43%
14	ain south h	63	7.9	497	N	82.1	2east /2west	4	10	0	0	0		4	down13.6%	up0	13.60%
15	ain south h	63	7.9	497	N	82.1	1east /1west	2	5	middle	3	8.8		5	down6.8%	up8.4%	15.20%
16	ain south h	63	7.9	497	N	82.1	2middle	2	5	middle	3	8.8		5	down6.8%	up8.4%	15.20%
17	ain south h	63	7.9	497	N	82.1	2middle	2	5	ldle/east/w	3	8.8		5	down6.8%	up8.4%	15.20%
18	ain south h	63	7.9	497	N	82.1	3east/3west	6	15	ldle/east/w	0	0		6	down20.4%	up0	20.40%
19	ain south h	63	7.9	497	N	82.1	1east /1west	2	5	least /2wes	4	10.4		6	down6.8%	up11.2%	18.00%
20	ain south h	63	7.9	497	N	82.1	2east /2west	4	10	east /1wes	2	5.2		6	down13.6%	up5.6%	19.20%
21	ain south h	63	7.9	497	N	82.1	2east /2west	4	10	least /2wes	4	10.4		8	down13.6%	up11.2%	24.87%
22	ain south h	63	7.9	497	N	82.1	3east /3west	6	15	east /1wes	2	5.2		8	down20.4%	up5.6%	26.00%
23	ain south h	63	7.9	497	N	82.1	3east /3west	6	15	least /2wes	4	10.4		10	down20.4%	up11.2%	31.60%
24	ain south h	63	7.9	497	N	82.1	2east /2west	4	10	least /3wes	6	15.6		10	down13.6%	up16.8%	30.40%
25	ain south h	63	7.9	497	N	82.1	1east /1west	2	5	least /3wes	6	15.6		8	down6.8%	up16.8%	23.60%
26	ain south h	63	7.9	497	N	82.1	3east /3west	6	15	t /3west/m	7	19.2		13	down20.4%	up19.6%	40.00%

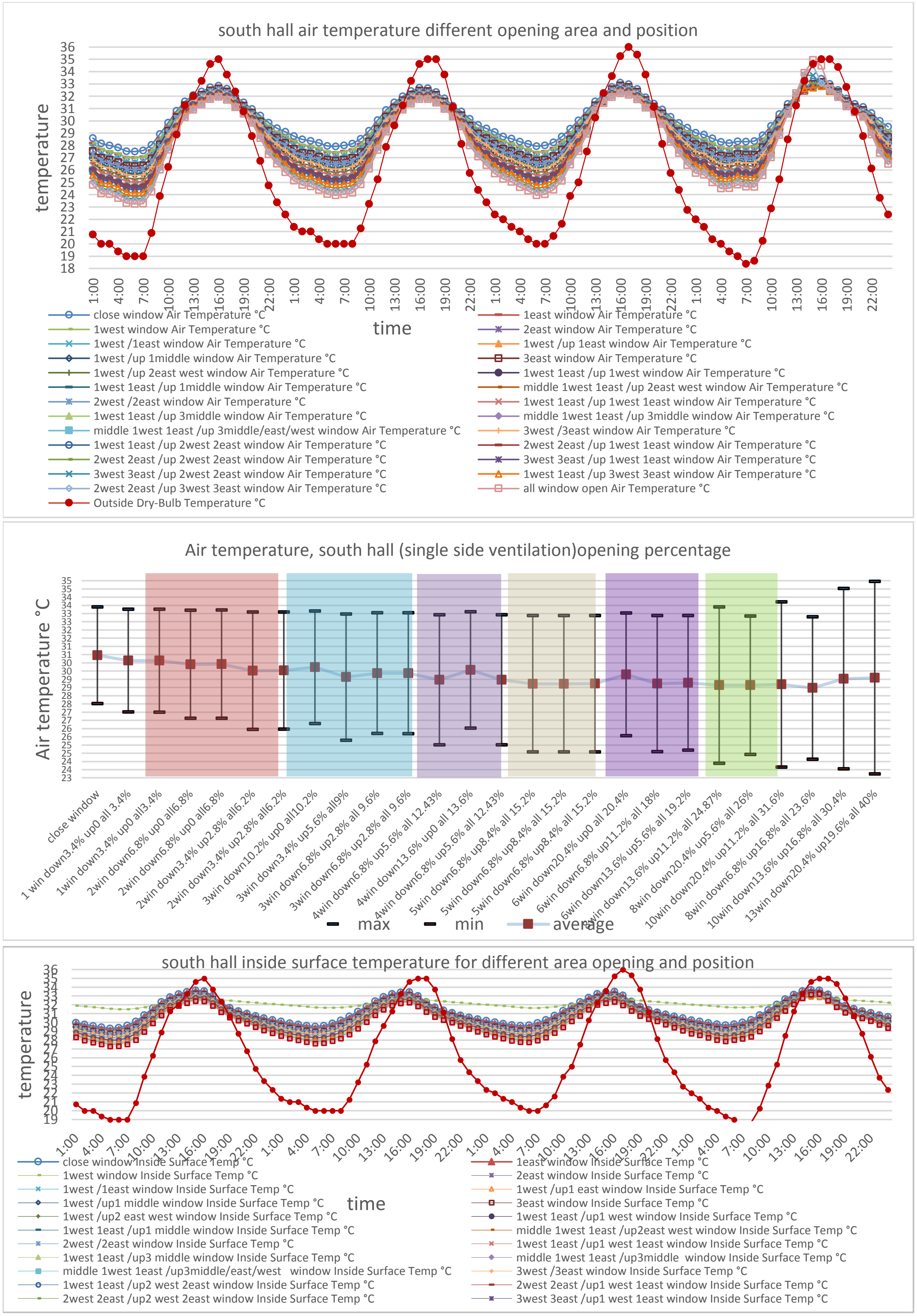


Figure 5-16: south hall single side stack ventilation , air temperature, inside surface temperature/for different cases opening.

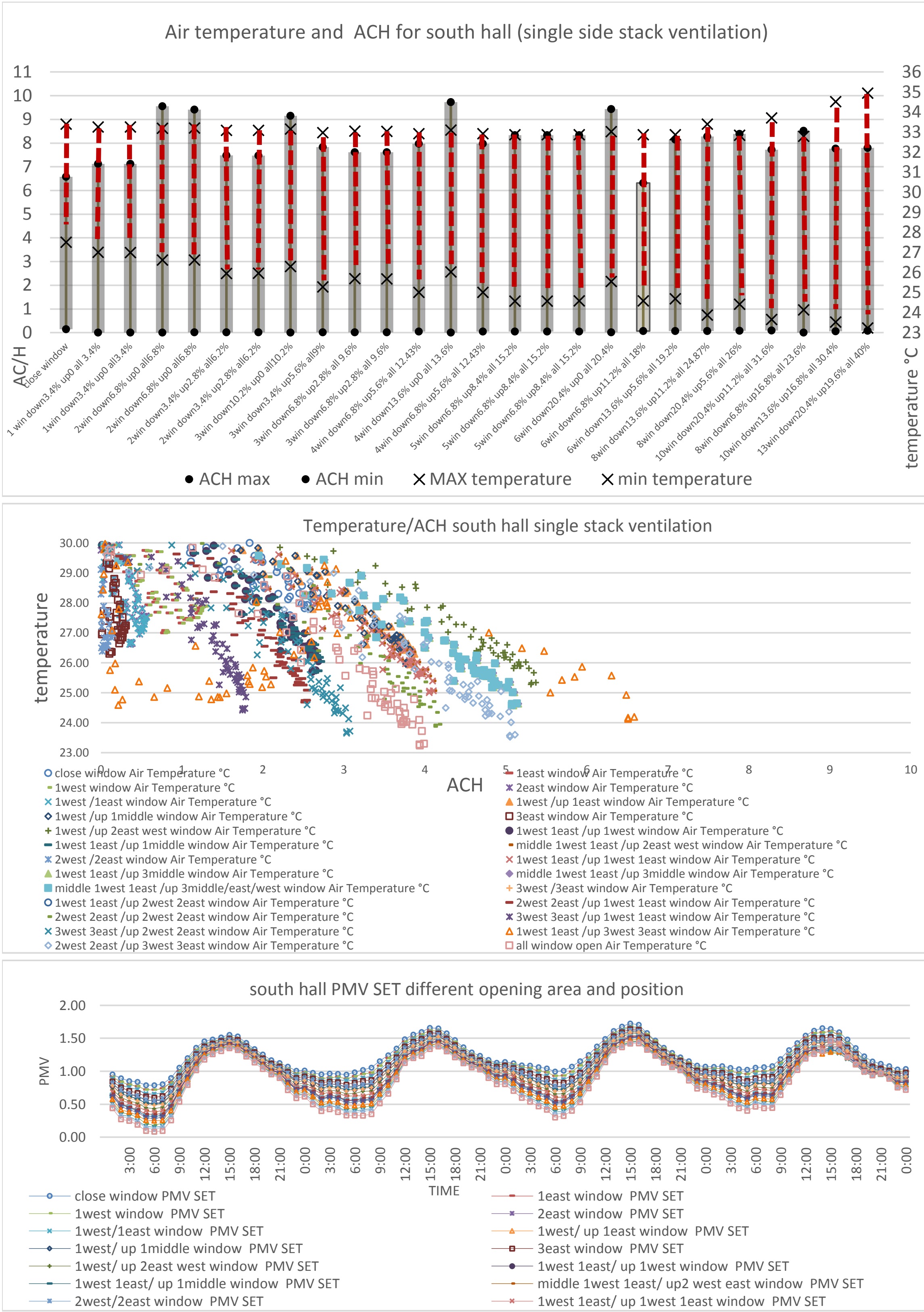


Figure 5-17: south hall single side stack ventilation relation of air change and air temperature, difference PMV SET thermal comfort .

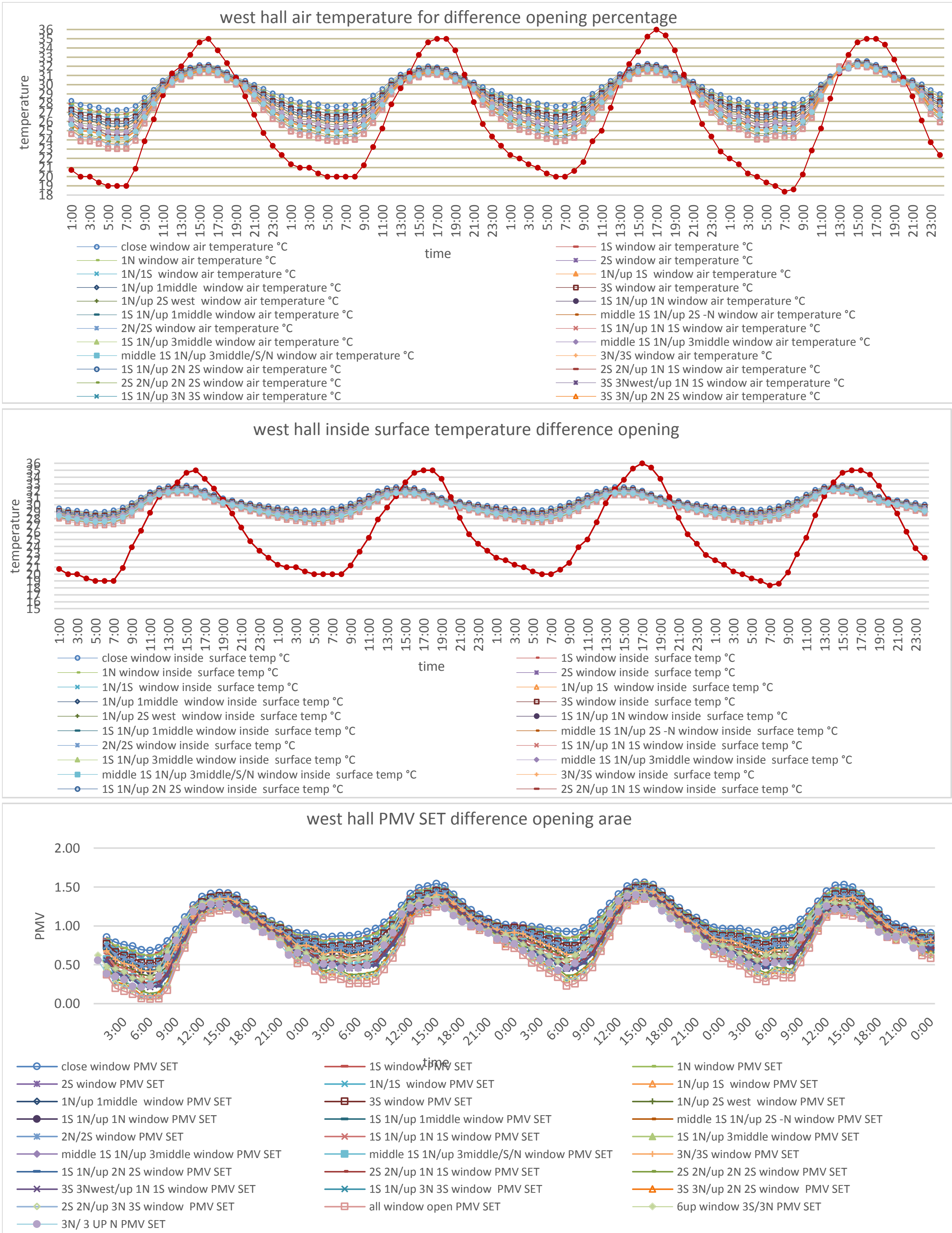


Figure 5-18: west hall single side stack ventilation , air temperature, inside surface ,PMV SET.

5.2.2 Cross ventilation

5.2.2.1 *Model case study*

1st floor north hall depend on cross ventilation, for more explanation about cross ventilation behavior, more simulations have done to deduce the effective area and percentage to position .

1st floor north hall has two facades south façade consist of two windows with WWR 20% , north façade also consist of two windows with WWR 20% .the opening at high level about 350 cm over hall floor , beside opening at west and east façade . Investigation concern at south and north façade opening.

The investigation include nine different cases in opening areas and position , part of this investigation merge with measurements of summer 2014th.

5.2.2.1.1 The first investigation:

This step is to discover the air flow and reflection on temperature behavior in hall space as monitoring and sensor position depend on difference at opening area and position also orientation.

The investigation depend on different opening areas and different level as **Table 5-3**.

Result :

This model shows a good agreement between measurement and simulation in acceptable range for error as ASHRAE limit .

- Air temperature

Figure 5-19 shows as expected the best result for four opening window for two façade.

For one windows opening WWR 10% hall temperature decrease about 2-3 °C degrees during night.

For cross ventilation four windows opening WWR 20% for each façade the hall temperature decrease about 6 °C degrees during night and about 2 °C degrees during day.

The difference between cross ventilation opening WWR 10% for each façade and WWR 20% opening, the latest one 20% decrease temperature 2 °C degrees more than WWR 10%..

Opening on south façade has more effective than north façade.

Cross ventilation with WWR 10% for each façade has roughly equal temperature result of normal opening (no cross ventilation) at south façade with WWR 20%.

Cross ventilation with south façade WWR 20% and north hall WWR 10% better performance than cross ventilation with south façade WWR 10% and north hall WWR 20% roughly 1 °C degree .

Figure 5-19 shows clearly the previous result temperature average related to opening area percentage.

- Inside surface temperature

Observe **Figure 5-19** explains the cross ventilation influence on light mass at inside surface temperature , concentrate the lower time shift . The clearly effect at cross ventilation with four windows opening through decrease temperature during day about 2 °C degrees and 5 °C degrees during night .

- Air flow

This result correlated to air flow and air change (the main factor to loos envelope the heat gain during day, Appendix E2.

Figure 5-20 shows the relation between inside temperature and ACH.

The highest ac/h for WWR 20% for each façade.

The influence of opening area percentage on air temperature **Figure 5-20** all cases with opening on one façade have roughly equal max air temperature. On other hand minimum air temperature proportion with opening percentage specially for cross ventilation cases that reduce temperature about two °C degrees.

Deduce from latest **Figure 5-20**Normal opening with WWR 20%(one façade) corresponded to cross ventilation WWR10% for each façade(similar opening percentage as total for a hall) get different result ,cross ventilation reduce average temperature 2°C and get better feeling through air flow increased ACH10%.

This result correlated to thermal mass of the timber wall and behavior of light mass properties [Factor reduction (attenuation) 0.23, Delay factor reduction (offset) 4.26 h ,Periodic thermal transmittance0.155 [W/m^{2}K]].

Difference pressure surface

Previous result depend on the relation between difference pressure (inside, outside) and outside temperature. The relation at cross ventilation is constant proportion with temperature rise, that means the air flow effect continually specially for upper windows air flow in/out **Figure 5-20** prove that.

- Thermal comfort

Figure 5-20 shows same previous result for opening percentage on air temperature reflected on SET comfort.

5.2.2.1.2 The second investigation

Investigate the rotate orientation (another direction , replace north , south orientation with east, west orientation , so east , west façade) investigation include nine different cases in opening area and position , part of this investigation merge with measurements of summer 2014 .

Investigation followed same step of previous investigation schedule at **Table 5-4**

Result:

Same previous investigation step and opening percentage, the result roughly equal 1st floor north hall with few differences.

- Air temperature

Figure 5-21 presents the difference between two orientation [east, west] air temperature higher about 2°C degrees than[south, north] but decrease the swing (day, night) the behavior more Constant .

For one windows opening WWR 10% hall temperature decrease about1- 2 °C degrees during night.

For cross ventilation four windows opening WWR 20% (for each façade) the hall temperature decrease about 6 °C degrees during night and about 2 °C degrees during day.

Cross ventilation opening WWR 10% for each façade (east, west) and only west façade WWR 20% opening the two cases have roughly equal result.

Cross ventilation with east façade WWR 20% and west façade WWR 10% has equal performance of case cross ventilation with east façade WWR 10% and west façade WWR 20%.

Cross ventilation on east, west direction the effective factor is WWR opening, no important for opening direction not like south, north direction the best performance for more opening at south façade

- Inside surface temperature

Cross ventilation effect on inside surface temperature, **Figure 5-21** shows equal result for all previous result.

- Air flow

The air flow in value lower than air flow out [hall] caused by upper window level Appendix E2.

- Thermal comfort

SET comfort influenced by previous result on opening percentage (air flow) and air temperature [fig21].

.

5.2.2.1.3 The third investigation

this investigation include nine different cases in opening area position, four different opening areas as the first investigation but the windows level at 90cm height from floor [as normal position], the other four cases have mix position for north façade the windows at lower position 90cm height from hall floor's and for south façade windows at upper level 330 cm height from hall floor's, part of this investigation merge with measurements of summer 2014th investigation.

The investigation aim to deduce the effective windows level for cross ventilation.

Result :

- Air temperature

Figure 5-22.presents expected result as previous the lower temperature caused by cross ventilation and WWR 20% , the best case opening level 90cm above floor [normal opening], the lower behavior for mix case .

Figure 5-22.presents the relation between inside and outside temperature and shows the effective of level 90 cm behavior.

- Inside surface temperature

Figure 5-22.shows same previous result the effective case was the case of level 90cm[cross ventilation WWR 20% for each façade].

- Air flow

Appendix E2 present the high air flow out to eject the hot hall air to outside for level 90cm .

For difference pressure as expected no different, the result roughly equal , because the same wind effect with same cross ventilation difference pressure constant relation and effect .

- Thermal comfort

From All previous results deduce the comfortable behavior for level 90cm **Figure 5-22** shows SET comfort scale.

5.2.2.1.4 Conclusion.

The best level for cross ventilation influence is normal level for all opening.

Cross ventilation for south, north axis has better effect that relate to wind direction and the solar direction.

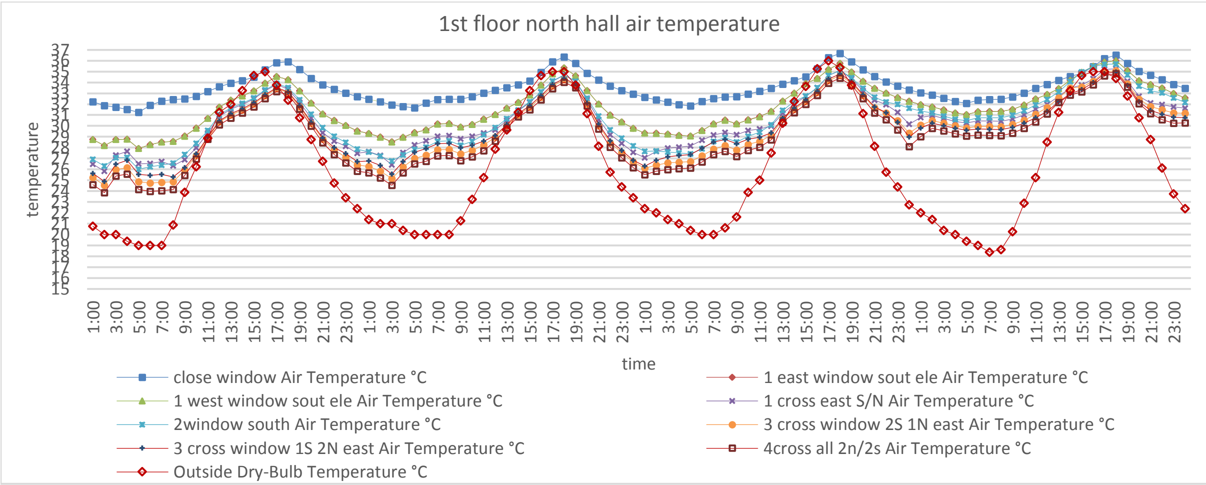
Cross ventilation for south, north axis has better effect than west, east axis in all parameters and more comfort.

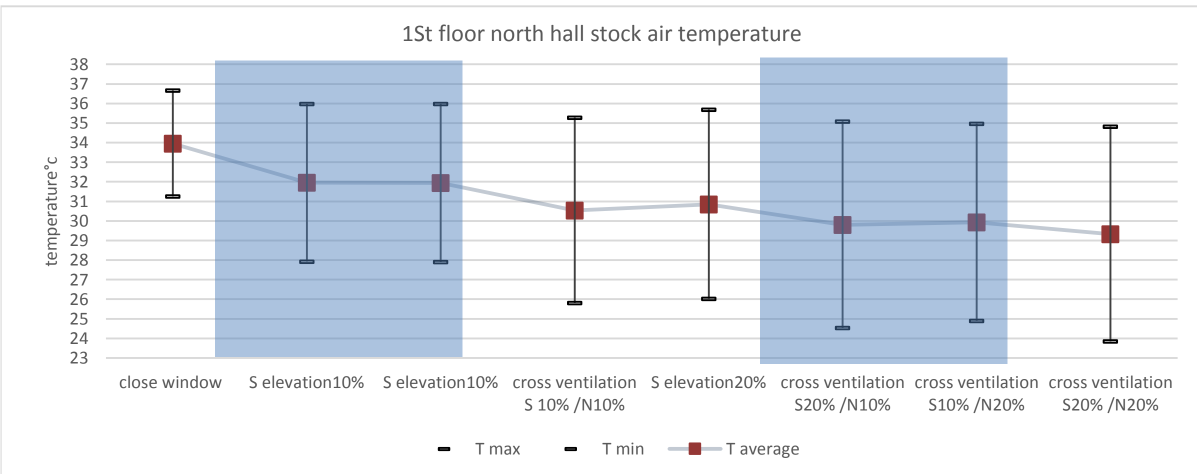
5.2.3 <u>Natural ventilation summary</u>

Form different previous investigations result deduces strategies for new apartment design and passive cooling technique to reduce energy consumption:

- Effective factors on natural ventilation proportional with thermal comfort: volume [the rate between height and area (depth), wall windows rate WWR % (depend on façade) and this result is same for each kind of natural ventilation.
- Cross ventilation depends on the area and volume the rate of height to deep is 1:1.5 -1:2 or bigger. The best solution has been cross ventilation
- Cross ventilation WWR 20-35 % for south and north façade, for west and east façade WWR 15-20% at normal height.

- Divided WWR to two windows if it possible, for better interior air flow reflected on occupant thermal comfort.
- Cross ventilation (adjacent windows) equal condition for cross ventilation, for more effective mixed between Cross ventilation (adjacent windows) and single side natural ventilation.
- Cross ventilation (adjacent windows) the WWR divided roughly 25% for high level.
- Single side (stack) natural ventilation has more influence than single normal ventilation (east hall MOUSLLI, BAIT WARRD):
- Single side (stack) natural ventilation is depend on the area and volume the rate of height to deep 1:1.5 or less and area of façade the rate between height and long is 1:1.5 -1:2.
- For more air flow at single side ventilation, the area of inlet air (window windward) shall be smaller than the outlet one (leeward).
- Single side 'stack' ventilation WWR 25-35% for north façade and WWR 20-25% for south façade, for west and east façade WWR 15-20% at normal height.
- Effectively percentage WWR divided roughly 50-65% for high level and 35-50% for down level.
- Effective faced Single side (stack) natural ventilation vertical design divided for 4 parts alternately open and close parts.
- West and East direction have same effect for opening area.
- Neutral high between two level of single stack ventilation bout 50% of vertical façade.
- Use void inside the apartment as wind tower (chimney) for more air flow effect.
- Apply materials generated related to traditional house thermal mass behavior and sustainable.
- Design function spaces as orientation definite.
- West façade design has high radiation effect which shall be more carefully during opening design as previous percentage also for structure materials





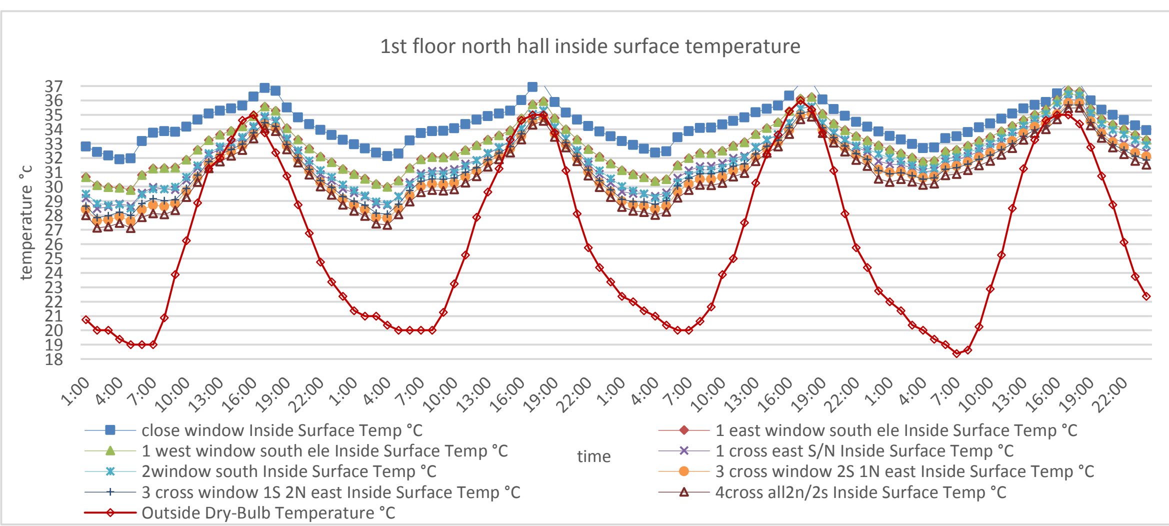
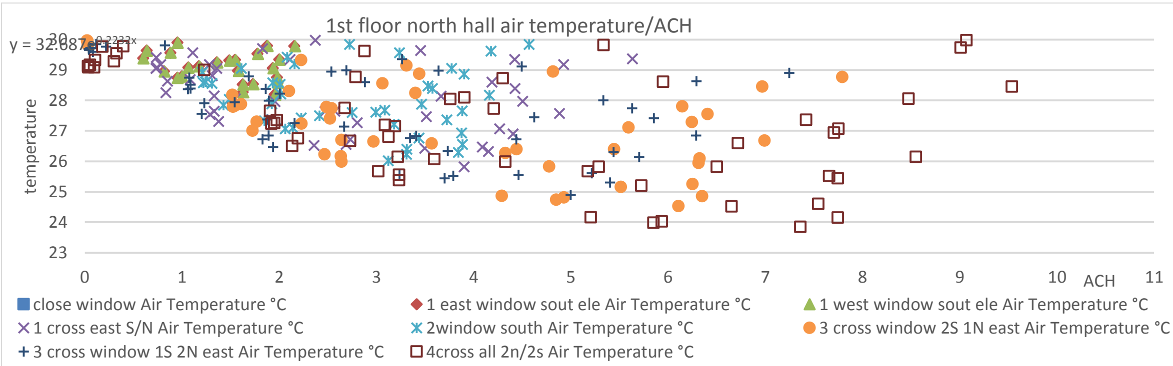
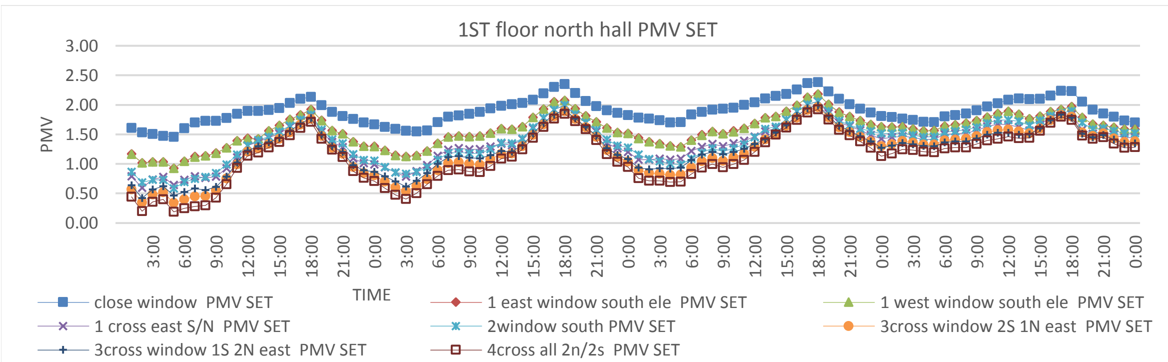
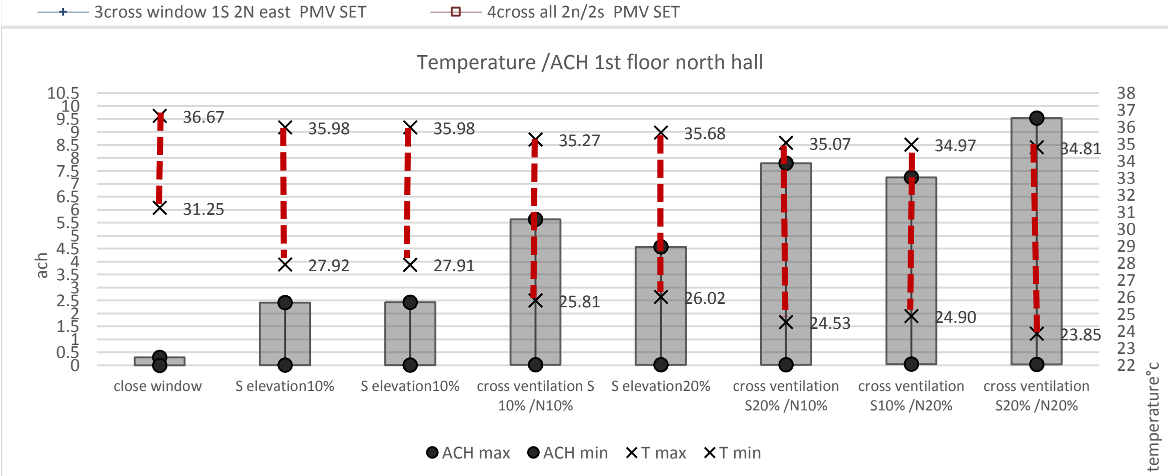


Figure 5-19: cross ventilation 1st floor north hall air temperature, minimum and maximum air temperature, inside surface temperature for different cases opening.


1st floor north hall air temperature/ACH
temperature
ACH
close window Air Temperature °C
1 east window sout ele Air Temperature °C
1 west window sout ele Air Temperature °C
1 cross east S/N Air Temperature °C
2window south Air Temperature °C
3 cross window 2S 1N east Air Temperature °C
3 cross window 1S 2N east Air Temperature °C
4cross all 2n/2s Air Temperature °C


1ST floor north hall PMV SET
PMV
TIME
close window PMV SET
1 east window south ele PMV SET
1 west window south ele PMV SET
1 cross east S/N PMV SET
2window south PMV SET
3cross window 2S 1N east PMV SET
3cross window 1S 2N east PMV SET
4cross all 2n/2s PMV SET


Temperature /ACH 1st floor north hall
ach
temperature°c
36.67
31.25
35.98
27.92
35.98
27.91
35.27
25.81
35.68
26.02
35.07
24.53
34.97
24.90
34.81
23.85
close window
S elevation10%
S elevation10%
cross ventilation S 10% /N10%
S elevation20%
cross ventilation S20% /N10%
cross ventilation S10% /N20%
cross ventilation S20% /N20%
ACH max
ACH min
T max
T min

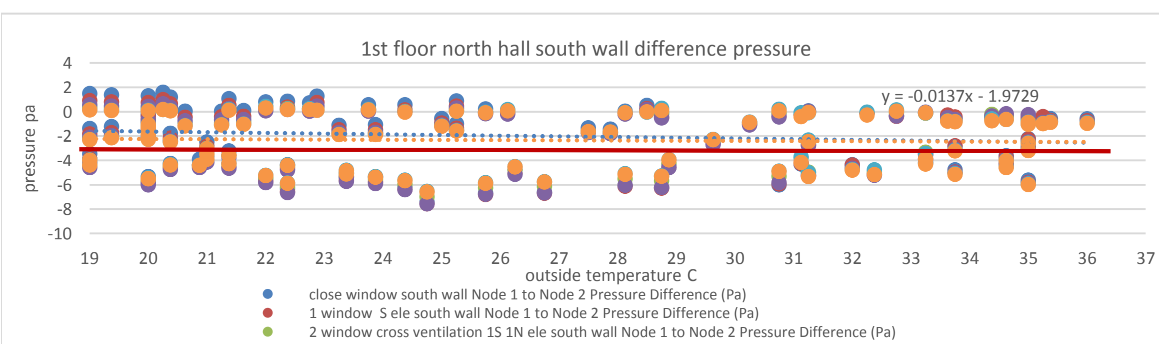
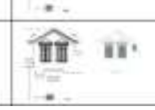

1st floor north hall south wall difference pressure
pressure pa
y = -0.0137x - 1.9729
outside temperature C
close window south wall Node 1 to Node 2 Pressure Difference (Pa)
1 window S ele south wall Node 1 to Node 2 Pressure Difference (Pa)
2 window cross ventilation 1S 1N ele south wall Node 1 to Node 2 Pressure Difference (Pa)
2 window S ele south wall Node 1 to Node 2 Pressure Difference (Pa)

Figure 5-20: cross ventilation 1st floor north hall air temperature/ACH light mass and minimum ,maximum value , PMV SET scale, pressure difference.

Table 5-3: first investigation cross ventilation 1st floor north hall, opening area schedule.

N	HALL	area M2	height	volume	elevation orientation 1	elevation orientation 2	elevation area 1	elevation area 2	OPEN POSITION 1	N open 1	area open	OPEN POSITION 2	N open 2	area open	open elevation plan / open elevation plan	open percentage
1	1 st floor north hall	50.3	6	301.8	S	N	31.9	31.9		0	0		0	0		0
2	1 st floor north hall	50.3	6	301.8	S	N	31.9	31.9	up /east	1	3					S elevation10%
3	1 st floor north hall	50.3	6	301.8	S	N	31.9	31.9	up / west	1	3					S elevation10%
4	1 st floor north hall	50.3	6	301.8	S	N	31.9	31.9	up / east	1	3	up / east	1	3		cross ventilation S 10% /N10%
5	1 st floor north hall	50.3	6	301.8	S	N	31.9	31.9	up / east up / west	2	6					S elevation20%
6	1 st floor north hall	50.3	6	301.8	S	N	31.9	31.9	up / east up / west	2	6	up / east	1	3		cross ventilation S20% /N10%
7	1 st floor north hall	50.3	6	301.8	S	N	31.9	31.9	up / east	1	3	up / east up / west	2	6		cross ventilation S10% /N20%
8	1 st floor north hall	50.3	6	301.8	S	N	31.9	31.9	up / east up / west	2	6	up / east up / west	2	6		cross ventilation S20% /N20%

Table 5-4: second investigation cross ventilation ,1st floor east hall, opening area schedule.

N	HALL	area M2	height	volume	elevation orientation 1	elevation orientation 2	elevation area 1	elevation area 2	OPEN POSITION 1	N open 1	area open	OPEN POSITION 2	N open 2	area open	open elevation plan / open elevation plan	open percentage
1	1 st floor east hall	50.3	6	301.8	W	E	31.9	31.9		0	0		0	0		0
2	1 st floor east hall	50.3	6	301.8	W	E	31.9	31.9	up	1	3					W elevation10%
3	1 st floor east hall	50.3	6	301.8	W	E	31.9	31.9	up	1	3					W elevation10%
4	1 st floor east hall	50.3	6	301.8	W	E	31.9	31.9		1	3	up	1	3		cross ventilation W 10% /E10%
5	1 st floor east hall	50.3	6	301.8	W	E	31.9	31.9	up up	2	6					W elevation20%
6	1 st floor east hall	50.3	6	301.8	W	E	31.9	31.9	up up	2	6	up	1	3		cross ventilation W20% /E10%
7	1 st floor east hall	50.3	6	301.8	W	E	31.9	31.9	up	1	3	up up	2	6		cross ventilation W10% /E20%
8	1 st floor east hall	50.3	6	301.8	W	E	31.9	31.9	up up	2	6	up up	2	6		cross ventilation W20% /E20%

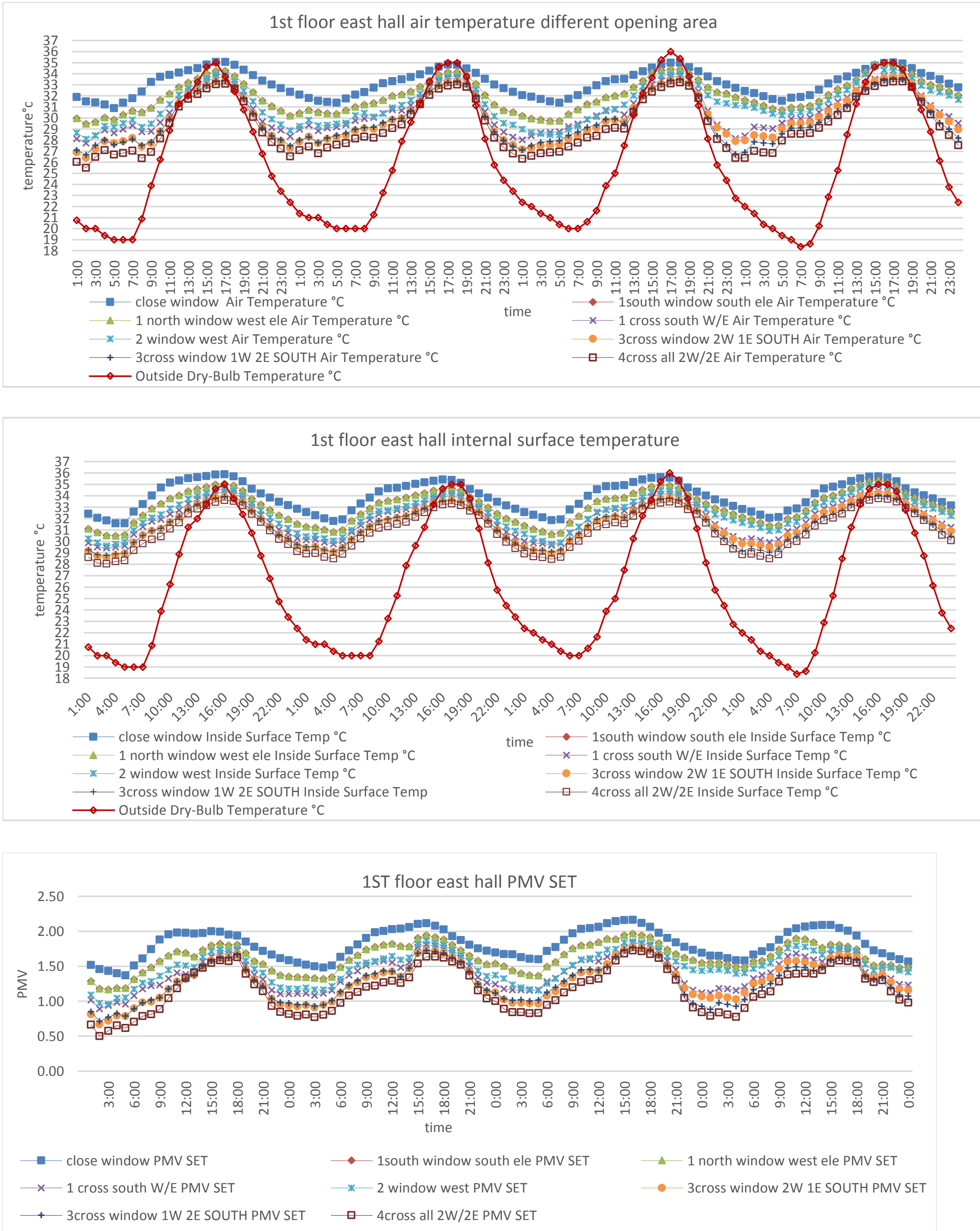


Figure 5-21: second investigation. Cross ventilation ,1st floor east hall, air temperature ,inside surface temperature, PMV SET for different cases opening.

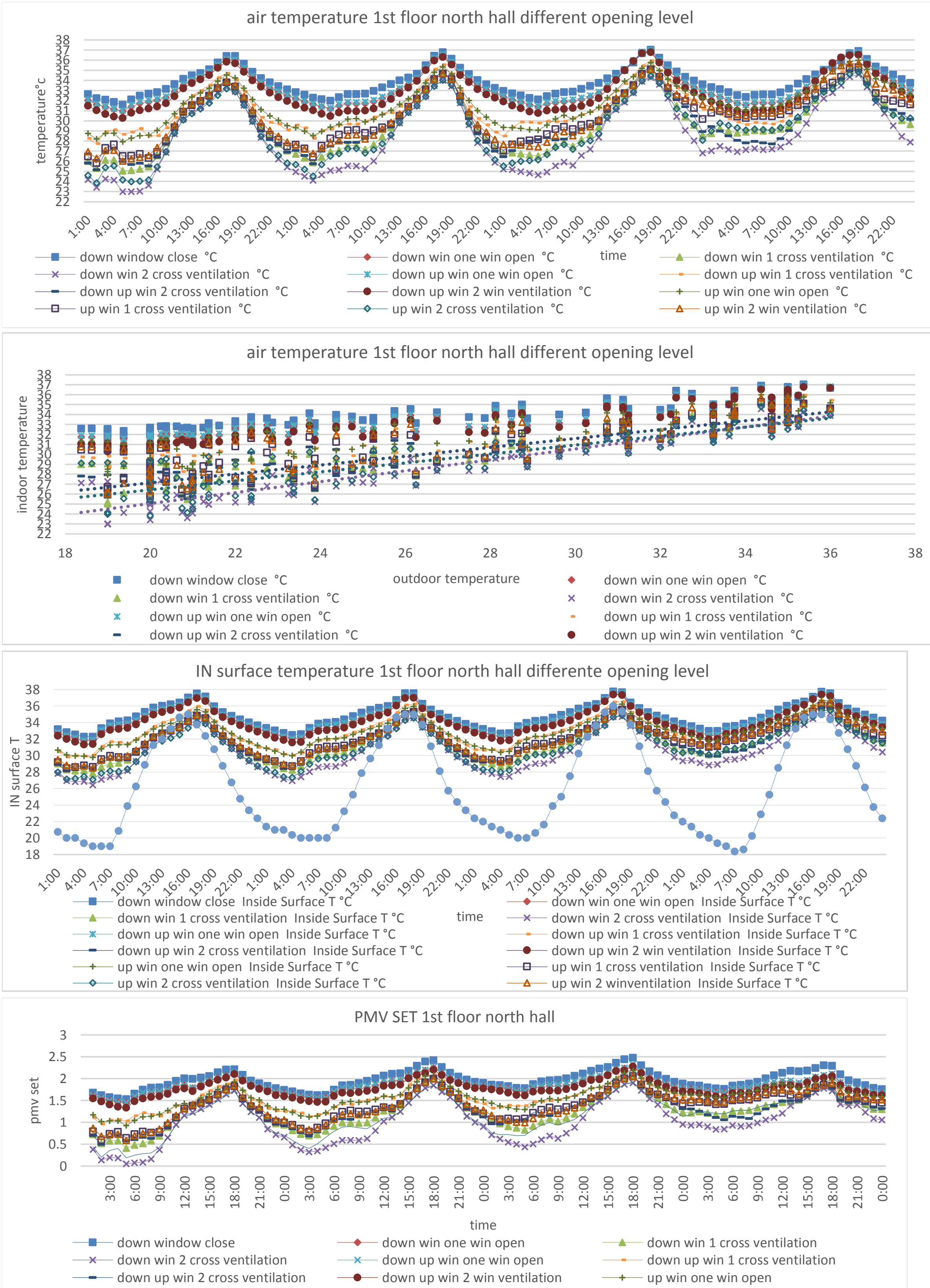


Figure 5-22: third investigation. Cross ventilation, 1st floor north hall, different opening levels, air temperature, inside surface temperature, PMV SET.

CHAPTER 6

RESULT AND NEW APARTMENT

Energy consumption in the long hot summer period case in the hot-dry climate region concern all the residential sector in the Middle East region. Therefore it is very important to design new buildings with higher level of utilizing the natural renewable energies and good healthy environment performance .That is an attempt to optimize the strong impact and relationship between the building envelope and the thermal comfort as well the indoor air qualities.

The building envelope represents the main connection part of the internal with the outside environmental conditions, It tries to modify the indoor environment as more suitable for utility and occupancy .Therefore should the building's design be in well fare harmony with the environment.

This chapter investigate the passive design strategies deduction of all previous chapters to optimize new residential buildings which divided into three investigation groups;

-the first investigate the influence of the envelope materials.

- The second investigate the orientation and shading device of the indoors environment; the thermal comfort and thermal behavior in hot climate for high residential building by using Design builder and Energy Plus simulation program.

-The third; investigate the natural ventilation methods (cross ventilation, single side stack ventilation) deducing from traditional houses form a modern context as well the passive strategies ability and consequences to apply it with the energy efficiency reduction and consumption.

Such investigation is done for one apartment (dwelling) on the fourth floor with adiabatic ceiling and slab design for summer period and winters as passive design strategies.

6.1 Optimize new residential apartment at hot-dry climate.

Case study Characteristics

The assumed typical buildings should be consist of 7 floors; Each of these apartment has 80 m^2 ,its height at the 4th floor above the ground is about 12.8m with floor and ceiling with adiabatic influence from adjustment (slab [concrete ,tile ,cement mortar] U= 1.466 W/m2.k).

The typical family has one son goes to school and the parents; one of them works and the other stay at home. That means; during the morning one person and at the night will be three person stay to gather.

The apartment characteristics as follow: **Table 6-1 -Table 6-2 - Figure 6-1**

Table 6-1: space apartments distribution.

rooms	Area m^2	Volume m^3	Gross wall area m^2	Window glass area m^2
Salon and dining	31.6	101.3	42.4	7.9
toilet	1.24	3.9	3.7	0
Kitchen	10	32	21.2	2.6
Master bedroom	18.3	58.7	25.2	6.3
Bedroom	12.7	40.9	28.6	2.6
Bathroom	2.9	9.4	6.1	0
Entrance	2.9	9.4	1	0
total	80	225.98	128.6	19.58

Table 6-2: Window wall rate.

	Total	North (315 to 45 deg)	East (45 to 135 deg)	South (135 to 225 deg)	West (225 to 315 deg)
Gross Wall Area [m2]	126.12	27.70	30.42	34.96	33.03
Window Opening Area [m2]	21.50	7.97	0.00	8.76	4.78
Window-Wall Ratio [%]	17.05	28.78	0.00	25.04	14.46

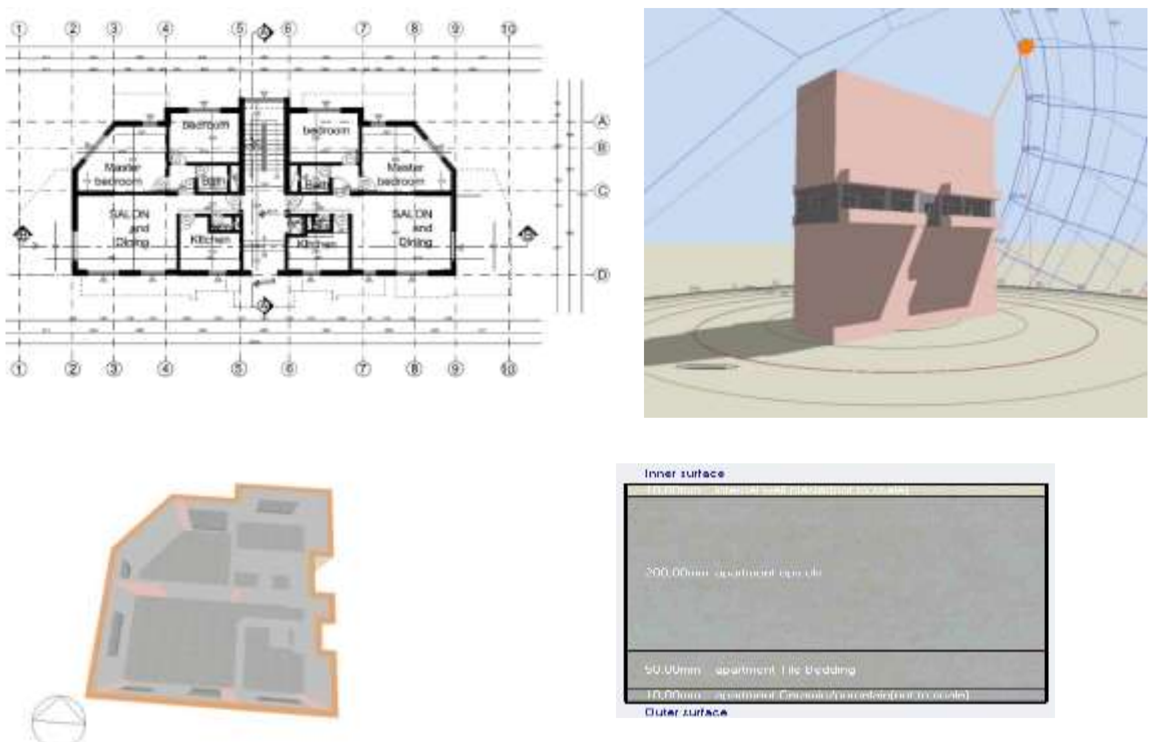


Figure 6-1: Apartment plan , slab characteristic .

Utilized: wooden door with U value 1.89 W/m2k size of indoor opening 50% for 5 times.
Double glass window with U 2.7 W/m2k as standards with aluminum frame.
To analysis heat transfer for envelope without window impact it had shading rolled from 9:00am to 15:00pm 50% from15:00pm to18:00pm 100% to 19:00pm 50%.
Partition from cement block with 7cm thickness and paint finishing inside surface.
Occupant activity about 1 met and for clothes (0.55clo summer,1clo winter).
Not focused on Lighting parameters utilize pest practice (5W/m^2 -100Lux), also for equipments.

Simulation arguments

The dynamic simulation made it for typical [hot-dry climate at Middle East region] apartment to analysis the heat flux , heat transmittance ,airflow , PMV /SET depending on performed for one city in hot dry climate for the first and second investigation for the third one it depend on performed of three cities in hot arid climate (Damascus , Cairo ,Riyadh) for summer and winter design period .
No cooling and heating only natural ventilation.

Assessment criteria:

According to ASHRAE standard 55P and fundamental the thermal comfort ‘the condition of mind which expresses satisfaction with the thermal environment (air temperature), predicted PMV of Fanger and for the given activity in the real environment Standard Effective Temperature, SET.

And envelop behavior (thermal mass) through evaluate:

The first factor will be the surface temperature .

The form of radiation (long-wave or short-wave) comes into contact with the external fabric of the building, heat conduction transfers energy through the envelope, adding heat gain to the interior space. This increases the surface temperature which accelerates the rate of heat conduction. This heat transfer through the envelope of the building varies over time. The surface temperature is called the sol-air temperature: and can be described as the equivalent outdoor temperature that will cause the same rate of heat flow at the surface and the same temperature distribution through the material as the current outdoor air temperature, the solar gains on the surface and the net radiation exchange between the surface and its environment.

The second one the heat transfer for each wall and orientation.

The surface inside face conduction Heat transfer Rate (W) output variables describe heat flow by conduction right at the inside face of an opaque heat transfer surface(influence on indoor environment and thermal comfort)/(zone opaque inside face conduction gain(W) that have only positive values or zero).

Average surface heat flux (W/m2).

Zone Opaque Surface inside Face Conduction Gain Energy [J] total power and energy for all opaque surfaces in a zone when that sum is positive.

This step divided to many levels: as follow:

- Investigate about insulation position outside, inside and middle of wall and thermal mass.
- Investigate for the best performance which utilize the common, economic and traditional sustainability materials and U value depend on standers.
- In this step will calculate the average of the envelope performance for apartment as one space.
- The second step:

The influence of envelope and orientation on the different apartment functions spaces.

6.1.1 Optimize envelope materials.

6.1.1.1 *Modeling data*

Applied previous characteristic depend on outside Damascus climate (hot-dry summer and winter) data to understand the behavior of heat transfer for each orientation and how the design builder and energy plus make simulation.

the analysis period will be short but for important period of the year to optimize new passive cooling design to summer design week (29 th of July / 4th of August) also for low energy building heating at winter in winter design week (5 th of February / 12 th of February). Assumption for this step the apartment as one zone to get average of the heat transfer. Time setup: 4.

6.1.1.2 *Optimize insulation position*

This step investigate best performance for insulation related to its position [inside, outside, middle] in envelope.

Insulation thickness 2.5cm, the wall consist of cement heavy block, cases followed **Table 6-3**.

Investigation have done for summer and winter period [A:25 to 29].

Result:

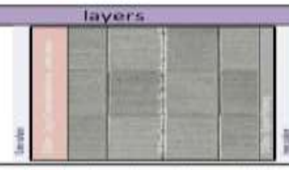
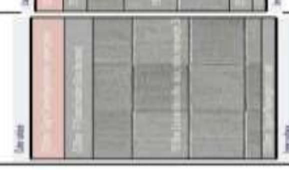
Figure 6-2 shows the best position for the insulation at outside layer of the wall which found as expected with increase the thickness (wall and insulation, capacity) that gives envelope better performance[wall 2,6].

Result shows inside insulation is the lowest performance this result correspond with the three parameters especially PMV/SET parameters [wall3].

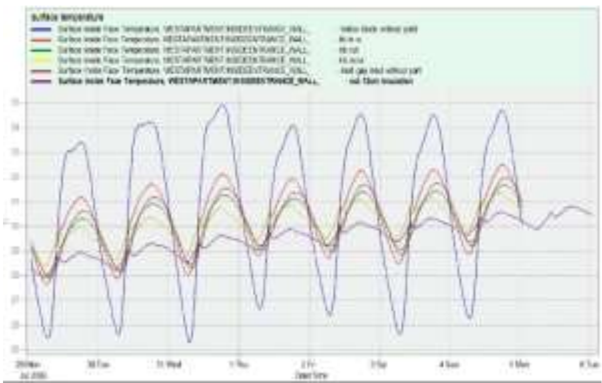
Figure 6-2winter period result correlated to summer period.

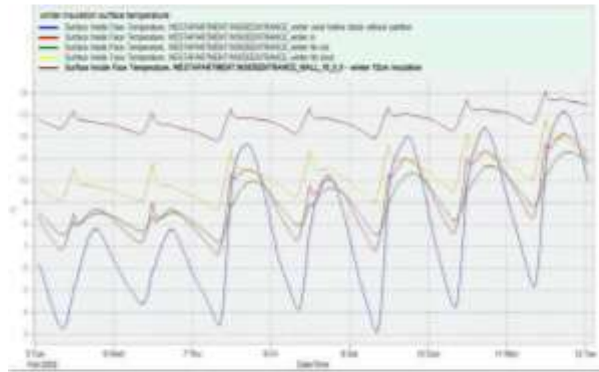
The best envelope performance during all the year the best insulation position outside wall with high thickness.

Table 6-3: insulation position investigation cases.

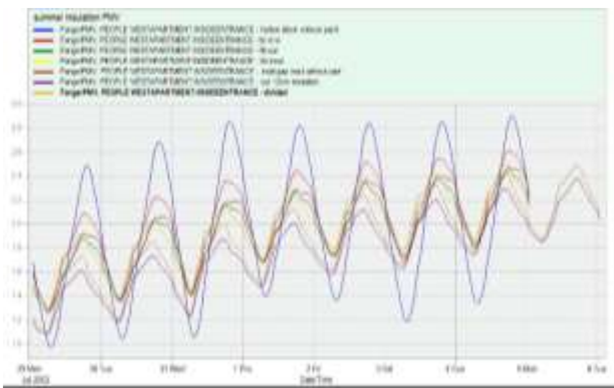
abbreviation	U (W/m2.K)	specification from outside	thicknessCM	layers
wall 1 without insulation	2.815	cemint plaster ,block,gypson plaste	19.3	
wall 2 outside insulation	0.953	cemint plaster, insulation2.5 cm ,block,gypson plaste	21.8	
wall 3 inside insulation	0.953	cemint plaster,,block ,insulation2.5cm ,gypson plaste	21.8	
wall 4 middle insulation	0.953	cemint plaster,block ,insulation2.5cm,block ,gypson plaste	21.8	
wall 5 in outside insulation	0.573	cemint plaster, insulation2.5 cm ,block,insulation2.5 cm ,gypson plaste	24.3	
wall 6 outside insulation	0.35	cemint plaster, insulation12.5 cm ,block,gypson plaste	31.8	

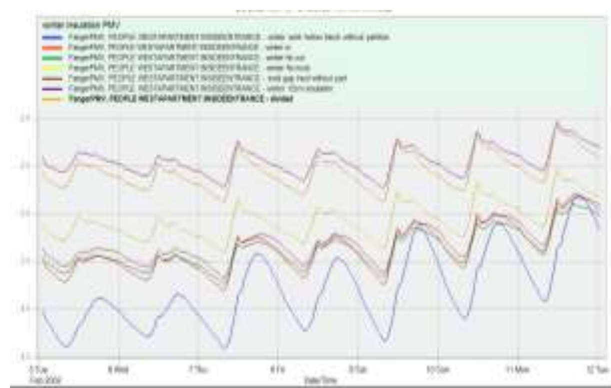
a . b.



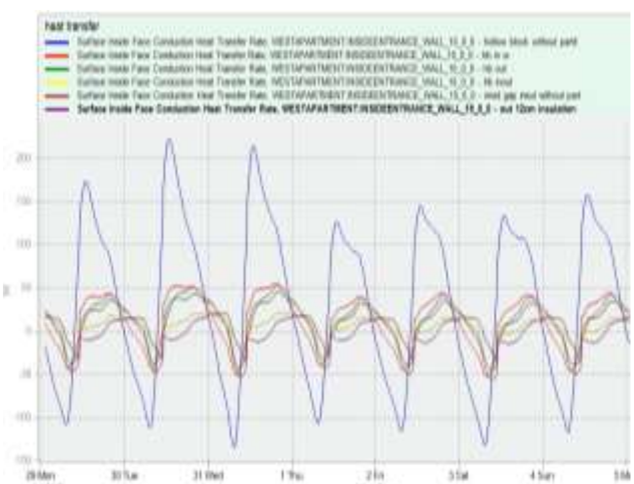


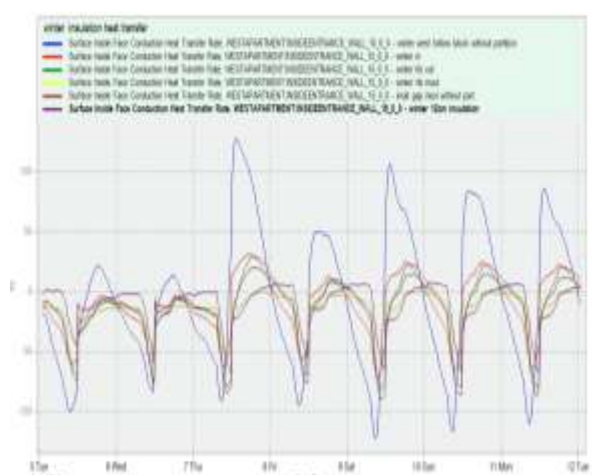
Inside surface temperature, insulation position summer/ winter





PMV/SET scale ASHRAE, insulation position summer/ winter





Conduction heat transfer, insulation position summer/ winter

Figure 6-2: a,b . comparison of Insulation position cases ,[wall: 1without insulation, 2outside .3.insid .4middle. 5.in/out insulation. 6.12cm out.

6.1.1.3 *Optimize envelop materials*

This step has been done to investigate performance for forty-eight different cases[A:1to 49] present at **Table 6-4**a,b.

This investigate divided to two main cases: the first: block wall, the second brick wall.

Each part divided also to five aspect cases:1. Single wall.2. Double block.3.trying PCM materials .4.natural (optimizing traditional) local materials.5. Prefabricate materials.

Include each previous cases many aspects related to materials and cladding (finishing out-surface materials, common finishing) , presented at Appendix F1.

- Block wall cases

1- Single block.

This investigate has nine different cases[A:17-24] include insulation position cases (with cement plaster cladding and out-insulation, granite cladding, lime stone cladding with- out/in-insulation, ceramic cladding with- out-insulation).

Analysis and result: Appendix F1.

The result for nine single block walls with different weight and thicknesses (thermal mass)as expected the thermal mass has the best performance special case (A:20,22 stone cladding with inside outside insulation) has best performance during all the year, [A:17,18]cases (cement and granite) have a good stability .

2- Double block

This investigate has twelve different cases[A37-49] as previous step as follows (double with air-gap 25mm and lime stone cladding with in/out insulation , double with air-gap 50/60mm and lime stone cladding with in/out insulation, double with air-gap 25/50mm and lime stone cladding, double with air-gap 25/50mm with in/out insulation, double with air-gap 25/50mm with inside insulation , double with air-gap 25mm with outside insulation, double block with middle insulation / outside/inside)all previous with thermal mass heavy block and hollow light block.

Analysis and result: Appendix F1.

The result approve the walls with heavy mass have the best performance wall [A39] (stone cladding, air gap 50, inside outside insulation).Moreover the air gap has a strong effect on stability.

In winter period has turbulence result that is depend on solar gain [heat transfer for light mass walls] .

3- Natural materials (optimizing traditional local materials)

This investigate has five cases[A:32-36] (single heavy block with cork board insulation and lime plaster, single heavy block with cork/ board insulation and lime stone cladding , single block/ mud block with cork/ board insulation , single block/ mud block with hemp insulation.

Analysis and result: Appendix F1.

The last case has the best performance during the year A36 using hemp insulation.

4- Block wall with PCM Martials.

Simulation arrangement: for this case the software use the conduction finite difference way for calculation and time set up 12 the Phase change materials characters depend on many temperature phase point 16 temperatures °C degree with correspond enthalpy.

This step investigate two cases (block with ceramic cladding and 50mm air-gap and PCM insulation / air mass include PCM insulation materials)[A30,31].

Analysis and result: Appendix F1**.**

These materials increase the performance of the wall and decrease the wall thickness at the same time, that is approve at the Appendix F1 for all parameters A30.

5- Prefabricate wall

This step inveterate three cases (prefabricate slc with lime stone cladding and 50mm airgap with out-insulation , prefabricate slc with lime stone cladding and 50mm airgap , prefabricate slc with painting finishing[A14-16]).

Analysis and result: Appendix F1**.**

The wall slc without insulation have decrease the PMV/SET parameters that is because the high respond for loss and gain the heat about 10%. That clearly at inside surface temperature for summer period only For winter period as expected the slc wall with stone cladding and outside insulation A14 has the best performance the surface temperature parameters 45% better than first caseslc wall.

- Brick wall

Followed same previous step.

1- single block:

Same block wall cases [A:2-6].

Analysis and result: Appendix F1**.**

The wall single with lime stone cladding and outside insulation has the best performance cause the high insulation thickness a bout 12cm A6 ,that gives it 35% better surface temperature than the single with inside outside insulationA3 .

This case shows the air gap high performance the different between 25mm and 50mm air gap in summer period.

2- Double brick wall:

As block cases and result [A10-13], the turbulence in result between two insulation position in, outside and single. The wall A12(stone cladding, insulation, double brick with air gap 50 mm) has better PMV/SET and surface temperature than wall (stone cladding, insulation, double brick with air gap 50 mm, insulation)which has better parameters for winter period also for heat transfer in summer Appendix F1.

3- Natural materials.

A:8,9 Same result of block wall the best performance A9(single brick and mud block with hemp insulation) Appendix F1

4- Wall with PCM insulation materials

A7 As previous block, those materials increase the performance of the wall and decrease the wall thickness at the same time.

- conclusion

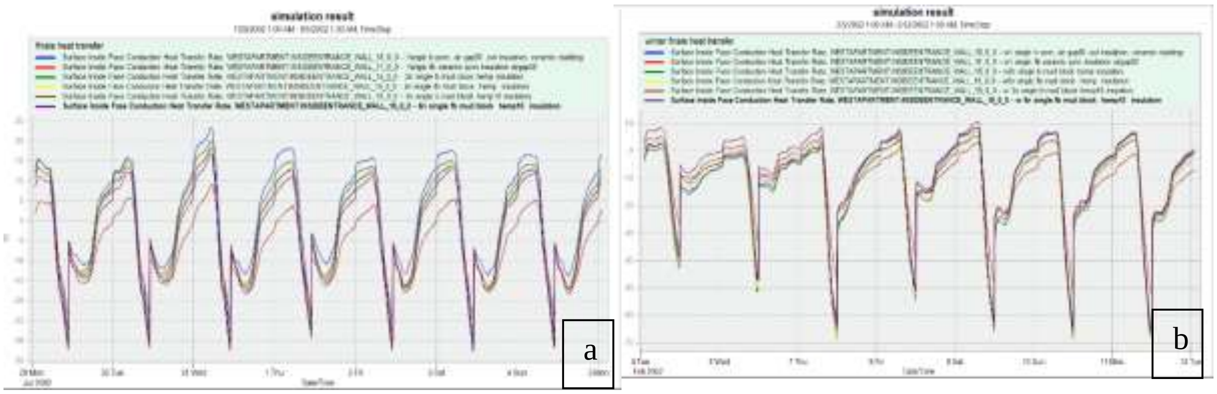
Block wall:

The best block walls performance shared between PCM materials and Natural materials.

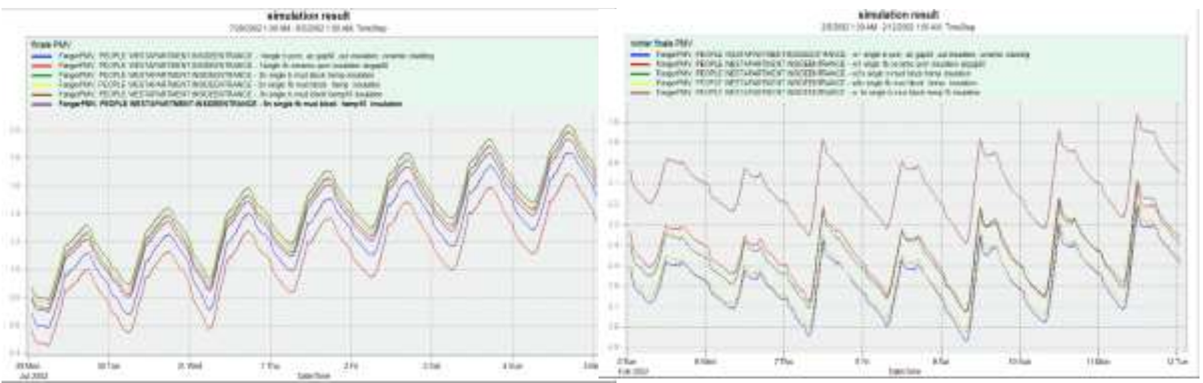
Brick wall:

The same result for block walls the best performance shared between PCM materials and Natural local materials.

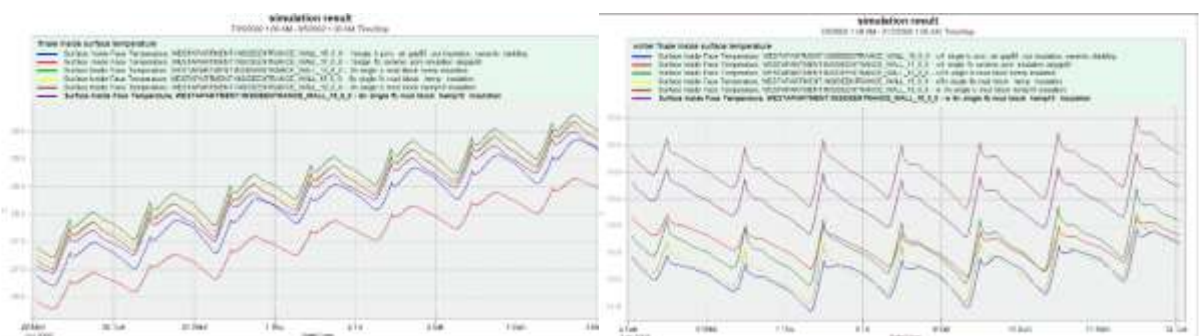
Figure 6-3.show turbulence in result between the PCM materials with block in summer and natural materials with brick with 10cm hemp insulation in winter for PMV/SET and surface temperature , which are the best walls performance during all year final assessment present at **Table 6-4**.



SET summer and winter period parameters for walls conclusion.



Heat transfer summer and winter period parameters for walls conclusion.



Inside face temperature summer and period parameters for walls conclusion.

Figure 6-3: comparison block/brick walls cases for optimizing envelop materials: the best performance cases for: a. summer, b. winter period.

Table 6-4: optimize envelope materials assessment.

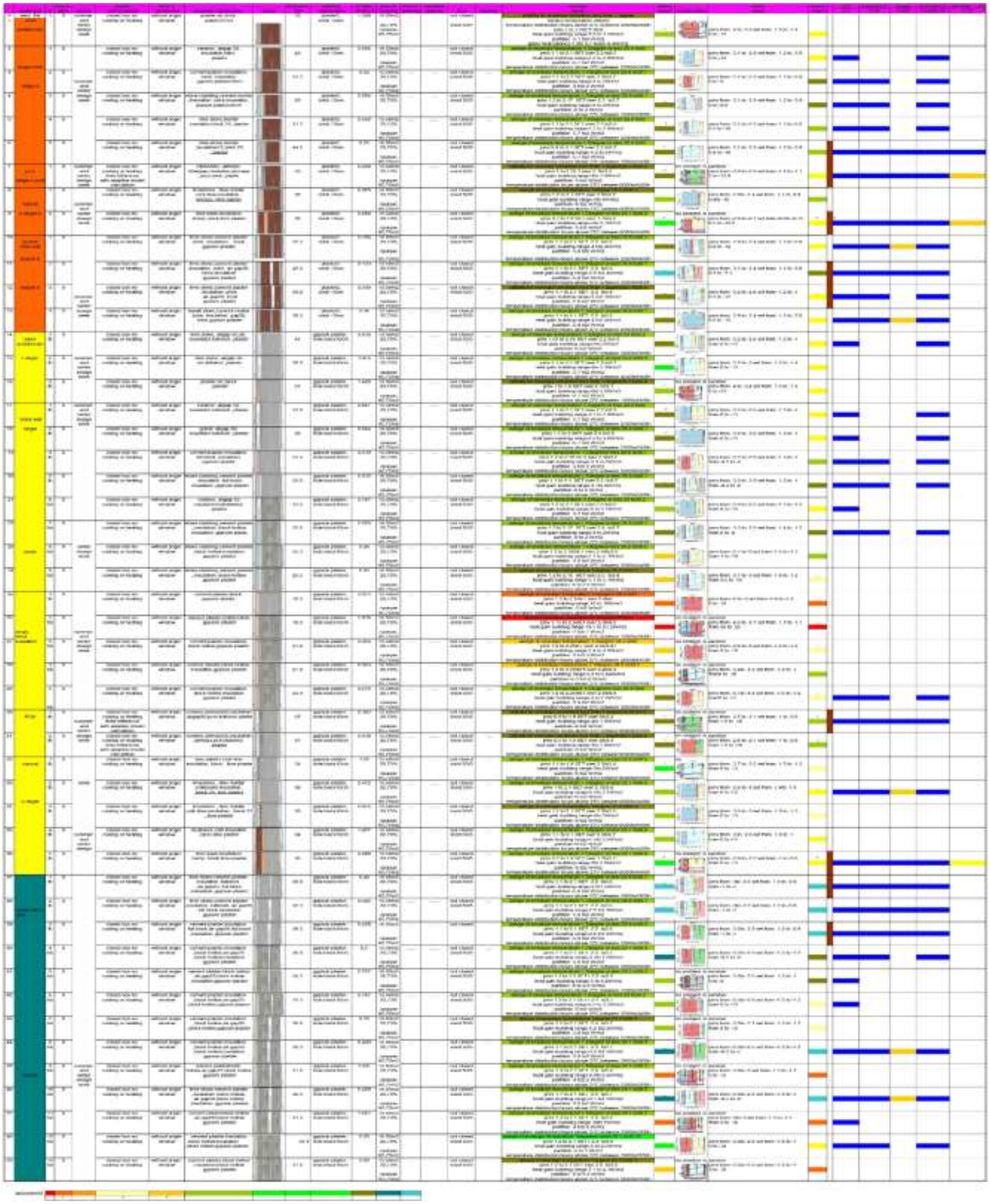
A	apartment	N	envelope construction	layers	thickness CM	U value W/M2.K	A	apartment	N	envelope construction	layers	thickness CM	U value W/M2.K
1	brick prefabricate	1	plaster,slc,brick ,plaster31cm		32	1.249	25		1 fb	cement plaster,block, gypson plaster		19.3	2.974
2	single brick	1	ceramic, airgap 50, insulation,brick ,plaster		43	0.606	26	single block insulation	2 hb	cement plaster,hollow block ,gypson plaster		19.3	2.815
3	single b	2	cement plaster,insulation, brick ,insulation ,gypson plaster20cm		24.3	0.52	27		3 hb	cement plaster,insulation, block hollow,gypson plaster		21.8	0.953
4		3	stone cladding,cement mortar ,,insulation ,brick,insulation , gypson plaster20cm		28	0.506	28		4 hb	cement plaster,block hollow, insulation,gypson plaster		21.8	0.953
5		4	lime stone,mortar ,insulation,brick 25, plaster		34.3	0.558	29		5 hb	cement plaster,insulation, block hollow,insulation ,gypson plaster		24.3	0.573
6		5	lime stone,mortar ,insulation12,brick 25 , plaster		44.2	0.22	30	PCM	1 fb	ceramic,airmass50,insulation ,airgap50,pcm,fullblock,plaste		37	0.302
7	pcm single b pcm	1	CERAMIC, airmass 50airgap,insulation,airmass ,pcm,brick ,plaste		46	0.298	31		2 fb	ceramic,airmass50,insulation ,airmass,pcm,fullblock ,plaster		37	0.318
8	natural	1	limestone , lime mortar ,cork lime insulation , brick25, lime plaster		38	0.975	32	natural	1 fb	lime plaster crok lime insulation, block , lime plaster		34	1.04
9	n single b	2	lime wash,mudblock ,hemp ,brick,lime plaster		36	0.268	33	n single	2 fb	limestone , lime mortar ,crokboard insulation , block 25, lime plaster		36	0.472
10	double brick wall double b	1	lime stone,cement plaster ,brick ,insulation , brick, gypson plaster		37.3	0.456	34		3 fb	limestone , lime mortar ,cork lime insulation , block 25 , lime plaster		38	0.975
11		2	lime stone,cement plaster ,insulation ,brick ,air gap50, brick,insulation ,gypson plaster		42.3	0.423	35		4 fb	mudblock,cork insulation ,block,lime plaster		34	1,077
12	double b	3	lime stone,cement plaster ,insulation ,brick ,air gap50, brick ,gypson plaster		39.8	0.599	36		5 fb	lime wash,mudblock ,hemp ,block,lime plaster		36	0.268
13		4	basalt stone,cement mortar ,brick ,insulation gap50, brick,gypson plaster		38.3	0.46	37		1 fb	lime stone,cement plaster, insulation ,fullblock ,air gap25, full block ,insulation ,gypson plaster		39.8	0.43

,a , characteristic all wall cases .

A	apartment	N	envelope construction	layers	thickness CM	U value W/M2.K
14	block prefabricate	1 fb	lime stone, airgap 50,slc, insulation,fullblock ,plaster		41	0.615
15	r single	2 fb	lime stone, airgap 50 ,slc,fullblock ,plaster		38.5	1.075
16		3 fb	plaster,slc,block ,plaster		31	1.409
17	block wall	1 fb	ceramic, airgap 50, insulation,fullblock ,plaster		34.5	0.621
18	single	2 fb	granit, airgap 50, insulation,fullblock ,plaster		35	0.624
19		3 fb	cement plaster,insulation, full block ,insulation, gypson plaster		24.3	0.519
20		5 fb	stone cladding,cement plaster ,,insulation ,full block ,insulation ,gypson plaster		32.8	0.512
21		6 hb	ceramic, airgap 50 ,insulation,hollowblock ,plaster		34.5	0.767
22		7 hb	stone cladding,cement plaster ,,insulation ,block hollow ,insulation ,gypson plaste		32.8	0.565
23	single	8 hb	stone cladding,cement plaster ,block hollow,insulation ,gypson plaster		25.3	0.93
24		9 hb	stone cladding,cement plaster ,,insulation ,block hollow ,gypson plaster		25.5	0.93

A	apartment	N	envelope construction	layers	thickness CM	U value W/M2.K
38	double block wall	2 fb	lime stone,cement plaster ,insulation ,fullblock ,air gap50 , full block,insulation ,gypson plaster		42.3	0.425
39		3 fb	cement plaster,insulation, full block,air gap50,full block ,insulation ,gypson plaster		39.3	0.429
40		4 hb	cement plaster,insulation ,block hollow,air gap25 ,block hollow,insulation ,gypson plaster		36.8	0.5
41		5 hb	cement plaster,block hollow ,air gap25,block hollow ,insulation,gypson plaster		34.3	0.767
42		6 hb	cement plaster,insulation ,block hollow,air gap25 ,block hollow,gypson plaster		34.3	0.767
43		7 hb	cement plaster,insulation ,block hollow,air gap50 ,block hollow,gypson plaster		36.8	0.75
44		8 hb	cement plaster,insulation ,block hollow,air gap50 ,block hollow,insulation ,gypson plaster		39.3	0.493
45	double	9 hb	cement plasterblock hollow,air gap25,block hollow ,gypson plaster		31.8	1.641
46		10 hb	lime stone,cement plaster ,insulation ,block hollow, air gap50,block hollow ,insulation ,gypson plaster		42.3	0.488
47		11 hb	cement plasterblock hollow ,air gap50,block hollow ,gypson plaster		34.3	1.564
48		12 hb	cement plaster,insulation ,block hollow,insulation ,block hollow,gypson plaster		34.3	0.55
49		13 hb	cement plaster,block hollow ,insulation,block hollow ,gypson plaster		31.8	0.89

,b , characteristic all wall cases .



c , wall cases assessment .

6.1.2 Optimize envelop and function orientation

6.1.2.1 *Optimize orientation*

Simulation argument:

The apartment simulated as one space to deduce the heat transfer from all elevations, with three person as previous case conditions.

Analysis inside surface temperature and heat flux depend on deviation (envelope single block).

The simulations have been done for all façade and for(0,5,10,15,20,25,30,35,40,45,50,55,60,65,70,75,80,85) deviation degrees for summer period.

Result and analyses:

- **Façade orientation:**

Inside surface temperature: the result arranged from the lowest temperature performance as follow: north, south, east, west.

Heat gain: the result arranged from lowest heat gain value as follow: north, south, west, east.

In summer time east and west elevation must be protection from the solar radiation by shadow device (tree , louvers) or decrease area.

- **Façade deviation**

The east facade:

Inside surface temperature: For the first six deviation from (0 to 25) degree the best inside surface temperature is without any deviation (0 degree), for the nest six deviation from (30 to 55) degree the best is the last one 55 degree , also for the last six deviation from (60 to 85) degree the best is 85 degree . The lowest east inside surface temperature taken by deviation 85 degree and 0 degree.

The heat gain increasing proportional with deviation Appendix F2.

The north facade:

The inside surface temperature proportional with increase deviation degree for this case the best result is without any deviation.

The heat gain increase proportional with deviation increase and the heat loss decrease this coefficient depend on the materials characteristics but gives sign for the envelop orientation behavior Appendix F2.

The west, north (chamfer) facade:

The inside surface temperature proportional with increase deviation degree from60 to 85 degree deviation. Inversely proportional from (5 to 60) deviation degree in this case the best result is at60 deviation degree.

Heat transfer as the inside surface temperature behavior Appendix F2.

The west façade :

The lowest west inside surface temperature taken by deviation 85 degree.

Heat transfer as the inside surface temperature behavior inversely proportional with deviation degree Appendix F2.

The south façade :

The inside surface temperature proportional with increase deviation degree for this case the best result is without any deviation as north elevation .

The heat gain increase proportional with deviation increase with heat loss decrease at the same time Appendix F2.

PMV/SET:

ALL have roughly equal performance, the best result for 85 devotion degree and without deviation **Table 6-5** and Appendix F2.

Table 6-5: orientation and deviation evaluation..

apartment	construction	U vale	shading	N	diviation	east elevation	north elevation	chamfer elevation	west elevation	south elevation	PMV
west apartment	 gypsum plaster3cm block 15cm cement plaster1.3cm	2.974	-----	A	0	T between 26.6to33 heat transfer-300 to 525	T between 26.4to31.5 heat transfer-290 to 112	T between 26.5to33.5 heat transfer-130 to 210	T between 26.7to34.3 heat transfer-150 to500	T between 26.3to32.3 heat transfer-420 to270	1.1 to 2.45
			-----	A	5	T between 26.7to33.1 heat transfer-299 to 533	T between 26.5to31.6 heat transfer-288 to 112	T between 26.5to33.3 heat transfer-132 to 190	T between 26.7to34.1 heat transfer-150 to588	T between 26.3to32.6 heat transfer-420 to330	1.17 to 2.5
			-----	A	10	T between 26.7to33.1 heat transfer-297 to 533	T between 26.6to31.6 heat transfer-286 to 112	T between 26.6to33.3 heat transfer-132 to 183	T between 26.7to34 heat transfer-150 to565	T between 26.5to32.6 heat transfer-420 to380	1.17 to 2.5
			-----	A	15	T between 26.8to33.2 heat transfer-292 to 526	T between 26.6to31.7 heat transfer-281 to 115	T between 26.5to33.2 heat transfer-134 to 153	T between 26.7to33.9 heat transfer-150 to554	T between 26.5to32.8 heat transfer-417 to407	1.17 to 2.5
			-----	A	20	T between 26.7to33.2 heat transfer-280 to 527	T between 26.6to31.9 heat transfer-277 to 118	T between 26.6to32 heat transfer-137 to 134	T between 26.6to33.9 heat transfer-150 to533	T between 26.6to32.95 heat transfer-416 to456	1.17 to 2.5
			-----	A	25	T between 26.8to33.3 heat transfer-290 to 525	T between 26.7to32 heat transfer-270 to 120	T between 26.5to32.2 heat transfer-137 to 112	T between 26.6to33.9 heat transfer-150 to512	T between 26.6to33.1 heat transfer-416 to489	1.17 to 2.5
			-----	A	30	T between 26.8to33.3 heat transfer-300 to 490	T between 26.7to32.05 heat transfer-269 to 120	T between 26.5to32.5 heat transfer-140 to 90	T between 26.5to33.9 heat transfer-150 to400	T between 26.6to33.3 heat transfer-415 to500	1.17 to 2.5
			-----	A	35	T between 26.8to33.4 heat transfer-310 to 450	T between 26.75to32.1 heat transfer-264 to 120	T between 26.5to32.5 heat transfer-140 to 84	T between 26.5to33.5 heat transfer-150 to385	T between 26.6to33.6 heat transfer-415 to565	1.17 to 2.5
			-----	A	40	T between 26.8to33.4 heat transfer-320 to 425	T between 26.75to32.25 heat transfer-255 to 127	T between 26.5to32.3 heat transfer-139 to 77	T between 26.5to33.1 heat transfer-150 to337	T between 26.6to33.75 heat transfer-415 to576	1.17 to 2.5
			-----	A	45	T between 26.6to33 heat transfer-315 to 430	T between 26.75to32.3 heat transfer-252 to 131	T between 26.6to32.3 heat transfer-140 to 77	T between 26.7to32.8 heat transfer-150 to310	T between 26.6to33.8 heat transfer-410 to600	1.17 to 2.5
			-----	A	50	T between 26.6to33 heat transfer-330 to 420	T between 26.8to32.4 heat transfer-248 to 139	T between 26.5to32.2 heat transfer-140 to 60	T between 26.6to32.5 heat transfer-150 to286	T between 26.6to33.8 heat transfer-410 to656	1.17 to 2.5
			-----	A	55	T between 26.5to32.9 heat transfer-370 to 400	T between 26.8to32.5 heat transfer-240 to 245	T between 26.6to31.85 heat transfer-139 to 60	T between 26.7to32.4 heat transfer-150 to243	T between 26.6to33.97 heat transfer-405 to675	1.17 to 2.5
			-----	A	60	T between 26.4to32.9 heat transfer-375 to 277	T between 26.8to32.8 heat transfer-239 to 288	T between 26.5to31.7 heat transfer-140 to 55	T between 26.7to32 heat transfer-150 to215	T between 26.6to34 heat transfer-405 to680	1.1 to 2.45
			-----	A	65	T between 26.4to32.8 heat transfer-375 to 233	T between 26.8to33 heat transfer-239 to 298	T between 26.6to31.95 heat transfer-140 to 59	T between 26.7to32 heat transfer-150 to181	T between 26.6to34 heat transfer-402 to687	1.1 to 2.45
			-----	A	70	T between 26.4to32.7 heat transfer-380 to 228	T between 26.8to33.2 heat transfer-237 to 310	T between 26.6to32 heat transfer-139 to 63	T between 26.7to31.05 heat transfer-150 to174	T between 26.6to34 heat transfer-401 to697	1.1 to 2.45
			-----	A	75	T between 26.5to32.5 heat transfer-384 to 300	T between 26.8to33.5 heat transfer-237 to 340	T between 26.5to32 heat transfer-139 to 68	T between 26.7to32 heat transfer-150 to143	T between 26.6to33.9 heat transfer-400 to700	1.1 to 2.45
			-----	A	80	T between 26.3to32.4 heat transfer-388 to 291	T between 26.8to33.7 heat transfer-236 to 387	T between 26.5to32.05 heat transfer-140 to 76	T between 26.7to31.05 heat transfer-150 to122	T between 26.6to33.9 heat transfer-400 to700	1.1 to 2.45
			-----	A	85	T between 26.3to32.3 heat transfer-390 to 285	T between 26.8to33.8 heat transfer-235 to 405	T between 26.5to32.1 heat transfer-139 to 80	T between 26.7to31.9 heat transfer-150 to100	T between 26.6to34 heat transfer-400 to700	1.1 to 2.45

6.1.2.2 *Optimize function direction*

Impact factor: solar transmission through envelop has big effect on indoor environment, the total Window Transmitted Solar of all the exterior windows in zone (The amount of beam and diffuse solar radiation entering a zone through an exterior window).

Simulation argument:

The apartment simulated as previous typical apartment consist of five spaces (conditions and input) to deduce the heat transfer from all function spaces, with three person as previous case conditions.

Envelope utilized double block with air gap 50mm with outside insulation (as region standard).

Spaces analyzed depend on air temperature and PMV /SET and heat transfer for summer and winter period.

Result and analyses:

The north direction gives comfort feeling in summer period.

In winter inversely result the south direction is the best one especially east, south same as kitchen then salon.

Mean air temperature (midday) corresponding to the latest result, same as PMV/SET the lowest. Temperature for master bedroom (west, north) direction then bedroom (east north) direction.

For winter period mean air temperature (midday) and PMV/SET winter time the best is south and east direction.

Solar transmission (midday) become higher at west direction and east correspond to salon and master bedroom.

In winter solar transmission correlate with other winter parameters with south direction salon and kitchen.

Peak opaque heat gain energy at midnight in salon and master that mean west direction Appendix F2.

Conclusion

In winter time the best directions is south and east .on other hand for summer period north façade.

From late result and correlate to space function and using schedule the best spaces direction as follow **Table 6-6**:

Salon: south east/west direction.

Bed rooms and kitchen: west, south and west north.

Bathroom: west and east.

Table 6-6: space function analyses.

			summer						winter					
apartment	zone	direction	PMV	T operative	T air	solar transmitted W	opaque inside gain W	opaque inside loss W	PMV	T operative	T air	solar transmitted W	opaque inside gain W	opaque inside loss W
west apartment	salon and dining	west south	0.95to2	28 to 30.95	28 to 31	[illegible]	[illegible]	[illegible]	-3.65 to-2.6	8.5 to 12.9	8.5 to 12.9	[illegible]	[illegible]	[illegible]
	master bedroom	west north	0.7to1.89	27.8to30.95	27.8to31	400	250	400	-3.8 to-3.4	7.5 to 9.5	7.5 to 9.5	500	200	400
	bedroom	east north	0.85to1.7	28to30.5	28to30.5	200	110	200	-3.88 to-3.6	7.3 to 8.5	7.3 to 8.5	250	85	228
	kitchen	east south	1 to 1.9	28 to 30.7	28 to 30.7	275	110	275	-3.65 to-2.38	8.5 to 14.3	8.5 to 14.3	1288	200	1300
	bathroom	east	0.95to1.7	28.5to30.2	28.5to30.2	—	0.5	—	-3.65 to-3.4	8.5 to 9.5	8.5 to 9.5	—	1.8	1
	WC	east	1.1to1.9	28.7to30.5	28.7to30.5	—	0.3	—	-3.65 to-2.85	8.7 to 11.8	8.7 to 11.8	—	1.8	2
	entrance	middle	0.9to1.7	28.5to30.2	28.5to30.2	—	0.8	—	-3.65 to-3.35	8.5 to 9.5	8.5 to 9.5	—	2.6	10

6.1.2.3 *Optimize shading device and windows.*

It is impossible to neglected the big influence of shading device and the kind of windows at envelope performance therefore this is short investigation to get indicate for that influence .
The investigation for first step tried four kind of shading devices[overhang, side device , blind roll ,environment shading (tree)].
For the second step take three kind of window double and two double separated window with 20cm distance , double and single window within three kind of glass.

- Shading device

Simulation argument: for this case utilized the same conditions (input) for the previous case study with the same shading schedule, but for more analyses there is another parameter for comparing the luminance (leed guide requirement).The shading device used as follow:
1 the performance of the normal double glass without any kind of shadow.
2 utilized blind roll from outside.
3 utilized overhang shadow device with width 40 cm.
4 utilized sides shadow devices with width 40 cm.
5 utilized louvers with angle 30 .
6 the reflection of the environment on the building envelope as trees from the west and east direction.
7 the performance of using outside blind roll and another with inside rolls beside the environment reflected by surround trees.
8 the influence of using overhang shadow device with outside blind roll.
9 the influence of using overhang with louvers with angle 40 could moving and 15 fixed .

Result and analyses :

- master bedroom (west ,north)direction:

PMV/SET parameters for The best result for using outside roll and the trees influence that give 85% better comfort than without any shadow device , 70% for using only outside roll and 60% for inside roll with trees effected , 15% for using fixed louver or side device or overhang , 45% for moving louver or coating glass.
This result reflected inversely on winter for fixing device like overhang, side device , fixed louver and coating glass which reduce reaching solar radiation to the space .
That is give the best performance for moving roll but the bad point is Lack of permanence for outside beside the trees effect which has disappear effect in winter.
Solar transmission parameters: The result similar of PMV/SET the best result for outside roll with environment trees effect which reduce the solar transmitted about 95% than without any shading devices. using fixing louver reduce it about 70%also coating glass, side or overhang shadow device reduced about 30% Appendix F2.

- Salon and dining room (west, south) direction :

PMV/SET parameters 85% better comfort result for outside roll shading device than without any shading device same as the master bed room result but in this case found the side effect increase the influence to 60% because the vertical device has big impact on west orientation.
Solar transmitted parameters: The result similar for master bedroom the best result for outside roll with environment trees effect which reduce the solar transmitted about 95% than without shading device case, using fixing louver reduce it about 70% also coating glass, side or overhang shadow device reduced about 30% Appendix F2.

- kitchen (south , east) direction:

PMV/SET parameters: The result were comparable with the previous rooms about 80% for the outside roll beside the environment trees effect better than without any shading device.

Solar transmission parameters : the best result for coating glass reducing solar transmission was about 75% special for south elevation but this result inverses in winter although the effect of roll device with environment reduce to 65% only at midday then the performance reach 85% which deduce the late is the best performance Appendix F2.

- Bedroom (north , east) direction:

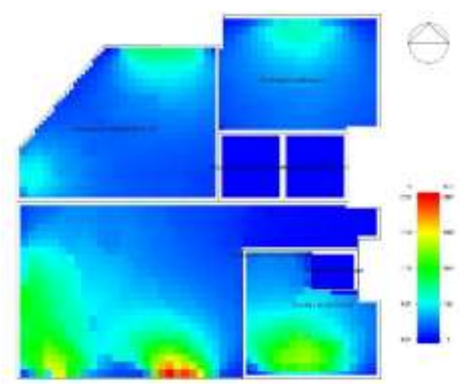
PMV/SET parameters: Similar result but in this case all parameters decreased 15% that is for the weaknesses of the solar influence at north elevation.

Solar transmission parameters : Similar result for kitchen special for north elevation because in north elevation the luminance impact more than solar for that result the big reduced about 62% for the kind of glass then for roll and trees effect which is better effect only at the midday Appendix F2.

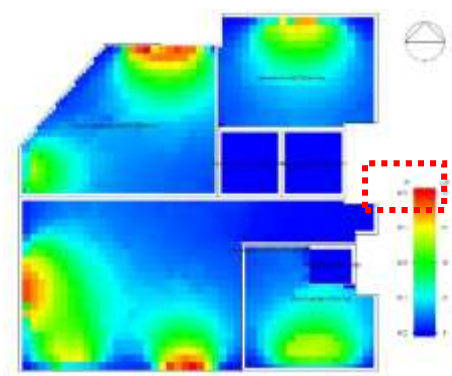
- Luminance effect:

The kind of glass has a big effect on the luminance of the space in this case study using coating glass not pass the requirement of LEED guide , also using louvers which reach 78 lux.

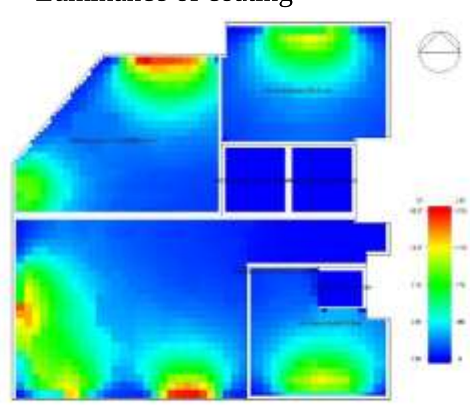
On other hand using blind roll device pass the LEED requirement with the surrounded ambient which reduce a little bit the luminance which reach 200 lux **Figure 6-4 Figure 6-5** Appendix F2.



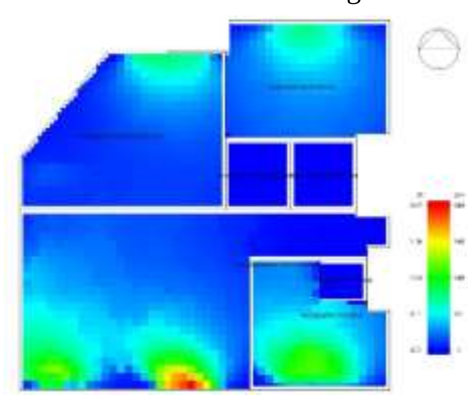
Luminance of coating



Luminance of normal glass

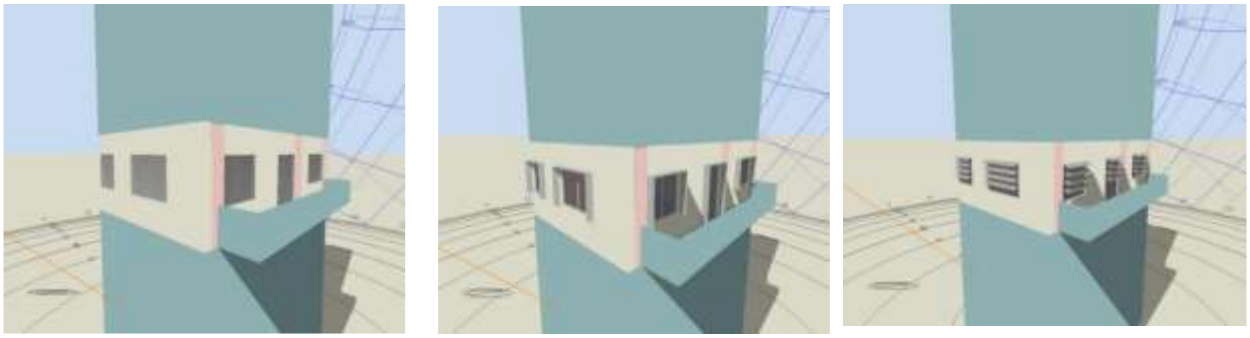


Luminance of normal glass with blind roll



Luminance of normal glass with blind roll And surrounded trees

Figure 6-4: shading device and Luminance effect for different shading devices.



Moving louvers — Side and overhang device — fixing louvers

Figure 6-5: fixing shading devices.

Daylighting Credit - LEED v3 NC 2009 IEQ 8.1

The aim of the daylighting credit is to encourage and recognize designs that provide appropriate levels of daylight for building users.

A daylighting credit is available if at least 75% of net lettable area in occupied spaces is adequately daylight, having illuminance within the range 25-500 fc.

For triple low E with roll blind outside medium opaque

Daylighting data	
Project file	C:\Documents and Settings\Stefania\Desktop\space 5.dsb
Report generation time	16/05/2014 12.37.01
Sky model	CIE clear day
Time 1	9:00
Time 2	15:00
Location	DAMASCUS (CIV/MIL)
Working plane height (m)	0,750
Max Grid Size (m)	0,200
Min Grid Size (m)	0,050
Illuminance lower threshold (lux)	110,000
Illuminance upper threshold (lux)	5400,000
Summary Results, average values for 9:00 and 15:00	
Total area (m2)	73,000
Total area above threshold (m2)	56,000
% Area within illuminance threshold limits	77,3
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Zone	**Block**	**Floor area (m2)**	**Min Illumination (lux)**	**Working plane area within Limits (%)**
salon,dining	west apartment	29,720	3,0	81,4
toilet	west apartment	0,990	0,0	0,0
kitchen	west apartment	9,030	0,0	85,2
master bedroom	west apartment	16,900	42,4	87,2
bedroom	west apartment	11,730	0,1	84,7

bathroom	west apartment	2,400	0,0	0,0
inside entrance	west apartment	2,400	0,0	0,0
Total		**73,000**	**0,0**	**77,3**

For overhang with normal double glasses

Summary Results, average values for 9:00 and 15:00	
Total area (m2)	73,000
Total area above threshold (m2)	62,000
% Area within illuminance threshold limits	85,5
LEED v3 NC 2009 IEQ 8.1 Status	PASS

For overhang and sides :

Summary Results, average values for 9:00 and 15:00	
Total area (m2)	73,000
Total area above threshold (m2)	62,000
% Area within illuminance threshold limits	84,9
LEED v3 NC 2009 IEQ 8.1 Status	PASS

Coating glass

Summary Results, average values for 9:00 and 15:00	
Total area (m2)	73,000
Total area above threshold (m2)	0,000
% Area within illuminance threshold limits	0,4
LEED v3 NC 2009 IEQ 8.1 Status	FAIL

For fixing louvers :

Summary Results, average values for 9:00 and 15:00	
Total area (m2)	73,000
Total area above threshold (m2)	1,000
% Area within illuminance threshold limits	1,9
LEED v3 NC 2009 IEQ 8.1 Status	FAIL

Overhang with side and roll blind out side:

Summary Results, average values for 9:00 and 15:00	
Total area (m2)	73,000
Total area above threshold (m2)	61,000
% Area within illuminance threshold limits	84,7
LEED v3 NC 2009 IEQ 8.1 Status	PASS

- Conclusion :

The fixing shading device has good performance in summer but inverse effect in winter like the coating glass with high SHGC performance also for luminance.
The best solution utilizing moving shading device like blind roll from outside and also the high performance for ambient which give the high performance in summer and winter special for east and west elevation but this environment result maybe has another reflected on natural ventilation
For the south elevation has the same effect but the kind of glass has great influence but that is as mentioned before with inversely effect in winter.

- Glass kinds

From the last result that gives another indicator to get better performance for summer and winter utilized the traditional way by using two window one has good influence in summer and the other for winter which allowed to use one and neglected the other for climate adaption .
All cases achieve LEED luminance requirements with blind roll shadow device in the outside glass cases follow :
1 :utilized triple clean glass.
2 utilized triple low E glass.
3 : utilized two windows the first one double low E glass , the second one single clear glass with distance 20cm.In summer used as it is in winter open the double low E one and use only the normal one to get more solar radiation inside the apartment .
4 : utilized two windows the first one double low E glass , the second one double clear glass as the normal one used as mentioned before with space 20cm between the two windows .in summer used as it is in winter open the low E one and use only the double normal one to get more solar radiation inside the apartment and keep it .

Result and analyses:
For summer period : the high parameter for two windows the first one double low E glass , the second one single clear glass with distance 20cm and the best performance for two windows with triple then 4glasses .
Winter period :The best performance open the double low E window and use the single clear glass (during day and triple during night) for west and east elevation , for south and north elevation use the two windows as triple one.
For solar transmitted to get the maximum solar for south can follow the same way for east and west elevation at the day on night use the tripe way for keeping the heat inside the hall Appendix F2.

Conclusion:
Utilize two windows as triple glass the first one double low E glasses the second one single clear glass the space between to windows 20cm in summer used as one triple glass with blind roll outside and trees surrounded tress with careful to natural ventilation situation.
For winter time open the first window during day to get the high amount of solar and close it during night.
The aim of the daylighting credit is to encourage and recognize designs that provide appropriate levels of daylight for building users.
A daylighting credit is available if at least 75% of net lettable area in occupied spaces is adequately daylit, having illuminance within the range 25-500 fc.

Daylighting data	
Project file	C:\Documents and Settings\Stefania\Desktop\space 5.dsb
Report generation time	16/05/2014 13.33.32
Sky model	CIE clear day
Time 1	9:00
Time 2	15:00
Location	DAMASCUS (CIV/MIL)
Working plane height (m)	0,750
Max Grid Size (m)	0,200
Min Grid Size (m)	0,050
Illuminance lower threshold (lux)	110,000
Illuminance upper threshold (lux)	5400,000

For triple with roll blind between the two window :

Summary Results, average values for 9:00 and 15:00	
Total area (m2)	73,000
Total area above threshold (m2)	57,000
% Area within illuminance threshold limits	78,7
LEED v3 NC 2009 IEQ 8.1 Status	PASS

For 4 glasses layers with low E double glasses :

Summary Results, average values for 9:00 and 15:00	
Total area (m2)	73,000
Total area above threshold (m2)	51,000
% Area within illuminance threshold limits	70,7
LEED v3 NC 2009 IEQ 8.1 Status	FAIL

6.1.3 Optimize natural ventilation

Simulation argument:

The dynamic simulation made it for typical apartment (as previous cases) to analysis the heat flux ,airflow , PMV/ SET depending on outdoor climate condition to understand the impact of natural ventilation and how the design builder make simulation and the result also CFD modeling.

the analysis period will be short but for the important period of the year to optimize new passive cooling design to summer design (July / August).

The widows utilized two windows double low E [as previous glass investigation], with U 1.066 W/m2k with aluminum frame, SHGC 0.475 .

The most important data for this case the operative opening the percentage and the schedule of opening and closed time for windows.

this investigation is for passive design depend on effective period the night natural ventilation, with blind roll shading medium opaque using essential at midday .the window utilized for stairs zone double low E without shading .

Utilized wooden door with U value 1.89 W/m^{2}k size of indoor opening 100% for 70 time to get the real impact of opening and the airflow between zones.

The partition used brick block and cement plaster10cm also void wall. The stairs wall is concrete and plaster 32cm.

Ceiling and floor U value 1.466 W/m^2.k with adiabatic influence from adjustment.

Outside Wall utilized from brick block with natural materials mud block and hemp insulation and lime wash and plaster U 0.268 W/m^2.k.

According to ASHRAE standard 55 and fundamental, predicted PMV of Fanger and for given activity in the real environment Standard Effective Temperature, SET.

The effective factor at natural ventilation is air flow, natural ventilation at simulation program take way as the air network, that can calculate as **Figure 6-6**

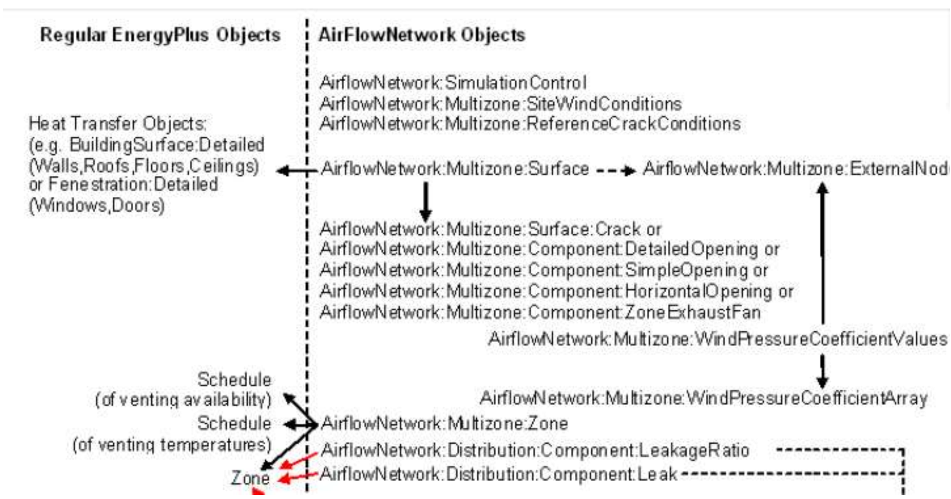


Figure 6-6: Relationships among Airflow Network objects (right-hand side) and between AirflowNetwork objects and regular EnergyPlus objects. An arrow from object A to object B means that A references B

Figure 6-6. Relationships among Airflow Network objects (right-hand side) and between AirflowNetwork objects and regular EnergyPlus objects. An arrow from object A to object B means that A references B

The value of the exponent, n, in the crack air flow equation. The valid range is 0.5 to 1.0, with the default value being 0.65. Crack flow is assumed when the window or door is closed. In this case, the value of this field is the exponent

The Opening Factor corresponds to the fraction of window or door that is opened.wind pressure coefficients are defined for each of the wind directions defined in the unique, Wind Pressure Coefficient Array object. In the air flow calculation, interpolation of the specified WPC values is done for time-step values of wind direction.

Without heating or cooling the apartment shown at **Figure 6-7**.

Time period : summer design week of July / August.

Time set up 4.

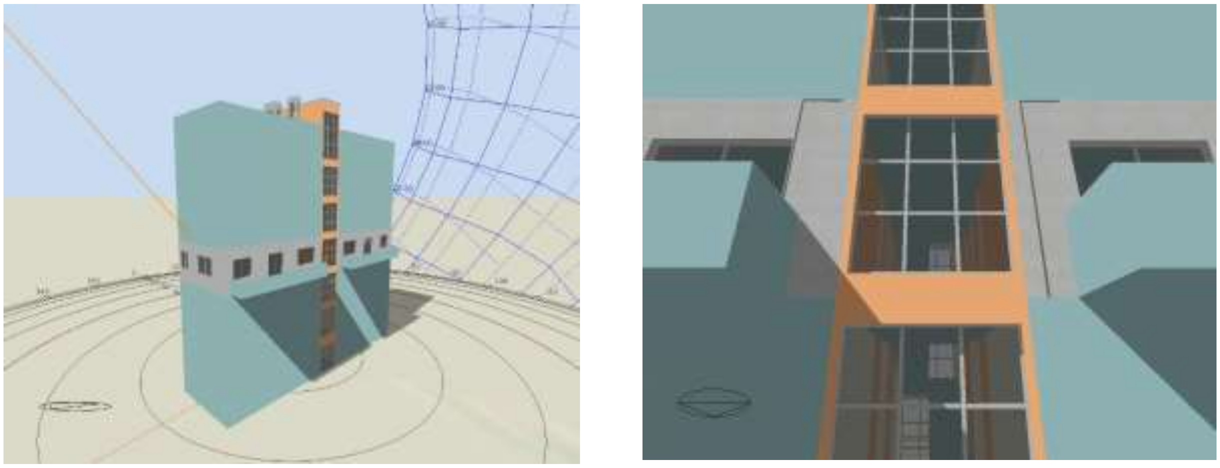
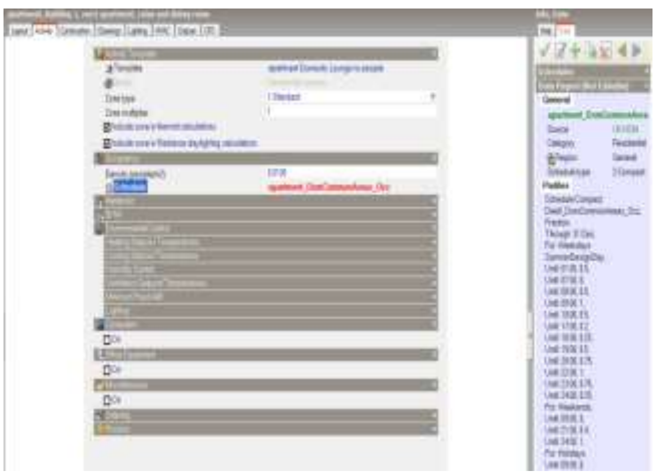
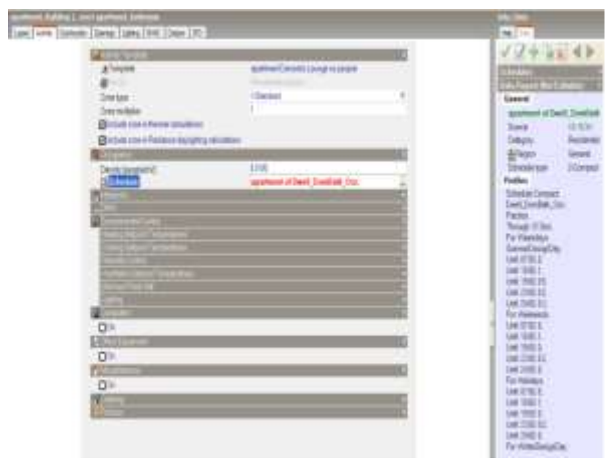


Figure 6-7: apartment investigation.

Utilized specific occupant schedule for every zone and Operation schedule as **Figure 6-8(a,b):**

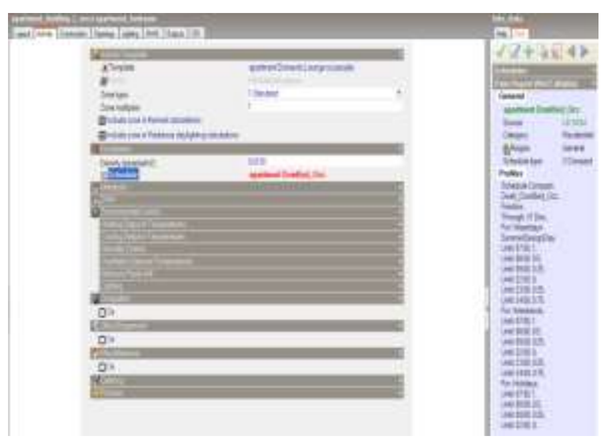


Salon schedule



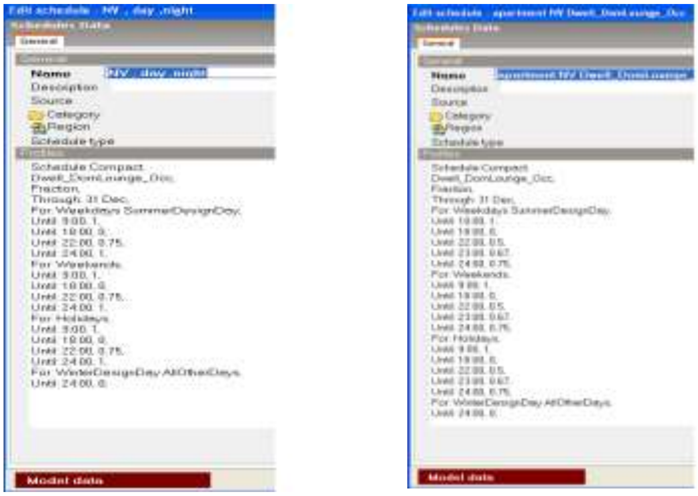
bed room schedule

Kitchen schedule



bath schedule

,a occupant space schedule



,b. Operation schedule for opening external window and inside (void).

Figure 6-8: a,b .occupant schedule for every zone and Operation schedule for case study.

- ➢ Wind direction and orientation.

The simulation made for (0,5, 15, 30, 45 , 60,75,85) deviation degree ,to analysis the impact of direction design depend on wind effect.

Result and analysis:

Salon: the airflow and inside zone temperature the high result for deviation 85 degree.

Airflow towards other adjacent zones has more movement at deviation 5,0,85 degree.

On other hand, the important parameters PMV /SET (that depends on the human core and the reality environment) best result for deviation 75 and less 5 degree Appendix F3.

Master bedroom: the airflow high result for deviation (75, 0) degree.

Airflow towards other adjacent zones has more movement at deviation 75 °C degree. For west window the high volume airflow for deviation (75,0) ,but for north side it has for deviation (75,15).

Moreover, the best result of PMV/ SET for deviation 75 degree and for less than 5 degree

Kitchen: the high airflow movement for 0 degree.

On other hand, the PMV/ SET as all zone the best result for deviation 75, 0 and less than 5 degree.

Bed room: all results corresponded to salon zone, the best result for all parameters are deviation 0,75 degree.

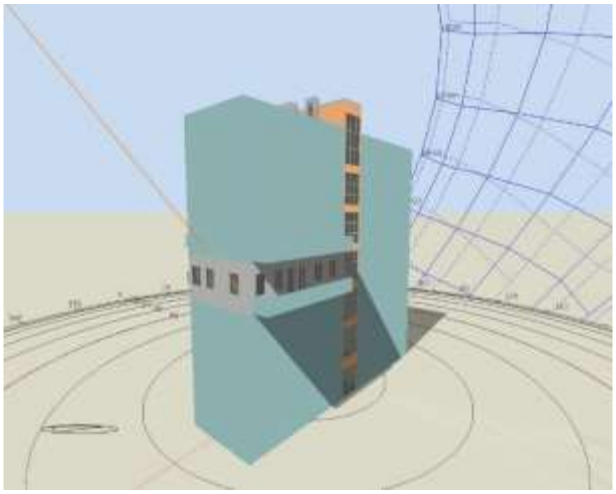
For PMV/SET as all others presents the best result for deviation 75 and less than 5 degree.

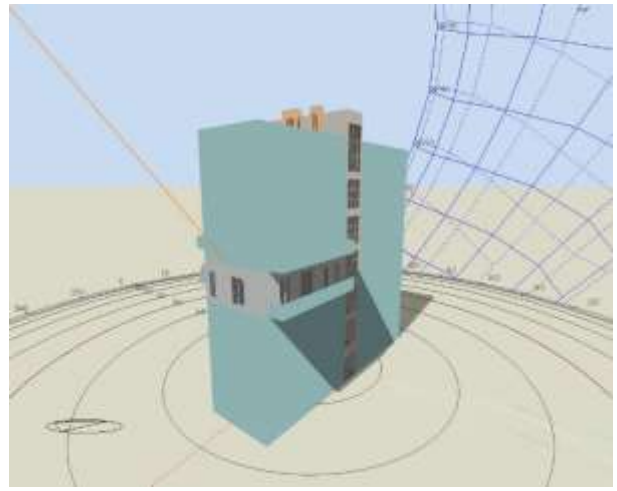
Conclusion: from all previous result for getting better air flow impact the best direction design (0,75) deviation degree (as traditional houses) which could get 75 deviation degree effect through chamfer design for window.

- ➢ Windows shape.

Cases study: the first case the general one , the second one divided each window area to two separated windows.

The third case French window with equal areas [high 200cm for all windows] present at **Figure 6-9**.





Second case windows third case French windows

Figure 6-9: windows shape investigation cases.

Result and analysis

Salon and kitchen : as expected the air flow increases proportion with increase the number of windows also air change per hours.

Airflow volume increases through using French windows design .On other hand, for using two windows for same area the result increase twice. Which explain through the thin and high window that allowed to increase the airflow volume and effect(single side stack ventilation, eddy area) .

PMV/SET slightly cool feeling for using France windows Appendix F3.

Master bedroom and bedroom: air flow result equal the result of salon zone.

The airflow through windows from north side has the best result for the general case(because there is no wind at north direction so that depends only on size also on (single side stack ventilation) as French windows design result).

For west direction the better result for divided area to two windows.

PMV/ SET as salon result for more cool feeling the French windows design Appendix F3 .

Conclusion:

From all previous analyzed using French design windows special for north and south direction (facade) to get the impact of single side ventilation (stack as traditional) and to increase the airflow volume.

For the west and east direction (façade) using two windows and French design windows could get more cool feeling roughly 15-20% comfort increasing.

- Opening size percentage.

Opening size percentage using the same input data with different opening percentage (0,10,30,50,75,100)% .

Result and analysis:

Salon, Master bed room:

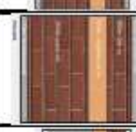
For those two zones the airflow effect increase through increasing the percentage of opening ,the range of opening between 10to100 the result changing between 40-75 %.

PMV/SET depend on the ventilation and the impact of 100% opening increasing comfort about 15-25% more than 5% opening.
All other zones have same result Appendix F3.

- Natural ventilation and envelop materials impact

Natural ventilation and envelope materials using same previous materials (cases have been done before for the better envelop behavior to reach thermal comfort) present at **Table 6-7**.
Simulation arrangement:
The input data as general cases without influence of stairs.

Table 6-7: envelop materials cases study with natural ventilation impact .

case N	abbreviation	U (w/m2.k)	specification from outside	thickness CM	layers
1	wall 1	0.318	single full block with out insulation , pcm materials , air mass 50mm, ceramic cladding.	37	
2	wall2	0.318	brick block with out insulation , pcm materials , air mass 50mm, ceramic cladding.	37	
3	wall 3	0.268	brick block, hemp insulation , mud block, lime wash.	32	
4	wall 4	0.174	brick block, hemp10cm insulation , mud block, lime wash.	36	
5	wall5	0.268	block, hemp insulation , mud block, lime wash.	36	

Result and analysis

Natural ventilation increase thermal comfort about 30-35% this result also depend on envelop behavior [the natural ventilation effect on PMV/SET parameter depend on materials , the result from lower value as follow :wall 4 brick hemp 10, wall 3 brick ,wall5 block hemp, wall1 pcm block, wall2 pcm brick. On other hand the PMV/SET parameter without natural ventilation which only depend on materials the result from lower value :wall1 pcm block ,wall5 block hemp ,wall4 brick hemp 10 ,wall 3 brick , wall2 pcm brick(as previous materials investigation)].
Kitchen zone has different arranged which related to the south orientation [the quantity of solar radiation]and the effect on materials special pcm materials Appendix F3.
Conclusion:
Natural ventilation has big impact on the envelop performance which depend on the capacity of materials.
For getting more cool feeling the better wall is wall 4 brick with hemp insulation 10cm or 6 cm.
For south zone direction the pcm materials has good effect at cool feeling.
All previous results of this chapter present confirmation of traditional houses design [analyzed as late results through the natural materials], space design direction , opening area and shape.

Figure 6-10 presents the optimize envelope materials correlated to traditional ones(monitoring data) and comparison behavior for summer and winter period which have a similar and more constant behavior (reach result as 1987 and reduce the climate change effect).

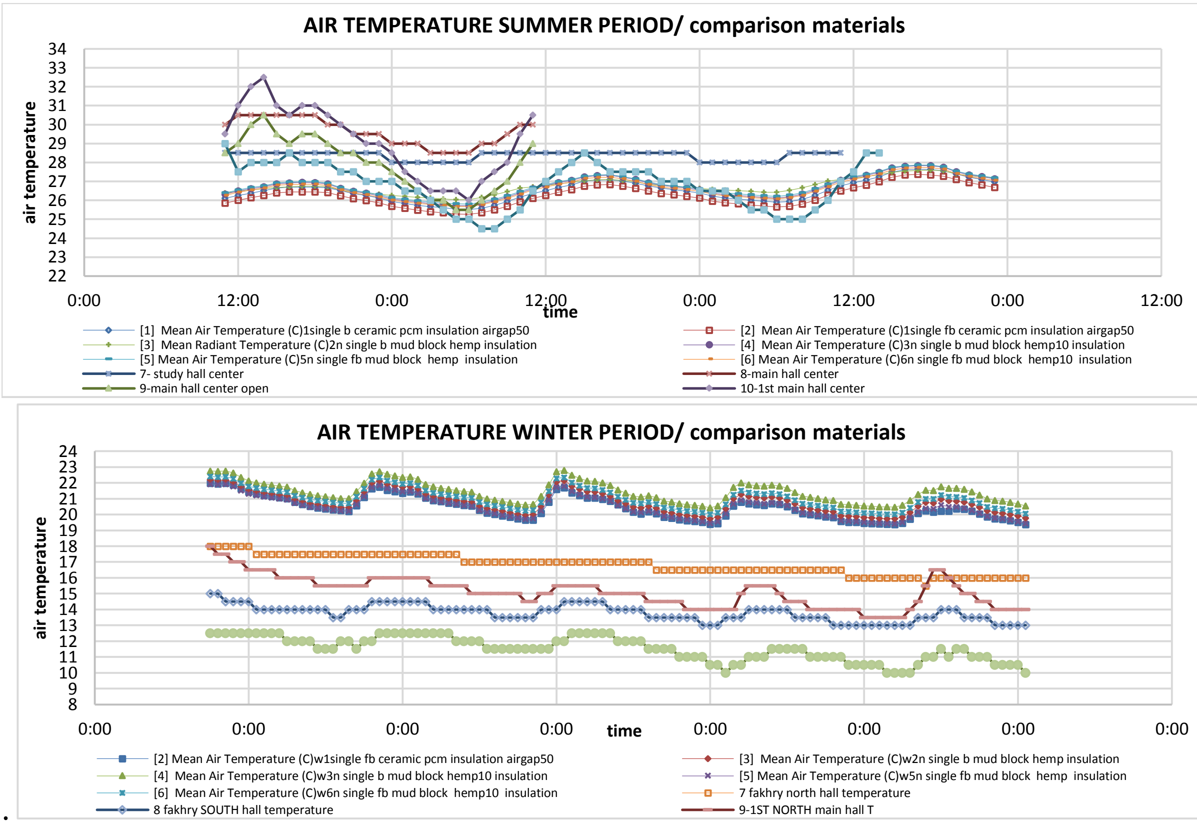


Figure 6-10: comparison between traditional materials (measurements) and optimize materials impact air temperature.

6.1.3.1 *Optimize cross ventilation design*

Simulation argument:
For this step applied all the previous results(best performance for hot-dry climate) merge it in one design (Wall utilized from brick block with natural materials mud block and hemp insulation and lime wash and plaster U 0.268 W/m2.k(roughly as ASHRAE 1.89),with adiabatic heat transfer for slab and floor , for typical family with one son go to school and the parents one is working and the other stay at home which means during the morning there is one person and at night there will be three persons stay to gather in the salon using common schedule for ordinary day life for each room as society behavior. In this investigation used void which use for installation and ventilation (breathing instrument similar to wind tower) as typical in those region (hot –dry) with small volume, merge between two kinds of natural ventilation for schedule during all day, double glass + one low E) for very hot dry climate used the night ventilation only Riyadh city.

The analysis of the outdoor air temperature for three cities in hot-dry climate with different level which arranged as follow: Damascus in Syria, Cairo in Egypt, Riyadh in Saudi Arabia, with high and extreme high temperature especially in summer time. Special attention should be taken in designing the south, east, and west facades.

According to ASHRAE standard 55 and fundamental the thermal comfort condition of mind which expresses satisfaction with the thermal environment , predicted PMV of Fanger and for the given activity in the real environment Standard Effective Temperature, SET beside adaptive model and psychometric-chart. The most commonly used indicator of thermal comfort is air temperature and for energy consumption energy cooling/heating load for all year which calculated related to CDD and HDD.

The assessment have done by comparing between three cases the ordinary apartment (as city code), the second the optimizing apartment (as all previous results and recommended point) , the third is the closed case with mechanical ventilation and HVAC system .

First step the second case without HVAC system. The second step utilize mixed mode which reduce energy [“Mixed-mode” refers to a hybrid approach to space conditioning that uses a combination of natural ventilation from operable windows (either manually or automatically controlled), and mechanical systems that include air distribution equipment and refrigeration equipment for cooling. A well-designed mixed-mode building begins with intelligent facade design to minimize cooling loads. It then integrates the use of air-conditioning when and where it is necessary, with the use of natural ventilation whenever it is feasible or desirable, to maximize comfort while avoiding the significant energy use and operating costs of year-round air conditioning. The input object Availability Manager: Hybrid Ventilation serves two purposes: 1) it prevents simultaneous natural ventilation and HVAC system operation, and 2) it allows users to examine various strategies to maximize natural ventilation in order to reduce heating/cooling loads. This availability manager works with either the Airflow Network model or the simple airflow objects to provide controlled natural ventilation. The controlled natural ventilation objects referred to here are either Airflow Network :Multi zone: Component Detailed Opening and Airflow Network: Multi zone: Component Simple Opening objects, or Zone Ventilation and Zone Mixing objects.

Temperature control input.

This control mode checks whether the outdoor air dry-bulb temperature is between the Minimum Outdoor Temperature and Maximum Outdoor Temperature specified. If the outdoor temperature is between the two values then natural ventilation is allowed, else natural ventilation is not allowed.

When natural ventilation is allowed, the control then checks the temperature difference between the zone temperature and the temperature setpoint (s) in the controlled zone based on the specified temperature control type (four available temperature control types) to make a final decision:

Single Heating Setpoint: If the zone temperature is below the setpoint, then the initial decision is overridden and natural ventilation is not allowed. This is intended to avoid overcooling a space, which could result in additional heating load.

Single Cooling Setpoint: If the zone temperature is above the setpoint, then the initial decision is overridden and natural ventilation is not allowed. This is intended to avoid overheating a space, which could result in additional cooling load.

Single Heating Cooling Setpoint: Since this temperature control type requires only a single setpoint, natural ventilation is not allowed. A recurring warning message is issued.

Dual Setpoint with DeadBand: If the zone temperature is beyond the dead band, the initial decision is overridden and natural ventilation is not allowed. This is intended to avoid either overcooling a space, which could result in additional heating load when the zone temperature is below the heating setpoint, or overheating a space, which could result in additional cooling load when the zone temperature is above the cooling setpoint].

6.1.3.1.1 Without mechanical cooling:

Figure 6-11 presents the more steady temperature and reducing the swing between day and night at new optimizing design[the natural ventilation as general reduce the temperature about 2 °C degrees as minimum result during all day and new design reduce another °C degree as total for all rooms through hottest period as August 2015th], beside the void effect which decrease Salon air temperature about one degrees, this result reflected on thermal comfort (air flow movements gives more comfortable feeling for occupant) which increase about 10-20% for summer period for winter period the new design increase the comfort about 30% psychometric chart **Figure 6-12** shows this results .

6.1.3.1.2 Cross ventilation with mixed mode

Simulation has done to get the total energy load (cooling/ heating load) for the year .

- Damascus case

In this case the second case the ordinary apartment as Syrian code [wall consist of double block (with insulation at outside and cement plaster with painting finishing total thicknesses 3+5+15+10+3=36cm/U =0.68W/m^2.k(roughly as ASHRAE 90)] .

Natural ventilation decrease cooling needs about 50%. On another hand the new design for cross ventilation apartment reduced cooling needs about 70-75% **Figure 6-13** shows this result for each rooms. Also temperature has similar average as design cooling temperature 24°c but the rang (day/night) different that depend on cooling schedule (at cooling schedule off the natural ventilation on, in this case the effective factors are design and envelop characteristics) the new design has the better performance which reflected on thermal comfort as previous result related to air movement impact **Figure 6-22-a CFD modeling** .For winter period the new optimizing envelop got better performance than code one and reduce heating needs roughly about 50% , Also for air temperature as previous result for design heating temperature 20°C **Figure 6-13**shows all previous results.

- Cairo case

In this case the second case the ordinary apartment as Egypt code [wall consist of three brick block as mud 20*7.7cm (heating insulation) with cement mortar and plaster the total thickness about 29 to 31 cm , /U =0.78W/m^2.k(roughly as ASHRAE 90)].

Natural ventilation decrease cooling needs about 35%. On another hand the new design for cross ventilation apartment reduced cooling energy about 50-55% **Figure 6-14** shows this result for each rooms. Also temperature has similar average as design cooling temperature 24°c but the rang (day/night) different that depend on cooling schedule (at cooling schedule off the natural ventilation on, in this case the effective factors are design and envelop characteristics) as expected the new design has the better performance which reflected on thermal comfort as previous result .

As Damascus result for winter period the new optimizing envelop got better performance than code one and reduce heating needs roughly about 35% , Also for air temperature as previous result for design heating temperature 20°C **Figure 6-14** shows all previous results.

- Riyadh case

In this case the second case the ordinary apartment as Saudi Arabia code [wall consist of double block (with heat insulation at the middle and cement plaster with painting finishing total thicknesses 3+15+5+10+3=36cm/U =0.68W/m^2.k(roughly as ASHRAE 90)]

As previous result with decreasing at natural ventilation only for night period, which decrease the effect to about 30% but for new design reduce cooling energy about 45-50% **Figure 6-15** shows this result.

Also temperature has similar average as design cooling temperature 24°c but the rang (day/night) different that depend on cooling schedule (at cooling schedule off the natural ventilation on, in this case the effective factors are design and envelop characteristics) as expected the new design has the better performance which reflected on thermal comfort as previous result .
Winter period as summer period the effect is more limited the new optimizing envelop got better performance than code one and reduce heating needs roughly about15-20% , Also for air temperature as previous result for design heating temperature 20°C **Figure 6-15** shows all previous results.

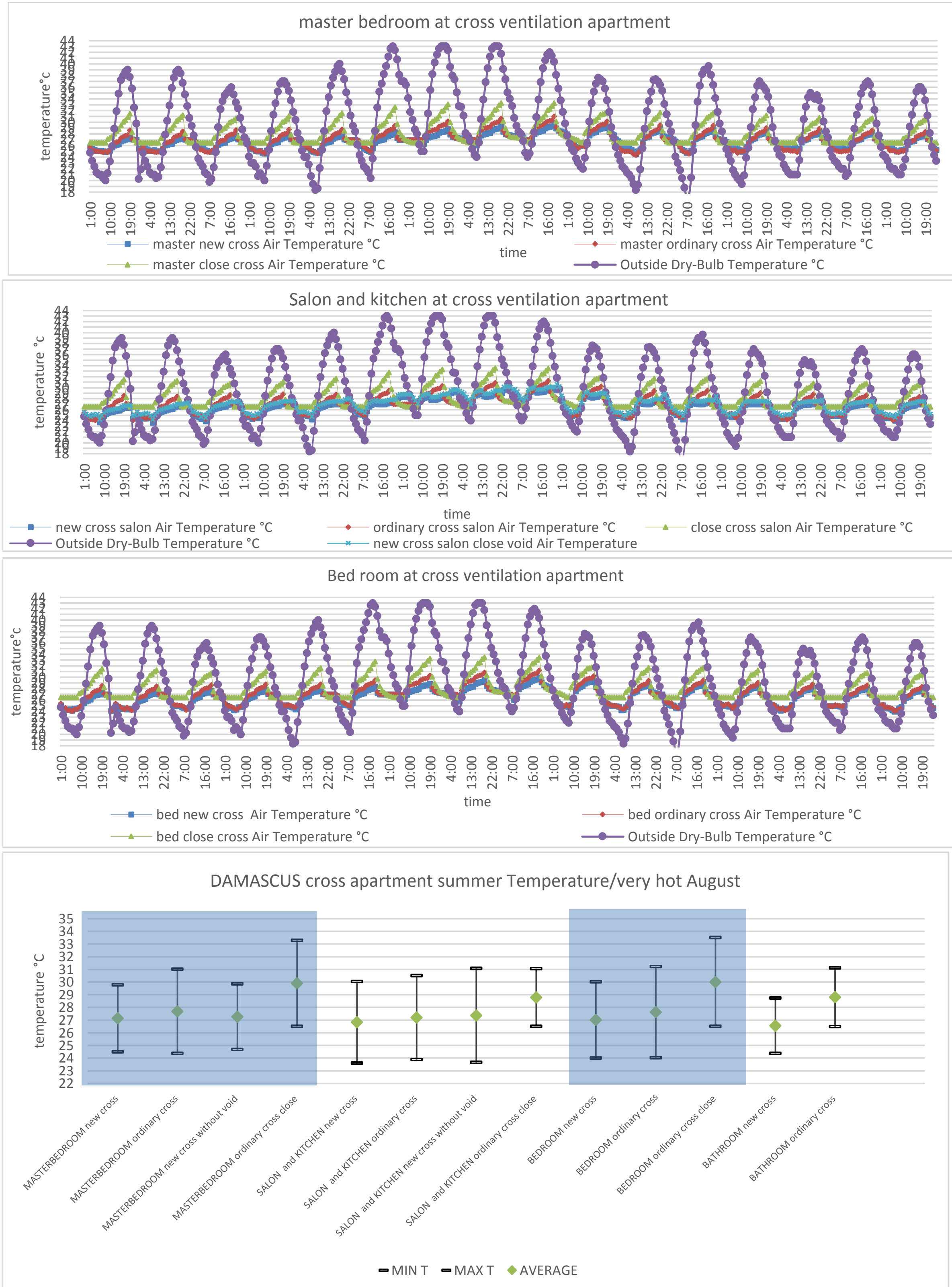


Figure 6-11: apartment with cross ventilation at hottest summer period August air temperature for different rooms functions.

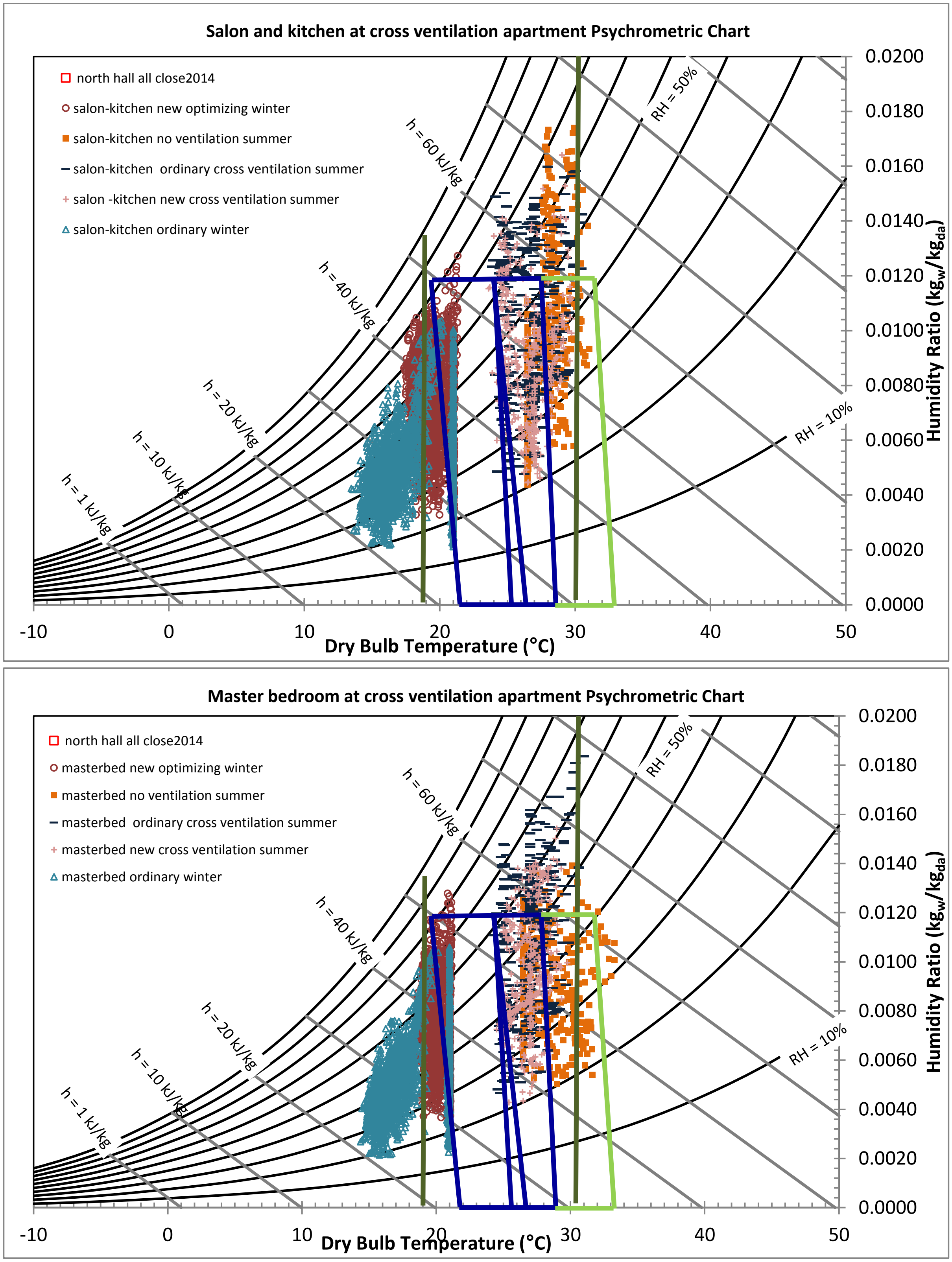


Figure 6-12: apartment with cross ventilation at hottest summer period August psychometric-chart for different rooms functions.

Figure 6-13: heating/cooling energy consumption for Damascus apartment[cross ventilation design].

Figure 6-14: heating/cooling energy consumption for Cairo apartment[cross ventilation design].

Figure 6-15: heating/cooling energy consumption for Riyadh apartment [cross ventilation design].

6.1.3.2 *Optimize single side ”stack” ventilation design*

Same simulation argument for cross ventilation and same steps.

6.1.3.2.1 Without mechanical cooling:

The apartment with only single side ventilation design **Figure 6-16** got higher indoor temperature than cross ventilation apartment’s one, that related to the air flow movement inside the room volume and the mixing between rooms and directions. Natural ventilation decrease temperature at least three degrees as total for all rooms through hottest period as August 2015th especially for west direction at afternoon **Figure 6-17**. New apartment design gives more steady temperature and reducing the swing between day and night at new optimizing design the natural ventilation reducing temperature about 1- 2 °C degrees less than the common code design, this result reflected on thermal comfort (air flow movements gives more comfortable feeling for occupant) which increase comfort about 20-25% for summer period for winter period the new design increase the comfort about 35% psychometric chart **Figure 6-18** shows this results.

6.1.3.2.2 Cross ventilation with mixed mode

Simulation has done to get the total energy load (cooling/ heating needs) for the year .

- Damascus case

the second case(as cross ventilation case) the ordinary apartment as Syrian code [wall consist of double block (with insulation at outside and cement plaster with painting finishing total thicknesses 36cm / U =0.68W/m^2.k(roughly as ASHRAE 90)] .
As cross ventilation the natural ventilation decrease cooling needs about 60%. The new single side stack ventilation design apartment reduced cooling about 75-80% **Figure 6-19** present results for each rooms. Rooms temperature has similar average of design cooling temperature 24°c or lower but with swing rang (day/night) different, which depend on cooling schedule (as cross ventilation results). as expected the new design has the better performance (reduce range and get lower temperature average value) that reflected on thermal comfort which also related for the air flow movement through enhancing the air movement by new design that improved the comfort feeling at hot-dry climate **Figure 6-22-b CFD modeling another evidence for that** .
For winter period the optimizing envelop got better performance than common one and reduce heating needs roughly about 60% , the temperature for design heating temperature 20°C get as previous results **Figure 6-19** shows all late results.

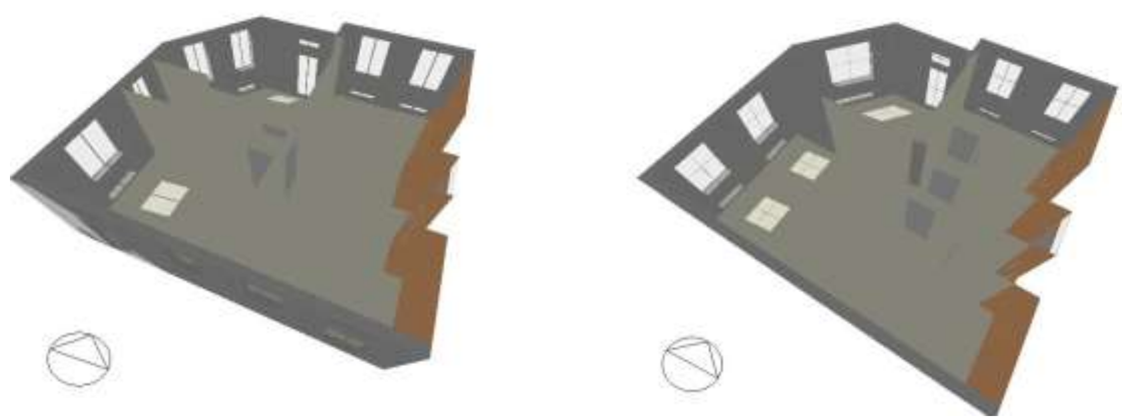
- Cairo case

the second case(as cross ventilation case) the ordinary apartment as Egypt code [wall consist of three brick block as mud 20*7.7cm (heating insulation) with cement mortar and plaster the total thickness about 29 to 31 cm , /U =0.78W/m^2.k(roughly as ASHRAE 90)].
As cross ventilation results the natural ventilation impact on reducing cooling needs about 35% and for the new design apartment the reducing about 55% **Figure 6-20** present results for each rooms. Air temperature has similar average of design cooling temperature 24°c or lower but with swing rang (day/night) different, which depend on cooling schedule (as cross ventilation results). as expected the new design has the better performance which reflected on thermal comfort as previous result .

For winter period (as Damascus result)the new optimizing envelop got better performance than common one and reduce heating needs roughly about 65% , Also for air temperature as previous result **Figure 6-20**.

- Riyadh case

the second case(as cross ventilation case) the ordinary apartment as Saudi Arabia code [wall consist of double block (with heat insulation at the middle and cement plaster with painting finishing total thicknesses 36cm/U =0.68W/m^2.k(roughly as ASHRAE 90)]
As previous result with decreasing natural ventilation period only for night time, which decrease the effect to about 20% and new design reduce cooling energy about 35% **Figure 6-21**. Also temperature has similar result of previous cities that reflected on thermal comfort as late result .
As previous cities result for winter period but as summer period the effect is more effective the new optimizing envelop got better performance than common one and reduce heating needs roughly about45-50% , Also for air temperature as previous result for design heating temperature 20°C **Figure 6-21**shows all late results.
Merging between natural ventilation and HVAC gives comfortable feeling for occupancy period .through mixing mode also get good reduction and energy consumption as previous result **Figure 6-23 - Figure 6-24** present that.



.b.

Figure 6-16: new apartment optimizing design a. cross ventilation, b. single side stack ventilation.

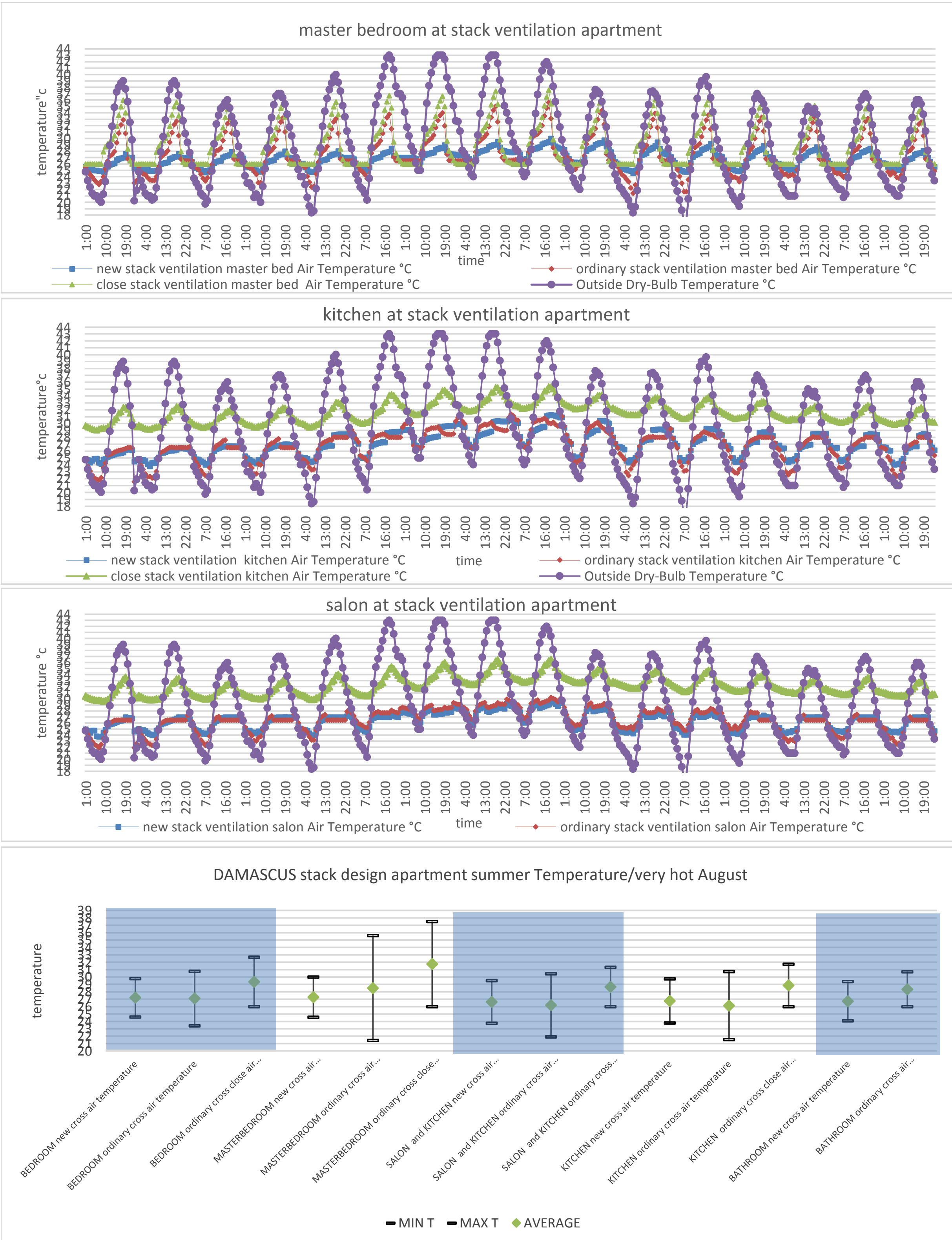
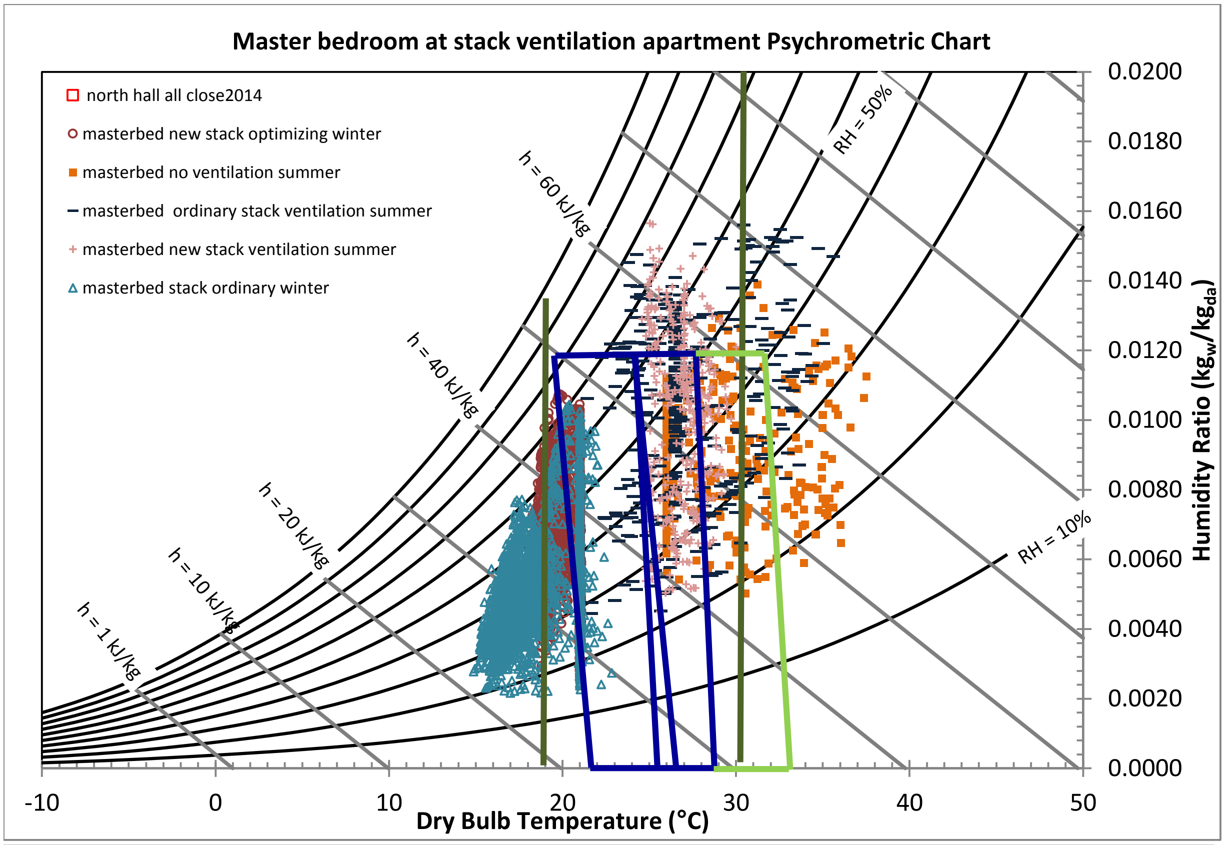


Figure 6-17: apartment with stack ventilation at hottest summer period August air temperature for different rooms functions.



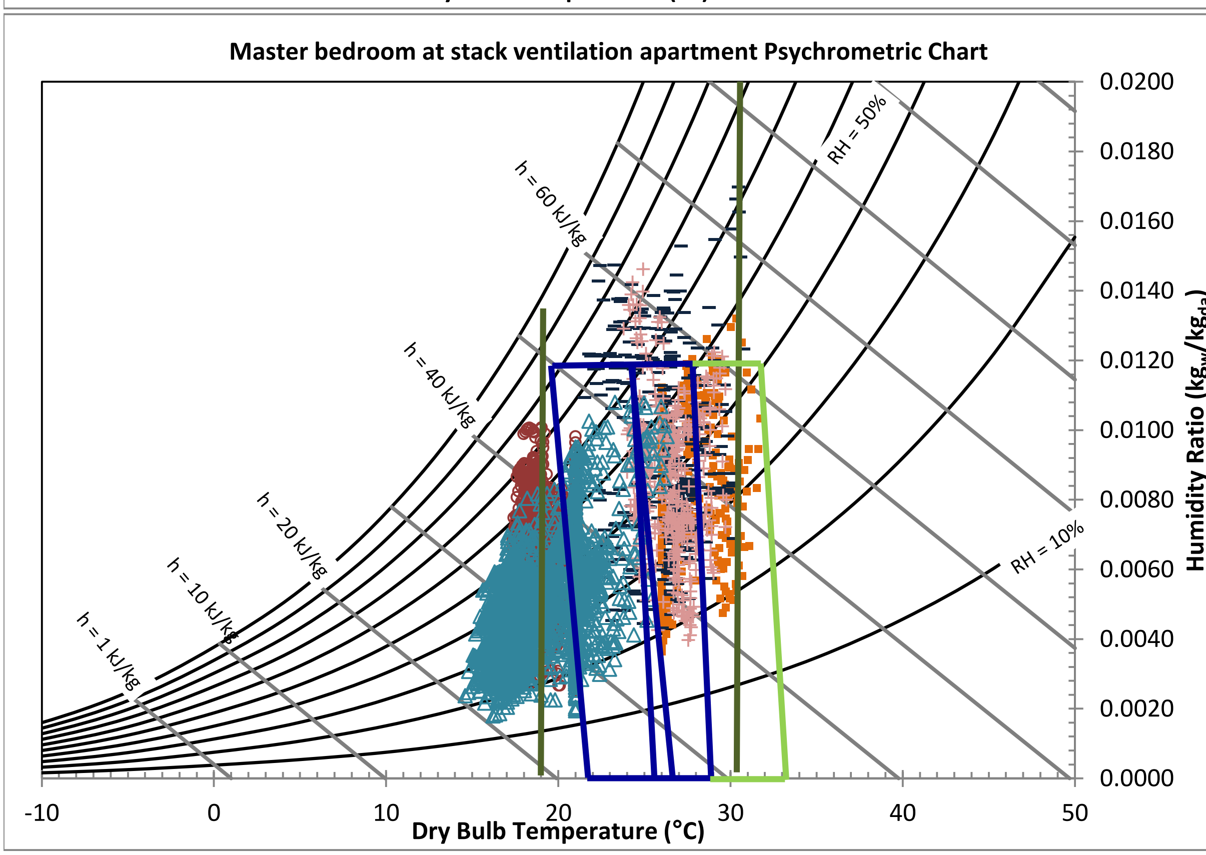


Figure 6-18: apartment with stack ventilation at hottest summer period August psychometric-chart for different rooms functions.

Figure 6-19: heating/cooling energy consumption for Damascus apartment [stack ventilation design].

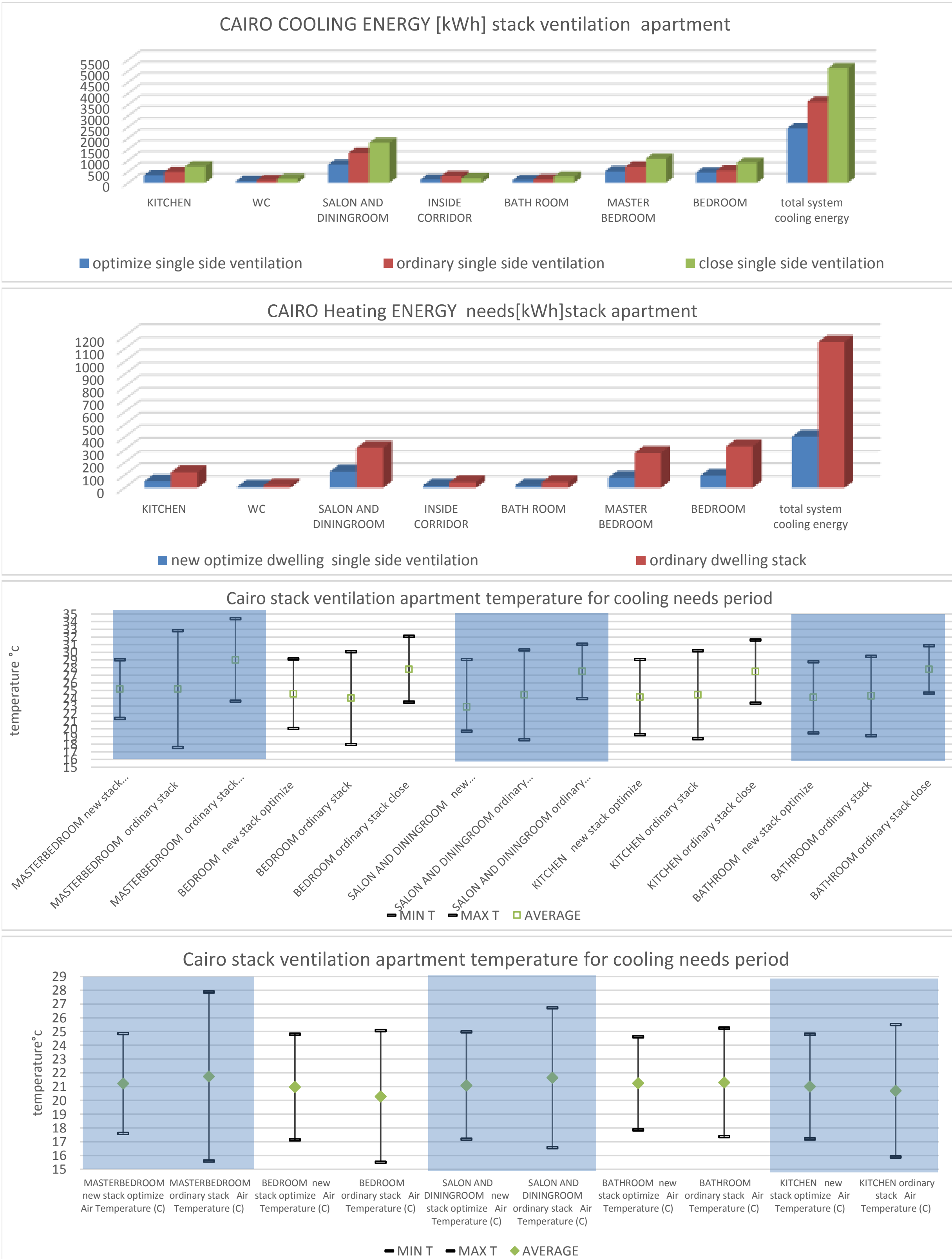
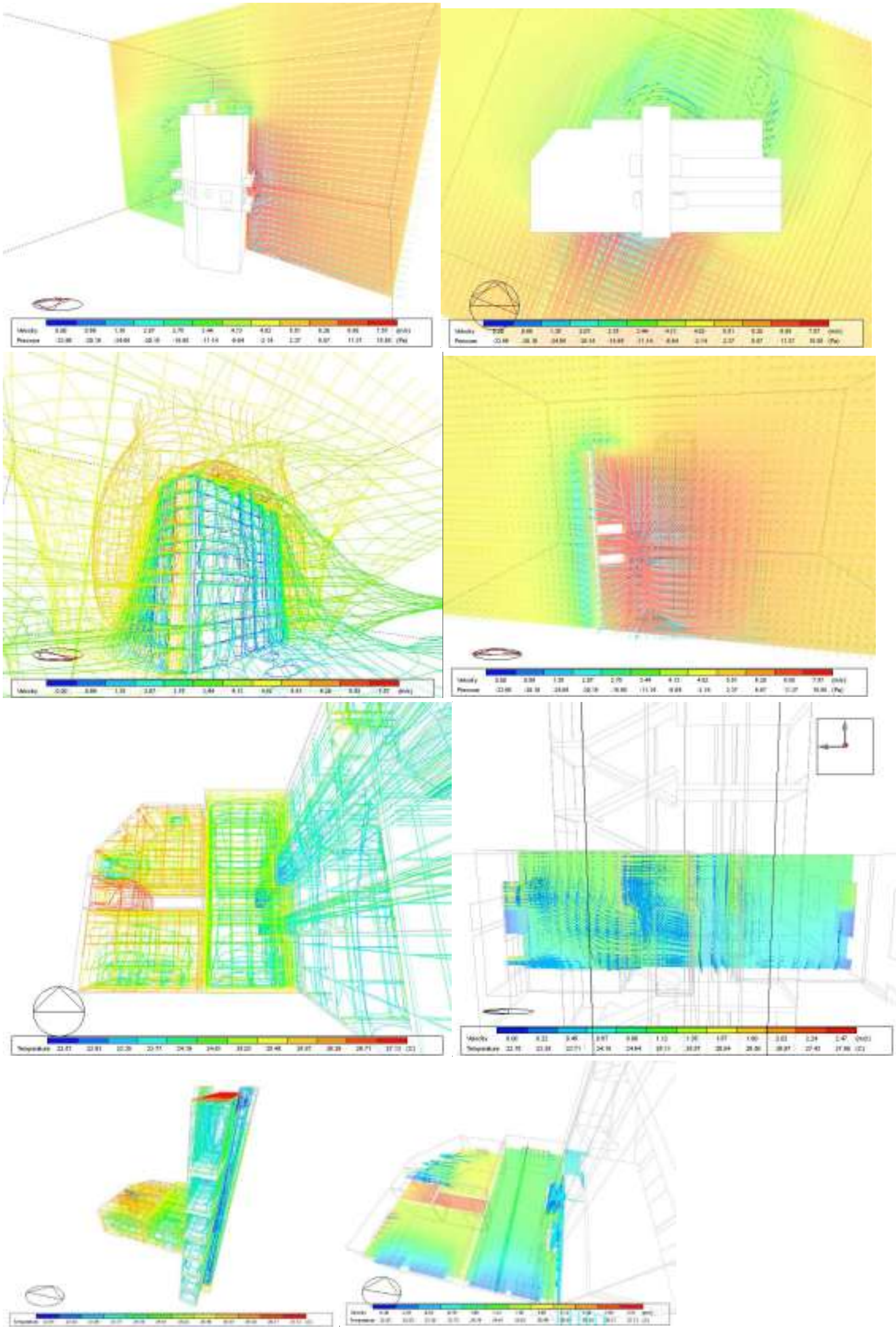
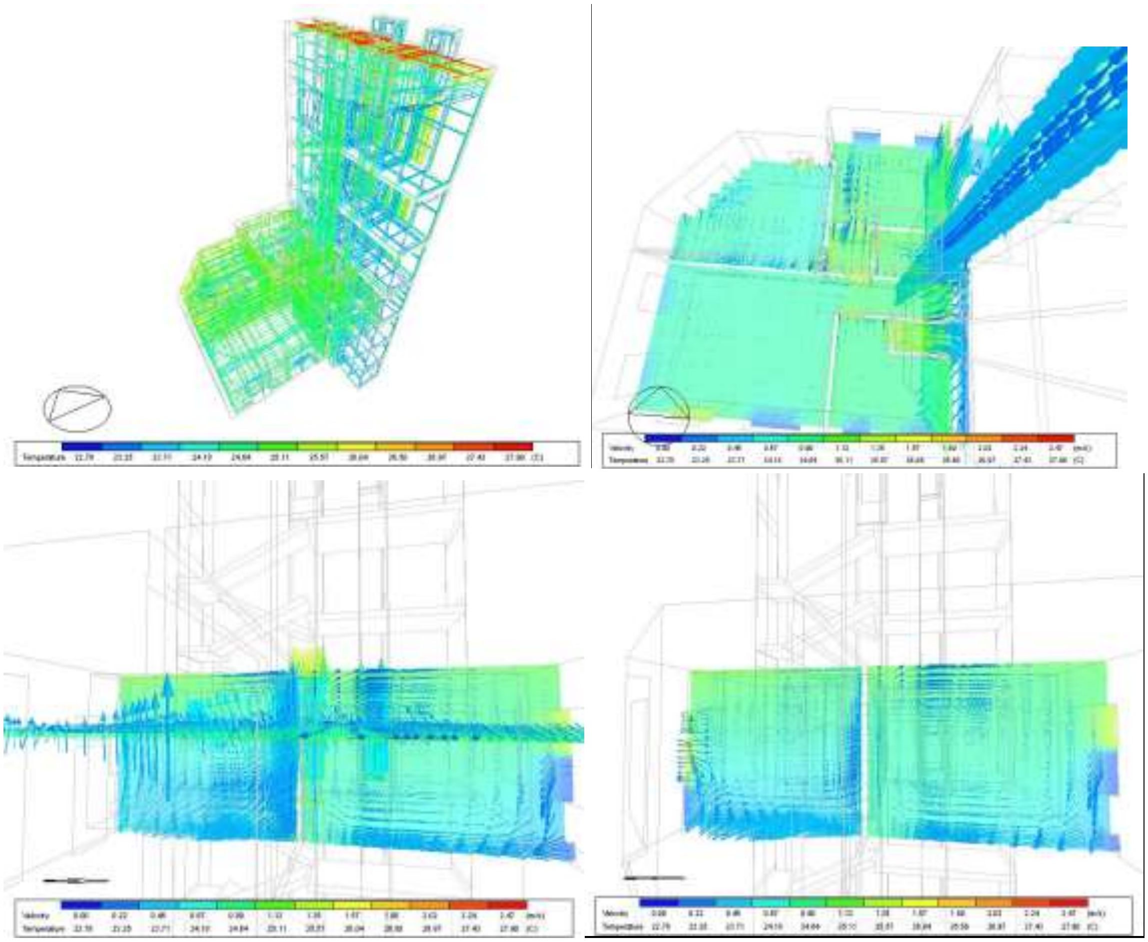


Figure 6-20: heating/cooling energy consumption for Cairo apartment [stack ventilation design].

Figure 6-21: heating/cooling energy consumption for Riyadh apartment [stack ventilation design].



a. CFD modeling outdoor air movement and temperature, indoor new apartment with cross ventilat



b. CFD modeling air movement and temperature, indoor new apartment with stack ventilation

Figure 6-22: CFD modeling outdoor air new apartment design [cross ventilation , single side 'stack' ventilation] .

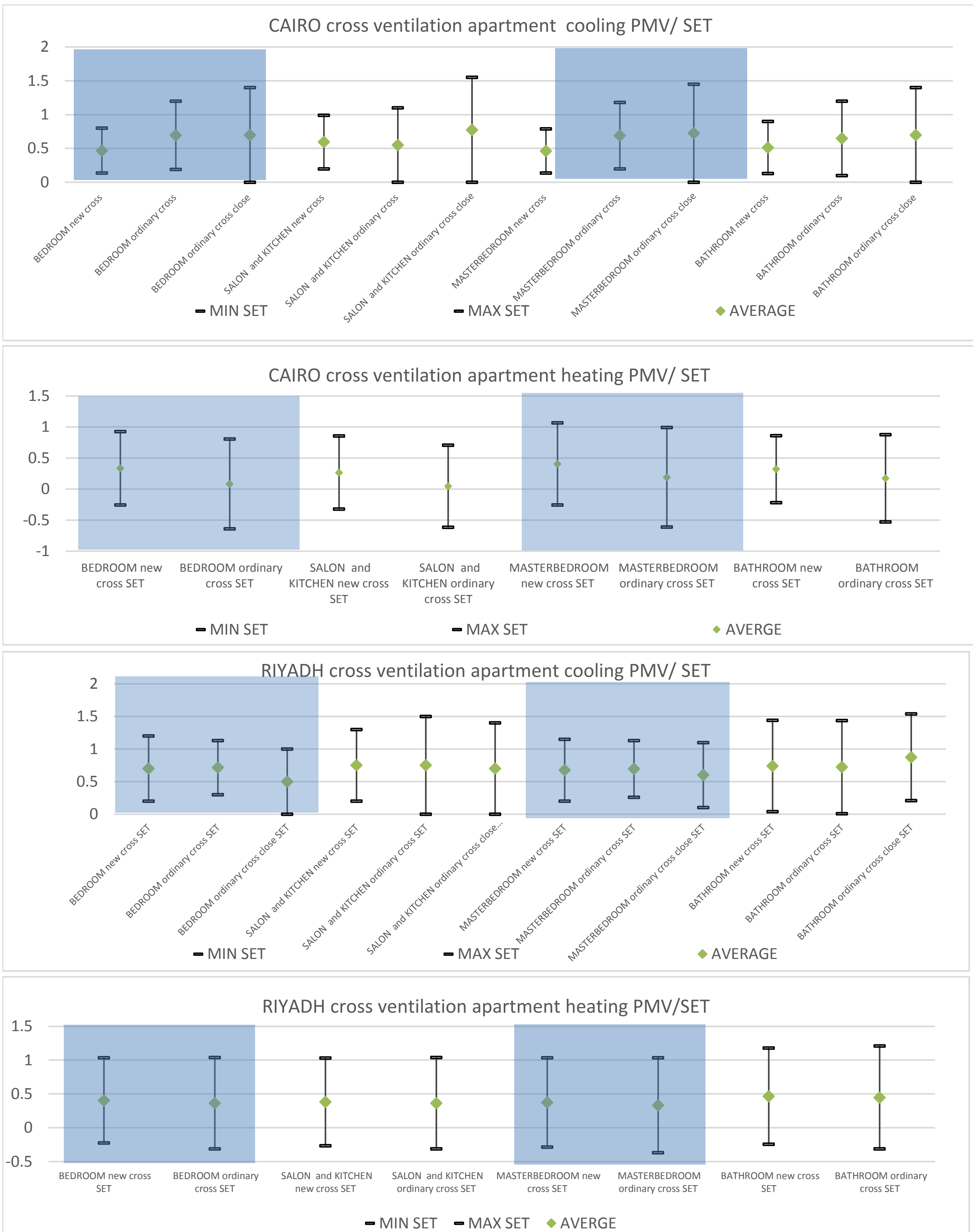


Figure 6-23: PMV/SET Cairo ,Riyadh new apartments design [cross ventilation].

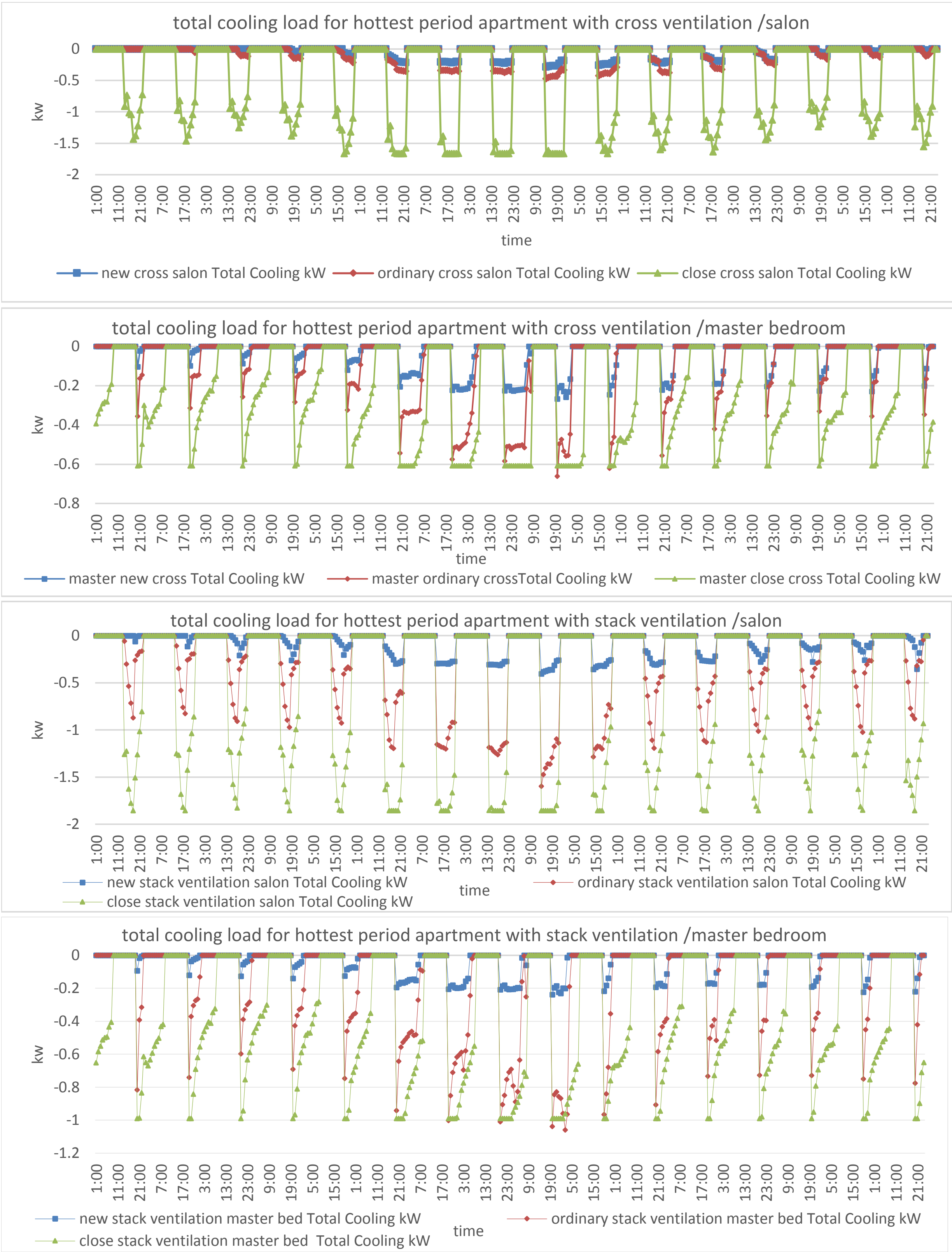


Figure 6-24: new optimizing apartment comparison cross/stack cooling energy

CHAPTER 7
SUMMARY CONCLUSION AND FUTURE RECOMMENDATIONS

One of the main settlers problems of the Middle East regions is the adaptation with their sever climatic variations ,where the hot –dry(arid and semi-arid) climate dominated with the great variation of the highest temperature difference amplitude either as diurnal(daily between days and nights) or annual(between the unusual hot summer and the unusual cold winter).Such problem is accompanied usually , with low relative humidity, and high solar radiation: this leads to a high risk of overheating.
That leads my architects scientific experimental investigation them about the antique traditional housing in Damascus Old City and its neighborhood to evaluate the thermal comfort by using Adaptive Model and psychometric-chart beside PMV/SET scale for simulation mixed mode and studying deeply the followed five steps:

I- Making up measurements through screened four traditional houses in the hot-dry climate region (in Damascus City) during the summer season's hot peak and in winter's cold period , using passive design through envelope[materials and thermal mass] and natural ventilation (cross ventilation and single side 'stack' ventilation). The study focus on hottest and coldest period at inverse seasons and their reflection on occupant comfort.

II- Calibration to generate modeling for traditional courtyard house for more investigation.

III- Evaluate traditional houses performance by using design Builder simulation program.

IV- Investigate and analysis natural ventilation (cross ventilation and single side 'stack' ventilation) impact and comfort.

V- Integrating and optimizing the new residential apartments through merge between traditional passive design points in modern context and present the cooling and heating energy consumption within occupant comfort at different cities as Cairo and Riyadh.

The methodology is followed by data gathering to prove its coincidence with other researchers and scientific works. The physical environment was monitored by using a set of 14 data loggers, beside the weather station used during studied period to reveal the difference between the air temperature and the radiant air temperature which did not exceed one °C.[This justified considering the air temperature measured by the data loggers as an operative temperature approximated by the simple average of the air temperature].
The collected data from a paper-based survey during the monitoring period used different forms related to ASHRAE scale which translated to the Arabic language. In particular, the different scale in the naming of the three values compared depend on ASHRAE scale. For comfort evaluation has been utilized the adaptive model and ASHRAE 55 psychometric-chart.

FINDINGS AND IMPLICATIONS

-Improving the thermal performance of the building's envelope through the use of energy standards that could provide a comfortable indoor environment. The analysis in this study have carried out and shown that an improvement in the indoor conditions could be achieved through the use of envelope component regulations. The thermal transmittance value and thermal mass of building's envelope, window areas, glazing type and shading devices contributes effectively on the internal thermal comfort. However, those components have different impacts on internal condition. Some of them have higher effects than the others.

-The high thermal mass has strong effect on the indoor conditions, but the combination with the thermal insulation and envelop thermal transmittance (lower U value) can provide more comfortable internal environment which could achieve by using local optimizing materials[at hot dry climate for very hot dry climate U vale may not be so important].
-On other hand windows components especially glaze have also huge effect especially through the inside surface temperature and glaze penetrated radiation which effect directly the occupant comfort. And it can improve by high SHGC and shading device (roll blind outside movable shading [attention to luminance performance]). Trees can be a good shading device for hot-dry climate through their leaves shadows in summer period to protect the envelope from direct radiation, while deciduous leaves allowed the radiation to reach the envelope during winter. Windows walls rate WWR have an effect on cooling loads and thermal comfort .They must be respected according to the orientation.
- Ventilation techniques can contribute to decrease significantly the cooling load and improve the comfort levels. The exact probable contribution of this ventilation (night ventilation during very hot-climate case).It is characteristic for a specific residential building function of the building structural and design's[the climatic conditions and the building's site layout] .The efficient coupling of air flow with the thermal mass[the existence of important thermal–structural mass increases the efficiency of the technique, since the inertia of the building is increased and the effect of ventilation can clearly be observed in the next day's indoor temperature profiles lower and delayed the indoor temperature peak.]. Effective factors on the natural ventilation proportional also with thermal comfort: volume [the rate between height and area 1:1.5 -1:2], WWR %[20-25 % for south(increase to 35% at stack ventilation) and north façade, for west and east façade WWR 15-20%] and for more air flow influence on occupant divide each window area to more than one window .For more ventilation effect mixing between Cross ventilation (adjacent windows) and Single side ventilation[vertical design divided for 4 parts alternately open and close parts in facade design] .In particular Cross ventilation has more impact on comfort which reducing energy loading for summer period , for winter period solar absorbing the important factor **Figure 7-1** For more details and behavior CFD modeling gives clear idea **Figure 6-22**)
Void inside the apartment improving air flow.
-Using the adaptive model gets results closer to human sensation survey [which shows a great variability of subjective sensations], bringing to consider more relevant at adaptive model.
-Using fan increases comfort occupant sensation and reduce energy.
-The thermal behavior is simulated by a sophisticated building simulation DB with the short-term measurements (ASHRAE scale) as input data and known material properties (U-value, thermal properties) gives good indicators.
- Standards assume that the indoor temperature is fixed to a set value and controlled by heating and air conditioning systems. In Middle East Arabian counties the heating and air conditioning systems, in case they exist, are not used continuously. Thus, the indoor temperature is fluctuating. The thermal sensation of the building occupants is the only controller of the ventilation of either the heating or the cooling of the building. The special feature of the future thermal regulation in Syria, Egypt, Middle East Arabian and Gulf countries in the hot-dry climate regions, are related to the fact that it must be ensure a minimum level of thermal comfort when the building is free running without any heating or cooling system specially at the popular residential buildings .
This study has shown that the traditional building in the hot dry climate have a large potential for the adaptation of occupants habits with the sever climate and weather conditions in all seasons.
Correlation between clothing and temperature relates such potential of adaptation.
-The comfort temperature can be correlated to the monthly mean outdoor temperature. Such concept can be used to design comfortable buildings.

The comparison between the comfort temperature and the maximum / minimum outdoors temperatures can help designer to decide whether passive-heating / cooling techniques are appropriate for the climate cases under the different considerations. The relationship between the indoor comfort temperature and the range of outdoors temperatures shows whether ventilation could be or not a way to keep the building cool in summer and help the designer to select the appropriate thermal capacity for the building (night ventilation).

When the evaporative heat loss of occupants is taken into account by using SET/ psychometric-chart, the night ventilation would not be the superior technique to the others in providing daytime thermal comfort mainly due to the hot-dry conditions. The indoor humidity control during the daytime such as by humidification would be needed when the night ventilation technique is applied to Middle East Arabian hot-dry climate terraced houses. Otherwise, full-day ventilation would be a better option compared with night ventilation. However, more air flow during day forced to improve the occupant's thermal comfort which is taken into account by using Adaptive models.

-Using local sustainable materials give satisfaction for occupant.

-Compact urban fabric proves better solutions for hot-dry region as continued buildings [steady adjacent envelop behavior].

- The weather changes from 1978 till now and the increasing in temperatures are reflected on indoor environment (traditional house case study: increasing/decreasing [summer/ winter] about 3-4°c degrees). The new passive technique could reduce that changing effect to reach comfort. Moreover reduce energy consumption about 55% in hot –dry climate regions.

-The building simulation provides accurate results, if the input parameters and boundary conditions are well known.

Recommendations for Future Research

-The analysis of the adaptive comfort model showed the need to revising the standards to be oriented towards different climatic zones, and to overcome the shortage of data gathered concerning the hot –dry climates. The classification of the standard into different climate zones and setting a specific temperature range to each climate may expand the range of acceptable temperatures and gives the opportunity for more energy conservation.

-The study of the relation between energy and thermal comfort implications is needed. It is important to know the effect of the various passive and mixed mode [as fan] strategies as well as their costs. The study of increasing the efficiency of existing passive techniques and development of new techniques are needed; this may require the research to develop mixed mode techniques.

-The development of adaptive standards to be more adequate to the variety of Buildings [courtyard], climatic and cultural situations in hot -dry climates is needed.

-Appropriate design for night ventilation systems requires exact consideration of all above mentioned parameters and optimization of the whole procedure by using exact thermal and air flow simulation codes.

- Applying the new design strategies for other very hot-dry climate regions and countries for trying to investigate the influence of its at hot-humidity climate regions.

- Considering easy procedures -to-use for calculating and applying courtyard microclimates weather files to buildings with courtyards (i.e., two weather conditions per simulation) more investigation about courtyard influence using CFD to deduce air flow behavior and develop improved simulation software for buildings utilizing natural energy, such as natural convection of fountains and trees impact as shadows and humidification to study impact on occupant comfort related to survey investigations Appendix E.

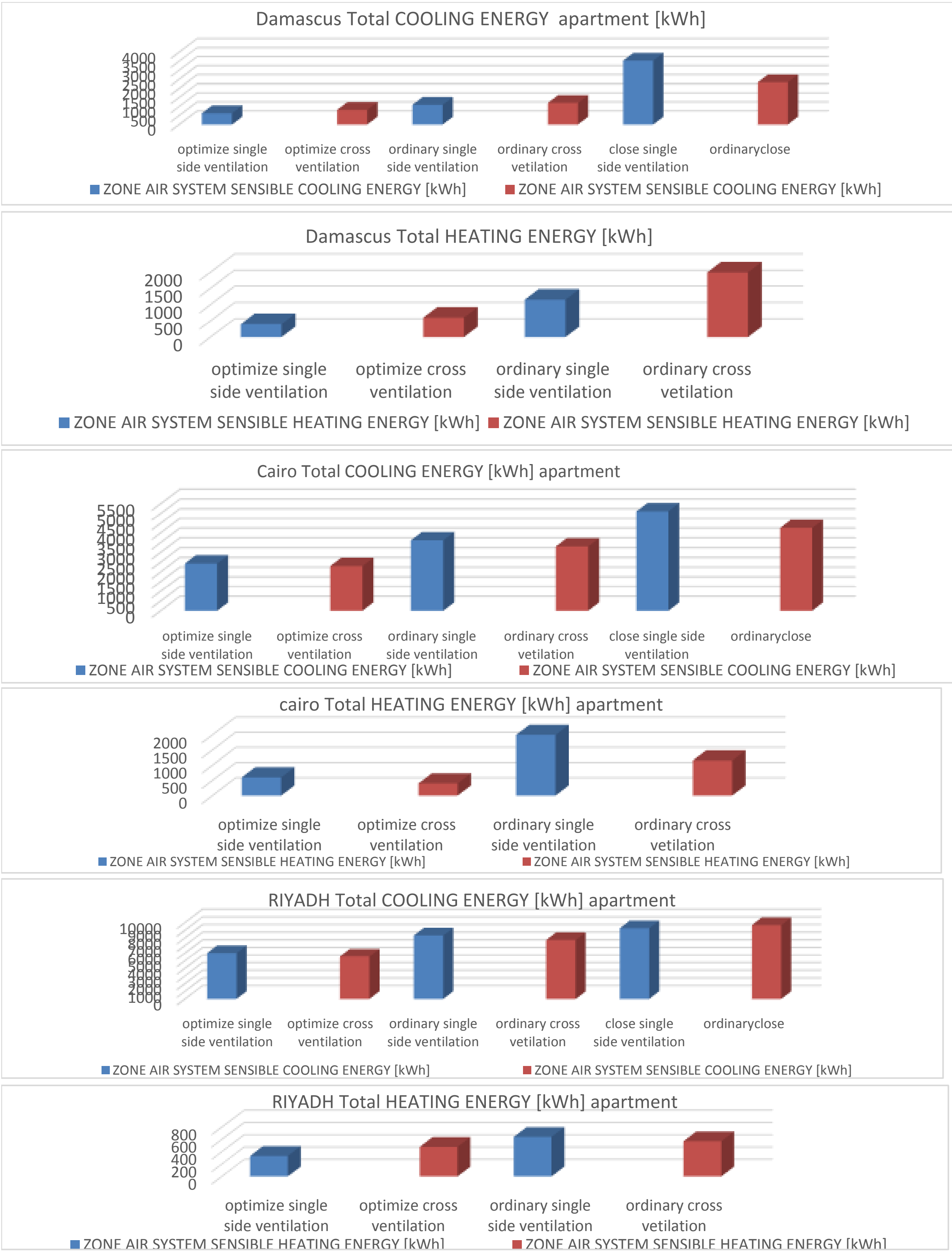


Figure 7-1: new optimizing apartment comparison cross/stack energy (Damascus ,Cairo, Riyadh)

APPENDIX A

Arabian-middle east code comparison

This appendix is to present codes recommendation and limits for envelope energy performance for some Middle East country and references.

On other hand classification for cities related to ASHRAE and temperature degree day HDD/CDD.

A.1 Damascus HDD/CDD

Table A-1: Damascus HDD/CDD-ASHRAE fundemental.

2009 ASHRAE Handbook - Fundamentals (SI) © 2009 ASHRAE, Inc.

DAMASCUS INT. AIRPO, Syrian Arab Republic WMO#: 400800

Lat: 33.42N Long: 36.52E Elev: 609 StdP: 94.22 Time Zone: 2.00 (SYR) Period: 82-08 WBAN: 99999

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB 99.6%	Heating DB 99%	Humidification 99.6% DP	99.6% HR	99.6% MCDB	99% DP	99% HR	99% MCDB	Coldest month 0.4% WS	0.4% MCDB	1% WS	1% MCDB	MCWS/PCWD to 99.6% DB MCWS	PCWD
1	-3.5	-1.9	-11.0	1.6	7.8	-8.3	2.0	8.4	14.1	9.5	11.9	10.1	1.4	10

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling 0.4% DB	0.4% MCWB	1% DB	1% MCWB	2% DB	2% MCWB	Evaporation 0.4% WB	0.4% MCDB	1% WB	1% MCDB	2% WB	2% MCDB	MCWS/PCWD to 0.4% DB MCWS	PCWD
7	18.7	39.1	18.5	37.8	18.2	36.2	17.9	21.0	30.6	20.3	29.9	19.7	29.5	4.5	210

Dehumidification 0.4% DP	0.4% HR	0.4% MCDB	1% DP	1% HR	1% MCDB	2% DP	2% HR	2% MCDB	Enthalpy 0.4% Enth	0.4% MCDB	1% Enth	1% MCDB	2% Enth	2% MCDB	Hours 8 to 4 & 12.8/20.6
19.0	14.8	22.8	18.0	14.0	22.5	17.1	13.2	22.2	64.0	30.6	61.4	29.9	59.3	29.0	766

Extreme Annual Design Conditions

Extreme Annual WS 1%	2.5%	5%	Extreme Max WB	Extreme Annual DB Mean Min	Mean Max	Std dev Min	Std dev Max	n=5 years Min	n=5 Max	n=10 years Min	n=10 Max	n=20 years Min	n=20 Max	n=50 years Min	n=50 Max
12.1	10.5	9.4	26.3	-6.4	41.6	2.1	1.8	-7.9	42.9	-9.1	44.0	-10.3	45.0	-11.8	46.3

Monthly Climatic Design Conditions

		Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	Tavg	17.1	6.6	7.9	11.2	15.9	20.8	24.7	27.2	27.1	23.9	18.8	12.2	7.8
	Sd		2.51	2.88	3.39	3.68	3.35	2.28	1.87	1.95	2.28	3.17	3.32	2.82
	HDD10.0	298	108	68	24	2	0	0	0	0	0	0	16	79
	HDD18.3	1527	363	292	221	91	17	0	0	0	1	32	183	327
	CDD10.0	2874	3	9	63	180	329	439	534	530	417	274	83	11
	CDD18.3	1060	0	0	1	18	88	189	276	272	168	48	1	0
	CDH23.3	14780	0	1	43	373	1462	2721	3683	3464	2247	769	38	0
	CDH26.7	8331	0	0	7	116	693	1577	2292	2132	1231	279	4	0

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB	17.9	21.2	27.2	32.8	37.1	39.1	41.6	41.0	38.2	34.0	27.0	20.8
		MCWB	10.5	10.7	13.3	15.3	16.9	17.7	18.8	19.4	17.9	16.3	14.1	12.1
	2%	DB	15.3	18.7	24.1	29.9	34.8	37.2	39.2	39.0	36.2	31.8	24.1	17.9
		MCWB	9.5	9.9	12.0	14.6	16.3	17.2	18.5	18.9	17.5	15.9	13.5	10.9
	5%	DB	14.0	16.8	21.9	27.4	32.8	35.9	37.8	37.2	34.8	29.9	22.0	15.9
		MCWB	8.9	9.1	11.1	13.6	15.9	17.1	18.2	18.7	17.3	15.7	12.7	10.3
	10%	DB	12.2	14.8	19.2	25.1	30.8	34.2	36.1	35.9	33.1	27.9	20.0	13.9
		MCWB	8.0	8.4	10.4	12.8	15.2	16.8	18.1	18.5	17.0	15.2	12.1	9.4
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB	12.0	12.0	14.9	17.0	18.5	20.0	22.0	22.2	20.5	19.0	15.9	14.3
		MCDB	15.1	18.3	22.9	28.7	32.0	31.8	32.7	30.6	30.0	25.8	21.4	17.2
	2%	WB	10.4	10.7	13.4	15.6	17.3	19.0	20.9	21.2	19.5	17.5	14.6	11.9
		MCDB	14.1	16.8	21.7	26.8	31.0	30.9	31.2	30.3	29.0	26.8	20.5	15.4
	5%	WB	9.4	9.7	12.0	14.5	16.6	18.3	20.1	20.6	18.8	16.7	13.8	10.7
		MCDB	12.9	15.1	19.2	25.3	29.8	30.8	30.1	29.8	28.6	26.2	19.9	14.7
	10%	WB	8.6	8.9	10.9	13.5	15.9	17.7	19.5	20.0	18.3	16.1	13.0	9.8
		MCDB	11.7	13.8	17.9	23.7	28.5	30.3	29.8	29.4	28.3	25.4	18.8	13.3
Mean Daily Temperature Range		MDBR	11.5	12.4	14.5	16.4	18.3	19.2	18.7	18.7	19.3	17.4	14.9	12.2
	5% DB	MCDBR	14.1	16.5	18.6	19.2	21.2	21.3	20.6	20.1	21.2	19.9	18.1	15.6
		MCWBR	8.9	9.0	8.8	7.9	7.8	6.5	5.8	5.8	7.6	8.6	9.6	9.9
	5% WB	MCDBR	12.7	14.0	16.2	17.9	19.2	19.3	18.4	18.6	18.9	17.5	14.9	13.5
		MCWBR	8.5	8.1	8.1	7.8	7.4	6.0	5.3	5.4	6.7	8.0	8.4	9.0
Clear Sky Solar Irradiance		taub	0.430	0.431	0.483	0.638	0.638	0.422	0.471	0.474	0.448	0.477	0.440	0.421
		taud	1.809	1.827	1.709	1.409	1.424	1.972	1.837	1.822	1.874	1.755	1.834	1.866
		Ebn,noon	743	799	790	688	695	863	819	810	812	741	727	726
		Edh,noon	174	188	226	317	316	183	208	208	189	197	168	158

CDDn Cooling degree-days base n°C, °C-day
CDHn Cooling degree-hours base n°C, °C-hour
DB Dry bulb temperature, °C
DP Dew point temperature, °C
Ebn,noon } Clear sky beam normal and diffuse horizontal irradiances at solar noon, W/m2
Edh,noon
Elev Elevation, m
Enth Enthalpy, kJ/kg
HDDn Heating degree-days base n°C, °C-day
Hours 8/4 & 12.8/20.6 Number of hours between 8 a.m. and 4 p.m. with DB between 12.8 and 20.6 °C
HR Humidity ratio, g of moisture per kg of dry air
Lat Latitude, °
Long Longitude, °
MCDB Mean coincident dry bulb temperature, °C
MCDBR Mean coincident dry bulb temp. range, °C
MCDP Mean coincident dew point temperature, °C
MCWB Mean coincident wet bulb temperature, °C
MCWBR Mean coincident wet bulb temp. range, °C
MCWS Mean coincident wind speed, m/s
MDBR Mean dry bulb temp. range, °C
PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East
Period Years used to calculate the design conditions
Sd Standard deviation of daily average temperature, °C
StdP Standard pressure at station elevation, kPa
taub Clear sky optical depth for beam irradiance
taud Clear sky optical depth for diffuse irradiance
Tavg Average temperature, °C
Time Zone Hours ahead or behind UTC, and time zone code
WB Wet bulb temperature, °C
WBAN Weather Bureau Army Navy number
WMO# World Meteorological Organization number
WS Wind speed, m/s

A.2 Cairo HDD/CDD

Table A-2: Cairo HDD/CDD-ASHRAE fundemental.

2009 ASHRAE Handbook - Fundamentals (SI)

CAIRO AIRPORT, Egypt

WMO#: 623660

Lat: 30.13N Long: 31.40E Elev: 74 StdP: 100.44 Time Zone: 2.00 (EGP) Period: 82-06 WBAN: 99999

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
1	7.7	8.7	-3.9	2.7	20.2	-1.4	3.4	19.3	11.6	14.7	10.1	15.8	2.3	90

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	11.5	38.1	21.1	36.7	21.3	35.2	21.5	24.9	31.8	24.2	31.0	23.7	30.3	5.4	350

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 & 12.8/20.6
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
23.1	18.0	27.3	22.3	17.1	26.6	21.9	16.8	26.4	76.1	32.0	73.4	31.0	71.3	30.3	930

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
9.4	8.1	7.2	28.8	5.1	42.0	2.1	1.4	3.6	43.0	2.3	43.8	1.1	44.6	-0.4	45.6

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	Tavg		22.1	14.2	15.1	17.5	21.5	25.0	27.7	28.6	28.7	27.3	24.1	19.6	15.5
	Sd			2.14	2.72	3.04	3.61	3.03	2.07	1.63	1.33	1.86	2.33	2.52	2.09
	HDD10.0		1	1	1	0	0	0	0	0	0	0	0	0	0
	HDD18.3		393	130	97	53	7	0	0	0	0	0	0	14	92
	CDD10.0		4416	131	142	232	346	464	530	578	579	518	438	287	170
	CDD18.3		1767	2	6	27	103	206	280	319	321	268	180	52	3
	CDH23.3		19113	19	56	245	1118	2288	3301	3857	3751	2785	1419	259	15
	CDH26.7		9392	2	14	77	513	1148	1796	2056	1907	1330	500	48	2
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		26.0	28.9	32.6	38.7	40.3	40.1	39.5	37.5	38.5	35.2	30.9	25.2
		MCWB		13.9	14.8	16.9	18.6	19.7	20.9	22.3	23.5	21.9	20.0	18.5	15.4
	2%	DB		21.9	24.8	28.8	35.0	36.9	37.6	36.9	36.0	35.8	33.0	27.9	22.5
		MCWB		13.2	13.2	15.3	18.0	19.1	20.8	22.6	23.4	21.8	20.3	17.9	14.8
	5%	DB		19.9	22.2	25.9	32.1	34.6	35.9	35.4	34.9	34.0	31.1	26.0	21.1
		MCWB		12.8	12.7	15.1	16.9	18.9	20.7	22.4	23.0	21.9	20.4	17.4	14.3
	10%	DB		18.7	20.2	23.6	29.2	32.4	34.1	34.1	33.8	32.5	29.3	24.6	20.0
		MCWB		12.4	12.4	14.3	16.3	18.6	20.6	22.3	22.8	21.8	20.0	16.9	13.8
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		15.7	16.1	18.6	20.7	21.6	23.8	25.5	26.2	24.7	23.1	21.0	17.6
		MCDB		20.7	23.8	27.9	32.3	32.7	32.9	33.2	32.8	31.2	29.3	26.8	21.9
	2%	WB		14.6	14.8	17.1	19.2	20.7	22.7	24.6	25.2	23.8	22.2	19.7	16.2
		MCDB		19.2	21.5	25.7	31.0	31.9	32.1	31.8	32.0	30.2	28.1	24.8	20.7
	5%	WB		13.7	13.9	15.9	18.1	19.9	22.2	24.0	24.5	23.2	21.6	18.8	15.3
		MCDB		18.4	19.8	23.0	29.2	30.8	31.0	31.3	31.1	29.5	27.3	23.7	19.7
	10%	WB		13.0	13.1	15.0	17.1	19.3	21.6	23.5	23.9	22.7	21.0	17.9	14.5
		MCDB		17.5	18.7	21.8	26.9	29.5	30.1	30.6	30.2	28.9	26.7	22.8	18.8
Mean Daily Temperature Range		MDBR		8.8	9.4	10.4	12.4	13.2	12.8	11.5	10.9	11.0	10.3	9.5	8.9
	5% DB	MCDBR		10.3	12.4	13.6	16.4	16.1	14.9	13.0	11.9	12.6	12.1	11.1	10.2
		MCWBR		5.2	5.4	5.1	5.8	5.0	4.3	3.8	3.4	3.6	3.7	4.7	5.2
	5% WB	MCDBR		9.5	10.5	12.2	14.5	14.1	13.0	11.8	11.2	11.5	11.2	9.9	9.6
		MCWBR		5.2	5.1	5.2	5.7	4.5	3.8	3.6	3.4	3.4	3.7	4.6	5.3
Clear Sky Solar Irradiance	taub			0.445	0.541	0.677	0.720	0.806	0.457	0.451	0.464	0.441	0.440	0.400	0.416
	taud			1.819	1.576	1.354	1.321	1.247	1.924	1.976	1.925	1.990	1.937	2.041	1.930
	Ebn,noon			755	710	643	639	590	836	840	825	831	799	803	765
	Edh,noon			180	245	324	350	380	192	182	190	172	171	144	156

CDDn Cooling degree-days base n°C, °C-day
CDHn Cooling degree-hours base n°C, °C-hour
DB Dry bulb temperature, °C
DP Dew point temperature, °C
Ebn,noon] Clear sky beam normal and diffuse hori-
Edh,noon] zontal irradiances at solar noon, W/m2
Elev Elevation, m
Enth Enthalpy, kJ/kg
HDDn Heating degree-days base n°C, °C-day
Hours 8/4 & 12.8/20.6 Number of hours between 8 a.m. and 4 p.m. with DB between 12.8 and 20.6 °C
HR Humidity ratio, g of moisture per kg of dry air

Lat Latitude, °
Long Longitude, °
MCDB Mean coincident dry bulb temperature, °C
MCDBR Mean coincident dry bulb temp. range, °C
MCDP Mean coincident dew point temperature, °C
MCWB Mean coincident wet bulb temperature, °C
MCWBR Mean coincident wet bulb temp. range, °C
MCWS Mean coincident wind speed, m/s
MDBR Mean dry bulb temp. range, °C
PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East

Period Years used to calculate the design conditions
Sd Standard deviation of daily average temperature, °C
StdP Standard pressure at station elevation, kPa
taub Clear sky optical depth for beam irradiance
taud Clear sky optical depth for diffuse irradiance
Tavg Average temperature, °C
Time Zone Hours ahead or behind UTC, and time zone code
WB Wet bulb temperature, °C
WBAN Weather Bureau Army Navy number
WMO# World Meteorological Organization number
WS Wind speed, m/s

A.3 Riyadh CDD/HDD

Table A-3: Riyadh HDD/CDD-ASHRAE fundemental.

2009 ASHRAE Handbook - Fundamentals (SI) © 2009 ASHRAE, Inc.

RIYADH OBS. (O.A.P.), Saudi Arabia WMO#: **404380**

Lat: **24.70N** Long: **46.73E** Elev: **620** StdP: **94.1** Time Zone: **3.00 (AFE)** Period: **82-06** WBAN: **99999**

Annual Heating and Humidification Design Conditions

Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest month WS/MCDB				MCWS/PCWD to 99.6% DB	
			99.6%			99%			0.4%		1%			
	99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD
1	5.9	7.2	-14.0	1.2	20.5	-11.1	1.6	24.3	10.0	15.9	9.1	16.8	1.6	320

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB	
		0.4%		1%		2%		0.4%		1%		2%			
		DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD
7	13.5	44.2	18.7	43.8	18.5	42.9	18.2	20.9	36.4	20.0	36.6	19.4	37.2	4.5	0

Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Hours 8 to 4 & 12.8/20.6
0.4%			1%			2%			0.4%		1%		2%		
DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB	
17.2	13.3	22.3	16.1	12.3	21.7	14.9	11.4	21.9	63.2	36.7	60.2	36.8	57.6	37.2	604

Extreme Annual Design Conditions

Extreme Annual WS			Extreme Max WB	Extreme Annual DB				n-Year Return Period Values of Extreme DB							
				Mean		Standard deviation		n=5 years		n=10 years		n=20 years		n=50 years	
1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
9.5	8.3	7.3	25.5	2.9	46.0	1.8	0.8	1.6	46.6	0.6	47.0	-0.4	47.4	-1.7	48.0

Monthly Climatic Design Conditions

			Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperatures, Degree-Days and Degree-Hours	Tavg		26.5	14.5	16.8	20.9	26.6	32.3	34.9	36.2	36.0	32.9	27.9	21.4	16.2
	Sd			3.24	3.49	3.65	3.44	2.50	1.59	1.50	1.67	1.93	2.53	3.21	3.56
	HDD10.0		6	3	1	0	0	0	0	0	0	0	0	0	2
	HDD18.3		301	124	64	17	1	0	0	0	0	0	0	11	84
	CDD10.0		6009	144	192	338	497	693	748	813	806	688	556	343	193
	CDD18.3		3264	6	22	96	247	434	498	554	548	438	298	104	18
	CDH23.3		51690	68	204	903	3032	6972	8723	9899	9712	7175	3942	914	146
	CDH26.7		35063	8	47	338	1597	4657	6339	7422	7238	4891	2208	300	18
Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		27.8	31.0	34.6	39.8	43.2	44.9	46.0	45.2	43.1	38.9	33.2	28.5
		MCWB		14.4	15.5	16.2	17.2	17.9	18.5	19.2	19.7	18.5	16.9	16.0	14.8
	2%	DB		25.2	28.0	32.3	37.8	41.9	43.8	44.3	44.2	42.0	37.2	31.7	26.9
		MCWB		13.1	14.1	15.3	17.0	17.8	18.1	18.5	19.1	18.1	16.4	15.4	14.3
	5%	DB		23.1	25.9	30.5	36.0	40.8	42.8	43.8	43.2	41.0	36.2	30.1	25.0
		MCWB		12.0	13.1	14.7	16.6	17.7	17.9	18.3	18.7	17.8	16.2	15.0	13.7
	10%	DB		21.0	23.8	28.2	34.0	39.2	41.9	42.9	42.8	39.9	35.1	28.2	23.0
		MCWB		11.5	12.4	14.0	16.1	17.4	17.5	18.0	18.5	17.4	16.1	14.5	13.3
Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		17.0	17.8	19.1	20.9	21.6	20.2	21.6	22.0	20.8	20.0	19.7	18.2
		MCDB		22.1	23.9	27.2	28.8	35.1	39.3	39.0	39.5	34.9	27.5	25.3	22.0
	2%	WB		15.3	16.3	17.6	19.6	20.2	19.4	19.9	20.8	19.3	18.8	18.2	16.7
		MCDB		20.7	23.2	26.2	29.0	34.5	40.4	41.7	40.4	38.6	30.0	23.9	21.7
	5%	WB		14.1	14.9	16.6	18.5	19.3	18.5	19.0	19.9	18.5	17.9	17.2	15.4
		MCDB		20.0	22.8	25.3	29.0	34.9	40.6	42.1	41.0	38.6	30.8	24.4	21.5
	10%	WB		12.7	13.6	15.6	17.7	18.5	18.0	18.4	19.2	18.0	17.0	16.2	14.2
		MCDB		18.8	21.9	24.3	29.1	35.4	40.4	41.6	41.1	38.3	32.2	24.9	21.2
Mean Daily Temperature Range		MDBR		10.8	11.4	11.6	12.2	12.8	13.8	13.5	13.5	13.8	13.4	11.6	10.7
	5% DB	MCDBR		14.0	13.7	14.0	14.1	14.1	14.5	14.1	13.7	14.3	14.3	13.5	13.4
		MCWBR		6.7	6.3	5.9	5.1	4.8	4.8	4.7	4.7	5.0	5.5	5.6	6.0
	5% WB	MCDBR		10.8	11.4	11.2	12.1	12.4	13.6	13.3	12.7	13.3	12.0	10.3	10.2
		MCWBR		6.1	6.2	5.9	5.1	4.8	4.9	5.0	4.8	5.0	5.4	4.9	5.4
Clear Sky Solar Irradiance	taub			0.424	0.632	0.699	0.709	0.744	0.721	0.766	0.749	0.642	0.481	0.499	0.427
	taud			1.834	1.379	1.302	1.300	1.258	1.267	1.239	1.254	1.376	1.687	1.630	1.827
	Ebn,noon			813	661	646	656	633	644	615	622	678	781	727	789
	Edh,noon			188	310	353	363	379	373	383	375	324	227	226	183

CDDn Cooling degree-days base n°C, °C-day
CDHn Cooling degree-hours base n°C, °C-hour
DB Dry bulb temperature, °C
DP Dew point temperature, °C
Ebn,noon } Clear sky beam normal and diffuse hori-
Edh,noon } zontal irradiances at solar noon, W/m2
Elev Elevation, m
Enth Enthalpy, kJ/kg
HDDn Heating degree-days base n°C, °C-day
Hours 8/4 & 12.8/20.6 Number of hours between 8 a.m. and 4 p.m. with DB between 12.8 and 20.6 °C
HR Humidity ratio, g of moisture per kg of dry air

Lat Latitude, °
Long Longitude, °
MCDB Mean coincident dry bulb temperature, °C
MCDBR Mean coincident dry bulb temp. range, °C
MCDP Mean coincident dew point temperature, °C
MCWB Mean coincident wet bulb temperature, °C
MCWBR Mean coincident wet bulb temp. range, °C
MCWS Mean coincident wind speed, m/s
MDBR Mean dry bulb temp. range, °C
PCWD Prevailing coincident wind direction, °, 0 = North, 90 = East

Period Years used to calculate the design conditions
Sd Standard deviation of daily average temperature, °C
StdP Standard pressure at station elevation, kPa
taub Clear sky optical depth for beam irradiance
taud Clear sky optical depth for diffuse irradiance
Tavg Average temperature, °C
Time Zone Hours ahead or behind UTC, and time zone code
WB Wet bulb temperature, °C
WBAN Weather Bureau Army Navy number
WMO# World Meteorological Organization number
WS Wind speed, m/s

A.4 Middle East –Arab countries energy Codes for envelope performance .

Table A-4: comparison table1 .

comparison between arabian middle east energy codes										
	ASHRAE 90.1(2010) [illegible]	ASHRAE 189.1(2009) [illegible]	IECC [illegible]	IGCC [illegible]	Kuwait code [illegible]	United Arabian Code	Syrian thermal isulation code (2010)	ISO 6946	QSAS	coparative note
intent	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
residential	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
existing buildings	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Climate	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Mixed occupancy	—	—	[illegible]	[illegible]	—	—	—	[illegible]	—	
building envelope										
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
insulation U value	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
insulation requirements	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]
Roof	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
Roof Solar Reflectance and Thermal Emittance.	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—	[illegible]	

Table A-5: comparison table2 .

thermal resistance R roof surfaces	[illegible]
wall	[illegible]
above grade wall	[illegible]
thermal resistance R wall surfaces	[illegible]
below grade walls	[illegible]
Floor	[illegible]
Slabs on grade floors	[illegible]
thermal resistance R floor surfaces	[illegible]
Doors	[illegible]

Table A-6: comparison table 3.

Radiant Floor Heating.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	[illegible]	[illegible]
Fenestration	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Maximum fenestration area.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]
Fenestration orientation	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	
Skylight Fenestration Area.	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—	[illegible]
Daylight control	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	[illegible]	

Table A-7: Template for inserting tables in Appendices.

Fenestration Solar Heat Gain Coefficient (SHGC)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	[illegible]
Shading fenestration	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	[illegible]	[illegible]	[illegible]	
Fenestration product rating	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—	
Air Leakage	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	[illegible]	
air barriers	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—	[illegible]

Table A-8: Template for inserting tables in Appendices.

Air leakage of fenestration and doors	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—	
Recessed	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	—	—	—	—	[illegible]

APPENDIX B
THERMAL COMFORT SURVEY

B.1 SHORT TIME survey ST

DIN department Bologna University /Italy	Faculty of Architecture Damascus University /Syria

Thermal environment survey

Name date time

الاسم التاريخ الوقت

1. Record the approximate outside air temperature and seasonal condition :
   سجل بشكل تقريبي درجة الحرارة الخارجية وفي اي فصل
   ☐ Winter ☐ Spring ☐ Summer ☐ Fall
   شتاء ربيع صيف خريف
2. What is your general thermal sensation ?(check the one that is the most appropriate)
   بشكل عام ماهو احساسك الحراري(تحقق مما هو مناسب واقرب لاحساسك)
   - ☐ Hot حار
   - ☐ Warm دافئ
   - ☐ Slightly warm دافئ قليلا
   - ☐ Neutral طبيعي
   - ☐ Slightly cool بارد قليلا
   - ☐ Cool بارد
   - ☐ Cold بارد جدا
3. Either (a) place an 'x' in the appropriate place where you are located now :
   أ.ضع اشارة على الشكل المرفق لتحديد مكان تواجدك الحالي

   Or (b) place an 'x' in the check box that best describes the area of the building where you located now .
   ب. أو ضع اشارة ضمن المربع لانسب شرح لمكان تواجدك ضمن المبنى
   - ☐ North الشمال
   - ☐ East شرق
   - ☐ South جنوب
   - ☐ West غرب
   - ☐ Core المركز
   - ☐ Don't know لا أعرف
4. On which floor of the building are you located now?
   في اي طابق من المبنى انت موجود الآن
   - ☐ 1st الطابق الارضي
   - ☐ 2nd الطابق الثاني
   - ☐ 3rd الطابق الثالث
   - ☐ Other(provide the floor number)----------
     اخرى (اكتب رقم الطابق)
5. Are you near an exterior wall?
   هل انت متواجد قرب الجدار الخارجي
   - ☐ Yes نعم
   - ☐ no لا
6. Are you near a window .
   هل انت متواجد قرب النافذة
   - ☐ Yes نعم
   - ☐ No لا
7. Using the list below , please check each item of clothing that you are wearing right now (check all that apply):
   استخدم القائمة في الاسفل و الرجاء وضع اشارة على كل انواع الملابس التي ترتديها الان .

☐ Short sleeve shirt قميص قصير الاكمام	☐ long sleeve shirt قميص طويل الاكمام
☐ T shirt قميص	☐ long sleeve sweatshirt قميص سميك طويل الاكمام
☐ Sweater سترة	☐ vest صدرية
☐ Jacket جاكيت	☐ knee-length skirt تنورة تطول الركبة
☐ Ankle-length skirt تنورة تطول الكاحل	☐ dress فستان
☐ Shorts بنطال قصير	☐ athletic sweatpants سروال رياضي
☐ Trousers بنطال	☐ undershirt قميص داخلي
☐ Long underwear bottoms سروال داخلي طويل	☐ overalls معطف كامل افارول
☐ Slip سروال داخلي قصير	☐ nylons نايلون

1

DIN department Bologna University /Italy	Faculty of Architecture Damascus University /Syria

Thermal environment survey

☐ Socks ☐ boots
جوارب بوط
☐ Shoes ☐ sandals
حذاء صندل

Other(please note if you are wearing something not described above , or if you thing something you are wearing is especially heavy)-------------------
غير ذلك(الرجاء اذكر اي لباس تلبسه لم يرد ذكره اعلاه او اي لباس يمتاز بسماكة خاصة)-----------

8. What is your activity level right now?(check the one that is most appropriate)
ماهو مستوى نشاطك الان

☐ Reclining مستلق
☐ Seated(passive work)جالس حركة بطيئة
☐ Seated(active work)جالس حركة نشطة
☐ Standing relaxed واقف باستراحة
☐ Light activity standing واقف مع نشاط قليل
☐ Medium activity standing وقوف مع نشاط متوسط
☐ High activity نشاط عالي المستوى

9. Control (take as appropriate)
التحكم والتوجيه(ضع اشارة حسب الوضع)

☐ Door open
باب مفتوح
☐ Window open
نافذة مفتوحة
☐ Blind/ curtains down
ستائر مغلقة/ابجورات
☐ Light on
اضواء منارة
☐ air condition on
تكييف مضاء
☐ fan on
مروحة مضاءة
☐ other (specify)------------
------------(حدد) غير ذلك

2

Figure B-2:ST survey .

B.2 LT survey.

E2. THERMAL ENVIRONMENT SATISFACTION SURVEY[1]

1. Either (a) place an "X" in the appropriate place where you spend most of your time:

SAMPLE

(Note to survey designer: Provide appropriate sketch for your space or building.)

or (b) place an "X" in the check box that best describes the area of the building where your space is located.

- ☐ North
- ☐ East
- ☐ South
- ☐ West
- ☐ Core
- ☐ Don't know

2. On which floor of the building is your space located?

- ☐ 1st
- ☐ 2nd
- ☐ 3rd
- ☐ Other (provide the floor number)________________

3. Are you near an exterior wall (within 15 ft)?

- ☐ Yes
- ☐ No

4. Are you near a window (within 15 ft)?

- ☐ Yes
- ☐ No

5. Which of the following do you personally adjust or control in your space? (Check all that apply.)

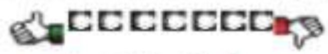
(Note to survey designer: This list can be modified at your discretion.)

- ☐ Window blinds or shades
- ☐ Room air-conditioning unit
- ☐ Portable heater
- ☐ Permanent heater
- ☐ Door to interior space
- ☐ Door to exterior space
- ☐ Adjustable air vent in wall or ceiling
- ☐ Ceiling fan
- ☐ Adjustable floor air vent (diffuser)
- ☐ Portable fan
- ☐ Thermostat
- ☐ Operable window
- ☐ None of these
- ☐ Other: ________________________

Please respond to the following questions based on your overall or average experience in the past [six] months.

(*Note to survey designer:* The above statement can be modified for a different span of time.)

6. How satisfied are you with the temperature in your space? (Check the one that is most appropriate)

Very Satisfied  Very Dissatisfied

7. If you are dissatisfied with the temperature in your space, which of the following contribute to your dissatisfaction:

a. In warm/hot weather, the temperature in my space is (check the most appropriate box):

(Note to survey designer: Include a scale or, as shown below, check boxes.)

- ☐ Always too hot
- ☐ Often too hot
- ☐ Occasionally too hot
- ☐ Occasionally too cold
- ☐ Often too cold
- ☐ Always too cold

b. In cool/cold weather, the temperature in my space is (check the most appropriate box):

(Note to survey designer: Include a scale or, as shown below, check boxes.)

- ☐ Always too hot
- ☐ Often too hot
- ☐ Occasionally too hot
- ☐ Occasionally too cold
- ☐ Often too cold
- ☐ Always too cold

c. When is this most often a problem? (check all that apply):

- ☐ Morning (before 11am)
- ☐ Mid-day (11am–2pm)
- ☐ Afternoon (2pm–5pm)
- ☐ Evening (after 5pm)
- ☐ Weekends/holidays

[1] This survey has been adapted from the CBE occupant IEQ survey developed by the Center for the Built Environment at the University of California at Berkeley.

Figure X2 Thermal Environment Satisfaction Survey

- ☐ Monday mornings
- ☐ No particular time
- ☐ Always
- ☐ Other:

d. How would you best describe the source of this discomfort? (Check all that apply):

*(**Note to survey designer:** This list can be modified at your discretion.)*

- ☐ Humidity too high (damp)
- ☐ Humidity too low (dry)
- ☐ Air movement too high
- ☐ Air movement too low
- ☐ Incoming sun
- ☐ Heat from office equipment
- ☐ Drafts from windows
- ☐ Drafts from vents
- ☐ My area is hotter/colder than other areas
- ☐ Thermostat is inaccessible
- ☐ Thermostat is adjusted by other people
- ☐ Clothing policy is not flexible
- ☐ Heating/cooling system does not respond quickly enough to the thermostat
- ☐ Hot/cold surrounding surfaces (floor, ceiling, walls or windows)
- ☐ Deficient window (not operable)
- ☐ Other: ______________________

e. Please describe any other issues related to being too hot or too cold in your space:

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Figure X2 (continued) Thermal Environment Satisfaction Survey

10 ANSI/ASHRAE Addendum o to ANSI/ASHRAE Standard 55-2010

Figure B-3:LT survey –ASHRAE .

APPENDIX C
CASES STUDY

C.1 BAIT FAKHRY AL BAROUDI

Roof structure : **Figure C-4**
Slab structure : **Figure C-5**
Timber wall structure 1st floor : **Figure C-6**
Sections : **Figure C-7**

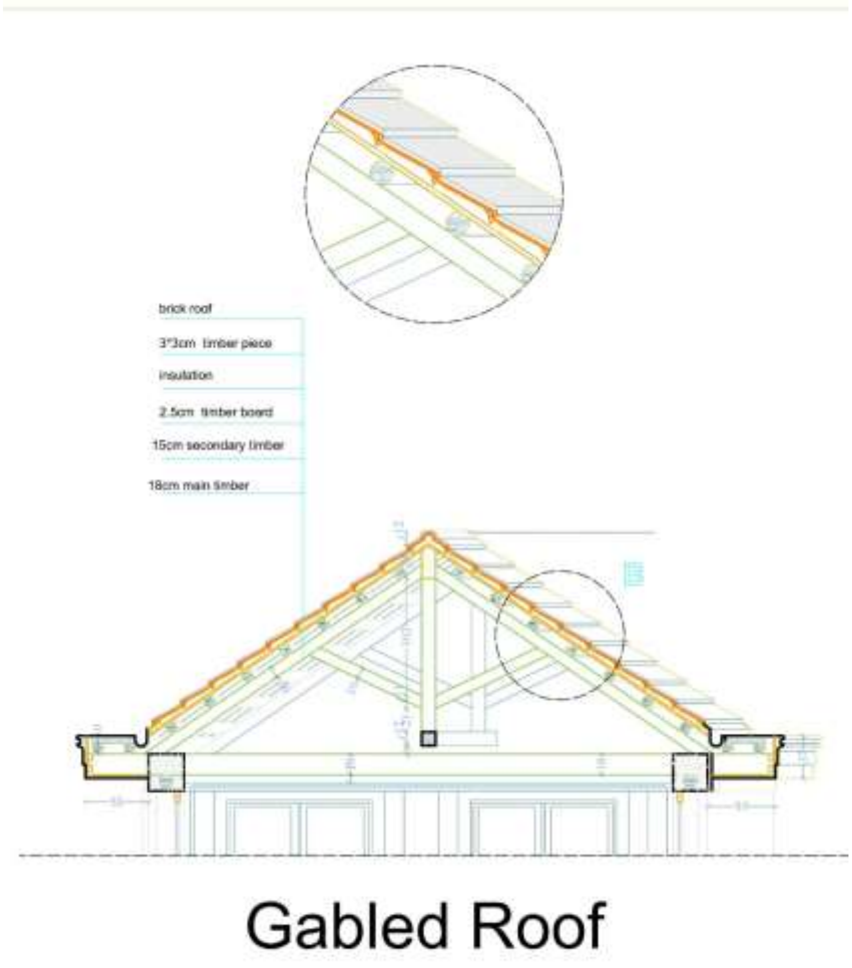


Figure C-4: FAKHRY roof.

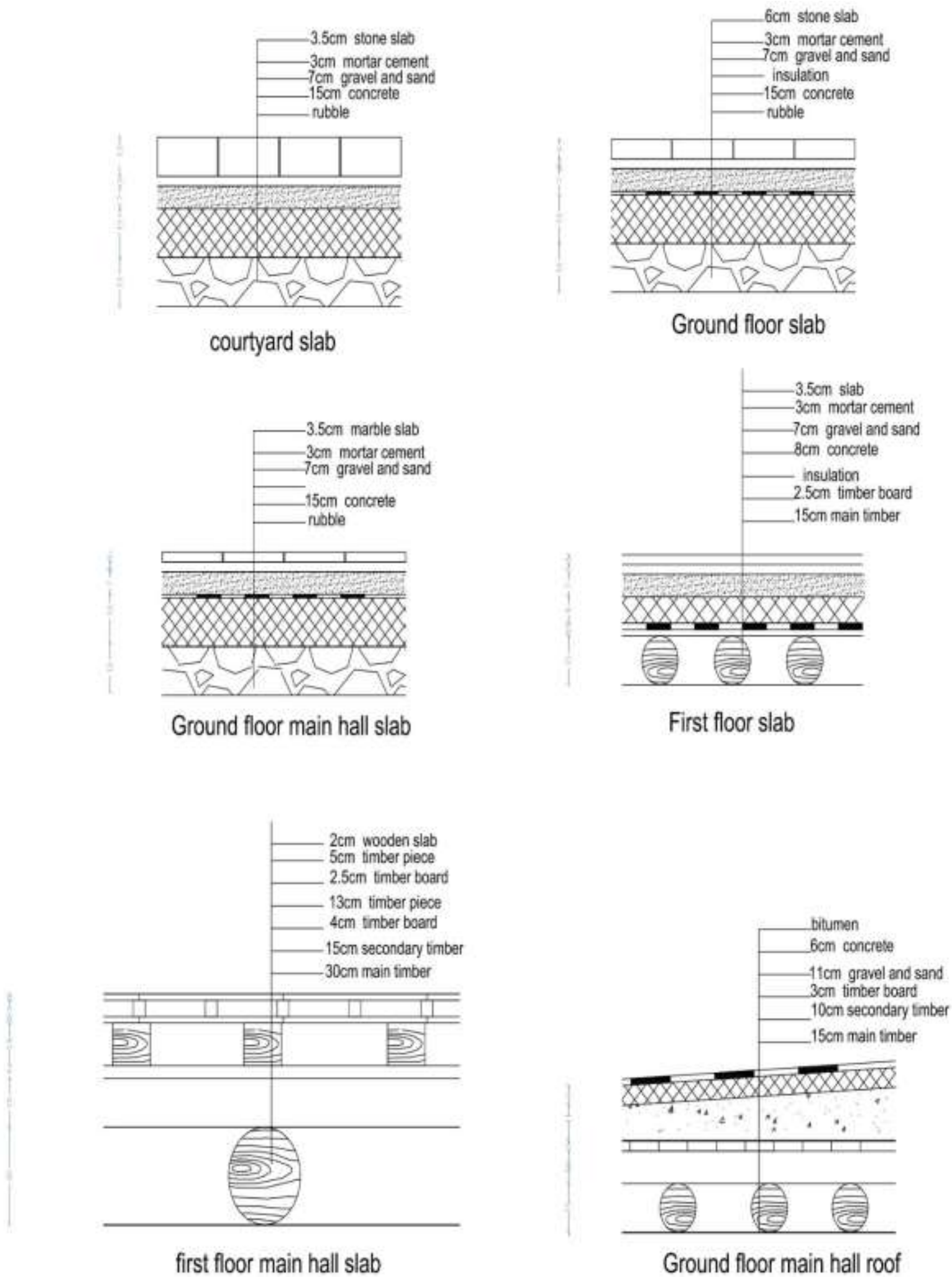


Figure C-5: FAKHRY slab structures.

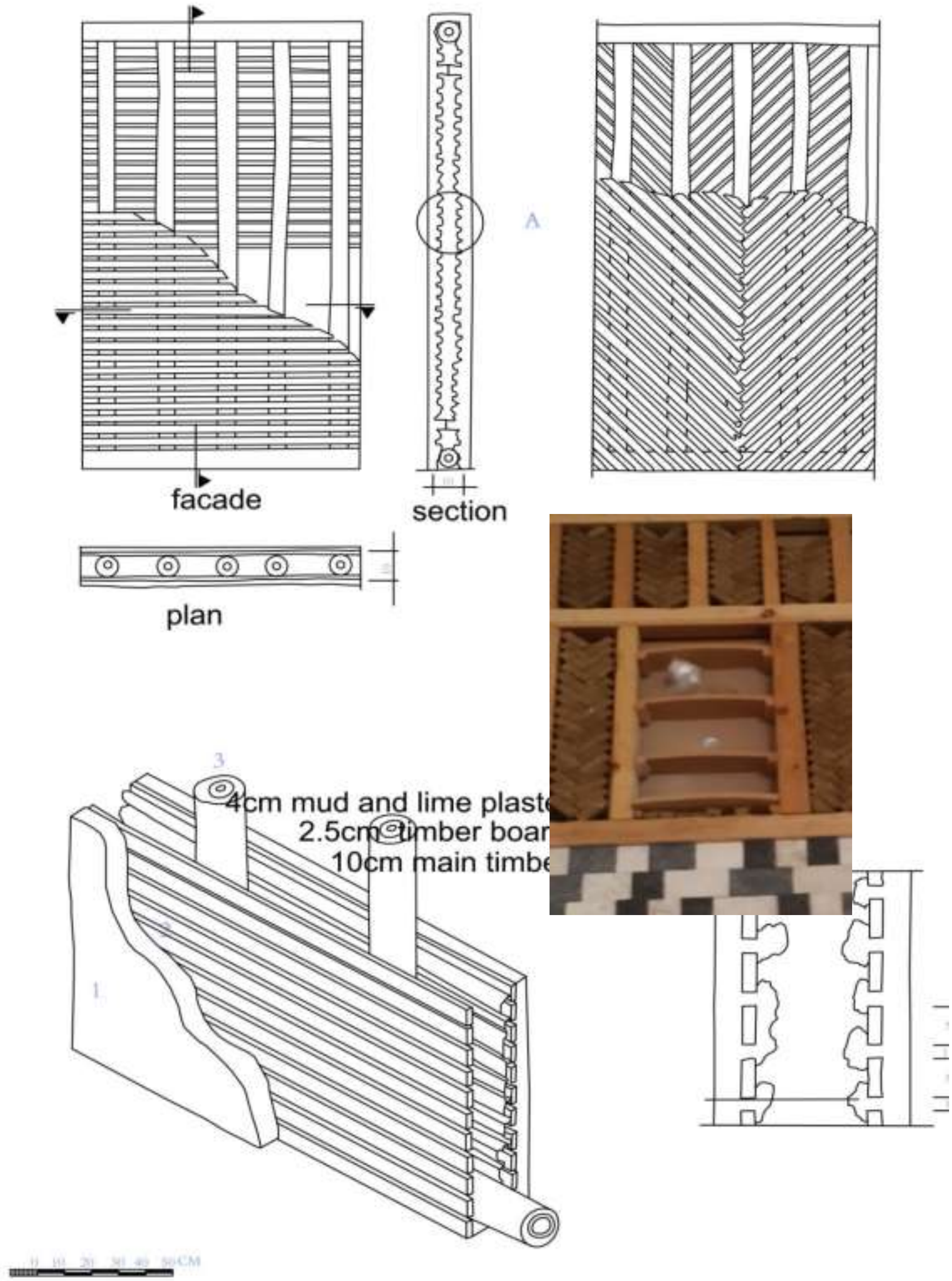


Figure C-6: FAKHRY timber wall structures.

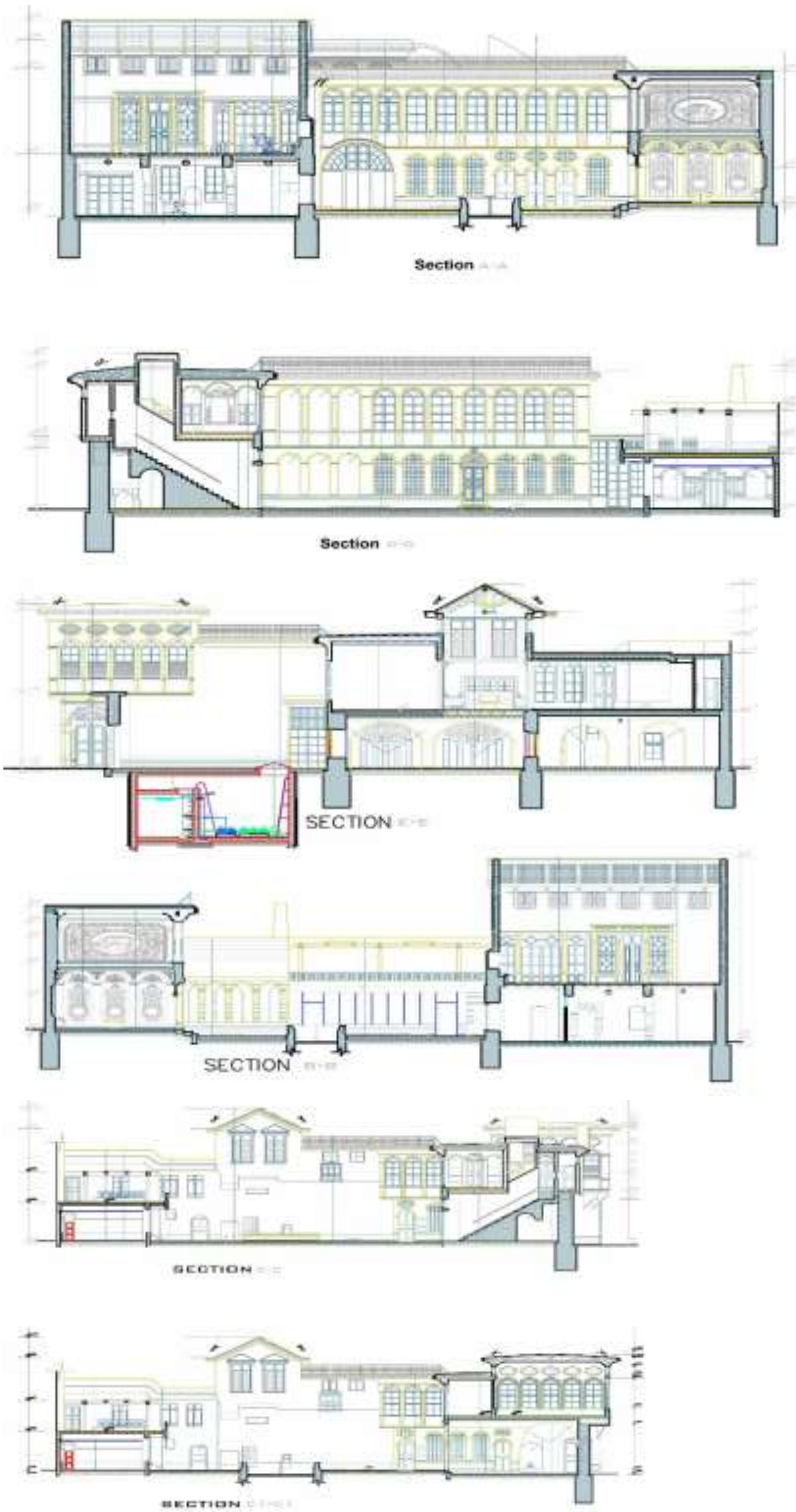


Figure C-7: FAKHRY sections.

BIET FAKHRY AL BAROUDI:

a FAKHRY pictures

,b FAKHRY pictures

Figure C-8: FAKHRY pictures.

C.1.1 Measurements stages

Second measurements stage instruments positions **Figure C-9-a**
Third measurements stage instruments positions **Figure C-9-b**

Figure C-9: FAKHRY a. second stage ,b .third stage instruments positions for summer 2014th .c. instruments positions for wither 2014th /2015th ,d. summer 2015th .

C.1.2 Measurements schedule

Monitoring data for winter 2014th /2015th follow **Table C-9**

Table C-9: a. FAKHRY schedule winter period 2014th /2015th b. FAKHRY schedule summer 2015th

FAKHRY AL BAROUDI						
USB N	floor	hall	position	high cm	day	time
13	ground floor	main hall	center	60	17-28/12/2014	11:00
7	ground floor	west glass	west wall	60	17-28/12/2014	11:00
14	ground floor	north study	center	60	17-28/12/2014	11:00
1	ground floor	courtyard	south wall	170	17-28/12/2014	11:00
2	first floor	main north hall	center	60	17-28/12/2014	11:00
5	roof	north	north wall	60	17-28/12/2014	11:00
13	ground floor	main hall	center	60	28-30/12/2014	12:00
14	ground floor	north study	center	60	28-30/12/2014	12:00
1	ground floor	courtyard	south wall	170	28-30/12/2014	12:00
2	first floor	main north hall	center	60	28-30/12/2014	12:00
7	first floor	east lab	east wall	60	28-30/12/2014	12:00
5	roof	north	north wall	60	28-30/12/2014	12:00
13	ground floor	main hall	center	110	30/12/2014-5/1/2015	12:00
5	ground floor	main hall	center	10	30/12/2014-5/1/2015	12:00
14	ground floor	north study	center	110	30/12/2014-5/1/2015	12:00
7	ground floor	north study	center	10	30/12/2014-5/1/2015	12:00
12	first floor	main north hall	center	170	30/12/2014-5/1/2015	12:00
2	first floor	main north hall	center	60	30/12/2014-5/1/2015	12:00
3	first floor	main north hall	center	10	30/12/2014-5/1/2015	12:00
1	ground floor	courtyard	south wall	170	30/12/2014-5/1/2015	12:00

,a. FAKHRY schedule winter period 2014th /2015th

FAKHRY AL BAROUDI south hall							
USB N	floor	hall	position	high cm	day	time	window opened
9	ground floor	courtyard	west wall	60	28-30/7/2015	12:00	close
16	roof	roof	north	60	28-30/7/2015	12:00	close
1	ground floor	south hall	center	60	28-30/7/2015	12:00	close
2	ground floor	south hall	center	10	28-30/7/2015	12:00	close
3	ground floor	south hall	center	120	28-30/7/2015	12:00	close
13	ground floor	south hall	west wall	60	28-30/7/2015	12:00	close
7	ground floor	south hall	east wall	60	28-30/7/2015	12:00	close
5	ground floor	south hall	north wall east window	60	28-30/7/2015	12:00	close
1	ground floor	south hall	center	60	30/7/-3/8/2015	12:00	all
2	ground floor	south hall	center	10	30/7/-3/8/2015	12:00	all
3	ground floor	south hall	center	120	30/7/-3/8/2015	12:00	all
13	ground floor	south hall	west wall	60	30/7/-3/8/2015	12:00	all
7	ground floor	south hall	east wall	60	30/7/-3/8/2015	12:00	all
5	ground floor	south hall	north wall east window	60	30/7/-3/8/2015	12:00	all

FAKHRY AL BAROUDI first floor north hall							
USB N	floor	hall	position	high cm	day	time	window opened
9	ground floor	courtyard	west wall	60	28/7-3/8/2015	12:00	close
16	roof	roof	north	60	28/7-3/8/2015	12:00	close
1	1st floor	1st floor north hall	center	60	3-6/8/2015	12:00-14:00	close
2	1st floor	1st floor north hall	center west	220	3-6/8/2015	12:00-14:00	close
13	1st floor	1st floor north hall	center west	180	3-6/8/2015	12:00-14:00	close
3	1st floor	1st floor north hall	south	60	3-6/8/2015	12:00-14:00	close
7	1st floor	1st floor north hall	east	180	3-6/8/2015	12:00-14:00	close
5	1st floor	1st floor north hall	north	60	3-6/8/2015	12:00-14:00	close
1	1st floor	1st floor north hall	center	60		12:00	all
2	1st floor	1st floor north hall	center west	220		12:00	all
13	1st floor	1st floor north hall	center west	180		12:00	all
3	1st floor	1st floor north hall	south	60		12:00	all
7	1st floor	1st floor north hall	east	180		12:00	all
5	1st floor	1st floor north hall	north	60		12:00	all

FAKHRY AL BAROUDI hall							
USB N	floor	hall	position	high cm	day	time	window opened
9	ground floor	courtyard	west wall	60	28-30/7/2015	14:00	close
16	roof	roof	north	60	28-30/7/2015	14:00	close
1	first floor	main north hall	center	60	12-13/8/2015	14:00	close
3	first floor	north hall	north	60	12-13/8/2015	14:00	close
7	ground floor	south hall	center	60	12-13/8/2015	14:00	close
13	ground floor	south hall	north window	60	12-13/8/2015	14:00	close
2	ground floor	north hall	center	60	12-13/8/2015	14:00	close
5	ground floor	north hall	west window	60	12-13/8/2015	14:00	close
1	first floor	main north hall	center	60	13-16/8/2015	12:00	open
3	first floor	north hall	north	60	13-16/8/2015	12:00	open
7	ground floor	south hall	center	60	13-16/8/2015	12:00	open
13	ground floor	south hall	north window	60	13-16/8/2015	12:00	open
2	ground floor	north hall	center	60	13-16/8/2015	12:00	open
5	ground floor	north hall	west window	60	13-16/8/2015	12:00	open

,b. FAKHRY schedule summer 2015th

C.2 BAIT AL MOUSLLI

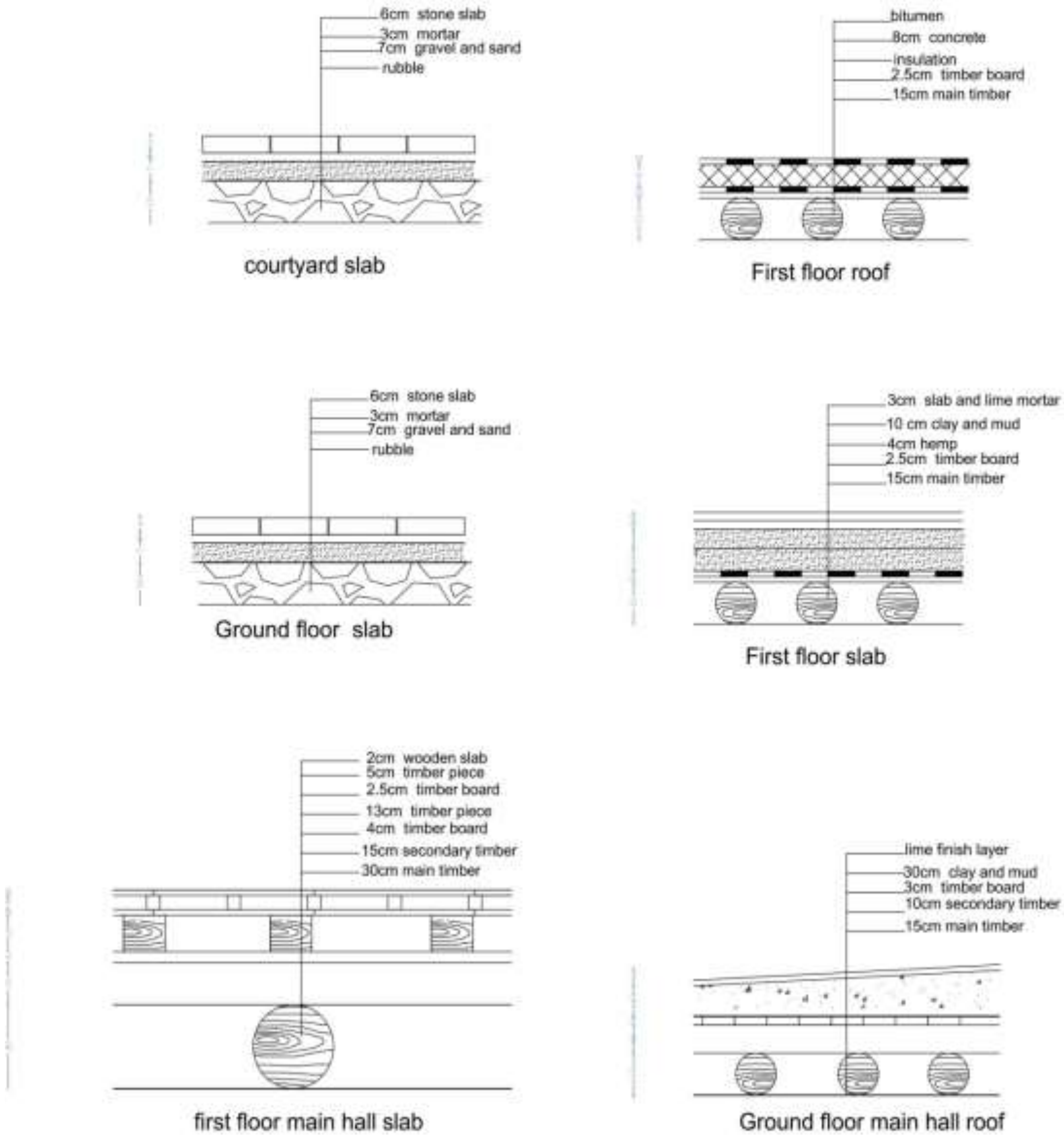
C.2.1 Measurements stages

The first measurements stage instruments positions **Figure C-10-a**

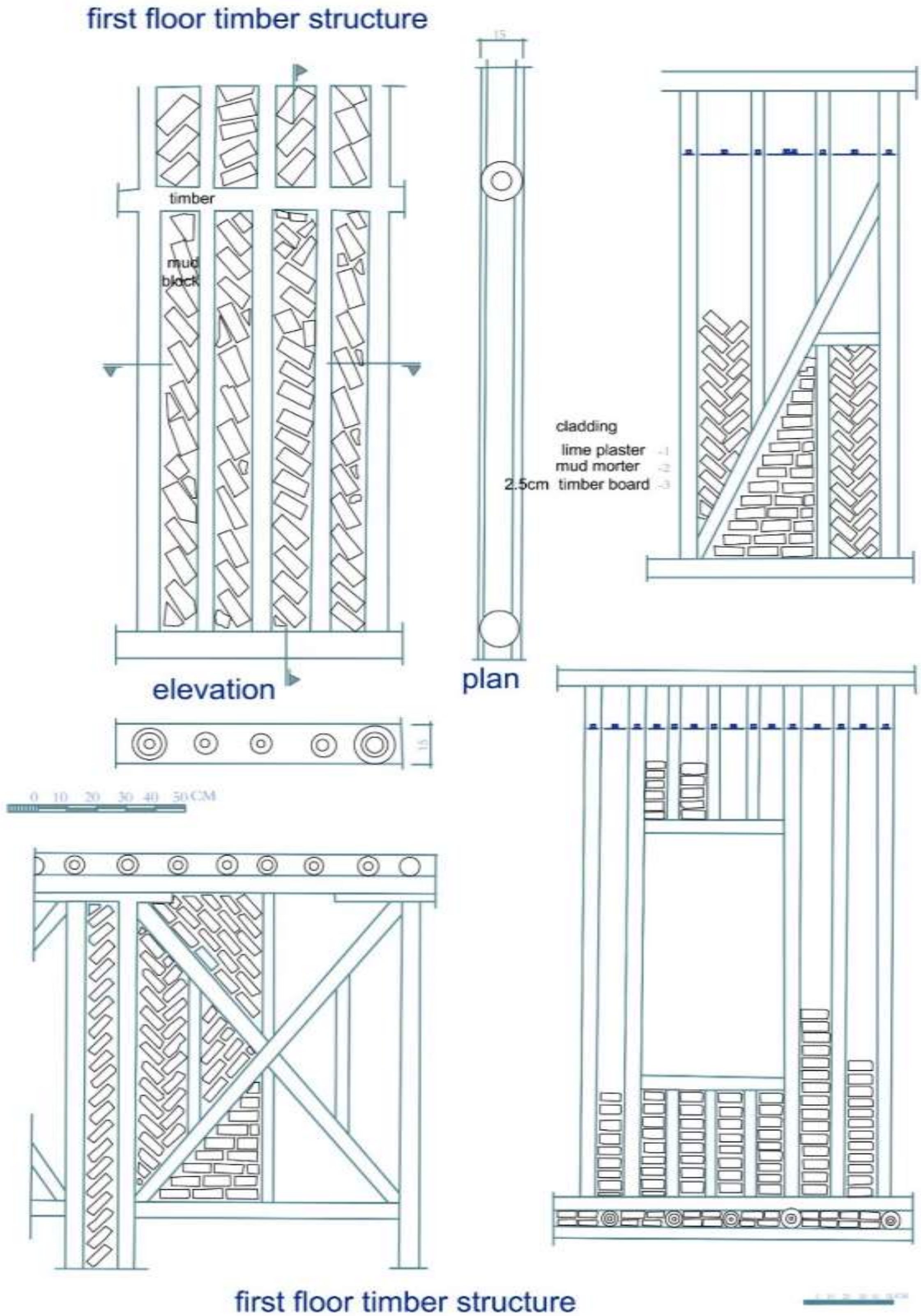
The second measurements stage instruments positions **Figure C-10-b-c** section,picture

Figure C-10: Mouslli measurements stages instruments positions summer 2014th , a .first stage, b .second stage .c. instruments position winter 2014th /2015th.

Figure C-11 a,b.shows the Mouslli envelope structures



,a. Mouslli slab structures for floors.



,b. Mouslli timber wall structure at the 1st floor .

,c. Mouslli pictures

Figure C-11, a. Mouslli slab structures for floors. b. Mouslli timber wall structure at the 1st floor. c. Mouslli pictures

C.2.2 Measurements schedule

Measurements schedule followed **Table C-10**,a summer 2014th , **Table C-10**,b winter period 2014th /2015th .

Table C-10: MOUSLLI measurements schedule ,a .summer 2014th ,b . winter period 2014th /2015th .

MOUSLLI										
USB N	floor	hall	position	high cm	day	time	window opened	window closed	up window opened	up window closed
9	ground floor	IWAN courtyard	south wall	60	21*22*23/7/2014	10:30				
14	ground floor	east	south wall	60			2north.2 west	1north.1west		
15	ground floor	north	main north wall	60			3south	1 south	2south	2south
2	ground floor	north	main north wall	60	4*5/8/2014	11:30	3south	1 south	3south	1south
7	ground floor	IWAN courtyard	south wall	60						
9	ground floor	west	south wall	60			2north.2 east	1north.1east		
14	ground floor	east	south wall	60			2north.2 west	1north.1west		
5	first floor	east	south wall	60			3east	0	door open	

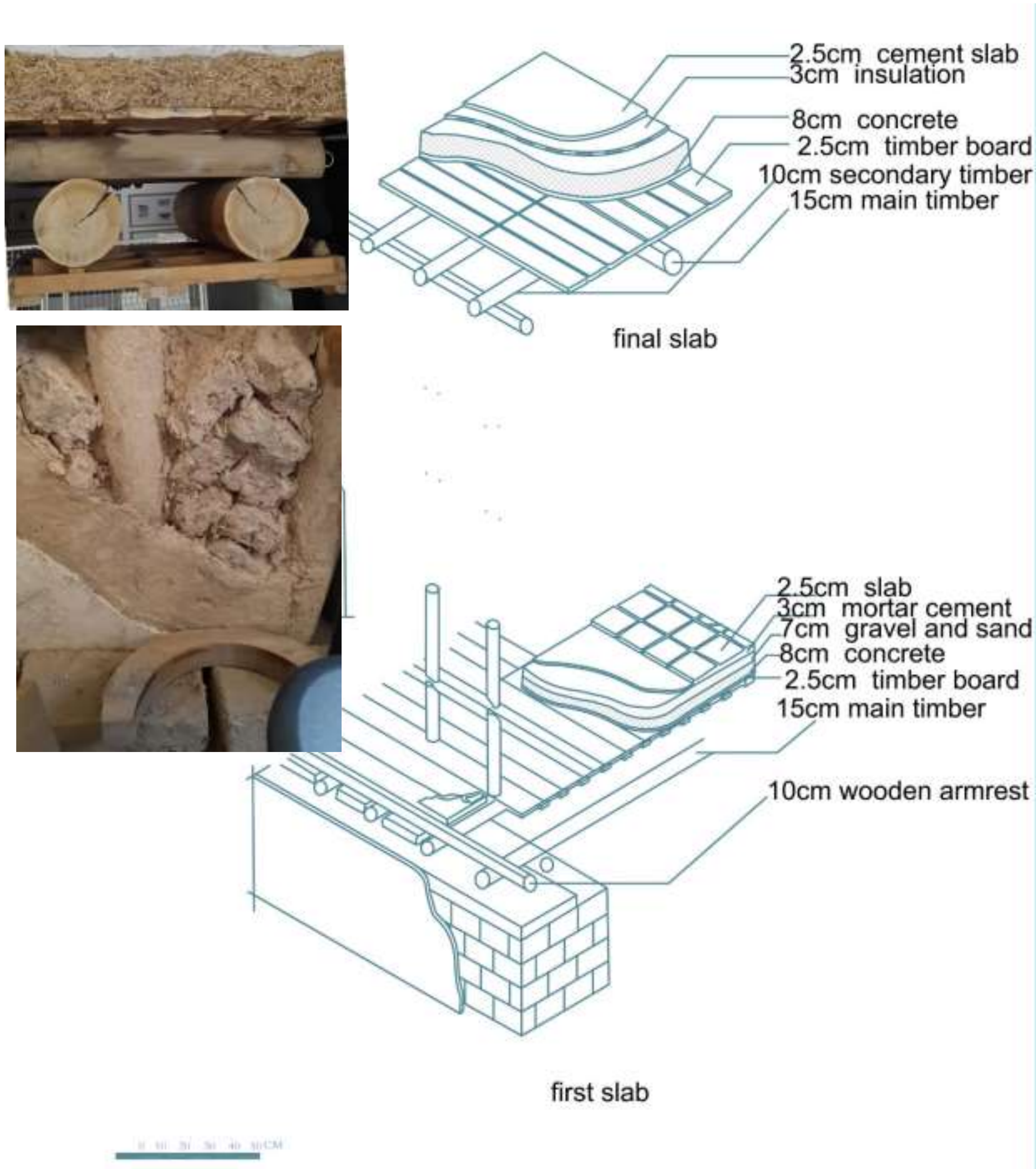
,a.summer 2014

MOUSLLI						
USB N	floor	hall	position	high cm	day	time
3	ground floor	IWAN courtyard	south wall	60	17-30/12/2014	11:00
10	ground floor	east	south wall	60	17-30/12/2014	11:00
6	ground floor	north	main north wall	60	17-30/12/2014	11:00
12	ground floor	west	south wall	60	17-30/12/2014	11:00
10	ground floor	north	main north wall	170	30/12/2014-5/1/2015	12:00
6	ground floor	north	main north wall	10	30/12/2014-5/1/2015	12:00

b . winter period 2014 /2015 .

C.3 BAIT WARRD

Structure as **Figure C-12**,a structure, b. picture



,a. BAIT WARRD structures .

,b. BAIT WARRD pictures

Figure C-12: ,a. BAIT WARRD structures . ,b. BAIT WARRD pictures

C.3.1 Measurements stages

Instruments positions as **Figure C-13**

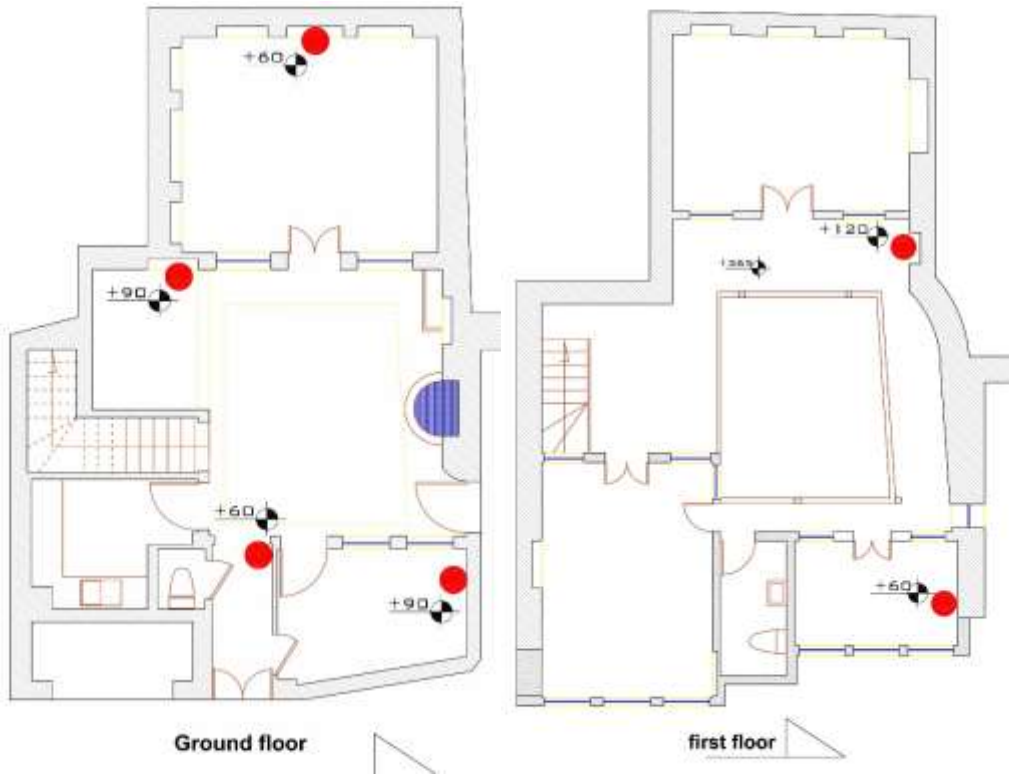


Figure C-13: BAIT WARRD measurements , instruments position .

C.3.2 Measurements schedule

BAIT WARRD measurements schedule as **Table C-11**

Table C-11: BAIT WARRD measurements schedule summer 2014th .

BIET WARD									
USB N	floor	hall	position	high cm	day	time	window opened	window closed	up roof glass opened
15	ground floor	entrance	north wall	60	13/8/2014	12:00			open
10	ground floor	IWAN courtyard	west wall	60					
3	ground floor	main west	westwall	60			0	all	
2	ground floor	east	north wall	60			1west	1west	
1	first floor	east	north wall	60			1 east	1east	
13	first floor	open	north wall	120					
15	ground floor	entrance	north wall	60	14/8/2014	13:00:00 PM			close
10	ground floor	IWAN courtyard	west wall	60	15/8/2014				
3	ground floor	main west	westwall	60			0	all	
2	ground floor	east	north wall	60			1west	1west	
1	first floor	east	north wall	60			1 east	1east	
13	first floor	open	north wall	120					
15	ground floor	entrance	north wall	60	16/8/2014	11:00:00 am-14:00			open
10	ground floor	IWAN courtyard	west wall	60					
3	ground floor	main west	westwall	60			0	all	
2	ground floor	east	north wall	60			1west	1west	
1	first floor	east	north wall	60			1 east	1east	
13	first floor	open	north wall	120					
15	ground floor	entrance	north wall	60	17*18/8/2014				close
10	ground floor	IWAN courtyard	west wall	60					
3	ground floor	main west	westwall	60			0	all	
2	ground floor	east	north wall	60			1west	1west	
1	first floor	east	north wall	60			1 east	1east	
13	first floor	open	north wall	120					

C.4 BAB AL SALAM HOUSE

Structures as all previous houses **Figure C-14**.

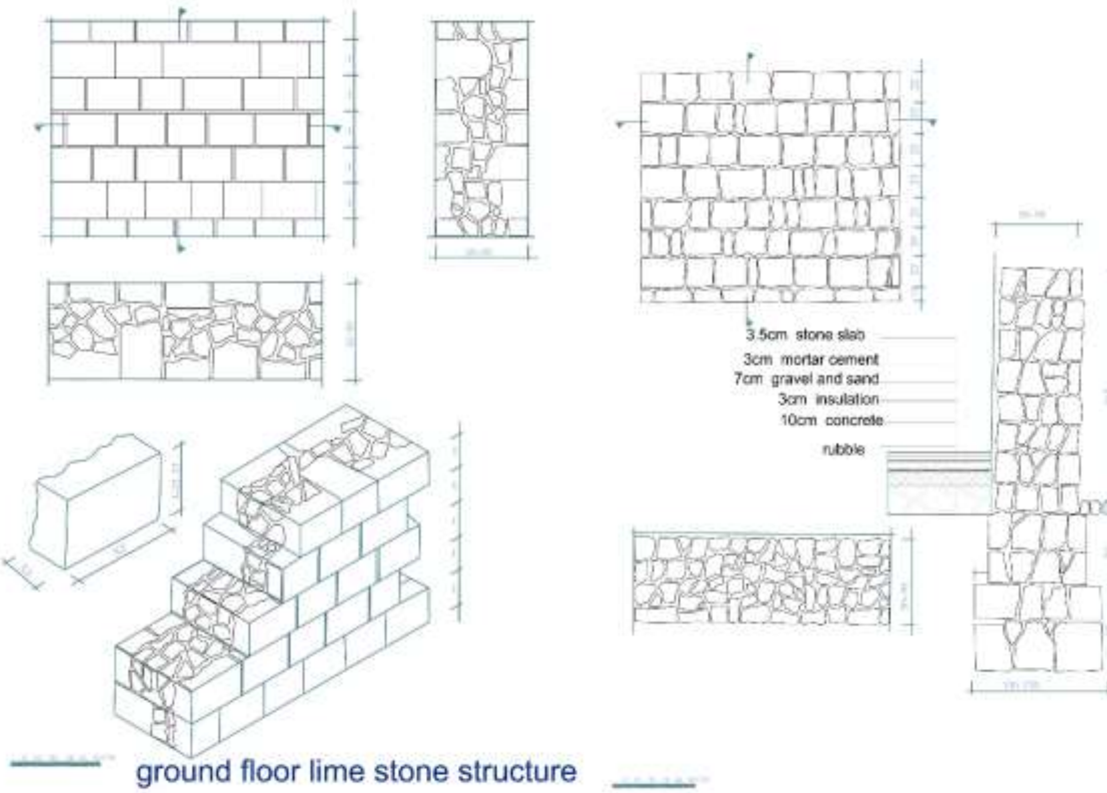


Figure C-14: BAB AL SALAM HOUSE stone wall structure for ground floor.

C.4.1 <u>Measurements stages</u>

Instruments positions as **Figure C-15**

,a. BAB AL SALAM HOUSE plans and instruments positions .

,b. BAB AL SALAM pictures

Figure C-15: BAB AL SALAM .

C.4.2 Measurements schedule

BAB AL SALAM HOUSE measurements schedule for summer 2014th as **Table C-12**

Table C-12: BAB AL SALAM HOUSE measurements schedule for summer 2014th ..

BAB AL SALAM										
USB N	floor	hall	position	high cm	day	time	window opened	window closed	up window opened	up window closed
5	ground floor	courtyard	south wall	25	18*21/8/2014	11:00				
14	ground floor	main north	center	60			2north	0	2	1middle
7	middle level	mizanin	north	60			1	0		
9	first floor	west	north	60			2south 1east	1south		

C.5 Data analysis

C.5.1 Thermal environment's characteristic

C.5.1.1 *BAIT FAKHRY AL BAROUDY:*

- Main south hall:

Figure C-16 shows changes in temperature depending on opening windows (1-all windows close: the highest temperature, 2- single side ventilation :two windows open, 3- single side ventilation :four windows open ,4-single side (stock)ventilation two level all down windows open+ first level two windows5-single side ventilation : two windows open with fountain in courtyard on specific schedule) from observation the effect of and all windows opened at least 1.5°C at midday rise up to 3.5° C at night, then the using of opening four windows equal the using of fountain with two open windows.

Relative humidity inversely proportion with temperature data highest relative humidity for lower temperature (all windows open) etc…..

- North hall's study:

Figure C-16 shows three different cases

Closed windows: steady thermal performance.

Single side open start to get different temperature degree through time.

Two sides open (cross ventilation) with 16 students.

Dig shows the cross ventilation case get lower, temperature (in spite of 16 students inside the room), than one single side ventilation .these results correspond with relative humidity.

FIRST FLOOR; Main north hall:

Figure C-17 shows the temperature decreased MIN 1.5 °C to MAX 4.5 °C during cross ventilation case especially in case four windows open (2 north's, 2 souths).

Inversely proportional with relative humidity.

All windows Closed case roughly has steady behavior (heavy mass)and lower relative humidity, proportion with hall high , in other hand big hall with high ceiling and heavy mass has little gap between day and night temperature roughly about 2°C, light mass about 3-4°C

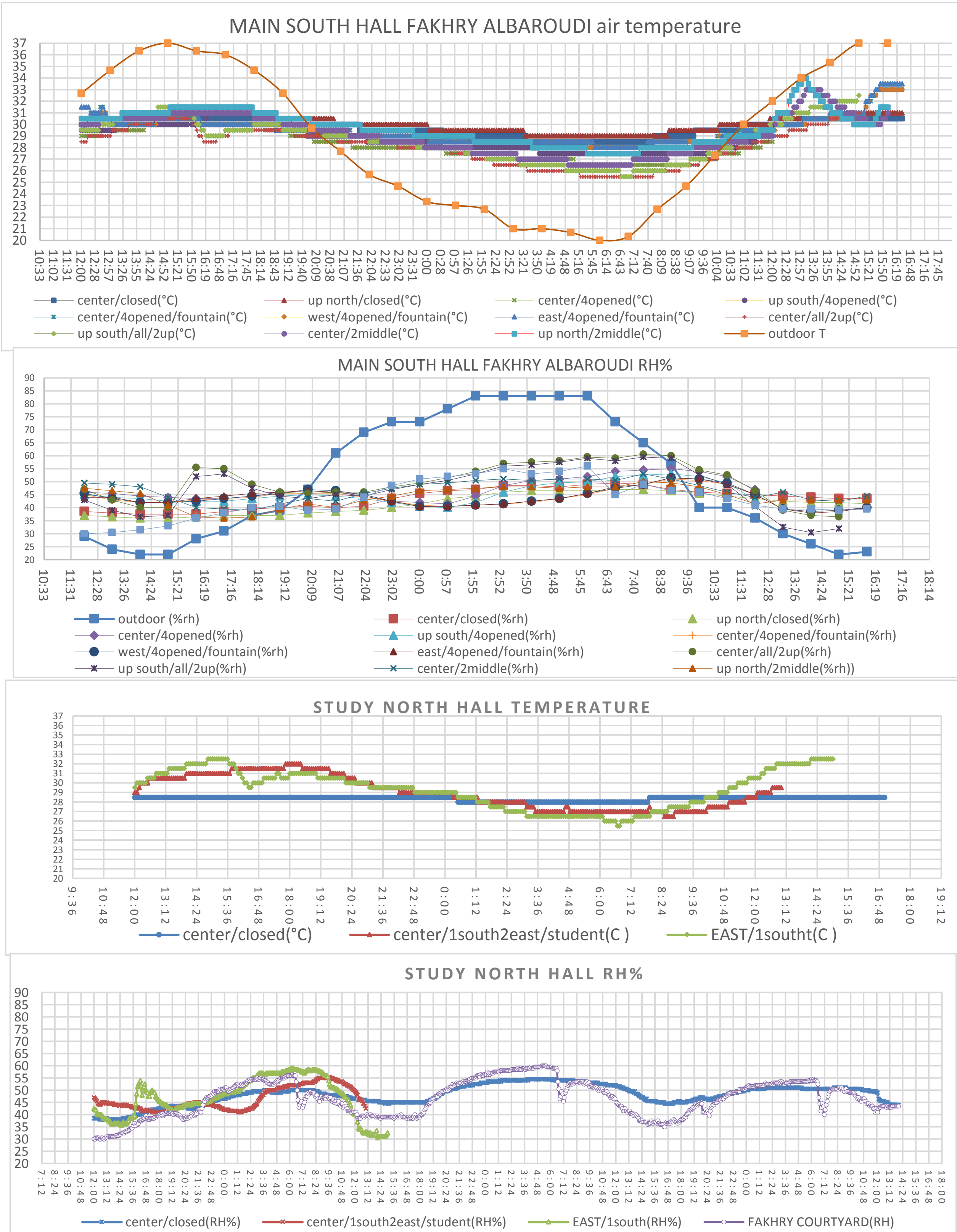


Figure C-16 BAIT FAKHRY ,north hall, south hall air temperature , relative humidity.

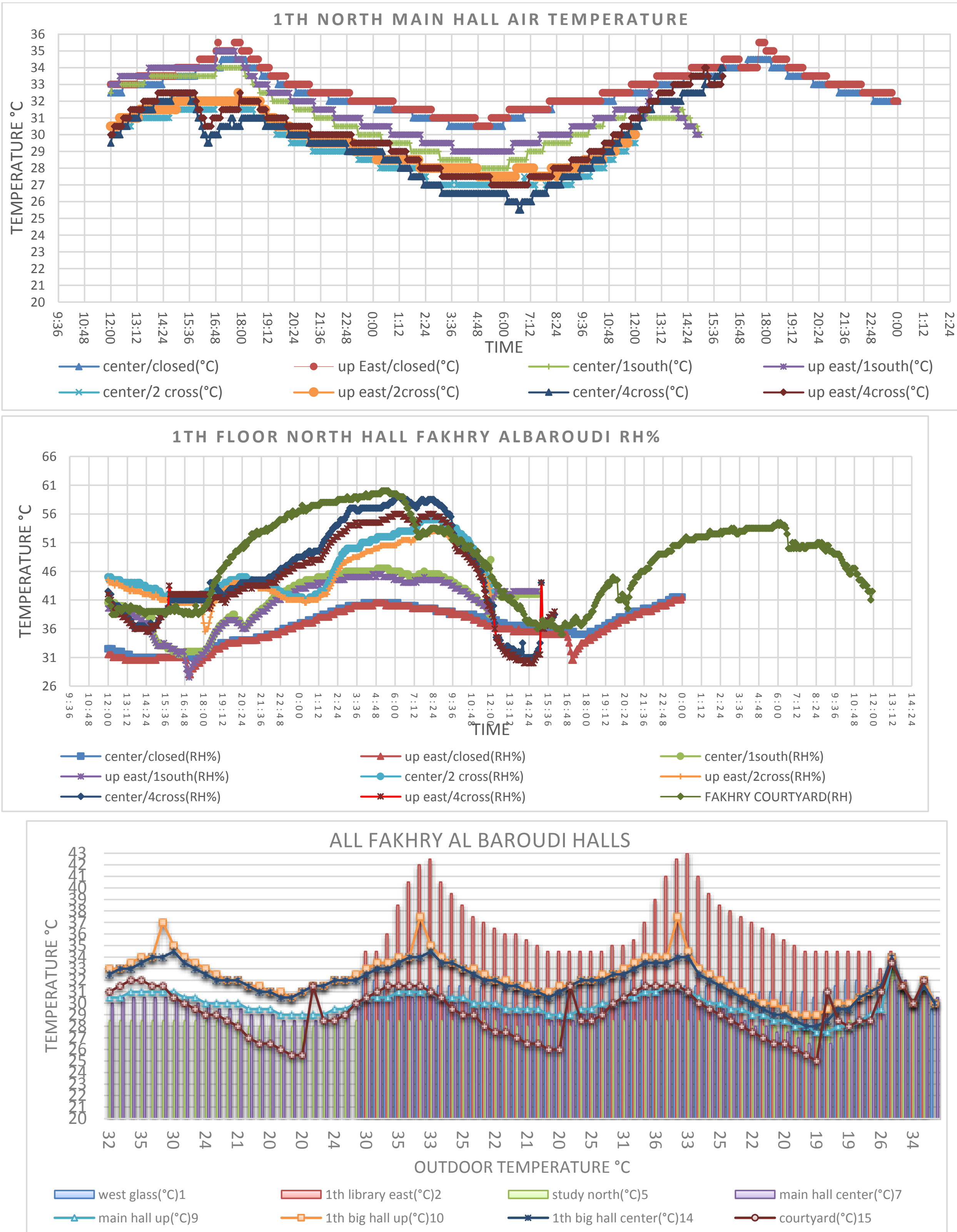


Figure C-17: BAIT FAKHRY 1st floor north hall(air temperature,relative humidity), compare all hall air temperature

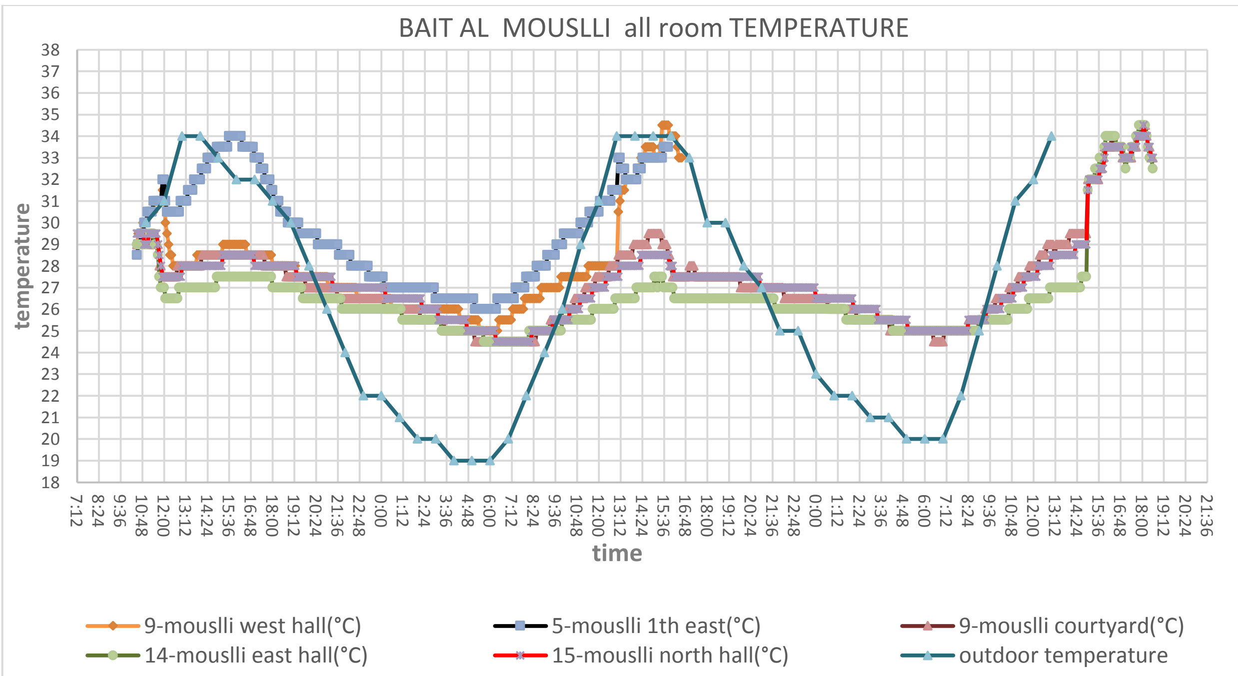
C.5.1.2 *BAIT AL MOUSLLI :*

Figure C-18 shows traditional structure thermal behavior , ground floor with heavy mass wall (stone) get best performance , the courtyard effect gives halls less gap between day and night more steady thermal behavior .

Three halls have the same structure roughly same size and height have same temperature

First floor with light mass (timber, mud) rapidly increased temperature at midday and decreased at midnight.

Relative humidity inversely proportion with temperature measurements.



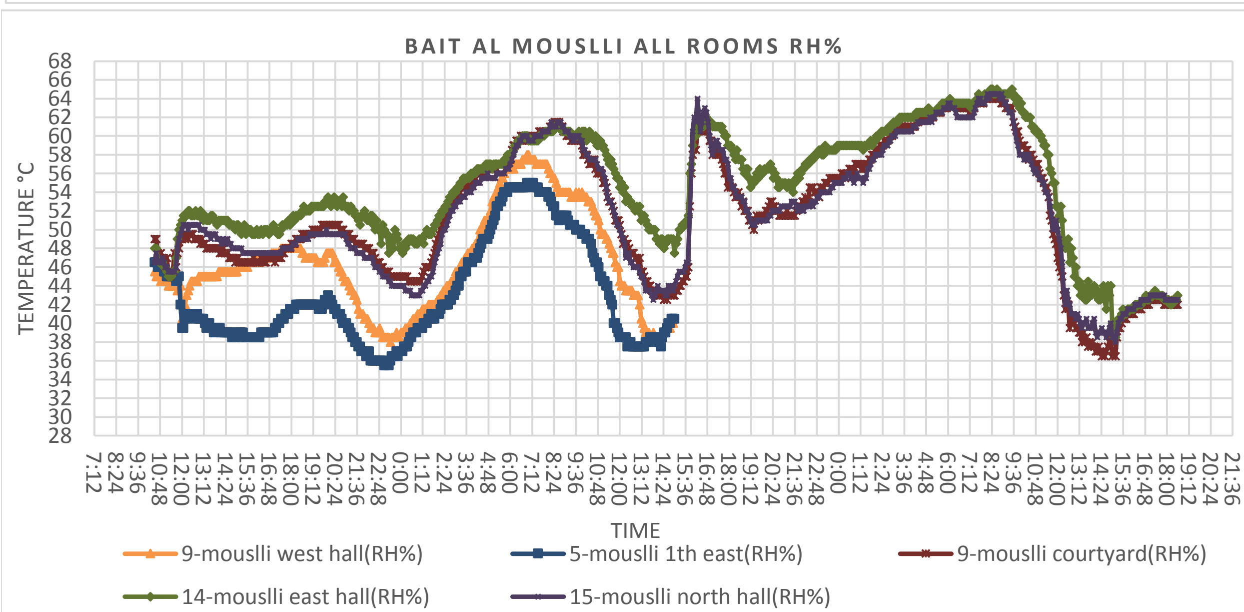


Figure C-18: MOUSLLI all rooms air temperature, relative humidity.

C.5.1.3 *BAIT WARRD :*

This is the second type of houses this case investigate courtyard influence by utilized sliding roof figure below shows at sliding roof closed the temperature raised at least 1.5 °C up to 2.5 - 3 °C .
Relative humidity has steady phase at closed sliding roof inversely at opened sliding roof case that's got unsteady phase **Figure C-19** present previous results.

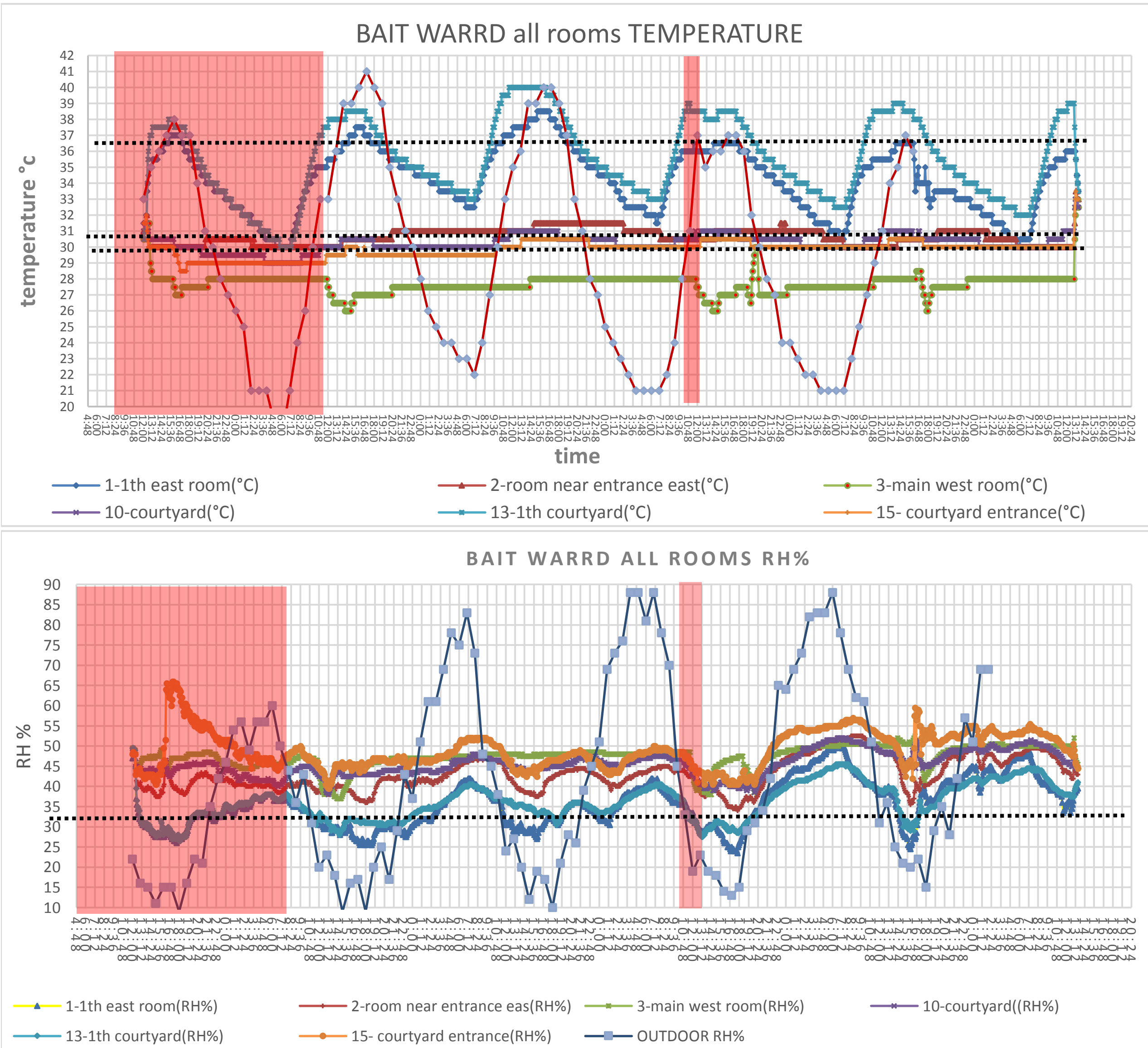


Figure C-19: BAIT WARRD all rooms air temperature , relative humidity.

C.5.1.4 *BAB AL SALAM HOUSE :*

Figure C-20 observed same temperature result for big hall with heavy and light mass , also relative humidity.

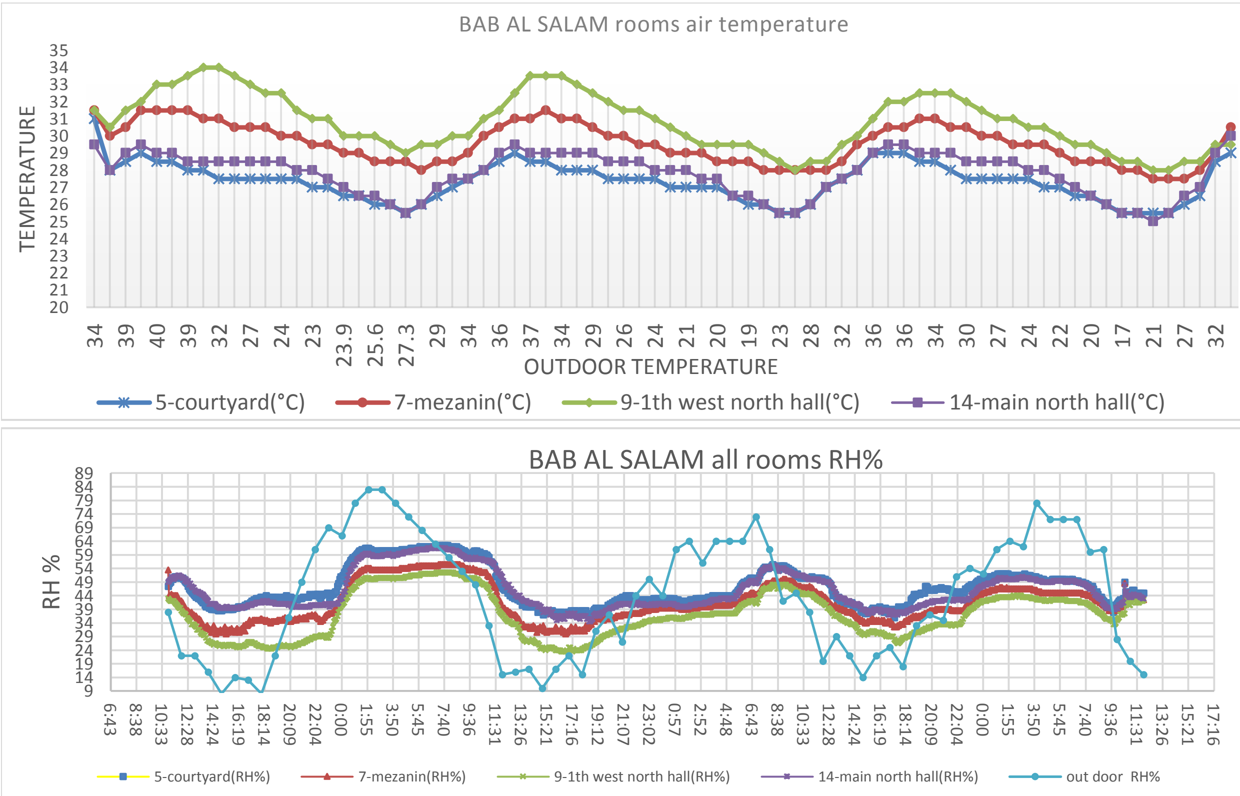


Figure C-20: BAB AL SALAM all rooms air temperature, relative humidity.

C.5.2 Thermal comfort

FAKHRY AL BAROUDI HALLS:

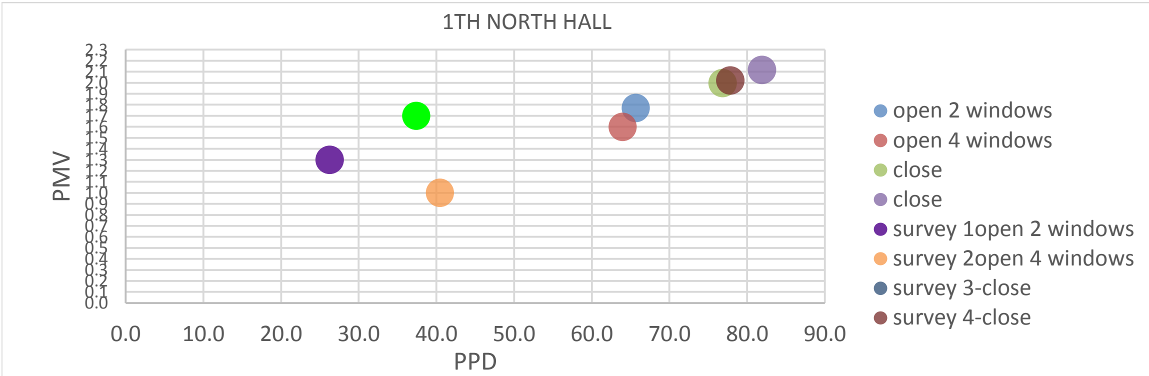
First floor north hall: (cross ventilation):

Depend on PMV/SET scale and sensation survey the **Figure C-21-a** shows all cases uncomforted except the case of cross ventilation ; two windows opened at south side and two windows opened at north side at survey at calculation all cases uncomforted .

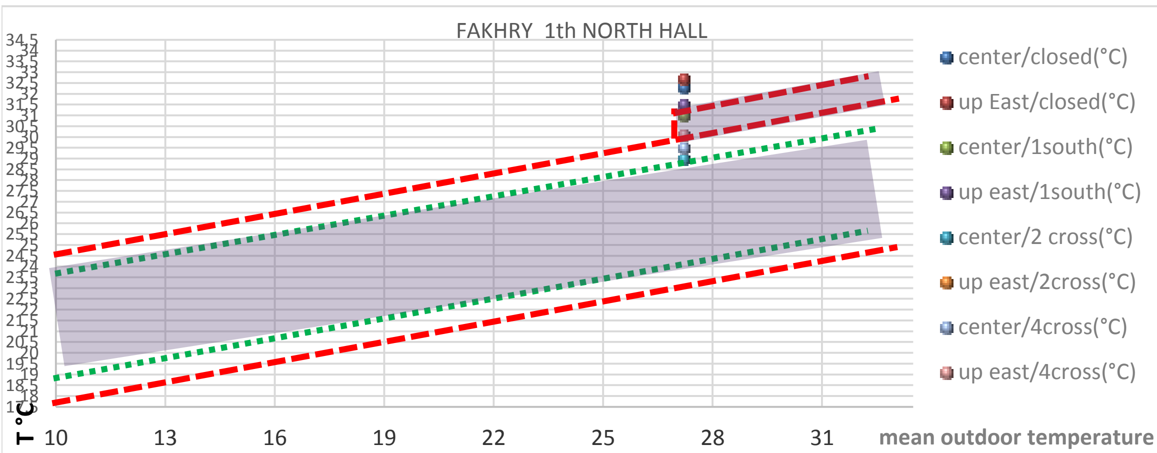
Adaptive model, ASHRAE STANDARD way over 0.3 to 0.6 m/s operative temperature increase 1.2°C degree this diagram more close to survey data **Figure C-21-(b-c)**.

At increasing operative temperature case opening four windows could be comfortable four occupancy.

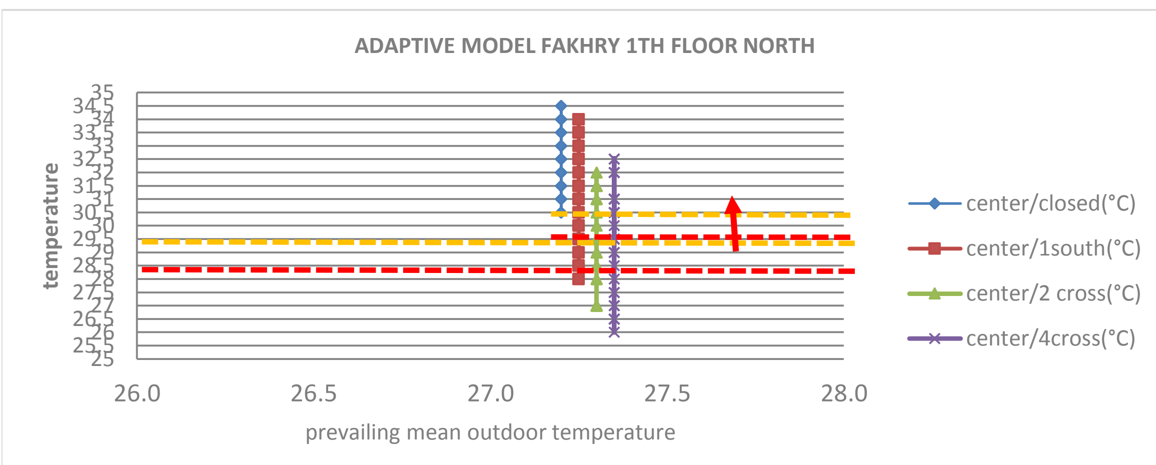
Consequences acceptability limits 80% for case one side ventilation 25% in other hand for case cross ventilation increased 50% to 55% comfort period due 0.3m/s air velocity for cross ventilation period increased roughly 20% acceptability period.



a



b



c

Figure C-21: FAKHRY 1st floor North hall,a .PMV/sensation,b .adaptive model, c.adaptive model t of degree .

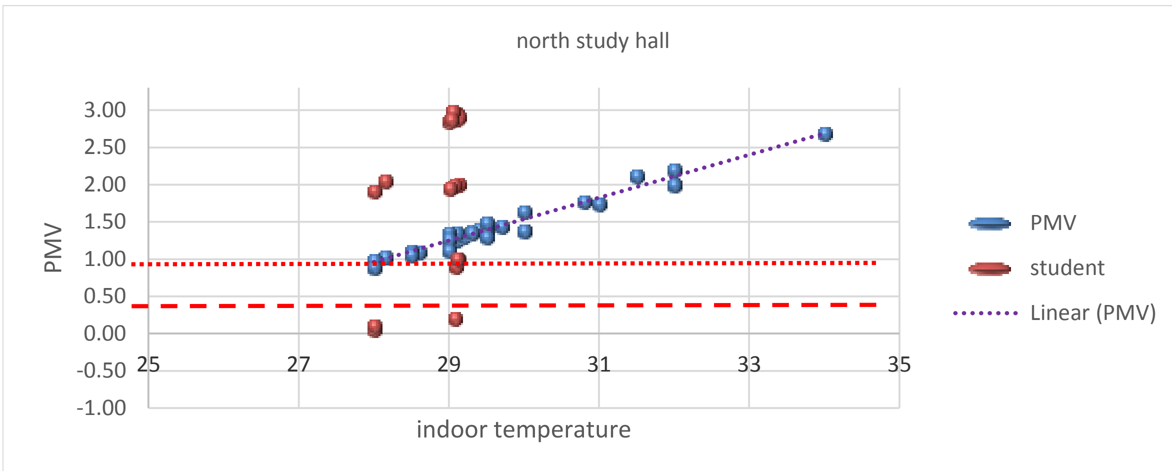
NORTH HALL STUDY (cross ventilation) :

PMV scale , Sensation in this case is more complicated because it has inside the hall about twenty person at the same time without control in staying at the same position with all windows door opened , cross ventilation adjacent windows.

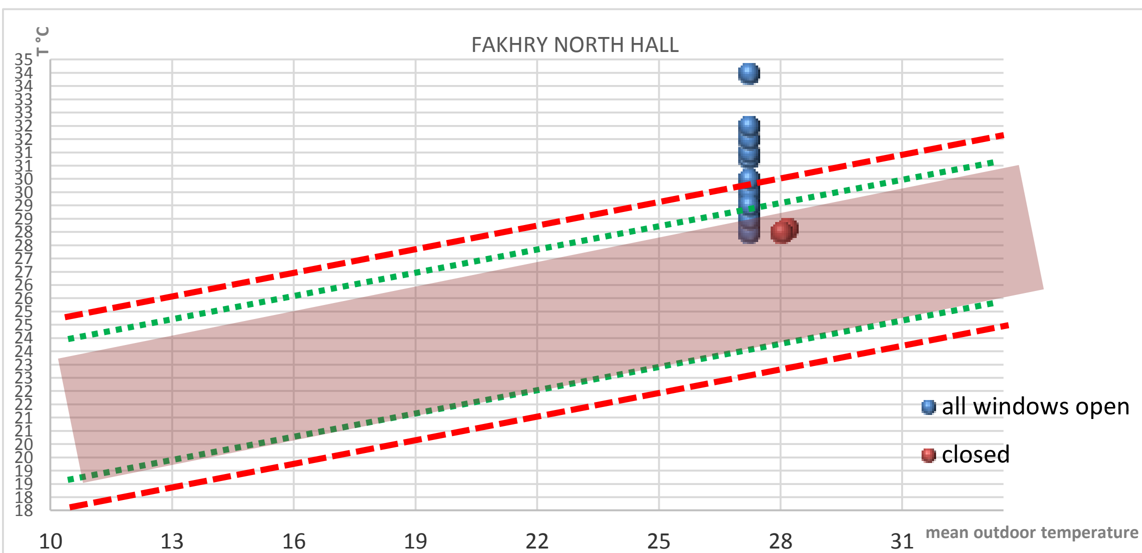
Sensation survey shows 35% of student felt comfortable and 65% discomfort) **Figure C-22-a**.

Adaptive model prevailing mean outdoor daily temperature calculate as ASHRAE STANDARD using weather station data for measurement period of the temperature was 27.2 °C .

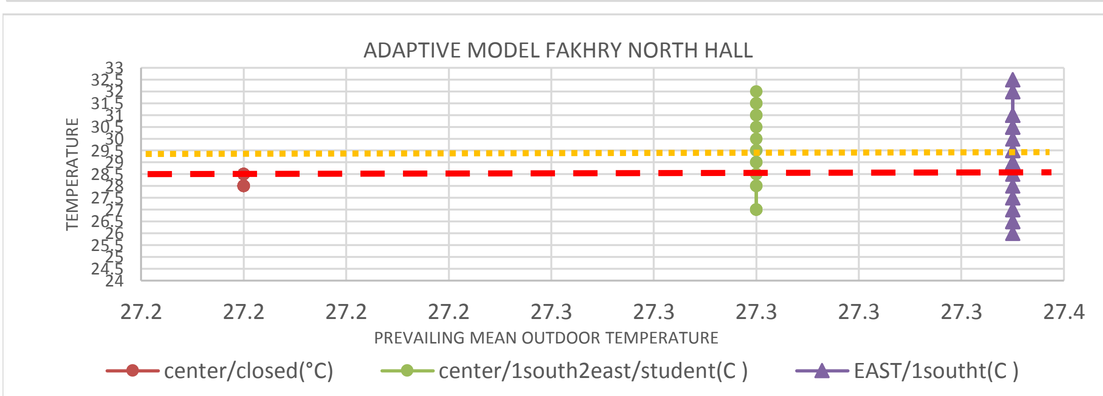
Adaptive model gives up to 50% comfortable , supposed a bout two person only no more .
Adaptive model (ST)measure :for comparison utilized part one °C degree to separate diagram for analyzing. in this case has different result depend on room position 25% size underground , closed case has steady behavior in other hand acceptability limits 80% for cross ventilation with 20 students 50% for one side with 2 students 53% **Figure C-22-(b-c)**.



a



b



c

Figure C-22: FAKHRY .North hall,a .PMV/sensation,b .adaptive model, c.adaptive model for part of degree.

C.5.3 Elements effects Materials and orientation and ventilation

C.5.3.1 *Summer 2014th*

Design elements :

The **Figure C-23** describe the halls behavior depend on there states .

Courtyard correlated to, temperature data and result ,the important factor traditional structure and traditional materials (MOUSLLI)and trees, then size and shaded (BAB AL SALAM), other important influence fountain .

For halls :orientation , from all cases all houses have direct orientation without any deviation ,there are many factors impact on comfort , cross ventilation has big effect the result arranged as :(MOUSLLI east hall) better than (BAIT WARRD east hall single side ventilation and its intervention) , single side ventilation (stack effect) two level of windows get more airflow (FAKHRY south hall with north elevation very high ceiling 7.9m),then west MOUSLLI hall (cross ventilation adjacent windows)better than west (FAKHRY)hall single side ventilation , north MOUSLLI hall (single side ventilation , stack effect) traditional structure with 5m height ceiling , then north BAB AL SALAM with 3.6M height ceiling and intervention .

For describe and analyze these factors **Figure C-23** shows that .

Ground floor: diagram observed higher ceiling got lower indoor temperature in spite of opening area correlate with structure .

North hall: three halls got equal temperature, but these three halls have different volume and high MOUSLLI has higher ceiling +2m with traditional structure (equation balance bigger volume, higher ceiling less opening equal lower volume, height area opening windows).

East hall : MOUSLLI has better parameters than BAIT WARRD by more*4 volume +1% opening + 2m higher ceiling + cross ventilation that gave it lower 5 ^{o}C .

West hall: MOUSLLI got better parameters same result as north hall

North hall :MOUSLLI has better parameters than BAB AL SALAM *4 volume(little depth) *2 high hall with less0.5 % opening windows got 2 ^{o}C decrease .(single side ventilation (stack)).

East hall: MOUSLLI, FAKHRY have same volume but the first has higher ceiling + more 10% opening got 6 ^{o}C decrease, in relative to the traditional structure.

First floor : the important factor cross ventilation which arranged :height ceiling (FAKHRY north hall cross ventilation with5M high ceiling)better than (north BAB AL SALAM single side ventilation 3m high ceiling) , and also structure (MOUSLLI east room with west elevation (high solar radiation)) better than (FAKHRY east room which has intervened new materials).

Correlate to natural ventilation mainly opening area.

The previews result corresponded with PMV/SET scale result (PMV scale result proportion with temperature result) .

Physical elements:

Figure C-23 shows the physical parameters influence percentage % on PMV scale and thermal comfort:

Air velocity roughly 8.8% for every 0.1m/s

Indoor temperature effect roughly 9.4% for every one degree °C changes.

Relative humidity effect roughly 1.2% for every 1% humidity changes.

Observed air velocity proportional with windows opening area.

Exceptional: natural ventilation cases (cross ventilation , stack single side)for these cases have got high velocity in spite of less windows opening area (except BAB AL SALAM NORTH HALL because it has smallest facade area related to its size).

Utilized fountain in courtyard could decrease opening area to half and still get same result PMV (FAKHRY SOUTH HALL).

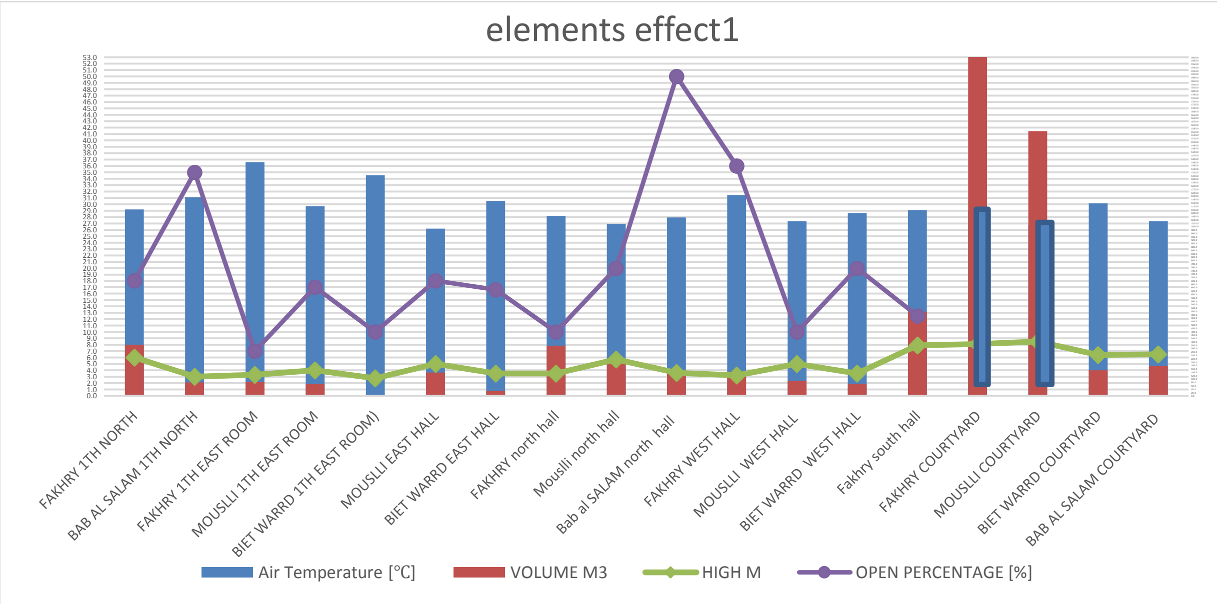
Having green plants and trees in courtyard get better result .

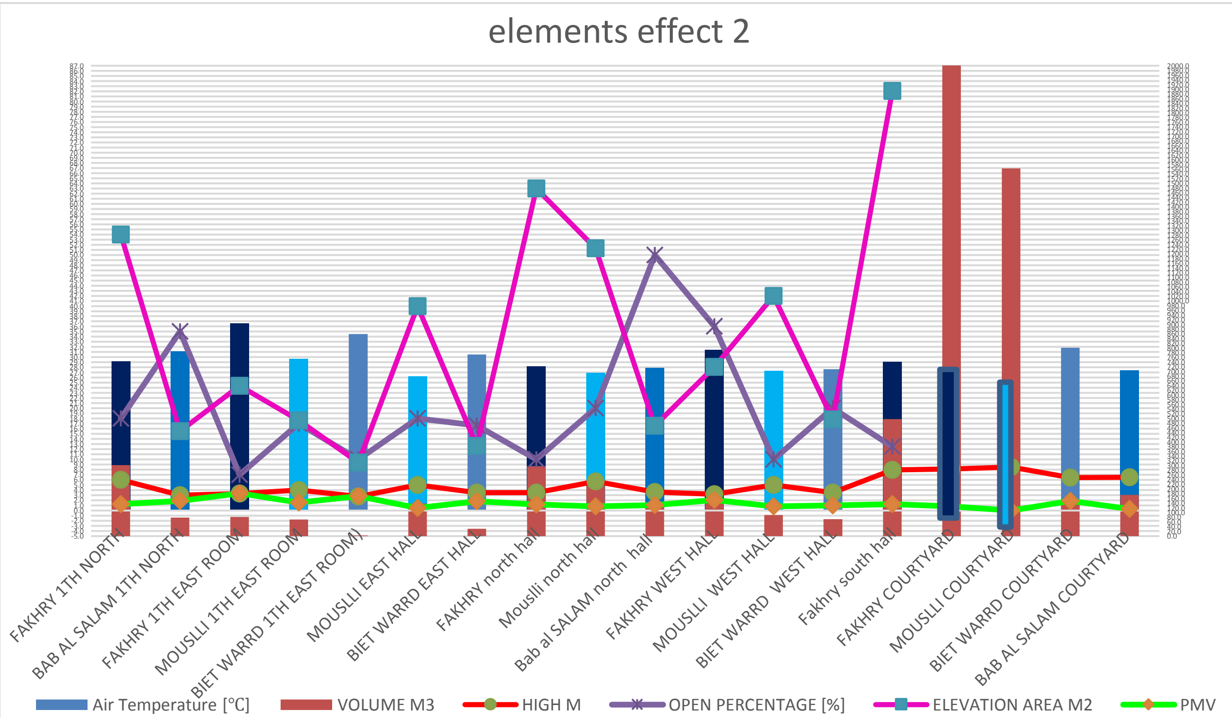
MOUSLLI has 35% green cover : higher RH and less temperature so better PMV.

FAKHRY has 25% green cover : higher temperature , in other hand utilized fountain got less temperature roughly 1°C degree for same period without fountain that means better PMV scale, ln spite of case lower air velocity period .

BAB AL SALAM : smaller area with 50% green cover allowed airflow inside courtyard for that gots better PMV scale than FAKHRY.

BAIT WARRD case: in courtyard it has one big tree covered almost all courtyard 95%(close courtyard roof) which means lower airflow and higher PMV scale .





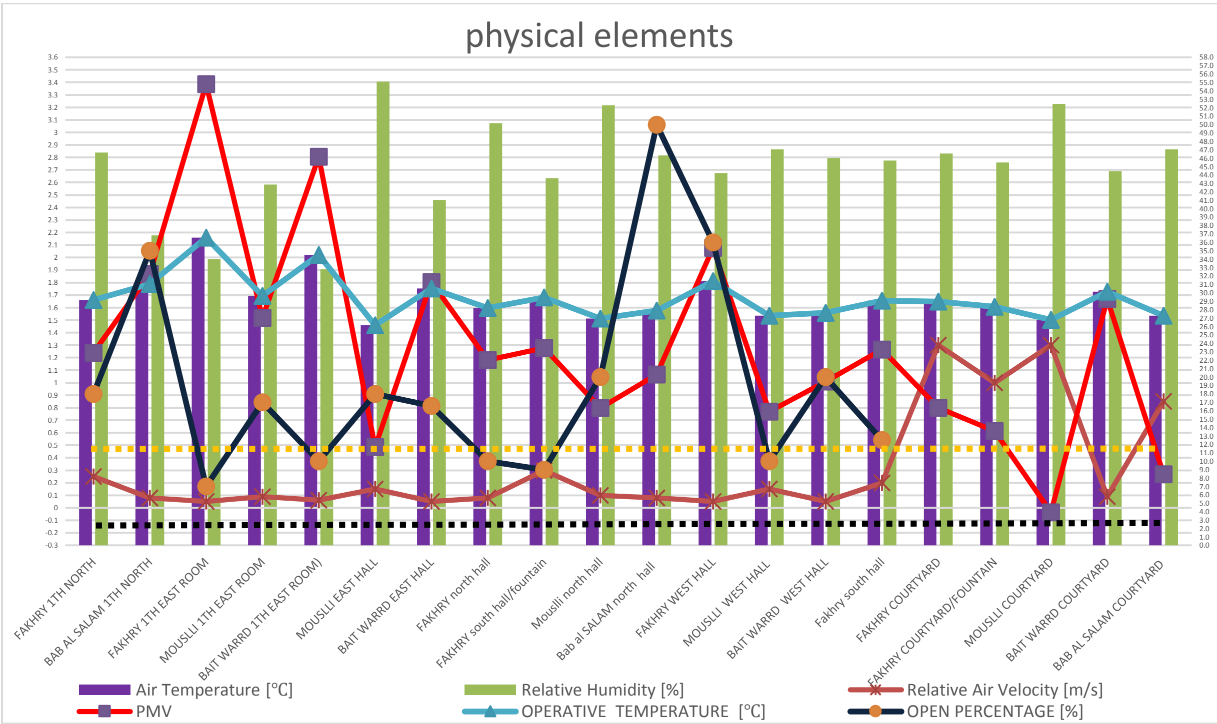


Figure C-23: elements effects on thermal comfort summer 2014th .

C.5.3.2 *Winter 2014/2015th*

Design elements:

The **Figure C-24** describe the halls behavior depend on there states .

Physical elements:

GROUND FLOOR :

North hall : there are correlation between summer result and winter result but with decrease in PMV value about 75%. For MOUSLLI halls this caused by the big infiltration because there aren't any kind of rehabilitation . the steady result of FAKHRY hall caused by position underground and heavy mass with solar direct gain through south façade .

West hall :there is correlation in same way of the latest result , figure below observed the big decreased for FAKHRY hall caused by concrete utilized at structure at rehabilitation as new interventions and its behavior. MOUSLLI hall has same result of the north hall.

FAKHRY south hall : same result as other caused by concrete behavior at roof , beside the big north façade .

Courtyards : FAKHRY courtyard has same behavior and result as other FAKHRY halls , on other hand MOUSLLI courtyard has good behavior and PMV/SET value in summer and winter period that caused by conservation at traditional structure and materials .

MOUSLLI east hall: same result as other MOUSLLI halls with little bit different in decrease value which is little decrease that shows the real behavior of traditional structure and materials , made the hall more comfortable in winter and summer period .

FIRST FLOOR :

North hall : which has few intervention at structure , this hall prove the traditional theory about live in first floor at winter (passive heating technique) solar direct gain with light mass ,which amendment The high ceiling , and getting a good comfort behavior for winter period , on other hand for summer period has high temperature and PMV scale that solved by (passive cooling technique) cross ventilation .

Latest result reverse with east room which has a lot of new intervention in structure and materials caused discomfort .

Figure C-24 shows height parameters doesn't has effect in winter as summer period .because this parameters influence by air movement and natural ventilation .

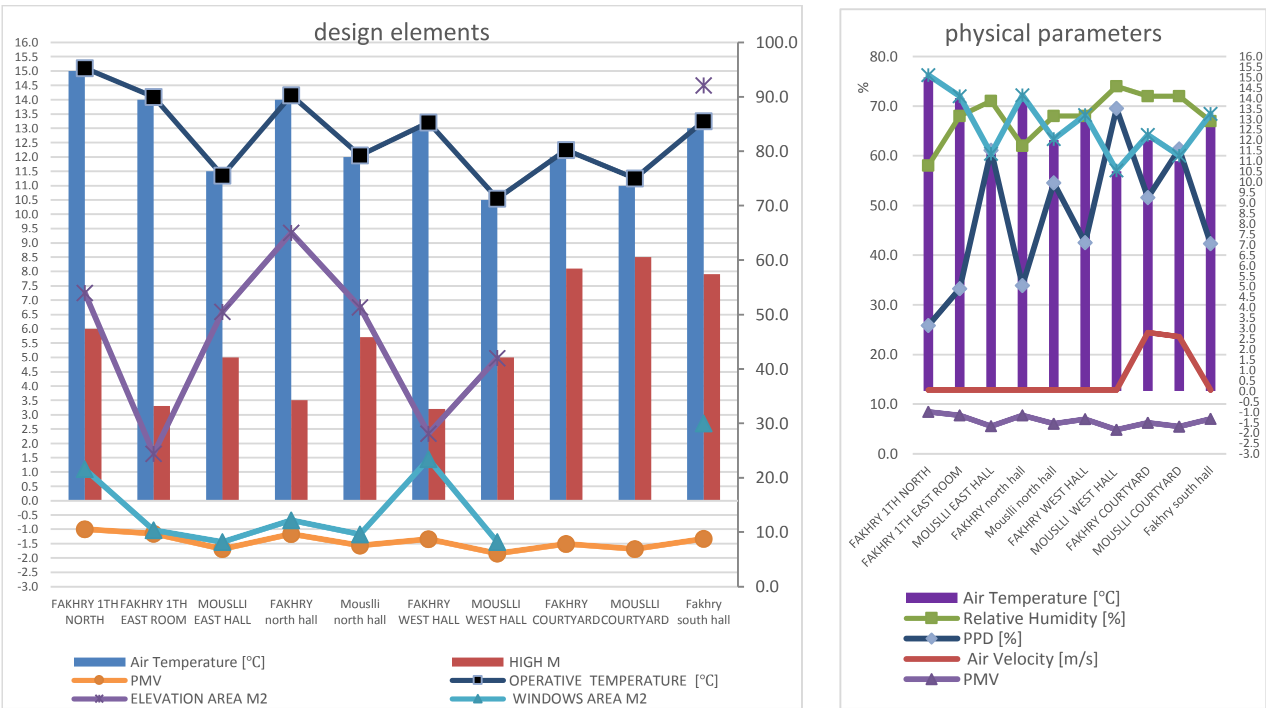


Figure C-24: elements effects on thermal comfort winter 2014/2015th .

APPENDIX D
MODELING AND CALIBRATION

D.1 Energy plus/DB Heat Balance calculation process.

Heat balance

Simulation process:

Conduction through the wall

Conduction transfer function module

The most basic time series solution is the response factor equation which relates the flux at one surface of an element to an infinite series of temperature histories at both sides as shown by Equation

$$q''_{ko}(t) = \sum_{j=0}^{\infty} X_j T_{o,t-j\delta} - \sum_{j=0}^{\infty} Y_j T_{i,t-j\delta}$$

Where q” is heat flux, T is temperature, i signifies the inside of the building element, o signifies the outside of the building element, t represents the current time step, and X and Y are the response factors.

While in most cases the terms in the series decay fairly rapidly, the infinite number of terms needed for an exact response factor solution makes it less than desirable. Fortunately, the similarity of higher order terms can be used to replace them with flux history terms. The new solution contains elements that are called conduction transfer functions (CTFs). The basic form of a conduction transfer function solution is shown by the following equation:

$$q''_{ki}(t) = -Z_o T_{i,t} - \sum_{j=1}^{nz} Z_j T_{i,t-j\delta} + Y_o T_{o,t} + \sum_{j=1}^{nz} Y_j T_{o,t-j\delta} + \sum_{j=1}^{nq} \Phi_j q''_{ki,t-j\delta}$$

for the inside heat flux, and

$$q''_{ko}(t) = -Y_o T_{i,t} - \sum_{j=1}^{nz} Y_j T_{i,t-j\delta} + X_o T_{o,t} + \sum_{j=1}^{nz} X_j T_{o,t-j\delta} + \sum_{j=1}^{nq} \Phi_j q''_{ko,t-j\delta}$$

for the outside heat flux (q”=q/A) where:

X_j=Outside CTF coefficient, j= 0,1,...nz.

Yj = Cross CTF coefficient, j= 0,1,...nz.

Zj = Inside CTF coefficient, j= 0,1,...nz.

Φ_φ= Flux CTF coefficient, j = 1,2,...nq.

Ti = Inside face temperature

To = Outside face temperature

q''_{ko}= Conduction heat flux on outside face

q'' = Conduction heat flux on inside face

The subscript following the comma indicates the time period for the quantity in terms of the time stepδ.

These equations state that the heat flux at either face of the surface of any generic building element is linearly related to the current and some of the previous temperatures at both the interior and exterior surface as well as some of the previous flux values at the interior surface.

The final CTF solution form reveals why it is so elegant and powerful. With a single, relatively simple, linear equation with constant coefficients, the conduction heat transfer through an element can be calculated. The coefficients (CTFs) in the equation are constants that only need to be determined once for each construction type. The only storage of data required are the CTFs themselves and a limited number of temperature and flux terms. The formulation is valid for any surface type and does not require the calculation or storage of element interior temperatures.

Outside Surface Heat Balance:

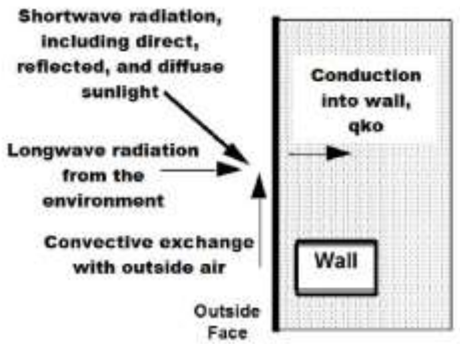
The heat balance on the outside face is:

$$q''_{asol} + q''_{LWR} + q''_{conv} + q''_{ko} = 0$$

Where:

q''_{asol}= Absorbed direct and diffuse solar (short wavelength) radiation heat flux.
q''_{LWR}= Net long wavelength (thermal) radiation flux exchange with the air and surroundings.
q''_{conv}= Convective flux exchange with outside air.
q''_{ko}= Conduction heat flux (q/A) into the wall.

All terms are positive for net flux to the face except the conduction term, which is traditionally taken to be positive in the direction from outside to inside of the wall. Simplified procedures generally combine the first three terms by using the concept of a *sol-air temperature*. Each of these heat balance components is introduced briefly below **Figure D-25**.



e D-25: Outside Heat Balance Control Volume Diagram

External Shortwave Radiation:

$q''_{asol}$is calculated using procedures presented later in this manual and includes both direct and diffuse incident solar radiation absorbed by the surface face. This is influenced by location, surface facing angle and tilt, surface face material properties, weather conditions, etc.

External Longwave Radiation:

$q''_{LWR}$is a standard radiation exchange formulation between the surface, the sky, and the ground. The radiation heat flux is calculated from the surface absorptivity, surface temperature, sky and ground temperatures, and sky and ground view factors.

generally agreed that reasonable assumptions for building loads calculations are (Chapman 1984; Lienhard 1981):

• each surface emits or reflects diffusely and is gray and opaque ($\alpha = \varepsilon$, $\tau = 0$, $\rho = 1- \varepsilon$)
• each surface is at a uniform temperature
• energy flux leaving a surface is evenly distributed across the surface,
• the medium within the enclosure is non-participating.

The total longwave radiative heat flux is the sum of components due to radiation exchange with the ground, sky, and air.

$$q''_{LWR} = q''_{gnd} + q''_{sky} + q''_{air}$$

Applying the Stefan-Boltzmann Law to each component yields:

$$q''_{LWR} = \varepsilon\sigma\, F_{gnd}\left(T^4_{gnd} - T^4_{surf}\right) + \varepsilon\sigma\, F_{sky}\left(T^4_{sky} - T^4_{surf}\right) + \varepsilon\sigma\, F_{air}\left(T^4_{air} - T^4_{surf}\right)$$

Where:

ε =long-wave emittance of the surface
σ =Stefan-Boltzmann constant
F_{gnd} = view factor of wall surface to ground surface temperature
F_{sky} = view factor of wall surface to sky temperature
F_{air} =view factor of wall surface to air temperature
T_{surf} = outside surface temperature
T_{gnd} = ground surface temperature
T_{sky} = sky temperature

T_{air} = air temperature.
Linearized radiative heat transfer coefficients are introduced to render the above equation more compatible with the heat balance formulation,

$$q''_{LWR} = h_{r,gnd}(T_{gnd} - T_{surf}) + h_{r,sky}(T_{sky} - T_{surf}) + h_{r,air}(T_{air} - T_{surf})$$

Where:

$$h_{r,gnd} = \frac{\varepsilon\sigma F_{gnd}(T_{gnd}^4 - T_{surf}^4)}{T_{gnd} - T_{surf}}$$

$$h_{r,sky} = \frac{\varepsilon\sigma F_{sky}(T_{sky}^4 - T_{surf}^4)}{T_{sky} - T_{surf}}$$

$$h_{r,air} = \frac{\varepsilon\sigma F_{air}(T_{air}^4 - T_{surf}^4)}{(T_{air} - T_{surf})}$$

The longwave view factors to ground and sky are calculated with the following expressions (Walton 1983):

$$F_{ground} = 0.5(1 - cos\emptyset)$$

$$F_{sky} = 0.5(1 + cos\emptyset)$$

where $\emptyset$ is the tilt angle of the surface. The view factor to the sky is further split between sky and air radiation by:

$$\beta = \sqrt{0.5(1 + cos\emptyset)}$$

The ground surface temperature is assumed to be the same as the air temperature. The final forms of the radiative heat transfer coefficients are shown here.

$$h_{r,gnd} = \frac{\varepsilon\sigma F_{gnd}(T_{surf}^4 - T_{air}^4)}{T_{surf} - T_{air}}$$

$$h_{r,sky} = \frac{\varepsilon\sigma F_{sky}\beta(T_{surf}^4 - T_{sky}^4)}{T_{surf} - T_{sky}}$$

$$h_{r,air} = \frac{\varepsilon\sigma F_{sky}(1 - \beta)(T_{surf}^4 - T_{air}^4)}{(T_{surf} - T_{air})}$$

Outdoor/Exterior Convection

Heat transfer from surface convection is modeled using the classical formulation:

$$Q_c = h_{c,ext}A(T_{surf} - T_{air})$$

where
Qc = rate of exterior convective heat transfer
hc,ext = exterior convection coefficient
A = surface area
T_{surf} = surface temperature
T_{air} = outdoor air temperature

Simple Combined

The simple algorithm uses surface roughness and local surface wind speed to calculate the exterior heat transfer coefficient (key: Simple Combined). The basic equation used is:

$$h = D + EV_Z + EV_Z^2$$

where
h = heat transfer coefficient
Vz = local wind speed calculated at the height above ground of the surface centroid
D, E, F = material roughness coefficients
The roughness correlation is taken from **Table D-13**, Page 22.4, ASHRAE Handbook of Fundamentals (ASHRAE 1989). The roughness coefficients are shown in the following table:

Table D-13: Roughness Coefficients D, E, and F..

Roughness Index	D	E	F	Example Material
1 (Very Rough)	11.58	5.894	0.0	Stucco
2 (Rough)	12.49	4.065	0.028	Brick
3 (Medium Rough)	10.79	4.192	0.0	Concrete
4 (Medium Smooth)	8.23	4.0	-0.057	Clear pine
5 (Smooth)	10.22	3.1	0.0	Smooth Plaster
6 (Very Smooth)	8.23	3.33	-0.036	Glass

The total convection coefficient is the sum of these components.

$$h_c = h_f + h_n$$

The forced convection component is based on a correlation by Sparrow, Ramsey, and Mass (1979):

$$h_f = 2.537 W_f R_f \left(\frac{PV_Z}{A}\right)^{1/2}$$

Where

Wf = 1.0 for windward surfaces or Wf = 0.5 for leeward surfaces.

For no temperature difference OR a vertical surface the following correlation is used:

$$h = 1.31|\Delta T|^{\frac{1}{3}}$$

For (ΔT < 0.0 AND an upward facing surface) OR (ΔT > 0.0 AND an downward facing surface) an enhanced convection correlation is used:

$$h = \frac{9.482|\Delta T|^{\frac{1}{3}}}{7.283 - |cos\sum|}$$

Where Σ is the surface tilt angle.

For (ΔT > 0.0 AND an upward facing surface) OR (ΔT < 0.0 AND an downward facing surface) a reduced convection correlation is used:

$$h = \frac{1.810|\Delta T|^{\frac{1}{3}}}{1.382 + |cos\sum|}$$

Where Σ is the surface tilt angle.

Exterior/External Conduction

The conduction term, $q''ko$, can in theory be calculated using a wide variety of heat conduction formulations. Typically in EnergyPlus, the Conduction Transfer Function (CTF) method is used. The available models are described in this section: Conduction through the Walls.

Inside Heat Balance

The heart of the heat balance method is the internal heat balance involving the inside faces of the zone surfaces. This heat balance is generally modeled with four coupled heat transfer components: 1) conduction through the building element, 2) convection to the air, 3) short wave radiation absorption and reflectance and 4) longwave radiant interchange. The incident short wave radiation is from the solar radiation entering the zone through windows and emittance from internal sources such as lights. The longwave radiation interchange includes the absorption and emittance of low temperature radiation sources, such as all other zone surfaces, equipment, and people.

The heat balance on the inside face can be written as follows:

$$q''_{LWX} + q''_{SW} + q''_{LWS} + q''_{ki} + q''_{sol} + q''_{conv} = 0$$

Where

q''_{LWX} =Net longwave radiant exchange flux between zone surfaces.

q''_{SW}= Net short wave radiation flux to surface from lights.

q''_{LWS}= Longwave radiation flux from equipment in zone.

q''_{ki}= Conduction flux through the wall.
q''_{sol}= Transmitted solar radiation flux absorbed at surface.
q''_{conv}= Convective heat flux to zone air.
Each of these heat balance components is introduced briefly below **Figure D-26**.

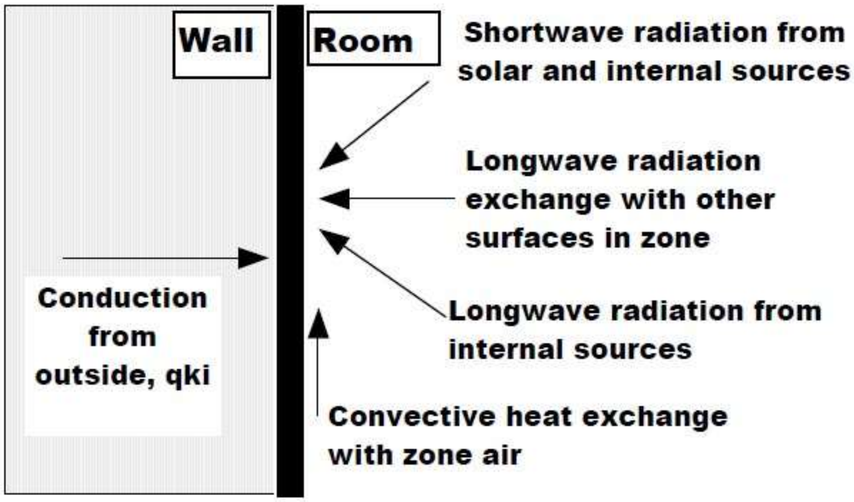


Figure D-26: Inside heat balance control volume diagram

Internal Long-Wave Radiation Exchange
LW Radiation Exchange Among Zone Surfaces
There are two limiting cases for internal LW radiation exchange that are easily modeled:
- The zone air is completely transparent to LW radiation.
- The zone air completely absorbs LW radiation from the surfaces within the zone. The limiting case of completely absorbing air has been used for load calculations and also in some energy analysis calculations. Energy Plus uses a grey interchange model for the longwave radiation among zone surfaces. This model is based on the "Script F" concept developed by Hottel (Hottel and Sarofim, Radiative Transfer, Chapter 3, McGraw Hill, 1967). This procedure relies on a matrix of exchange coefficients between pairs of surfaces that include all exchange paths between the surfaces. In other words all reflections, absorptions and re-emissions from other surfaces in the enclosure are included in the exchange coefficient, which is called Script F. The procedure has two steps:
1) Determine the total area of other surfaces "seen" by a surface.
2) Approximate the direct view factor from surface 1 to surface 2 as the ratio of the area of surface 2 to the total area "seen" by surface 1. Once the Script F coefficients are determined, the longwave radiant exchange is calculated for each surface using:

$$q_{i,j} = A_i F_{i,j}\left(T_i^4 - T_j^4\right)$$

where $F_{i,j}$ is the ScriptF between surfaces i and j.

Thermal Mass and Furniture

LW Radiation From Internal Sources
The traditional model for this source is to define a radiative/convective split for the heat introduced into a zone from equipment.
Internal Short-Wave Radiation
SW Radiation from Lights
The short wavelength radiation from lights is distributed over the surfaces in the zone in some prescribed manner.

Transmitted Solar

Transmitted solar radiation is also distributed over the surfaces in the zone in a prescribed manner.

Convection to Zone Air

The convection flux is calculated using the heat transfer coefficients as follows:

$$q''_{conv} = h_c(T_S - T_a)$$

The inside convection coefficients (*hc*) can be calculated using one of many different models. Currently the implementation uses coefficients based on correlations for natural, mixed, and forced convection.

Interior Conduction

This contribution to the inside surface heat balance is the wall conduction term, q''_{ki} shown in Equation:

$$C = \frac{Q_0}{C_p \rho V_{max}}$$

This represents the heat transfer to the inside face of the building element. Again, a CTF formulation is used to determine this heat flux.

Interior Convection

There are many different modeling options available in Energy Plus for inside convection coefficients, *hc*. There are four different settings to direct how EnergyPlus managers select *hc* models during a simulation. There are numerous individual model equations for *hc* in EnergyPlus to cover different situations that arise from surface orientations, room airflow conditions, and heat flow direction.

Adaptive Convection Algorithm

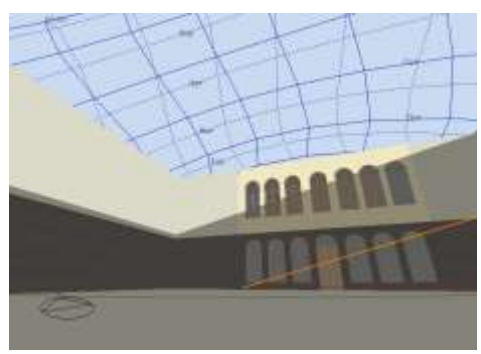
Beausoleil-Morrison (2000, 2002) developed a methodology for dynamically managing the selection of *hc* equations called *adaptive convection algorithm*. The algorithm is used to select among the available *hc* equations for the one that is most appropriate for a given surface at a given time.

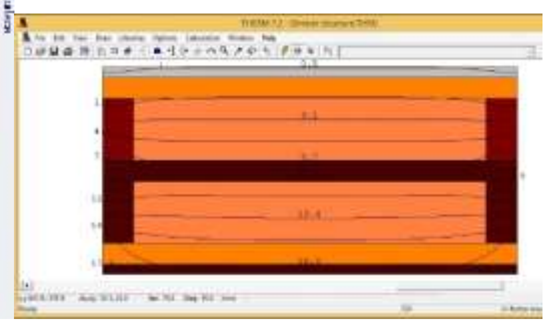
The adaptive convection algorithm implemented in Energy Plus for the inside face has a total of 45 different categories for surfaces and 29 different options for *hc* equation selections.

D.2 Characteristic courtyard case study modeling input:

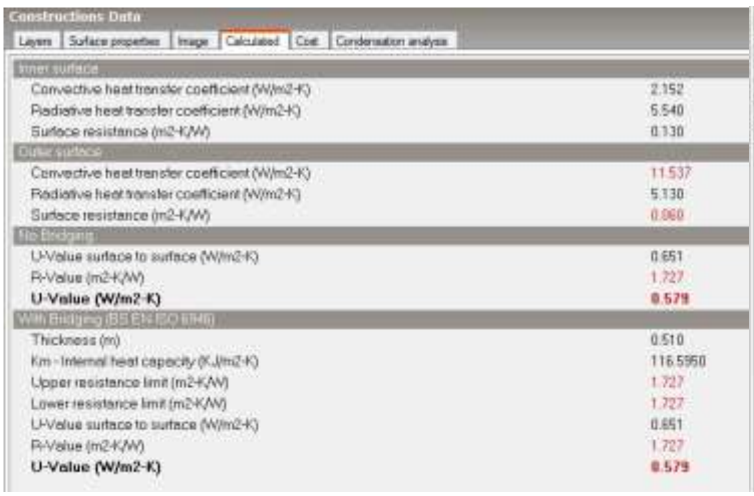
Followed **(Figure D-27**a,b - **Figure D-28** - **Figure D-29** - **Figure D-30** - **Figure D-31)**present case structure and program input data and Using the Calculated option increases the complexity of the model and slows simulations down.


a





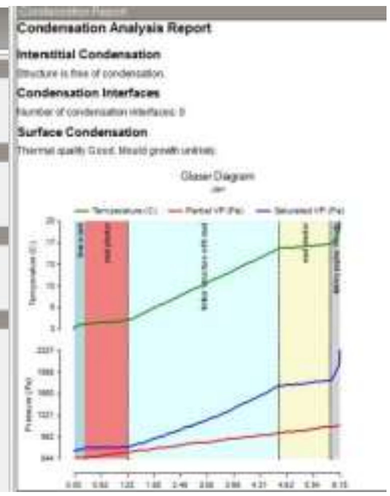
Timber wall structure THERM program calculate U value



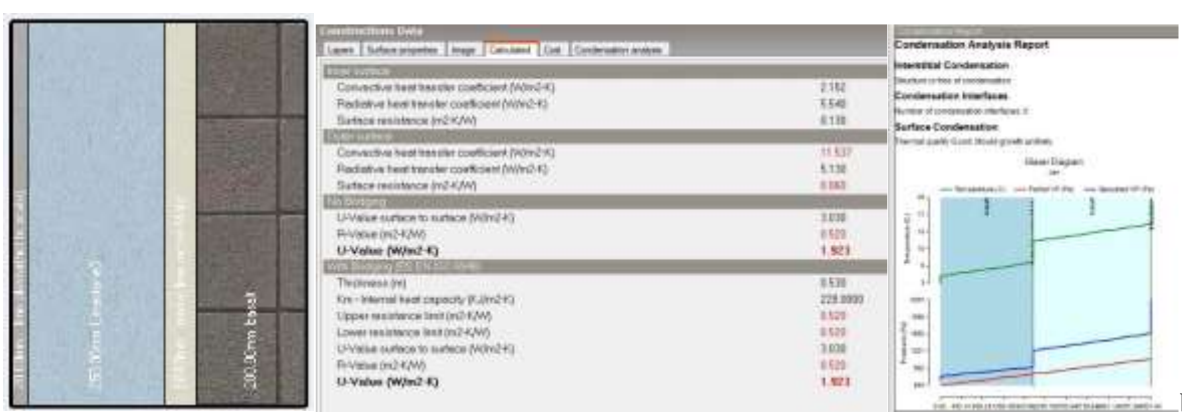
Constructions Data

Layers | Surface properties | Image | Calculated | Cost | Condensation analysis

Inner surface	
Convective heat transfer coefficient (W/m2-K)	2.152
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.130
Outer surface	
Convective heat transfer coefficient (W/m2-K)	11.537
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.060
No Bridging	
U-Value surface to surface (W/m2-K)	0.651
R-Value (m2-K/W)	1.727
U-Value (W/m2-K)	**0.579**
With Bridging (BS EN ISO 6946)	
Thickness (m)	0.510
Km - Internal heat capacity (KJ/m2-K)	116.5950
Upper resistance limit (m2-K/W)	1.727
Lower resistance limit (m2-K/W)	1.727
U-Value surface to surface (W/m2-K)	0.651
R-Value (m2-K/W)	1.727
U-Value (W/m2-K)	**0.579**



,b.structure U value and condensation

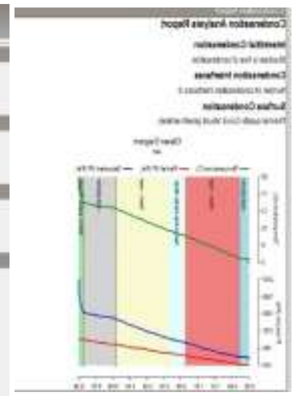


b

Figure D-27: a,b. Case study structures input.

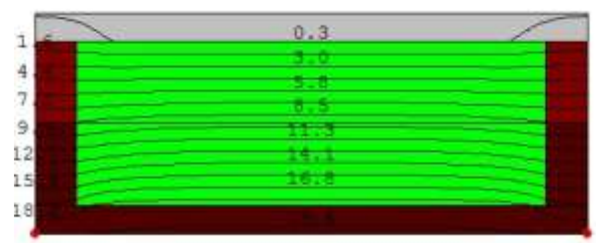
Basalt wall

Inner surface	
Convective heat transfer coefficient (W/m2-K)	2.152
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.130
Outer surface	
Convective heat transfer coefficient (W/m2-K)	11.537
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.060
No Bridging	
U-Value surface to surface (W/m2-K)	1.155
R-Value (m2-K/W)	1.056
U-Value (W/m2-K)	**0.947**
With Bridging (BS EN ISO 6946)	
Thickness (m)	0.530
Km - Internal heat capacity (KJ/m2-K)	143.5240
Upper resistance limit (m2-K/W)	1.056
Lower resistance limit (m2-K/W)	1.056
U-Value surface to surface (W/m2-K)	1.155
R-Value (m2-K/W)	1.056
U-Value (W/m2-K)	**0.947**



Gilled mud wall

South hall roof



surface condensation potential roof timber structure THERM program

Inner surface	
Convective heat transfer coefficient (W/m2-K)	0.342
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.178
Outer surface	
Convective heat transfer coefficient (W/m2-K)	11.537
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.068
No Bridging	
U-Value surface to surface (W/m2-K)	0.128
R-Value (m2-K/W)	8.064
U-Value (W/m2-K)	**0.124**
With Bridging (BS EN ISO 6946)	
Thickness (m)	0.484
Km - Internal heat capacity (KJ/m2-K)	14.0760
Upper resistance limit (m2-K/W)	8.064
Lower resistance limit (m2-K/W)	8.064
U-Value surface to surface (W/m2-K)	0.128
R-Value (m2-K/W)	8.064
U-Value (W/m2-K)	**0.124**

South hall roof u value

Total solar transmission (SHGC)	0.819
Direct solar transmission	0.775
Light transmission	0.881
U-value (ISO 10292/ EN673) (W/m2-K)	5.718
U-Value (ISO 15099 / NFRC) (W/m2-K)	**5.778**

Figure D-28: Case study structures input timber wall, glass.

Location template:

Occupancy schedule:

Program setup :

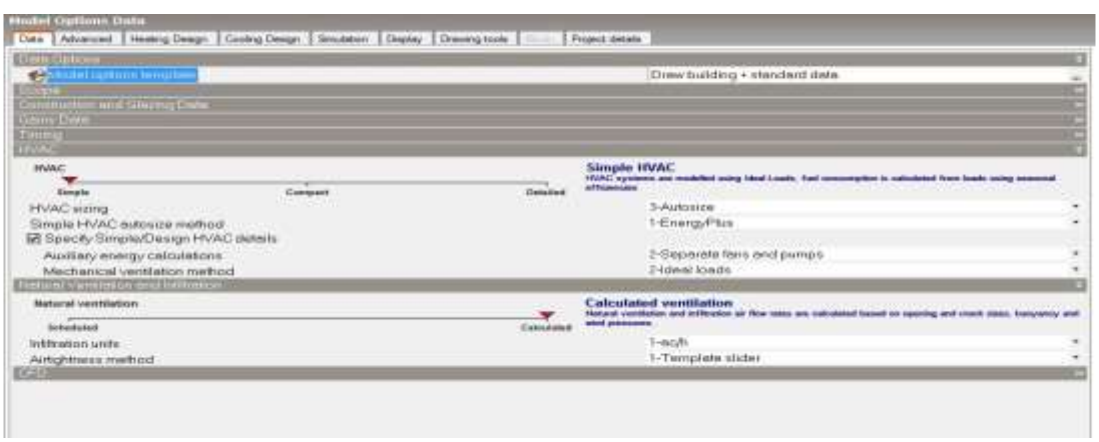
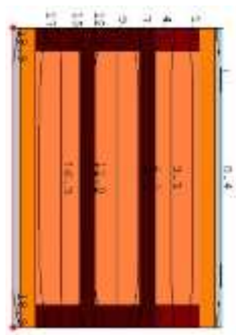
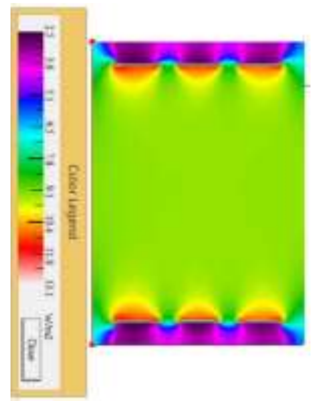


Figure D-29: location, occupant, program set up

North hall floor.

North hall ceiling.





Double timber structure wall

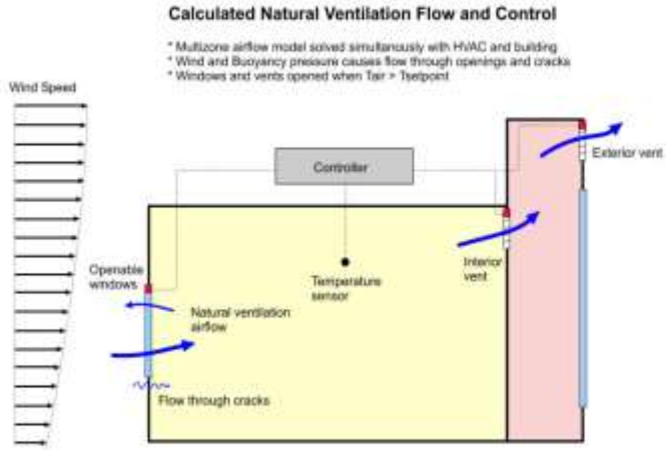
Convective heat transfer coefficient (W/m2-K)	4.460
Radiative heat transfer coefficient (W/m2-K)	5.540
Surface resistance (m2-K/W)	0.100
[illegible]	
Convective heat transfer coefficient (W/m2-K)	11.637
Radiative heat transfer coefficient (W/m2-K)	5.130
Surface resistance (m2-K/W)	0.060
[illegible]	
U-Value surface to surface (W/m2-K)	0.164
R-Value (m2-K/W)	6.209
U-Value (W/m2-K)	**0.160**
[illegible]	
Thickness (m)	0.272
Km - Internal heat capacity (KJ/m2-K)	6.4118
Upper resistance limit (m2-K/W)	[illegible]
Lower resistance limit (m2-K/W)	[illegible]
U-Value surface to surface (W/m2-K)	0.164
R-Value (m2-K/W)	[illegible]
U-Value (W/m2-K)	**0.160**

Pitched roof

nber structure wall

under pitched roof

Figure D-30: structure.



Rooms roof structure

Figure D-31: structure and DB natural ventilation calculation.

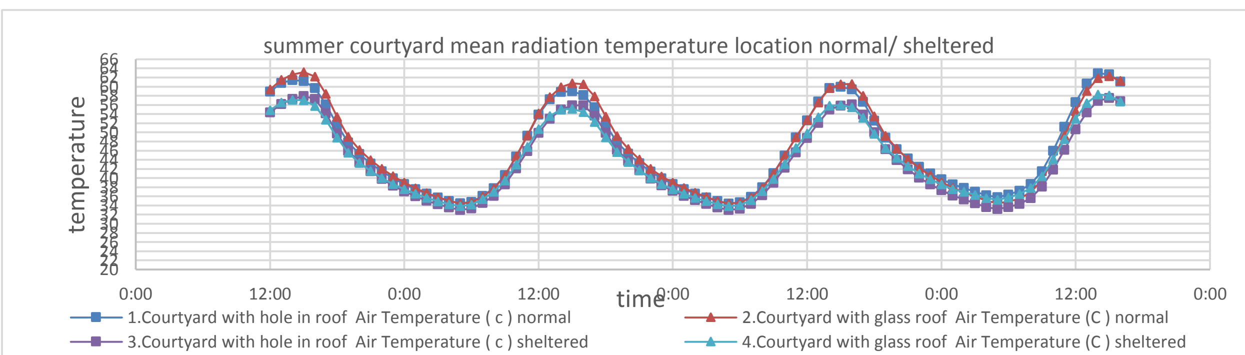
D.3 Calibration steps

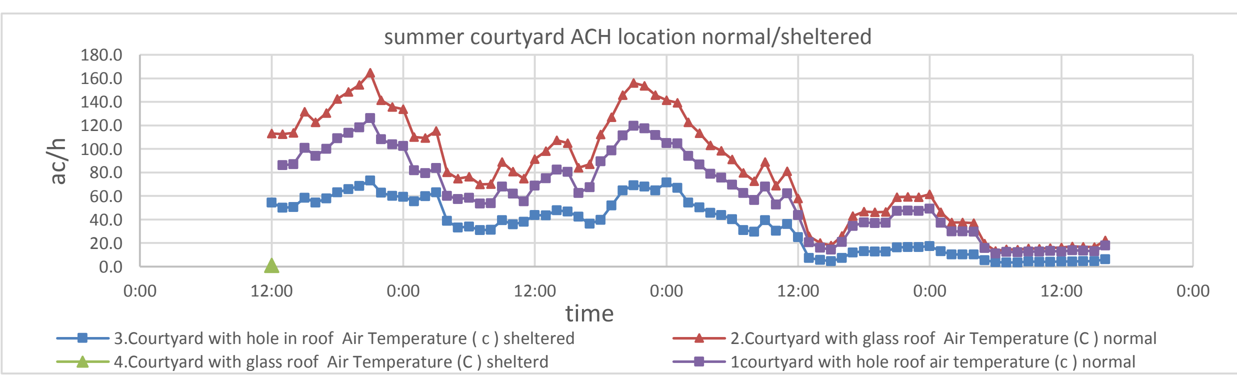
D.3.1 First calibration modeling :courtyard modeling

Defined exposure to wind in location normal and sheltered.

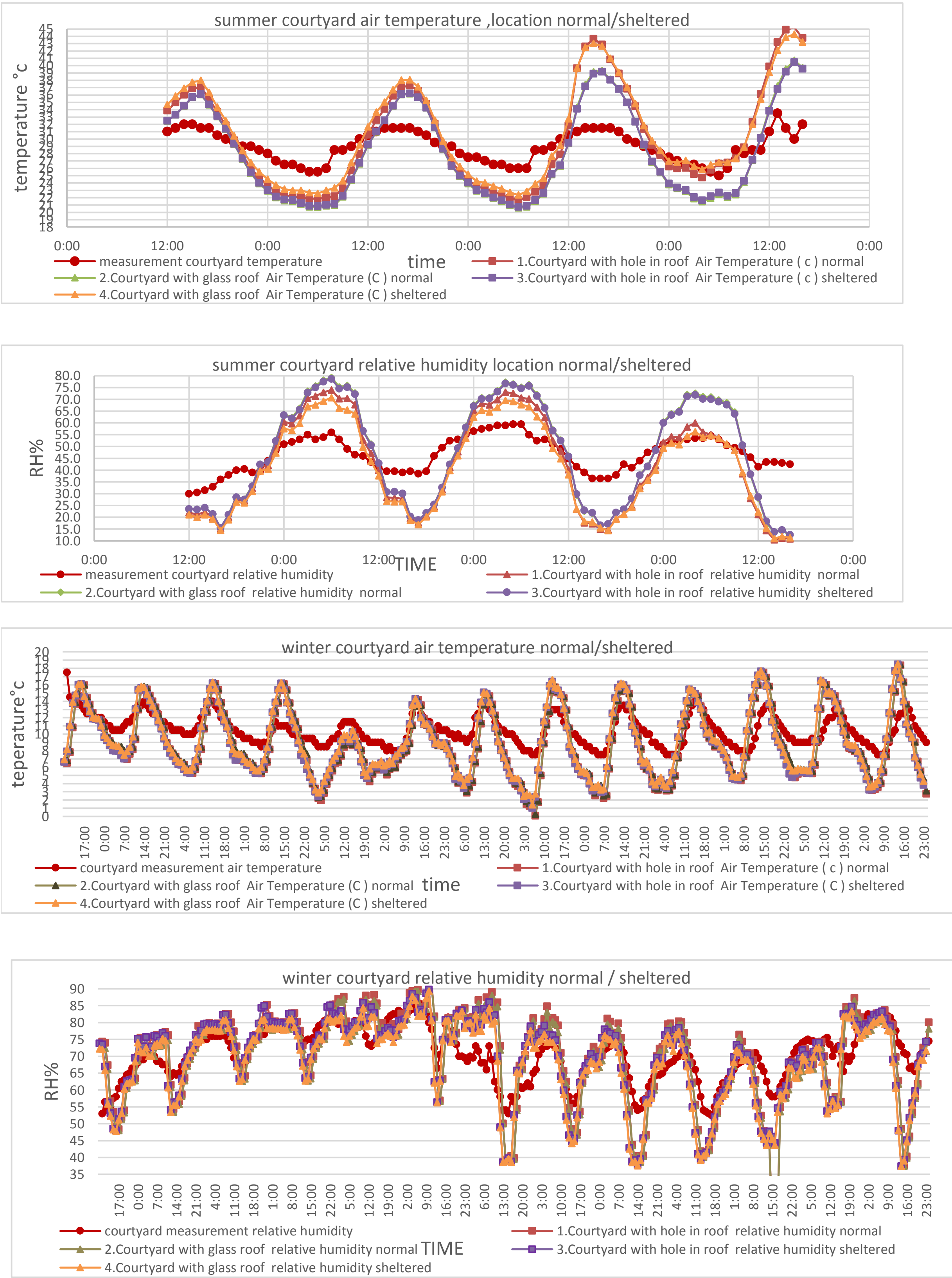
b

Figure D-32 - a,b





,a. Defined Exposure to wind in location normal mean radiation and ACH

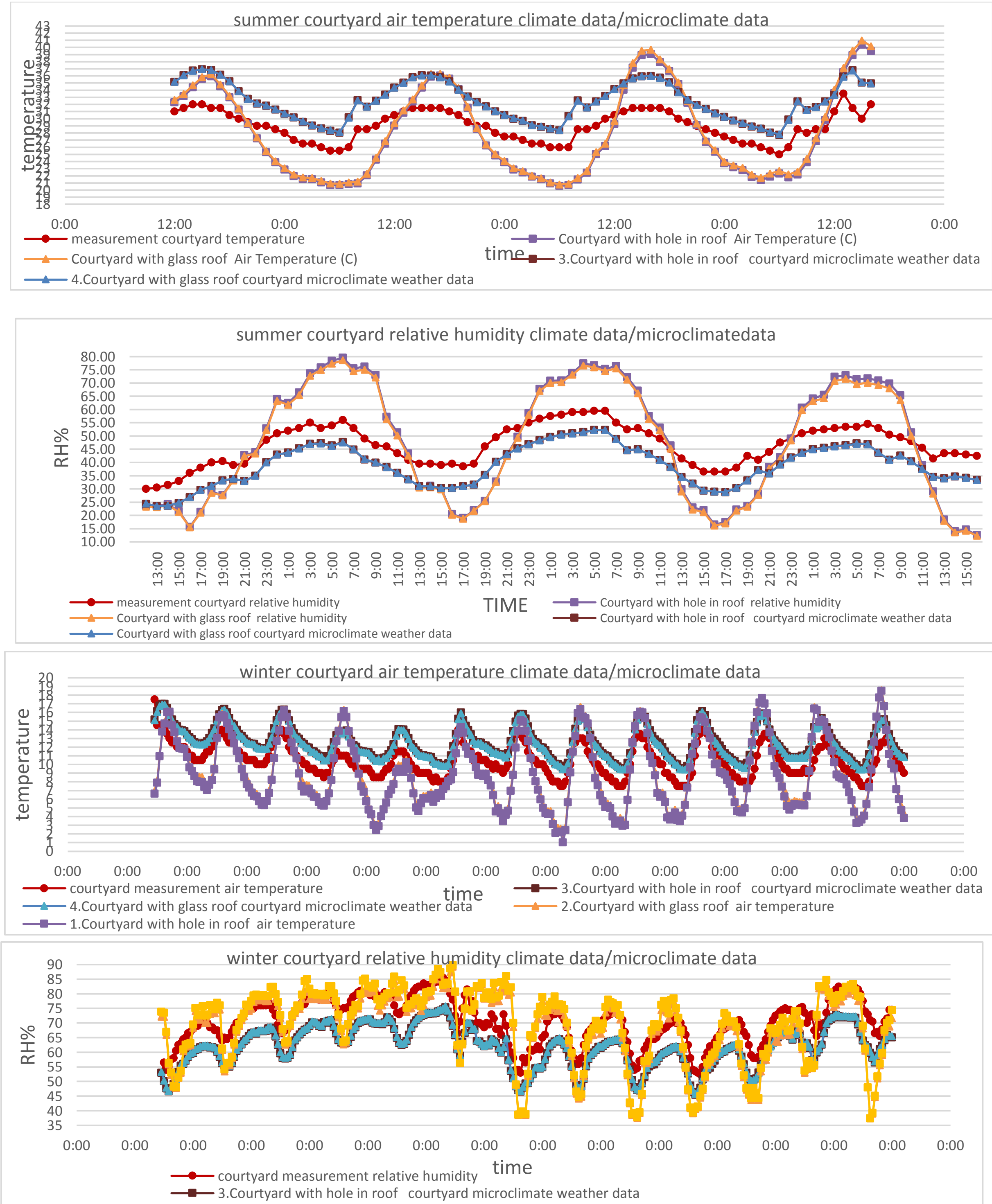


b

Figure D-32: b,Defined Exposure to wind in location normal and sheltered air temperature, relative humidity/summer, winter.

D.3.1.1 *Apply simulation :EPW weather station data/ courtyard microclimate*

Result **Figure D-33**,



third calibration . summer/winter courtyard temperature,relative humidity climate data/ microclimate data

Figure D-33: EPW station weather data/ courtyard microclimate.

For more verification and analyze courtyard thermal performance , the courtyard divided for seven zones to get more calibration accuracy corresponded to sensors positions at zone 6 ,4 for summer period at the last week of July **Figure D-34**.

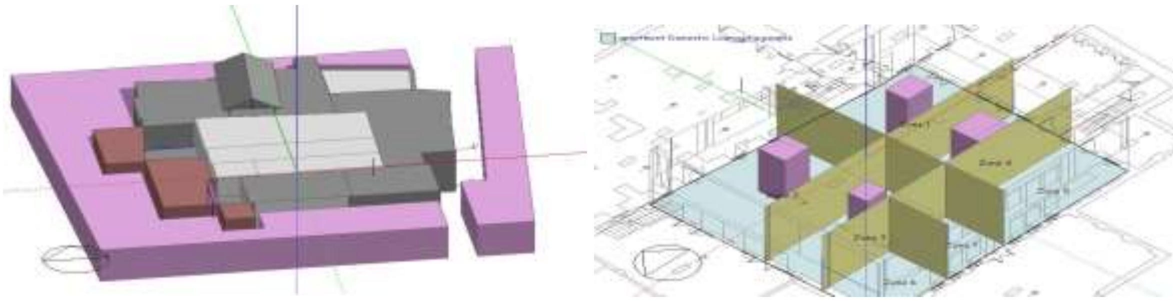


Figure D-34: courtyard partitions.

The division made by visual partition , A virtual partition is a partition between 2 zones which exists purely to sub-divide the space up and has no corresponding wall in the actual building.
Virtual partitions are commonly used for separating perimeter zones from core zones when there is to be different HVAC provision or when carrying out daylighting or solar overheating studies in situations where a large open plan space is subject to a high level of solar gain around the perimeter. Virtual partitions can be placed to create separate perimeter and core zones so that the local effect of the solar gain in the perimeter zone may be calculated. In the absence of virtual partitions, the risk of overheating could be underestimated due to the distribution of solar gain throughout the open plan space.
Result : air temperature air calibration **Figure D-35** :
Zone 4 :
ASHRAE calibration value : MBE 4.3 % , CVRMSE 9.6 %.
Zone 6 :
ASHRAE calibration value : MBE 1.1 % , CVRMSE 3.6 %.

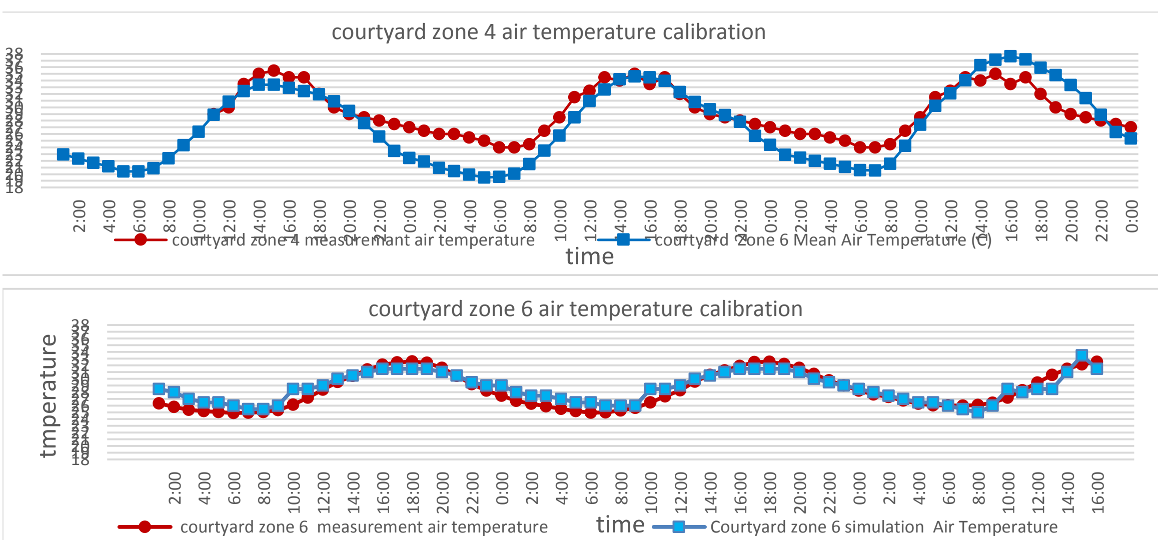
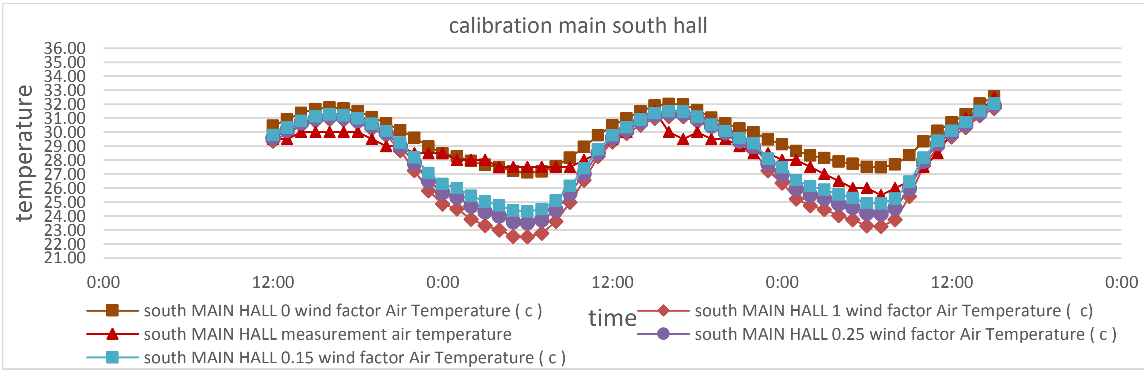
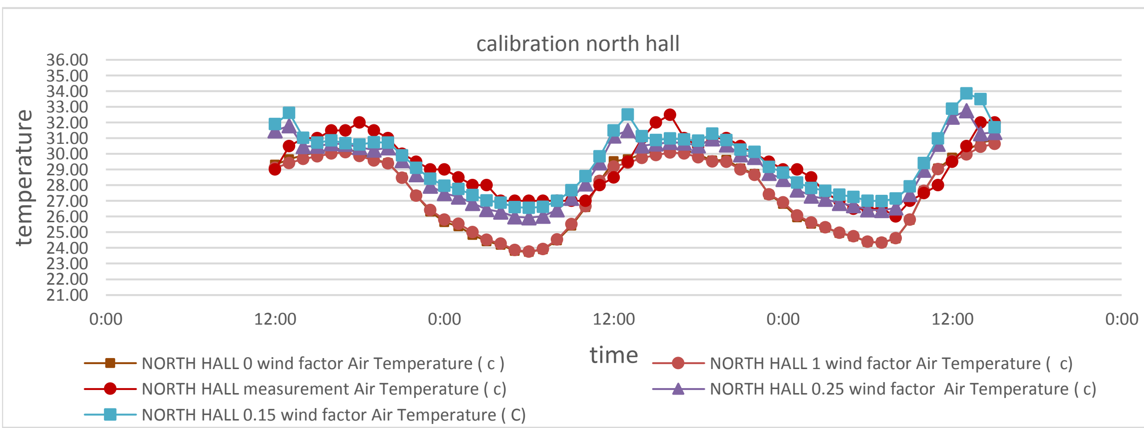


Figure D-35: courtyard zone 6 air temperature measurement / simulation calibration.

D.3.2 Second calibration modeling :halls modeling (natural ventilation)

Figure D-36-37-38,a,b-39-40a,b .





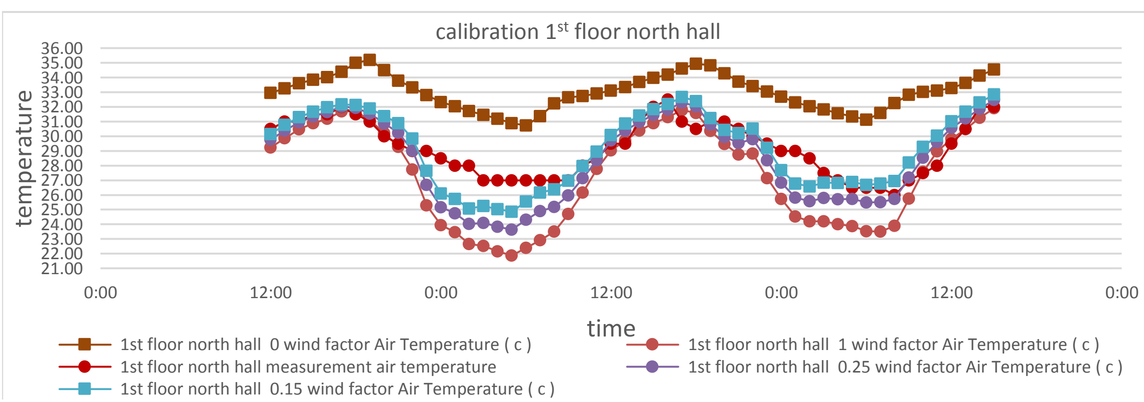
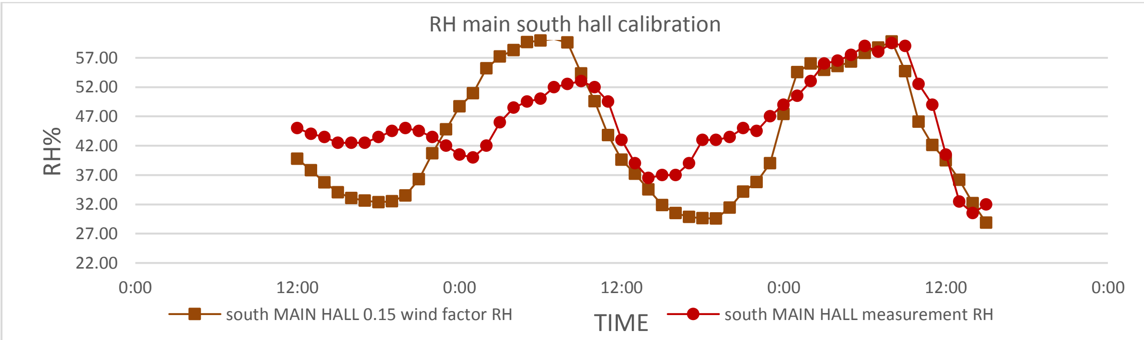
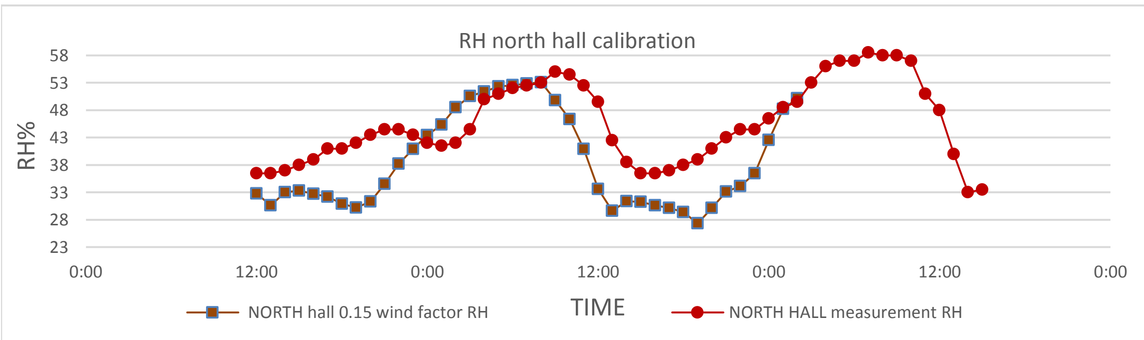


Figure D-36: south hall, north hall.1st floor north hall air temperature calibration .fourth week of July .





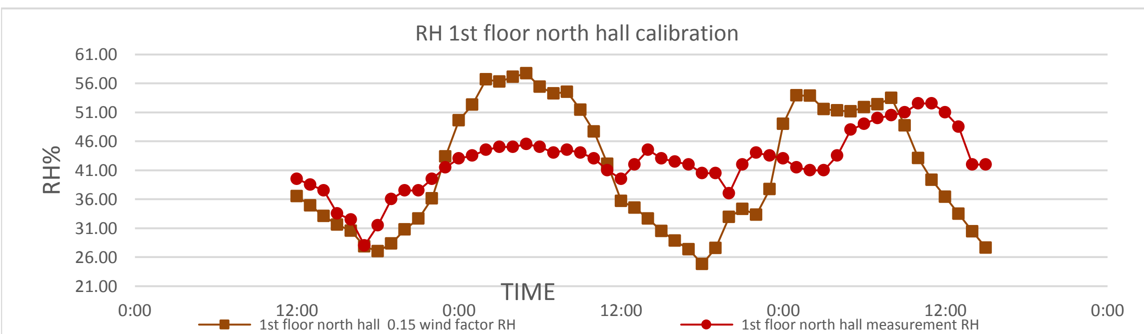
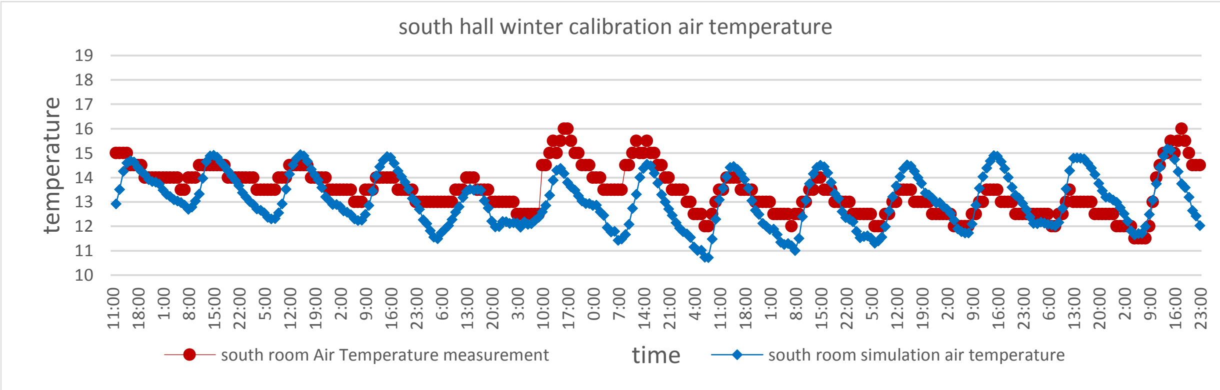
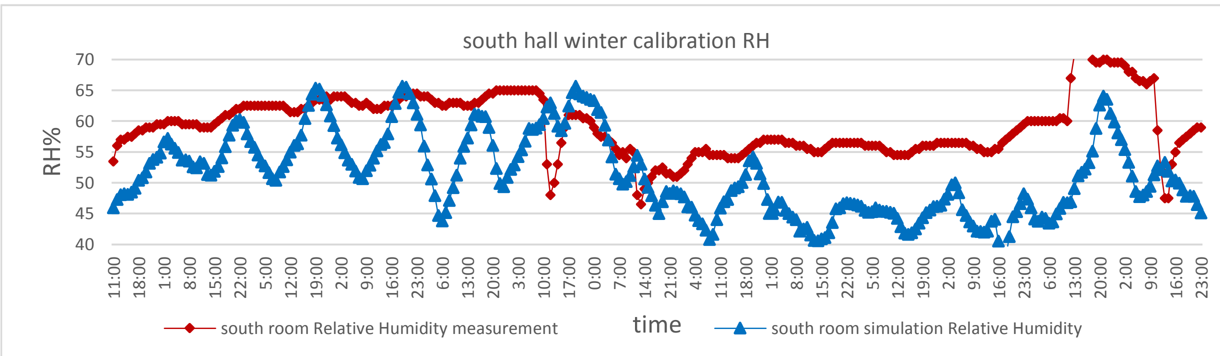


Figure D-37: south hall, north hall.1st floor north hall RH% calibration .fourth week of July



,a. south hall winter calibration air temperature .



,b. south hall winter calibration relative humidity .

Figure D-38: a,b .south hall winter calibration.

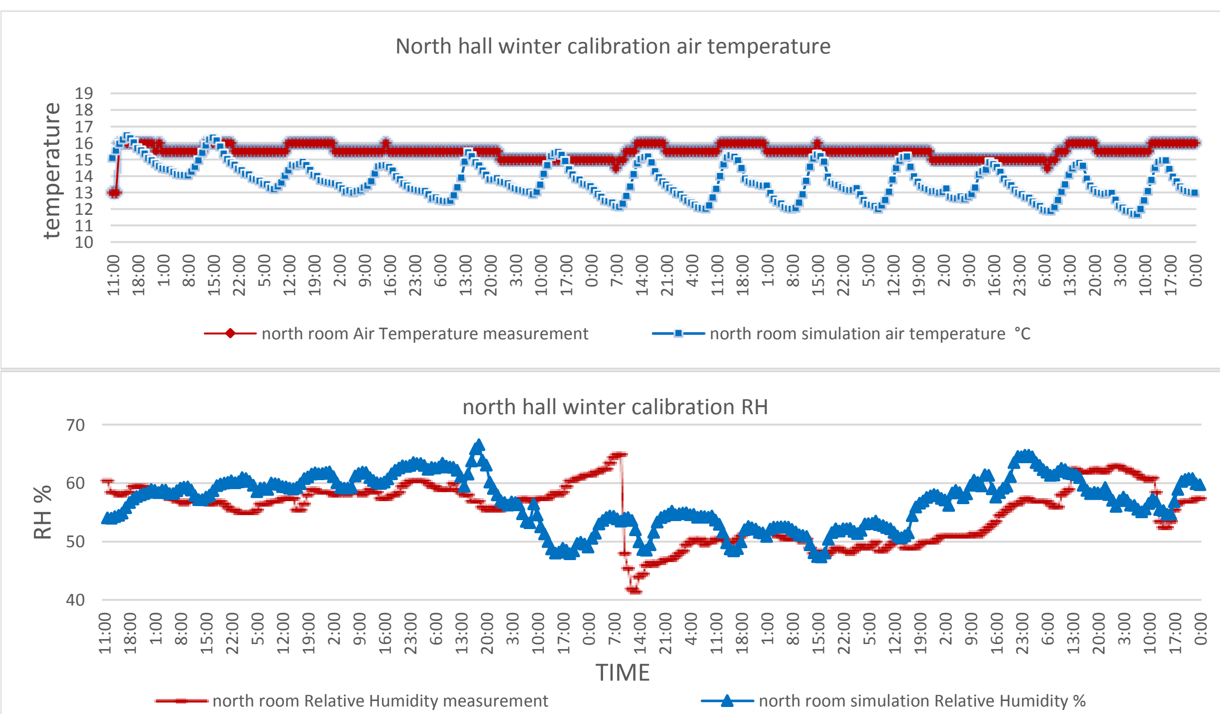
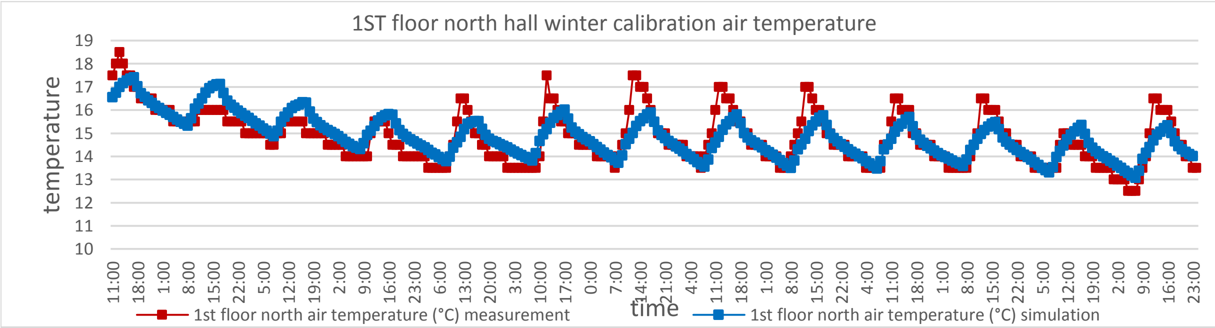
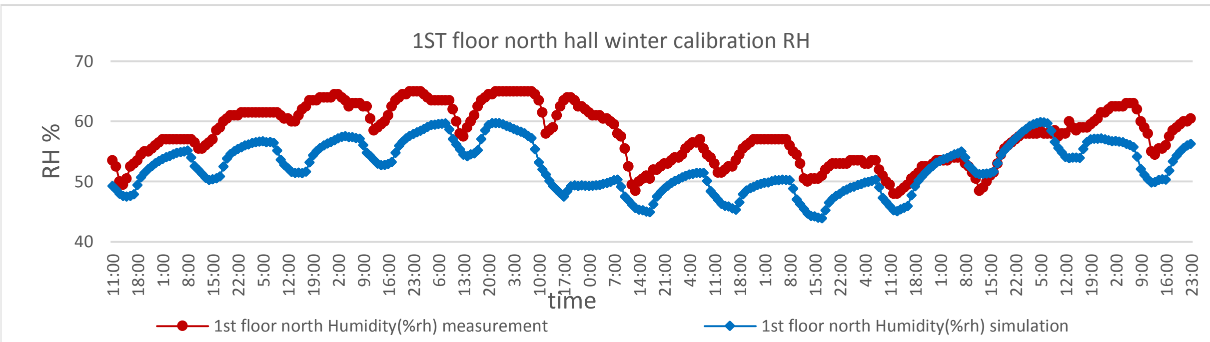


Figure D-39: north hall winter calibration air temperature ,relative humidity



,a. 1st floor north hall winter calibration air temperature .



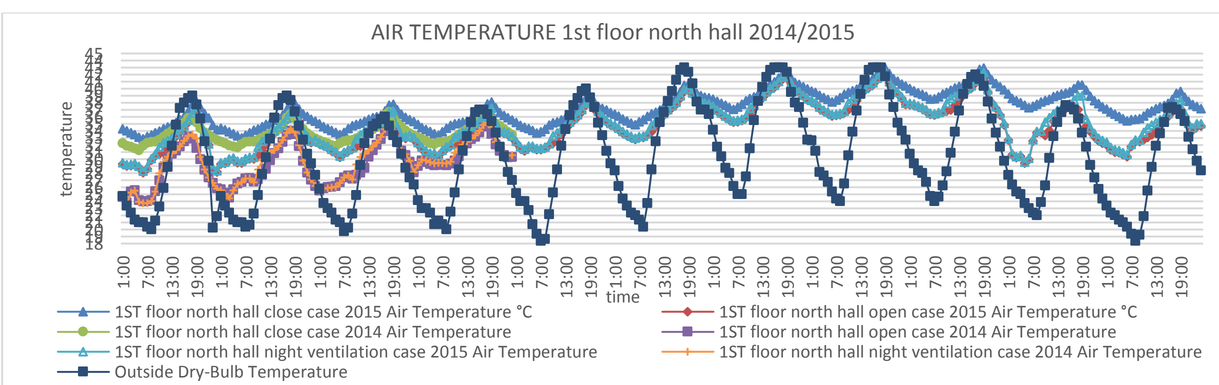
,b . 1st floor north hall winter calibration relative humidity .

Figure D-40: a,b .1st floor north hall winter calibration.

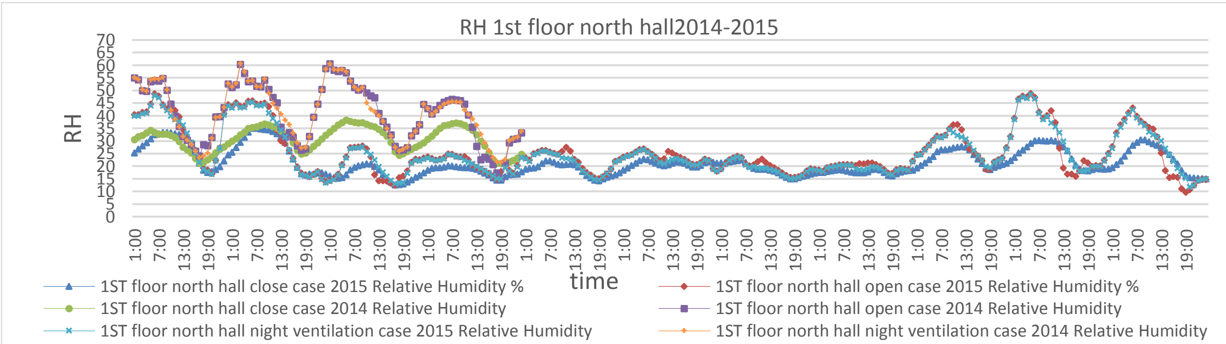
D.4 Evaluation of Merge between Measurement and Modeling

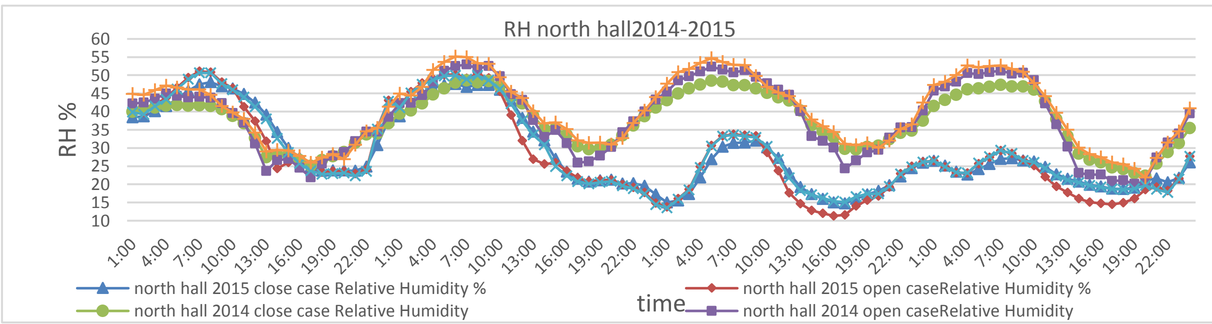
D.4.1 Thermal environment's characteristics

1st floor north hall and north hall air temperature and relative humidity **Figure D-41**.



,a. 1st floor north hall air temperature 2014/2015





b

Figure D-41:a,b . 1st floor north hall, north hall .temperature, relative humidity.

D.4.1.1 *Inside surface temperature*

1st floor north hall , north hall inside surface temperature **Figure D-42**.

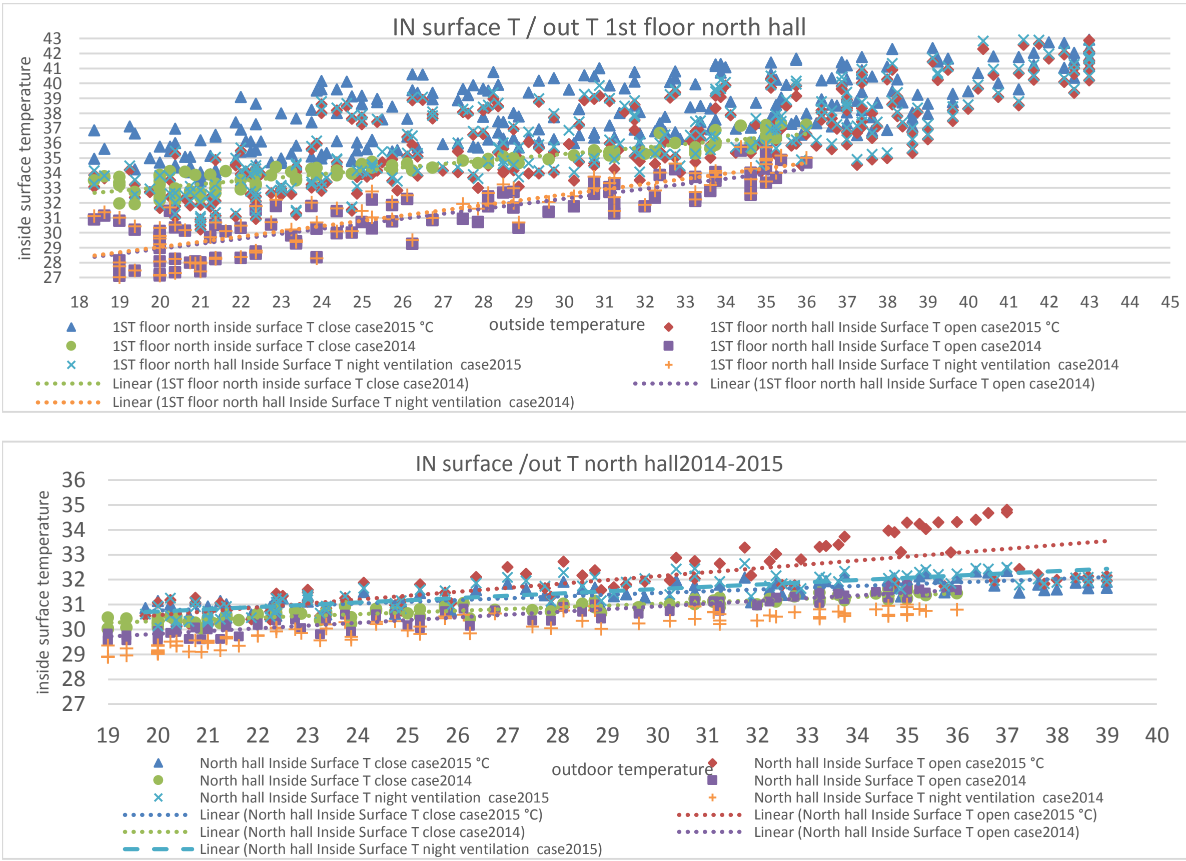


Figure D-42: north hall, 1st floor north hall .inside surface temperature.

D.4.1.2 *Pressure Difference*

South hall, 1st floor north hall, north hall: Figure D-43, Figure D-44 , Figure D-45

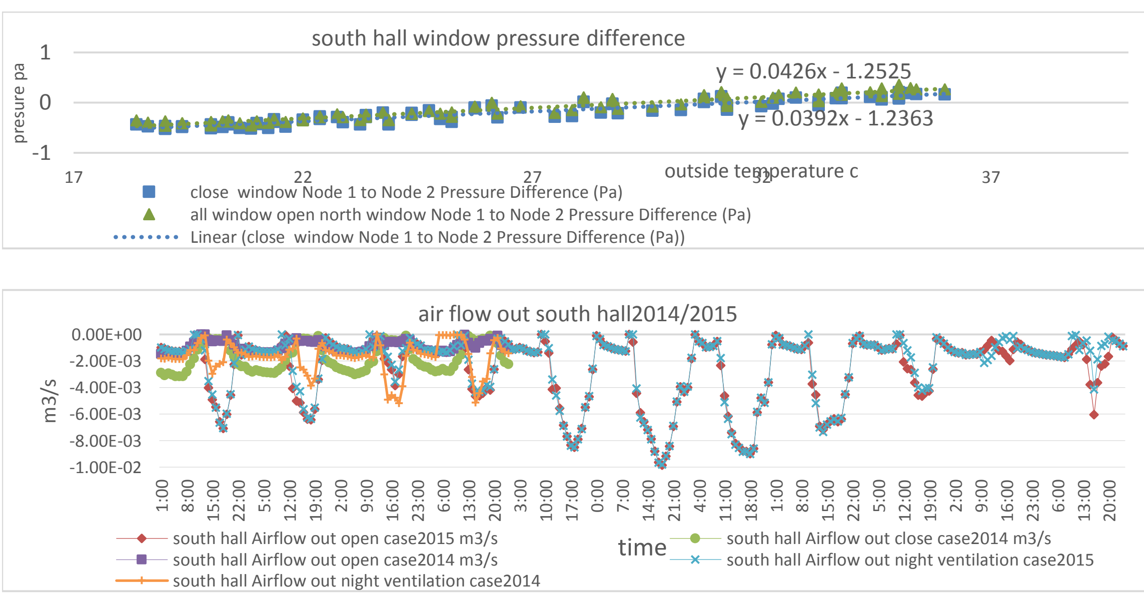


Figure D-43: difference pressure window, air flow out south hall .

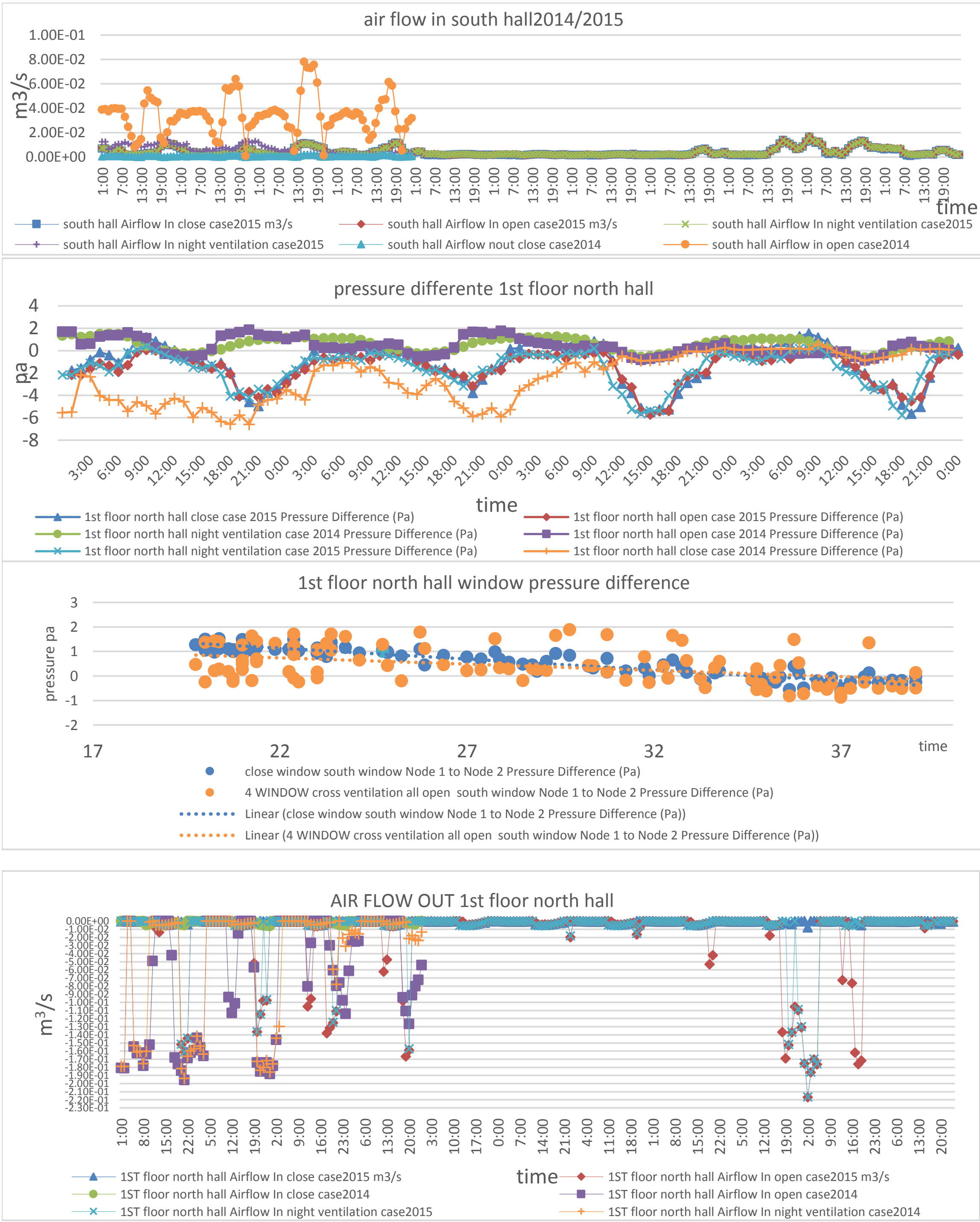


Figure D-44: south hall air flow in, 1st floor north hall difference pressure surface/windows ,air flow out -2014-2015 .

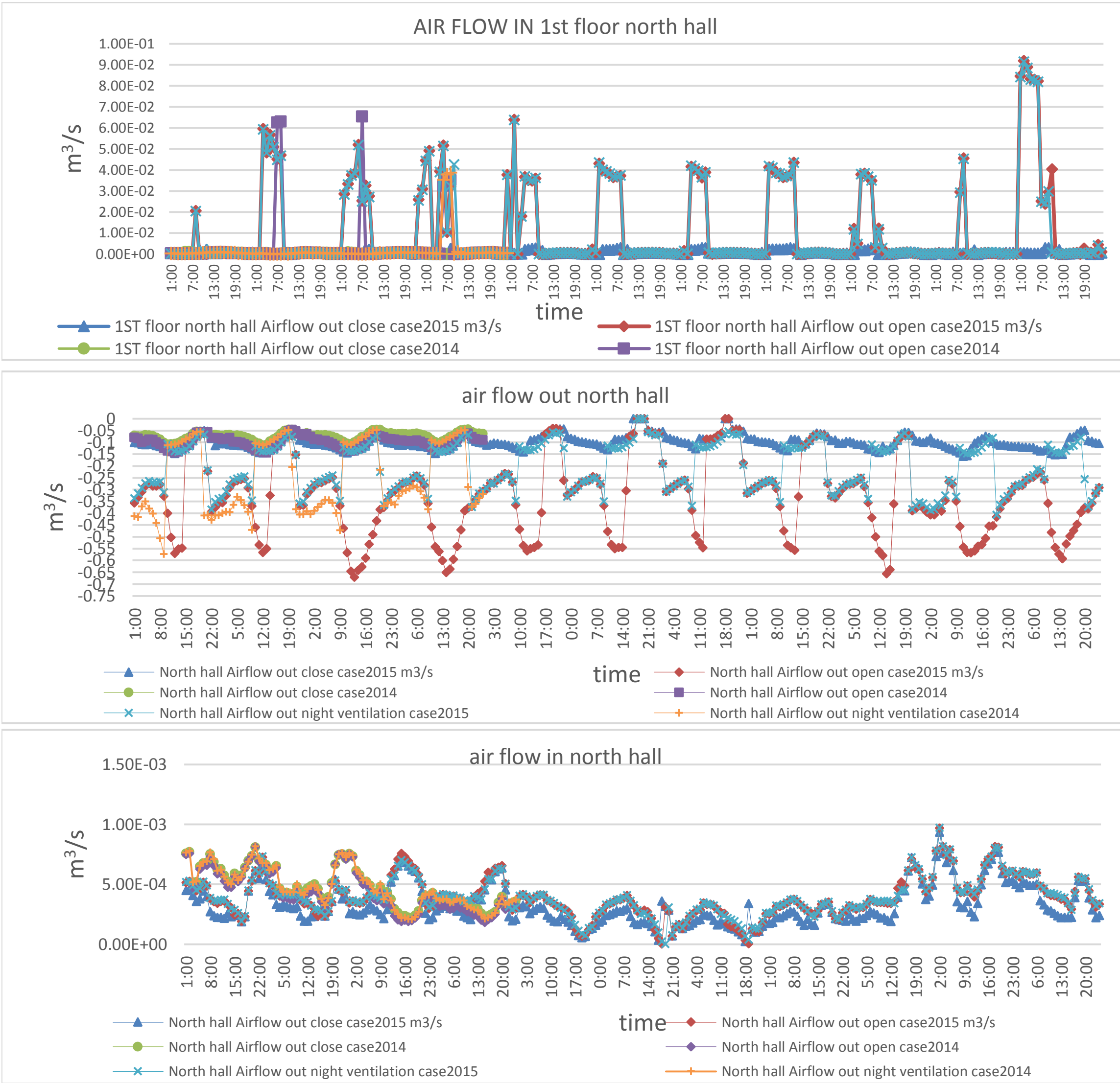


Figure D-45: north hall.1st floor north hall. Air flow in/out .2014-2015.

D.4.2 Thermal comfort

D.4.2.1 *PMV/Survey sensation*

- **South hall: Figure D-46 .**
- **1st floor north hall: Figure D-46**

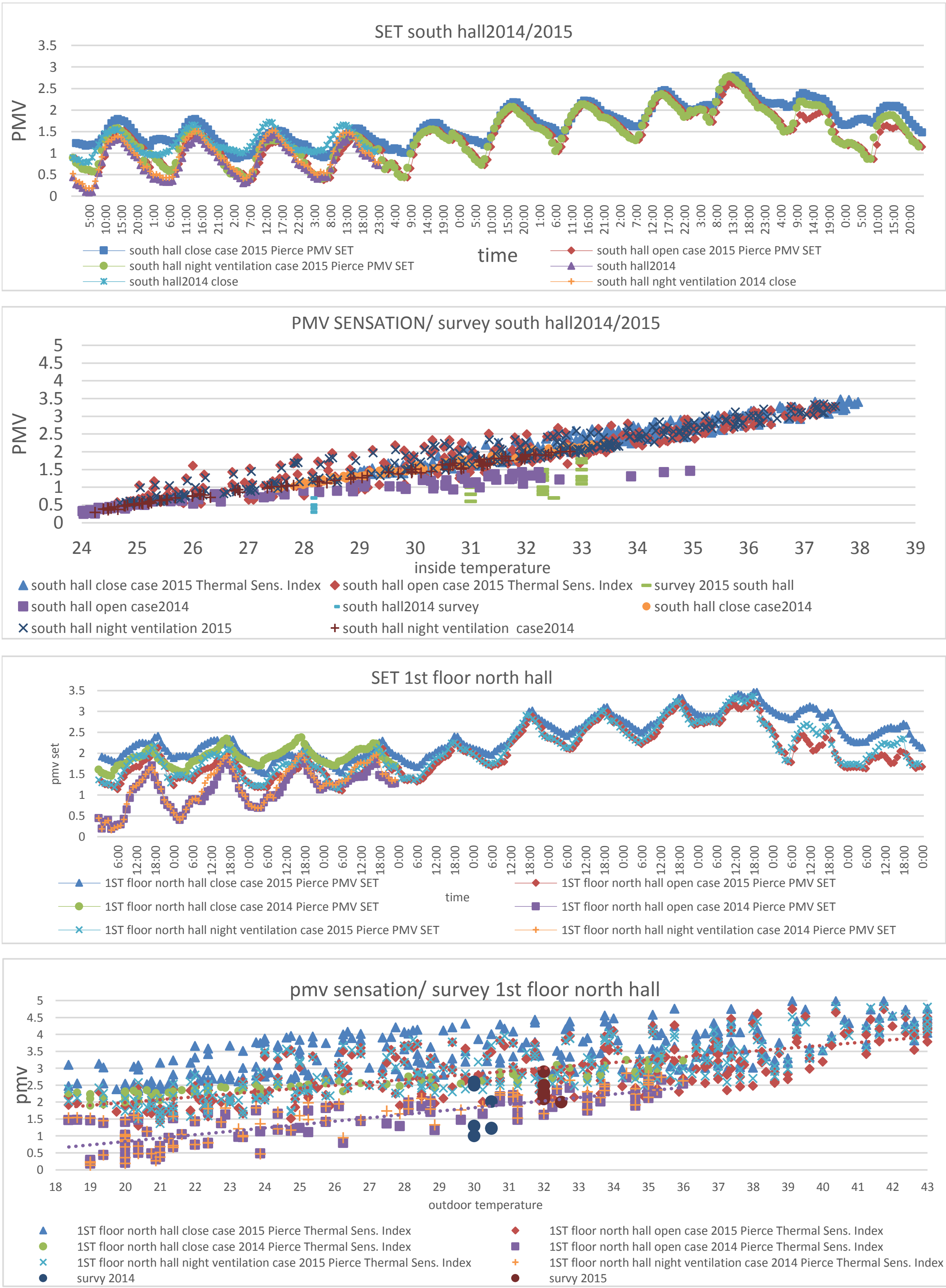


Figure D-46: south hall , 1st floor north hall PMV /SET/survey –open,close ,night ventilation-2014/2015.

APPENDIX E
EVALUATION OF MERGE BETWEEN MEASUREMENT AND MODELING

E.1 Single side stack ventilation:

E.1.1 First investigation:

Air flow and difference pressure, **Figure E-47 - Figure E-48**

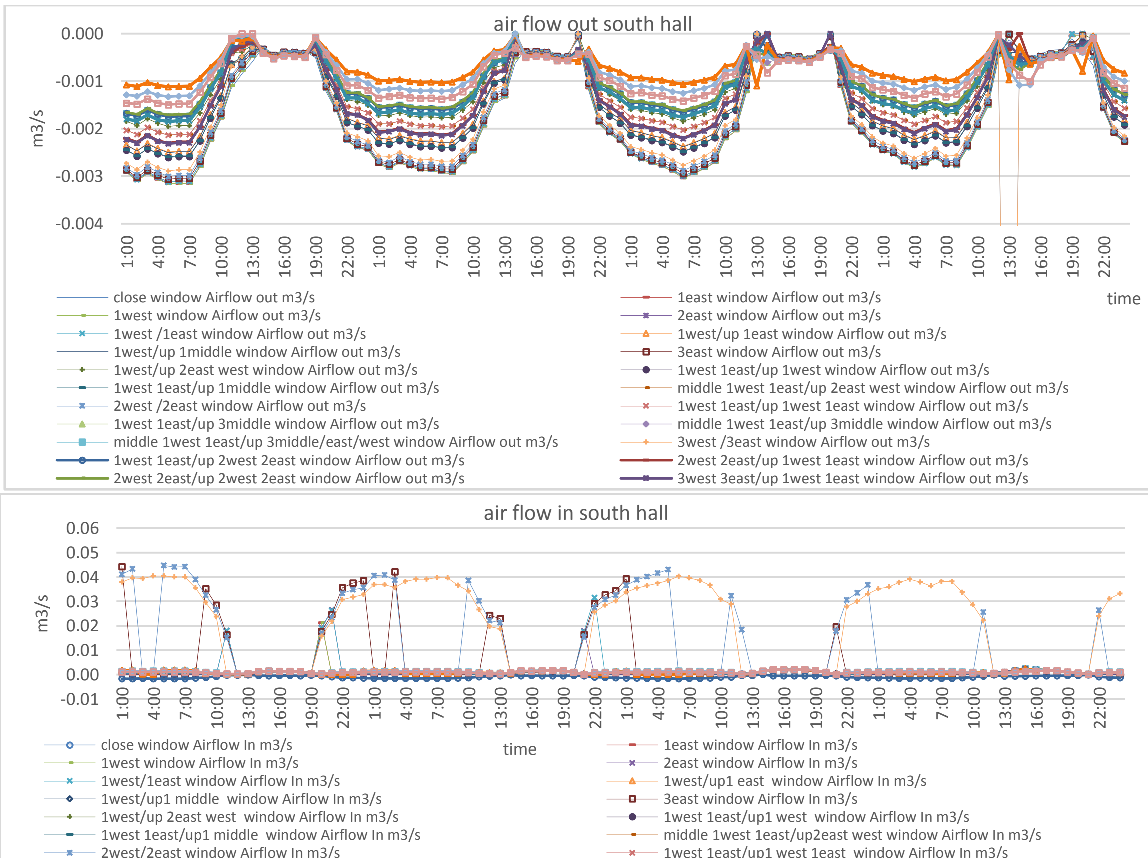


Figure E-47: south hall single side stack ventilation air flow.

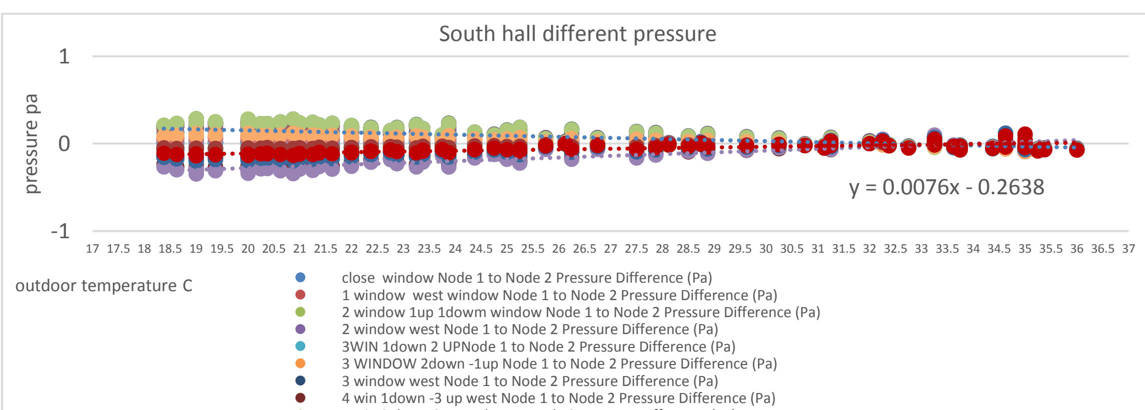
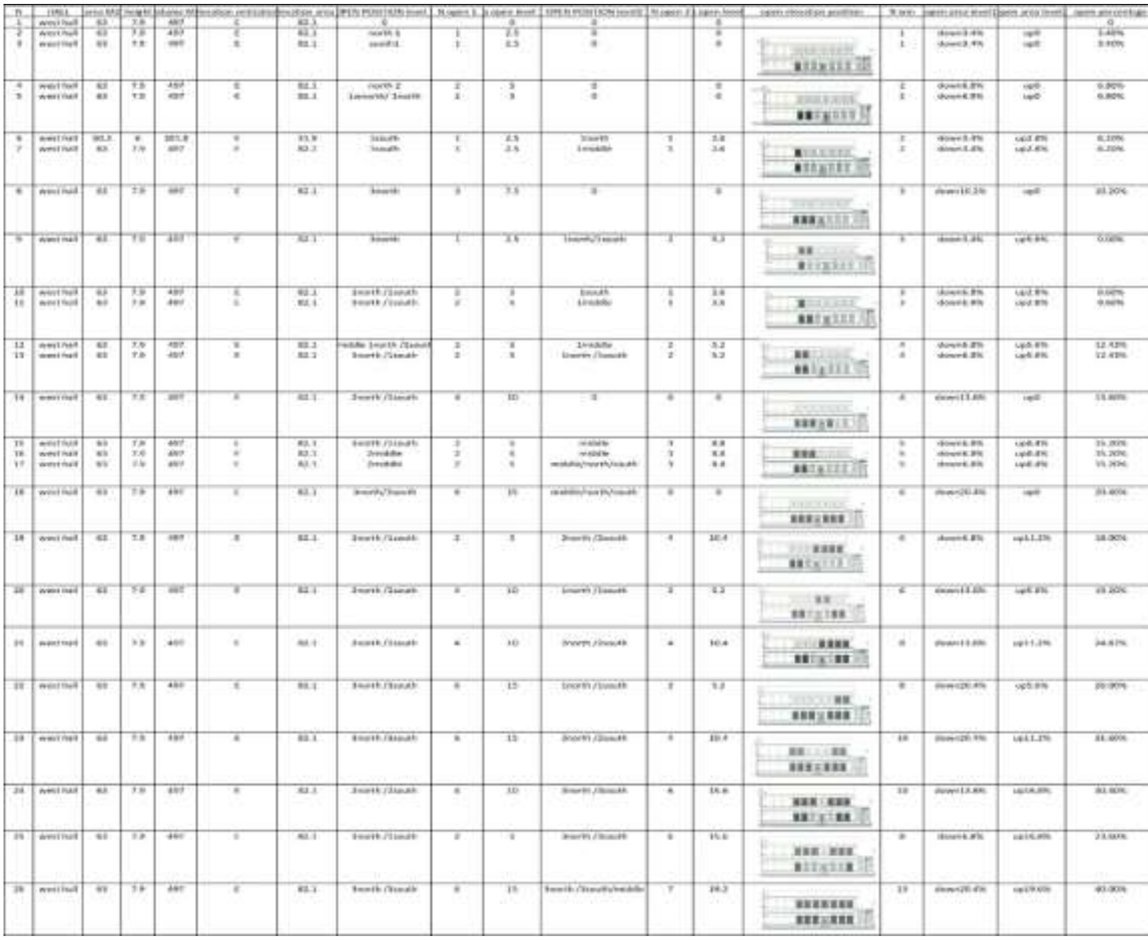


Figure E-48: south hall single side stack ventilation difference pressure.

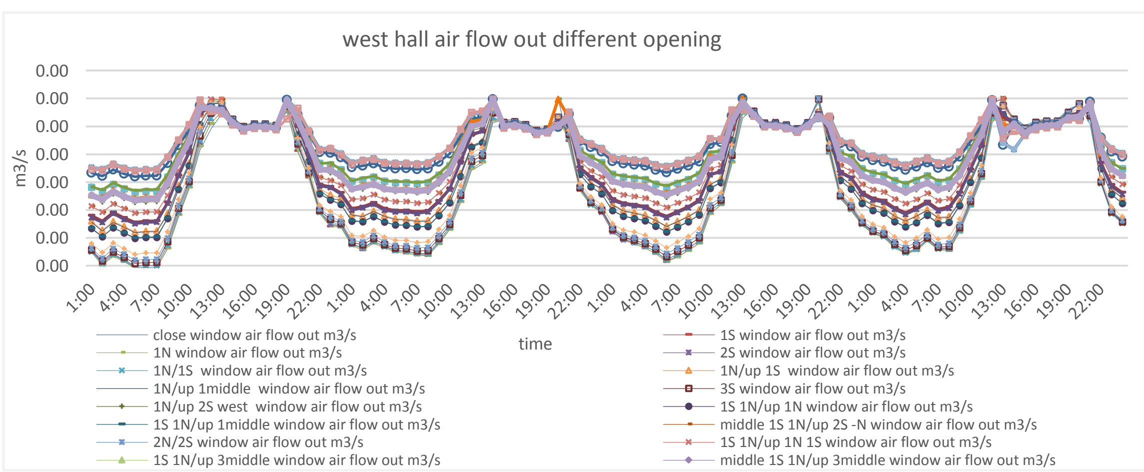
E.1.2 Second investigation

Investigation follow **Table E-14**

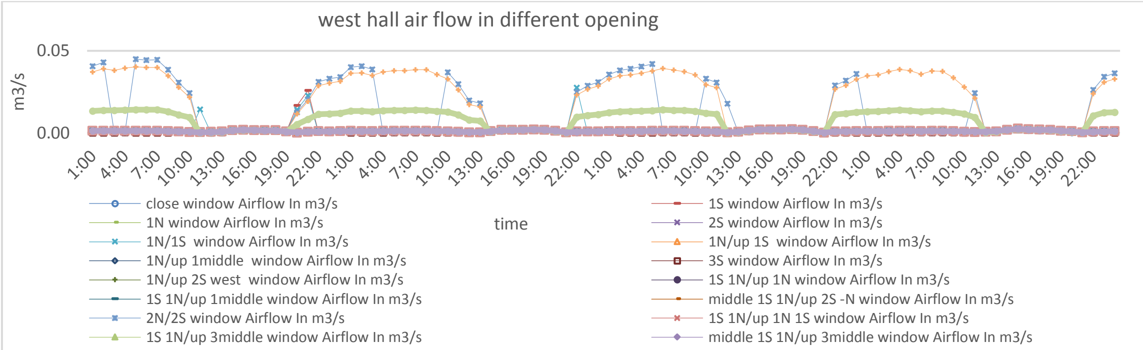
Table E-14: west hall opening investigation schedule.



Air flow : Figure E-49a,b



a



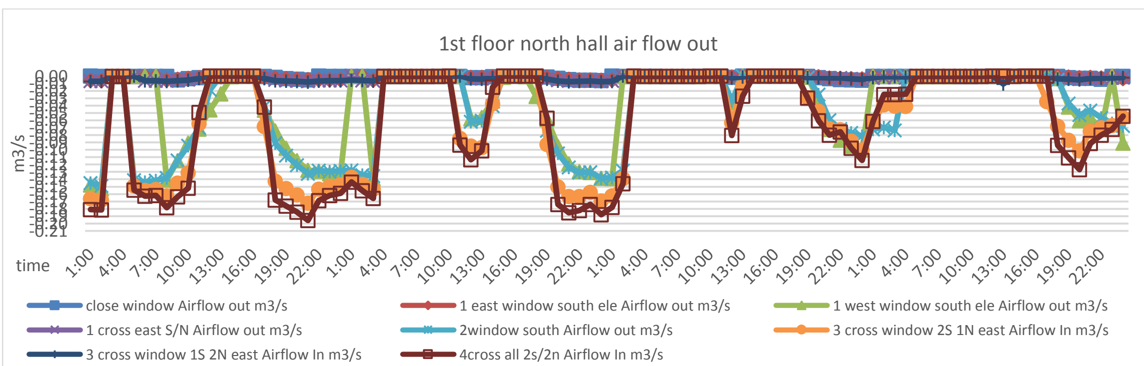
b

Figure E-49:a,b west hall air flow in/out.

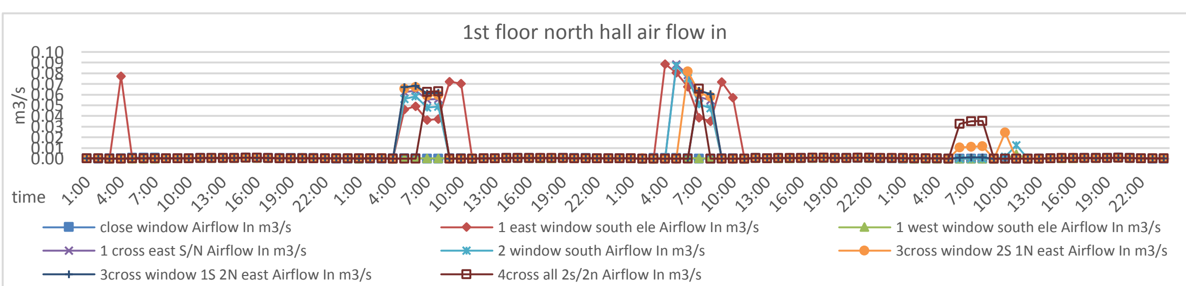
E.2 Cross ventilation

E.2.1 The first investigation ç1st floor north hall

Air flow **Figure E-50**



,a first investigation ,1st floor north hall, air flow

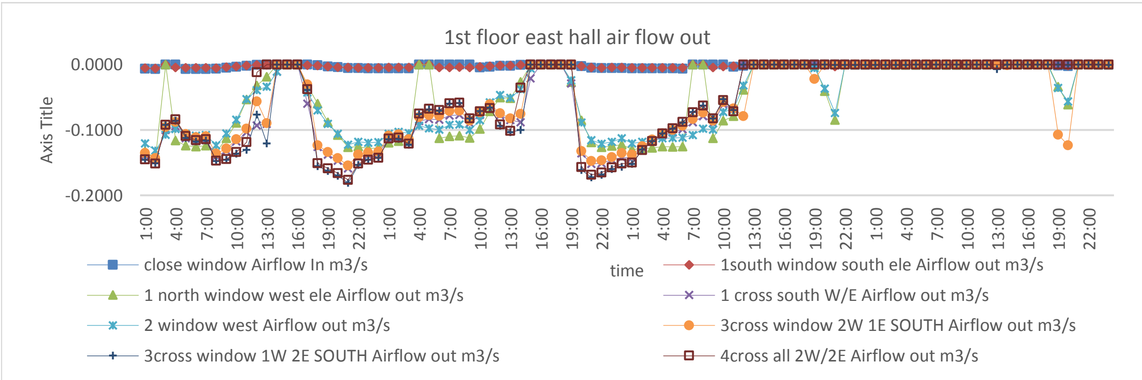


,b first investigation ,1st floor north hall, air flow

Figure E-50: 1st floor north hall.

E.2.2 The second investigationç1st floor east hall

Air flow **Figure E-51**



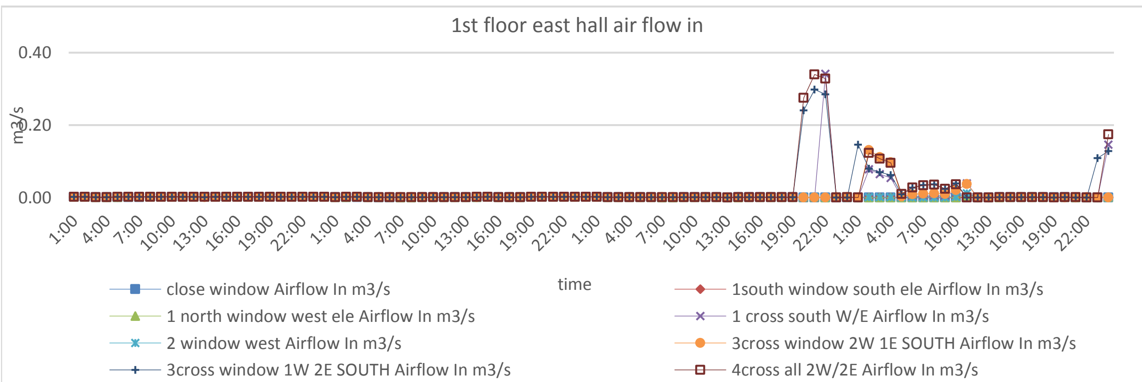


Figure E-51: second investigation, 1st floor east hall, air flow.

E.2.3 Third investigation 1st floor north hall different opening levels

Air flow **Figure E-52**

CFD modeling **Figure E-53**

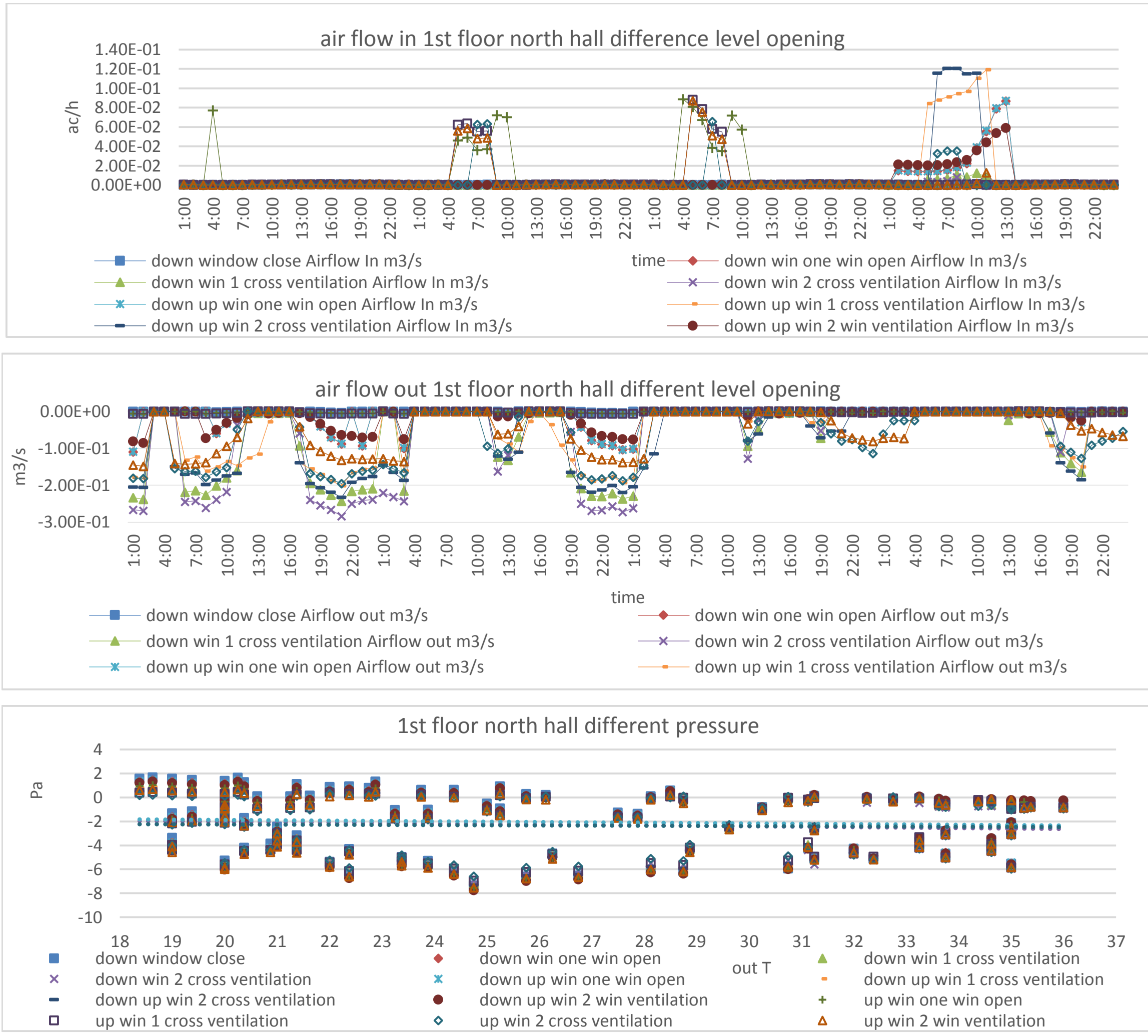


Figure E-52: third investigation, 1st floor north hall, difference opening levels, air flow, different pressure.

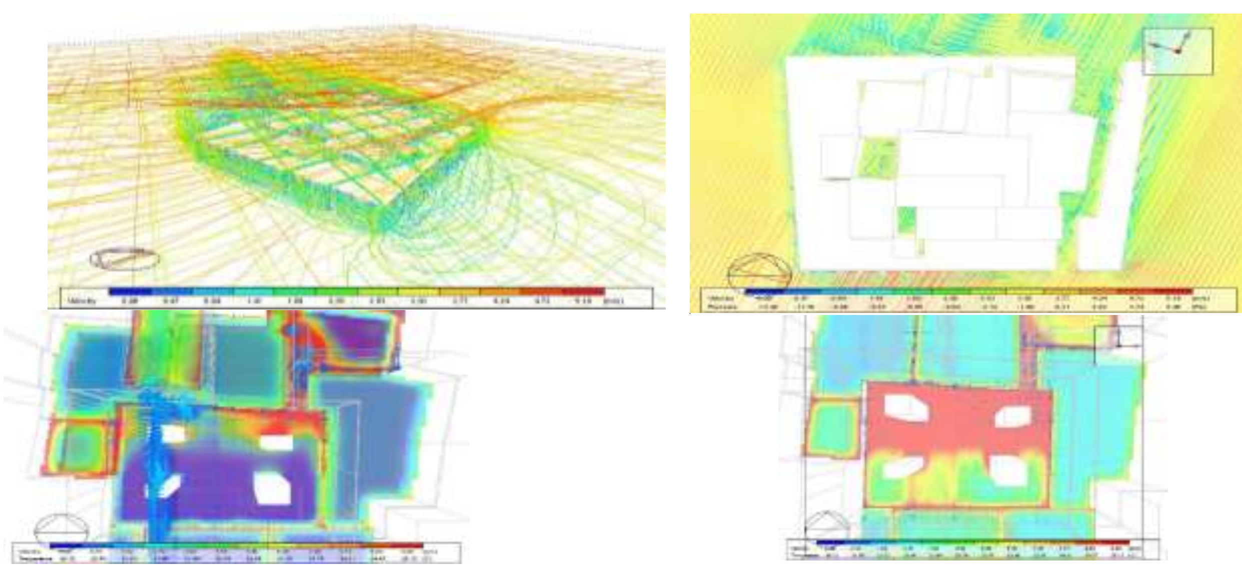


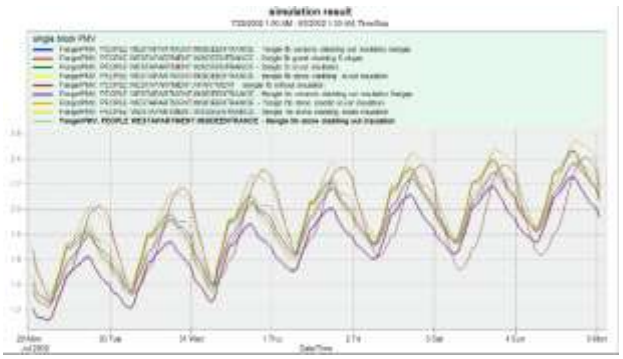
Figure E-53: courtyard and hall CFD modeling air flow.

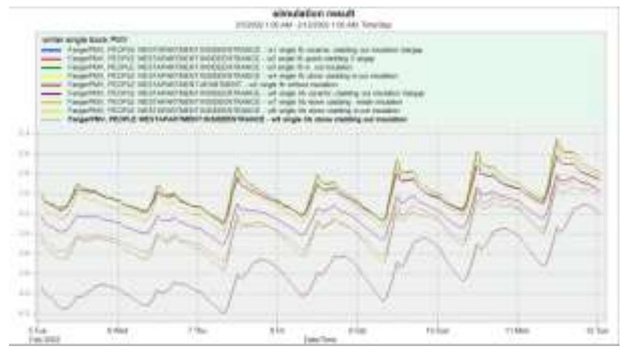
APPENDIX F
OPTIMIZE NEW RESIDENTIAL APARTMENT AT HOT-DRY CLIMATE

F.1 Optimize envelope and materials

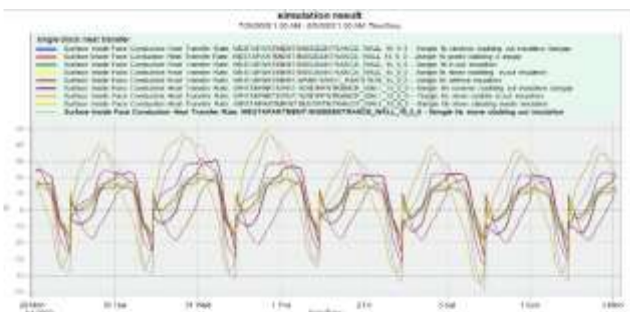
F.1.1.1 *Optimize envelope materials.*

F.1.1.1.1 Block wall: 1- Single block case. **Figure F-54** summer ,a winter ,b





PMV/SET summer and winter period parameters for single block walls.



Heat transfer summer and winter period parameters for single block walls.

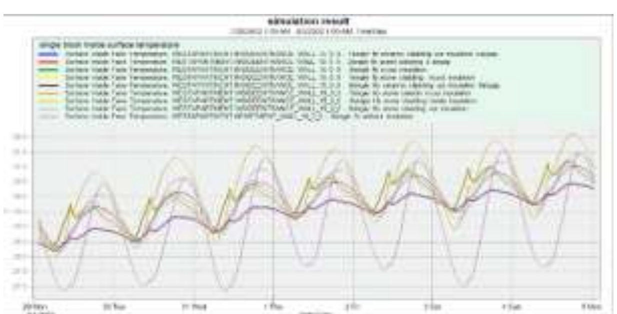
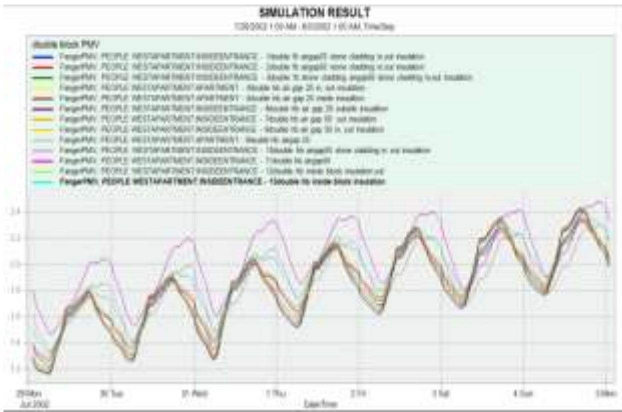
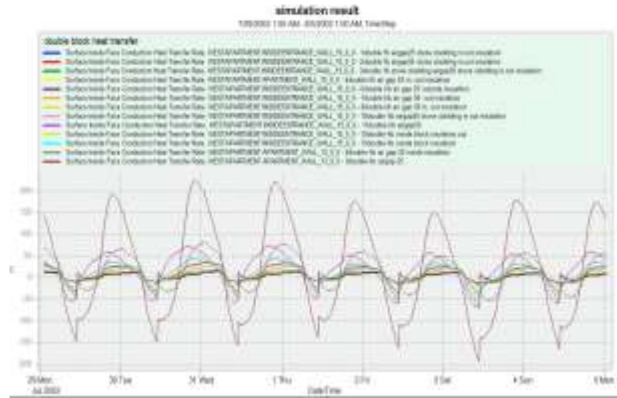


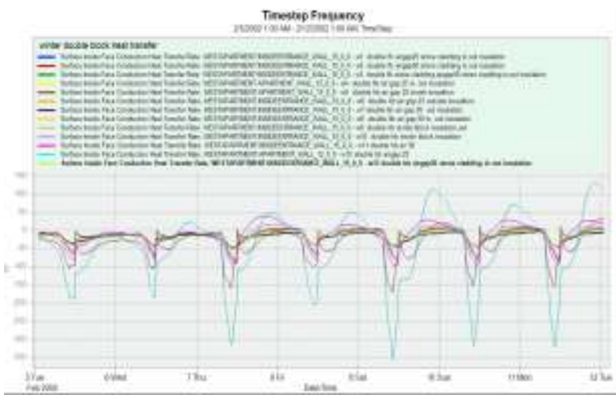
Figure F-54: single block case/ inside face temperature summer and winter period parameters..

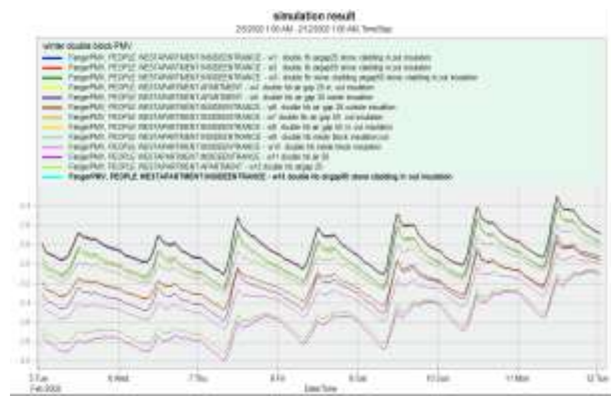
2-Double block **Figure F-55** summer ,a winter ,b.



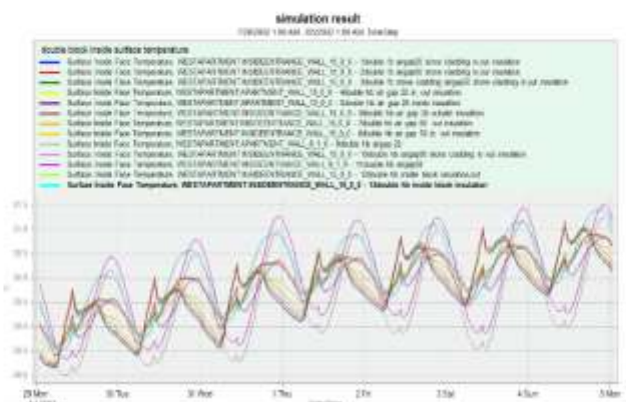


PMV /SETsummer and winter period parameters for double block walls.





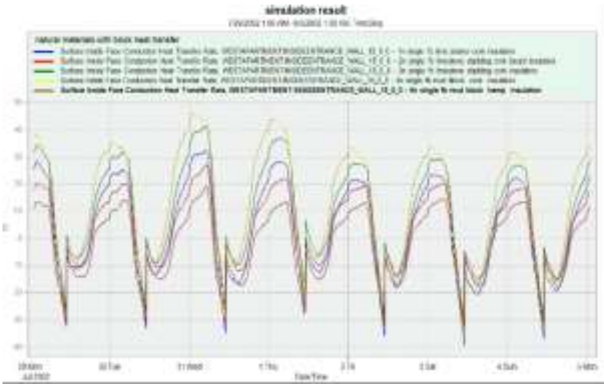
Heat transfer summer and winter period parameters for double block walls.

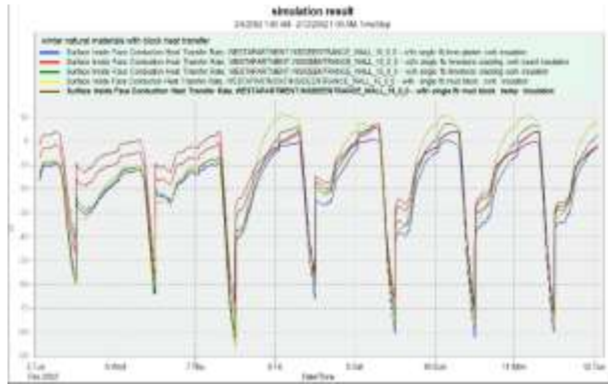


Inside face temperature summer and winter period parameters for double block walls.

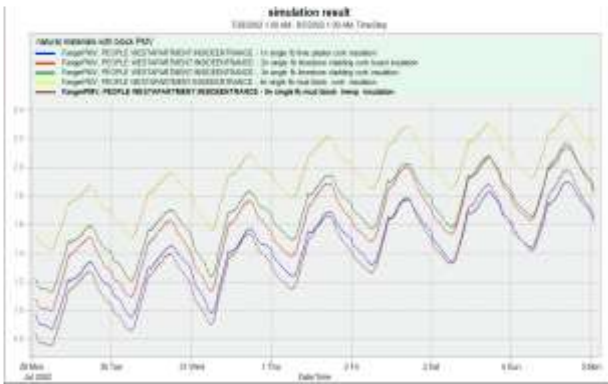
Figure F-55: double block investigation cases, , a. summer ,b.winter.

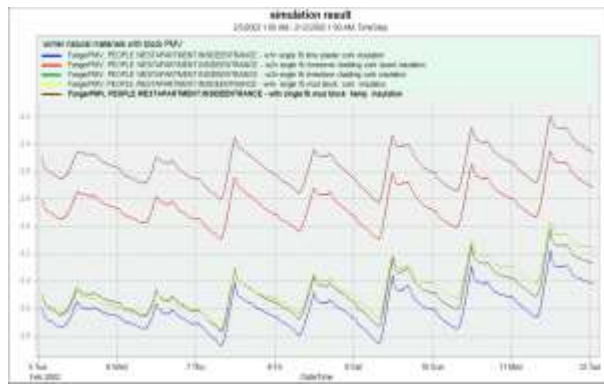
3-Natural materials : **Figure F-56** summer ,a winter ,b.



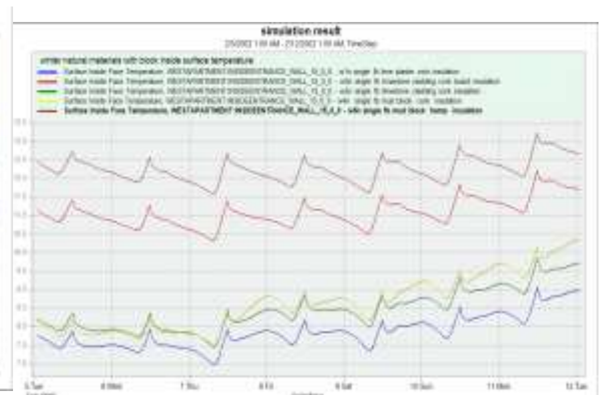


PMV/SET summer and winter period parameters for natural materials with block walls.





Heat transfer summer and winter period parameters for natural materials with block walls.

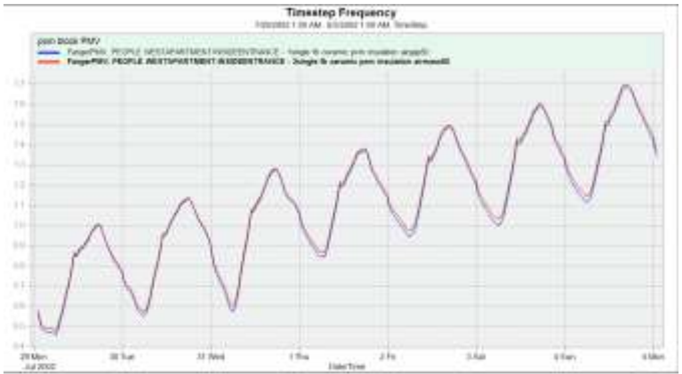


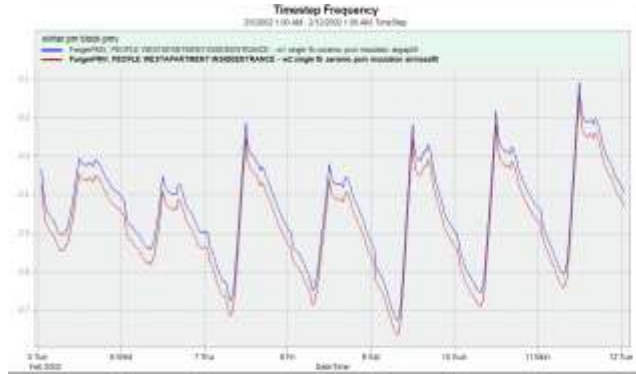
Inside face temperature summer and winter period parameters for natural materials with block walls.

Figure F-56: natural materials cases , a. summer ,b.winte

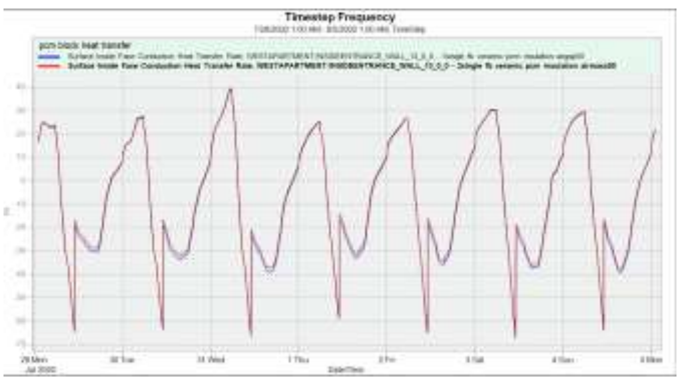
4-PCM materials

Figure F-57 summer ,a winter ,b.

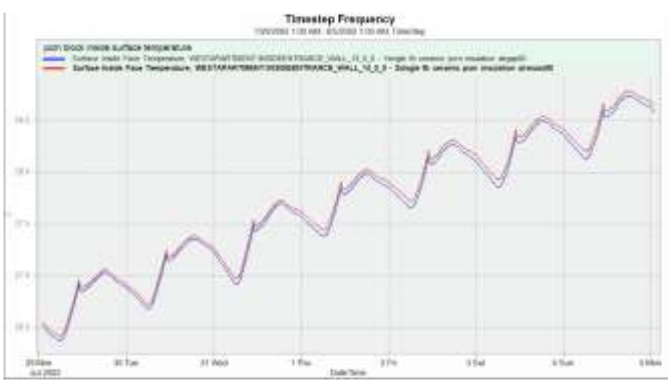


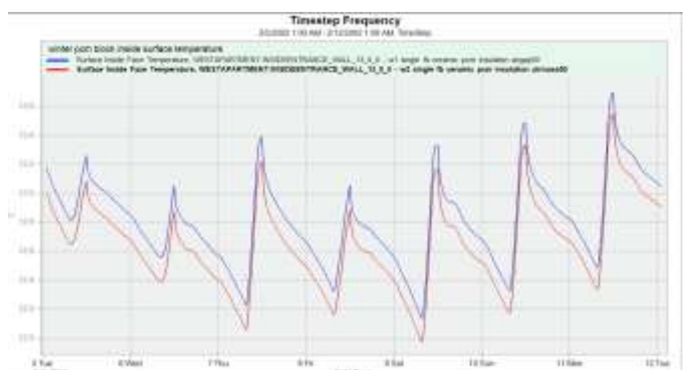


PMV/SET summer and winter period parameters for PCM materials with block walls.



Heat transfer summer and winter period parameters for PCM with block walls.aterials



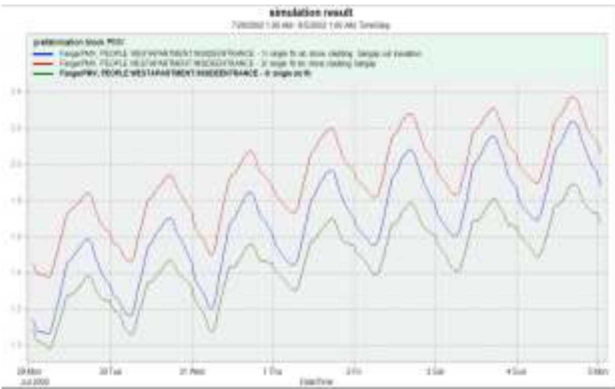


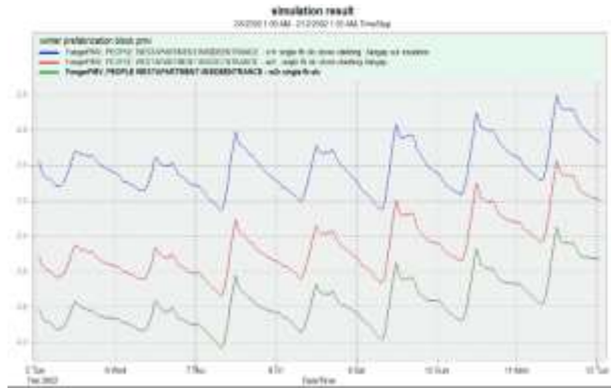
Inside face temperature summer and winter period parameters for PCM materials with block walls.

Figure F-57: PCM materials cases , a. summer ,b. winter.

5-Prefabricate wall

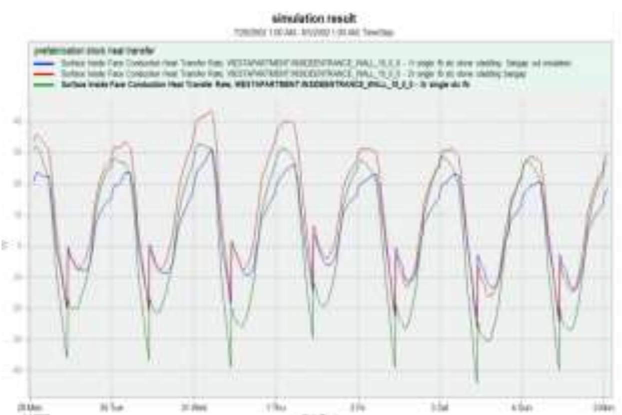
Figure F-58 summer ,a winter ,b.

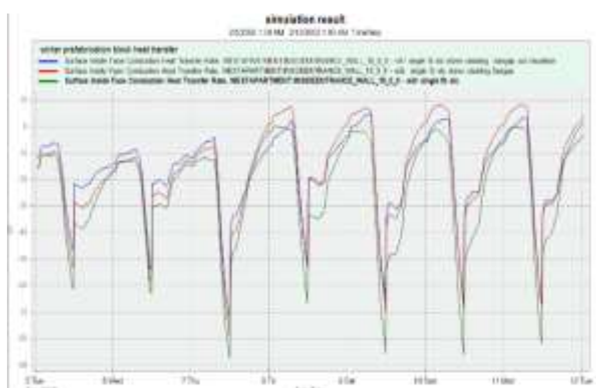




PMV/SET summer and winter period parameters for prefabrication walls.

heat transfer summer and winter period parameters for prefabrication walls.





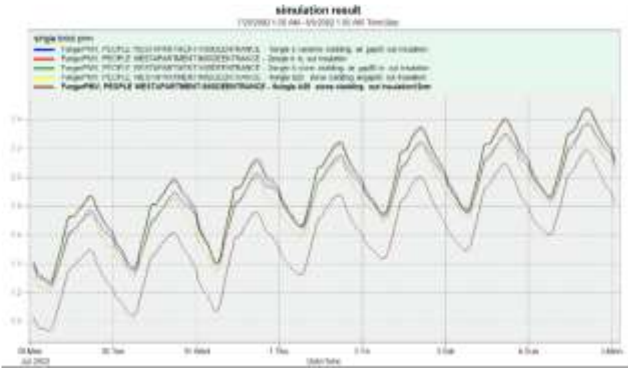
inside face temperature summer and winter period parameters for prefabrication walls.

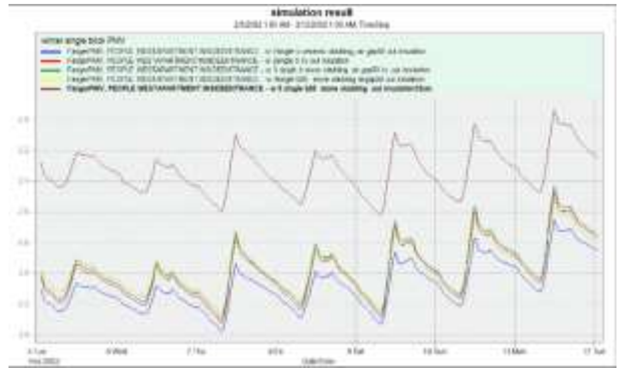
Figure F-58: prefabricate materials cases , a. summer ,b.winter .

F.1.1.1.2 Brick wall

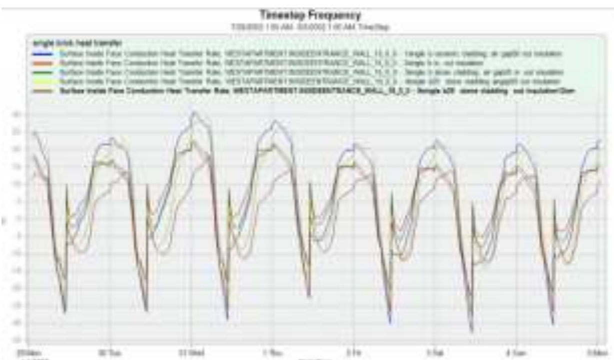
1- Single wall.

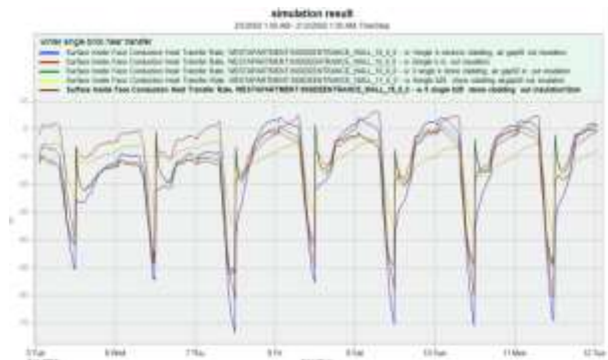
Figure F-59 summer ,a winter ,b.



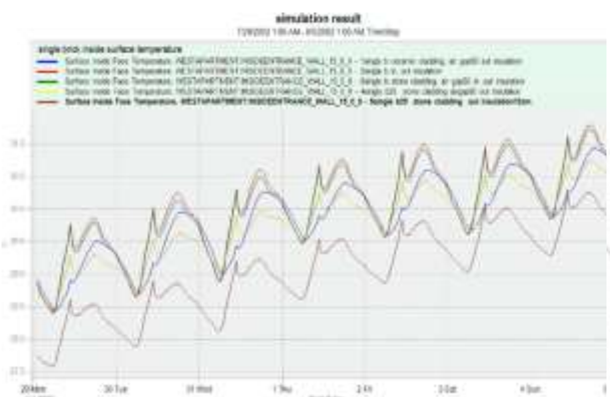


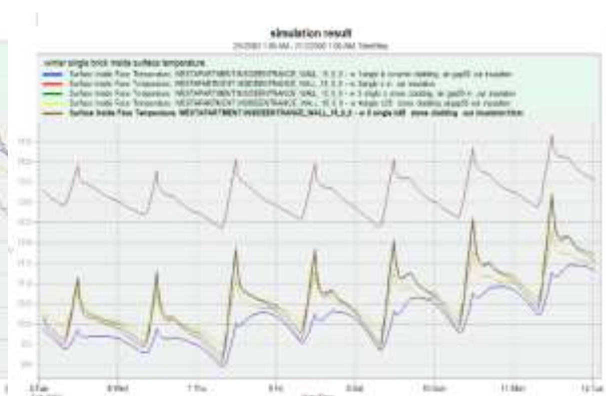
PMV/SET summer and winter period parameters for single brick walls.





heat transfer summer and winter period parameters for single brick walls.



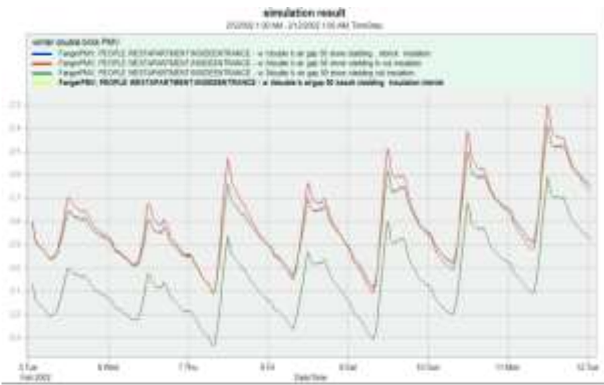


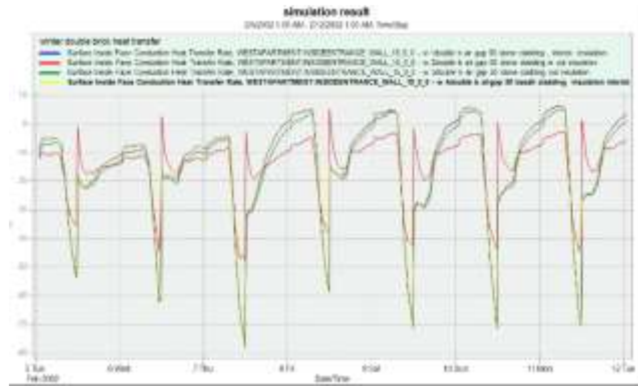
inside face temperature summer and winter period parameters for single brick walls.

Figure F-59: single brick cases , a. summer ,b.winter.

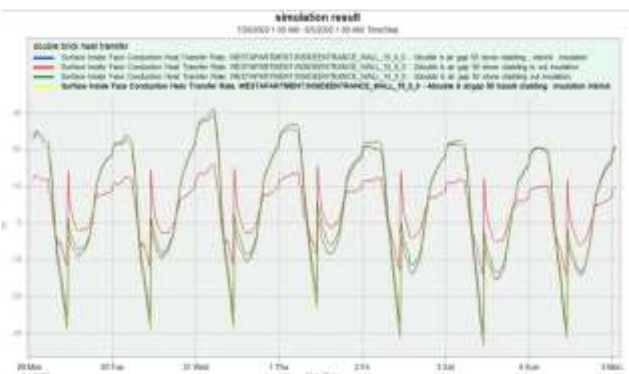
2-double wall.

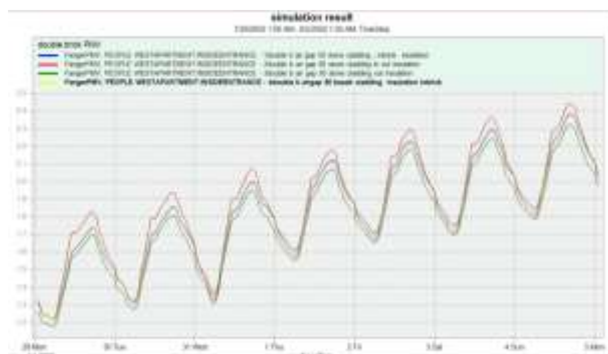
Figure F-60 summer ,a winter ,b.





PMV/SET summer and winter period parameters for double brick walls.





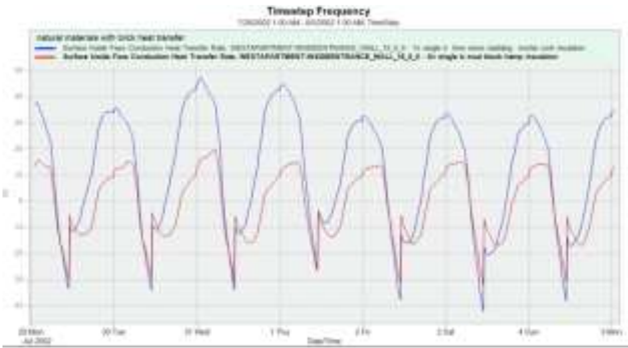
Heat transfer summer and winter period parameters for double brick walls.

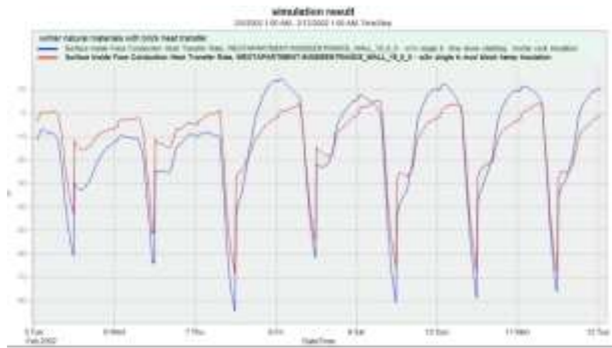
Inside face temperature summer and winter period parameters for double brick walls.

Figure F-60: double brick cases , a. summer ,b.winter .

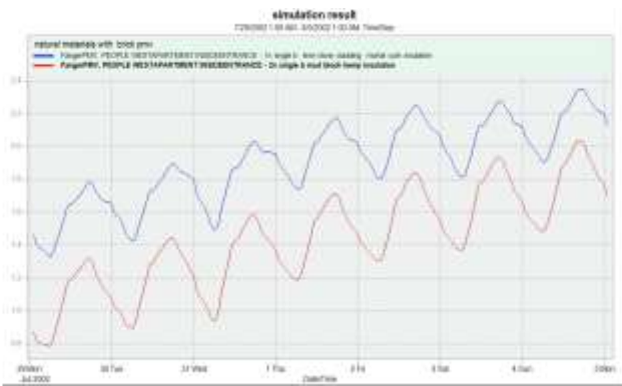
2- natural materials

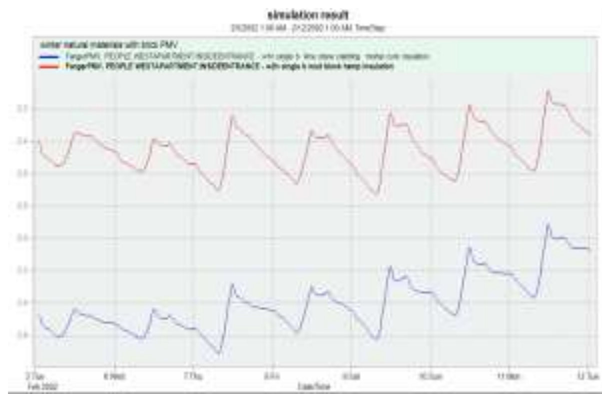
Figure F-60,a ,b all result summer ,a winter ,b.





PMV/SET summer and winter period parameters for natural materials with brick walls.

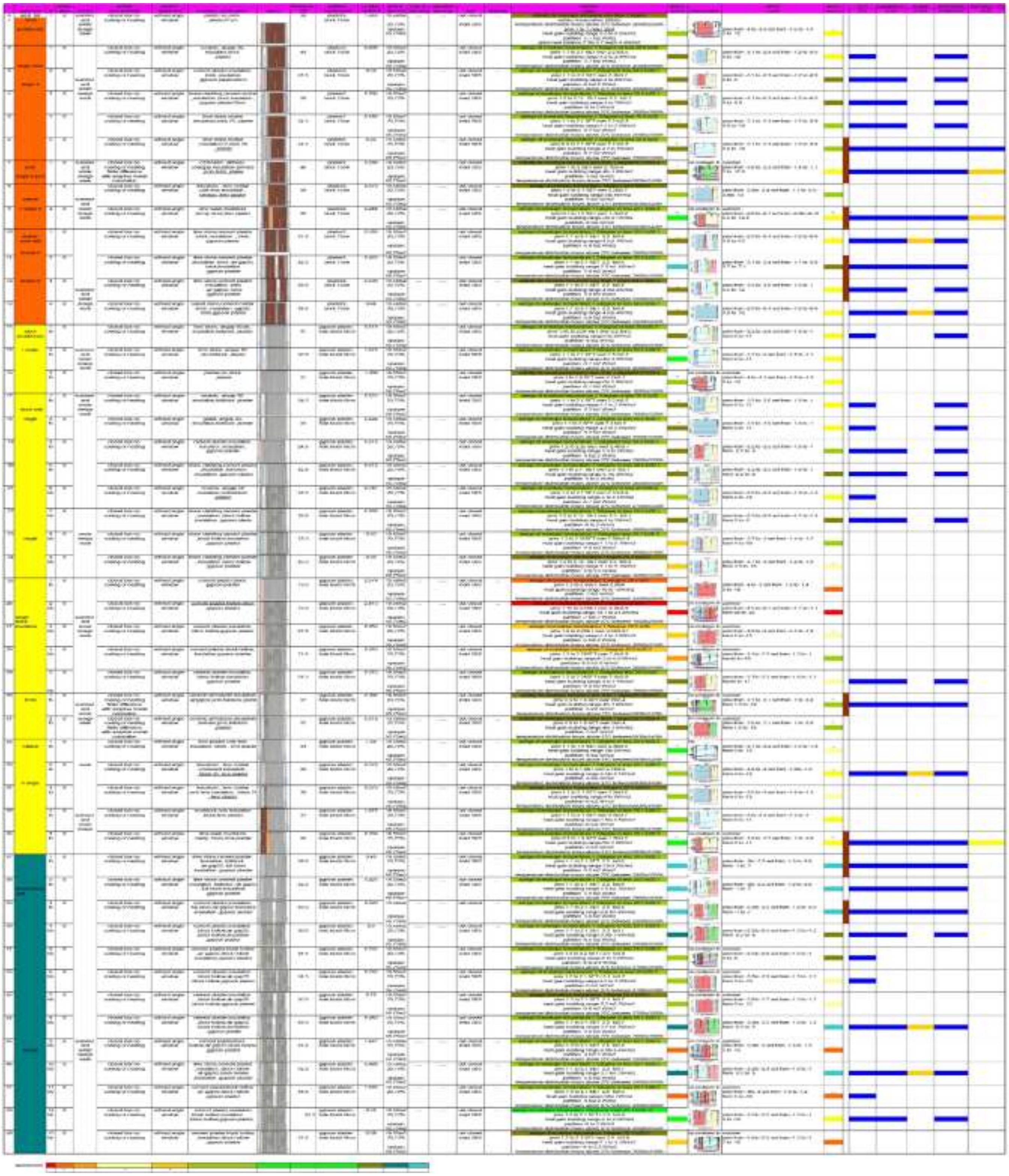




Heat transfer summer and winter period parameters for natural materials with brick walls.

Inside face temperature summer and winter period parameters for natural materials with brick walls.

,a natural materials brick cases , a. summer ,b.winter



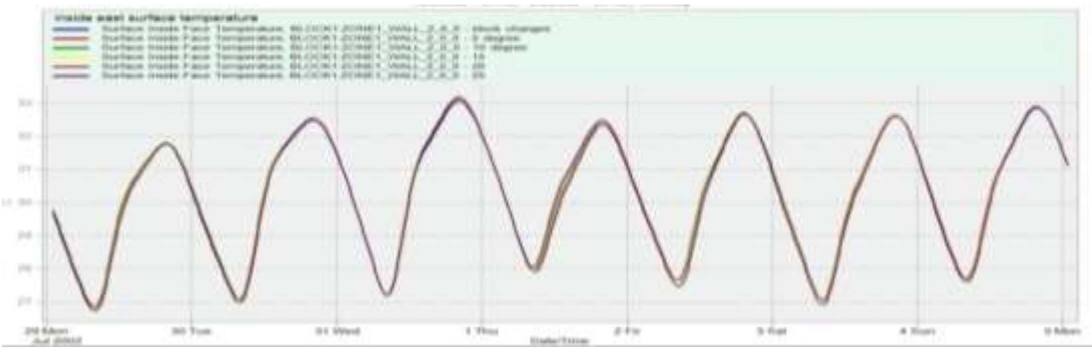
,b materials investigation assessment

Figure F-61:a, natural materials , b . materials final assessment.

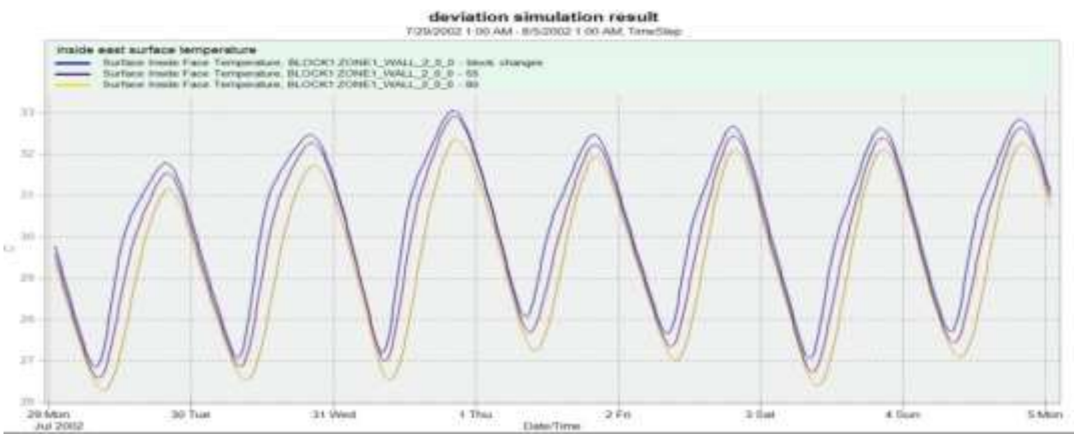
F.2 Optimize envelop and function orientation

F.2.1.1 *Optimize façade deviation*

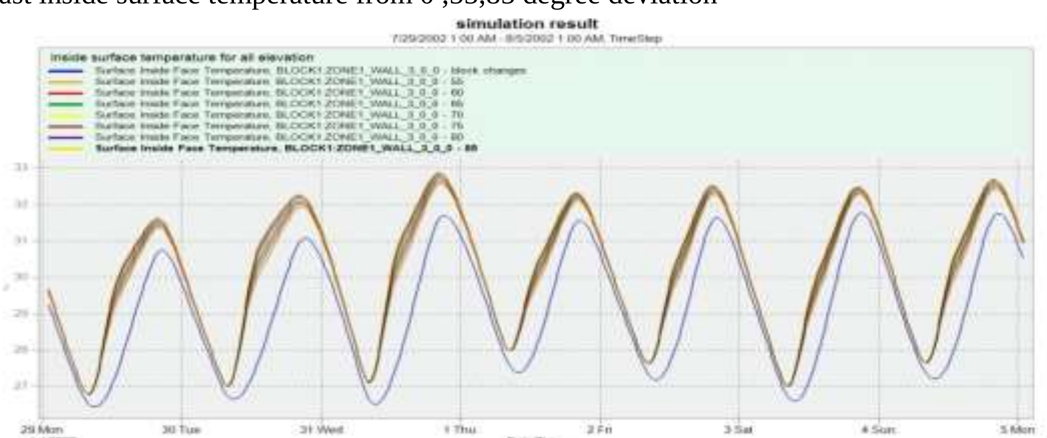
East façade **Figure F-62**



east inside surface temperature from 0 to 25 degree deviation



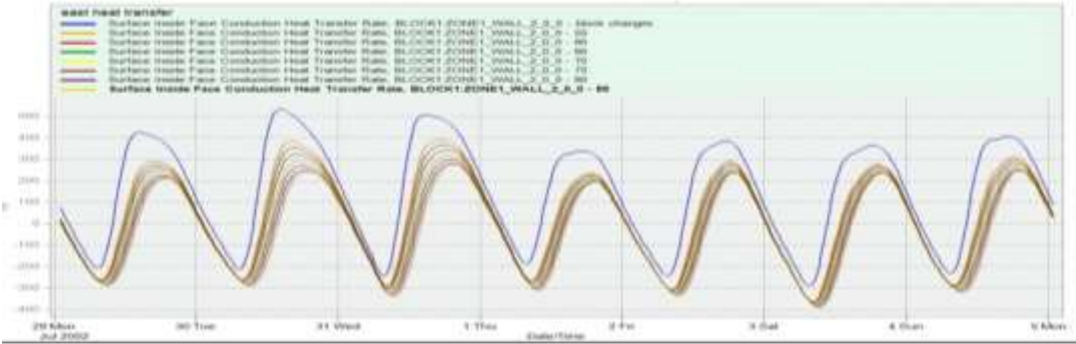
east inside surface temperature from 0 ,55,85 degree deviation



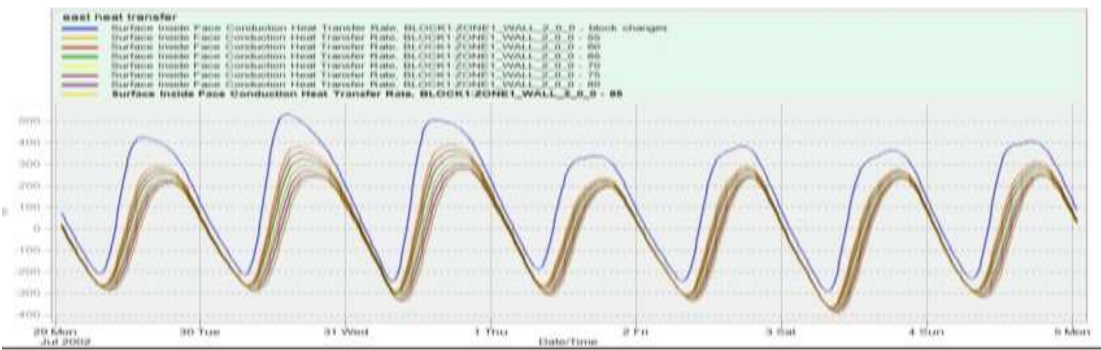
east heat transfer from 0 ,55,85 degree deviation.

Figure F-62: east façade deviation analysis, heat transfer and inside surface temperature.

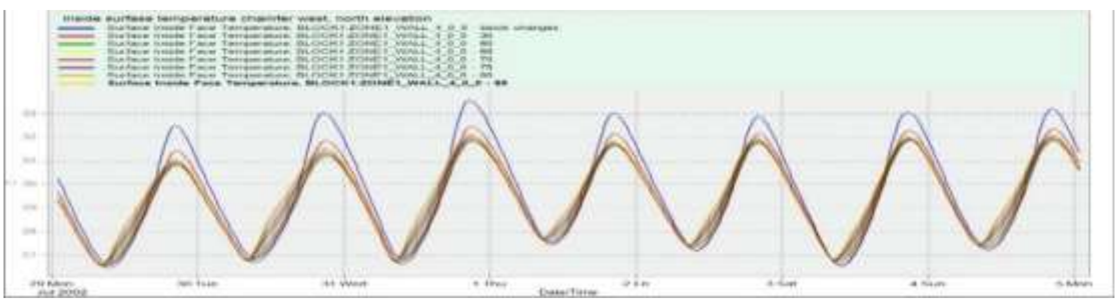
North façade and west, north(chamfer) façade **Figure F-63**



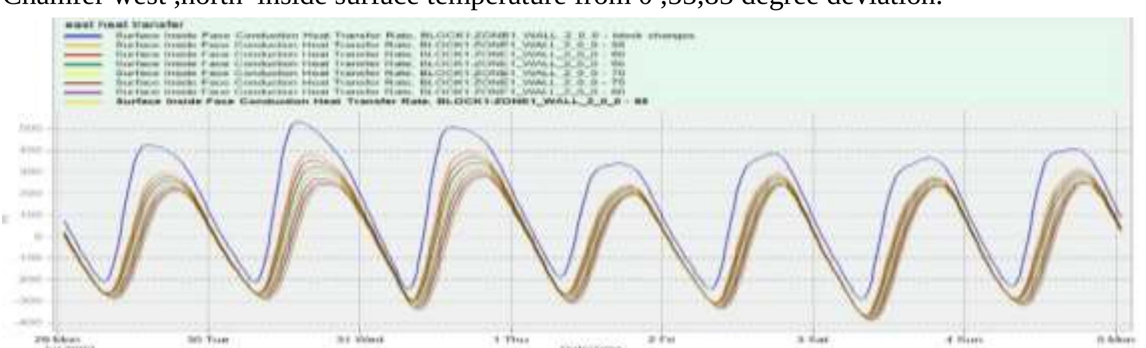
North inside surface temperature from 0 ,55,85 degree deviation.



North heat transfer from 0 ,55,85 degree deviation



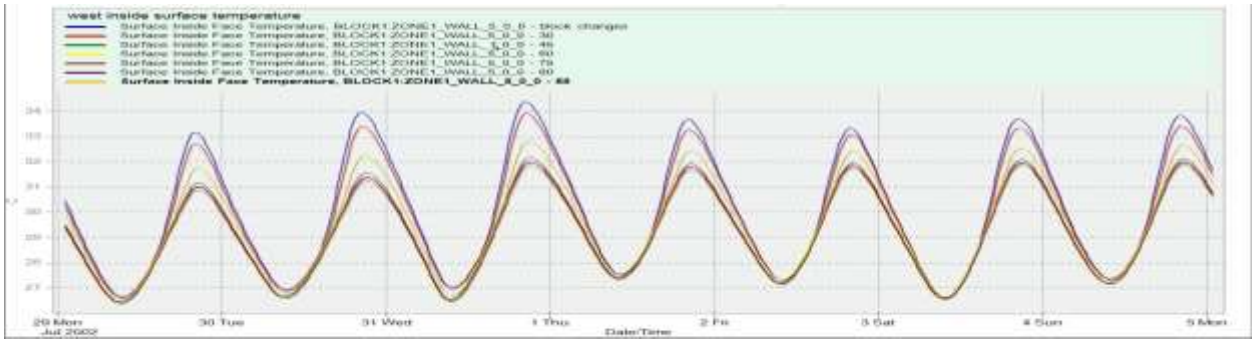
Chamfer west ,north inside surface temperature from 0 ,55,85 degree deviation.



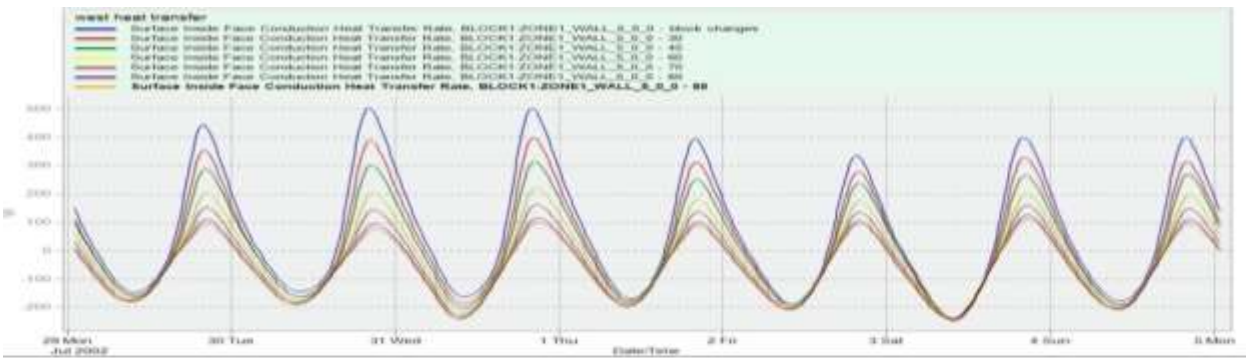
chamfer west ,north heat transfer from 0 ,55,85 degree deviation

Figure F-63: north and west, north façade deviation analysis, heat transfer and inside surface temperature.

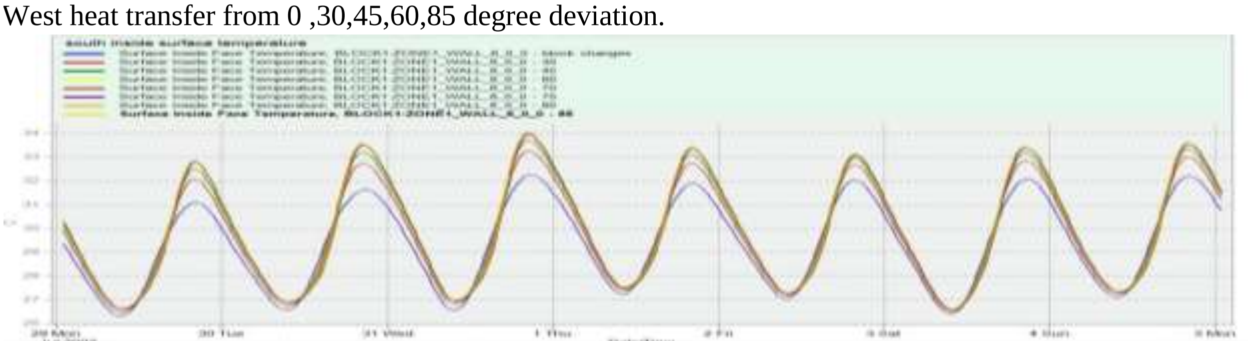
West façade and south façade **Figure F-64**



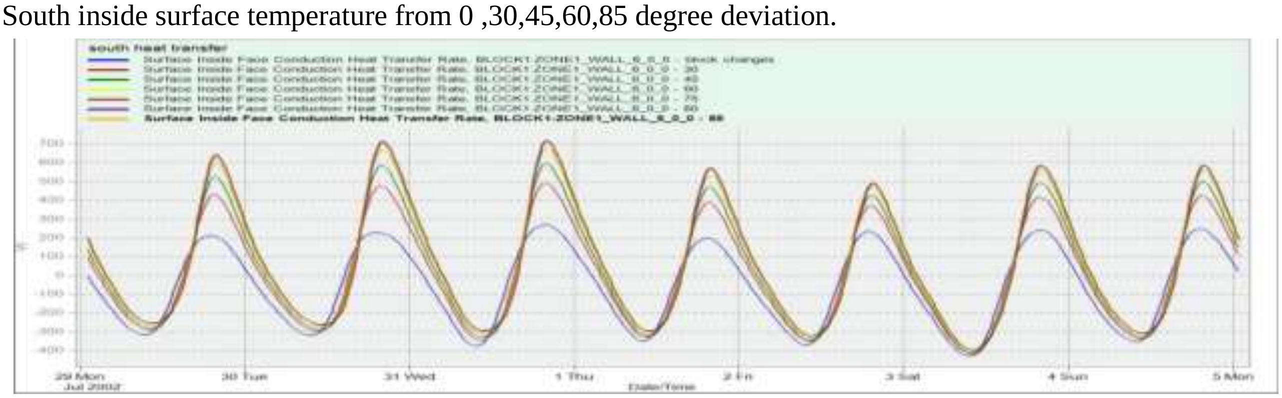
West inside surface temperature from 0 ,30,45,60,85 degree deviation.



West heat transfer from 0 ,30,45,60,85 degree deviation.



South inside surface temperature from 0 ,30,45,60,85 degree deviation.



South heat transfer from 0 ,30,45,60,85 degree deviation.

Figure F-64: west and south façade deviation analysis, heat transfer and inside surface temperature.

PMV/SET for all space deviation **Figure F-65**

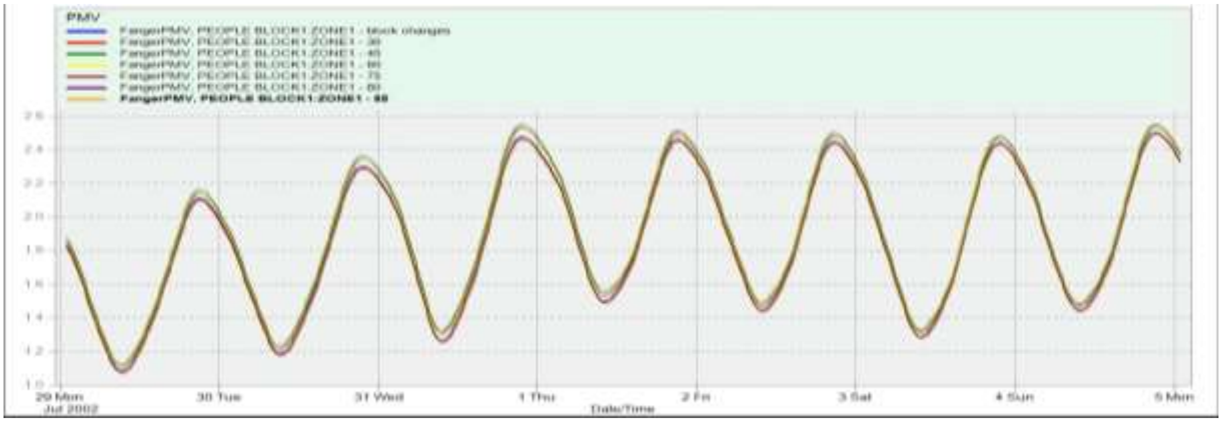


Figure F-65: optimize façade deviation PMV.

F.2.1.2 *Optimize function direction*

PMV/SET scale for summer and winter period **Figure F-66**

Air temperature and operative temperature for summer and winter period **Figure F-67**,a,b.

solar transmittance **Figure F-68** .

.a, summer b.winter

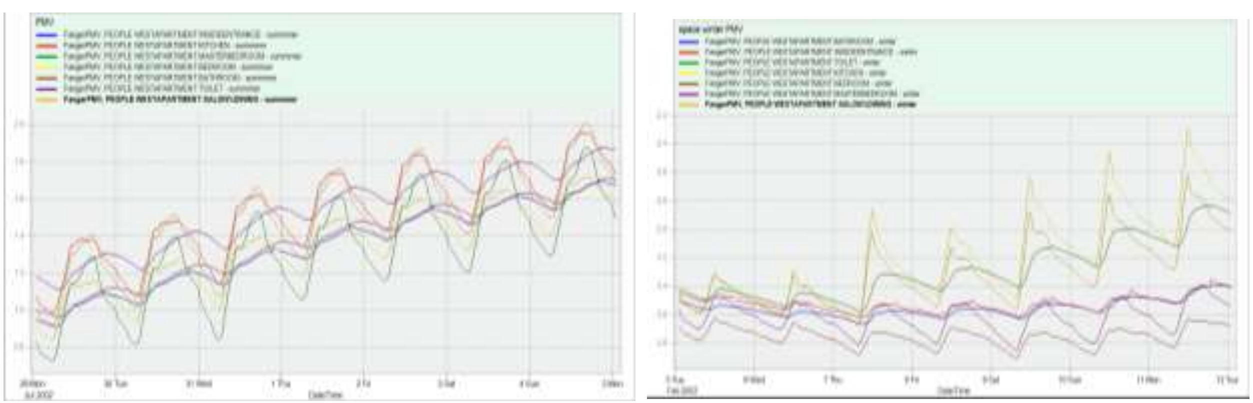
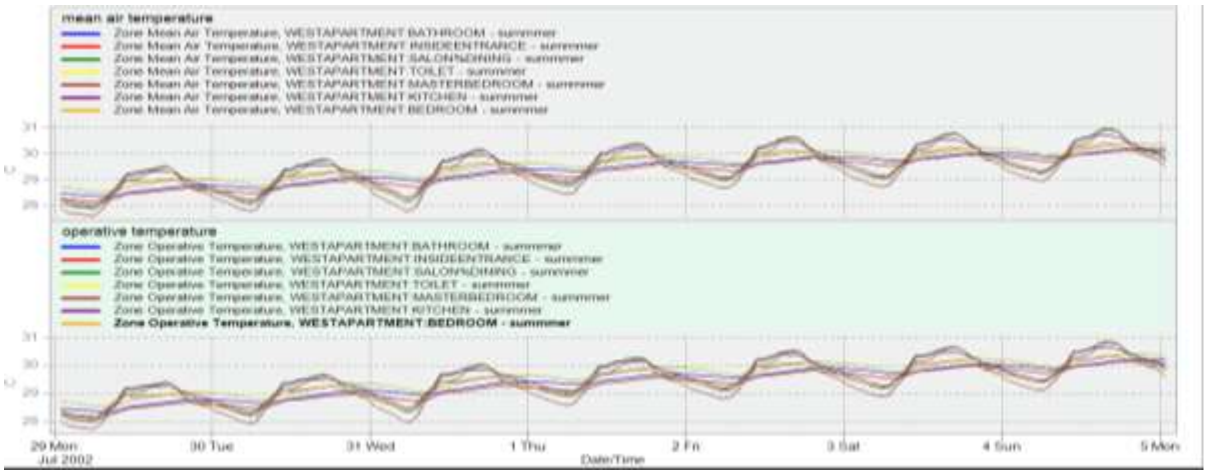
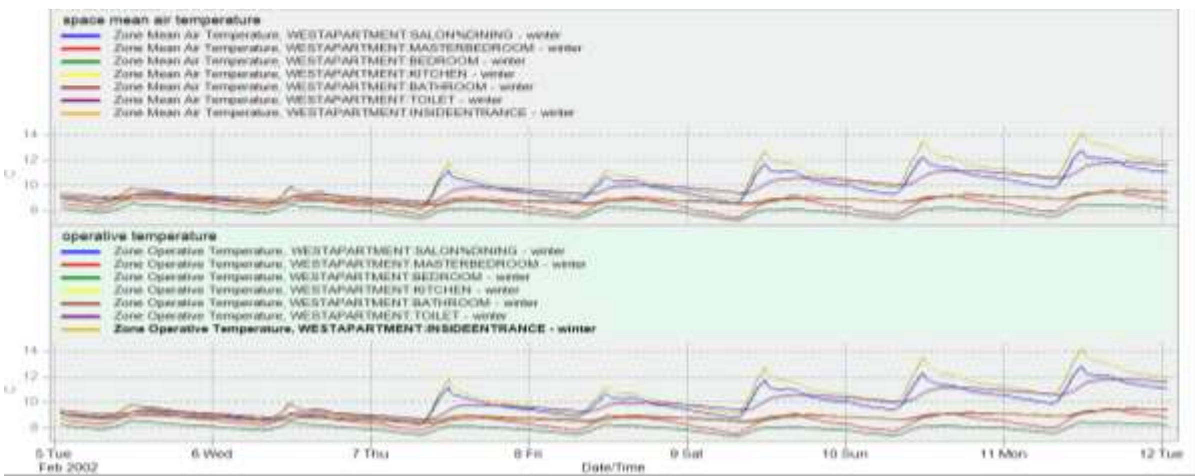


Figure F-66: PMV/SET scale space function for summer and winter period .



.a ,space function summer period



,b, space mean air and operative temperature .

Figure F-67: a,b. space function for summer and winter period . mean air and operative temperature .

.a, summer b. winter

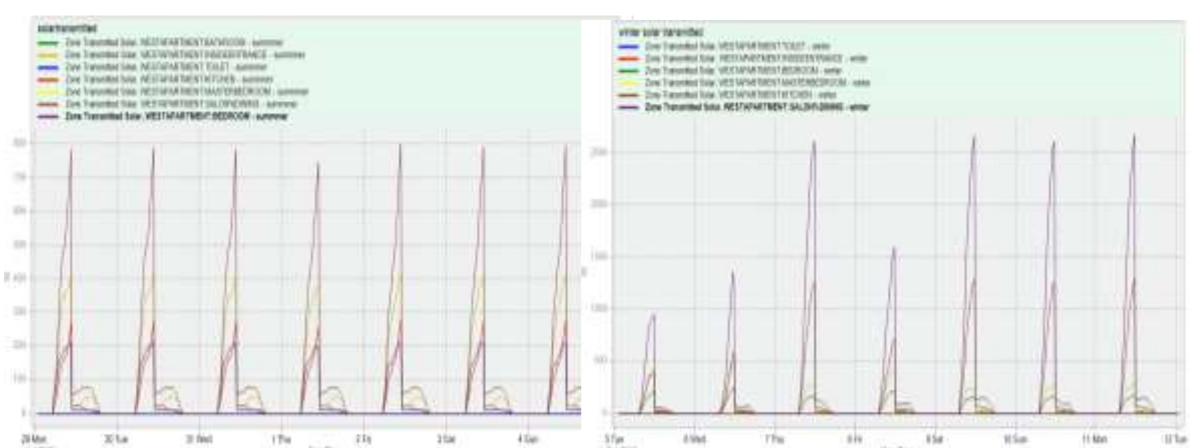
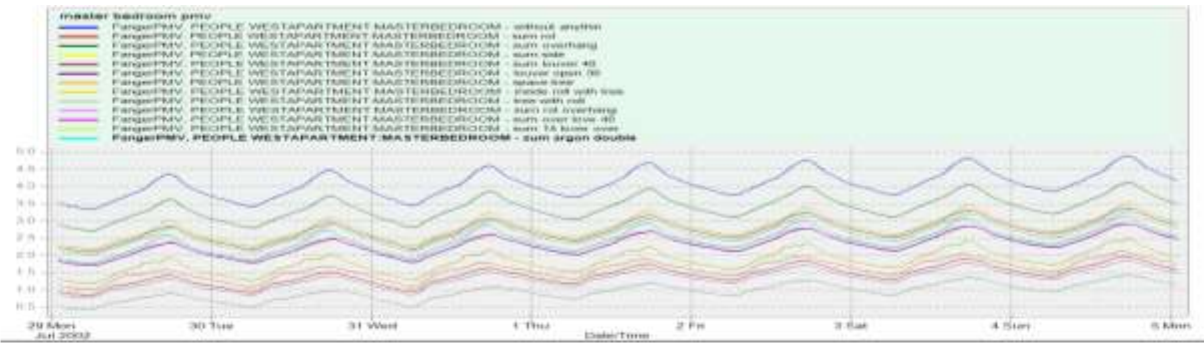


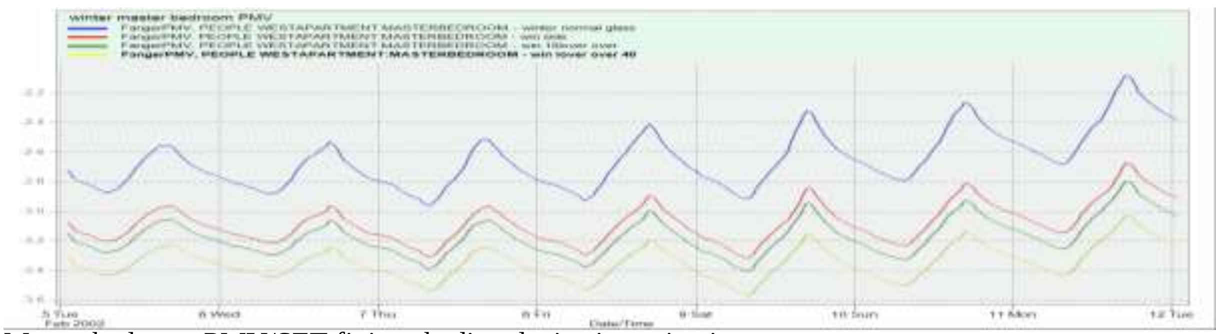
Figure F-68: a,b.space function for summer and winter period solar transmitted

F.2.1.3 *<u>Optimize shading device and windows</u>*

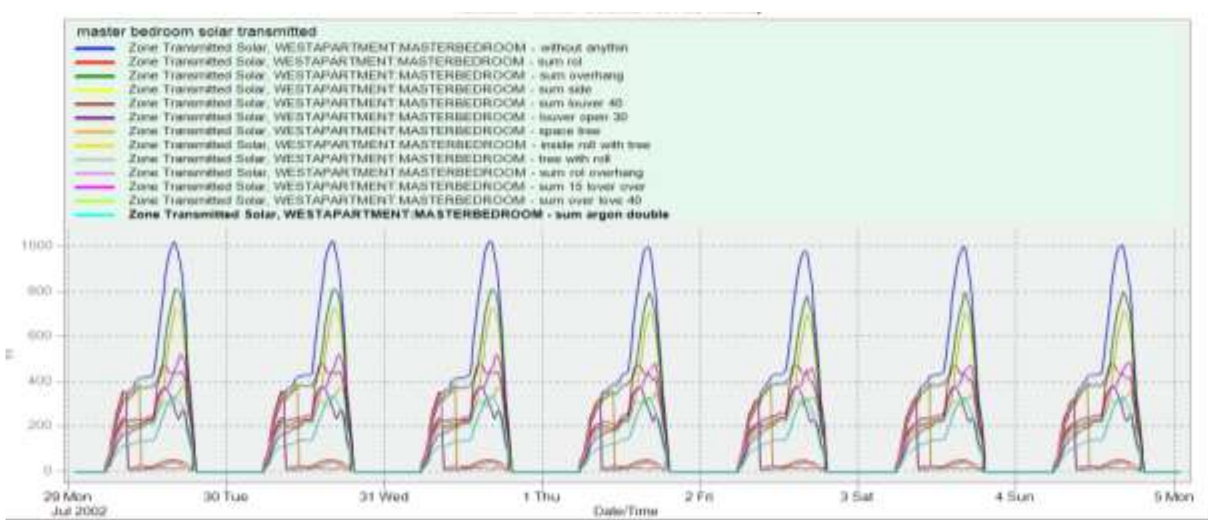
Master bed room Figure F-69



Master bedroom PMV/SET shading device investigation



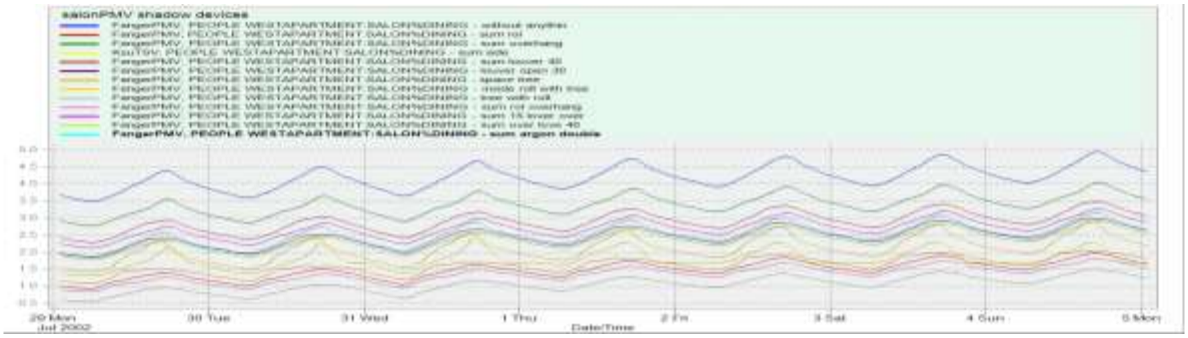
Master bedroom PMV/SET fixing shading device investigation



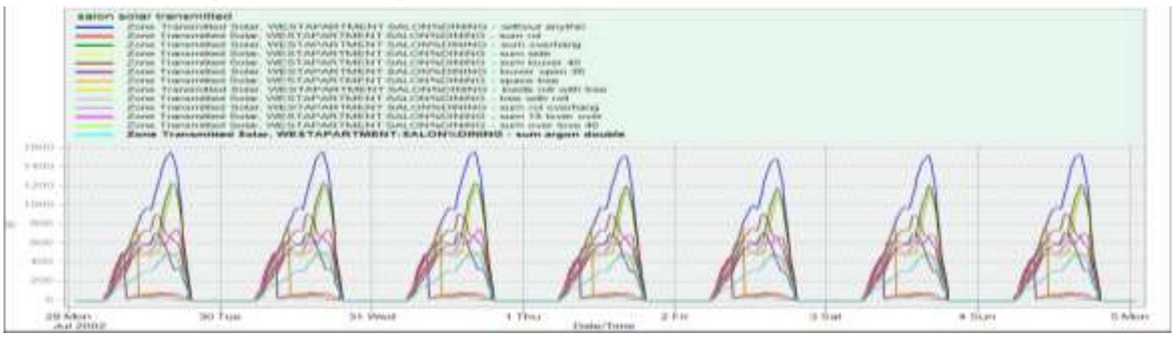
Master bedroom summer solar transmitted parameters for shading devices.

Figure F-69: master bedroom shading device investigation PMV/SET ,solar transmitted

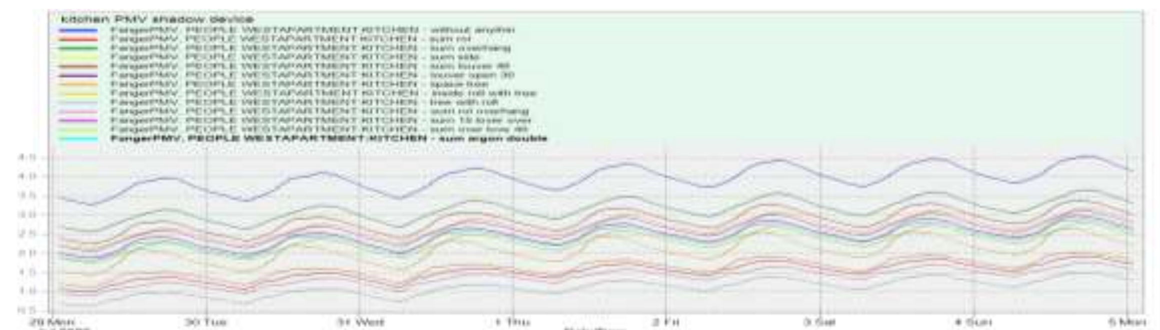
Salon and kitchen Figure F-70



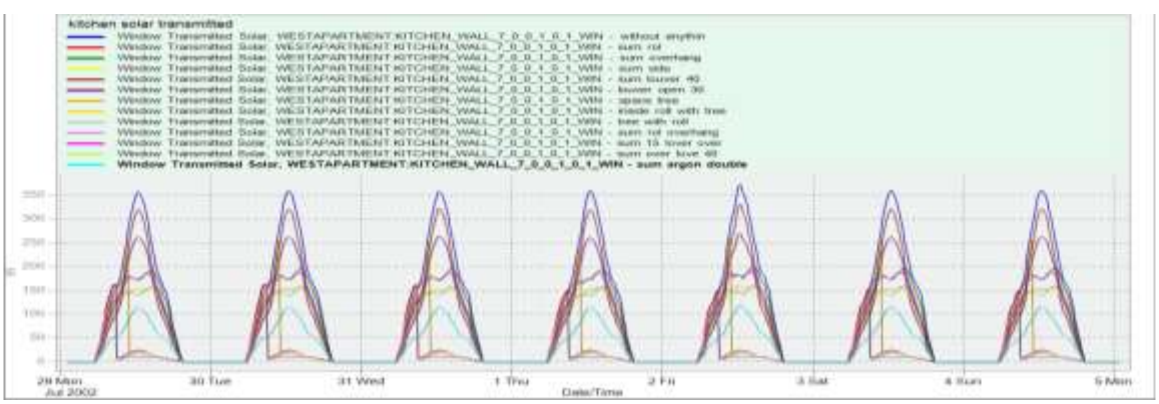
PMV/SET shading device investigation



Salon and dining room summer solar transmitted parameters for shading devices.



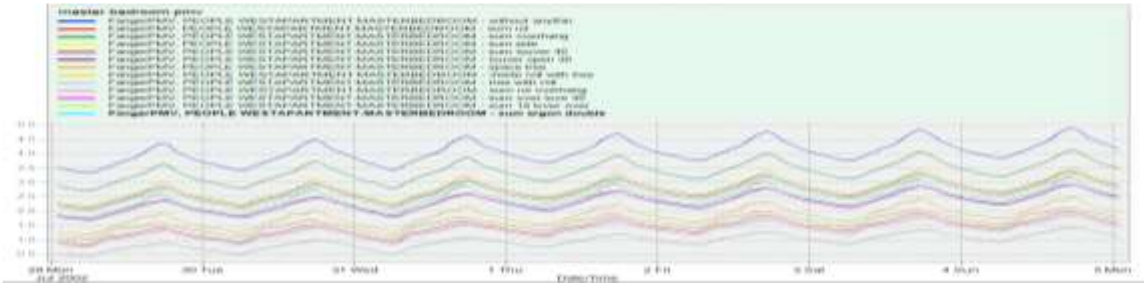
Kitchen summer PMV/SET parameters for shading devices.



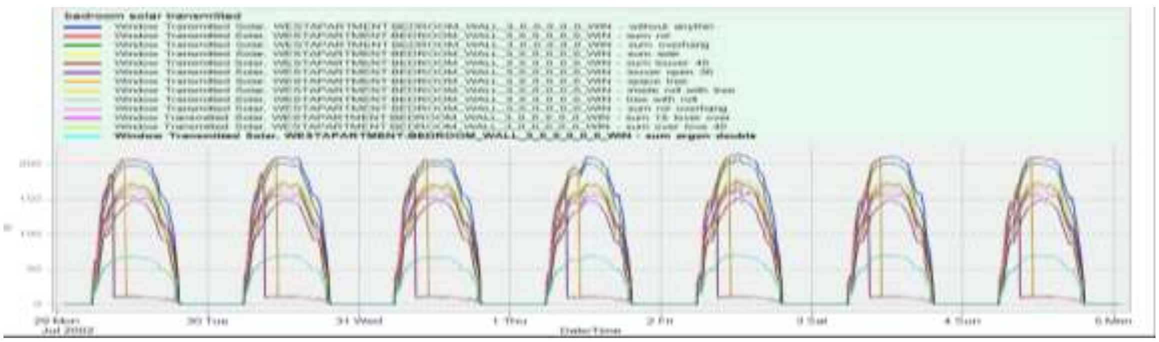
Kitchen summer solar transmitted parameters for shading devices.

Figure F-70: salon and kitchen shading device investigation PMV/SET ,solar transmitted.

Bedroom Figure F-71



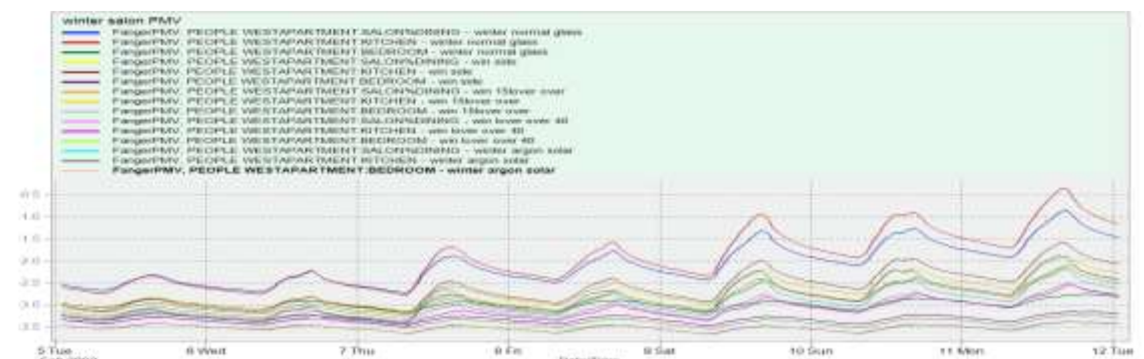
Bedroom summer PMV/SET parameters for shading devices.



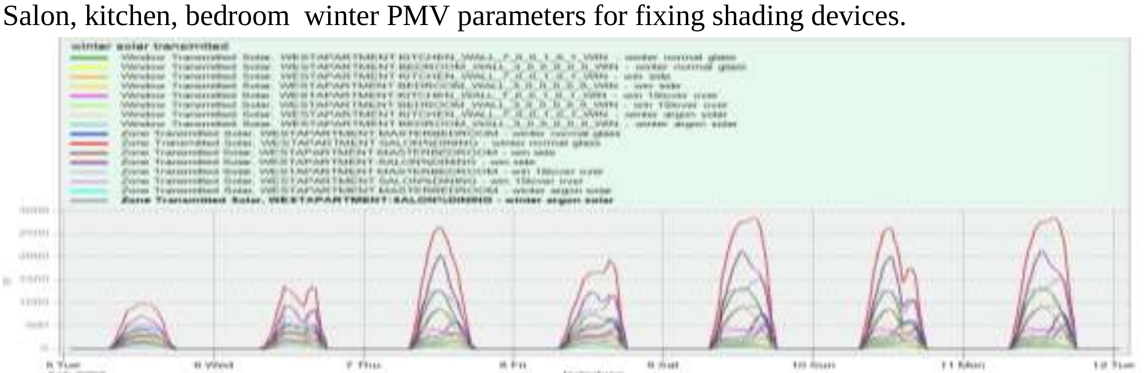
Bedroom summer solar transmitted parameters for shading devices.

Figure F-71: bedroom shading device investigation PMV/SET ,solar transmitted.

Winter period Figure F-72



Salon, kitchen, bedroom winter PMV parameters for fixing shading devices.

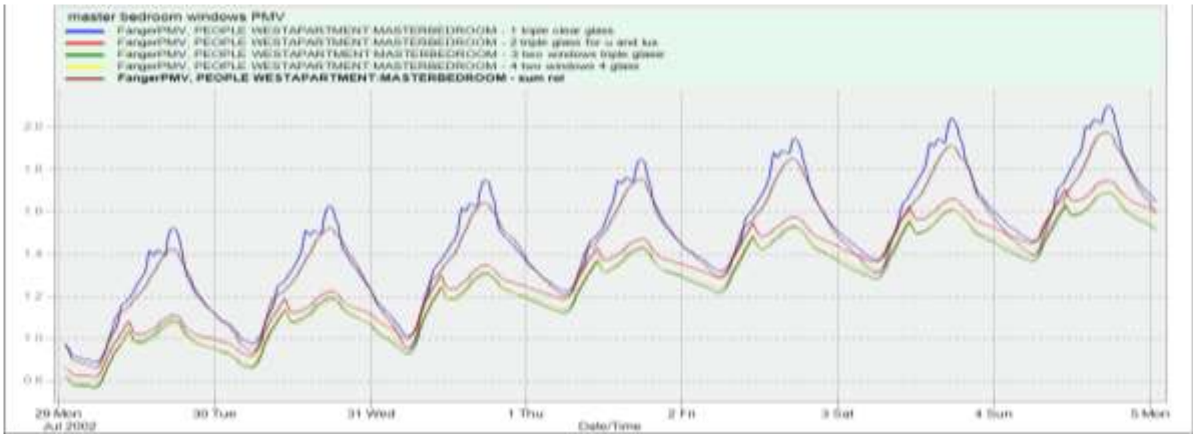


Master, Salon , kitchen, bedroom winter solar transmitted parameters for fixing shading devices.

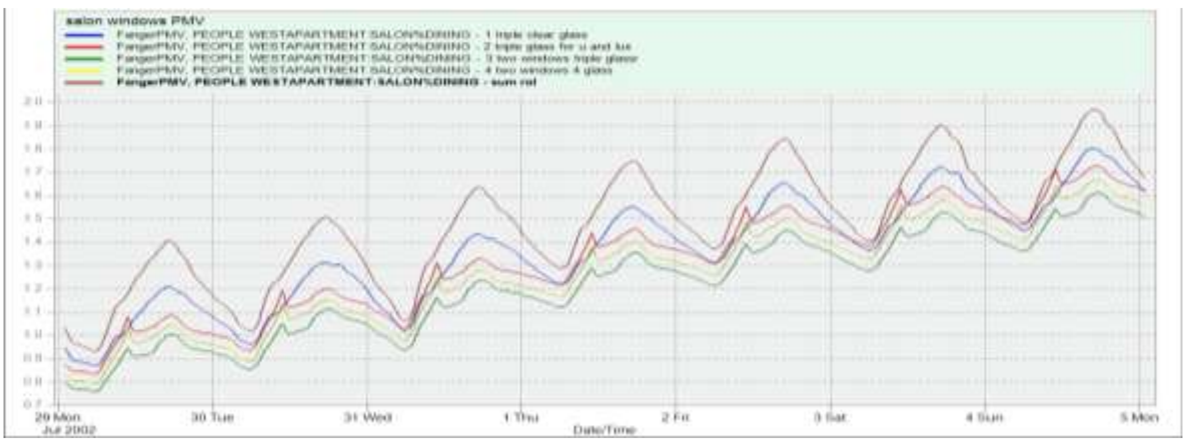
Figure F-72: fixing shading device investigation PMV/SET ,solar transmitted for winter period.

F.2.1.4 *Optimize windows*

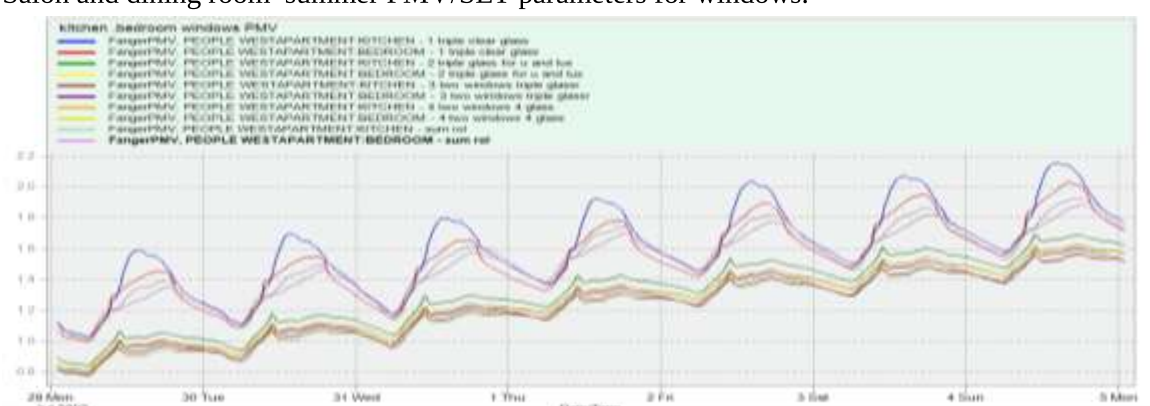
Master bedroom, salon , kitchen, bedroom PMV/SET **Figure F-73** solar transmitted **Figure F-74** .



Bedroom summer PMV /SETparameters for windows.

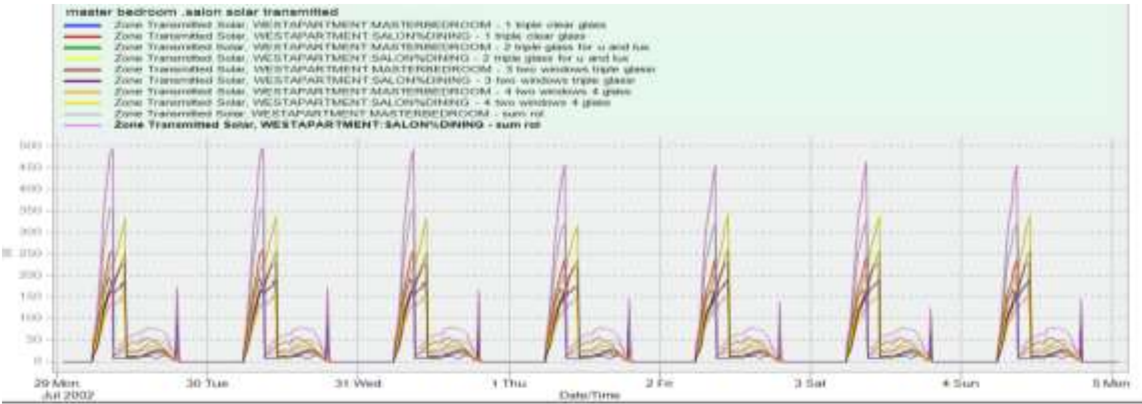


Salon and dining room summer PMV/SET parameters for windows.

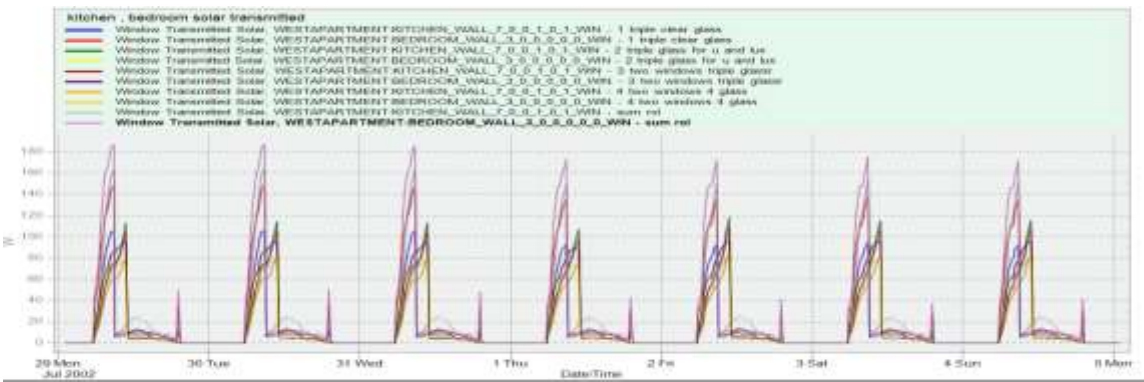


kitchen and bed room summer PMV/SET parameters for windows.

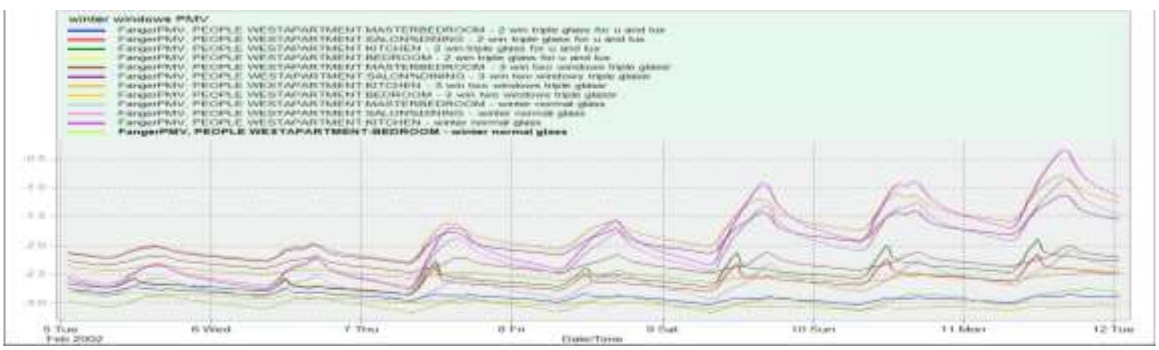
Figure F-73: windows kinds PMV/SET.



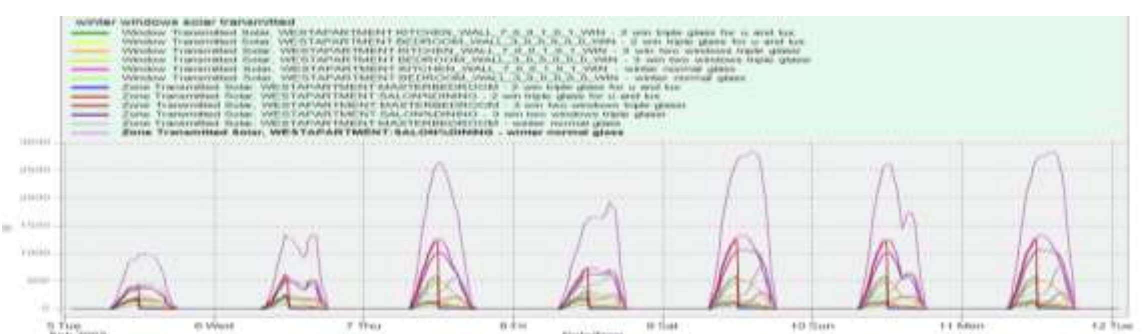
Master bedroom and salon summer solar transmitted parameters for windows.



Bedroom and kitchen summer solar transmitted parameters for windows.



Bedroom, Salon , kitchen, bedroom winter PMV/SET parameters for windows winter period.



Master bedroom, Salon , kitchen, bedroom winter solar transmitted parameters for windows.

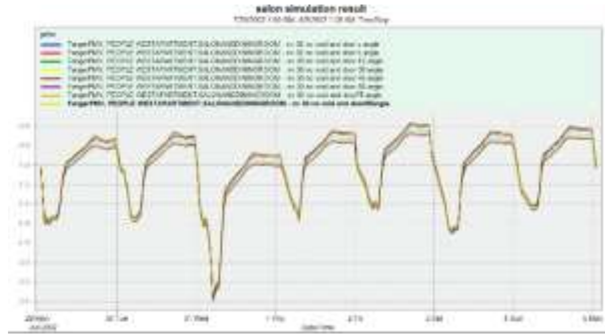
Figure F-74: windows kinds solar transmitted summer / winter PMV/SET , solar transmitted.

F.3 Optimize natural ventilation

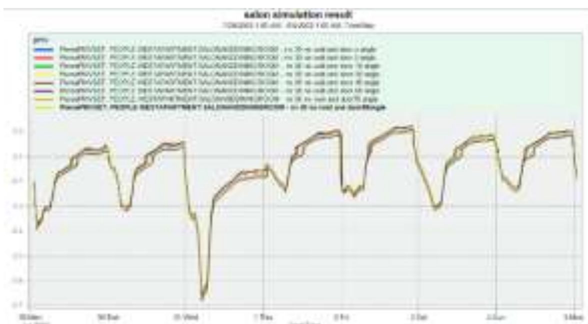
F.3.1.1 *Wind and direction*

Salon air flow and comfort behavior **Figure F-75**.

Salon air change rate



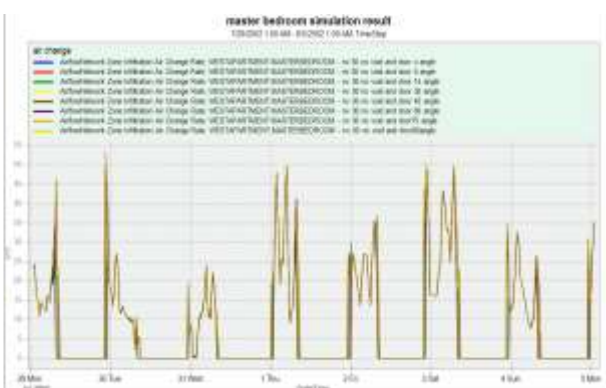
salon PMV



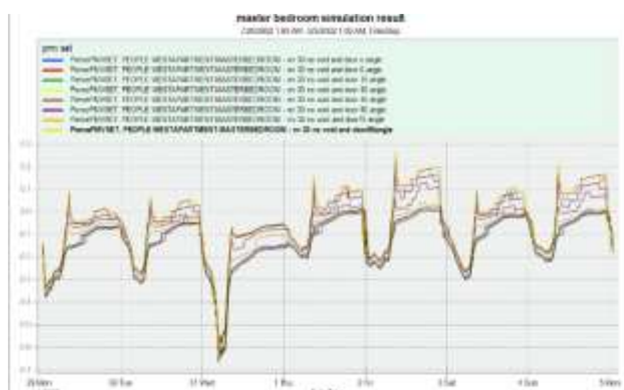
Salon PMV /SET

Figure F-75: Wind and deviation investigation, salon .ACH, PMV, PMV/SET.

Master bedroom air flow and comfort behavior **Figure F-76**.



Master bedroom air change rate



Master bedroom PMV /SET

Figure F-76: Wind and deviation investigation, master bedroom .ACH , PMV/SET.

Kitchen air flow and comfort behavior **Figure F-77**.

Kitchen air change rate Kitchen PMV /SET

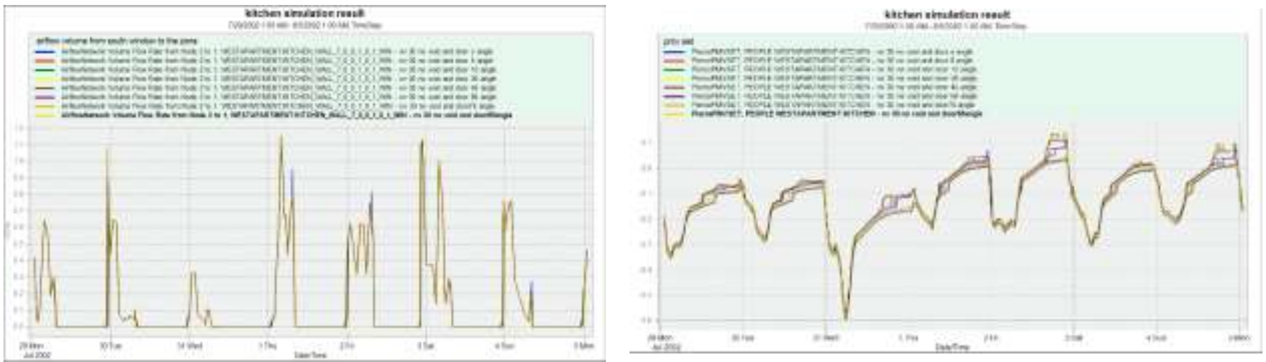
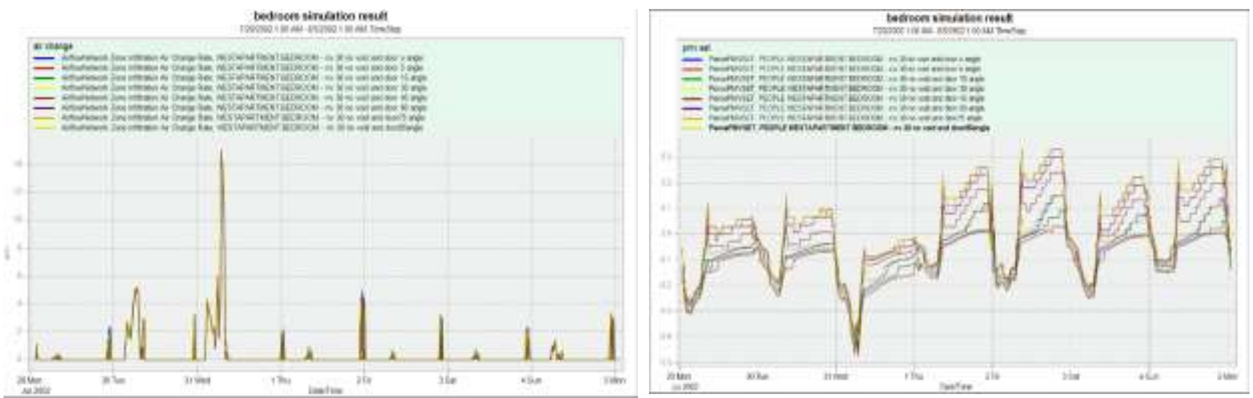


Figure F-77: Wind and deviation investigation, kitchen .ACH , PMV/SET.

Bedroom air flow and comfort behavior **Figure F-78**.

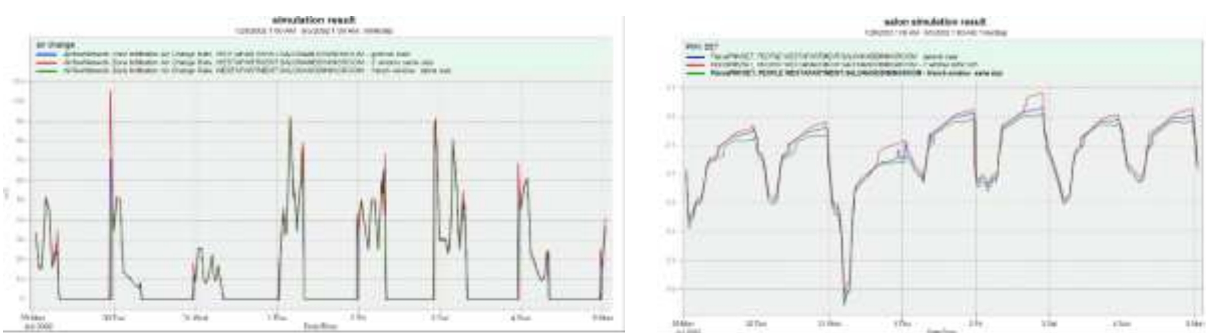


bedroom air change rate bedroom PMV /SET

Figure F-78: Template for inserting figures into Appendices.

F.3.1.2 *Windows shape*

Salon air flow and comfort behavior **Figure F-79**.

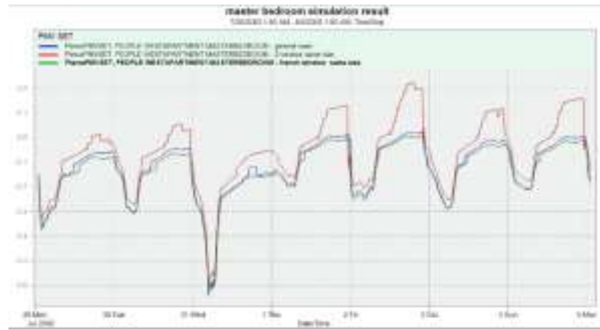


salon air change rate salon PMV /SET

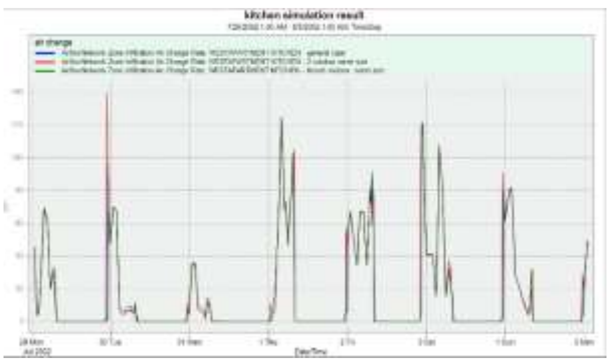
Figure F-79: Windows shape investigation, salon .ACH , PMV/SET.

Master bedroom, kitchen, bedroom air flow and comfort behavior **Figure F-80**.

Master bedroom air change rate



master bedroom PMV /SET



kitchen air change rate

kitchen PMV /SET

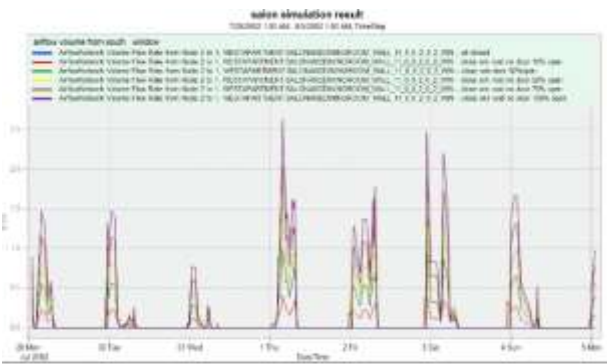
bedroom air change rate

bedroom PMV /SET

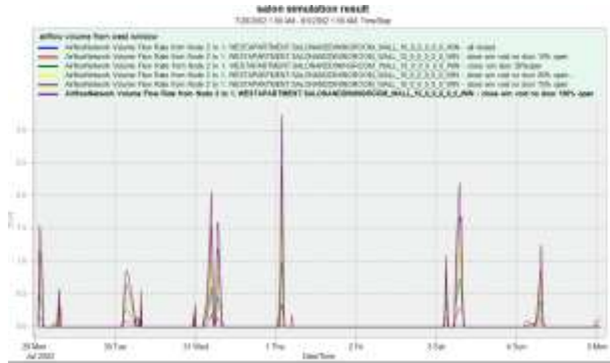
Figure F-80: Windows shape investigation master bedroom, kitchen ,bedroom.ACH , PMV/SET.

F.3.1.3 *Size and operative temperature*

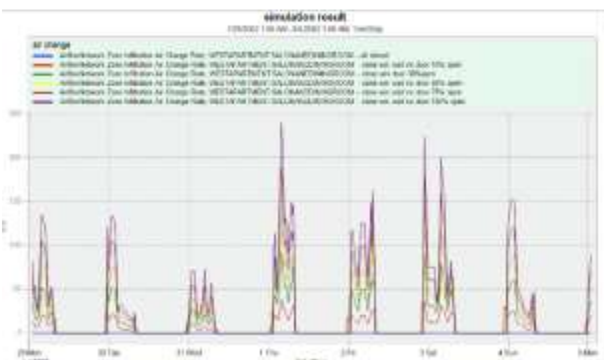
Salon air flow behavior, PMV/SET **Figure F-81**



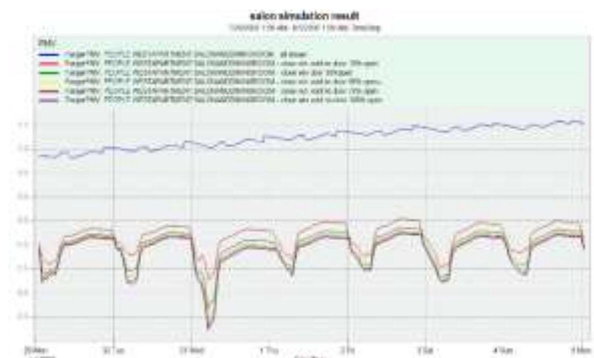
Salon airflow volume from south window



Salon airflow volume from west window



Salon air change rate



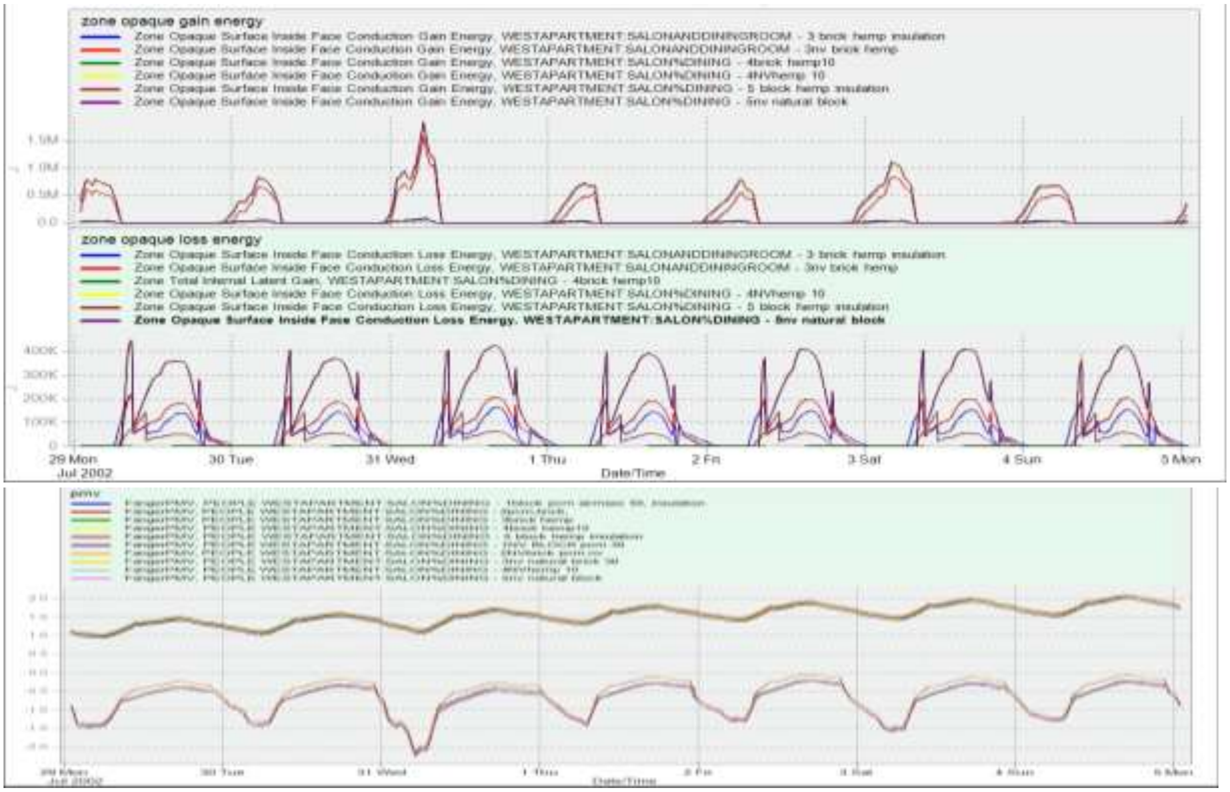
salon PMV

Salon pmv set

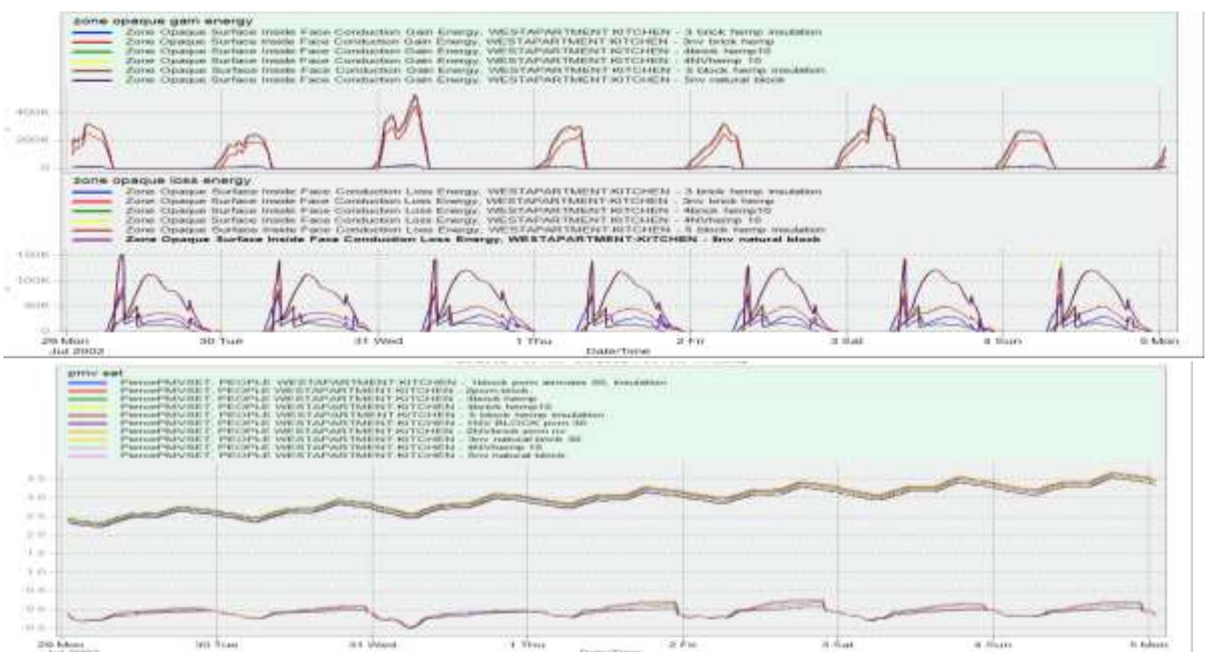
Figure F-81: opening percentage investigation .salon airflow behavior ,PMV/SET

F.3.1.4 *Natural ventilation and envelop materials impact*

Salon , kitchen opaque energy gain ,PMV/SET **Figure F-82**



Salon envelop behavior



Kitchen envelop behavior

Figure F-82: Template for inserting figures into Appendices.

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