Natural ventilation and the effect on thermal comfort as sustainable strategies in dry hot arid climate: a Case study in Damascus.

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Abstract

Dry-hot arid climate has specific characteristic especially in Mediterranean area, and traditional houses, which offer good examples for adaptive and sustainable respond.

This paper aims to help promote energy efficient architectural design in dry-hot arid climate by reviving the use of natural ventilation process (cross ventilation, single side ventilation 'stock ') and positive envelope properties of the traditional houses and urban traditional environment for courtyard housing clusters in a modern context. Such houses located in Damascus old city were traditionally renowned for their distinctive thermal comfort and adaptability.

Four typical traditional houses are distributed inside and outside the ancient walls of old Damascus city (traditional urban environment, modern urban environment). Those houses are consist of two levels: the first represents the ground floor with heavy mass (stone), the second: with light mass (timber and dried mud structure). This house has different rooms size, windows distribution and different kinds of natural ventilation. Several monitoring data (air temperature, humidity and air velocity) were acquired during a hottest summer period, in parallel with occupancy survey, beside the studies of two houses, with the help of the dynamic computer simulations.

The paper shows results of air temperature and other parameters related to different structure materials (intervention as concrete), natural ventilation, the opening windows (area and location), influence of urban environments. The comfort conditions were calculated according to adaptive model of ASHRAE and subjective survey are presented. Furthermore; simulation modelling was utilized to Verified results to contribute as strategies for sustainable design in this area.

1 Introduction

Using natural phenomena to reach indoor comfort has been known since the early eras and the oldest architectures and engineering of the middle east region have responded with such phenomena as very good solution specially for dry-hot region (temperature and radiation height at the summer longest days light, big swing interval between day and night temperatures also between summer and winter). It realized the optimum comfortable temperature easily outside its urban environment and inside its houses throughout the most 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 which are common in these days as passive design strategies and reducing energy consumption.

As consequences for all these prefaces and looking at the native architecture engineering civilization view obviously that no separation between architecture, engineering, environment's planning and the adopted human behaviour as they are in the old Damascus city . A real example, through absorb heating's surplus throughout the creation of the integrated texture (thermal mass combine with the natural ventilation). If the old city Damascus were as detached in smaller masses as it is now, the outer surfaces were increased too much larger and exposed to the disturbances of cold-hot strikes waves and of heat either in winter or in summer. That means, each building needs an artificial ventilator. Therefore many researcher by worldwide specially at the Middle East and north Africa region have studied the passive control method of the traditional buildings which were comfort over years: [1] Ahmad E. (1985) monitored the traditional courtyard house within 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, Libya. [2]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. [3] Abdulhak Mohammed (2007) Investigate environment factors impact on urban fabric and reflection on planning concept at new and old urban fabric at dry-hot climate in Damascus city, the result present the influence of old streets structure on ambient relative humidity which were more than new street structure about 8%, the courtyard relative humidity increase about 12-19% higher than new streets structures. Ambient air temperature for old fabric lower than new fabric about 3.3°Courtyard has big influence to reduce the environment factors inside it. [4]Abdulhak Mohammed (2009) The research may contribute to the study of the effect of climatic factors on Human in the Republic of Yemen and to what extent he adapts to them in each region, the research has also worked on a bioclimatic evaluation study of some Yemeni cities, which contrast in region differences, Sana'a (Cold –in Winter), 'Adan (Hot-Humid) and Say'un (Hot – Dry),.[5] Farghal- AMGAD (2011) This study focused on investigating the thermal environment and its effect on the comfort mechanism in the hot arid climate of Cairo, also the natural ventilation effect for spring and autumn period.

.[6] 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.[7-11] at others region studied thermal comfort for traditional building also courtyard . [12]Taleghani, M Tenpierik, A Dobbelsteen (2012) investigate the effect of courtyards, atria(atrium) and sunspaces on indoor thermal comfort and energy consumption for heating and cooling. [13] 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.

This research to investigate natural ventilation for traditional house that gives high energy efficiency in providing cool indoor air through ventilation (single sided , cross ventilation)and envelope behaviour (effect of natural materials and the intervention with concrete and other new materials)beside orientation and urban planning environment effect , with the procedure of measurements combination with simulation program model Design Builder and calibration , to improve middle east new residential city building through utilize passive cooling techniques to reach thermal comfort (temperature control) over interior condition. This strategies are utilized from sustainability viewpoint through reduce energy in a dry-hot arid region.

2 Investigation

2.1 Measurement

The basic selection depended on the difference between the ambient locations of typical Damascus traditional houses; the first one represents the old urban city (compact fabric) with one or three courtyards for each house. The second represents the traditional houses at new ambient (surrounded by new high buildings, separate fabric (Fig1.a)). Each one consists of two levels (stories) with different orientation and different materials intervention. The cases have two levels contain heavy mass (stone and lime) at first level and light mass of timber structure with pressed dried mud and lime at the second one

- The first one that located at different part of the old urban city shows the influence of old urban fabric special for wind tunnel. BAIT FAKHRY AL BAROUDI (Fig.1.b): has Restoration works lime and mud mortar replaced by concrete, also hemp and clay replaced by bitumen roll; BAIT AL MOSLLI: house is still maintains old configuration and structure. BAB AL SALAM HOUSE : 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 .
- The Second: BAIT WARRD: the courtyard covered with sliding plastic roof .this investigation have being with natural ventilation (cross ventilation, single side ventilation).

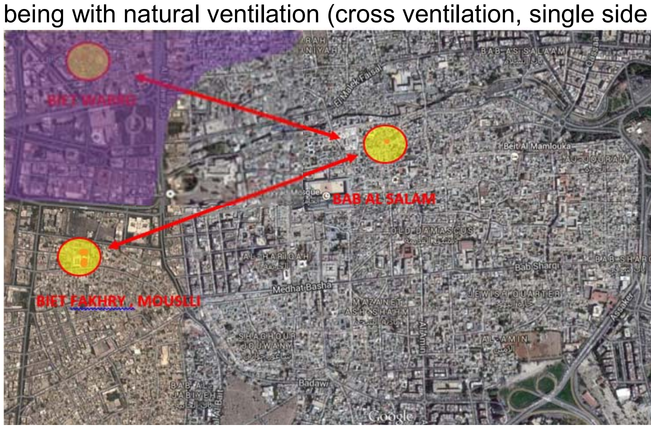

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Fig.1; a. cases location, b. BAIT FAKHRY AL BAROUDI. a; ground floor .b; first floor . c; section AA

2.1.1 Measurement setup

Several measurements on microclimate conditions of indoor and outdoor courtyard have been done in summer period 2014 .Measuring were made according to ASHRAE standard for temperature, relative humidity and air velocity all data recorded every 5minute to get good indicator, the measurement made parallel with survey (ASHRAE 55). Air velocity collected manual corresponded with experiment measurements and survey. The instruments position is based on three points:

- The first one is related to investigation of thermal comfort according to standard ASHRAE: positions are at(60 , 110 cm) height (60 cm high for adaptive comfort model calculation) at the center of rooms and far away from walls at least 1m (position south wall means far 1m from wall); measurement intervals are 5 minutes.
- The second consideration is related to natural ventilation investigation, to evaluate air velocity behavior and effect on comfort condition depending on opening windows position (one or two levels). In case of high halls the measurements are divided into two levels: first one to height 3m, the second above 3m.
- The third one is related to analyze room orientation and floor level; besides its protection from direct solar radiation.
- Rooms were chosen depending on natural ventilation way: cross ventilation (facing windows or adjacent), single side ventilation at one façade or single side with stack (two levels of windows).

External climatic weather data are collected from the next weather station of the faculty of agriculture at Damascus University. It provides many weather data for every hour: temperature, relative humidity, wind speed, dew point, pressure, wind direction.

Operative temperature (T_{op}) is calculated in specific periods using air velocity manual data corresponding with experimental measurements of other physical parameters, in parallel with sensation survey based on PMV scale (7 point scale: from -3=cold, to +3=hot). For personal activity conditions and clothing, data collected from surveys are used for calculations: for relaxing conditions 1.2 met was set; for personal insulation clothes the average thermal clothing resistance for all surveys of student and people (long trouser, short sleeve shirt, socks, and shoes) was used, equal to 0.58 clo.

Comfort analysis was performed using the Adaptive model proposed by ASHRAE-55 2010 Standard [12]: this model allowed to get the effect of outdoor climate (and more specific the effect of natural ventilation) on occupants. This standard introduce the prevailing mean outdoor temperature (T_{mo}) as the input variable for the adaptive model. It is based on the arithmetic average of the mean daily outdoor temperatures over no fewer than 7 and no more than 30 sequential days prior to the day in question: for the period under study, T_{mo} is about 27.2 °C. The relations corresponding to the acceptable operative temperature (ASHRAE 55/2010) according to adaptive model ASHRAE handbook [14,15] are:

- Upper 80% acceptability limit (°C) = 0.31 * T_{mo} +21.3 =29.73
- Upper 90% acceptability limit (°C) = 0.31* T_{mo} +20.3 =28.73
- Lower 80% acceptability limit (°C) = 0.31 * T_{mo} +14.3 =22.73
- Lower 90% acceptability limit (°C) = 0.31 * T_{mo} +15.3 =23.73

2.1.2 Data analysis

The most collected data, recorded during of July 15th-22th and August 4th-13th, 2014, can be considered as a representative of a typical summer period. The weather condition during those weeks was sunny, clear and hot. Maximum outside temperature, 39-41°C, was typical values during this period of the year or little bit higher about one or two degrees. About 1250 measurement was made, the total result about 100 measurements for every house [16].

Thermal performance : some comparison of thermal performances between all different houses under study , in order to evaluate influences of building type, that depend on urban environment, orientation, construction materials (traditional materials and new intervention systems), opening size and position, in order to investigate its impact on internal temperature and the natural ventilation behaviour on comfort.

- COURTYARD. Typical temperature trends inside courtyard are reported in Fig.2, were houses with traditional structure gives best values for temperature and relative humidity (43%-63%) corresponding to courtyard size. The effect of a cover-up over the courtyard and urbanism observed at Bait Waard : high heat storage and a large thermal gradient: at ground level, with surrounding heavy mass, low stationary temperature were recorded(urbanism effect, on other hand revers effect of tree that made kind of heat balance through temperature, relative humidity and low air flows) , 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 concrete for wall plaster and roof covering (Fakhry) increase temperature, while the activation of fountain in the same courtyard decreased temperature (min 1°C).
- NORTH halls. Fig.3 shows the difference between two types of halls: Fakhry hall (3 m high, 75 cm underground) presents adjacent cross ventilation at one level windows causing more stationary temperature during day and night periods; Mouslli hall, with two windows level, have more temperature difference between day and night. Very important in this case is the impact of the intervention on structure using new materials (especially concrete) that increased the internal temperature of 1°C at least (Bab Al Salam).
- 1st Floor north hall (Fig.4) the effect of cross natural ventilation decrease the temperature of 1°C to 3°C (at Fakhry hall due to high ceiling).
- EAST halls. In this case the kind of structure impacts on the thermal behavior due to stack single side natural ventilation for two levels which gives lower temperature (in Mouslli halls) compared to traditional houses structure Fig.5.
- WEST halls have the same impact as east halls. In the other hand at Bait Warrd, roughly close to Mouslli house, measurements with sliding roof and big tree has shaded the whole courtyard and west halls for all days (reduce the urban environment effect). Fakhry hall (3m high, concrete intervention) increased temperature (min 3°C).

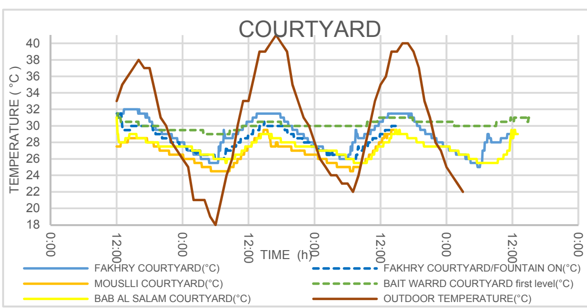


Fig.2; Temperature trends for different courtyards.

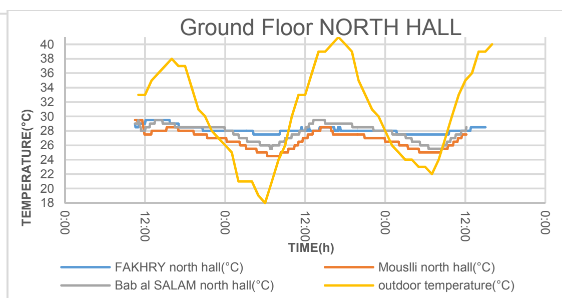


Fig.3; Temperature trends for north halls.

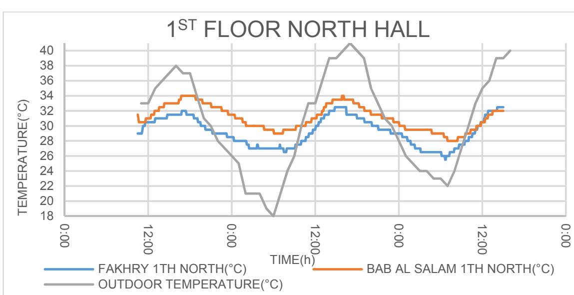


Fig.4; Temperature trends for 1st floor north halls.

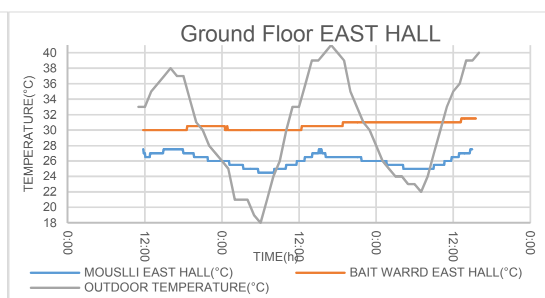


Fig.5; Temperature trends for east halls.

Thermal comfort: thermal sensation for occupancy based on collected survey data and thermal measurements, sensation results from survey data compared to measured temperature, Fakhry halls, in two conditions: non ventilation and with ventilation. Significant differences were found between non ventilation condition (comfort values higher than 2PMV sensation scale), and with ventilation condition (values ranging between 0 and 1scale) due to the effect of kind of the natural ventilation kind (cross “adjacent” ventilation; north hall, single side “stock” ventilation; south hall “two levels of windows”). Otherwise, the adaptive model are too closer to occupancy sensation for 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 non-ventilation, depending on the kind of ventilation, orientation, structure, height and size and opening area. The adaptive model results: temperature measurements for different houses that fall within 90% limits of acceptability.

For North halls all cases fall within the acceptability limits of 90%, but Mouslli house presents better results, depending on structure and materials more than Bab al Salam.

For First floor north hall results confirm that cross ventilation increase acceptability limit roughly 20% to 25% comfort period Fakhry 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.

2.2 Simulation

The second step of this investigation to sophisticate building modelling simulation using measurements and monitoring data within dependable model (shows a good agreement between measurement and simulation using design Builder simulation program base depend on ASHRAE average for calibration accepted).
The two procedures are merged in order to develop a method for data evaluation in residential building with natural ventilation by getting more parameters and factor to evaluate and to provide a simple model for integration in residential building strategies to reduce load of building.

As a basic principle, results from experiments in traditional houses 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

- Evaluation of measured data based on standardized graphs and indices.
- Sophisticated building simulation using measured data and boundary conditions.
- Data evaluation of the results from the building simulation with standardized boundary conditions using a parametric model.

2.2.1 Natural ventilation

In modelling the natural ventilation effect there are some crucial points:

-Natural ventilation: As most ventilation concepts are based on a free ventilation concept, the air change rates must be calculated. Due to the different driving forces (wind, buoyancy and fan driven ventilation (generate simple model for residential building)), the design of free ventilation and inter zonal air exchange is complex.

- Heat transfer: As the natural ventilation cools down the building construction, an accurate modelling of the convective heat transfer coefficient is essential for the simulation of natural ventilation.

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

The difference between natural ventilation all day and night ventilation as passive strategies focus on thermal comfort.

The simulation made for summer period (applied EPW file of weather data collected before) for July and August.

Single Side Stack Ventilation integrated Investigation: South hall ventilation depend on single stack ventilation, for more explanation for stack behaviour, more simulation has done 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 .it has divided for five vertical parts through alternate configuration between opaque and window which started by 8% opaque, 25% window, 25% opaque, 25% window, 17% opaque.
Consequences: air flow throw opening area, position and orientation:
- Best natural ventilation influence for over 20% opening percentage: up level opening about 70% and down level opening about 30%.
- Best natural ventilation influence for under 20% opening percentage: up level opening about 60-65% and down level opening percentage about 40-35% (Fig.6) present latest result.
The influence of opening areas on air temperature present at (Fig7) 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 [7] single stack ventilation achieve lower temperature with lower ACH than ordinary opening and lower opening percentage.

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% (Fig.7).
On other hand, this result depend also on thermal mass and the behaviour of heavy mass properties.

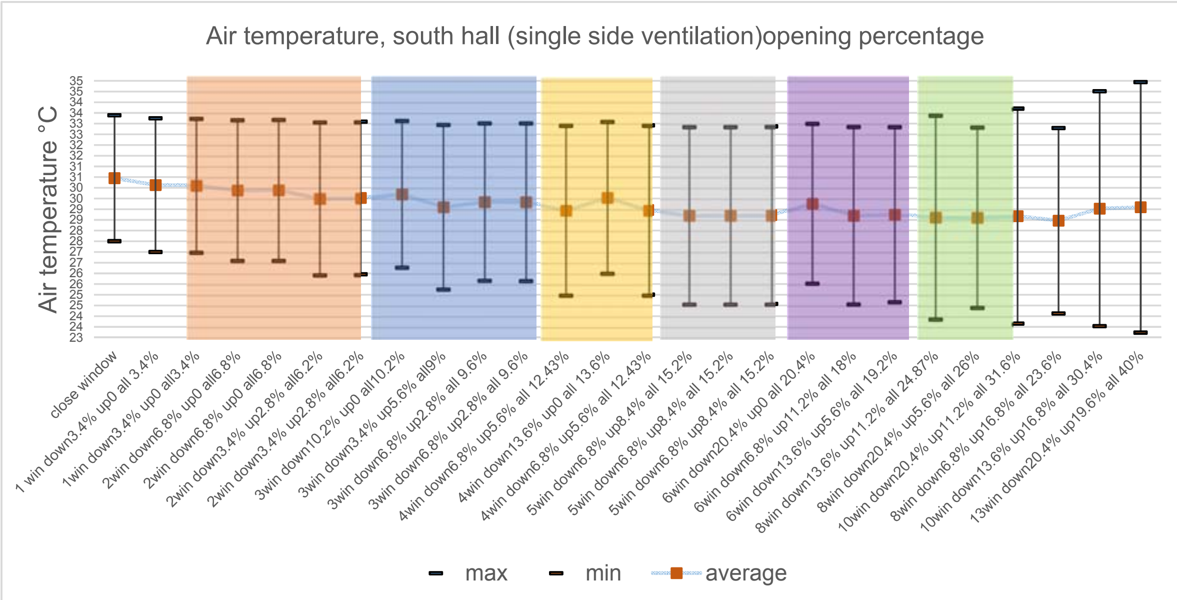


Fig 6. Air temperature related to opening area for Single side stack ventilation .

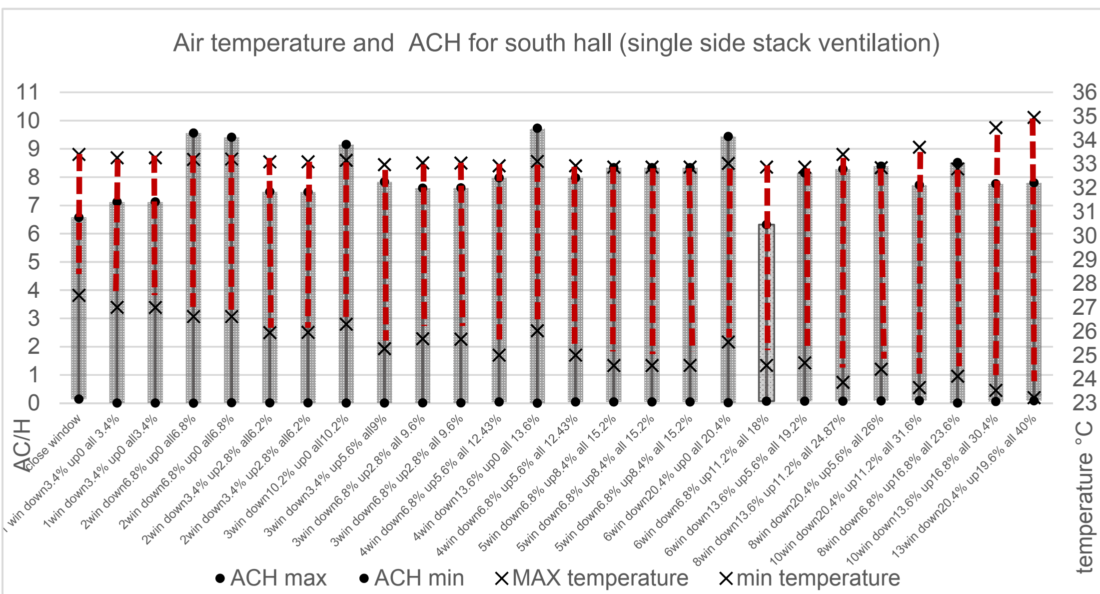


Fig.7 Relation between inside air temperatures with air change inside hall per hour.

3 Conclusion and future work

Analysis inside courtyard shows the importance of the traditional materials structure and ancient urbanism (compact fabric, Mouslli) beside the size and shaded area (Bab Al Salam), the presence of trees and another important factor the influence of fountain. Building structure (heavy thermal mass at the ground floor) and ceiling height have main influence on thermal comfort. Opening area 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 of adaptive model (Fig 8) present the effective percentage of each elements on thermal comfort. From previous the compact fabric planning has best performance for dry-hot arid (Mouslli) .

Thermal mass (heavy mass) utilize natural sustainability materials gives more comfort for occupancy which increase by merging with natural ventilation as passive cooling strategies.

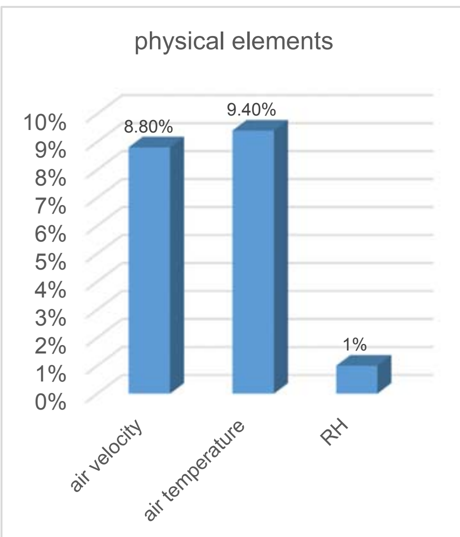
Effective factors on natural ventilation proportional and thermal comfort: volume [the rate between height and area (depth), WWR % (depend on façade) and it is same for each kind of natural ventilation.

Divided WWR to more than one area as possibility, for better interior air flow influence 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.

Single side (stack) natural ventilation has more influence than single normal ventilation (east hall MOUSLLI, BAIT WARRD).

Future work more investigation about the influence of natural ventilation during very hot summer period as expressional years 2015th consequences for global warming and increase earth heating effect was clearly at 2015th for make design and planning flexible for more changing also for winter period.



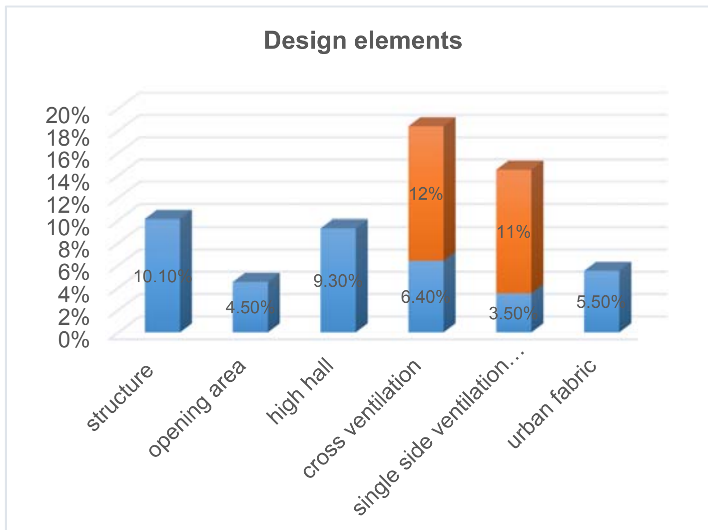


Fig 8 .Elements effective on thermal comfort.

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