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Effect of Microclimates Conditions on Architectural Design of Residential Buildings in Saudi Arabia

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ABSTRACT

Recently, an increased attention is turned to increase the building energy performance in Saudi Arabia in order to improve the global energy saving strategy and to achieve the required indoor thermal comfort. The local environmental microclimate conditions can play an important role in the thermal-energy behaviour of residential buildings. Consequently, the architectural design of the residential buildings in Saudi Arabia can be greatly altered according to the local environmental microclimate conditions in the different regions. The purposed work tries to find out how the residential buildings in Saudi Arabia can be affected by microclimate boundary conditions in different regions. Two different regions have been considered in the present study; namely, Mecca city and AlShifa-Taif region, where intensive changes in microclimate conditions can be observed. Previously, the designed residential building in both regions was not differing in architectural design and exterior requirements. The present work indicates that an essential difference in architectural as well internal and external design of the residential building in such similar regions should be taken into considerations. This can contribute to the strategy of the global energy saving in Saudi Arabia and improve the building energy performance as well.

Key words: Architectural design, Microclimate conditions, Residential buildings, Thermal comfort

INTRODUCTION

Thermal comfort can play an important role in human performance at both physical and mental levels [1]. The thermal discomfort can cause lower emotional health manifested as psychological distress, depression and anxiety as well as lower physical health manifested as heart disease, insomnia, and headache [2-3]. The modern researches of building design are concerned by the achievement of the thermal comfort either by considering the ambient climate conditions to introduce internal natural ventilation or through minimizing the energy required for delivering the thermal comfort. This can lead to an increase in the building energy performance and draw our attention towards the nearly-zero energy building design in the near future [4].

One of the important goals of Saudi Arabia's vision 2030 is how to improve the energy saving techniques in all life sectors, especially, in residential buildings. The local climate boundary conditions in different area of Saudi Arabia can play an important role on the obtained thermal comfort and consequently, the appropriate design of the residential building in such areas. Therefore, our novel idea in the present work is how to construct a different design for residential buildings according to the published data of microclimate conditions existed in a specified region of Saudi Arabia. Two different regions are considered here for the current research; namely, Mecca city and AlShifa-Taif region, where serious changes in microclimate conditions can be found. Figure 1 shows the location of both regions on Saudi Arabia map printed from Google. The results of the present study can be applied in similar regions of Saudi Arabia as the ambient microclimate conditions are known. It is common knowledge that the microclimate conditions depend on light regime, air and soil temperatures, humidity and solar radiation in specified area or region. By monitoring such parameters in three different time aspects (monthly, daily and hourly) we can determine spatial variability of microclimate conditions [5]. In other researches, the average values of such parameters are considered to be sufficient in design and planning purposes [6]. The most important basic internal microclimate parameters can be seen in the Table-1 below. Also, other microclimate parameters can be found and specified, for more details one can see [7].

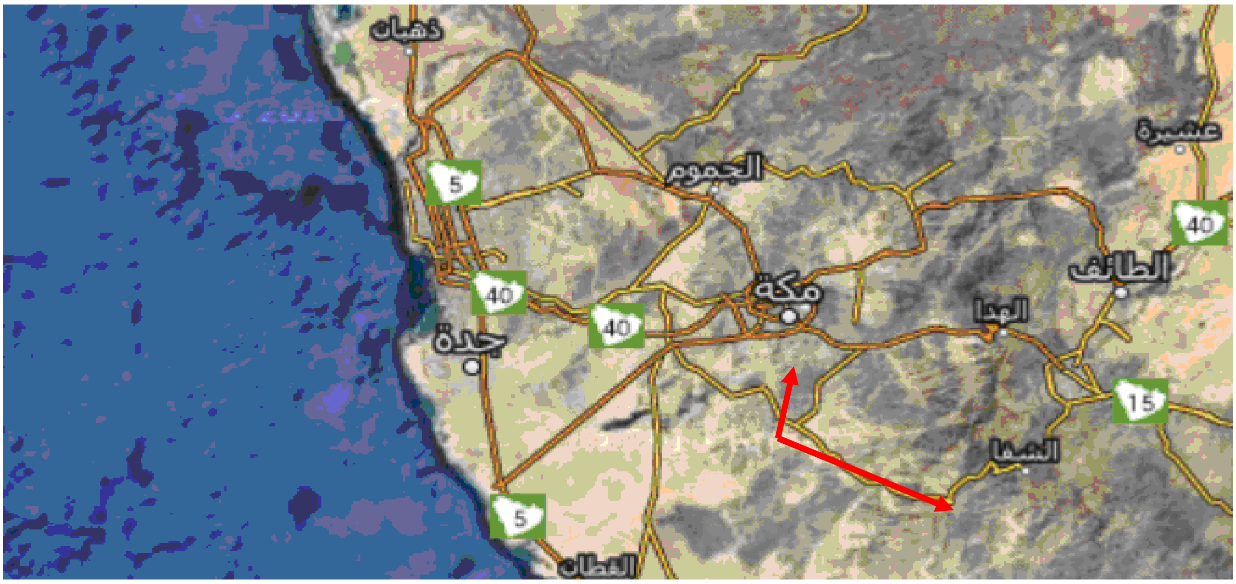

Fig.1 Location of Mecca City and AlShifa-Taif region on Saudi Arabia Map

Table -1 Internal Microclimate Parameters

No	Parameter	Identification Symbol	Unit
1	Air temperature	t_{air}	ºC
2	The mean radiation temperature	t_r	ºC
3	Air flow speed	v_{air}	m/s
4	Relative humidity	R_h	%
5	Radiation intensity	I	kWh/m^2

BUILDING ENERGY PERFORMANCE (BEP)

The standard way of estimating the energy performance of a building specifies a general framework for the assessment of overall energy use of a building, and the calculation of overall energy ratings in terms of primary energy, CO2 emissions and of parameters defined by national energy policy. Separate standards calculate the energy consumption of the different services inside the building, such as heating, cooling, hot water, ventilation, and lighting, and then produce results that are used in combination to show overall energy use.

It is well known that local environmental boundaries can play an essential role in determining microclimate conditions affecting the building energy performance. According to different local microclimate conditions, it is expected that the scenario of the thermal energy performance can be changed. Different regions were considered in the literature; namely, rural area, suburban area and urban area. The continuous microclimate monitoring of such areas should be carried out, and comparative analysis of the different boundary conditions should be performed in order to conclude the different effects on BEP.

SUGGESTED BUILDING DESIGN APPROACH

Recently, the new design of the residential buildings worldwide is trying to conform the local microclimate conditions. Although, this approach is not a new concept as such, however, it is considered to be an important issue in the modern architectural engineering [8]. Tracing back from history, different treatments have been performed to adjust the building design to the local climate conditions and the human life requirements, staring from food shelters and wind catcher to the placing of windows on the southern direction to capture adequate needed heat for thermal comfort. More recently, it has been argued that the outset of the countries and the climate in which buildings are built should be taken into consideration [9]. In more advanced argument, we suggest that the forecasting of the climate changes worldwide should be considered during the process of the building design.

In the following, the required steps for linking the building design with the local microclimate conditions is presented and explained.

Zone Properties of the Designed Residential Building Model

The purpose of this item is to define “tailored” weather data sets to be representative of the real local microclimate boundary conditions on which the residential building will be designed and built. Such set of weather data can determine the thermal-energy behaviour of the building. Example of such properties is illustrated in Table -2 for Mecca city and in Table -3 for AlShifa-Taif region.

Building's Construction Properties

The construction properties should also described in details for the designed building as can be seen in Table -4.

Layers Materials

Additional data about the layer materials and its thermal properties should be included in the design approach of the building; samples of such data were presented in [10, 11] and are shown in Table -5.

Dynamic Simulation

The previous data of the location and the building's construction properties can be used in dynamic simulation tools to estimate building energy performance variations in different boundary conditions. According to the output results of the dynamic simulation, the suggested design of the building is illustrated.

Table -2 Location Properties of the Designed Building (Mecca City)

No	Property	Description
1	Location	Mecca city, Saudi Arabia
2	Latitude	21.39 ºN
3	Longitude	39.86 ºE
4	Elevation above sea level	302.0m
5	Daily lower average air temperature	18.9 ºC
6	Daily upper average air temperature	43.7 ºC
7	The mean radiation temperature	255 ºC
8	Air flow speed	1.4 m/s
9	Relative humidity	43 %
10	Radiation intensity	3.98 kWh/m^2/day

Table -3 Location Properties of the Designed Building (AlShifa-Taif region)

No	Property	Description
1	Location	AlShifa-Taif region, Saudi Arabia
2	Latitude	21.44 ºN
3	Longitude	40.51 ºE
4	Elevation above sea level	2244.0m
5	Daily lower average air temperature	10. 9 ºC
6	Daily upper average air temperature	24.09 ºC
7	The mean radiation temperature	239 ºC
8	Air flow speed	3.1 m/s
9	Relative humidity	46 %
10	Radiation intensity	>1 kWh/m^2/day

Table -4 Building's construction properties

Type	Thermal Transmittance	Internal Heat Capacity
External wall	0.3 W/m^{2}K	130 kJ/m^{2}K
Internal wall	3.5 W/m^{2}K	70 kJ/m^{2}K
Roof	0.2 W/m^{2}K	50 kJ/m^{2}K

Table -4 Building's layers materials

Type	Layers	Thickness
External wall	Brickwork	120 mm
	Plasterboard	10 mm
	EPS expanded polystyrene	90 mm
	Brickwork	250 mm
	Gypsum plastering	20mm
Internal wall	Cement plaster	20 mm
	Perforated brickwork	80 mm
Roof	Clay tile (roofing)	15 mm
	MW stone wool	15 mm
	Air gab 300 mm	50 mm
	MW stone wood	80 mm
	Aerated concrete slab	200 mm
	Gypsum plastering	15 mm

MAJOR FACTORS CONSIDERED IN BUILDING DESIGN

The major factors affecting human comfort as found in the literature include temperature, humidity, in the form of vapour and precipitation, wind and air movement, exposure to radiant heat sources (solar radiation), and cool surfaces to radiate for cooling. Additionally, it is important to state that the air temperature and mean radiant temperature of a homogeneous environment affect the "dry" heat exchange of the human body by convection and radiation. Similarly, air humidity on the other hand, indirectly affects the body thermal comfort and determines the evaporative capacity of the air and hence the cooling efficiency of sweating.

Consequently, the major factors needed to be considered when designing a climate responsive building include the following:

- Building orientation
- Integration of renewable energies
- Building envelope and materials
- Water bodies
- Site vegetation/landscape
- System participation in building design
- Daylight Strategies

SKETCH OF BUILDING DESIGN IN THE CONSIDERED AREAS

In this section, an illustration of two different designs suggested for the two different regions considered in our present work; namely Mecca city and AlShifa-Taif region. It is well known that Mecca has an average monthly Global Horizontal Irradiance (GHI) of 4.06 kilowatt hours per square meter per day (kWh/m^2/day), which is approximately 2% greater than the average monthly Direct Normal Irradiance (DNI) of 3.98 kWh/m^2/day. Solar installations in Mecca that are always titled at the latitude of Mecca (Average Tilt at Latitude or ATaL) average 4.66 kWh/m2/day, or about 15% greater than the average monthly GHI of 4.06 kWh/m^2/day and approximately 17% greater than the average monthly DNI of 3.98 kWh/m^2/day. However, in Taif City the average value of GHI does not exceed than 1 kWh/m^2/day. There are many techniques which can be used in order to provide more comfortable and sustainable buildings at the early stage of design. The figures provided (1 and 2) show some of which strategies which can be used to save energy in the operation of the buildings. For instance, many architects and engineers tend to use vegetation, shading devises and windows to control the indoor building environment which reflect the amount of energy required to generate the building with respect to its microclimate location.

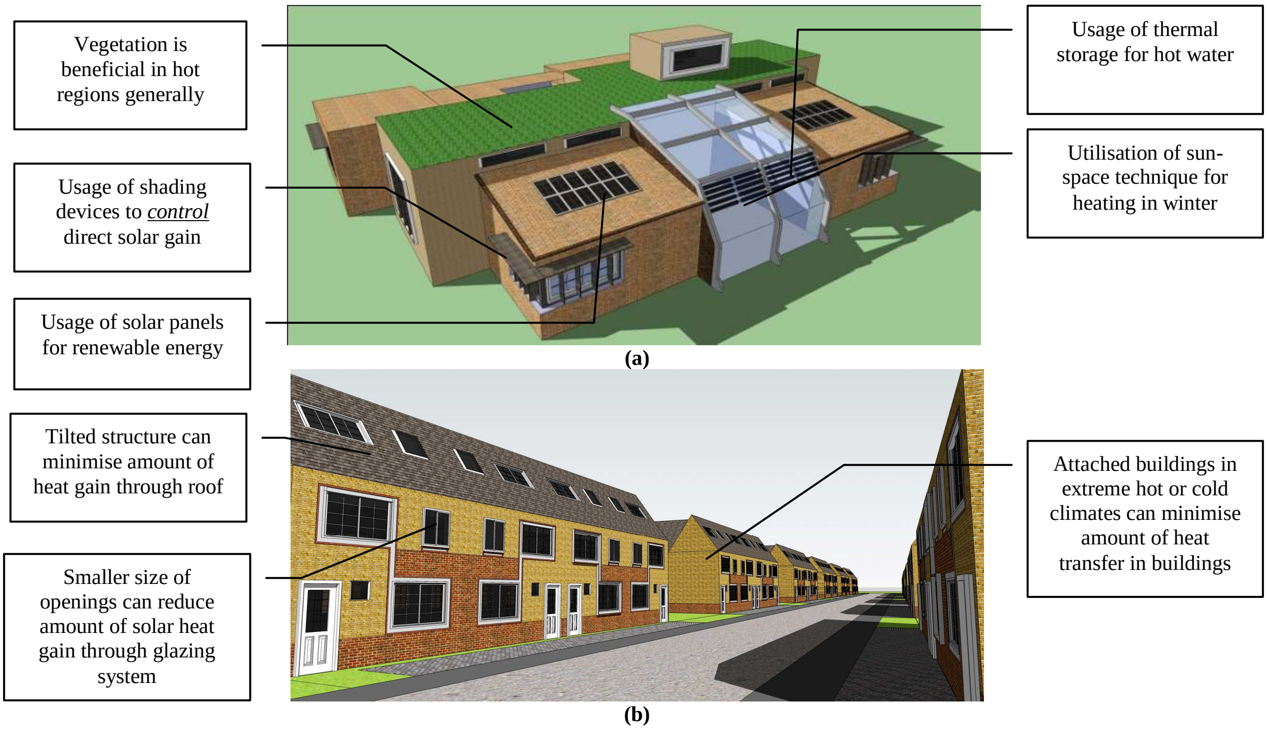

Fig. 1 Sketches of two buildings suitable for AlShifa region (a) and Mecca City (b)

CONCLUSION

According to the recent increased attention to link the building energy performance with microclimate conditions in order to improve the global energy saving strategy and to achieve the required indoor thermal comfort, the current work is presented. Different factors affecting the thermal comfort and linking the microclimate conditions with the building design are discussed and explained. The main idea of the present work is applied to obtain two different architectural design of residential building in two different areas in Saudi Arabia; namely Mecca City and AlShifa-Taif region, where intensive changes in microclimate conditions can be seen. The future work of our group will be directed on the dynamic simulation of the building design to obtain details about the designed building energy performance.

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