EVALUATING THE IMPACT OF SHADING DEVICES ON THE INDOOR THERMAL COMFORT OF RESIDENTIAL BUILDINGS IN EGYPT

***Ahmed A. M. Ali*[a] *Tarek M. F. Ahmed*[b]**

[a] PhD Student, Department of Architecture, Assiut University, Assiut, Egypt
Corresponding author email: ahmed.monteleb@hotmail.com
[b] PhD Student, School of Architecture & Building, Deakin University, Geelong, Australia
eng_tarek911@hotmail.com

ABSTRACT

The building and spaces shape have a great impact on indoor temperature. Well-Designed sun control and shading devices can dramatically affect indoor temperature. The thermal performance of internal spaces in hot arid desert is highly influenced by various passive design techniques, e.g. space dimensions, facade colors, fenestration ratio, glazing type; and vertical and horizontal shading devices. Simulation tools play an important role in taking decision during early design phase that could help in improving the thermal performance of buildings. The aim of this paper is to explore the impact of different shading devices on the thermal performance of residential buildings in Egypt. To achieve this aim of the research, first, the climatic analysis of New Assiut City is introduced followed by identification for the prevailing residential prototypes within the city and the selected residential type. Second, the role of the used Performance simulation tool in enhancing the designs is highlighted. Finally, a simulation has been run for the selected residential site in NA City for the four principal orientations. The results of the study showed that the use of vertical fins have a reducion of 1.5°C in indoor temperature for the northern, eastern, and western orientations. wheras, the combined shade and overhang reduced the temperature by 1.5°C for the southern orientation.

1. INTRODUCTION

Climate is an important factor in the determination of the buildings design parameters such as: the distance between buildings, building geometry, orientation, and envelope. Different design techniques, that could improve thermal comfort, vary greatly from one climatic region to another. Passive design techniques and environmental have a noticeable impact on improving the thermal performance of residential buildings particularly in hot arid desert, however people are no longer using it [9] *"**NA**: New Assiut, **TAS**: Thermal analysis software is a tool developed by the EDSL Company, used to simulate the day lighting, the sun, ventilation, and air flow in buildings"*

Building Peformance Simulation tools play an important role during early design stages. It could helps in design decisions related to shading devices and hence improve the indoor thermal comfort. In Egypt, due to the high temperature and hot climate, people depend on the mechanical equipments to improve the indoor thermal comfort and neglect the use of the passive strartegies that could be more suitable to this extremely arid weather. NA City in Egypt represents a good example of the new desert cities adopted by the government as an alternative solution for the housing problem [7]**.** Consequently, a case study building is selected within the city and simulation is run to identify the appropriate shading device and to what extent the thermal comfort can be imrpoved using the suggested devices.

2. METHODOLOGY

The research has been carried out in two parts. The first part consisted of a introduction and definition of the problem follwed by analysis of the climate. Next, a brief analysis for the case study area and reasons behind the case selection. Finally, a description of the simulation method used and the phases are explained.

The second part is simualtion-based analysis by applying different shading devices for the different orientation of the selected building type Z using TAS simulation tool, readings were taken every hour to obtain the average temperature of the hot period: the study period is as follows: the entire months of May, June, July, August and September; March from 10 am till sunset; April and October from 8 am till 11 pm; and finally the month of November from 12 p.m. till sunset.

2.1. CLIMATIC ANALYSIS OF NA CITY

NA City lies on the eastern bank side of the River Nile, at the intersection point of Cairo-Sohag desert highway with Assiut-Hurghada highway. The city is located approximately 20 km from Assiut, Fig.(1). For the co-ordinates, the city latitude and longitude is 27° 3' N and 31° 15' E respectively and its altitude range from 70 to 100 m above sea level.[1]

NA City consists of two main residential districts divided by a major central service axis. In addition, there is a future extension area for the residential purpose with approximate area (950 feddans: *Feddan: unit used in Egypt to measure land areas, 1 feddan = 4200 m2*). The city also comprises an industrial zone with an area about (180 feddans), Fig (2).

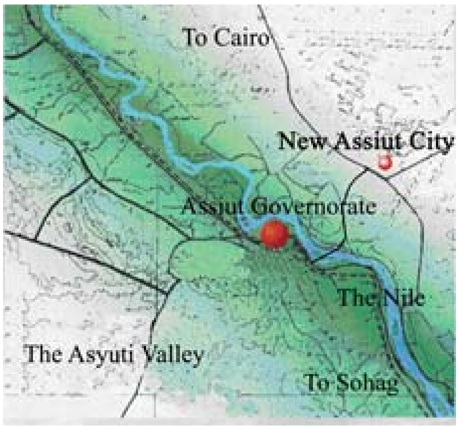
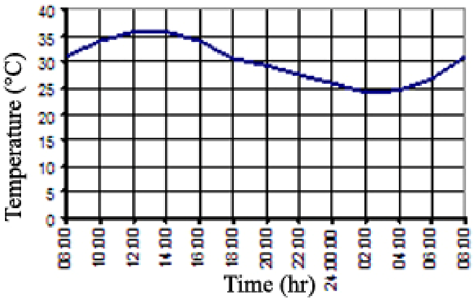


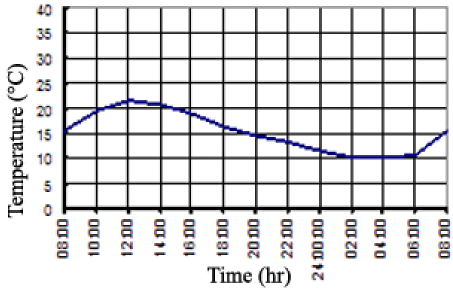
Fig 1 Location of New Assiut City in relation to Assiut Governorate [2]

Fig 2 Master plan of New Assiut City [2]

The climate analysis has been carried out using the data gathered from the Egyptian Meteorological Authority[1], such as Solar radiation intensity, Air temperature, Relative humidity, precipitation and prevailing Wind. Temperature as a climatic variable it varies greatly from one region to another, as a result of different solar exposures. Fig (3) shows the average outdoor temperatures for the hot and cold periods in Egypt. Fig (4) shows the maximum, minimum, and average temperatures all over the year. It illustrates that the maximum temperature in January is 20.8°C, and the minimum is 6.6°C. whereas, the maximum temperature in June is 37.4°C, with a minimum of 21.3°C. while the average temperature in June and January is 29.5°C and 13.6°C respectively.[7]



Average temperatures for summer period (June, July, August)



Average temperatures for winter period (December, January, February)

Fig 3 The average outdoor temperatures for the hot and cold periods in New Assiut City [1]

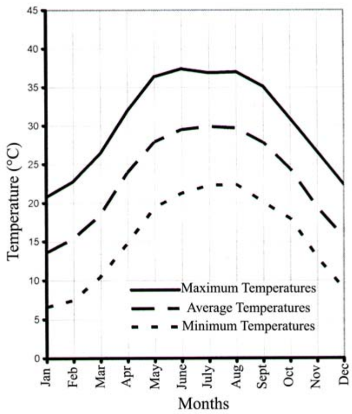


Fig 4 The maximum, minimum, and average temperatures all over the year in New Assiut City [1]

2.2. *IBN BAYTAK* RESIDENTIAL TYPOLOGY

There are various types of residential typologies in the new cities, according to the policy adopted by the government for cities development, and the timetable for establishing such cities and their relevant housing patterns. NA City reveals that there are 14 residential patterns. These typologies are: *Family, Youth and Future; Ibn Baytak, Developed, National and Investment Housing; Urgent Stage, El-zohour, Businessmen and Villas district*. In addition, there are numerous land uses property other than residential ones, e.g. service centers, industrial zones, educational and religious facilities, commercial quarters. Finally, a avacant area allocated for the future extension of Assiut University.[2]

In order to select the case study residential typology and analyze the different types it comprises, the total built-up area for each typology had to be calculated, and the per cent of this typology to the total residential patterns should be identified. Analysis for different residential typologies in NA City revealed that *Ibn Baytak* occupies the largest per cent in the city estimated to be 33.15 of the total area. [2]Consequently, this pattern was selected for conducting climate analysis for its residential sites, and studying the impact of different orientation and shading devices on the thermal performance of the buildings.

Ibn Bytak typology is located in five phases within the city. Fig (5) shows the different phases of *Ibn Baytak*. It is noticed that the first and third phase are located in the second district of the NA City. Whereas the fifth stage is located in the first district. Howver, the second and fourth phases are located in the future extension area of the NA city. The case study in the paper was selected in the first phase. *Ibn Bytak* comprises three building types *X, Y* and *Z*. Type *X* is attached from one side and with three free facades. On the other hand, both Type *Y* and *Z* are attached from two directions and free from the other two, i.e. only two facades. Fig (6) shows the distribution of the three models (*X, Y, Z*) of the first phase of *Ibn Baytak* in NA city.

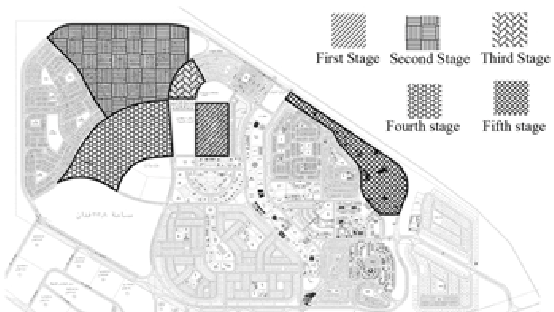


Fig 5 different stages of Ibn Baytak typology in New Assiut City

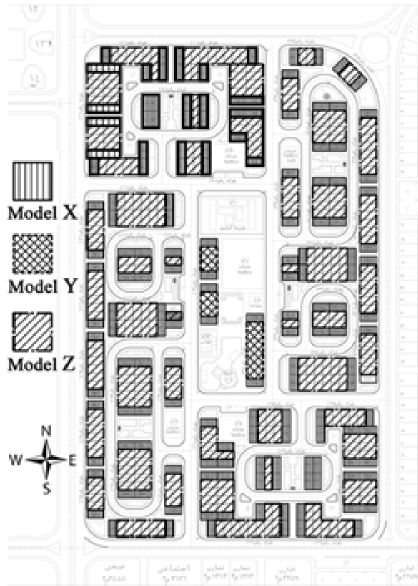


Fig 6 The distribution of the three types (X, Y& Z) in the first stage of Ibn Baytak typology in New Assiut City. [2]

Table (1) illustrates the numbers and percentages of the three models.[2]In this paper simulation is done only for type *Z*. The gross floor area of type Z is 150m2 (17.5x8.6m). The residential type is semi-detached low rise apartment building with a single flat in every floor. It consists of ground and two typical floors with a standard floor height of 2.70m. The 2nd floor (Below the roof) in the residential pattern was chosen to study the impact of shading devices on thermal comfort of the spaces. The reason behind this selection was because the second floor receives the maximum solar radiation intensity, hence the maximum indoor temperature. It should be noticed that during the simulation no thermal insulation on the roof top of the building, was taken into account for the four orientations of the building. Fig (7) shows the architecture plans and facades of type *Z*.

Table 1 percentage of the three Ibn Baytak residential types X, Y&Z

Type	Number	Percentage
Type X	206 plots	40,95 %
Type Y	13 plots	2,60 %
Type Z	234 plots	56,45 %

Back facade of type Z

Typical floor plan [1]
Fig 7 Plans and facades of the selected type Z in Ibn Baytak typology, New Assiut City [2]

2.3. BUILDING SIMULATION TOOL **TAS** DESCRIPTION

During the last five decades, numerous simulation programs – studying the thermal behavior inside buildings – have been developed. These programs are based on information presented by software developers about: general modeling characteristics, outside climatic elements (daylighting, solar gain, ventilation, and air flow), as well as studying the electrical systems and equipment, HVAC systems.[3]

TAS is a building performance simulation tool for the assessment of thermal performance of buildings. It calculates the heating and cooling loads resulting from inside and outside the residential building. The program adopts the mechanical simulation principle, by tracking the thermal behavior of the building via various snapshots taken every hour. This gives users a detailed image of the way the building performs.[4] Fig (8) shows a diagram of the internal & external processes. It shows heat transfer to and from the building, via different heat transfer mechanisms.[5] The program, Thermal Analysis Software, is a sophisticated calculations engine for a 3D model maker (Also called: Tas3D).[6]There are three main components of the program: **TAS** 3D Modeler, **TAS** Building Simulator, **TAS** Results Viewer. Fig (9) shows the normal sequence of performing simulation for each application in the triple TAS package. First, the 3D model-maker is used for making the geometrical shape of the building, and specifying the borders of each space. Then the geometrical shape, the building elements, zones, and surfaces are sent to the building simulation application. In the course of sending, different calculations may be performed. [6]

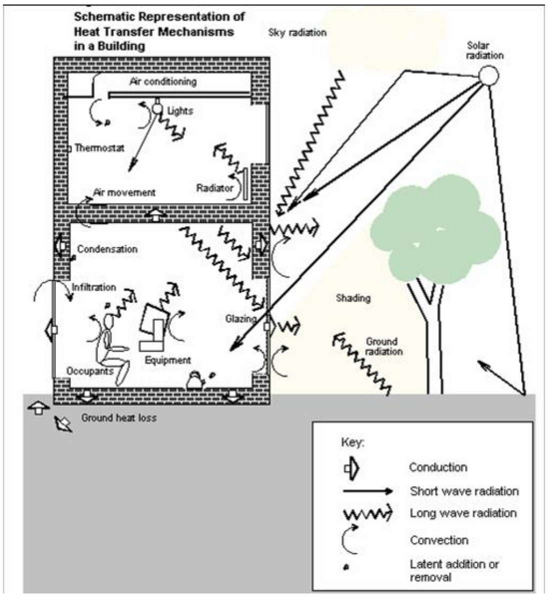


Fig 8 The influence of temperature on the outer envelop of the building andindoor.[6]

Fig 9 The logic sequence of using TAS [6]

The program interface includes orders of preparing and drawing the building, making door & window openings, different shades for openings, as well as other settings. This facilitates use and makes the program more productive. Below is an explanation of these components.[6]TAS has the capability of drawing the 3D building to be simulated. It can also draw buildings under planning or in the sketching phase, or even import AutoCAD drawings for making more detailed models – fig. (10).From this model, a 3D image – displaying shade in complete – can be made. Also, the program calculates sun light penetration into the building between spaces. In addition, the model can be exported to a 3D program.

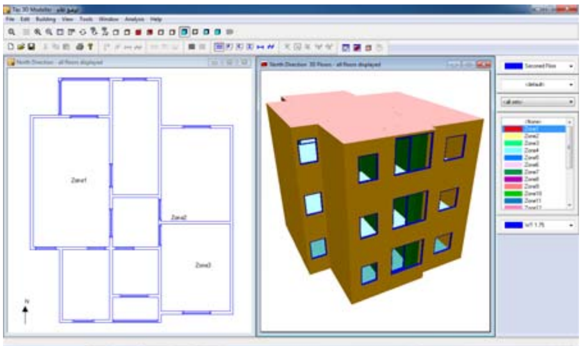


Fig 10 Building up the model. [6]

The software requires entering all the data of the residential model. These data include: the climatic data of the region, the building occupancy hours, vacancy hours, structural elements constituting the building, number of hours in which windows are open and the ratio of openings, the potential of providing different shading devices, and the thermal loads resulting from elements inside residential spaces (people, equipment and lighting) as shown in fig. (11).

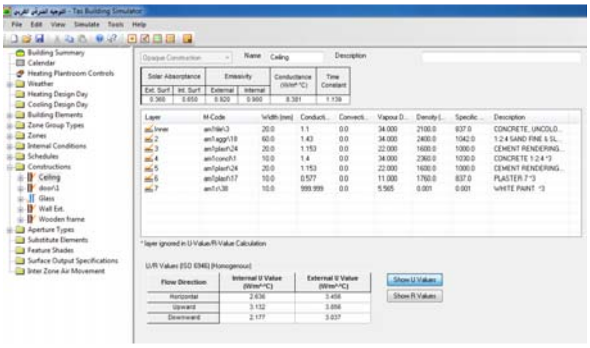


Fig 11 Data insertion for the simulation model in TAS.

Any given set of parameters, for any number of zones and surfaces, can be displayed and compared in the form of tables and curves. So, other parties' applications can be incorporated using the automation software for the purpose of input and output data. Even large simulation results files, up to hundreds of megabytes, can be rapidly processed using this technique. They can be converted to file such as Word and Excel for analytical purposes – fig (12).[6]

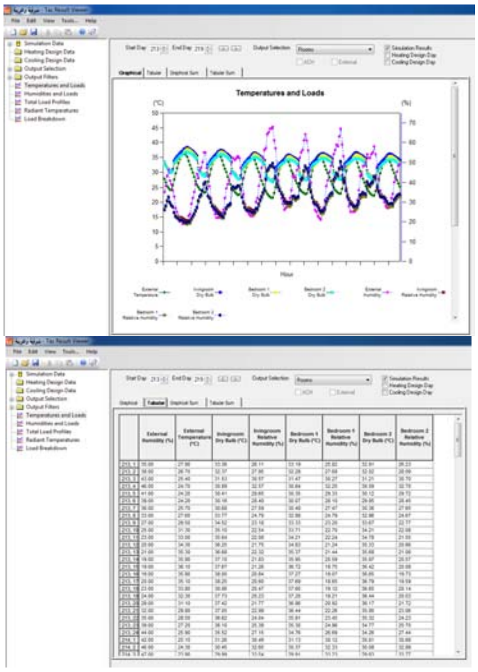


Fig 12 Method of displaying the results (tables & curves)

3. ANALYSIS & RESULTS

A field measurements was previously done by (El-Shemiry, 2006) for a different building type located in the same city. Results from the study were gathered and a simualtion calibration model was built by the author to inevstigate the validation of the simulation tool in prediciting the building performance. The simuation was validated via comparison between the filed measurements and simulation results for the hot and cold period. The calibration model showed that the difference between both were only 2% which makes the tool results reliable in hot climate in NA city.

In the simuation phase three shading devices that have proven to be appropriate to the hot arid climate in Egypt, the vertical fins, overhangs and combined one (combination between both vertical fins & overhangs). [1]. In addition to basecase scenario without any shading device. For all the shading scenarions fixed thickness 12cm for the devices is chosen and different projection of 12, 25, 38, 50, 75 and 100cm is applied. For the vertical fins , it is assumed that the fins extend along the building façade on both sides of the window. In all the simualtion scenarios, constant building materials, finishing, glass and window type, openings ratio are taken into account. In Table (2), (3) and (4) the specification and characteristics of different building components are presented. For the internal thermal loads, occupation density of 2person/room, furniture, appliances, two florscent lighting are taken into account during the simulation. The calculation of the loads included appliance and light heat; occupants body heat; and occupants heat due to respiartion and activities and Infiltration of outside air Accordingly, the total internal thermal loads are estimated to be 26 w/m2. Ibn Baytak residential pattern is an unnconditined one. However, No HVAC systems were added during simulation as the purpose of the study is to investigate only the impact of passive design strategies only on improving the indoor thermal comfort.

Table 2 Roof attributes for residential type Z

Material	Width (mm)	Conductivity (Watt/m. °C)	Specific Heat (J/ kg. C)
Concrete slab	20	1.10	837
Sand	60	1.43	1042
Mortar	20	1.513	1000
Reinforced concrete	120	2.40	1030
Cement covering	1	0.577	837
White paint	0.1	999.99	0.001

Table 3 Building materials attributes for internal & external walls

Material	Width (mm)	Conductivity (Watt/m. °C)	Specific Heat (J/ kg. C)
Cement covering	1	999.99	0.001
White paint	0.1	0.577	837
Mortar	20	1.53	1000
Red Brick	120	1.33	920
Mortar	20	1.53	1000
Cement covering	1	0.577	837
White paint	0.1	999.99	0.001

Table 4 Glazing thermal attributes

Material	Width (mm)	Solar reflection	emissivity	Specific Heat (J/ kg. C)
Glass	6	0.15	0.845	0.001

Simulation was run hourly during the day for the master building room in residential Type *Z*, fig.(13). Thus, the average temperatures for the hot period and the over heated period can be obtained as shown in fig. (14); as stated[8].

Fig13 Typical floor Ibn Baytak residential type.

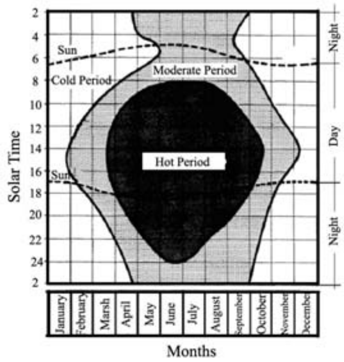


Fig 14 climatic periods in New Assiut City [1].

3.1. THE NORTHERN ORIENTATION

In the northern orientation, the values of indoor temperatures of the Master bedroom for different shading devices types adjoining the room window are shown fig (15). From the figure, it was observed that temperatures were reduced when shading devices were used in the hot period. A noticeable reduction of 1.5°C was ccomplished in the indoor temperature when the vertical shade was used on both sides of the window in the northern façade. The highest temperature was recorded at 6 p.m., while the lowest was at 6 a.m.

. The highest temperature was 34.01°C.; the lowest was 27.09°C. The overhang recorded the highest values of indoor temperatures. The highest temperature was 34.81°C; the lowest was 27.85°C. Finally, the combined shade recorded the highest temperatures inside the space; the highest was 35.15°C and the lowest was 28.22°C. It was obeserved that the vertical fins adjoining the wiindows recorded the lowest temperature among other shading devices. By applying different shading projection, vertical fins with projection of 38cm recorded the lowest indoor temperature. It was also noticed that by any increasing in the projection and up to 100cm results only in a slight decrease in the indoor temperature.

3.2. THE EASTERN ORIENTATION

In the eastern orientation, the values of indoor temperatures of the master bedroom for different shading devices types adjoining the room window are presented in fig (16). From the figure, it was observed that temperatures were reduced when shading devices were used in the hot period. As per the northern facade a noticeable reduction of 1.5°C was accomplished in the indoor temperature when the vertical fins were used on both sides of the window. The highest temperature was recorded at 6 p.m., while the lowest was at 6 a.m. For the base case scenario, the highest temperature was 34.22°C and the lowest was 27.08°C. While, the overhang recorded a maximum temperature of 34.68°C and the minimum was 27.56°C. Finally, the combined shade recorded the highest indoor temperatures were the maximum was 35.47 °C and the minimum was 28.33 °C. It was obeserved that the vertical fins adjoining the window recorded the lowest temperature among other shading devices. By applying different shading projection, vertical fins with projection of 100cm recorded the lowest indoor temperature with a reduction 1.5°C. A projection of 12 cm showed only a slight decrease in indoor temperature.

3.3. THE SOUTHERN ORIENTATION

In the Southern orientation, the values of indoor temperatures of the master bedroom for different shading devices types adjoining the room window are presented in fig (17). From the figure, it was observed that temperature was reduced when shading devices were applied in the hot period. A noticeable reduction of 1.5°C was accomplished when the combined shade was used in the southern façade. The maximum temperature was reached at 5 p.m., while the minimum was at 6 a.m. The combined shade recorded the lowest values of indoor temperatures in the hot period for the southern orientation. For the base case scenario, the highest temperature was 34.30°C.; the lowest was 27.31°C. on the other hand, the overhang recorded a maximum temperature of 34.86°C; the minimum was 27.83°C. Finally, the vertical fins recorded the highest indoor temperatures the maximum was 35.10°C and the minimum was 28.08°C. By applying different shading projection, combined shade with projection of 100cm recorded the lowest indoor temperature were the highest temperature during the day was 33.51°C and the lowest was 26.70°C.

3.4. THE WESTERN ORIENTATION

In the western orientation, the values of indoor temperatures of the master bedroom for different shading devices types adjoining the room window fig are presented in fig(18). From the figure, it was observed that temperatures were reduced when shading devices were used in the hot period. As per the western facade noticeable reduction of 1.5°C was accomplished when the vertical shade was used on both sides of the window. The maximum temperature was reached at 6 p.m., while the minimum was at 6 a.m. For the base case scenario the highest temperature was 35.16°C and the lowest was 27.32°C. Next, was the overhang recorded a maximum temperature of 35.61°C and the minimum was 27.80°C. Finally, the combined shade recorded the highest indoor temperatures the maximum was 36.44°C; and the minimum was 28.67°C. By applying different shading projection, combined shade with projection of 100cm recorded the lowest temperature were the highest temperature during the day was 35.33°C and the lowest was 27.36°C.

4. CONCLUSION

This study aims to study the passive desgin strategies i.e. shading devices on indoor thermal comfort of residential buildings in hot arid areas. Climatic analysis for the NA city was introduced. A residential prototype *Ibn Baytak* in NA city was chosen as case study and detailed analysis for the prototype was provided. A semi detached unconditioned low-rise type *(Z)* was used to conduct the analysis. Three types of shading devices, vertical fins, Overhang and combined of both, adjoined to the window were applied. The study presented a short description for the simulation tool to explore its capabilities. Simulation-based analysis was done for the different shading devices over the four orientations for the hot period. The vertical fins proved to be more efficient in the northern, eastern and western façade were a reduction of 1.5°C was achieved as the sun is close to the horizon. Wheras for the southern façade the combined one proved to be more efficient with average reduction of 1.5°C as the sun is far away from the horizon. Passive design strategies are powerfull in hot arid climate were. By using these strategies a noticeable reduction in indoor air temperature could be achieved without the need to use mechanical systems for cooling and thus energy savings. Shading devices is only one technique others such as building orientation, glazing type and openings ratio, wall thickness, and insulation etc. can play an important role in reducing indoor temperature as well.

Using simulation software in early design phase for different kinds of buildings is important in order to achieve a climatic responsive architecture for newly designed residential buildings and to observe the existing situation for retrofitting purposes. There is a need for a computational simulation-based tool that could provide a combination between all these passsive design strategies to achieve the optimum thermal comfort.

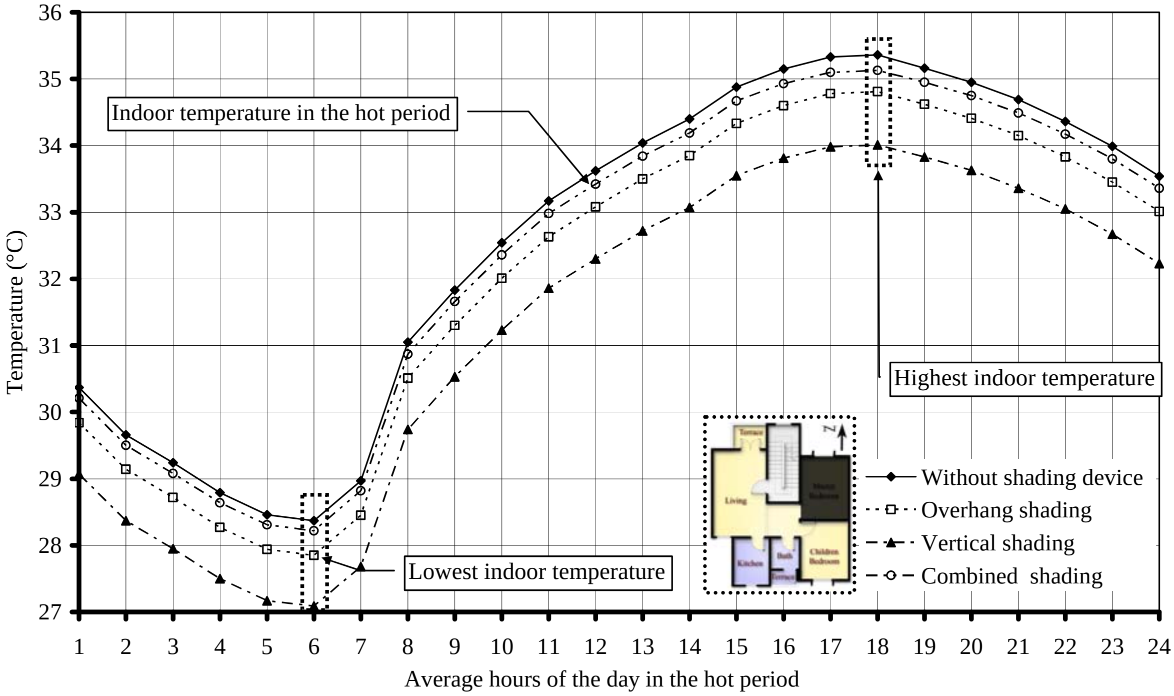


Fig 15 Values of indoor temperatures for the Northern oriented bedroom, for different shading devices types adjoining the room window – in the residential model (hot period)

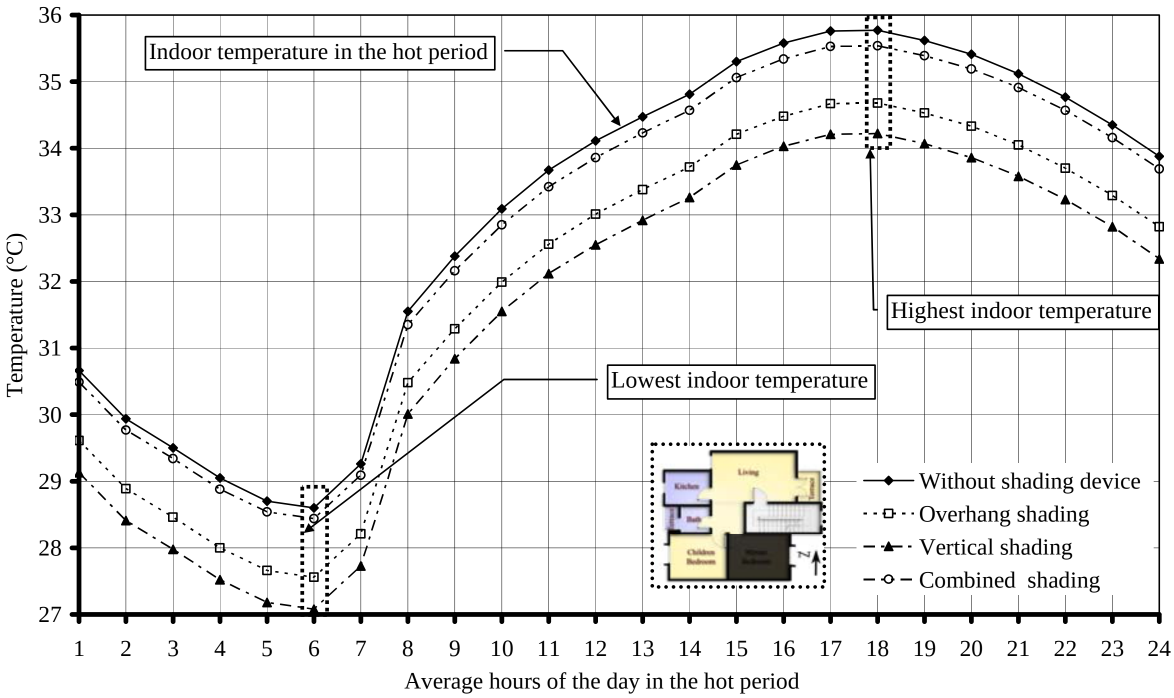


Fig 16 Values of indoor temperatures for the Eastern oriented bedroom, for different shading devices types adjoining the room window – in the residential model (hot period)

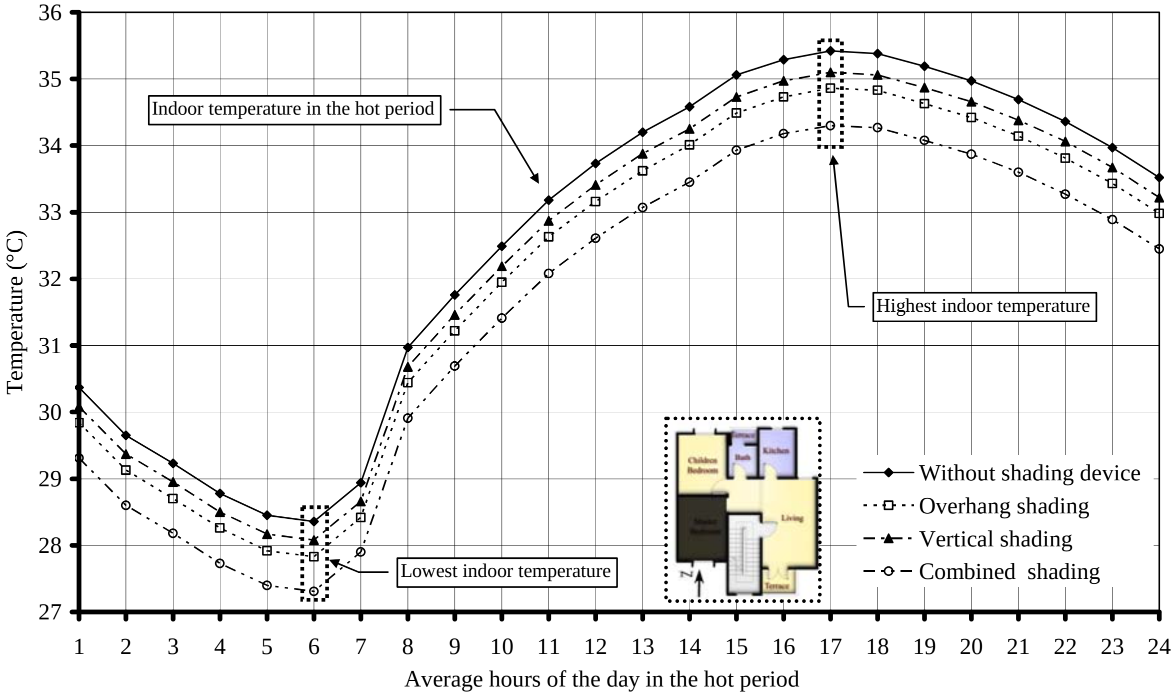


Fig 17 Values of indoor temperatures for the Southern oriented bedroom, for different shading devices types adjoining the room window – in the residential model (hot period)

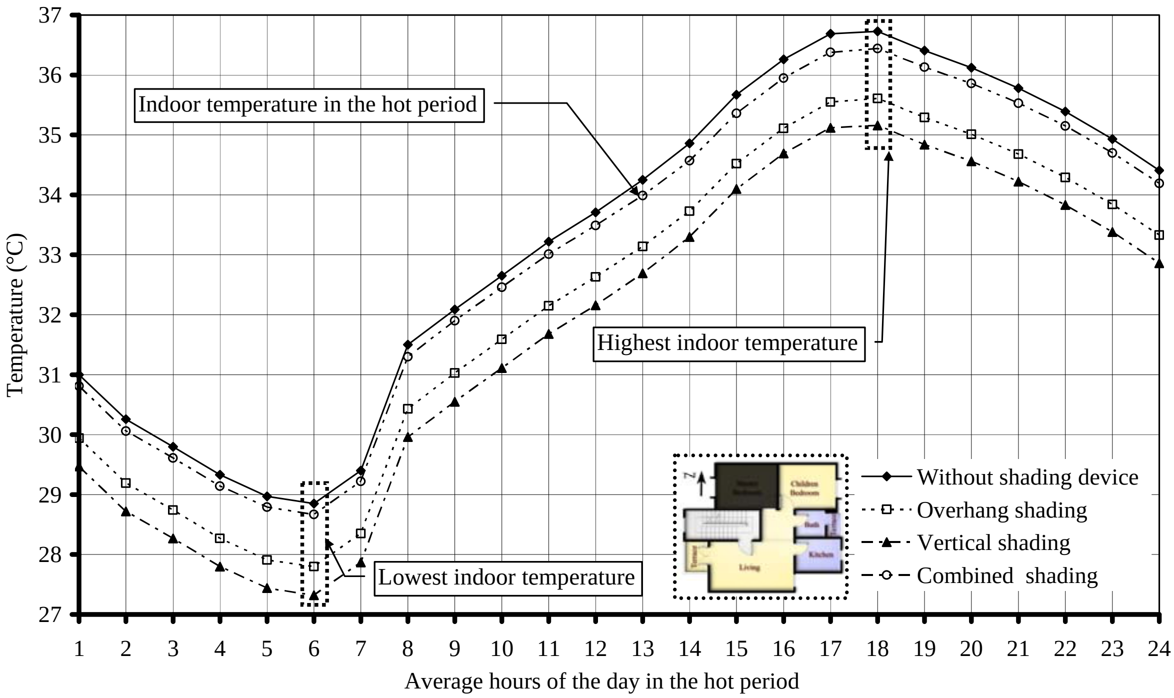


Fig 18 Values of indoor temperatures for the Western oriented bedroom, for different shading devices types adjoining the room window – in the residential model (hot period)

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