Military Technical College
Kobry El-Kobbah,
Cairo, Egypt

9th International Conference on Civil and Architecture Engineering
ICCAE-9-2012

Passive design techniques: The effect of Shading devices on the thermal performance of residential buildings in Egypt

Ahmed Abd El-Monteleb Mohammed Aly [a]

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 interior 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 present the effect of 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 patterns within the city and the selected residential model. Second, the role of the used simulation tool in enhancing the designs is highlighted. Finally, a simulation has been run for the selected residential model in New Assiut City over the four cardinal orientations. The results of the study showed that the vertical louvers decrease of 1.5°C in indoor temperature in northern, eastern, and western orientations as compared to the southern one. Also, the study showed that the Composite shades and horizontal shading device decrease of 1.5°C in the southern orientation.

Keywords:

(Simulation tools; Shading devices; Thermal performance; New Assiut City)

1. Introduction

Climate is an important factor in the determination of the design parameters such as: the distance between buildings, building shape, orientation, and envelope. The design techniques, which influence thermal comfort, vary greatly from one climatic region to another. Passive design techniques have an obvious impact on the thermal performance of residential buildings particularly in hot arid desert.

Simulation software are new tools that could be used during early design phase to evaluate the performance of different shading devices in order to assist in choosing the more suitable ones. NA City in Egypt represents an example for the desert areas in Egypt. Therefore, the case study was chosen in this area where the

---

Abbereviations: **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.

[a]Assistant Lecturer, Department of Architecture, Faculty of Engineering, Assiut University, Egypt, Tel: 002/010/5490811, ***ahmed.monteleb@hotmail.com***

simulation is applied on the selected model to explore the impact of the shading device types on the thermal performance of residential buildings.

2. Method

The research has been carried out in two parts. The first part consisted of a literature review and analysis of the local context. The second part is based on simulation for the residential model.

In the first part, the local climate for NA City is analyzed. In order to choose the residential model, i.e. the case study, analysis of residential patterns exis t in the city is done to determine the percentage of each pattern in the city, and it was found that the residential Type (Ibn Bytak) ranks the first among all in terms of area. Accordingly, the study focuses on this type and the different residential mo dels it comprises. Type Z, a semi- detached low-rise residential model, was selected to study the impact of shading devices on the thermal performance of this model.

In the second part, a simulation is run for the aforementioned residential model Z using TAS, 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. The 2nd floor (Below the top floor) in the residential model was chosen to study the effect of shading devices on the residential spaces in it, because it receives the maximum intensity of solar radiation, hence the maximum indoor temperature. It should be noticed that no thermal insulation on the roof top of the building, was taken into account during the simulation running for the four orientations of the building.

3. The 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 and Assiut-Hurghada highway, distant approximately 20 km from Assiut, Fig.(1). The city latitude and longitude is 27° 3' N and 31° 15' E and its altitude range from 70 to 100 m above sea level.[1]

The urban mass of NA City consists of two main residential districts sep arated by a major central service axis. Moreover, there is a future extension area for the residential purpose with approxima te area (950 feddans)[*] and it also embraces an industrial zone with an area about (180 feddans), Fig (2).

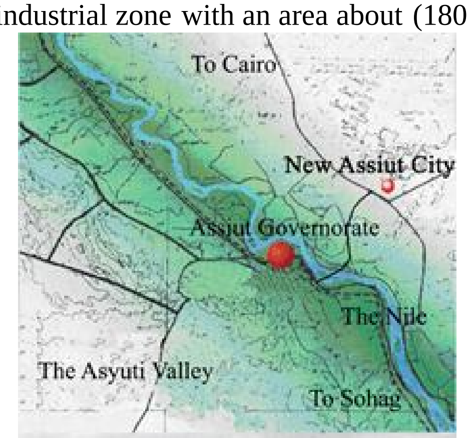


Fig (1): Location of New Assiut City

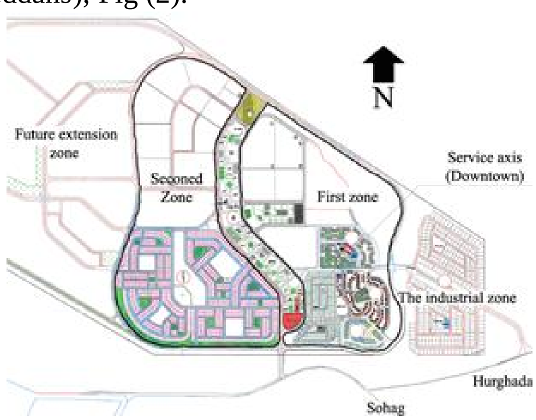
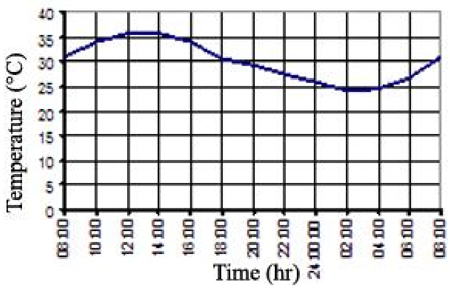


Fig (2): Site of New Assiut City [2]

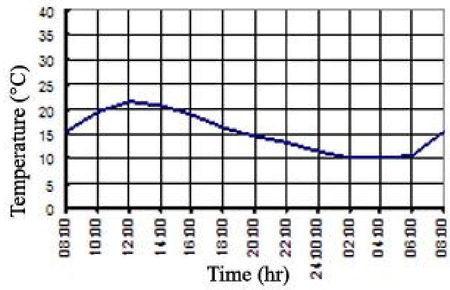
[*] Feddan: is the a unit used in Egypt to measure land areas , 1 feddan = 4200 m2.

in Assiut Governorate [2]

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

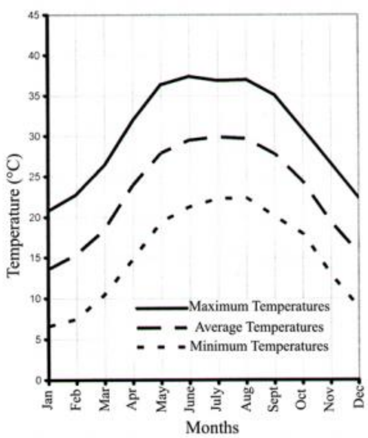


Average temperatures for summer months (June, July, August)



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

Fig (3): shows the average outdoor temperatures for the hot and cold periods in New Assiut City [1]



Fig(4): shows the maximum, minimum, and average temperatures all over the year in New Assiut City [1]

4. Ibn Bytak residential Model

There are various types of residential patterns 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 patterns 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, e.g. service centers, industrial zones, educational and religious facilities, commercial quarters and an area allocated for the future extension of Assiut University .[2]

To study a residential pattern and analyze its models, the area of each pattern had to be calculated, along with its percentage in the housing of NA City. Analysis for housing patterns in NA City shows that Ibn Baytak ranks first in the city with a 33.15

% of the total patterns area. Consequently, this pattern was selected for conducting climate analysis for its residential models, and studying the impact of different orientation and shading devices on the thermal performance of the buildings.[2]

Ibn Bytak consists of five phases. Fig (5) shows the different phases of Ibn Baytak project in the city. It is noticed that the first and third phase are located in the second district. Whereas the fifth stage in the first district, and the second and fourth phases are located in the future extension area of the city.

The case study is chosen in the first phase for studying the impact of shading devises on the thermal performance of the model.

The selected model comprises three building types X, Y and Z. Model X is attached from one side and with three free facades. For Models Y and Z both two 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.

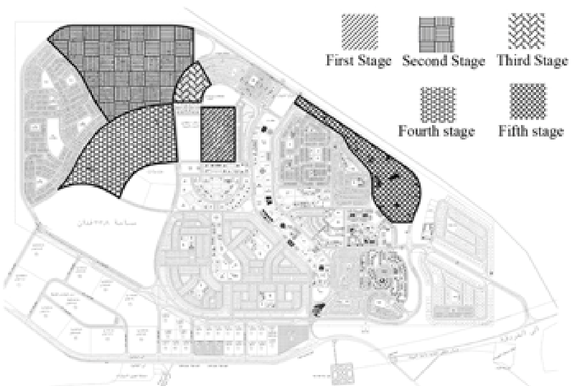


Fig (5): Stages of implementing Ibn Baytak in New Assiut City

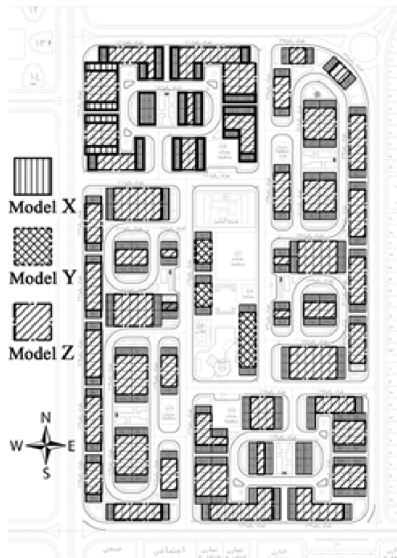


Fig (6): The distribution of the three models (X, Y, Z) of the first stage of Ibn Baytak in New Assiut City. [2]

Table (1) illustrates the numbers and percentages of the three models.[2]In this paper analysis is done only on type Z. The total area of the model Z is 150m^2 (17.5x8.6m). The model consists of ground and two typical floors with a floor height of 2.70m. Fig (7) shows the plans and facades of model (Z).

Table (1): Numbers and percentages of the three Ibn Baytak models

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

Back facade of model Z Front facade of model Z Typical floor plan [1]

Fig (7): shows the plans, and facades for the selected model (z) – Ibn Baytak project, New Assiut City [2]

5. Building Simulation software TAS

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, the sun, ventilation, and air flow), as well as studying the electrical systems and equipment, HVAC systems. [3]

TAS is a program for the assessment of thermal behavior. 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]

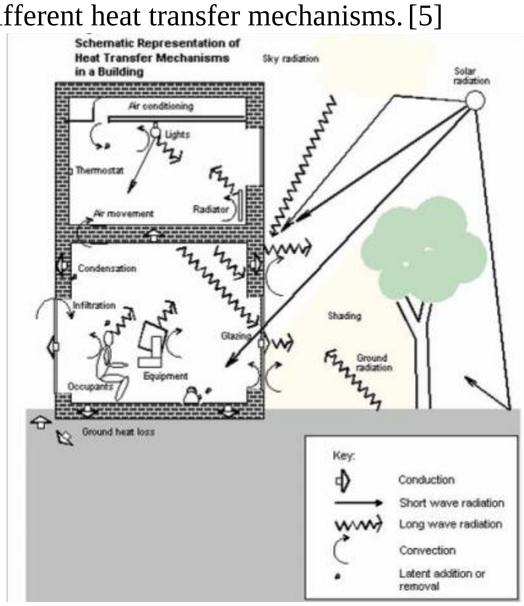


Fig (8): The influence of temperature on the outer envelop of the building and its interior spaces.[6]

The program, **T**hermal **A**nalysis **S**oftware, 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 (9): The normal 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 pr oductive. 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.

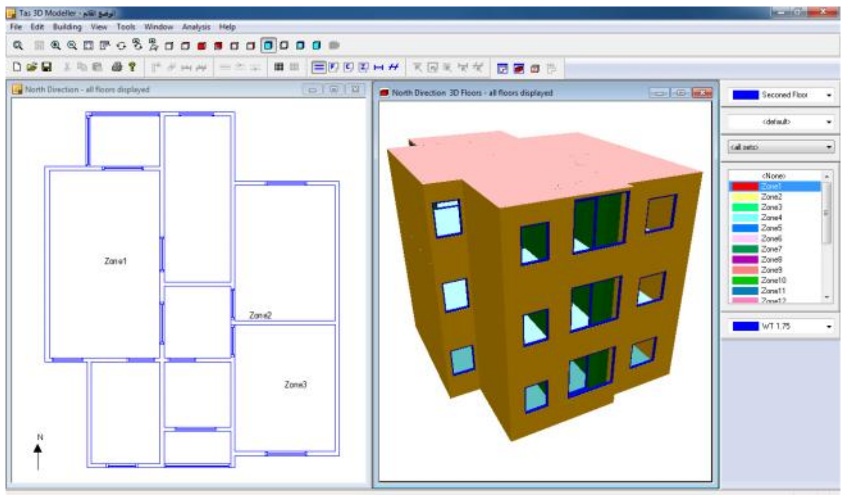
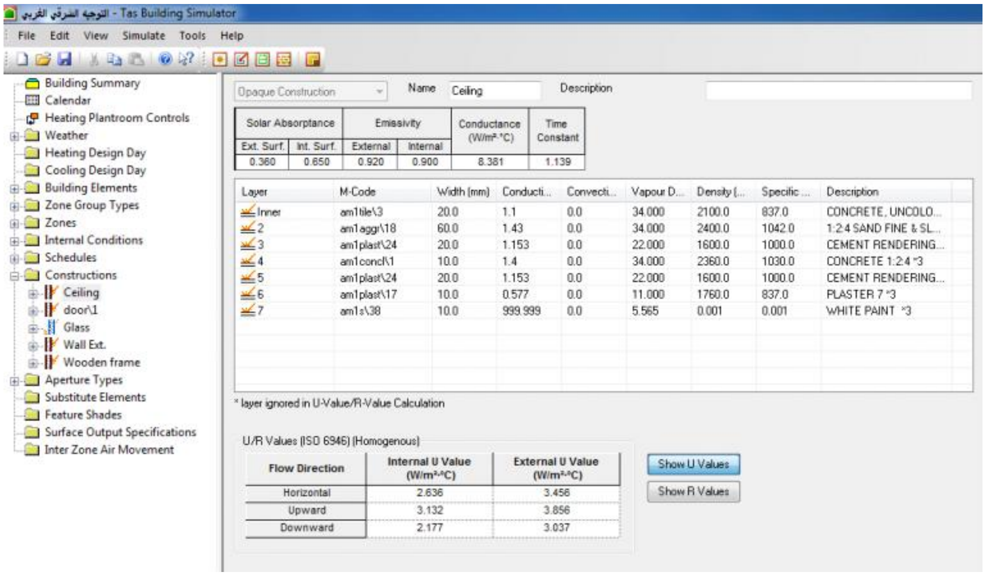


Fig (10): The program window for the residential model to be simulated. [6]

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 reside ntial spaces (people, equipment and lighting) as shown in fig. (11).



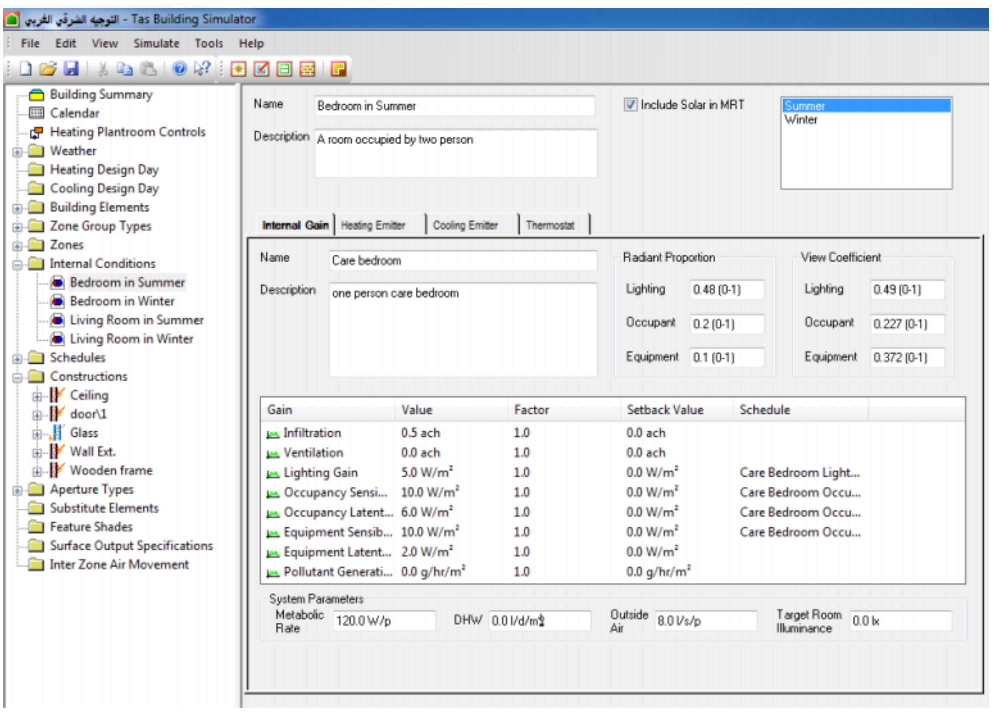
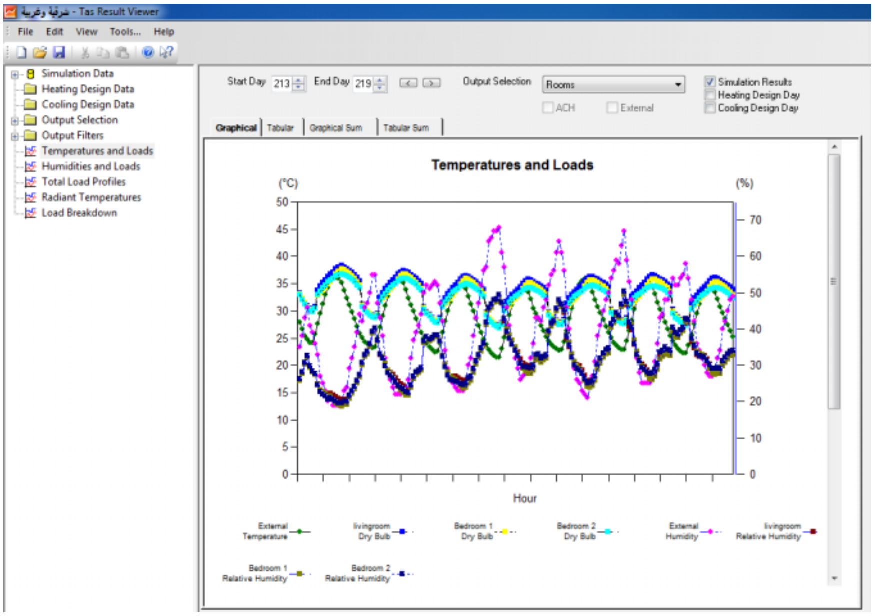
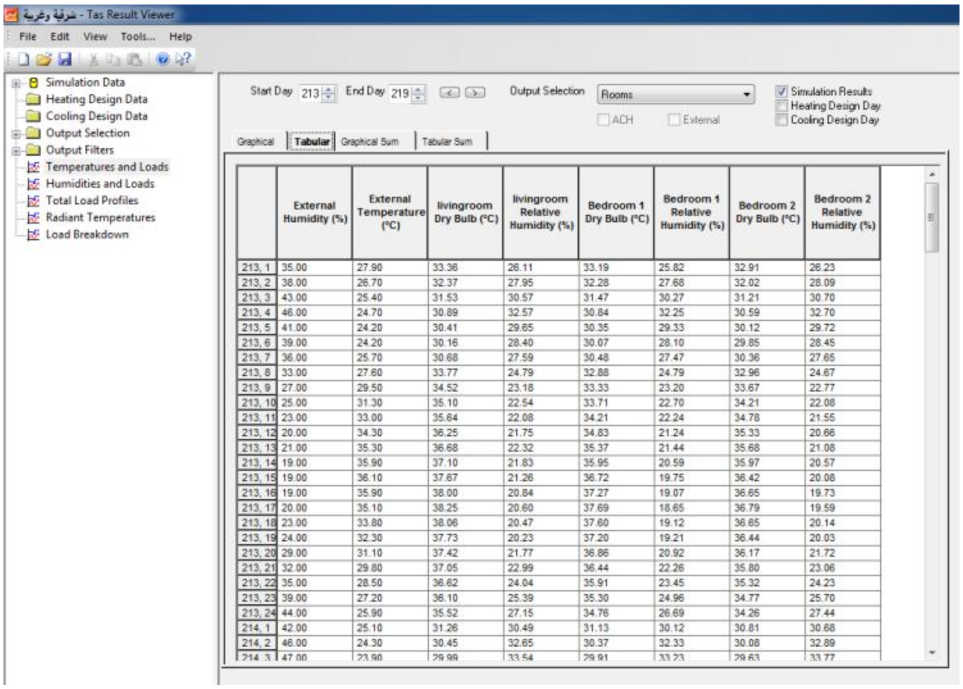


Fig (11): The window of entering the data of the residential model to be simulated.

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]





	External Humidity (%)	External Temperature (°C)	livingroom Dry Bulb (°C)	livingroom Relative Humidity (%)	Bedroom 1 Dry Bulb (°C)	Bedroom 1 Relative Humidity (%)	Bedroom 2 Dry Bulb (°C)	Bedroom 2 Relative Humidity (%)
213, 1	35.00	27.90	33.36	26.11	33.19	25.82	32.91	26.23
213, 2	38.00	26.70	32.37	27.95	32.28	27.68	32.02	28.09
213, 3	43.00	25.40	31.53	30.57	31.47	30.27	31.21	30.70
213, 4	46.00	24.70	30.89	32.57	30.84	32.25	30.59	32.70
213, 5	41.00	24.20	30.41	29.65	30.35	29.33	30.12	29.72
213, 6	39.00	24.20	30.16	28.40	30.07	28.10	29.85	28.45
213, 7	36.00	25.70	30.68	27.59	30.48	27.47	30.36	27.65
213, 8	33.00	27.60	33.77	24.79	32.88	24.79	32.96	24.67
213, 9	27.00	29.50	34.52	23.18	33.33	23.20	33.67	22.77
213, 10	25.00	31.30	35.10	22.54	33.71	22.70	34.21	22.08
213, 11	23.00	33.00	35.64	22.08	34.21	22.24	34.78	21.55
213, 12	20.00	34.30	36.25	21.75	34.83	21.24	35.33	20.66
213, 13	21.00	35.30	36.68	22.32	35.37	21.44	35.68	21.08
213, 14	19.00	35.90	37.10	21.83	35.95	20.59	35.97	20.57
213, 15	19.00	36.10	37.67	21.26	36.72	19.75	36.42	20.08
213, 16	19.00	35.90	38.00	20.84	37.27	19.07	36.65	19.73
213, 17	20.00	35.10	38.25	20.60	37.69	18.65	36.79	19.59
213, 18	23.00	33.80	38.06	20.47	37.60	19.12	36.65	20.14
213, 19	24.00	32.30	37.73	20.23	37.20	19.21	36.44	20.03
213, 20	29.00	31.10	37.42	21.77	36.86	20.92	36.17	21.72
213, 21	32.00	29.80	37.05	22.99	36.44	22.26	35.80	23.06
213, 22	35.00	28.50	36.62	24.04	35.91	23.45	35.32	24.23
213, 23	39.00	27.20	36.10	25.39	35.30	24.96	34.77	25.70
213, 24	44.00	25.90	35.52	27.15	34.76	26.69	34.26	27.44
214, 1	42.00	25.10	31.26	30.49	31.13	30.12	30.81	30.68
214, 2	46.00	24.30	30.45	32.65	30.37	32.33	30.08	32.89
214, 3	47.00	23.90	29.99	33.54	29.91	33.23	29.63	33.77

Fig (12): The window for displaying results (tables & curves)

6. Results [*]

Simulation is run for the Z residential model, 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 before for every hour by hour during the day. This simulation

[*] The accuracy of simulation results was compared to a previous study (R.M. El-Shemiry, The Effect of Climatic Conditions on Residential Clusters of Desert Cities in Upper Egypt, (Assiut New City as a Case Study), M.Sc., Dept. Architecture, Faculty of Engineering, Assiut University, 2006). The correction factor was 2.00-2.50 %.

has been applied over the four cardinal directions (north, east, south, and west) and the following types of shading devices are studied: the vertical, the horizontal, and the composite.

Fig (13): The Ibn Baytak residential model being studied.

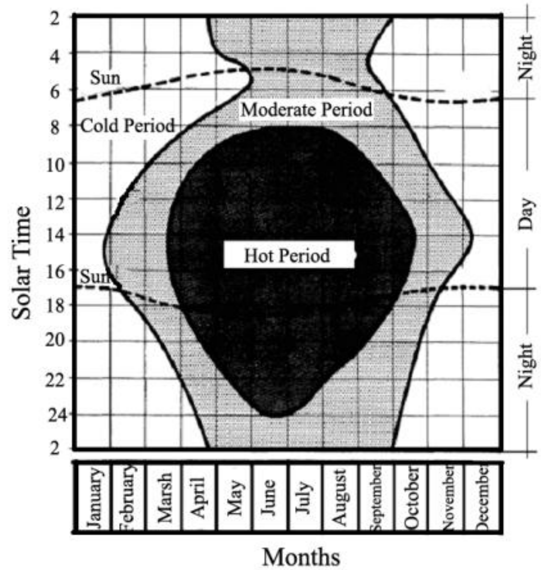


Fig (14): Table of the annual times for climatic periods in New Assiut City [1].

6.1. The Northern orientation

In the northern orientation, the values of indoor temperatures of the bedroom for different shading devices types adjoining the room window fig (15).

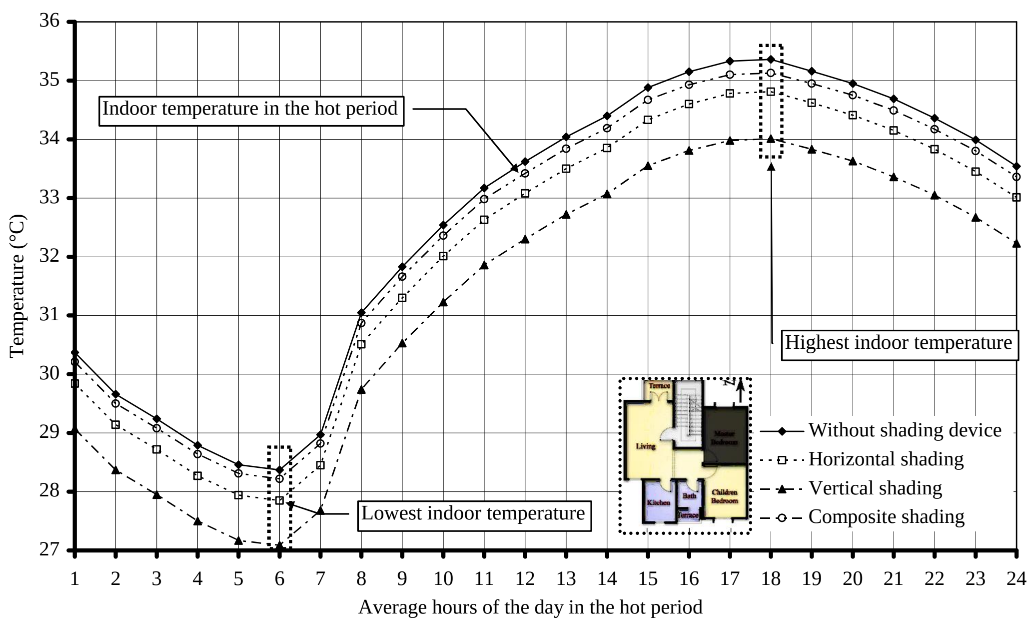


Fig (15): Values of indoor temperatures for the Northern oriented bedroom, for different shading devices types adjoining the room window – in the residential model (hot period)

From the above figure, it was observed that temperatures were reduced when shading devices were used in the hot period. A noticeable reduction was accomplished when the vertical shade was used on both side s of the window in the northern façade; about 1.5°C. The maximum temperature was reached at 6 p.m., while the minimum was at 6 a.m.

Vertical shades recorded the lowest values of indoor temperatures in the hot period. The highest temperature was 34.01°C.; the lowest was 27.09°C. The horizontal shading device recorded the highest values of indoor temperatures. The highest temperature was 34.81°C; the lowest was 27.85°C. Finally, the composite shade recorded the highest temperatures inside the space; the highe st was 35.15°C; and the lowest was 28.22°C.

From the above, it can be inferred that the most appropriate shading device for the northern facade spaces is the vertical one on both sides of the window. The worst device is the composite shade.

6.2. The Eastern orientation

In the eastern orientation, the values of indoor temperatures of the bedroom for different shading devices types adjoining the room window fig (16).

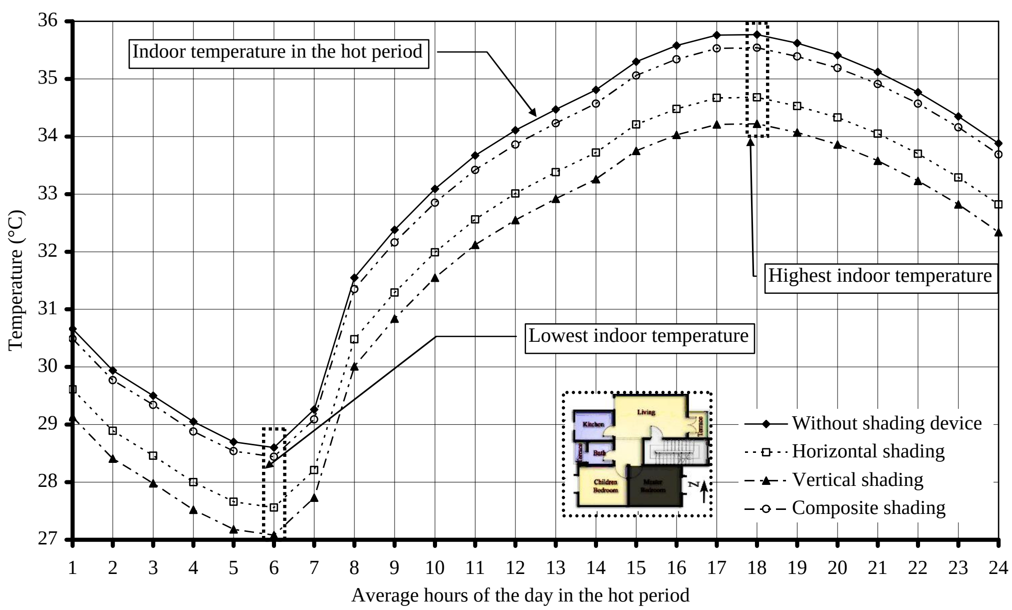


Fig (16): Values of indoor temperatures for the Eastern oriented bedroom, for different shading devices types adjoining the room window – in the residential model (hot period)

From the above figure, it was observed that temperatures were reduced when shading devices were used in the hot period. A noticeable reduction was accomplished when the vertical shade was used on both sides of the window in the eastern façade; about 1.5°C. The maximum temperature was reached at 6 p.m., while the minimum was at 6 a.m.

Vertical shades recorded the lowest values of indoor temperatures in the hot period; for the eastern orientation. The highest temperature was 34.22°C.; the lowest was 27.08°C. The horizontal shading device recorded a maximum temperature of 34.68°C; the minimum was 27.56°C. Finally, the composite shade recorded the highest temperatures inside the space; the maximum was 35.54°C; and the minimum was 28.44°C.

From the above, it can be inferred that the most appropriate shading device for the eastern façade spaces is the vertical one on both sides of the window. The worst device is the composite shade.

6.3. The Southern orientation

In the Southern orientation, the values of indoor temperatures of the bedroom for different shading devices types adjoining the room window fig (17).

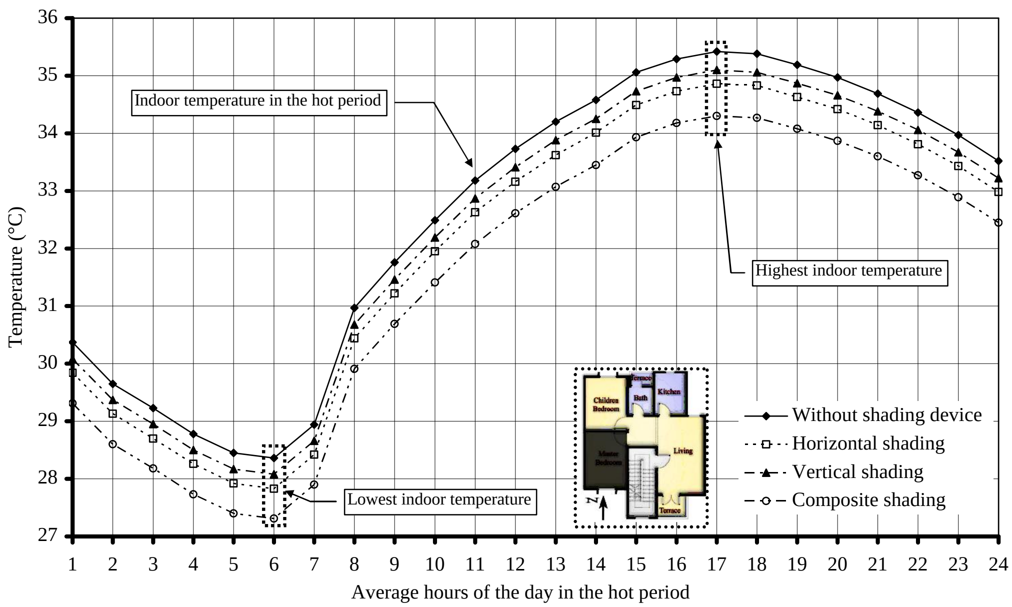


Fig (17): Values of indoor temperatures for the Southern oriented bedroom, for different shading devices types adjoining the room window – in the residential model (hot period)

From the above figure, it was observed that temperatures were reduced when shading devices were used in the hot period. A noticeable reduction was accomplished when the composite shade was used in the southern façade; about 1.5°C. The maximum temperature was reached at 5 p.m., while the minimum was at 6 a.m.

Composite shades recorded the lowest values of indoor temperatures in the hot period; for the southern orientation. The highest temperature was 34.30°C.; the lowest was 27.31°C. The horizontal shading device, coming second, recorded a maximum temperature of 34.86°C; the minimum was 27.83°C. Finally, the vertical shade recorded the highest temperatures inside the space; the maximum was 35.10°C; and the minimum was 28.08°C.

From the above, it can be inferred that the most appropriate shading device for the southern façade spaces is the composite one. The worst device is the vertical shading one (vertical shades on both sides of the window).

6.4. The Western orientation

In the Western orientation, the values of indoor temperatures of the bedroom for different shading devices types adjoining the room window fig (18).

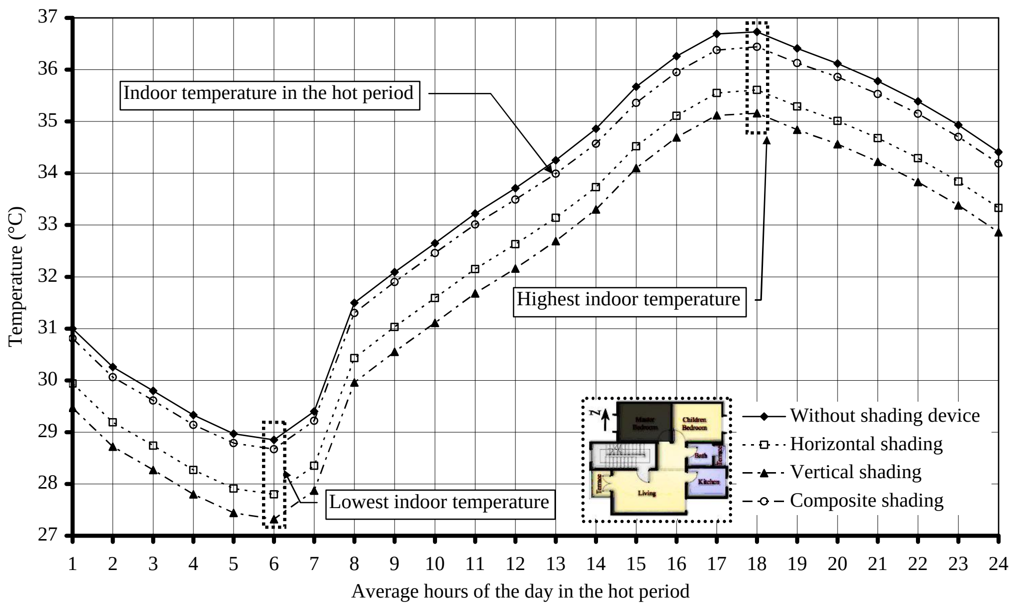


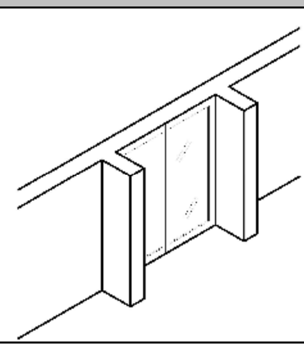
Fig (18): Values of indoor temperatures for the Western oriented bedroom, for different shading devices types adjoining the room window – in the residential model (hot period)

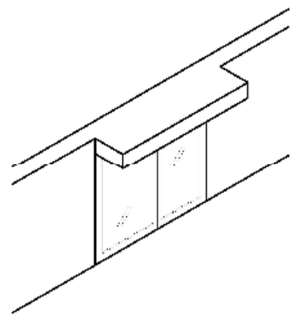
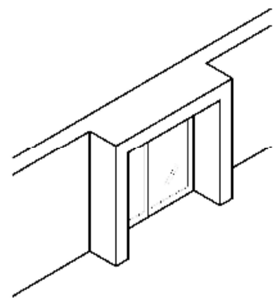
From the above figure, it was observed that temperatures were reduced when shading devices were used in the hot period. A noticeable reduction was accomplished when the vertical shade was used in the western façade ; about 1.5°C. The maximum temperature was reached at 6 p.m., while the minimum was at 6 a.m.

Vertical shades recorded the lowest values of indoor temperatures in the hot period; western orientation. The highest temperature was 35.16°C.; the lowest was 27.32°C. The horizontal shading device, coming second, recorded a maximum temperature of 35.61°C; the minimum was 27.80°C. Finally, the composite shade recorded the highest temperatures inside the space ; the maximum was 36.44°C; and the minimum was 28.67°C.

From the above, it can be inferred that the most appropriate shading device for the western façade spaces is the vertical one (vertical shades on both sides of the window). The worst device for such façade is the vertical shading one.

7. Conclusion

Climatic treatment	Results for the hot period	Examples of shapes
Vertical shading devices	Vertical shades recorded the lowest values of indoor temperatures for the northern, eastern, and western orientations as compared to the southern one.	
	A profound influence for increasing the prominence of vertical shades in the southern, eastern, and western facades.	

Horizontal shading devices	Horizontal shades recorded the lowest values of indoor temperatures for the southern orientation, as compared to other orientations.	
	Horizontal shades recorded the highest values of indoor temperatures for the northern orientation, as compared to other orientations; thus indicating their insignificance in this direction.	
Composite shading devices	Composite shades recorded the lowest values of indoor temperatures for the southern orientation, as compared to other orientations.	
	Composite shades recorded the highest values of indoor temperatures for the northern orientation, as compared to other orientations; thus indicating their insignificance in this direction.	

8. Recommendations and future work

Based on the results, the author recommends:

- 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.
- Considering the climatic design of residential buildings, because of its value in improving the thermal performance within spaces. This issue should be considered in different design phases.
- Windows position & shape should be considered as to facing the air desired air direction, and providing ventilation in a path without obstacles, if possible. Windows should be closed at noon, to prevent hot air bearing dust from entering. This must last to a late hour of the day.
- Using passive design techniques, e.g. composite devices in southern facades, and vertical ones in eastern, western, and northern facades to reduce low solar radiation. Such devices are extremely important in raising indoor temperatures of spaces in the cold period of the year, and lowering them in the hot period.

This paper is a part of ongoing master thesis; simulation is done utilizing other passive design techniques such as openings ration, glazing type, building materials and envelope color to study the impact of all these techniques on the thermal performance to achieve an integrated model for residential buildings in hot arid deserts in Egypt.

9. References

[1] The Egyptian Meteorological Authority. The climatic atlas of Egypt. Ministry of transport, ARE, 1996.

[2] Ministry of Housing, Utilities & Urban Communities, GOPP. General planning of the new urban community in the Assyuti Valley, 1997.

[3] D.B. Crawley, J.W. Hand, M.l. Kummert, B.T. Griffith, Contrasting the capabilities of building energy performance simulation programs, Building and Environment, V(43), (2009).

[4] J.Y.P. Lee, BASc, LEED AP, Sustainable Solution To Building Mechanical System – Simulation Of Thermo-Active Slab With Thermal Mass Using TAS, Earth Tech Canada Inc., Global Facility and Infrastructure, Mechanical Engineering Vancouver, British Columbia, Germany, 2010.

[5] T.G. Habib, Trains of Urban Development in Egypt, Update Evaluation for the Experience of New Urban Communities, Ph. D., Faculty of engineering, University of Assiut, 2000.

[6] http://www.edsl.net/main/Support/Documentation.aspx 27-5-2011