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STUDY ON THE VISUAL PERFORMANCE OF A VERNACULAR DWELLING IN EGYPT

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ABSTRACT:
Vernacular dwelling buildings located in hot arid regions are well known for their sensitive architecture response to the region's climatic conditions and the socio-cultural norms. The architectural value of these buildings is not only limited to their historical merit, but also to the human conscious adaptation to its context and the optimum utilisation of natural resources creating both a pleasant and a functional environment. The majority of these traditional dwellings are well recognised for their unique perforated fenestration system and courtyard arrangement that evolved to control the harsh solar, climatic conditions without compromising the quality of space and occupants' wellbeing. However, the successful design of these features and solutions cannot be fully appreciated without understanding the nature of daylight and solar radiation in which these buildings are revealed. This paper investigates the impact of the characteristic of the dense narrow streets of medieval cities on the visual performance of a typical courtyard house in Cairo.
The paper examines the daylight behaviour of one of the well-known historic alleys and of a courtyard house in Cairo. The paper analyzes and measures the variability in the visual perception and comfort for a typical pedestrian street and the occupants of the house using a simulation modelling tool (Integrated Environmental Solutions (IES) software). The paper gives an insight into the overall visual performance of the urban fabric that shapes of the microclimate, which is an important ingredient of the overall identity of the place.

Conference Topic:
New Approaches to Urbanisation
The Earth/Desert/Green and Sustainable Buildings

Keywords:
Vernacular Architecture, Daylight, Visual Performance, Sustainable-Place Making, Place Identity.

1. INTRODUCTION:

Vernacular architecture is a term often used to categorize structures built outside of academic tradition. The distinguishing feature of traditional vernacular is the development of various architectural solutions over many generations of traditional society to create a more comfortable microclimate using natural energy sources only (Fathy, 1982). Most recently, this subject of traditional vernacular has become the focus of serious academic studies and the current trend in practice towards "green" approaches to design has led to the reappraisal of many traditional buildings and settlements concerning their environmental performance.

The influence of climate in shaping the uniqueness of the traditional architecture of the Arabian region is widely recognized. Many scholars have discussed the environmental performance of traditional buildings and settlements in the Arabian region which were formed under the influence of the physical, technological and socio-cultural structure of a society and in harmony with its climatic conditions. However, despite the attention given to traditional vernacular of this region, research on visual and thermal comfort in compact urban environments in hot-arid zones in general (Tablada *et al*, 2009), and in the Arabian regions in particular, is rather limited /scarce. A great deal of studies that deal with this subject matter tend to focus on assessing the environmental performance of buildings (e.g. Al-Shareef, 2001; Manioglu, 2008) in isolation from its urban context. Given the fact that much of the character of these traditional regions came from the collective visual perception of their architecture components as well as urban patterns, this paper aims to investigate the impact of the characteristic of the dense narrow streets of medieval cities on the visual performance of a typical courtyard house in Cairo. The paper gives an insight into the overall visual performance of the urban fabric that shapes the microclimate, which is an important ingredient of the overall identity of the place.

2. THE STUDY AREA: OLD CAIRO

Egypt is a desert country, located between northern latitudes 22° and 32° and eastern longitudes 25° and 36°. Cairo is the capital of Egypt and has served as the capital of numerous Egyptian civilizations. It lies between latitude 30° north and longitude 31°east. A hot and dry climate predominates in most of the country a large part of the year. Cairo's weather is hot in summer, mild in winter with some rain, but usually there are bright, sunny days and cold nights. The average daily temperature in Cairo can reach 36 degrees Celsius during the summer. Winter nights can fall to 20 degree Celsius, with average hours of sunshine varying from 12 to 7 hours in summer and winter, respectively.

In such a geographical context, the hot arid climate was vital to the development of certain architectural features and certain urban patterns, such as narrow lanes and streets. Traditional Cairene architecture exploited different masonry devices to promote thermal and visual comfort including the use of courtyards, mashrabiyya, malqaf (wind-catcher), internal gardens and so on. Examples of some of these vernacular motifs that still survive to this day can be traced in the traditional architecture of the residential dwelling examined in this work. Typically, it was the projecting profile of the mashrabiyya, the characteristic features alongside the Carinen streetscape that further blocked the sunlight along the narrow winding lanes. This work explores a range of environmental design solutions embedded in historic residential buildings located in hot arid regions. It also provides an investigation of daylight performance along one of the well-known alleyways in old Cairo.

3. CLIMATE RESPONSE DESIGN STRATEGIES IN THE TRADITIONAL SETTLEMENTS OF CAIRO:

The Building Research Energy Conservation Support Unit (BRECSU, 1997) classified the design parameters that have an impact on daylighting performance in buildings and urban settlements into three levels. These are the micro scale, where the interest is concentrated upon the geometry of fenestration elements; the meso scale, deals with the significance of openings within the external fabric of the building and the effect of building depth; and the macro scale where the considerations are at the level of urban planning. The essential design parameters related to the characteristics of space configuration affecting daylight performance at the urban scale (the macro scale) are the orientation of space, compactness ratio (enclosure ratio), refection specifications or photometric properties of the surrounding surfaces and the use of shading devices (Al-Maiyah and Elkadi,2007). Besides the influence of these spatial parameters, daylighting performance of buildings also depends upon a number of design parameters related to the geometry of buildings (the meso scale). Among these parameters, building form, building size, building orientation and the size and location of light openings in the building envelop are the most influential (e.g. Baker et al, 1993). As this paper aims to investigate the impact of the characteristic of the dense narrow streets of medieval cities on the visual performance of a typical courtyard house in Cairo, a similar framework is adopted by this study in which two main phases of daylight analysis are conducted. While in the first phase of analysis, parameters related to the macro scale are considered, the second phase of analysis focus on the elements of the meso scale though assessing daylight performance of a selected number of spaces (see figure 5).

3.1 Fenestration System: latticework

In the hot-arid climate of Egypt, a complex perforated fenestration system, made of highly crafted lattice arrangements, was developed forming part of the traditional architecture of Cairo. In so-called mashrabiyya, plain or projected lattice screens made of unvarnished wood, fixed over the openings, were traditionally used as a device for lightening and ventilating the domestic spaces in the dense city while at the same time protecting women's privacy. To control the passage of light and airflow while maintaining privacy, a typical mashrabiyya was composed of two parts presenting different lattice arrangements. While the lower part of the mashrabiyya was composed with a tight lattice pattern of turned wood to satisfy the visual and social demands of the "conservative residences", the upper part above eye level was composed with a more open lattice pattern of turned wood to compensate for the reduction in light and air caused by the lower part (closed pattern) (Abdel Gelil, 2006). In this arrangement, the size of interstices between the wood pieces at the eye level was critical to obtain different intensities of light on either side of the screen, helping to maintain a combination of privacy and outward view. Privacy, as explained by Baker and Steemers (2002), is the result where the lighter side of the screen allows those outside to see the screen, but be unable to see the detail through it to the darker interior.

3.2 Building form: The courtyard house arrangement:

The Courtyard house type is one of the well known architectural elements characteristic of traditional architecture in hot arid regions. The main architectural feature that characterises this house style from other types of houses is the outdoor space that is enclosed within the interior volume and ultimately had became the heart of its morphology and spatial organization. The selected house, known as El Suhaymi House, constitutes a complete example of the traditional Cairene residential buildings of the 17th and 18th centuries. It has all the traditional components of the house of the period and it is believed to be the only remaining complete example of private houses of that period (Egyptian Ministry of Culture, 2002). It covers an area of over 2000 square metres, with a total of 115 spaces distributed on five levels surrounding a main internal court with

an area of more than 200 square metres. Its structure suffers primarily from the effects of a combination of natural and man-made deterioration factors. In 1931, the ownership of the house went to the Egyptian government and five dates later (in the1980s) the house was added to the list of historical monuments, recorded as number 399. Ever since, some of its vulnerable sections have undergone various phases of restoration. The final full restoration of the house was completed in 2000, supported by the Arab Fund for Economic and Social Development and it subsequently became a museum.

As a house type, traditional houses with central courtyards involved a certain spatial arrangement that was composed of several space types. Adding to the central courtyard arrangement, they were typically characterised by five key space types. These core space types are: the bent entrance (dihliz), qa′ a (reception area), takhtabush (covered outdoor setting area), maka' ad (covered loggia), and Haramlek or Harim (female quarters). Operational definitions of these space types are given in a recent study by Salama (2006) and their locations within the house are shown in Figure 5. Given the value of these core elements in shaping the overall architecture of the house, three of these core space types are selected here as a base for evaluating the visual performance of a typical courtyard house.

3.3 Traditional urban layout

In hot dry zones, two of the main problems facing local builders were to ensure protection against intense solar radiation and to provide adequate cooling (Koenigsberger et al, 1974). For that reason, enclosed, compactly planned urban forms, such as internal narrow streets, were among the most suitable forms developed in this type of climate to meet the problem caused by excessive heat. By placing buildings close to each other, surfaces exposed to the sun were often reduced with a large amount of shade and coolness that decrease the heat gains on external walls.
As in most warm climates, tight busy streets and narrow winding alleyways characterise the historic urban fabric of Cairo. Within this tight urban layout, narrow alleys make connecting links through the residential districts in the area. The alleyway under study is placed in the heart of the historic spine or "heritage corridor" where nine clusters of monuments worthy for conservation were identified by the UNDP plan in the 1990s. Known as El Darb el Asfar, the alleyway occupies an area that is located between the main thoroughfares leading from the north gates of the Fatimid wall towards the south: al-Mu'iss Street and al-Gamaliya Street. It is located in al-Gamaliyya district, which itself has gained special historic value, including the highest density of historic monuments in the area (Meinecke, 1980). The alleyway was renovated in the mid 1990s and today it is part of the tourist centre of the old city, close to many Islamic monuments and Medieval Cairo's principle historic bazaar, Khan el-Kalili.

3.4 Shading

In addition to the narrow winding streets and central opening courtyards that dominate the old city layout, covering the streets is another strategy that complements the architecture of Cairo. In residential areas, shading the facades of buildings is often achieved as result of the cantilevered volumes, the projecting latticework. Shade is also brought to the commercial streets and tight alleyways by means of various types of urban roofing, including temporary shading devices. For a single building or courtyard arrangement, shade is often obtained by architectural elements such as projecting roofs, covered loggias, open galleries and supplementary plants or by introducing special devices such as the mashrabiyya to shield the openings, as explained above.

4 The method:

In assessing the daylight levels along the alleyway and in the courtyard, a three- dimensional model is created using IES model builder (Model IT). A set of two-dimensional drawings, architectural plans and historic maps that were collected during the site visit in October 2004 is used in building up the digital model (Figure 1). The photogrammetric approach explained in previous study(s) by the authors (Elkadi and Al-Maiyah, 2007), in which a set of digital photographs was used to identify the geometry of the three-dimensional facades of the case study, is also applied in this work. A system of reference points arranged along the alleyway (20 points) and within the courtyard field of vision (30 points) was used to measure the daylight levels in both spaces, as shown in Figure (1). This is similar to the technique previously used by the authors in prior study(s). Daylight levels are predicted at 0.85 m using Radiance IES simulation tool for June and December the 15th at three time intervals (9.00 am, 12.00 am and 3.00pm). Information on the reflection coefficients of surface materials were obtained from relevant daylight textbooks and assigned to the model and the Apache weather file in the software was used in setting up the climatic data of the city.

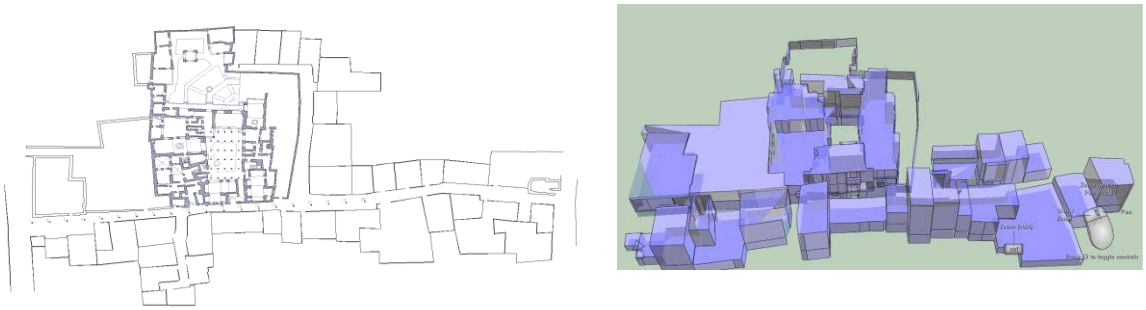

Fig.1 three-dimensional model of the alleyway and the courtyard house in Cairo (right), Plan showing the distribution of reference points in the courtyard and the alleyway (left)

5 Daylight simulation:

5.1 Phase one: Daylight performance of the courtyard and the alleyway

The analysis of the early morning scenario for June 15th, under sunny sky conditions, shows the impact of the orientation and the geometry of the courtyard in maintaining daylight levels at an average that varies between 4600 and 4300 lux in the middle of the courtyard, around 2700 lux at the eastern side and about 4000 lux at the western part. The influence of solar geometry on the distribution and levels of daylight in the courtyard is also evident. As illustrated in Figure 2, points located at the western side of the courtyard tend to receive an average of 32% in daylight levels higher than the average received by those located at the eastern side of the courtyard. Recent study has produced quantitative evidence on the effect of the daily sun movement on the conditions of the courtyards' internal envelope and thus on its thermal performance (Muhaisen, 2006).

However, despite this slight variation in daylight levels in terms of the pattern of distribution, the 9.00 am simulation modeling shows that overall there is a smooth translation of daylight distribution across the courtyard, which in turn has a direct impact on the visual experience and use of the courtyard before midday. Unlike this pattern of distribution, the pedestrians of the alleyway tend to have a different visual experience with sharp changes of daylight levels and sudden changes in illuminance values moving from

dark to strong daylight spots. At a moment when the average illuminance level in the courtyard is about 4000 lux, the level in the alleyway varies widely between 60000 lux in the sunny spots and as low as 1500 lux in the shade. Unlike the 9.00 am case, when the low angle of the sun has helped in maintaining a homogenous daylight pattern across the courtyard, a dramatic increase in daylight is obtained in both the alleyway and the courtyard as the day progresses. The only exception is for the shaded points at the southern side of the courtyard with an illuminace level of about 2500 lux. As the sun moves to the west, after midday, the change in the shading conditions in the courtyard allows the average illuminace value at the shaded areas of the courtyard to fall to 4000 lux by 3.00pm. Average illuminace level is around 46,000 lux in the alleyway at 3.00pm (Figure 3).

Although the shading provided by the internal envelope of the courtyard at the early morning and late afternoon hours gave the house occupants a living zone where the average daylight conditions are lower than of the street, supplementary shading was critical. Courtyards were often planted and sometimes being shaded by a canvas awning, which was a traditional defence against the high sun and intensive solar radiation in summer. Traditional canopies were also popular in the narrow alleyways of Cairo. However the impact of this supplementary shading element on daylighting levels in both spaces (courtyard and alleyway) has not been considered in the simulation modelling.

This sharp contrast in the visual perception between the inside and the outside is further accentuated with the intense change in daylight conditions provided by the design of the bent entrance, explained in the following section. Having arrived in the courtyard the visitor is confronted by the brightness of the courtyard, which was planted, possibly with trees, and probably had a fountain placed at the centre.

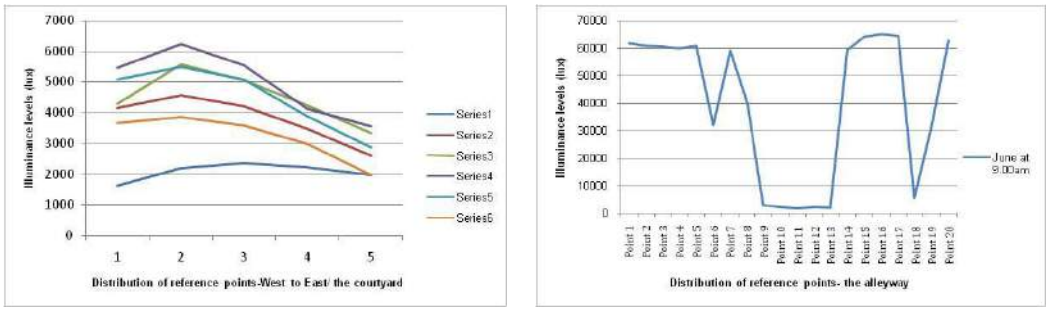

Fig. 2 Illuminance levels (lux) in the courtyard and the alleyway on June 15th at 9.00am

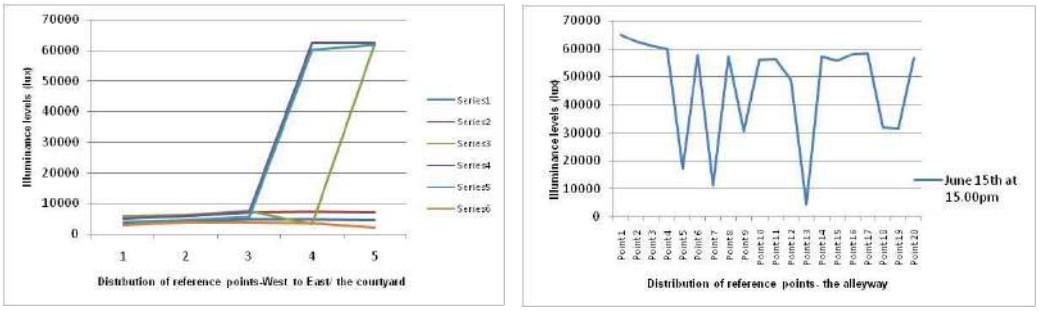

Fig. 3 Illuminance levels (lux) in the courtyard and the alleyway on June 15th at 15.00am

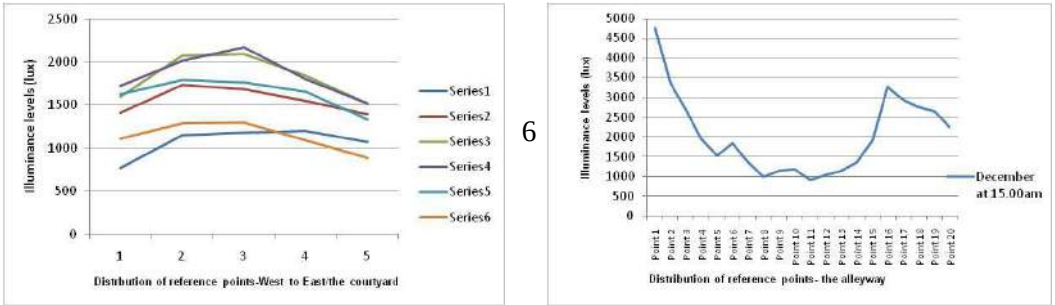

Fig. 4 Illuminance levels (lux) along the alleyway and the courtyard at the examined times on December the 15th

Daylight performance at the urban scale relates to a combination of direct sunlight, diffused skylight and the reflector of daylight from the surroundings. As the diffused energy of daylight is the main contributor to the total energy of daylight during winter in Cairo (as it was found by the authors in another study), both the courtyard and the alleyway tend to have approximate illuminance value on December the 15th (Figure 4). Unlike the summer case, in which the obstruction of the direct sunlight by the courtyard internal envelope has led to a wide range of illuminance between the alleyway and the courtyard, a slight difference in the average illuminace is observed between the alleyway and courtyard in midwinter ranging between 2300 lux to 1750 lux, respectively (9.00 am).

5.2 Phase two: Daylight performance of selected spaces of the house

As explained previously, three core space types are intentionally selected for assessing the daylighting performance of the house. Each of these spaces was designed to serve a specific social activity where various levels of privacy and daylight conditions are required and assessing their visual performance provides an interesting base for illustrating the influence of this parameter in shaping the architecture of the house. As with the first phase of analysis, daylight levels in each space type, are predicted for a typical summer (June 15th) and winter day (December 15th) and at three time intervals on each day (9.00 am, 12.00 am and 3.00 pm) and a comparative analysis is conducted with the daylight levels at the courtyard and the alleyway to provide a comprehensive insight into the overall visual experience of the place.

Fig. 5 Ground and First floor plans showing the 3 key selected spaces highlighted in red

5.2.1 Space type 1: The bent entrance

In most of the traditional houses in Cairo, entrances were usually bent. As the house residents lived within a rigid stoical pattern, protecting their privacy from the streets pedestrians was a prime consideration in the design of the house which had its impact on the doorway's design. By bending the main entrance, local builders managed to provide privacy for the house residents through preventing the street pedestrians from seeing the inside of the house. In addition to providing a threshold separating the inside from the outside, bent entrances exerted another fundamental role in protecting the interior of the house from wind, dust and noise. Attached to the entrance was a doorway which was usually arranged so that it led immediately into the courtyard where the visitors of the house experienced different daylight conditions from the alleyway's ambience.

Whatever the levels of daylight outside the house, the compact configuration of the bent entrance has helped in maintaining a constant low daylight levels along this walkway at various times of the day and in different seasons (Figure 6). While the alleyway's users receive an average daylight levels that might reach as much as 60000 lux at the sunny spots (as explained above) the modeling results suggest dramatic reduction in daylight levels along the main entrance with some points receive no daylight at all.

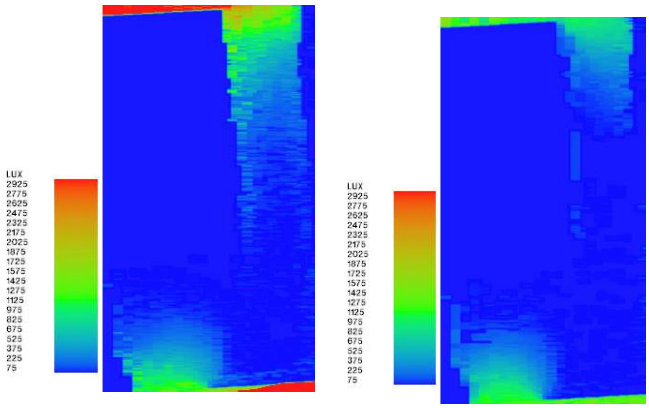

Fig. 6 Illuminance levels (lux) along the bent entrance on mid June (right), and December (left) at 9.00am

5.2.2 Space type 2: the Takhtabush (a covered outdoor sitting area)

A takhtabush is a "type of loggia, or a covered outdoor setting area at the ground floor level located between the courtyard and the back garden, opening completely onto the courtyard with a mashrabiyya onto the back garden" (Fathy, 1982). In the traditional architecture in Cairo, this element played an important part in ameliorating the extremes of temperature. Initially the takhtabush concept was developed to ensure a cool meeting place for the inhabitants and occasional visitors since it allowed for air circulation via its mashrabiyya from the courtyard to the back garden. In the investigated house and as illustrated in the plan arrangement at the ground level (Figure 5), the takhtabush is south facing, and its central location in the courtyard provides a direct access from the main entrance without allowing the exposure of the private spaces to the guests.

At 9.00 am when the average daylight levels in the middle of the courtyard is around 4600 lux (previous section) , average illuminace values in the takhtabush ranges between 1100 lux at the north side of the takhtabush and around 1700 lux at the south edge (Figure 7). This soft transition in daylight distribution is a result of the complementary effects of the latticework on the space's north facade and the overall north orientation of the space occupying one of the most prestigious spaces/locations in the house. As the sun reaches its highest altitude at midday and both the courtyard and the alleyway receive the highest

amount of solar radiation in the day, the takhtabush occupants experience an average illuminace values between 980 lux at the back of the space and around 5400 lux at the south edge (Figure 8). Unlike the 12.00 am case, when the shelter provided by the first and second floors above the loggia prevents direct solar penetration, points located at the southern edge of the loggia show a considerable increase in daylight levels at 3.00pm due to the low angle of the sun. However, apart from these sunny spots a more soft distribution of illuminace values is predicted at the rest of the space at 3.00 pm averaging between 600 lux and 2100lux (Figure 9).

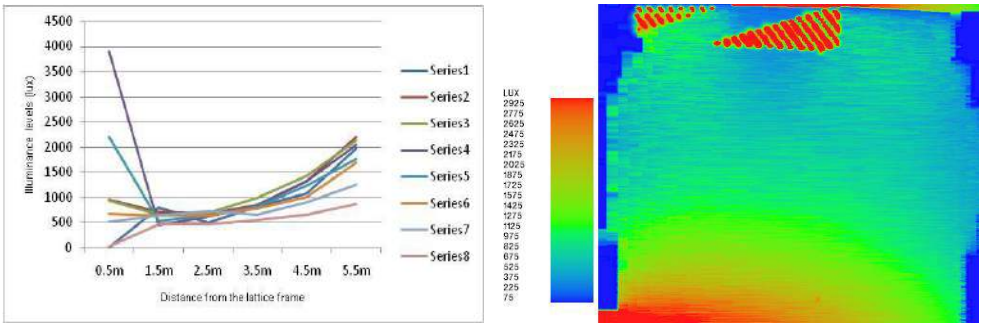

Fig.7 Illuminace levels distribution of space the Takhtabush at 9.00am on mid June

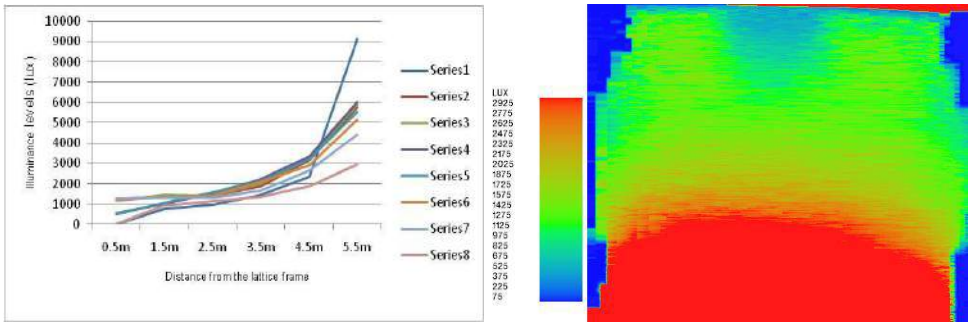

Fig. 8 Illuminace levels distribution of the Takhtabush at 12.00am on mid June

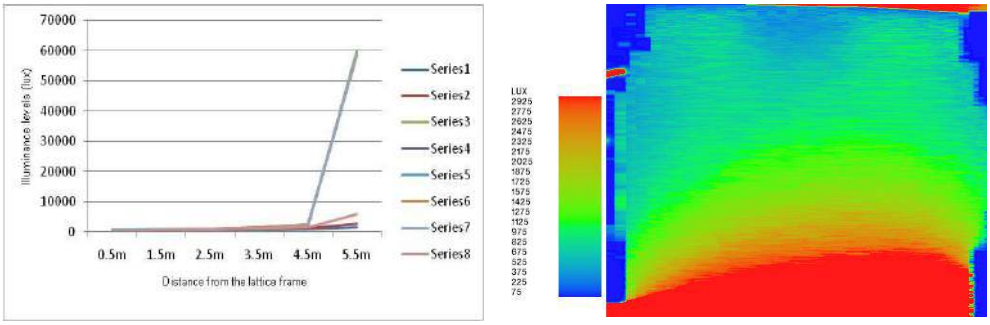

Fig. 9 Illuminace levels distribution of space the Takhtabush at 15.00pm on mid June

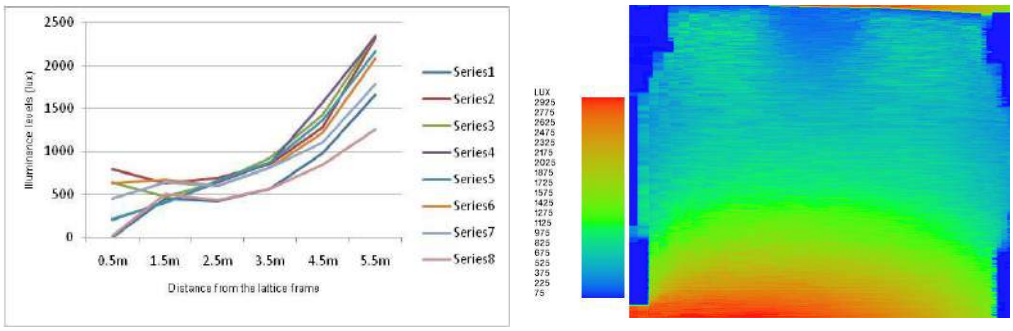

Fig.10 Illuminace levels distribution of space of Takhtabush at 15.00pm on mid December

The takhtabush was normally used for receiving male visitors during the summer and less used in winter. The simulation modelling for December the 15th, shows the space with a more homogenous illuminace pattern than in summer. This is related to the high contribution of the diffused solar radiation to the total energy of daylight during wintertime in Cairo. As illustrated in Figures 10 (15.00pm scenario), the users of the takhtabush tend to experience similar daylight conditions in the early morning and early afternoon hours averaging between 1060 lux and 910 lux, respectively and a higher illuminance value during the midday (about 1450 lux).

5.2.3 Space type 3: the Maka'ad (covered loggia)

Whereas the Takhtabush usually provided a seating area for the house's formal guests the maka'ad was originally used as a gathering space for the house residents, acting as a family area. It is usually rectangular or square in shape, opened with its entire facade onto the court, and essentially oriented to the north in grasp/in favour of the soft breeze (Salama, 2006).

At a moment when the average daylight levels in the middle of the courtyard is around 4600 lux, the average illuminace of the first floor loggia can be about 1340 lux on the outward facing north side and about 80 lux at the back of the room. As the day advances and sun reaches its highest point at midday, the projected mashrabiyya/ lattice screens from the second floor above the loggia usually acts as a horizontal shading device providing the occupants of the space with the most homogenous daylight distribution during the day (Figure 11). This will vary from 1600 to 115 lux between the outward facing north side and the inward facing south side. As accepted the 3.00pm simulation scenario reveals the highest illuminace in the loggia ranging between 2200 lux on the outward facing side and around230 lux at the back of the space.

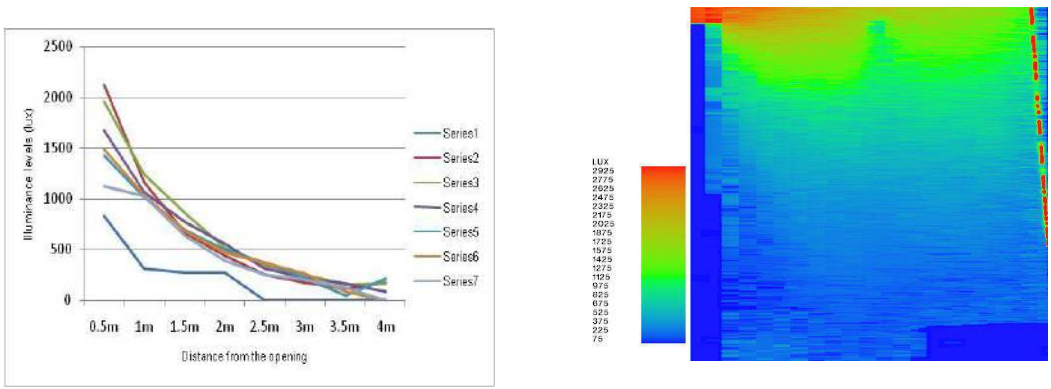

Fig. 11 Illuminace levels distribution of space of the maka'ad at 12.00 am on mid June

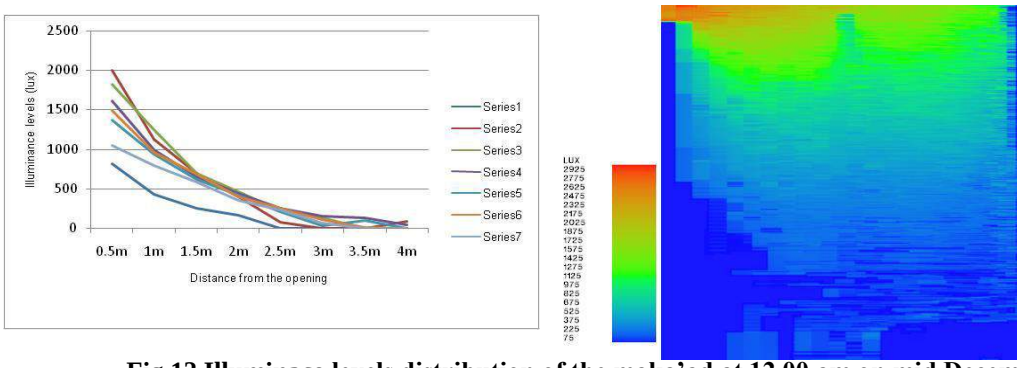

Fig.12 Illuminace levels distribution of the maka'ad at 12.00 am on mid December

At a moment when the ground ambient reaches about 7500 lux at midwinter (9.00 am scenario) the predicted average illuminace value in the maka'ad ranges between 1000 lux on the outward facing side and about 50 lux at the back of the room (3 meters away from the north facing opening). An increase in the illuminace value is predicted at the middle of the day ranging between 1500 lux on outward facing side and 80 lux on the indoor facing side (3 meters away from the opening). As the evening advances the ground ambient falls to 6450 lux , the average illuminace in the space can fall to 890 lux and as low as 45 lux at 3 meters away from the space main opening. Oil lamps were traditionally used by the house residents to illuminate the internal spaces and to compensate for the low level of daylight during winter months.

7. Conclusion

Al Suhaimi house in Cairo is one of the main traditional 17th Century houses that were extensively analysed, has been carefully analysed. Most of the studies explored the cultural aspects of the design as well as the favourable thermal qualities that is evident in entering the house through the bent pathway. The sharp contrast of visual and physical experience between the house and the surrounding alleyways has attracted scholars' attentions. A combination of the sharp contrast from the hustle of life in the surrounding alleyways combined by pleasant visual experience due to daylight and favourable thermal conditions is a key to such successful design. This paper argues that a key element of such favourable conditions in the house is the design of the house that allows careful distribution of daylight. The paper explored the characteristics of daylight levels through simulation of three key semi private places of the house; the bent entrance, the Takhtabush and the Meqaad.

The analysis of the simulation technique for both the house and the surrounding alleyways show sharp changes of daylight levels and sudden changes in illuminance values moving from dark to strong daylight spots. The daylight levels in the alleyways vary widely where illuminance levels of 60000 lux in the sunny spots and as low as 1500 lux are detected in the shade. In contrast investigation of the house shows a smooth translation of daylight distribution across the courtyard with an average of 4000 lux, which in turn has a direct impact on the visual experience and use of the courtyard. The shading conditions in the courtyard also allow the average illuminace value at the shaded areas of the courtyard to fall to 4000 lux by 3.00pm as average illuminace level is around 46,000 lux in the alleyway. The shape of the courtyard with its elongated rectangle (1:2) across the north south also ensures provision of quality northern daylight while minimising solar heating. Courtyards were also

often planted to further improve the visual experience and pleasant transition between shades and shadows particularly during midday.

The paper shows that the sharp contrast in the visual perception between the inside and the outside is further accentuated with the intense change in daylight conditions provided by the design of the bent entrance. Visitors to the house are almost visually purified through a bent in the entrance that reaches almost complete darkness prior to the introduction to the new pleasant environment in the courtyard. The Takhtabush, where occasional visitors were seated, maintain a homogenous illuminace pattern of around 1500 lux throughout the year. The design, the depth of the space, as well as the two small openings at the back of it ensure not only homogeneity and avoidance of dark corners but also provide thermal comfort through cross ventilation.

The Maq'ad with its square shape, opened with its entire facade onto the court. The space is oriented to the north to allow the soft breeze and good daylight levels. The paper shows that when the average daylight level in the middle of the courtyard is around 4600 lux, the average illuminace of the first floor loggia remains around 1340 lux on the outward facing north side and about 80 lux at the back of the room. The projected mashrabiyya above the loggia usually acts as a horizontal shading device providing the occupants of the space with the most homogenous daylight distribution throughout the day.

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