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STUDY ON THE VISUAL PERFORMANCE OF A TRADITIONAL RESIDENTIAL NEIGHBORHOOD IN OLD CAIRO

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ABSTRACT

Traditional dwellings located in the hot arid zones of the Arabian regions are well known for their sensitive architectural response to the region’s climatic conditions and socio-cultural norms. The majority of these dwellings are well recognized for their courtyard arrangement and perforated fenestration system that evolved to control the harsh solar, climatic conditions without compromising the aesthetic quality of space and occupants’ wellbeing. However, the unique visual characteristics of these structures cannot be fully appreciated by assessing the visual performance of buildings in isolation from their urban context. Given the fact that much of the character of the traditional settlements of this region came from the collective visual perception of their architectural components as well as urban patterns. This paper presents a methodology that can be used to assess daylight behaviour at an architectural level as well as at an urban scale. The work examines the daylight behaviour of a well-known historic alleyway and of a courtyard house in the old city of Cairo. The variability in the visual perception and comfort for a typical pedestrian street and the occupants of the house was predicted using Radiance IES simulation modelling tool and a scaled model under an artificial sky dome. A comparative analysis between simulated results and measured values at target points was conducted and the results reveal a reasonable agreement with the simulation results. Preliminary results from the first phase of modelling were presented that give an insight into the overall visual experience in the traditional settlements in the Old City of Cairo where daylight has contributed to the place unique sense of identity.

INTRODUCTION

The influence of climate in shaping the uniqueness of the traditional architecture of the Arabian region is widely recognized (e.g. Salama, 2006; Al-Shareef, 2001; Warren and Fethi, 1982). 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. Hassan Fathy’s pioneering writings in the early 1970s and mid 1980s provided detailed descriptions of the environmental aspect of traditional dwellings of the region in general and of Egypt in particular. The majority of these dwelling units are well recognized for their courtyard arrangement and perforated fenestration system that evolved to control the harsh solar radiation without compromising the aesthetic quality of space and occupants’ wellbeing. However, the unique visual characteristics of these dwellings or structures cannot be fully appreciated by assessing the visual performance of buildings in isolation from their urban context. Given the fact that much of the character of the traditional settlements of this region came from the collective visual perception of their architecture components as well as urban patterns, this paper presents a methodology that can be used to assess daylight behaviour at architectural level as well as at an urban scale. One of the well known traditional residential neighborhoods in the old city of Cairo was used as a core for investigation. The paper gives an insight into the overall visual experience, and daylight microclimate in the traditional buildings and settlements in the old City of Cairo where daylight has contributed to the place unique sense of identity.

The paper is structured into three main sections. It starts by providing a brief description of the study area and the main architectural features and urban components that shaped its microclimate. The second section provides a detailed description of the methodology and the validation work, while the final part includes preliminary results of the first phase of analysis that dealt mainly with assessing the intensity and diversity of illuminance in two distinct forms: an alleyway and a courtyard house.

THE STUDY AREA: OLD CAIRO

The historical significance of the Old City of Cairo is globally well recognised. Sir Fletcher (1996), for example, put Cairo high on the list of cities of outstanding historic value with an immense legacy of buildings dating back to the Middle Ages. Grabar (1984) raised the same point, yet ascribed the city’s character and sense of place to the way in which historical monuments and towers have shaped the physical fabric of the city, forming a network of visual signs that helps passers-by to navigate the city. In Tung’s view, it is the “adaptivity” of the metropolis to its climate that most accounted for Cairo’s unique appearance. In “Preserving the world’s greatest cities” (2001) he wrote “in a part of the world where the sun was intense and nearly vertical, one of the few forms of relief was shade. Thus as the density, height and population of the city increased, the streets were not widened, since deep, narrow canyons resulted in an environment of cool shadow”.

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 where a high intensity of solar
irradiation predominates for a large part of the year. The average annual global radiation can reach 2600 kwh/m²/year in the southern parts of Egypt, and the direct normal solar radiation varies between 1970 and 3200 kwh/m²/year with low levels of cloudiness. The annual sunshine duration hours vary between 3200 and 3600. In such a geographical context, the hot arid climate was vital to the development of certain architectural features and urban patterns. In addition to the compact configuration of the medieval urban fabric that shaped the local microclimate at the street level, traditional Cairene architecture exploited different masonry devices to promote thermal and visual comfort including the use of courtyards, mashrabiyya (perforated screens), malqaf (wind-catcher), internal gardens and many others. A brief description of some of these traditional motifs that can be traced in the medieval residential neighborhood examined in this work is given below.

Urban layout

In hot arid climatic regions, protecting the building blocks from intense solar radiation was one of the main problems facing local builders. For that reason, enclosed, compactly planned urban forms, such as internal narrow alleyways, were among the most suitable urban forms developed in this type of climate to reduce the heat problem caused by excessive direct radiation. 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 (Koenigsberger et al, 1974). Like many other cities in the Arabian region, tight busy streets and narrow winding alleyways are the most recognizable urban components that form the urban fabric of old Cairo. Among the outstanding examples of these indigenous urban components are those alleyways that lie 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 late 1990s. The selected alleyway, El Darb el Asfar (Figure 1), is one of these alleyways that occupy the area located between the main historical thoroughfares leading from the north gates of the old Fatimid wall towards the south: al-Mu'iss Street and al-Gamaliya Street. It is part of al-Gamaliyya district, which itself has gained special historic value, including the highest density of historic monuments in the area. 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 Cairo’s principle historic bazaar, Khan el-Kalili.

Building form: The courtyard house arrangement

The courtyard house type is another well known architectural arrangement that characterises the traditional architecture of Cairo. The main feature that differentiates this house style from other types of houses is the outdoor space that is enclosed within the interior volume to act as the heart of its morphology and spatial organization. Among the few surviving traditional courtyard houses in the region are those located in the heart of the old City. The significance of the house selected in this study lies in its historical value. Located on the northern side of the examined alleyway, El Suhaymi House presents a complete example of the traditional
Cairene residential buildings of the 17th and 18th centuries (Figure 1). It has all the traditional components of the house of the period and according to the Egyptian Ministry of Culture (2002) it is the only remaining complete example of private houses of that period. Excavations in the courts of the house also indicate that the site on which it was erected had been populated and built on since the Fatimids founded Cairo in the 10th Century. The house 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 suffered primarily from various natural and man-made deterioration factors for several decades. In 1931, ownership of the house went to the Egyptian government and around five dates later it was added to the list of historical monuments, recorded as number 399. Whereas some of its vulnerable sections underwent various phases of restoration, the full restoration of the house was only completed in 2000 and it subsequently became a museum.

Figure 1: Views of the examined alleyway (right) and the selected courtyard house (left) in old Cairo

Shading Strategies

In addition to the narrow winding streets and central opening courtyard house types that dominate the old city urban fabric, covering the streets is another strategy that complements the traditional architecture of Cairo. In residential areas, shading the facades of buildings is often achieved as result of the cantilevered volumes of the projecting latticework or mashrabiyya. 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 that shields the openings.

Orientation

The orientation of street and internal courtyard plays an important role in the levels of shading and daylighting (e.g. Koster, 2004; Littlefair et al, 2000). The long axis of each form
can be directed to the N-S, E-W, NW-ES or NE-SW, all of which have varying impact on the produced shading or exposure patterns in both spaces and hence on their visual behaviour. In a study on the influence of different street orientations located in Southern Europe over the solar gain (Littlefair et al, 2000), the findings suggested that the NE-SW/SE-NW typical grid pattern of the streets has significantly less sun penetration than an E-W/N-S grid. This is the result of the changes of the angle of the sun, which varies widely with the time of the day and time of the year. Although the same amount of direct solar radiation enters the top of each alley, with the E-W alleyway more solar radiation reaches the ground, while with the N-S alleyway the direct radiation is more likely to strike the east-and west-facing buildings at an oblique angle, resulting in less solar gain. It is also evident that in hot regions courtyard forms with an orientation between the NE-SW, NW-SE and the N-S can provide extra shade as they stop the access of direct solar radiation at ground level for most of day (Littlefair et al, 2000; Muhaisen, 2006). As illustrated in the ground floor plan (Figure 3), the orientation of the examined house is within 15 degrees of North, thus representing one of the most preferable orientations of a courtyard building form in a hot arid climate. By contrast, the alleyway shows one of less successful streets orientations in terms of blocking direct solar radiation in this type of climate. The impact of orientation on the intensity and diversity of illuminance in both forms is discussed below.

ASSESSING DAYLIGHT PERFORMANCE OF A TRADITIONAL SETTLEMENT OF CAIRO

The Building Research Energy Conservation Support Unit (BRECSU, 1997) classified the design parameters that have an impact on daylight levels in buildings, urban spaces and 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 main design parameters related to the urban space configuration and affecting daylight levels at this scale (the macro scale) are the orientation of space, compactness ratio (enclosure ratio), reflection properties of the surrounding surfaces and the geometry of the sectional profile of space (Al-Maiyah and Elkadi, 2007). Besides the influence of these spatial parameters, the daylight levels in buildings also depends upon a set of design parameters related to their geometry (the meso scale). Among these parameters, the form, the size, the orientation of building 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 provide an understanding of the overall visual experience found in traditional urban settlements by assessing daylight levels in a typical dense narrow street and courtyard house in Cairo, a similar framework is adopted by this study in which two main phases of daylight analysis are conducted. Whilst in the first phase of analysis, parameters related to the macro scale were considered, the second phase of analysis focused on the elements of the meso scale though assessing daylight performance of a selected number of internal spaces of the house. However, in this article, which is part of a research project, only the preliminary results related to the first phase of analysis are presented as the work on the second phase of modelling is ongoing.
Methodology:

The study went through several stages: firstly, due to the absence of the required architectural drawings of the target buildings a photo survey was conducted as a part of the site visit to identify the geometry of the case study. Around 100 digital photographs of the alleyway and the house were recorded to outline the geometry of their facades. Simple tape measurements were also conducted to determine the scale of the digital model and assess its accuracy at a later stage. This approach is referred to as photogrammetric approach. It was previously introduced by Mantzouratos et al (2004) as part of an illumination study of one of the 19th century neo-classical buildings in Athens and also adapted by the authors in previous study (Al-Maiyah and Elkadi,2007). Historic maps and two-dimensional drawings that were collected during the site visit were also used in building up the digital model.

In the second stage, the three-dimensional model of the examined configuration was created using Model IT, (the building modeller) in IES virtual environment and a preliminary phase of daylight simulation was conducted. Daylight illuminance values at target points along the alleyway and inside the courtyard were predicted using Radiance IES simulation tool. Radiance is a powerful highly accurate simulation tool which is increasingly being used to simulate complex lighting environments. Although the accuracy of Radiance in simulating light behaviour in a complicated internal environment has been rigorously validated (e.g. Mardaljevic and Lomas, 1995) its capability in providing accurate calculation at the urban scale is yet to be tested. Therefore, a validation experiment that is based on a physical model and an artificial sky dome was conducted in the third stage of the work to provide more confidence in the simulation modelling. Similar to the digital model created in stage 2, a 1:50 physical model of the alleyway and the house was carefully constructed using light plastic materials. The actual alleyway measures 7.5 m in width at its western end, 3.2 m at the central section, around 5.8 to 3.8 m at the east and is 166 m long. However, due to the limitations set by the size of the sky dome simulator and the practical difficulties associated with building up a 1:50 model of such a long street, only the central part of the alleyway where the house is located was constructed and tested. It measures 46 m in length and presents the most compact sectional profiles found in the alleyway with a height to width ratio of 3.2:1. The model was then tested using the artificial sky dome at the Bartlett, University College London (UCL) (Figure 2). This large scale facility comprises a 5.2m diameter hemispherical dome, covered with an array of 270 compact fluorescent luminaires which are individually controlled to adjust the luminance distribution; thus allows modelling various sky conditions.

Four main phases of measurements were carried out in which a system of reference points was used to assess daylight illuminance values at target points on the model. A total of 18 points that were assembled on three main axes were used to measure illuminance values in the courtyard and another 9 points that were assembled along the main axis of the alleyway were selected to measure the values at the street level. The distribution of the measurement points along the alleyway is shown in Figure 2. Illuminance data at the targets areas were recorded respectively using a Megatron lightmeter which can measure illuminance levels at 12 different points simultaneously. The illuminance data at each target point was recorded four times in two measurement sessions over two days on May and June 21st and the average illuminance value at each reference point was then calculated. A Konica Minolta LS-110 luminance meter was used to measure the reflectance value of the physical model and the
data logger and controlling PC were programmed to take measurements at the two sessions. At the same time simulations using overcast sky conditions similar to those assigned to the sky simulator were made and comparative analysis between measured and predicted data was conducted to validate the simulation exercise. The agreement between simulated and measured values was quite acceptable. The experiment concludes that the absolute relative difference between simulated and measured illuminance values along the alleyway and in the middle of the courtyard lay in the range of -0.14 to 0.36% and -0.11 and 0.22%, respectively (Figure 3). The digital model of the alleyway was then adjusted to include the other sections of the original setting and simulations were carried out to predict the illuminance values on the summer solstice and winter solstice at three time intervals (9.00 am, 12.00 pm and 3.00 pm). The summer simulation was carried out under clear sky conditions and the winter scenario under the CIE overcast sky.

Figure 2: Images of the scale model and sky simulator facility

Distribution of reference points along the alleyway (lower right)
Daylight performance of the courtyard and the alleyway: preliminary results

As stated before, a total of 18 points that were assembled on three main axes were used to predict the illuminance values in the courtyard. Whereas axis 1 was arranged to assess the illuminance levels on the eastern side of the courtyard, the other two axes (2 and 3) were arranged along its central and western side. The analysis of the early morning scenario on the summer solstice clearly showed the impact of the courtyard’s north-south orientation on its daylight behaviour. The internal envelope of the courtyard blocked the low angle of the sun in the early morning to reach the points located at the eastern side of the courtyard (axis 3) while allowing direct sunlight to reach the other two axes. The average daylight illuminance values received by the courtyard at 9.00am on the summer solstice were about 1269 lux at the eastern side, 1770 lux in the central part and about 2004 lux at the western part. These figures suggested a variation of around 37 - 40% in illuminance values between the shaded eastern side of the courtyard and its exposed parts. However, despite this variation in the intensity of illuminance across the courtyard, the 9.00 am simulation results showed that overall there was a smooth transition of daylight distribution across the courtyard, which in turn had a direct impact on the visual experience and the use of the courtyard before midday.

The quartile deviation is a strong indicator of variability within a population of data; the lower the value, the less variation about the mean or the average. This metric is used here to assess the diversity of illuminance in both forms before and at midday on the summer solstice. Whereas a large spatial variation in illuminance is predicted along the alleyway, the courtyard showed less variation among its illuminance values. At 9.00 am, the upper and lower quartiles of the mean were around 12% of the mean in the case of the courtyard and more than 40% in the alleyway. The large variations of illuminance along the alleyway before midday are the results of the partial obstruction of the low sun by the alleyway’s internal envelope leading to a wide range of light and shades spots along its main access. As a result, the pedestrians of the alleyway tend to experience different ambient daylight conditions to those of the users of the courtyard with sharp changes in illuminance values moving from dark to lighter daylight areas (Figure 4). At a point in time when the average illuminance
value in the courtyard is about 1700 lux, the intensity of daylight in the alleyway varies between 4200 lux in the exposed/sunny spots and as low as 1300 lux in the shaded areas.

Unlike the 9.00 am case, when the obstruction of the low angle of the sun by the courtyard’s internal envelope has helped in reducing the intensity of its illuminance, the noon sun angle has led to a significant increase in the intensity of illuminance in both the alleyway and the courtyard. The average intensity of illuminance received by the alleyway and the courtyard at noon on the summer solstice was 6068 lux and 5190 lux, respectively. This is the result of the high solar angle at noon that allowed more intense sunlight to reach most of the target points in both forms. It is, however, important to point out the role of the temporary covers that are usually used (and still in use in the original settings) during the summer time in areas with lower aspect ratios. Such temporary shading elements would play a major role to reduce the intensity of solar radiation and thus improve the uniformity of illuminance at the street level. Courtyards were also often planted to further improve the visual experience by providing a pleasant transition between shades and shadows particularly during midday. However the impact of these supplementary shading elements on the intensity of illuminance in both spaces has not been considered in the simulation modelling. After midday, the change in the shading conditions as the sun moves to the west allows the overall values of illuminance in both the courtyard and the alleyway to fall by around 50 % from midday values. However, despite this identical reduction value in the two spaces, the intensity of illuminance remains more uniform in the courtyard than in the alleyway.

Unlike the summer solstice, when the constant change in the shading conditions over the course of the day led to a wide range of illuminance values between the alleyway and the courtyard, a slight difference of less than 20 % in the average illuminance is observed between the two spaces on the winter solstice. This is the result of the high contribution of the diffused skylight component to the total energy of daylight during winter period. In urban open spaces the intensity of illuminance relates to a combination of direct sunlight, diffused skylight and the reflector of daylight from the surroundings. Previous research by Al-Maiyah and Elkadi (2007) on daylight behavior in selected traditional urban forms in Cairo demonstrated that the diffused component accounts for around 70% of the total energy of daylight during winter. The predominance of the diffused component also led to a more homogenous distribution of illuminance along the alleyway on the winter solstice than on the summer solstice, particularly before midday.
SUMMARY

This paper is part of an ongoing research project designed to assess daylight behaviour in the traditional settlements of old Cairo. The unique visual experience characteristic of these settlements is well documented and often described as part of the overall identity of the city. However, assessing the characteristics of these settlements in terms of their daylight behaviour is a rather difficult task that requires an understanding of the diversity of illuminance at various architectural scales as well as urban patterns. Accurate simulation modelling tools, on the other, such as Radiance that is increasingly being used for illumination studies in internal spaces can assist in standardizing the diversity of illuminance at various scales and across different spatial typologies. Accordingly, a simple methodology for the study of the daylight behaviour of traditional settlements in old Cairo was proposed and tested using a combination of simulation and physical –based measurements. The proposed methodology proved capable of predicting illuminance values quite acceptably. The predicted results such as those presented in the above section can be used by town planners or support local decision-makers by assessing, for example, the implications of intervention schemes on daylight conditions in a dense urban fabric.

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