

Traditional Residential Architecture in Cairo from a Green Architecture Perspective

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Abstract

In Egypt, traditional residential architecture of Islamic eras accorded a great deal of importance and respect to the environment, the source of the construction materials that give form to architectural elements. It also contributes to creating architectural spaces that realize mental and physical comfort of users while complementing the surrounding environment. In this paper, various components and design patterns of the traditional residential architecture in Cairo (Cairene houses) were observed and analyzed from a green architecture perspective in order to determine best building techniques and elements of environmentally friendly design. First, the climatic system of Egypt is explained, second a description of the traditional residential architecture in Cairo is provided, third, green principles in the design patterns and elements of Cairene houses were observed and analyzed in detail in terms of: 1) solar heat energy, 2) solar light energy, 3) wind energy, 4) construction materials, and 5) sound insulation

Keywords: Cairo, Cairene houses, green architecture, *maq'ad*, *takhtabush*, *mashrabiyya*, *qa'a*, *shokhshekha*, *malqaf*, solar heat, solar light, wind, construction materials, sound insulation.

1. Introduction

Architecture is a mirror that reflects the various elements of its environment and surroundings, such as climate, geographical characteristics, standard architectural principles, and social, cultural and scientific developments. Muslims of different regions were able, through architecture, to portray their temperaments and environments, free of external influence. It was a vehicle through which Muslims expressed their ideas and beliefs.

In Egypt, traditional architecture of Islamic eras accords a great deal of importance and respect to the environment, the source of the construction materials that give form to architectural elements. It also contributes to creating architectural spaces that realize mental and physical comfort of users while complementing the surrounding environment. Islamic architectural details adapt to changes of time and location.

Cairo is characterized by its dry climate, low rainfall and strong sunshine. Its residential traditional architecture adopted construction methods that made use of these climatic conditions. Houses were built in close proximity to one another, thus presenting a single architectural bloc to combat climatic elements. Inner courtyards provided air and natural light and ensured the privacy of occupants. Islamic city plans were designed so that markets were located at a distance from residential areas. To reduce noise levels in residential areas, each trade or craft had its own market. The thick walls and inner courtyards of residential buildings minimized noise and provided shade and shelter from the sun (Garcin et al. 1982, Hakim 1988, Maury et al. 1983) Numerous solutions were adopted such as minimizing exposed building surfaces and reducing the rate of heat transmission through constructing buildings in groups (complexes), adapting to changing temperatures through the use of brick and mud to build thick walls with a minimal number of openings, to reduce energy exchange with the outside air and to limit the inflow and collection of dust, reducing heat absorption by building deep inner courtyards, surrounded by rooms, and by planting the courtyards, using solar energy to heat rooms reserved for winter use and storing energy in the walls and ceilings; to conserve energy, heating in winter is reserved for living rooms and bedrooms only, using local materials to construct walls of sufficient thickness to combat heat and humidity. Cairene (of Cairo) traditional residences thus provides an excellent example of architectural innovation and borrowing that is adaptable to environmental and climatic conditions.

In this paper, various components and design patterns of Cairene homes were observed and analyzed from a green architecture perspective in order to determine best building techniques and elements of environmentally friendly design. First, the climatic system of Egypt is explained, second a description of the traditional residential architecture in Cairo is provided, third, green principles in the design patterns and elements of Cairene houses were observed and analyzed in detail in terms of: 1) solar heat energy, 2) solar light energy, 3) wind energy, 4) construction materials, and 5) sound insulation

2. Climate system of Egypt

Egypt is divided into a number of distinctive climatic regions. With the exception of its northern regions, the country falls in the dry climate zone characterized by hot temperatures and strong sunlight. The northern parts of Egypt fall into the warm temperate zone and have a near Mediterranean climate (hot and dry during the summer months, moderate temperatures and some rainfall, especially in coastal areas, during the winter). There are two seasons in Egypt; a hot, dry summer season (May to October) and a mild winter season with some rainfall (November to April). The average minimum temperature in January is 9C – 11C, and the average maximum temperature is 20C – 24C. In July and August, the average minimum temperature is 21C – 25C, and the average maximum temperature is 37C – 42C. Winds generally blow in a northwest and northeast direction. Between the end of March and the middle of May, hot winds, laden with dust (*khamaseen*) blow in from the south and southwest. There is very little rainfall at long intervals and constant sunshine. Year-round relative humidity levels are twice as high in the north (Alexandria region and the Nile Delta) than they are in Aswan in the south. Low rate of relative humidity characterizes its winter (Al-Wakeel & Serag 1989, ASHRAE 2001, U.S. National Oceanic and Atmospheric Administration 2001).

3. Description of the Traditional Residences in Cairo

What is meant by traditional residential architecture in Cairo are Cairene homes from late Mamluk period (1259 – 1517) and throughout the Ottoman period (1517 – 1805). While the idea of a private house was consistent, differences in scale were determined by household status. Therefore, traditional residences varied from palaces and houses to collective housing units. In the following, a description of traditional Cairene private houses is provided.

Entrances generally opened onto secondary streets or cul-de-sacs, with indirect corridors giving access to interior courtyards that were concealed from outside view. Unlike courtyards in other Arabic-Islamic countries, Cairene courtyards were not considered social spaces for housework or other purposes, but a means of ventilation, lighting, and communication between various quarters of the home (Behrens-Abouseif 1990, Maury et al.).

Opening the entrance door, one normally faced the *magaz*: a vestibule followed by a corridor and sometimes a room of the doorkeeper (figure 1). *Magaz* was the name given to this type of corridor, which served to shield the house from the view of passers-by. It is formed of one or two turnings, in order not to allow the visitor a look into the interior (Lane 1954, Goitein 1983, Maury et al., Revault 1988). In addition to the entrance door, the first turning is equipped with an intermediate door perpendicular to it, preventing thus view and access to the courtyard and protecting from wind, dust, noise and the harshness of the outside (Salama 2006). Reaching the second turning, the courtyard was entered by an arch following and perpendicular to the intermediate door (Maury et al., Revault).

The courtyards contained most of the entrances (figure 2), including a special entrance to the *haramlik*. Arranged on two or three stories, house quarters consisted of two zones. The *salamlik* (used for receiving male guests and accessible directly from the courtyard) consisted of one or several *qa'as* (reception halls) (figure 3), a *maq'ad* (loggia overlooking the courtyard, see figure 4), and a *takhtabush* (courtyard arcade) (figure 5). A typical *qa'a* consists of two elevated living areas each called an *iwan* (a three-walled area with a ceiling) flanking from a central lower space named *durqa'a*. Usually, the latter is topped with a *shokhshekha* (a small skylight). Situated on the upper floors, *haramlik* consisted of one or more wings, each with its own living and sleeping rooms (besides the *salamlik* and *haramlik*, the house includes also the *manafi'*, or services, consisting of latrines, kitchen if present, storage, and the servants' rooms, see Maury et al., Revault). To hide the *haramlik* from view while allowing women to watch the events occurring outside, *mashrabiyyas* were installed between the *haramlik* and *salamlik*, *haramlik* and courtyard, and *haramlik* and street (figure 6). They are latticework made of turned wood applied to the windows of traditional residences in the Arab world to both veil women from the gaze of men and to ameliorate the region's hot arid climate.

M*anzil* (house) *Amna bint Salim*, *manzil al-Kiridliya* and *bayt* (house) *al-Suhaymi* are typical examples of traditional Cairene private houses (on these houses, see Maury et al.). The *manzil Amna bint Salim* (built in 1540) and *manzil al-Kiridliya* (1631) shown in figures 7 & 8 were built next to the *Ibn Tulun* mosque in the southernmost part of Islamic Cairo. The passageway containing their entrances is all that remains from the narrow street that once ran through the formerly dense residential quarter. On the ground floor of each house, the *salamlik* begins with a room near an entrance, followed by a *maq'ad* accessible via a staircase and directly linked to a *qa'a*. The *qa'a* of *al-Kiridliya* served a dual purpose as an everyday *haramlik* and a *salamlik* during special events. When those events occurred, the women of the household moved either to upper rooms (since removed) or to a *qa'a* on the east side of the house. With its three-sided opening, this *qa'a* gave them a panoramic view of the *maq'ad*, the courtyard, and the surrounding streets. The *haramlik* of *manzil Amna bint Salim* is also notable for occupying almost the entire upper part of the first floor *qa'a*. The *haramlik*'s rooms and galleries overlook this *qa'a* with large *mashrabiyyas* and many windows that open upward. During parties, these *mashrabiyyas* veiled the harem's members and female singers, thus allowing guests to listen to their performances without seeing them.

Bayt (house) *al-Suhaymi*, on the other hand, is comprised of two sections, a South section and a North section (see figure 9, and on its architectural description see Maury et al. and Fathy 1986). A *magaz* (bent indirect corridor) leads into the house. The *magaz* leads to the southern courtyard, around which all the most of the house quarters are arranged, in the traditional style. The courtyard contains a *takhtabush* and the house is composed of a *salamlek* (including the *takhtabush*) and a *haramlek*. *The salamlek* is located in the first (South) section of the house and comprises a large *qa'a* with two *Iwans* separated by a *durqa'a*. Male guests were received in this hall. Above the *qa'a* was the *maq'ad*, with one side opening on the northern side (figure 9). The second part of the house contains another, larger, *salamlek qa'a*, topped with a *shokhshekha* (a small skylight with openings to let in light and release hot air). *Shokhshekhas* are architectural elements designed to ensure that the air in the hall is constantly renewed (hot air rises and cool air sinks downward, this is explained later in detail). Most of the halls in the *Suhaymi* house have this feature. *Tanoors* (oil and wick lanterns used in Egypt before the advent of electricity) decorate the ceilings. The *Suhaymi* House contains a steam bath. This is a small room with marble floors and a domed ceiling that is decorate with square and circle-shaped openings covered in colored glass. There is a place in the bath for the water tank and a hearth for heating the water and producing steam (Okasha A. 2008). *The haramlik* consists of inner rooms and halls featuring *mashrabiyya* windows that open unto the courtyard. Windows on the upper floors, more numerous and larger than those in the halls and rooms, are covered in colored glass.

4. Green Principles in Cairene Houses

4.1 Solar Heat Energy

The system of orienting building spaces inwards resulted in the existence of two types of façades in Islamic houses. The first of these, external façades that face outwards towards the street, are semi-solid, with few, if any openings. Openings in external façades are covered with *mashrabiyyas*. The second type, the internal façade surrounding the inner courtyard, is also covered by *mashrabiyyas*. This internal façade is considered the main façade, and its openings are wider than are those in external façades. Additionally, certain elements such as *maq'ads* and *takhtabushes* are built facing north. A typical *qa'a* follows a North-South axis in such a manner that one of the two *iwans* faces the northern direction for summer use and the faces the southern direction for winter use (Fathy, Garcin et al., Goitein, Maury et al., Revault).

Step-shaped projections are built into the higher parts of both external (overlooking the street) and internal (overlooking the inner courtyard) façades. They offset the sun's rays, shading the walls of lower spaces and helping to provide protection against direct sunlight. Increasing the height of spaces helped to shade large areas of indoor house space, shielding them from direct sunlight (Fathy).

Moreover, using inner courtyards ensures that cool air layers collect in the courtyard during the night, thereby cooling indoor spaces, particularly during the early part of the day (see figure 10). As evening advances, the warm air of the courtyard rises and is gradually replaced by the already cooled night air from above. This cool air accumulates in the courtyard and seeps into the surrounding rooms, cooling them. The courtyard thus serves as a reservoir of coolness. Additionally, the walls overlooking the inner courtyard shade large sections of its floors. Solar energy stored in the walls and floors of the courtyard throughout the day is released back into the atmosphere, and at the same time, the cool air stored in the courtyards at night serves to keep it cool during the mornings of the following day (Fathy, Gianni S. 1988).

Openings face inwards and there are fewer of them on external building façades. A typical *mashrabiyya*, shown in figure 11, is made of unvarnished pieces of wood fixed together without glue of nail (Behrens-Abouseif), is either flush with or extends out from the façade (Abdel 'Alim F. 2000), and consists of the following parts.

1. The main *mashrabiyya* opening, which consists of two parts. A lower part below eyelevel with fine turned pieces in a tight lattice pattern, and an upper part above eyelevel with a more open lattice pattern.

The former insured privacy and intercepted the intense sunlight of Cairo, and the latter provided lighting and airflow (Fathy, Revault).

2. An overhang found immediately above the main *mashrabiyya* for breaking sunrays, preventing them thus from entering through the wide pattern of the upper part (Fathy).
3. A flat window above the overhang (*qamariyyah*) of a wide pattern of latticework, grating of wood, or stucco filled with colored glass (Lane). It was often added if the *mashrabiyya* does not provide sufficient airflow or light (Fathy).

Mashrabiyya was also equipped with some or all the following. 1) Small niches that extend out from the main lattice for earthen water drinking bottles by the evaporating effect of airflow (Fathy, Lane). 2) Sliding or hinged openable parts in the main fixed panels for increasing lighting and ventilation (Lamei et al. 1996). 3) Internal glass protecting from coolness or dust (lane). 4) External wooden shutters for more protection and privacy. In addition, while preserving its role, *mashrabiyya*'s typical form varied according to the household's social class, the space's function, and the façade's orientation. For instance, *mashrabiyya* of lower class housing, or the less important spaces in a private house, was often without the upper window; and hanging shutters opening upward replaced the fine latticework of the lower part. The façade's orientation, on the other hand, influenced the size of the *mashrabiyya*'s opening, pieces, interstices, and overhang

At night, the *mashrabiyya* absorb moisture carried on the wind and passing through the interstices. When heated by sunlight, it release the moisture into the air that passes through, thereby increasing humidity within a home and reducing its temperature (figure 12, see Fathy).

The construction of thick exterior walls (up to 50 cm thick) using materials with a low level of thermal conductivity (such as limestone) was adopted to minimize heat transmission into building interiors. The greater the wall-floor area ratio, the more shaded a space is. The use of small and medium size spaces (inner courtyards) therefore reduces the amount of heat emitted from the ground and increases the area of spaces not exposed to direct sunlight. The use of double ceilings made of wood for thermal insulators, as in the Beshtak Palace (Waziri Y. 2004).

Moreover, natural elements are used to moderate temperatures and raise humidity levels. One of the most important of these is water, used in fountains and *salsabeels*. The fountain occupies a place in the centre of the courtyard or the *durqa'a*, displaying its water and mixing it with air to increase humidity, decreasing thus the temperature (figure 13). Placed in the center of the inner courtyard, fountains served as ornamentation and cooled the air that came into contact with the water before moving into indoor spaces (Fathy). *Salsabeel* is a rippled marble slab inserted in an opening in the wall facing the '*iwan*', or living area. It allowed water in the air to condensate on its surface, making the climate in that area cooler and more refreshing (Fathy, Zuhairy, A. & Sayigh A. A. M. 1991).

4.2 Solar Light Energy

Distribution of openings in individual façades depends on the façade's orientation and the degree to which it is exposed to the sun's rays (Fathy).

Inner courtyards fulfill an essential role in conserving energy consumed for lighting indoor units. The larger the courtyard area, the more natural lighting indoor units receive. The amount of deflected light depends on the walls; light colors deflect the sun's rays.

Most indoor spaces depend on natural lighting coming in from the uncovered inner courtyard through numerous wide, open doors. When the doors are closed, the light comes in through the *qamariyyahs* located above most doors. *Mashrabiyyas* were used as a means to let in sunlight while avoiding dazzle. As explained earlier, the openings in the wood latticework are smaller in the lower section of the *mashrabiyya* than in the higher section, leading to a graduated inflow of light. An overhang above the exterior side of the *mashrabiyya* serves as a sunshade and prevents the entrance of direct sunlight, especially on south and west-facing building façades (Fathy, Waziri). The wooden pieces of the *mashrabiyya* are rounded, which leads to a gradual penetration of intense light, thus reducing the contrast between the interstices and the dark wooden pieces of the *mashrabiyya* (see figure 14).

Muslim architecture also use *madawys* (small openings, covered with a glass tile or the bottom of a bottle and placed high on the walls or in domed ceilings) to provide lighting in baths (Waziri). *Shokhshekhas* or skylights enhance lighting. Generally used to cover *durqa'as*, *shokhshekhas* may be square, octagonal, flat, pyramid-shaped, or dome-shaped, and they have wood windows at the top (Waziri, see figure 15).

The concept of using various heights for adjacent spaces provides lighting for upper floors. The *durqa'a*, for instance, is at a lower level than the two *Iwans* on each side of it, which are both at the same level, and is covered with a *shokhshekha* to provide light for the double height of the *qa'a*.

4.3 Wind Energy

Designers use the inner courtyard to re-arrange the indoor orientation of the building. Typically, the axis of the courtyard follows a north-south direction, creating thus several north facades. Traditional elements and components also follow certain orientations. For instance, the *maq'ad* on the short side of the courtyard faces north. *Qa'as* with *durqa'as* are placed at a right angle to the *maq'ad*. *Malqafs* (wind catchers) are used to recapture the breeze in building spaces that do not overlook either the inner courtyard or the outside (see figure 16). The *maq'ad* and *takhtabush* both face north (Fathy).

In the *Al-Suhaymi* House, although the *takhtabush* faces south, a cool draft is created from the southern small shaded courtyard to the northern large sunny one (figure 17). *Takhtabush* is a covered outdoor sitting area at ground level opening completely onto a courtyard and through a *mashrabiyya* onto a back garden. Since the back garden is larger and thus less shaded than the courtyard, air heats up more readily there than in the courtyard. The heated air rising in the back garden draws cool air from the courtyard through the *takhtabosh*, creating a cool draft. *Iwans* are another design element that serves as protection against the heat and to capture the breeze. *Iwans* also shield the rooms that surround them from climatic elements, both in the summer and in the winter (Fathy).

Hollows in the building block create different pressure zones and enhance smooth airflow. A number of small inner courtyards create empty spaces within buildings and serve to store cool air at night. When they are connected to a sunny courtyard where the temperature is higher, low-pressure zones draw in the cool air from the smaller courtyards, where the pressure is relatively higher. The difference in the size and degree of exposure to the sun's rays between these spaces creates a constant current of air passing through the building (Fathy).

Malqafs or wind catchers (figure 16), used to capture the cool outside breeze, are ventilation traps built into the corner of rooms or halls that faces the direction from which the wind blows (north or northwest). To capture the air and propel it into the rooms, their roofs slope upwards in the direction from which the wind blows (Fathy, Waziri). *Malqafs* have several advantages over other openings and windows. These include: the air passing through them is relatively dust-free due to its composition (see below), air movement is faster because the higher air from the ground the more is its speed, it ventilates rooms and indoor spaces that do not have windows to the outside and it moderates the temperature of air passing through them. There are several types of *malqafs*, including:

Roof *malqaf*: The simplest type; it consists of an opening that rises above building rooftops. It has a sloped (at a 45-degree angle) roof, or cover, made of wood and it is closed on all sides except that facing the wind. The sides, or walls, of the *malqaf* are made of wood or brick. Roof *malqafs* operate differently depending on whether the wind is blowing or is still. When the wind rises (night or day), it enters through the *malqaf* opening, replacing the hot air that moves upwards and out through the *shokhshekha* openings. If the wind is still during the daytime, the temperature of the *malqaf's*' sloped roof, exposed to the sun, rises, creating a low-pressure zone at the entrance to the *malqaf*, and the air is drawn out from the building's interior, to be replaced by the cooler air from the shaded courtyards. If the wind is still during the night, cool air, propelled by its high density, enters through the *malqaf* into the building and hot air moves out through the upper *shokhshekha* openings (Fathy, Zuhairy & Sayigh, Waziri).

Air well *malqaf*: This *malqaf*, equipped with an air well, is usually built in the corner of a hall that faces the wind. Its thick limestone walls are not exposed to the sun and they play an important role in cooling air temperature. Its roof, sloped at a 45-degree angle, is usually made of wood with brick or stone sides. The difference between this type of *malqaf* and the roof *malqaf* is that it has an air well that opens into the hall or space in need of ventilation. An air well *malqaf* also uses elements to cool and raise the humidity level of the air passing through the well: An earthenware pot filled with water is suspended in the upper part of the well, and coal is often laid out on a grid at the bottom of the well, acting as an air filter to minimize dust entering the building. Air well *malqafs* were a feature of Mamluk buildings and are also found in houses in Upper Egypt (Fathy, Zuhairy & Sayigh, Waziri).

*Shokhshekha*s, on the other hand, are skylights placed on top of the roofs of *durqa'as*, which are higher than those of the rest of the building. They have etched windows through which hot air escapes, and is replaced by cool air. They fulfill their function well in combination with architectural features such as *mashrabiyyas* and *malqafs*, the *shokhshekha* / *malqaf* ventilation system shown in figures 18 & 19 is the most efficient. When the wind is still, the roof of the *shokhshekha* is exposed to the sun's rays and heats up, creating a low-pressure zone, which draws air to the outside through the *shokhshekha* windows. When the wind rises, the *malqaf*, which is at a higher level than the *shokhshekha*, captures the cool air which in turn pushes the rising hot air out through the *shokhshekha* windows (Fathy).

In Islamic houses, ventilation and lighting is provided by wide windows that open unto the inner courtyard and, in some cases, narrow windows high up on the walls. Units made of gypsum openwork or carved wood are placed above window level. *Mashrabiyyas* are used to enhance air circulation inside rooms; air is drawn into the room through the small openings of the *mashrabiyyas* lower section and hot air moves out through the large openings of its upper section. This enhances and speeds air circulation in indoor spaces. When air temperature decreases, its size diminishes and both its density and its weight increase. The resulting rise in air pressure makes the air blow into the rooms through the small openings. As the temperature of the air in the rooms rises, it increases in size and diminishes in density and weight. The lower pressure causes the air to move upward and out of through the large openings in the upper section of the *mashrabiyya*. Additionally, the rounded surfaces of latticework parts enhance smooth airflow. *Mashrabiyyas* were equipped with solid wood and glass shutters to shield against the winter cold (Lane).

4.4 Environmentally Friendly Construction Materials

During Islamic eras, construction materials readily available in hot climate environments were carefully selected; light-colored materials with high thermal insulation properties helped to decrease temperature and increase humidity.

a. Stone was a widely construction material during the Ayyubid and Mamluk eras, and marble was used by the Mamluks.

b. Limestone was used in the construction of ground floors in most Islamic houses. Thick limestone walls contributed to the thermal insulation of indoor spaces (in most houses, external ground floor walls were built 50 cm thick). The light color of the stone meant that it deflected much of the sun's rays. Because of limestone's elevated thermal capacity, it took longer for outside heat to penetrate into indoor building spaces. Since the ground floors in Islamic houses were not normally used as sleeping quarters, the heat stored in the limestone walls during the day and released into indoor spaces at night was not a source of discomfort (Waziri).

c. Wood was used for building flat, horizontal roofs, *mashrabiyyas*, *takhtabushes*, windows, *malqafs*, *shokhshekhas* and as scaffolding during the construction of walls (Abdel-Fatah M. 2007). In the Beshtak Palace, the double ceilings made of wood with earthenware jars between their layers alleviated the structural load on the building and its lower spaces, and their porous properties helped to minimize indoor temperature (Fathy, Waziri).

d. Brick is one of the most important construction materials used in Islamic architecture, particularly in Egypt, where it is known as 'red brick'. It is used to build load-bearing walls, vaults and domes. Thick brick constructions provide good thermal insulation (Fathy, Waziri)..

4.5 Sound Insulation

Islamic house design is based on a sound knowledge of acoustics. This is apparent in the horizontal arrangement of rooms according to how they are affected by outside noise, in the use of thick walls made of stone and in the internal courtyards that created quiet indoor spaces (Fathy, Waziri).

Conclusion

Cairo is characterized by its dry climate, low rainfall and strong sunshine. Its residential traditional architecture adopted design patterns, elements and construction methods that made use of these climatic conditions. This study observed and analyzed various traditional components of Cairene houses from a green architecture perspective. The climate of Egypt was explained and typical designs of traditional residences in Cairo were described. Green principles and elements of environmentally friendly design were observed and analyzed such as the courtyard, *maq'ad*, *takhtabush*, *mashrabiyya*, *qa'a* design, water elements, *shokhshekha*, *malqaf* and construction materials in terms of solar heat energy, solar light energy, wind energy, construction materials, and sound insulation.

References

Abdel 'Alim F: *Al-Tatawwor al-Tarikhi wal-Athari lel-Mashrabiyya*; in Nazih T (eds): *al-Mashrabiyyat wal-*

Zujaj al-Mu'asha'fi al-'alam al-Islami, Proceedings of the International Seminar: Crafts in Traditional Islamic Architecture with Special Focus on Mashrabiyya and Stucco Colored Glass, 3-9 December, Cairo, 1995. Istanbul, IRCICA, 2000, pp 225-230.

Abdel-Fatah M: *Falsafet al tashkeel wa al ta3beer 3an al qeyam al thaqafeya fi 3ama'er al mogtama3ad al islameya al mo3assera wa al mostaqbaleya*: PhD dissertation thesis, Cairo University, Faculty of Engineering, Cairo, 2007.

Abdel-Gelil N: A new mashrabiyya for contemporary Cairo: Integrating traditional latticework from Islamic and Japanese cultures: Journal of Asian Architecture and Building Engineering (JAABE) 2006;5(1):37-44.

Abdel-Gelil N: A New Mashrabiyya for Contemporary Cairo: Integrating Traditional Latticework from Islamic and Japanese Cultures: PhD dissertation thesis, Hosei University, Graduate School of Engineering and Design, Tokyo, Japan, 2007.

Al-Wakeel SA, Serag MA: Al-Manakh wa 'imarat al-Manatek al-Hara. Cairo, Alam al-Ketab, 1989.

ASHRAE: International Weather for Energy Calculations (IWEC Weather Files) User's Manual and CD-ROM. Atlanta, ASHRAE, 2001.

Behrens-Abouseif D: Mashrabiyya; in Bosworth CE, Donzel V, Lewis B, Pellat C (eds): The Encyclopaedia of Islam New Edition. Leiden, E.J. Brill, 1991, pp 717-720.

Behrens-Abouseif D: Note sur la Fonction de la Cour dans la Maison Moyenne du Caire Ottoman; in (eds): l'Habitat Traditionnel dans les Pays Musulmans autour de la Mediterranee Cairo, Institut Francais d' Archeologie Orientale, 1990, pp 411-418.

Cairo: Encyclopaedia Britannica. Encyclopaedia Britannica Online, 2006. Available at: http://www.britannica.com/EBchecked/topic/88520/Cairo#toc275558.

Fathy H: Vernacular Architecture: Principles and Examples with Reference to Hot Arid Climates. Chicago, The University of Chicago Press, 1986. 47 p.

Garcin JC, Maury B, Revault J, Zakariya M: Palais et Maisons du Caire I Epoque Mamelouke. Paris, Centre National de la Recherche Scientifique, 1982.

Gianni S: Climatic Design in the Arab Courtyard House: Environmental Design: Journal of the Islamic Environmental Design Research Centre 1988;1(2):82-91.

Goitein SD: A Mediterranean Society: The Jewish Communities of the Arab World as Portrayed in the Documents of the Cairo Geniza: Vol. IV Daily Life (Mediterranean Society). California, University of California Press, 1983.

Hakim BS: Arabic-Islamic Cities: Building and Planning Principles. 2nd ed. London and New York, Kegan Paul International, 1988.

Institut Français d'Archéologie Orientale du Caire, editor. L'Habitat traditionnel dans les pays musulmans autour de la Méditerranée. Cairo: Institut Français d'Archéologie Orientale du Caire; 1988.

Lamei S, Fahmi A, Zeinhom M, Nagib E: Light Screens: The Arabian Turned Wood Work (Mashrabiya) and Stucco Coloured Glass Windows in Egypt. Cairo, Arab Egyptian Center, 1996.

Lane EW: Manners and Customs of the Modern Egyptians. Reprint of the 1860 3rd ed. London, Dent, 1954.

Maury B, Raymond A, Revault J, Zakariya M: Palais et Maisons du Caire II Epoque Ottomane. Paris, Centre National de la Recherche Scientifique, 1983.

Okasha A: Al 'emara al islamiya fi misr. Cairo, Bardy Pub., 2008.

Revault J: l'Architecture Domestique au Caire a l'Epoque Ottomane; in (eds): l'Habitat Traditionnel dans les Pays Musulmans autour de la Mediterranee. Cairo, Institut Francais d' Archeologie Orientale, 1988, pp 43-60.

Salama A: A typological perspective: the impact of cultural paradigmatic shifts on the evolution of courtyard houses in Cairo: METU-JFA 2006;23(1):41-58.

U.S. National Oceanic and Atmospheric Administration: Comparative International Statistics; in U.S. Census Bureau (eds): Statistical Abstract of the United States: 2001. Washington, DC, US GPO, 2001, pp 819-868.

Waziri Y: *Al'emara al islameya wa albee'a*. Kuwait, *'Alam al Ma'refa*, The National Council for Culture, Arts and Sciences, 2004.

Waziri Y: Environmentally-Friendly Architectural Design: Towards Green Architecture. Cairo, Madbouly Library, 2007.

Zuhairy, A., & Sayigh, A. A. M. (1991). Evaporative air cooling in Islamic Architecture. In A. A. M. Sayigh (Ed.), *Energy Conservation in Buildings: The Achievement of 50% Energy Saving: An Environmental Challenge?* (pp. 90-99). Various countries: Pergamon Press.

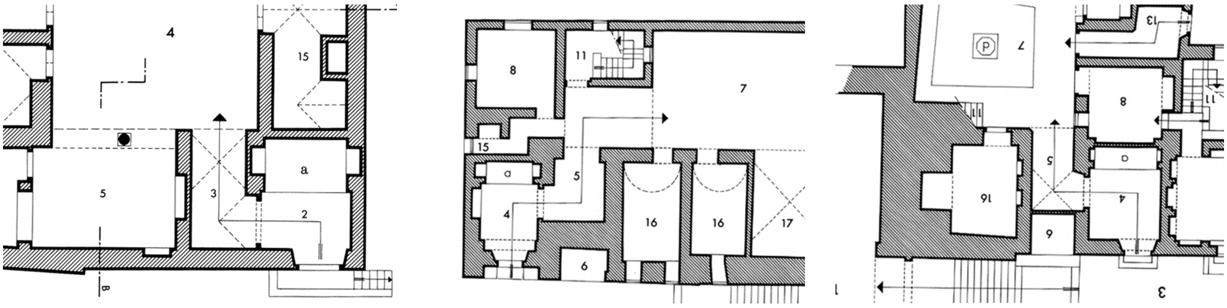


Figure 1. *Maggaz* (indirect entrances). Left, *Bayt Shabshiri*, middle, *manzil Amna bint Salim*; right, *manzil al-Kiridliya* (Maury et al. 1983).

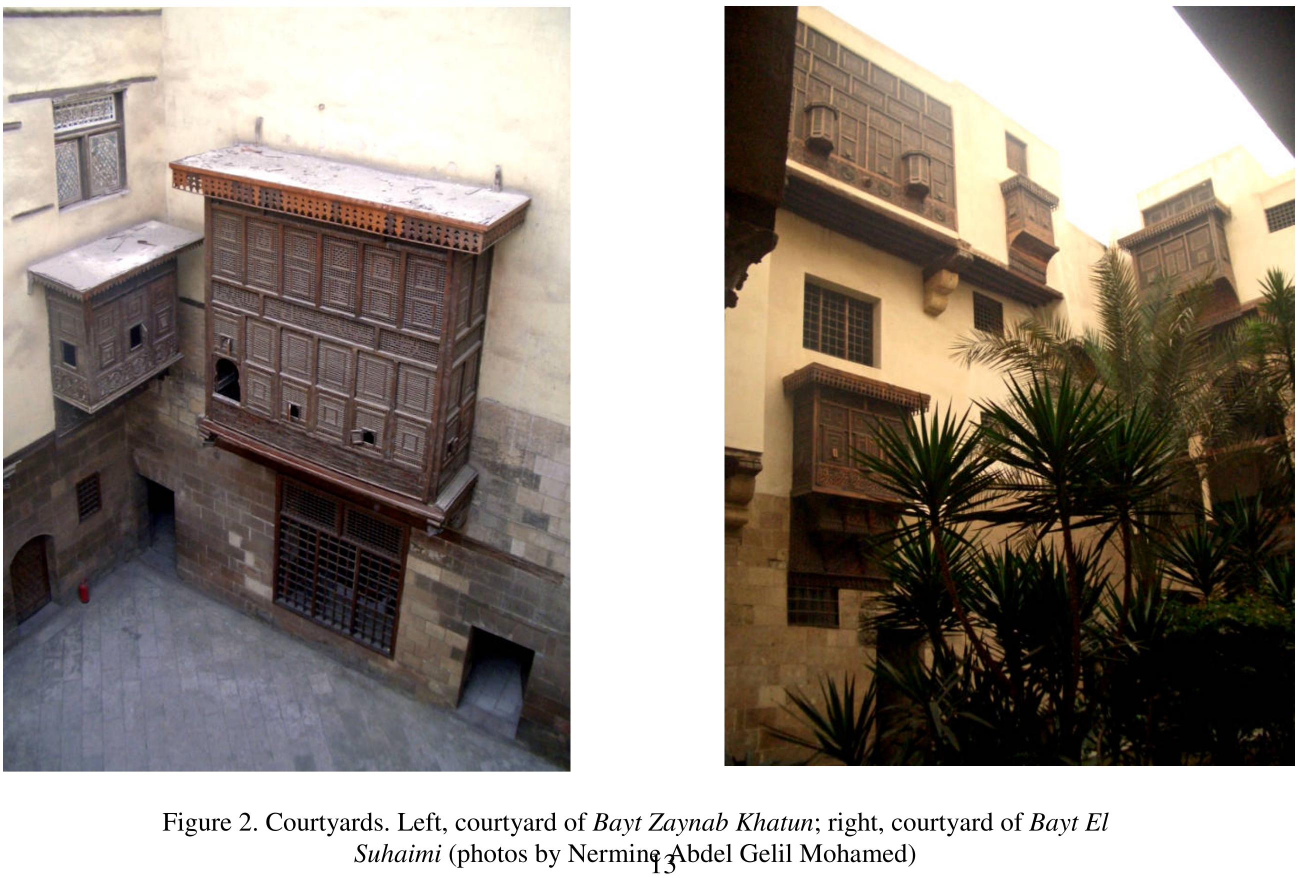


Figure 2. Courtyards. Left, courtyard of *Bayt Zaynab Khatun*; right, courtyard of *Bayt El Suhaimi* (photos by Nermine Abdel Gelil Mohamed)

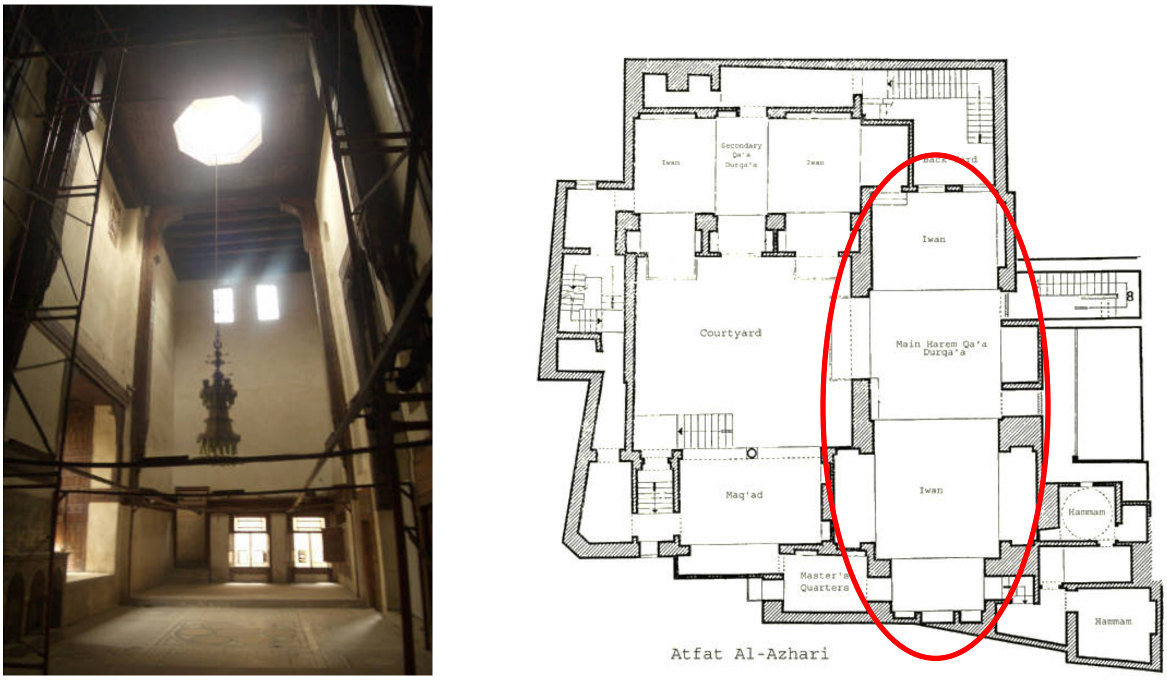


Figure 3. The *qa'a of Bayt Zaynab Khatun* (photo by Nermine Abdel Gelil Mohamed); right, first floor plan (Garcin 1982)

Figure 4. *Maq'ad* of *Bayt Zaynab Khatun* (photo by Nermine Abdel Gelil Mohamed)

Figure 5. *Takhtabosh* of *Bayt Al Suhaimi* (photo by Nermine Abdel Gelil Mohamed)

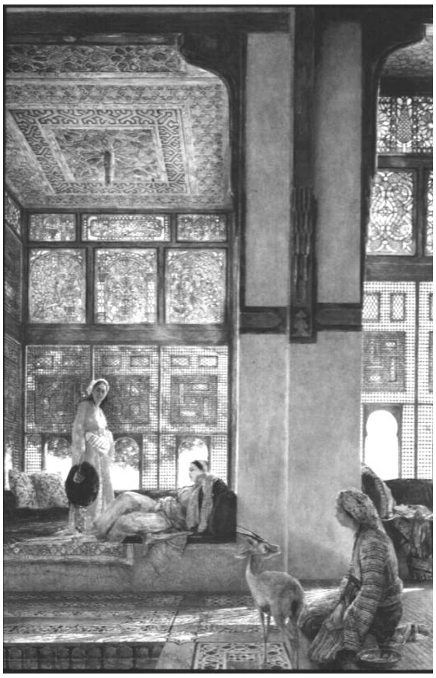
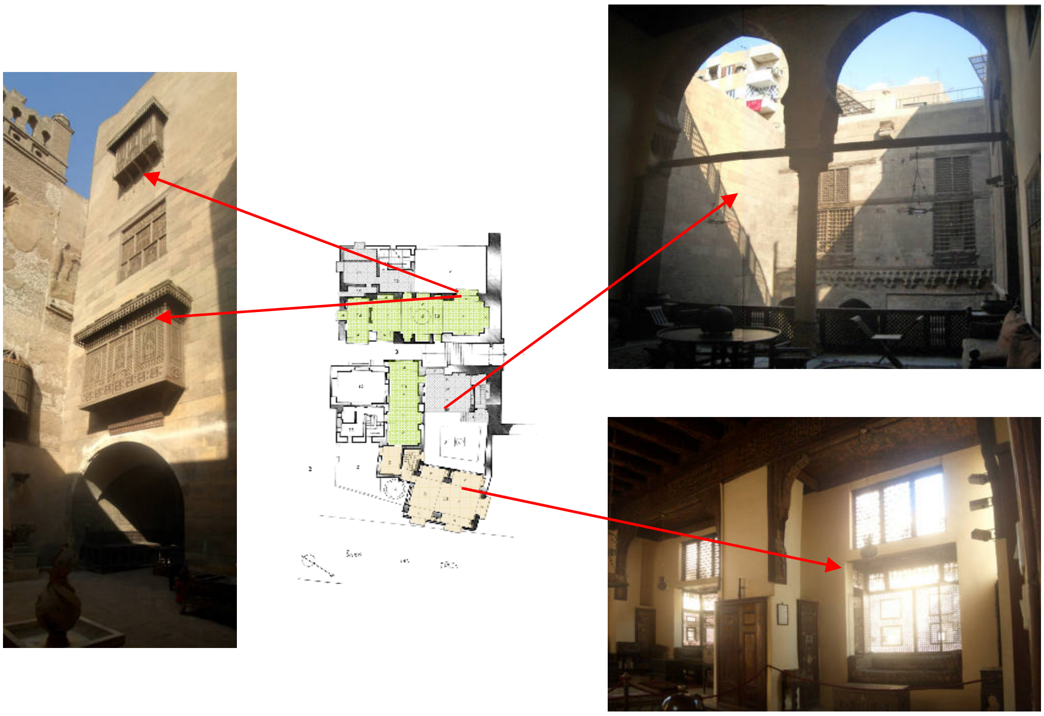
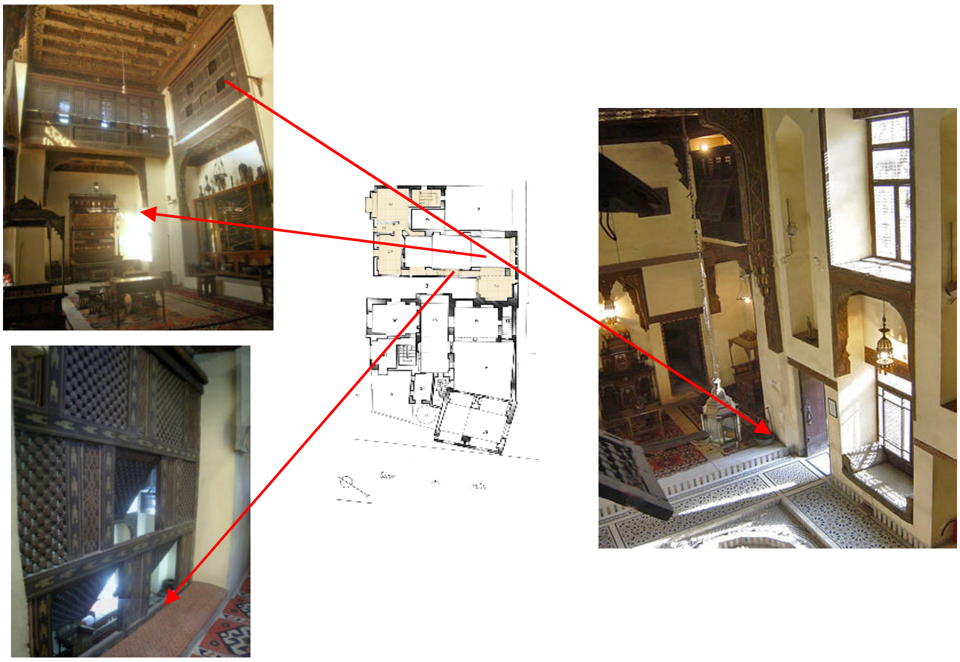


Figure 6. Women behind a harem's *mashrabiyya* (paintings by Lewis J.F. 1873)

Figure 7. *Manzil Amna bint Salim* (back) and *manzil al-Kiridliya* (front), located adjacent to Ibn Tulun Mosque on Ibn Tulun Street. Above, photo from the street by Nermine Abdel Gelil Mohamed; below, ground, first and second floors (Maury et al. 1983).



Left, the double height *qa'a* overlooking the courtyard of *manzil Amna bint Salim;* right, *qa'a* and *maq'ad* of *manzil al-Kiridliya*



Left, the double height *qa'a* of *manzil al-Kiridliya* showing the overlooking *haramlik*

Figure 8. *Qa'as*, *haramlik* and *maq'ad* of *manzil Amna bint Salim* and *manzil al-Kiridliya* (photos by Nermine Abdel Gelil Mohamed).

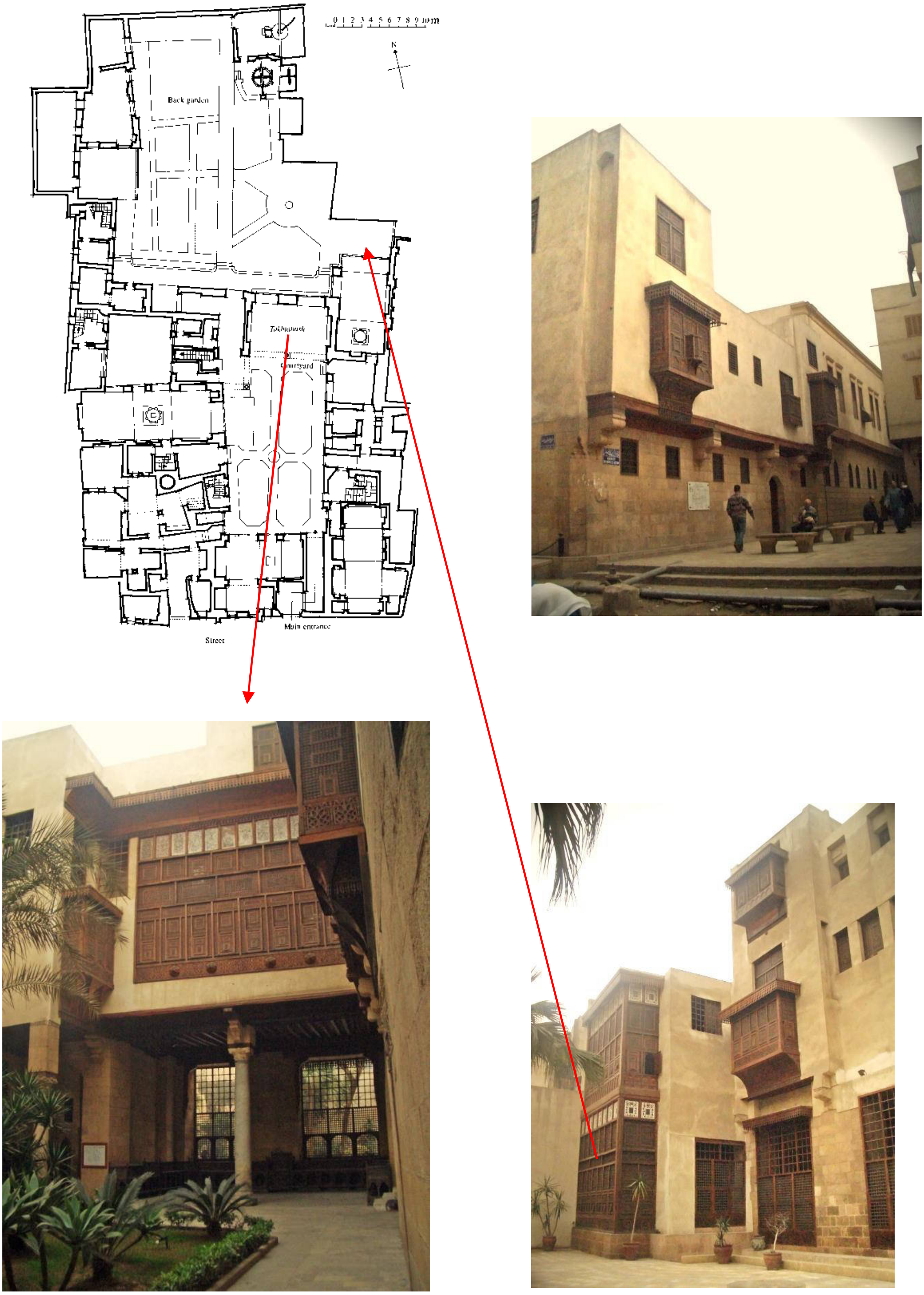


Figure 9. *Bayt Al Suhaymi* (1648-1796). Above left, ground floor plan (Hassan Fathy); above right, entrance façade from *al Darb al Asfar* alley; below left, *takhtabush*; below right, north façade on the back garden showing the *takhtabush* and huge *mashrabiyya* of one of the *qa'as* (photos by Nermine Abdel Gelil Mohamed).

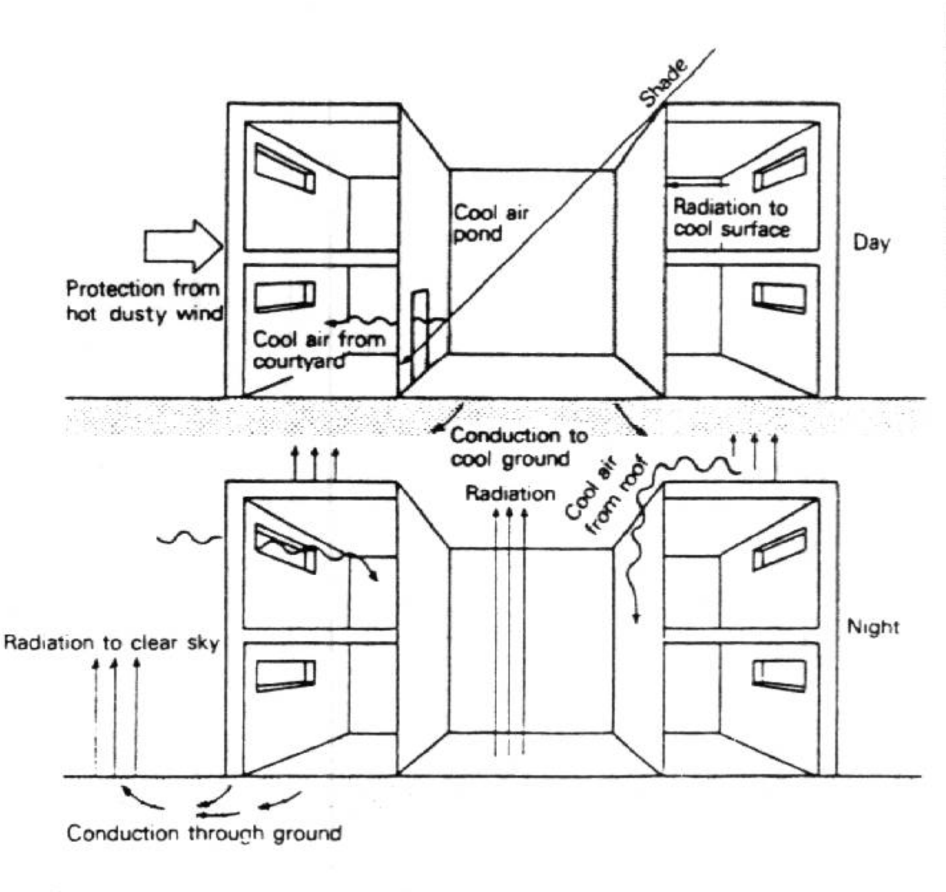


Figure 10. The courtyard thermal behavior (Gianni S. 1988)

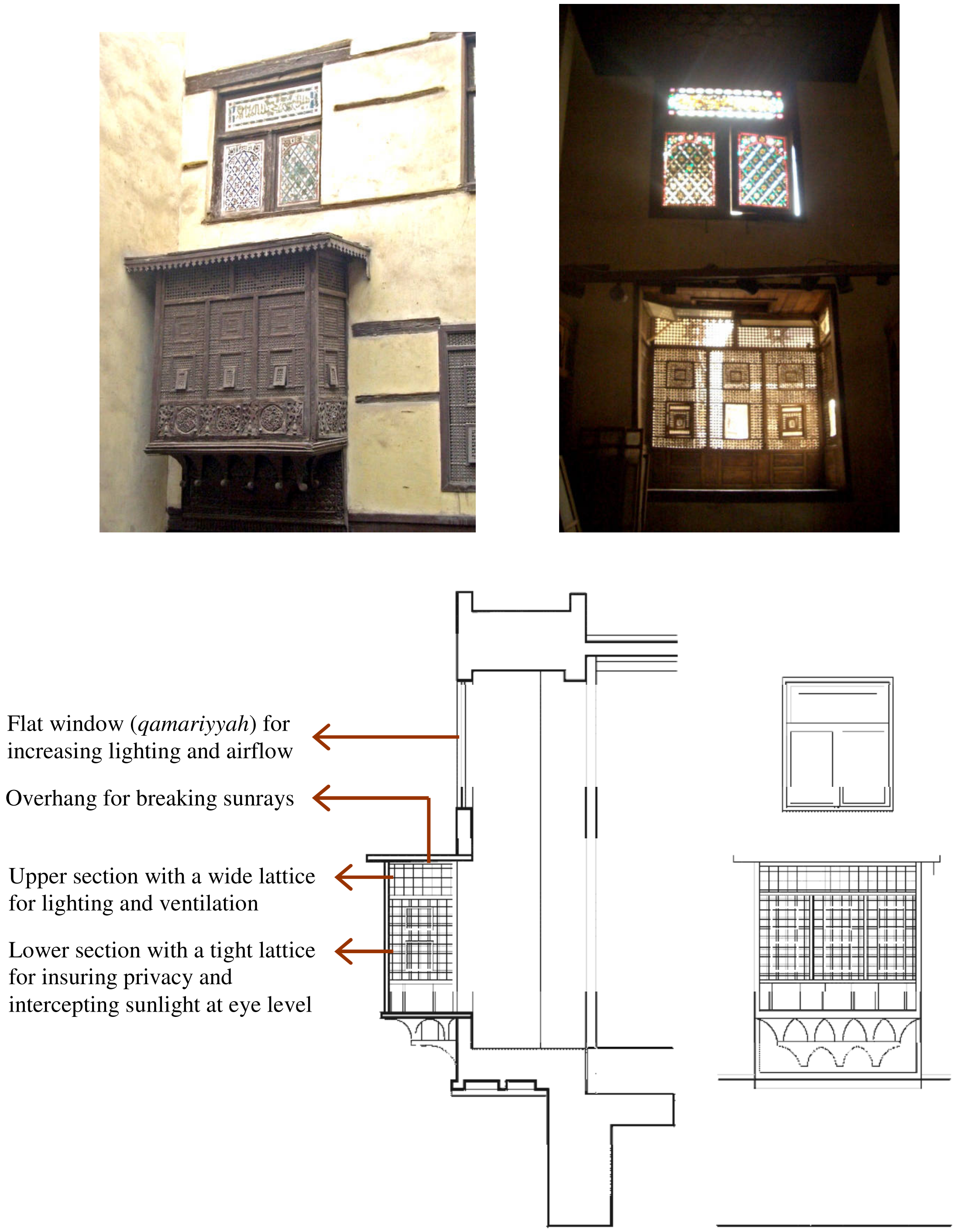
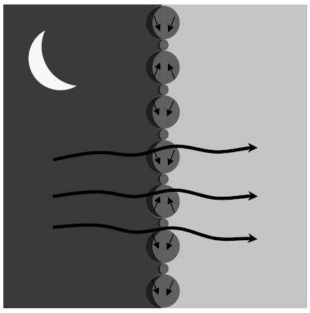


Figure 11. A typical *mashrabiyya* in the Northern *qa'a* of *Zaynab Khatun* House (photos and drawings by Nermine Abdel Gelil Mohamed)

At night, the *mashrabiyya* absorb moisture carried on the wind and passing through the interstices.



When heated by sunlight, it release the moisture into the air that passes through, thereby increasing humidity within a home and reducing its temperature

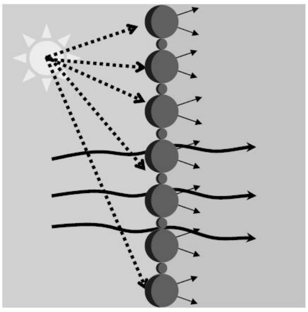


Figure 12. *Mashrabiyya*'s cooling effect through the evapo-transpiration process (Fathy, illustration by Nermine Abdel Gelil Mohamed)

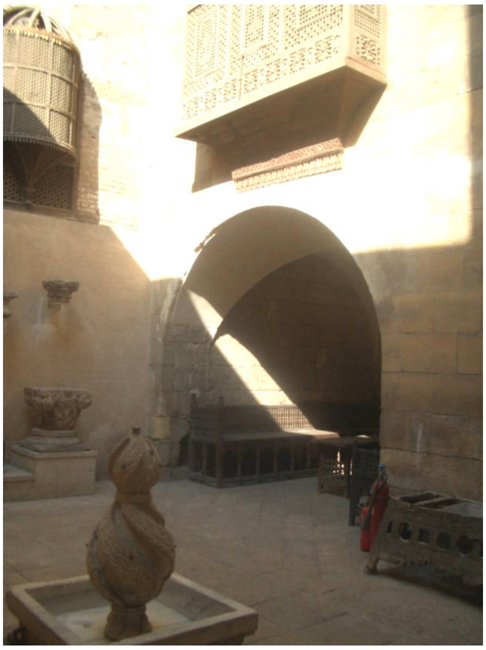


Figure 13. Fountains in traditional Cairene houses: left, fountain in the courtyard of *manzil Amna Bint Salem*; right, fountain in the durqa'a of *bayt El Harrawy* (photos by Nermine Abdel Gelil Mohamed).

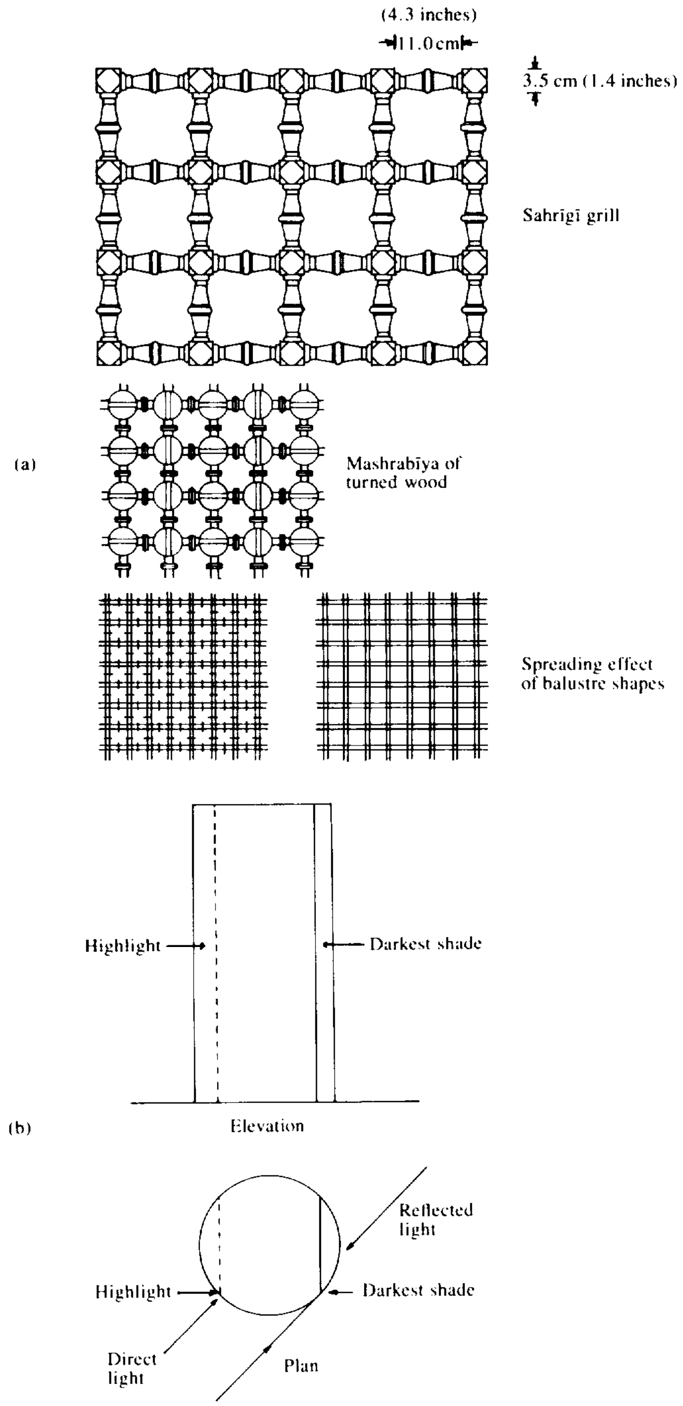


Figure 14. Hassan Fathy's analysis of light falling on a *mashrabiyya*: the cylindrical shapes of turned wood pieces graduate the penetrating light thus reduce the dazzling effect of dark and light contrast which occurs when looking from the inside toward the outside (Fathy).

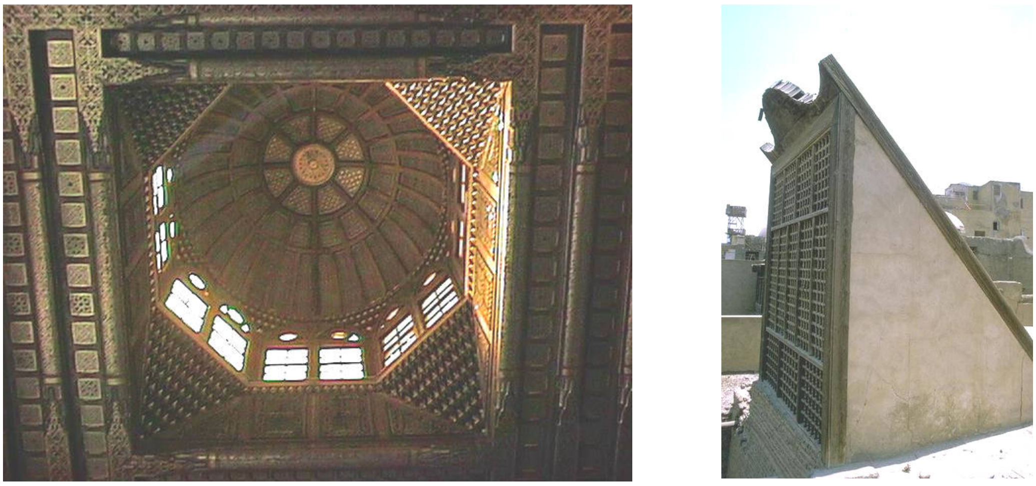


Figure 15. *Shokhsheikha* and *malqaf* in *bayt al-Suhaymi* (photos by Nermine Abdel Gelil Mohamed)

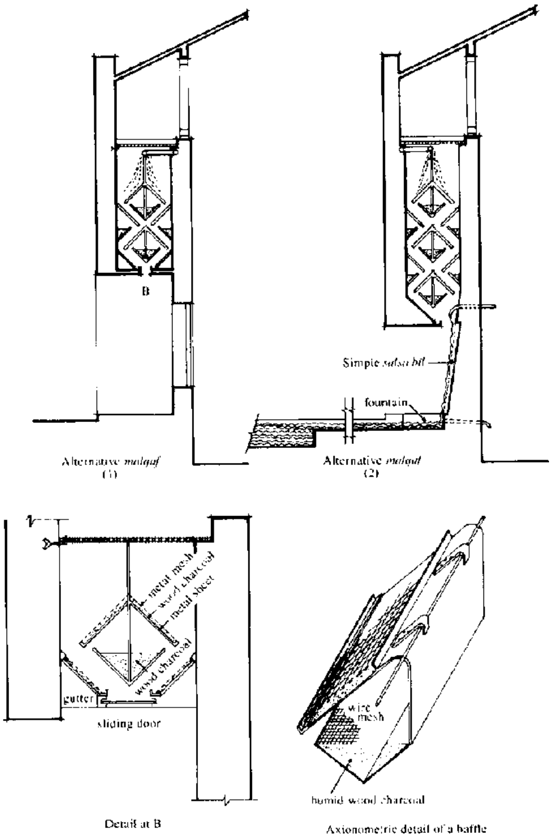
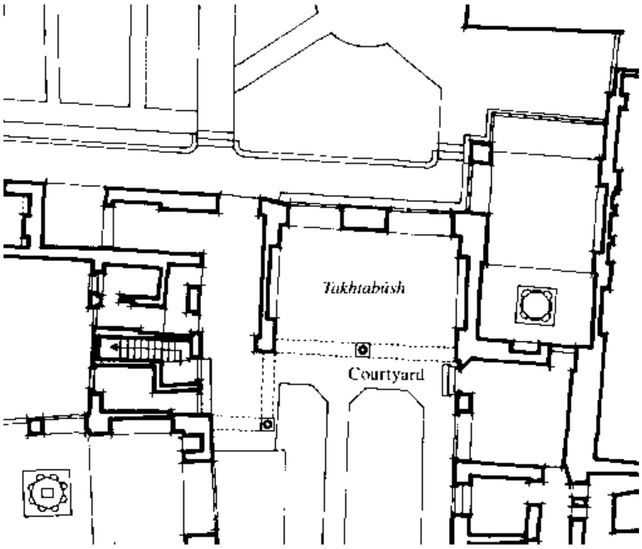


Figure 16. *Malqaf* with wetted baffles and a wind-escape; design by Hassan Fathy (Fathy)



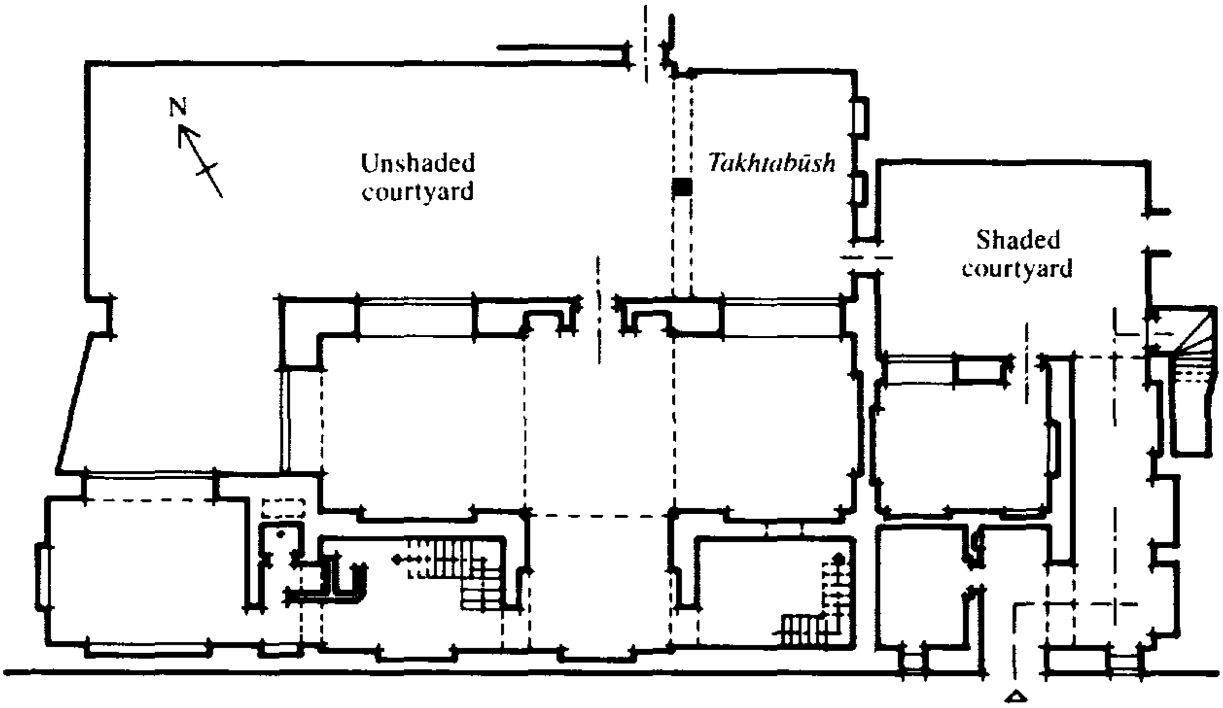


Figure 17. Unshaded courtyard – *takhtabush* – shaded courtyard relationship. Above, *bayt al-Suhaymi* (plan, Fathy, photo by Nermine Abdel Gelil Mohamed); below, ground floor of *Qa'a* of *Muhib Al Din Al Shaf'i* (Fathy)

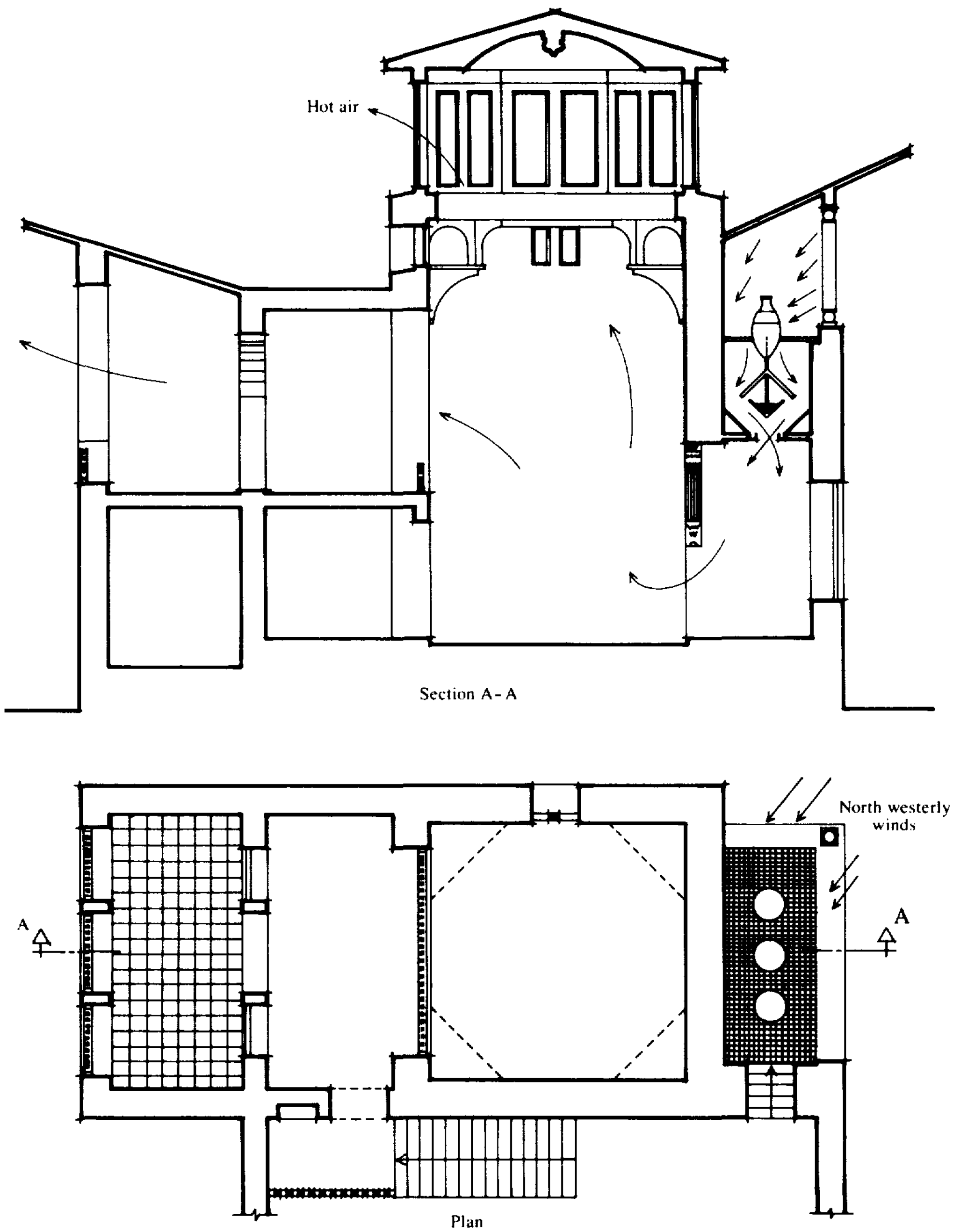


Figure 18. *Shokhshekha* / *malqaf* ventilation system designed by Hassan Fathy (Fathy)

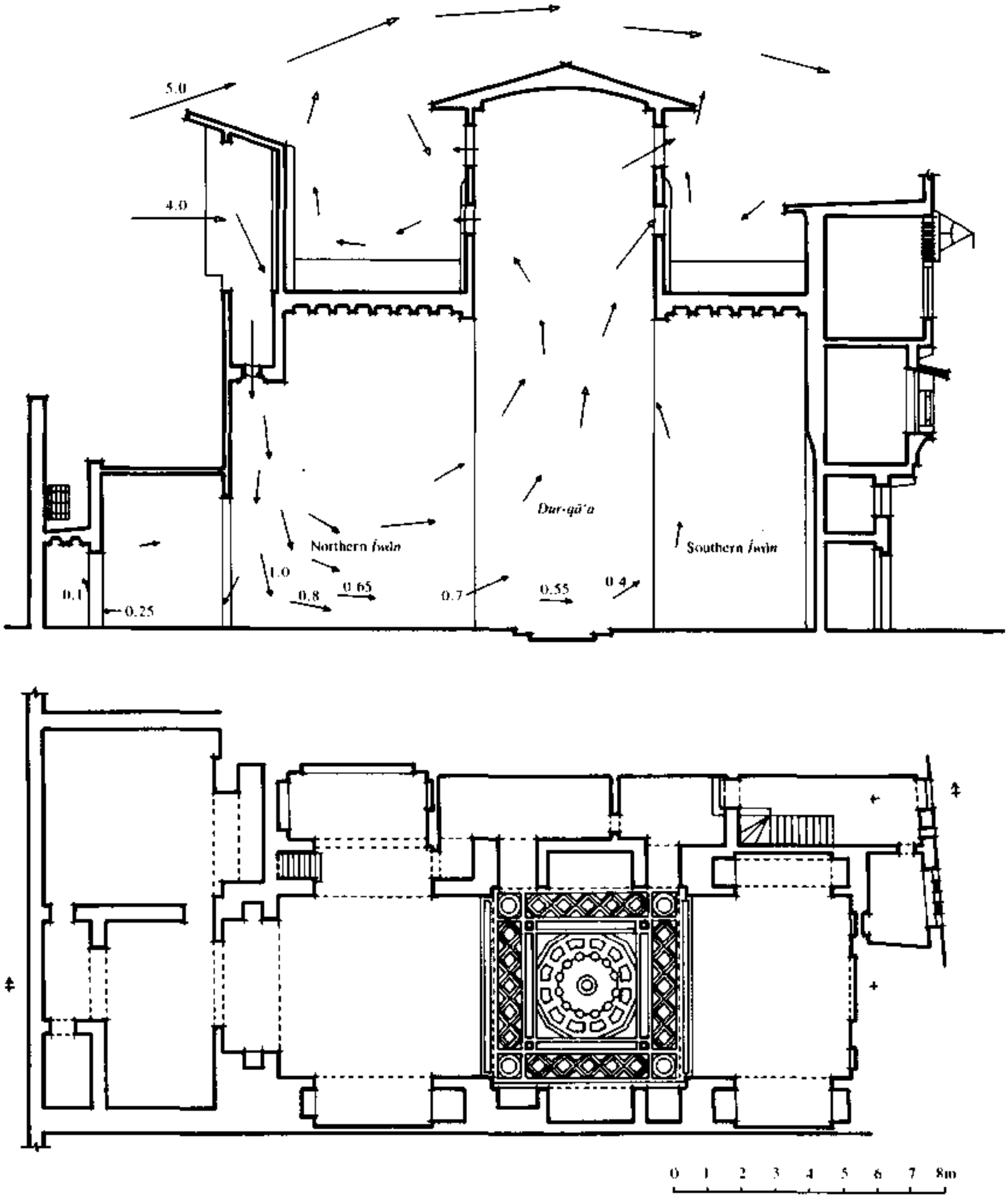


Figure 19. *Shokhshekha* / *malqaf* ventilation system in *Qa'a* of *Muhib Al Din Al Shaf'i* (Fathy)