

## Passive Cooling in Traditional Construction: Case of Domestic Architecture in Egypt

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### Abstract

This research, dealing with environmental protection, defence and the reuse of the traditional constructive techniques, finds appropriate answers in the study of the forms, technique and features of Mediterranean cities. Starting from a urban scale analysis and a traditional town planning, you arrive at the study of its architecture and its extrinsic systems: court house, the takhtabush, the loggias, courtyards, covers, the mashrabiya, the claustrum, the wind-escaper, the malqaf, the badgir, the qà'a, the salsabil, the landscape. These cities, subject to extreme climatic situations, since the past, have given simple and efficient architectural and technical answers. For example, the relative humidity and the temperature were both controlled through stone and raw brick construction. This condition, combined with a control operation of cooling systems and their use in a hot-dry climate, exploits the high thermal mass of stone or cooked or raw brick masonry. This process can slow down the passage of heat inside and maintain low temperatures during the hottest hours.

**Keywords:** *environmental protection, extrinsic system in Mediterranean architecture, cooling system.*

## **1 Form and technique in domestic architecture of Cairo.**

The research comes from the study of singular places within the Mediterranean basin, which, in the past, gave architectural and technical answers, both efficient and practical considering the extreme climatic conditions.

The complex relationship between architecture and climate is the origin of this discussion, up to the achievement of wealth and comfort, dealing with the climatic problem in architecture through physics.

Egypt has a climate distinctly desert, characterised by sultry heat and drought, owing to the geographical position of the country in a north African large desert tropical strip. The extreme shortage of water affects the landscape. Vegetations and agriculture are possible only near rare humid climatic zones.

Cairo, placed at latitude 30° north and longitude 31° east, has the typical features of the northern Egypt desert climate, an extremely dry climate, characterised by rare rainfall in winter semester and only for a few days.

The traditional architecture in Cairo converts the extreme climatic conditions into a sophisticated local construction culture that anticipates the modern bioclimatic approach to design.

The climatic conditions of these areas, in fact, have determined the inclusion of specific techniques of passive climate control, which, in the past, favoured a better thermal comfort inside houses. The urban structure is organized so that spaces are controlled, regular, introverted, thus providing, on the one hand, for the environmental wealth, ensuring light and ventilation, on the other hand it becomes an expression of urban culture.

“Les Maisons du Caire” is among the most complete examples of architecture in harmony with the ecosystem. These houses are considered case studies strongly explanatory of this research and tools of methodological definition.

## **2 The Formal and Constructive Parties of the Cairo House.**

The domestic architecture in Cairo has a very different style from that of other African places from Mamelouk period (thirteenth-sixteenth century) onwards. Whether the Mamelouk houses are built within the Fatimid walls, on the banks of the Nile, or near the Citadel, they generally overlook the street or a private courtyard. They are strongly influenced by the place and have a well-organized structure.

On the ground floor there are usually kitchens, storages for food or stalls, rooms for housework and reception that represent the organizing and administrative heart of the most private part related to everyday household.

The upper floor with its bedrooms, living rooms or service rooms, is almost entirely closed, to protect from the heat and outsiders. This part of the house

combines two important aspects of everyday life, joining in an antithetical, but at the same time symbiotic way, the public and private sphere of family. The rooms are divided into women's rooms and men's rooms. These spaces are characterised by lack of large openings, which reflect the unique character of the Cairo house, and where tranquillity and privacy are guaranteed by the complex architecture.

Among the most important elements of houses in Cairo there is the court: on the ground floor, just like on the upper floor, all the rooms and spaces are organized around the court, that is the heart of the house, but it can be also considered one of the most important elements for natural ventilation of the all domestic architecture. The court-system is useful for natural air-cooling.

The court may also take the role of staging area for the reception of merchants passing along the caravanned way on which most of the houses overlook. To enter this area it is necessary to cross the bayonet entrance and the following maq'ad.

From the court you reach the most emblematic space of the house in Cairo: the qa'a. This space, depending on the circumstances, devoted to family meetings, receptions or parties, is the representative part of the house, the place where to stay, live, receive and relate to others. This place is the founding element of the house and, as evidenced by the literature, the house itself was named after it: the qa'a house, which knows its decline only in the late Ottoman era.

The need for a reception and representation room is transformed over the centuries and becomes more and more important. In the fifteenth century there is indeed a new reception room reserved for men, called maq'ad.

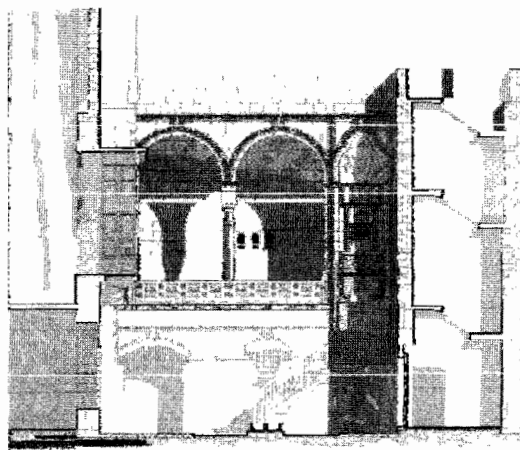


Figure 1. Drawing section of a Maq'ad (Qa'a Zaynab Kathun).



Figure 2. Qa'a Zaynab Kathun Maq'ad.

It opposes, in its architectural design, the qa'a, that was usually closed and not very bright, almost dark, with large balcony that overlooks widely on the court or the garden, across two or more arches, ensuring a moment of openness and breathing more than the ever-present qa'a, which does not escape the foundational role that sets it apart.

In the seventeenth century, as witness to this constant and relentless path, it is added to the ancient loggia above the maq'ad, a new place of rest and reception, a sort of porch, or takhtabush, that is related and organized within the court or the garden.

The takhtabush is a place reserved to men; it is just a place like a portico, on the ground floor, that appeared in XVI – XVII century. Takhtabusch is usually covered by a wooden ceiling supported by stone columns. This place, near the entrance of the house, is opened on the south side of the court, but natural ventilation is also ensured by mushrabiye. It is a space of shadow and light breeze, it plays an important role in the Cairo house, because of its technical and aesthetic function. The court, with its distribution value, has a semi-public vocation.

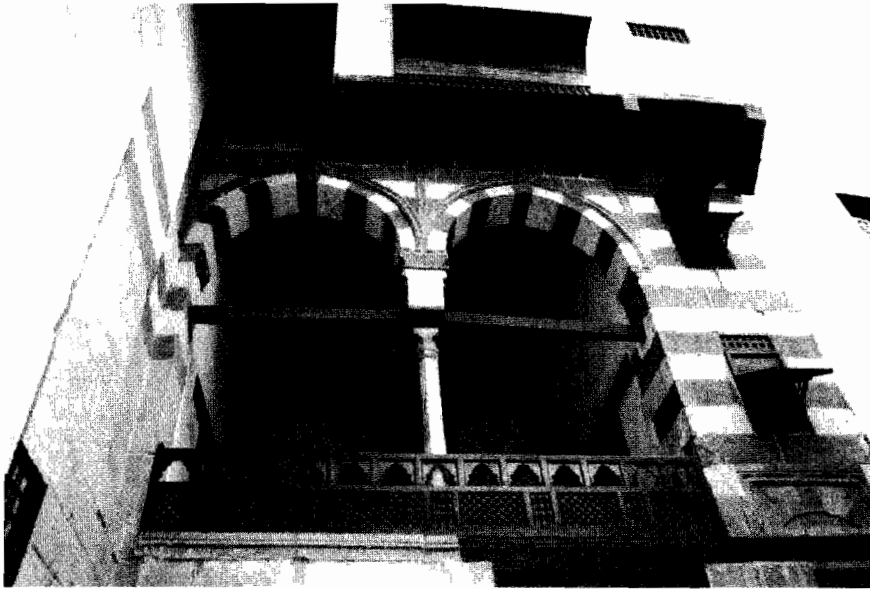


Figure 3. Constructive detail of the maq'ad.

The house then undergoes significant and important changes that will lead to find the most mature form of the Cairo house, reaching its highest expression in the Ottoman era.

## 2.1 The Qa'a

The Qa'a is the main room of the all house and, being formal and constituent part of the Cairo house, it is made up of two strongly hierarchic elements: the central Durqa'a and two or four Iwan, which are lengthwise or widthways located.

The durqa'a is generally a square or rectangular space, with a double-height slightly lowered, compared with the iwan side, from which stands out a lantern, the Marmaq, ensuring the ventilation and lighting of qa'a. On the heart of durqa'a often takes place a fountain has aesthetic role, and that collaborates with refreshment of the room by mixing air and water for increasing the humidity . In fact, the durqa'a with its lantern, while being one of the most important space of domestic architecture, is also an important element to leave convective motions of the air.

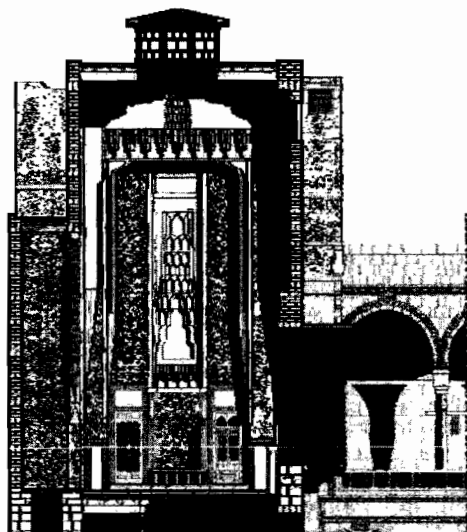


Figure 4. Drawing section of Qa'a (Qa'a Zaynab Kathun).



Figure 5. Qa'a al Dardir iwan.

Iwans' side assume the role of relax spaces where you can comfortably attend events organized by the owner of the house.

It is usually located on the ground floor, but it can also be found upstairs, but in this case it is specifically a mu'al-laqa.

The qa'a also has secondary spaces all around: a vestibule, lavatories, a khurustan, some windows (taqat) and it usually has a higher room, called tabaqa.

The mandara is a specialization of qa'a, usually placed on the ground floor, exclusively devoted to men. The presence of mandara carries qa'a to the upstairs. When you find a mandara in domestic architecture, it is often possible to find a qa'a, on the upper floor, for women. Several rooms are attached to the mandara as rest rooms, used by households.

The qa'a generally is illuminated and takes air through a sophisticated wall and a ceiling system. In the central elevated area is placed a skylight roof.

By the end of the Mamelouk period and the beginning of the Ottoman one, there is an increase of Mandara and qa'a within a single household group, as for example in Bayt Al Suhaymi. This type of house, sumptuously decorated, is emblematic of the complex house in Cairo.

The Maq'ad, or porch, appears in the fifteenth century and represents a new reception room devoted exclusively to men and placed at the ground level of the house. The porch overlooks the courtyard of the house. Its specific function is that of living room or reception room and it is the preferential area of the house, richly furnished with cushions and carpets. This space opens on the garden, through windows and doors with grilles, mashrabiya.

Element of mediation between the road and the house, the maq'ad is the place to wait for guests before accessing the private space of representation of the house: the qa'a.

### **3 Structure and Systems of the Cairo House and Tectonic Sequences**

The systems that allow a balanced relationship between the city and home, between the house and collection devices in the Cairo house, are defined and structured. The skifa, an entry bayonet that allows the opening on the road and especially proper ventilation, however keeping the visual privacy of the same and the court are systems, which contribute together with the malqaf to produce the passive cooling.

In winter blows the harmattan, a north-west aliseo, that blows from the Sahara carrying a large amount of red-dish dust; the cloud of dust, travelling, has a vertical structure that can reach 5000 m in height. In the spring blows khamsin, a warm and dry wind, that comes from the south-east. This is not a monsoon, as it does not blow constantly for long periods of time, but intermittently, it is active during the period between late winter and the start of the summer. The name derives from Arabian khamsun or hamsin, which means fifty, which is the approximate number of days during which it blows, carrying with him sand storms. Less frequently, the khamsin may also blows in winter, as the wind, relatively cold, always carries sand and dust. The orientation of the urban fabric is historically determined by a complex set of cultural religious and functional factors, but we cannot overlook the role of climatic factors.

The environmental and morphological characteristics of the site determine

the shape and orientation of buildings. The structural, distributive and formal of the house are influenced by materials and by wooden grids, which protect the intimacy of the house from the outside world and ant the same characterize them aesthetically. By shielding the window, it is possible to reduce the glare of the sun and to regulate humidity of the breeze passing through it.

These techniques of guidance of the main direction of the winds, of shading, of thermal mass and convection currents, set up a consolidated system in the traditional construction of ancient residences, but at the same time would be useful in modern buildings.

Such techniques are also present in the texture of roads drawn from the Fatimid for the foundation of the ancient city, a grid, designed so that only the large Al-Muizz street could have north-south orientation, squarely with the evolution of the sun to get the shade during most of the day. The secondary roads branch off the main one in a east-west direction, remaining constantly in shade, due to their very small section and thanks to the upper floors of the houses, that protrude from both sides above them. The only area exposed to direct sunlight is the intersection of routes with the main artery.

These elements represent a complex architecture and a urban system in which the form follows the technique and technology declines its materials.

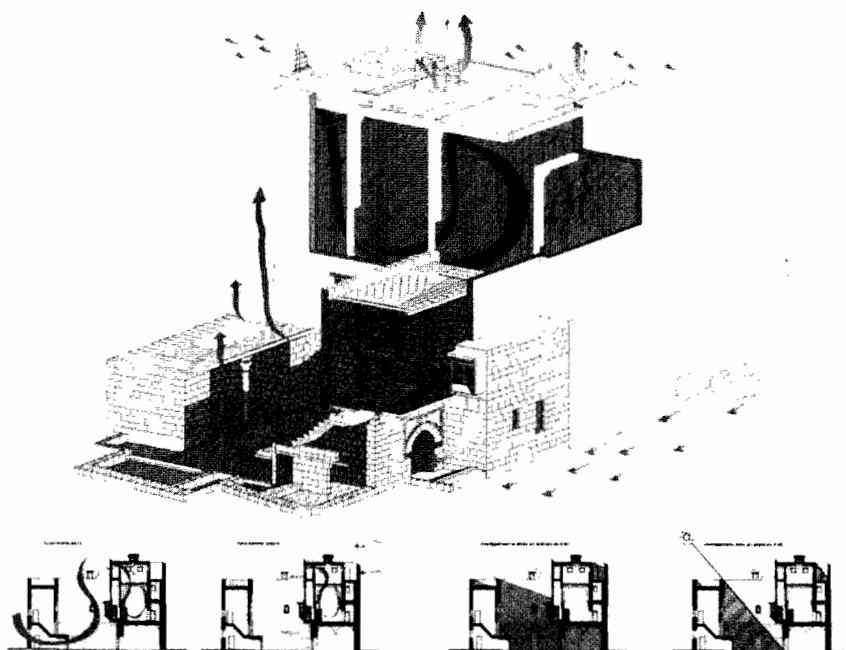


Figure 6. Representation of air cooling and natural ventilation in domestic architecture.

Through proposed architectural solutions, it is possible to ensure flows and



currents of natural air in desert areas, using some physics principles.

By tapping wind through badahaug and malqaf, there is an architectural response to the problem of high temperatures in a desert climate. In these areas, therefore, this device has had a great development and it is still a characterizing element of the local architecture

Among the factors that better explain this phenomenon is the northern malqaf channeled the north cool breeze and brings in the qa'a result of pressure from the air, caused by the wind at the entrance.

The Bernoulli-Venturi effect is fundamental to understanding how the differential pressure generated by currents can produce air flow.

In fact, the difference in speed produces a differential pressure that causes a blast from areas with most pressure to those of least pressure; the air heats up inside the qa'a, rises and gets in touch with fresh introduced by malqaf, the wind comes into iwan, rises to the top of dur-qa'a, accelerates by form and escaping from musharabbye.

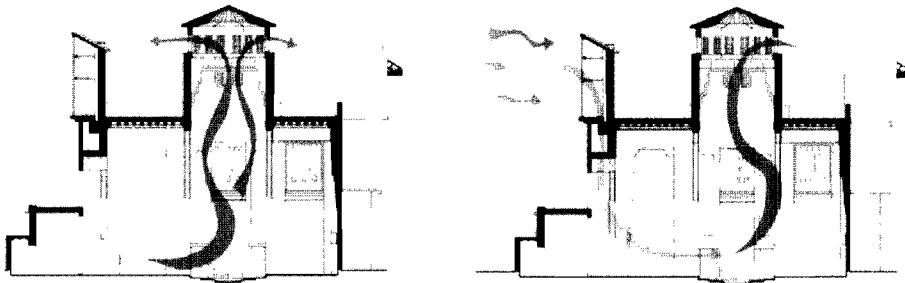


Figure 7. Diagram of operation of Malqaf.

The final product is once again a perfect balance between human needs and qualitative and morphological characteristics of the soil.

### 3.1 Tha Malqaf System

Malqaf, then, are wind towers, with the opening facing north, devices that can capture the dominant breezes and avoid direct solar radiation penetrates courtyards or the covered premises.

This architectural device directs the wind inside the house, with the aim of providing controlled natural ventilation, which is essential for the comfort of the inhabitants of the house.

The main feature of this device is the structure that stands out from the top of the roof, designed precisely to capture the wind.

For the proper functioning of this component, it is necessary it has a system to close and filter.

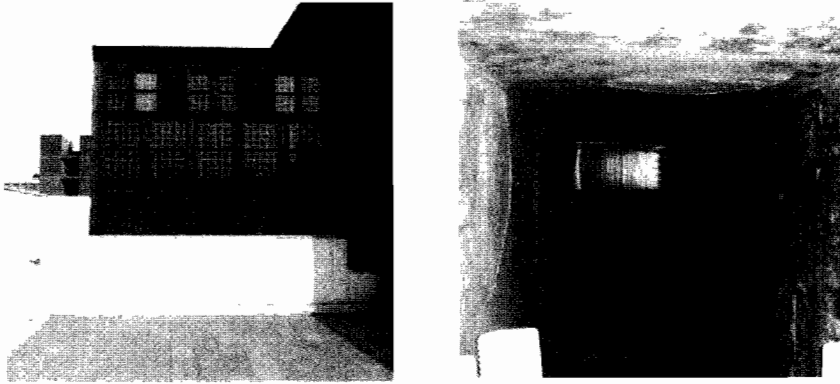


Figure 8 – 9. The Malqaf System.

The malqaf channels inside the prevailing current of air from the north, and then adjusts the flow and access in qa'a, through a series of different openings within it. The air, directed towards the central part of qa'a, is further cooled by a fountain on the floor of durqa'a; when the air becomes warmer it tends to rise upward, it comes out through the high central tower of the room, the shuksheika, which is a hexagonal or octagonal or circular lantern, and fitted with openings on the sides, then it expedites the flow of air masses up and facilitates the expulsion of hot from the tower to the outside.

Finally, the dome of high tower durqa'a, that is a light wood building, allows it to warm up and increase even higher convective cycle, creating air currents inside even when the air is completely stopped.

The malqaf is characterized by:

- a projecting roof, which is a very lightweight wood building. The system, which is absolutely essential in the process of tapping wind, is characterized by two vertical supports on which rests a horizontal beam. This simple element, which supports part of the cover, also defines the main opening towards the north which is the central part of the structure;

- an internal or external masonry conduit that passes through the various levels of construction and that serves to channel and redistribute the wind inside the building. These conduits have shapes and sizes, which vary widely;

- a draft system: the fresh wind cannot penetrate the collector to arrive then in the room unless it is related to a series of openings that allow air, already present in the room and overheated now, exiting through a large and soaring opening, the skylight or mamraq;

A system of monitoring and closing of the wind collector. There may be windows, wooden grates, grills, shutters of wooden doors, depending on the type

of collector;

A filtering system: it can be found inside the masonry and outside conduit, a series of small wooden shelves, often staggered, used to purify the wind from insects and sand that characterize the Cairo hot desert wind. They represent real filtering systems.

### 3.2 The Mashrabiya

In the seventeenth century the opening becomes the window in the wall, but it is screened by a flat or rounded wood carved grate, which will be literally called mashrabiya.

The term "mashrabiya" literally means "place used to store drinks" and it is a small projection in a dim light, that served for support of small jars that needed to stay cool; exposed to light, this kind of balcony is composed of small carved wooden items that are then assembled to create a grid. Over the centuries the term has been extended and large wooden panels, made with this technique, have the same name: mashrabiya.

The mashrabiya is a window element that automatically activates a convective cycle that moves air masses from the zone of high pressure to that of low pressure.

This ventilation phenomenon gives also comfort to the small streets naturally. In the afternoon hours, when the court begins to warm up, the malqaf system returns the air in court as far as the secondary roads, until the evening, thus creating a perfect balance between the different areas of the house.

In the Arab system of the house three functions are entrusted to openings: ensure the lighting of the room without the glare effect; ensure ventilation of the room through humidity and impurities filtering system, given by a more or less dense mesh, and allow people, who are in the room, to have a look on road without sacrificing privacy.

The grid can have a large or small mesh depending on the function of the room:

- the larger mesh allows air and light to penetrate; it ranks at the top of the opening, closer to the ceiling of the room;
- the smaller mesh ranks in the lower openings of the complex system, thereby protecting the privacy of women of harem, preventing any kind of indiscreet glance from the outside, but at the same time ensuring a safe and fair view of city life.

The entrance is a real filter between the macrocosm of town and the microcosm of the house, between public and private, a sacred and symbolic ritual joining and separating two worlds that keep a strong antithetical relationship.

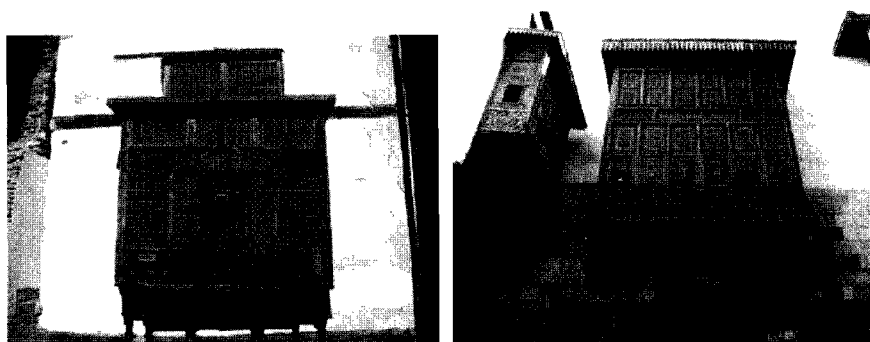


Figure 9. Qa'a al Dardid mashrabiya

Figure 10. Qa'a Zaynab Kathun mashrabiya.

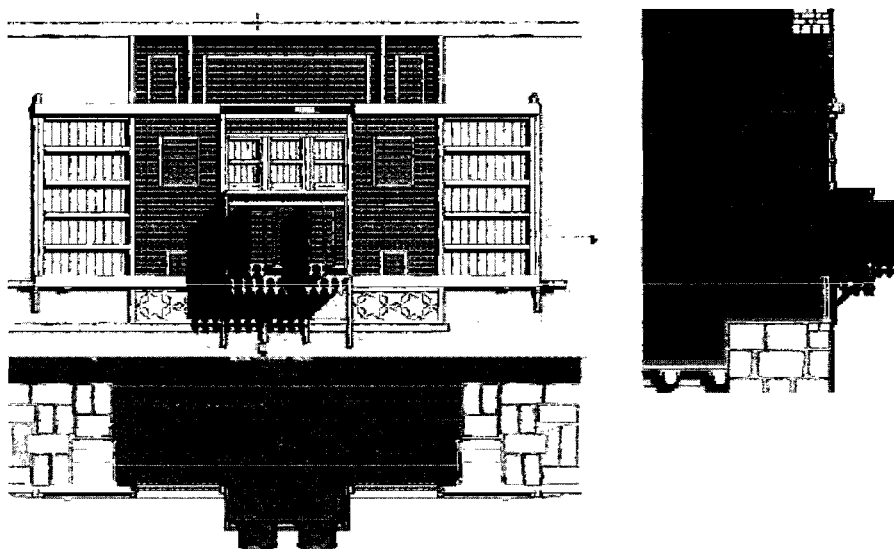


Figure 11. Drawing plant, section and façade of Qa'a al Dardir mashrabiya.

#### 4 Conclusions

The compilation of a manual of good practice is based on the traditional construction, with particular reference to experiences of the History.

The close analysis of the morphological genesis of places and their close dependence on climatic phenomena, have confirmed the need to use again these

construction techniques, without changing the distinctive features of the place.

Architecture has its own “natural” order, which is not influenced by history or styles; it is the order of physical function. Styles update, languages change, but the physical principles of behaviour of buildings remain. The perfect functioning corresponds to a right link between the technical possibilities and the ability to read the external environmental conditions.

In architecture it is essential to understand the vocation of a place. This means to study and analyze the traditional architecture and to propose updated morphological and typological solutions, considering the geographical potential and the emergence of new needs.

The environmental issue requires a radical departure from the indiscriminate use of energy.

The project must make choices and then direct them towards the use of local, climatic and materials resources, thus opening new eco-efficiency scenarios. A planning, which takes great care over energy conservation and sustainability, must pay attention to the technical and cultural features of its own environment.

To make an environmental control means to ensure a climatic comfort. Such a control can be made by constructing buildings with thick and solid walls characterized by high thermal mass, so to oppose external conditions to a conservative behaviour of the internal environment, thus causing the thermal inertia.

Another form of environmental control is determined by the correct employment of the building elements: doors, windows, screens. These elements facilitate ventilation and prevent overheating.

These intervention models are based on passive methods, on the one hand isolating the building from the outside by using a high thermal mass construction, thus securing the day heat all through the night, in winter, and the night cool during the day, in summer; on the other hand using openings with special shielding. These openings are sophisticated devices, which enable to create gentle breezes and to maintain the coolness of the rooms. They are always made of wood, a material that does not become red-hot even if it is exposed to sunlight for a long time, therefore the air itself, passing through it (the *mashrabiya*), does not warm up.

In conclusion I believe that the contemporary design must be able to reinterpret the local building knowledge. To design in Mediterranean contexts today, means to understand the reasons related to the climate, the natural resources and materials of the places.

This does not mean a slavish imitation of the forms of traditional architecture, but rather an innovative and critical reinterpretation of the reasons that for centuries have guided the construction.

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