CLIMATIC DESIGN IN THE ARAB COURTYARD HOUSE

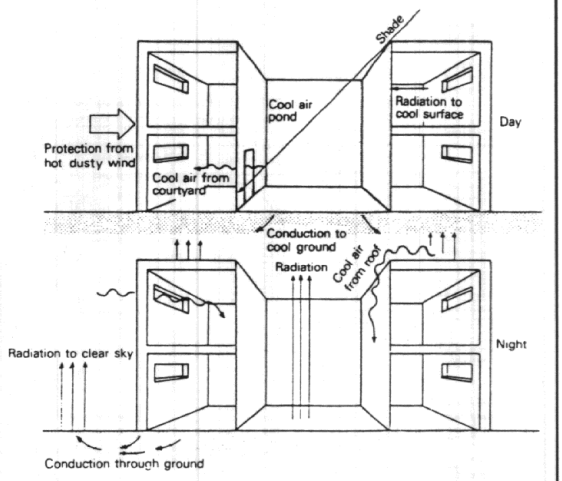
Introduction

The courtyard Arab house may be considered as prototype diffused in many variations through all Arab countries and Islamic areas extending from the Arabian Gulf to the Atlantic Ocean, between latitudes of 10° and 37° North. The "courtyard house" or "patio house" is a typology in which all living areas ("iwans" or alcoves and loggias) are distributed around the courtyard ("shan").
"This prototype seems to have been conceived to produce the same variety of contacts with open space, the same response to shade and to the movement of the air at each hour of the day, as the Arab experienced when he lived in tents. ... The loggias allowed the occupants of the house to sit in shade under the open sky, most probably in the early and in the late hours of the day, as their ancestors had sat at the doorway of their tent. The deeply recessed 'iwans' provided complete shelter from the heat and from the glare of the hottest hours".[1]
The courtyard house creates a complex regulating system that creates a microclimate, which historically worked, and still works, in a "passive way": heat transfer processes are all natural, without mechanical devices powered by non-renewable energy. The courtyard house system manipulates the architectural components ("shan", "iwan", "loggia", fountain and "darqua'a" or covered courtyard) in order to achieve the best inside thermal comfort, day and night, from natural resources (sun, wind, sky, water and vegetation) within the constraints of locally available resources (building materials and technologies, cooling technologies, etc.).
The courtyard house is the end-product of a sophisticated historical process of unconscious "climatic design". It was certainly a long, intercultural, and evolutionary "trial and error" process, which is quite impossible to achieve today. The passive cooling technologies, developed as an "architectural system", were, and still are, a strong lesson for a modern "climatic approach" to design.[2]

Cultural Roots

Arabs had the opportunity to learn from local sophisticated cultures, particularly ancient Iranian architecture, which developed a deep knowledge of natural cooling processes, with an ability to build large structures functioning as hot-arid climate modifiers — "wind catcher" "ice maker", etc. so well described in the work of Mehedi Bahadori.[3] The knowledge of cooling processes was based on a deep pre-scientific understanding of the exchanges of energy fluxes in the earth-atmosphere system, namely the cooling effect of night radiation to the sky;[4] the convective process, namely the cooling effect of air movement determinated either by "stack effect" or by wind; and, the evaporative process, namely the cooling effect of the change phase process, typically water vapor.[5]
How much Iranian (and, later, Islamic) cosmology played a role in developing such strong basic empirical knowledge on thermal behaviour is a matter of research. It is important to point out the close relation between cosmology and the house. The Arab house was a microcosm linking, in space and time, land and sky through the symbolic meaning of its components. "The four walls of the courtyard represented the four columns carrying the dome of the sky. The sky is then drawn down into intimate contact with the living rooms by reflecting it in a basin which has the form of a dome on squinches. Thus,

A GENERAL SCHEME OF THE COURTYARD HOUSE TERMAL BEHAVIOUR.

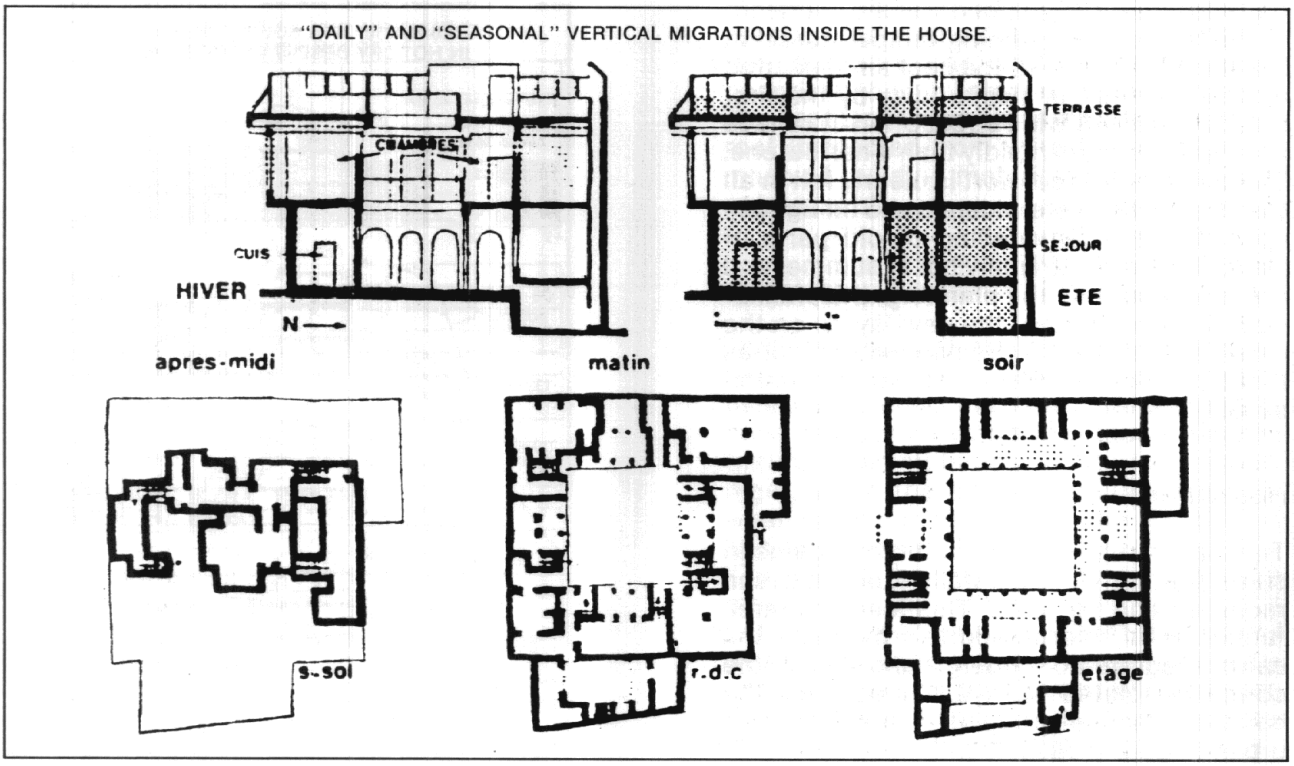


nature and space are brought into the townhouse by their transposition into architectural forms and by symbolism".[6]
In this microcosm, all cultural, religious, technical and natural resources are directed towards the best thermal comfort and delight in a hot arid climate. Natural fluxes have a continuity inside architecture and, to some extent, they become architecture through the Arabesque language which determine flux perception.[7] The continuity land-sky has a central "topos" in the house: especially the garden ("bagh") which is a metaphor and an anticipation (place of pleasure) of Paradise on land.[8]
Arab culture diffused this complex knowledge through the Islamic world with a technological transfer process similar to that of "qanat" technology.[9]

Thermal Performance

"The thermal performance of the courtyard house comprises heat exchange processes taking place among the environments of three interrelated spaces: the indoor space, the courtyard space and the external open spaces between houses.
Concerning the indoor thermal environment, heat is exchanged through: (a) the inner envelope (courtyard walls) and (b) the outer envelope (external walls and roof).
The different surfaces of the two envelopes are constantly exposed to the outside air temperature, however their exposure to solar radiation varies with time. This emphasizes the importance of studying means to control the exposure to solar radiation. In such control, the inner envelope is more critical since most of the openings are located there.
Regarding the physical system, which represents the impact of solar radiation upon the indoor space passing through the inner envelope, two subsystems are identified. The external subsystem deals with: (a) the insulation of the courtyard surfaces which is a joint function of the sun's geometry and the courtyard geometry; and (b) the thermal balance of the surfaces as affected by the incident radiation. The internal subsystem deals with the heat flow taking place through the opaque as well as the transparent materials of the envelope".[10]

"DAILY" AND "SEASONAL" VERTICAL MIGRATIONS INSIDE THE HOUSE.



Appropriate Cooling Technologies

When outdoor conditions are very severe (in summer mean maximum temperature from 43° to 48°C during the day, and from 27° to 32°C during the night; diurnal temperature swing from 17° to 27°C) the system has to resist thermal gains, minimizing hot air infiltration, solar radiation and heat conduction and to thermal losses through earth cooling, ventilation, radiant cooling and evaporative cooling.[11]
Let us briefly describe in term of built environment forms and cooling technologies the six different levels of interaction between microclimate and courtyard house. We can group the levels in six topics: urban, texture and landscaping of the house, interior organization, nature of walls and roof, openings, ventilation and humidifier systems.

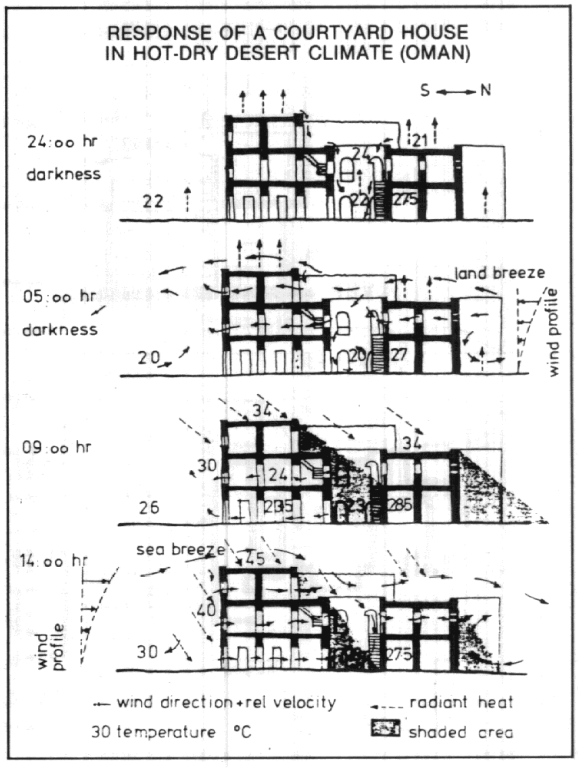
Urban Texture and Landscaping

The urban structure is usually a continuous pattern of courtyard building, clustered together and connected by a very diffuse network of "cul de sac" narrow roads departing from the main road system. Urban texture contributes to the thermal protection because the narrow winding streets are partially covered. They function as the courtyard in the house by regulating temperature. "In a wide straight street, the cool air deposited during the night is swept away by the first breath of wind. A wide street offers no shade and heats up more rapidly than a narrow one. The difference in comfort is clearly felt in all the streets that were widened and straightened during the remodelling of old parts of Cairo. They are extremely hot in summer and are full of dust. In the planning, the planner simply superimposed the new layout on the existing one as if it were non-existent, or as if his plan were made for an underground system".[12]

House Form

The main strategy to resist thermal gains in summer is to reduce the walls exposed to sun radiation and hot wind. This leads to three fundamental morphological models: the earth integrated or underground house, the compact isolated courtyard house, and the courtyard house grouped in a continuous urban-texture ("casbah").

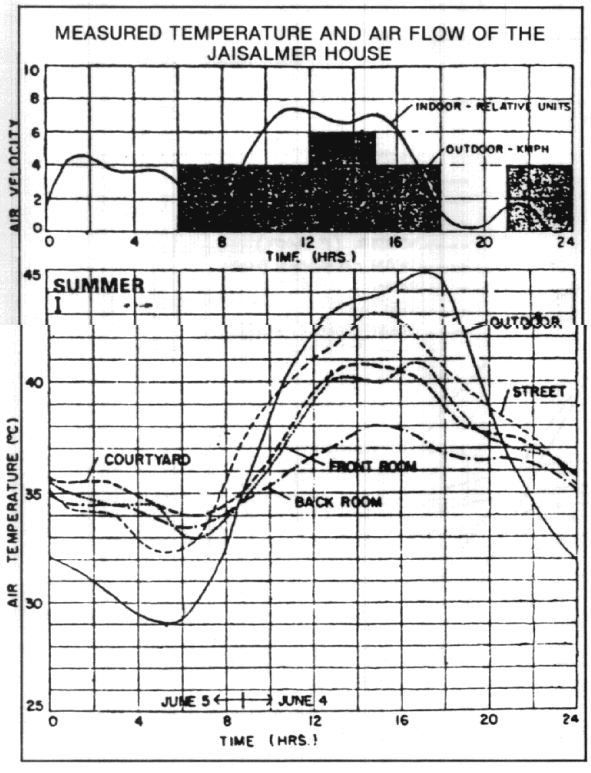
The underground model is diffused in particular areas like Matmata in south Tunisia, where high cooling load combines with a soft ground which makes possible the underground technology.
The compact isolated and "casbah" models are diffused through all Arab countries in different variations appropriate to local culture, physical environment and resources. Both models are based on an inner space (the court) surrounded by outer space (house space). Inner and outer envelope have a surface much greater than a closed cubic model. Most of the openings are located in the inner envelope.[13] Houses are clustered in a close packing pattern which three main different spaces: indoor house space between inner and outer envelope completely covered by roof; internal space surrounded by inner envelope and open to the sky (the courtyard space); and external open space formed by outer envelopes of the houses.[14]
Both compact and isolated models vary in density (number of storeys), courtyard-built ratio, covered-uncovered courtyard ratio, etc., depending on climatic and cultural conditions.



Interior Organization

The main element is the courtyard ("sahn"). The central space (called also "patio" when partially covered), protected from solar radiation, has two functions: one of light source, and the other of thermal regulation. Indoor space (rooms or "iwan") facing into the courtyard is protected by the courtyard and the clustering of houses. The courtyard shelters all day long the indoor space, which remains at a lower temperature than the average exterior temperature. Some vegetation may also be grown to increase shading, and to provide air dampness and cooling by evaporation. Cooling can be further increased by humidifying devices functioning by water evaporation. The courtyard may be covered by light and movable shading devices to increase shadow surface of the walls.

The courtyard and loggia also from part of the distribution migration system which supports inside the house during the day and night a better utilization of inner microclimate; functional distributions are also based on inner space. Daytime shady loggias and rooms near the courtyard are employed to eat, have siesta and work; at night people sleep on the roof terrace, taking advantage of the night cooling.[15] In regions with a marked climatic difference between seasons, migration also takes place. For this reason the rooms of the upper floors are utilized in winter, while those on the ground floor are used in summer.



Walls and Roofs

The selection and treatment of materials to control day and night temperature swings are of the greatest importance. Heavy weight envelope has a great advantage and is strongly recommended in spaces used during the day because of its high heat storage capacity. This attenuates the thermal effect of outside climate. Thermal resistance and density of materials determine a great variation in thermal behaviour: a dry earth wall has a better thermal performance than a concrete wall because its thermal resistance is very high compared with the internal temperature variations of a 220 cm. wall in concrete and dry earth.

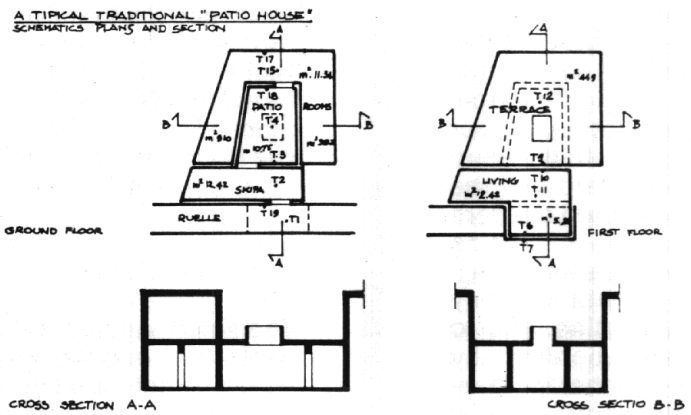
External colour also plays role: white colour has a high reflectivity which diminishes the effect of solar radiation. The roof is the most critical component of the whole building: it receives the greatest amount of solar radiation during the day, and emits the greatest quantity of heat by night radiation to the sky. The heat loss to the sky is maximum with flat roof (protected from wind by lateral walls) made of building materials (mud-brick) and painted white.

Openings

Outside openings are usually few, and are provided with shading devices which allow a minimum lighting and outside view that maintains visual privacy from the outside. The ventilating opening is usually used during late night, when the air temperature is cooler; when used during the day, the entering air has to be cooled by evaporation.

"To reduce the glare without reducing the movement of air in those rooms which could not be provided with a 'malkaf', the window was fitted with a lattice screen called a 'mushrabeya', made of small wooden bars. These bars are circular in section, so that they have the effect of breaking up the light

THE PATIO HOUSE MODEL IN OUARGLA: A) PLANS AND SECTIONS; B) THE TERMAL NETWORK; C) THE SIMULATED TEMPERATURES



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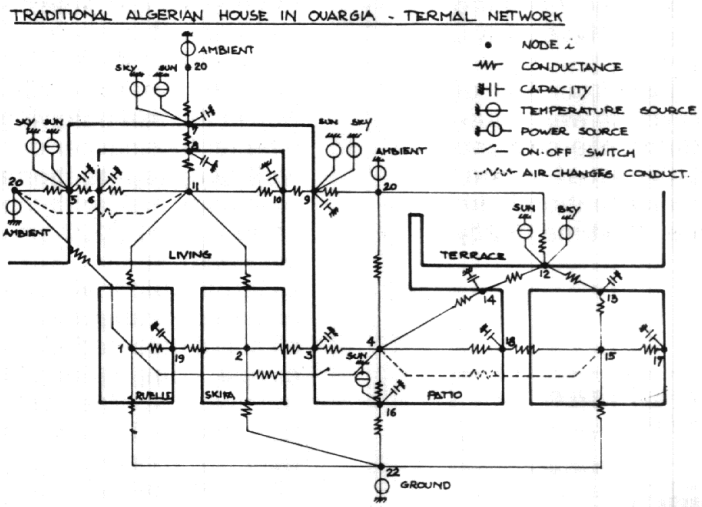

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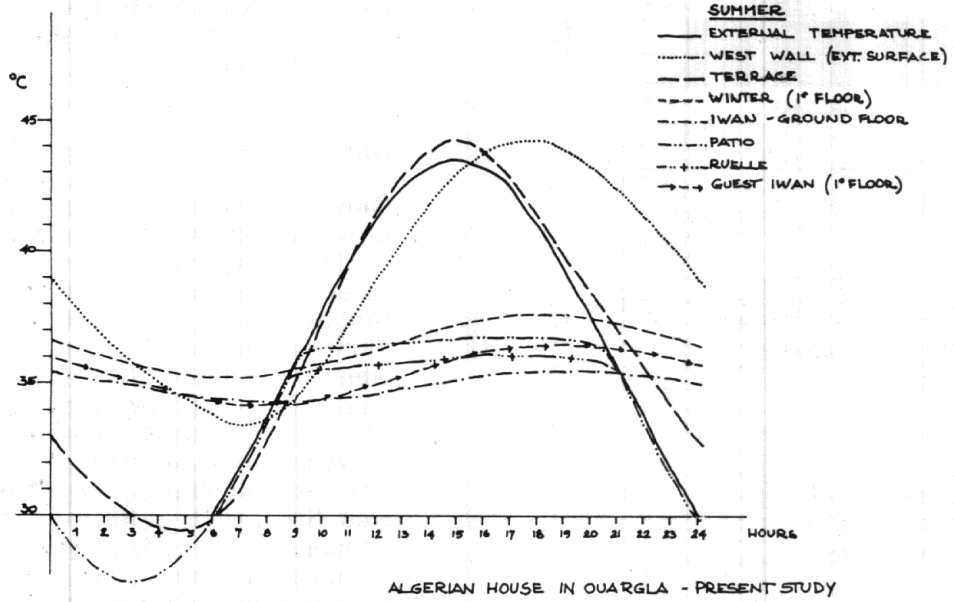


C

ALGERIAN HOUSE IN OUARGLA - PRESENT STUDY

which falls on them; thus, there are no sharp edges visible, nor is there any harsh contrast between the darkness of the lattice and the brightness of the light. The glare is softened and the eye is not dazzled".[13]

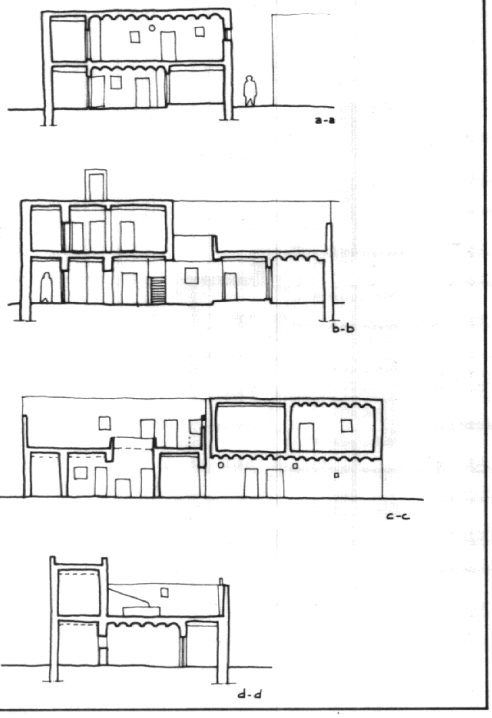
Convective and Evaporating Cooling Devices

Air movement inside the building can be used either to cool the structure or for physiological cooling. Air movement can be generated by wind effect or by "stack" effect (temperature difference).
When the wind is warm it is better to generate ventilation by stack effect; when the wind is cool the natural convection can be activated with a device able to catch winds and drive them into the rooms. "Wind catchers" are very frequent in Iran, Iraq and Egypt; they project on roofs to intecept cooler, faster, less dusty air flows. During the day (when inside temperature is lower than outside one) hot inside air flows down the walls of the wind tower, loses heat, and enters fresher than outside air into the room; it absorbs heat (refreshing ambient air), and then is evacuated through windows. During the night if wind is not blowing, wind towers function as a chimney sucking exhausted hot air from rooms, and replacing it with outside fresh air entering through openings.
Natural convection and ventilation can be improved by adding a device for the evaporation of water. This lowers the temperature by means of latent heat loss by evaporation. "Wind catchers" are often combined with fountain and humid underground tunnels.
Water, which is quite rare in dry countries, is to be found in the habitation, and its usage is well defined and efficient in witness to its scarcity. It may be utilized in "patios" with basins, water-spouts, and fountains, or little streams which sometimes also allow the watering of the ground. It may flow on "silsabils" (which are decorated inclined surfaces where a fine stream of water flows emphasizing the evaporation process), or it may make the air cooler due to a porous jar which catches the air through a "wind tower" or a "musharabiyya" window.

Climatic Design and Case Studies

Very little quantitative work has been done

HOUSES AT OUARGLA. SECTIONS



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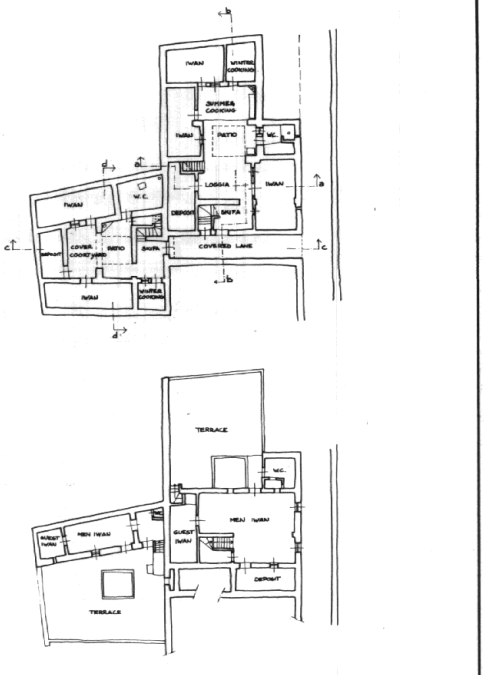


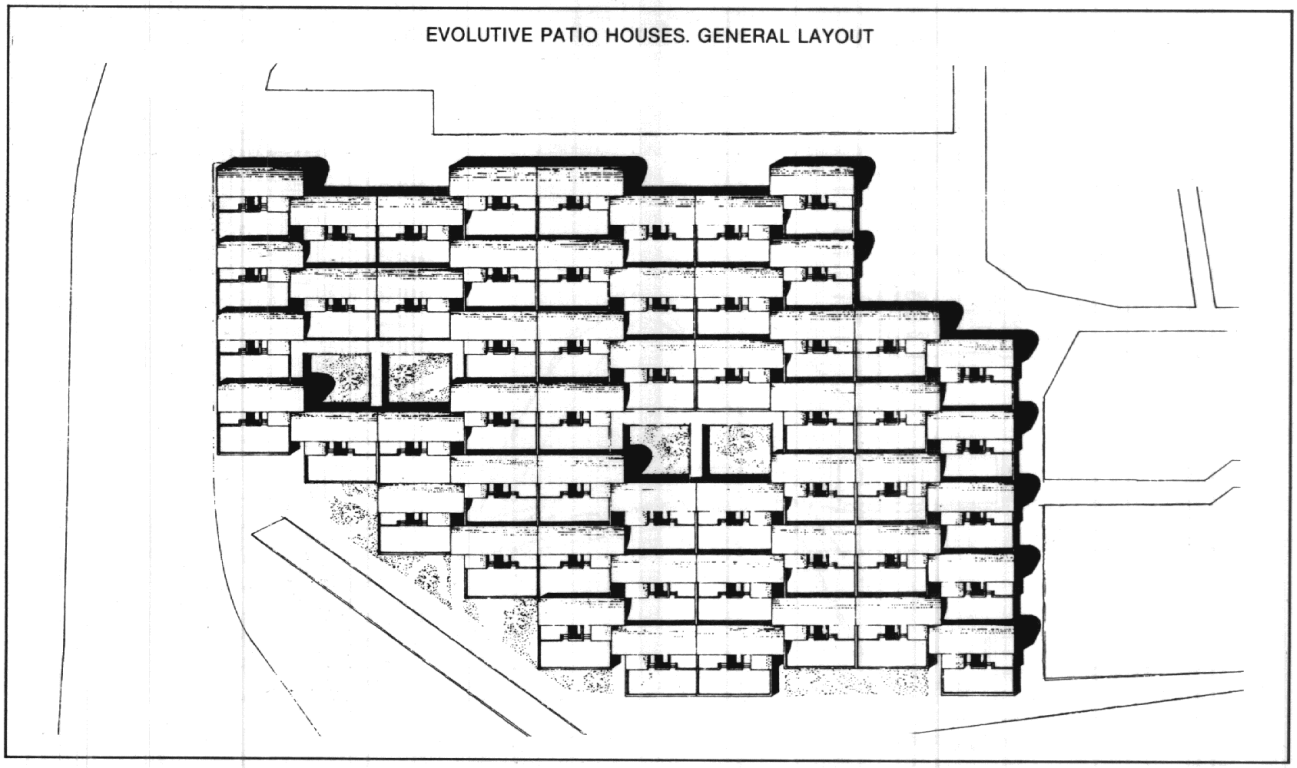
to understand the thermal behaviour of the courtyard typology as a system in different climates and cultures; simplified methods, design guidelines and monitoring campaigns are very poor, except for some well known traditional studies and design recommendations in the field of "bioclimatic design".[14] Very few field measures have been recently done and only some comprehensive simulation models developed.[15] In the following two studies on "patio" and "courtyard" Arab houses, thermal simulation and design will be presented.

Ouargla Study (Algeria)[19]

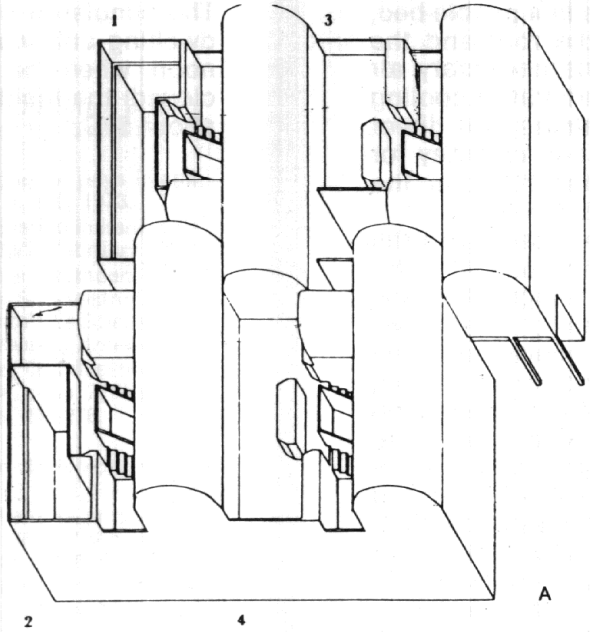
The simulated thermal behaviour of a typical Algerian patio house is described here. Ouargla is an ancient commercial town in the north border of the Sahara desert (31°, 54' lat. north). The general aim of the project was to design for a close-packing urban rehabilitation of a particularly ruined area of Ouargla. The specific aim was to understand the interaction between the thermal behaviour of a particular patio house and the changing social behaviour of the Ouargla enlarged family. This knowledge was considered basic for an "evolved patio house". The design was to be consistent with the invariants of patio typology, but also open to change pattern of the family (i.e. children and boys studying). The new patio house was designed to perform a thermal behaviour better than the traditional one. The inner temperature is in fact, 3°-4°C below the temperature of the traditional solution which was close to the upper comfort limit accepted for hot arid climate.

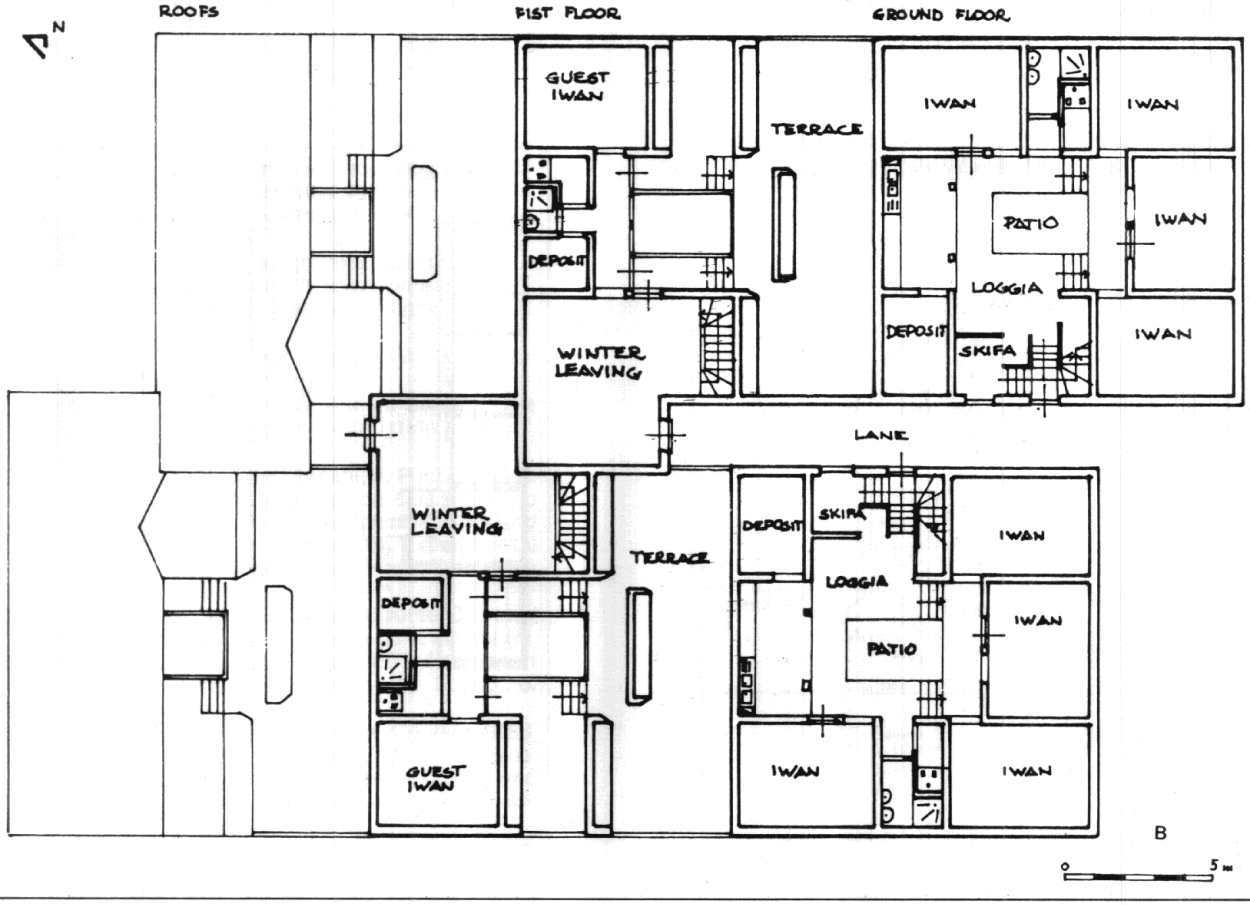
Z'Malet Study (Algeria)[20]

The second work is the design of a naturally cooled, courthouse settlement to enlarge an existing agro-pastural village in the Algerian Highlands (Z'Malet-El-Emir Abdel Kader, 35° lat. north). The courtyard house unit is east-west oriented and protected by two buffer zones: the south one connecting the court to the inner space, the north one containing entrance, w.c. and the pebble-bed for the cooling system. The natural cooling system is



EVOLUTIVE PATIO HOUSE: A) AXONOMETRIC VIEW; B) PLAN OF THE DWELLING

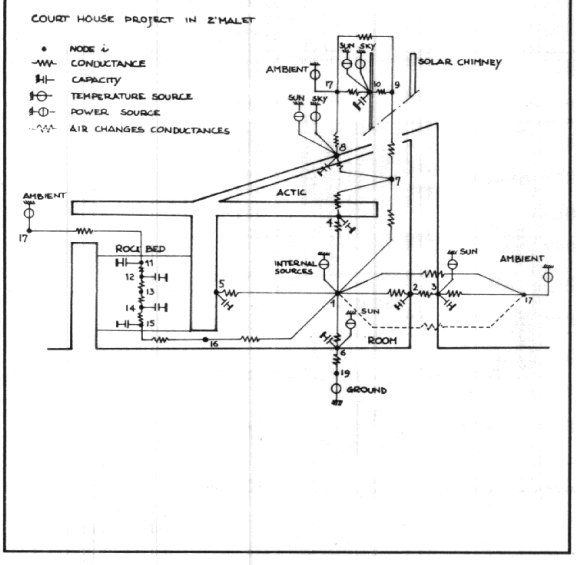




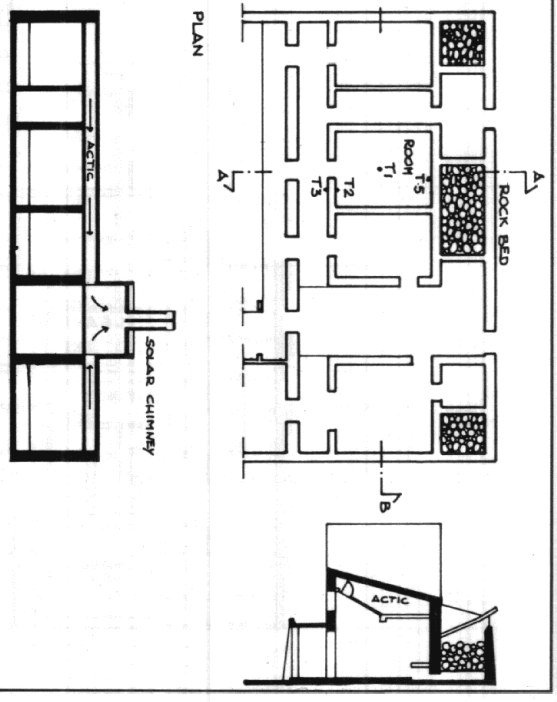
selected according to the life-style of the occupants who live indoors in the afternoon. The system uses the following sources: storage of night's coolness in a pebble-bed; sky radiation cooling of the roof and the court; wind to circulate the necessary air through the pebble-bed; evaporative cooling of air by porous water containers; and, direct solar radiation gain of a solar chimney for partial air circulation to the room in the absence of sufficient wind.
It is expected that the door opening to the courtyard is closed from 12 to 3 p.m. At night, the pebble-bed temperature is higher than the room air temperature, and the colder air flows through the bed by natural convection. This process goes on all night and early morning, thereby cooling the pebble-bed. In the morning the solar chimney creates a small draft. A small wind catcher operates about noon, when the door to the courtyard is closed and the wind is blowing. The air passing through the bed is cooled to the lowest night room air temperature. Porous water containers in the inlet of the pebble-bed further increase the cooling effect of the convective process.
A more detailed description of the system is given in the report by M.N. Bahadori, who was responsible for the cooling system definition and calculations during the project.[21]
The simulated cooling performance of the dwelling unit was quite good: in the afternoon, when the system is operating (door closed) the inside air temperature drops of about 5°C.

Gianni Scudo

COURT HOUSE PROJECT IN Z'MALET



SCHEMATIC PLAN, SECTION AND THERMAL NETWORK OF THE UNIT



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[12] H. Fathy, *op. cit.*, p. 8.
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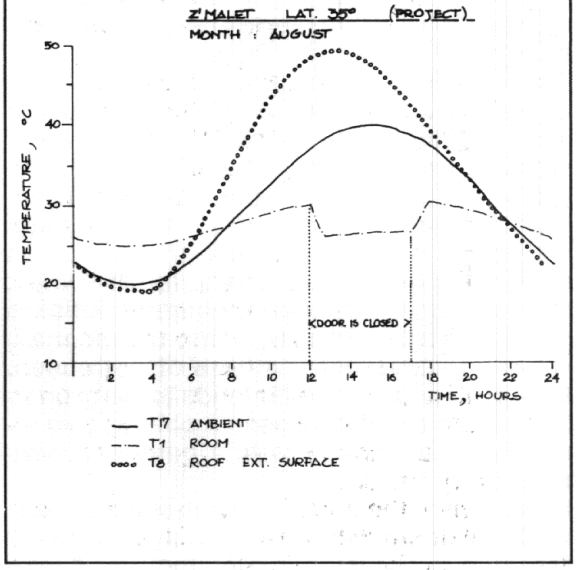
MEASURED TEMPERATURE OF THE Z'MALET HOUSE