INDIGENOUS ARCHITECTURE AND NATURAL COOLING

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INTRODUCTION

The coolness of an old building on a hot summer afternoon never fails to impress the visitor and makes one wonder how the indigenous builders could create such comfortable buildings without the aid of modern scientific knowledge. Spurred on by the energy crisis, we are today accumulating a vast body of technical literature on "passive cooling systems" and yet our present-day buildings tend to be poor performers compared to the well-tempered indigenous buildings. The purpose of this paper is to examine how our predecessors tackled thermal design problems and what tools and techniques were available to them in the hot dry regions.

It is important to understand the difference between the present-day strategy and that of the indigenous builders. When architects talk of passive cooling, it is as if the maintenance of certain specified temperatures in a building is an end in itself. On the other hand, the indigenous builder could not care less if the building was cool or warm so long as people could be comfortable within or without the building. And in this, the builder's task was simplified by the willingness of the building users to put up with minor inconveniences. The indigenous buildings were either humble dwellings or monumental palaces and temples. In either case, devoted workers in adequate numbers were available to maintain the buildings. The task of the modern architect who designs not only residences but factories, offices, hotels, hospitals, commercial centres, educational institutions and places of entertainment, is a lot more complicated. Some of these new buildings have more exacting requirements than those of the older ones, while the use is strictly impersonal. However, the tools, materials and techniques available today are more than what the indegenous builders had access to.

The theory of passive cooled or naturally cooled (as the author prefers to call them) buildings is well-developed. Various techniques suggested for environmental control in modern buildings are:
(a) shading of building surfaces from sun
(b) damping of temperature variations by thermal mass
(c) selective ventilation
(d) radiation to night sky, and
(e) evaporation of water.
The indigenous builders used these and some other techniques that are perhaps out of our reach today.

SPACE USE

The single most powerful tool used in traditional building design was the willingness and the ability of the users, to organise daily activities in space and time so that not all spaces had to be maintained at equal levels of comfort all the time. At any given time the active use of the building could be restricted to the areas most comfortable at that time. In practice this meant that people would not only take off or put on additional clothing as we do today, but that they would physically move from a less comfortable area of the building to a more comfortable one. Millions of simple residential buildings were designed and built to be used in this way. At times when the entire building became uncomfortably hot, they would move to another building or even to the outside. There are stepwells in Gujarat (Fig. 1) that were meeting and resting places for men on hot summer afternoons.' In winter when the wells were uncomfortably cool, the same men would meet and rest in the open under the sun. In the rainy season the meetings and rest could take place in a verandah. In the Amber Fort there are many cooling devices used, but there is also a garden in the middle of a lake (Fig. 2) just outside the fort, that would be used for relaxation at uncomfortably hot times. In the houses of Shahjahanabad (Fig. 3) people spend the hot summer days

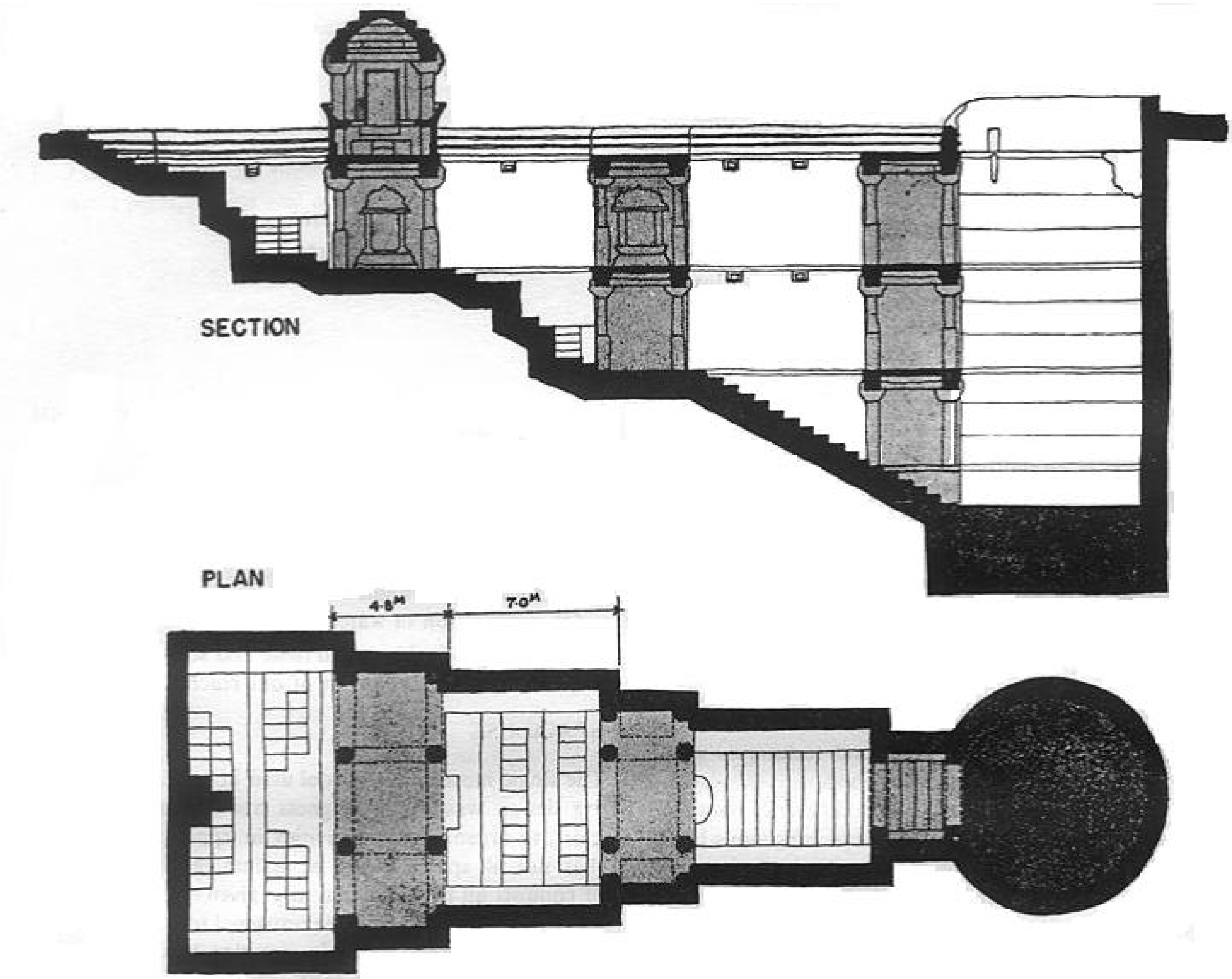


Fig. 1 A step-well from Gujarat. The various pavilions were used as resting places in summer.

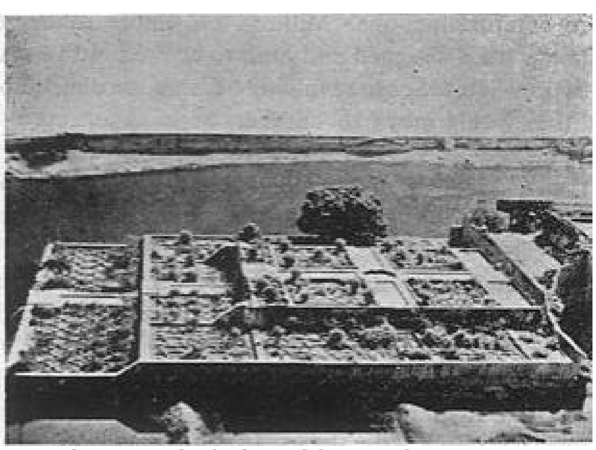


Fig. 2 Pleasure garden built in a lake at Amber

in the lower floors of the buildings but the evenings and nights are spent on the roof-top fully exposed to the cool night sky. In winter the days are spent on the sunny terrace whereas people move into the house at night.

FLEXIBLE BUILDING ENVELOPE

The second important tool used was the ability to vary considerably the thermal characteristics of the skin of the buildings, the variations taking place according to the time of the day or according to the seasons. By this device it was possible to protect the building interior from solar radiation in summer, to retain warmth or coolth as required and even to cool the building interior by evaporation of water from the skin. The physical mechanism required for this purpose was a framework

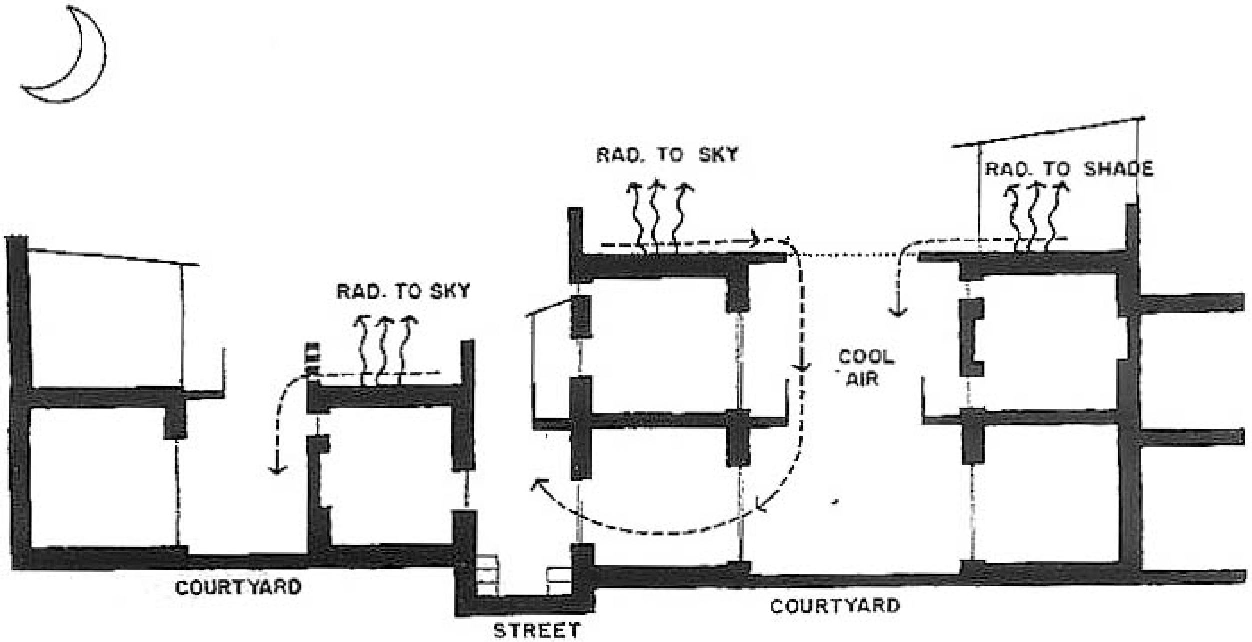


Fig.3 Typical section through Shahajahanabad House. To Facilitate the moment of cool air into the house, parapets are not built towards the courtyard

that defined the building exterior and within which suitable panel elements with different thermal priorities could be fixed at different times.

Some of the most interesting spaces of our traditional buildings have been designed to function in this fashion. Without the use of movable screens and curtains, the Diwan-e-khas in the Red Fort at Delhi and Panchmahal at Fatehpur Sikri (Fig. 4) would have been no more comfortable than an open space. The emperor's throne in Diwan-e-khas (Fig. 5) is surrounded by two sets of columns about four metres apart. Each set of columns

Fig. 4 Panchmahal at Fatehpur Sikri. Space enclosure was by use of movable screens

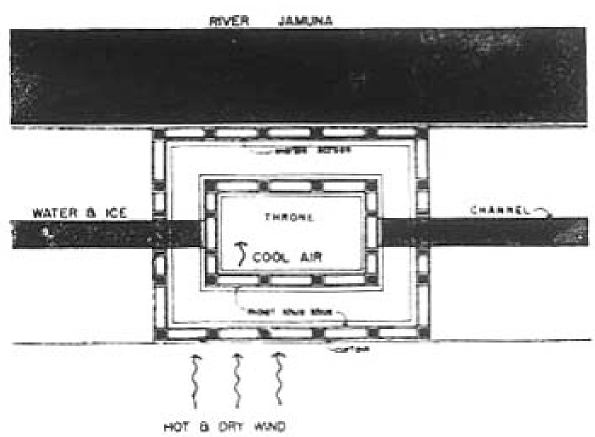
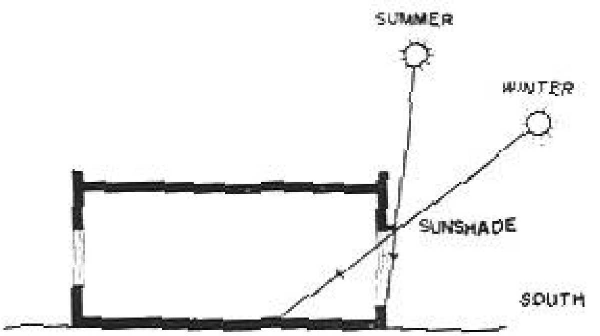


Fig. 5 Cooling system-Diwan e-Khas, Red Fort, Delhi

could accept curtains and screens according to the need at any time. It is said that in summer there were three sets of screens used, two of them of grass mats kept wet by sprinkling of water. Heavy quilted curtains were suspended in place of these screens in winter. In the daytime these curtains were raised up to allow the sun to warm up the building interior and they were lowered in the evening to retain the warmth. Curtains of this type exist in the *Deegh Palace* near Bharatpur in Rajasthan even today.

Window design today consists of a fixed sun-shading device (Fig. 6), a louver that is supposed to cut out the sun during summer and to allow sunlight into the building in winter, the presumption being that it is possible to determine a cut-off date at which sunlight may be allowed to enter or stay out of a building. The only problem is that air temperatures do not keep pace with the uniform movement of the sun from summer solstice to winter solstice. It is particularly around the cut off dates that there are extraordinary warm and cool periods, resulting in excessive or inadequate sun penetration. The humble traditional movable shading device—the roll-up bamboo screen can provide the correct shading not only for the extraordinary weather but also for problematic East and West orientations.



MICROCLIMATE MODIFICATION

Control Of the microclimate around the building was always important in indigenous design. This happened not only for the palaces but for simple dwellings as well. In Shahjahanabad (old Delhi) and Jaisalmer (Fig. 7) the urban form ensured that individual buildings were not exposed to the sun. Dense clustering of buildings not only prevents heat gain but it also keeps hot winds out while ensuring movement of cooler air through the buildings and open areas.The effect of urban design on microclimate can be seen from Fig. 8 which shows the temperatures recorded at three points within the town of Jaisalmer and at one point near a building just outside the town. Although these temperatures were measured on different days, it can be seen that the maximum temperatures within the town were always lower than those recorded at the meteorological station while the temperature outside the town was higher than at the meteorological station.

In more grandiose structures, the entire building was surrounded by a garden as at Red Fort in Delhi or by a water garden as at the Deegh Palace, Bharatpur (Fig. 9). In either case, landscaping lowered the temperatures around the buildings. The treatment of open space was

Fig.7 Town plan of Jaisalmer. The major streets are oriented away from dusty winds

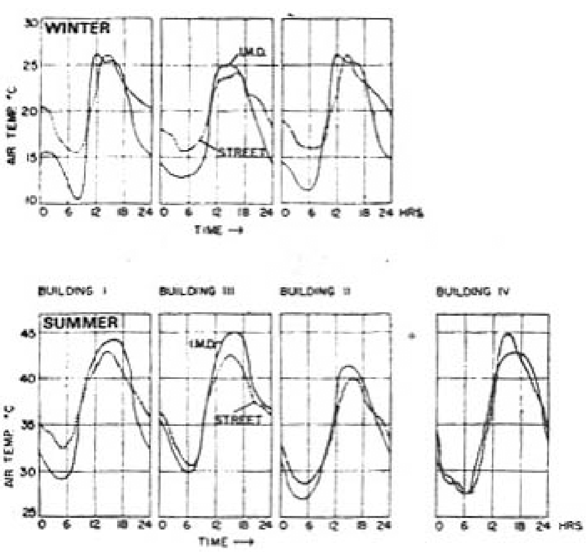


Fig. 8 Street temperatures in summer and winter in Jaisalmer as compared to temperatures at the meteorological station

a key issue in building design. These spaces were either rather small and sheltered from sun by the surrounding buildings,or when they were larger, trees, grass and water pools protected them from excessive heat gain. The garden and, courtyard, thus came to be built all over the Islamic world.2

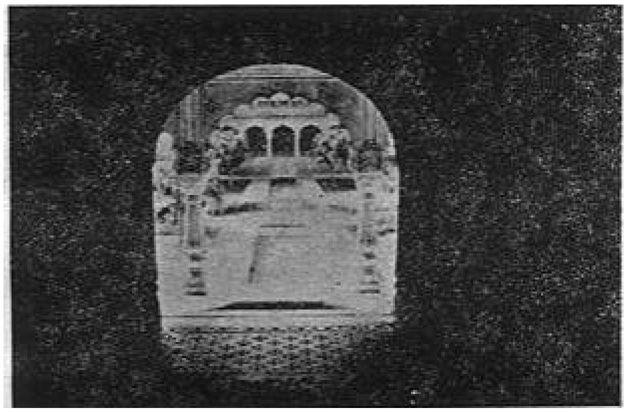


Fig. 9 Water garden at Deegh Palace

OPENINGS IN THE BUILDING ENVELOPE

Today we identify apertures in the building with glazed windows, and we expect such apertures to serve a number of functions, namely those of providing light, ventilation and view. Having no access to glass as we know it, the indigenous builders designed apertures to serve one function only. A number of different apertures combined together met the needs of light, ventilation and view. Not having to worry about the other functions, each of these apertures could be optimized for one purpose, leading to a more satisfactory thermal design.

There are windows in the Amber Palace (Fig. 10) which are no larger than I cm in diameter, that let in practically no light or ventilation. And yet because the wall is thinned out at this point, these windows can provide a view of the outside. Other apertures (Fig. II) that were designed solely for ventilation are best seen in Shabjahanabad. These are really divided into two parts, one near the floor and the other high up near the ceiling. An equivalent window in Amber consists of an opening protected by stone louvers tilted towards the inside. Frequently, large openings were filled in by *"jalis"* (screens) that let in air and some light. At times these *Jalis* (Fig. 12) also had a built-in shuttered opening for view.

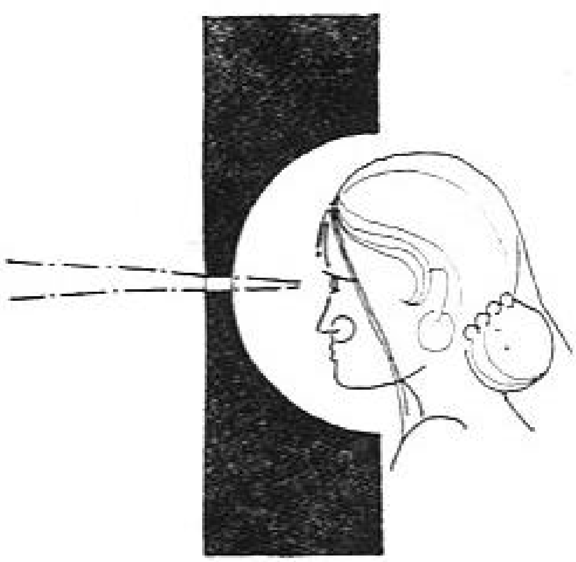


Fig. 10 Small window used for viewing out at Amber Fort

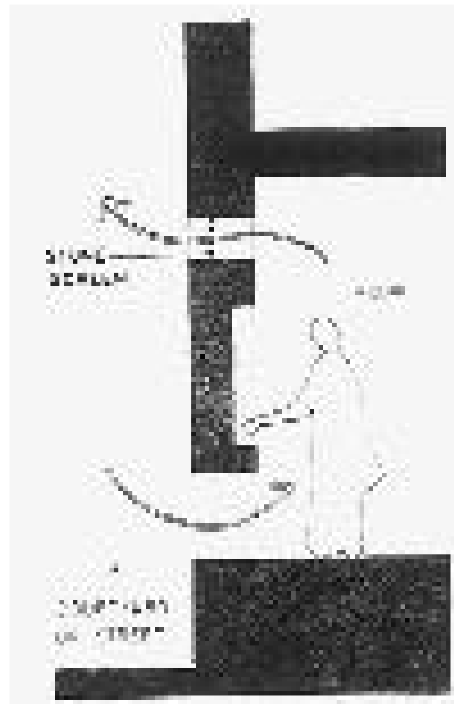


Fig. 11 Duble apertures used for ensuring ventilation in Shahjahanabad houses

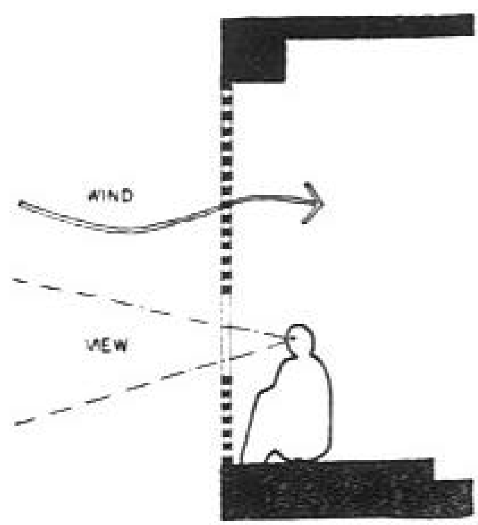


Fig. 12 Window for view and ventilation used at Amber Fort

VENTILATION

Ventilation is needed for comfort and hygiene, more air movement being needed for the former than for the latter. Comfort ventilation is required in buildings even on a hot summer day when the outdoor is warmer than the building interior. To avoid the heating of interior space it is essential to treat the air before it enters the building. Unlike what happens in modern buildings, a great deal of attention was given to pre-treatment of ventilation air intraditional buildings. In Iran (Fig. 13) air entered the building only after travelling through a tall tower with thick walls and sometimes even through an underground tunnel where it cooled down due to contact with the cool walls of the duct. Further air cooling was achieved by passing it over wet charcoal or a fountain.3 In Jaisalmer, the courtyard effect (Fig. 14) is used to ventilate the building, air getting cooled as it passes over the cool shaded building surfaces in the street. Measured airflow in Jaisalmer (Fig. 15) shows how the courtyard plan regulates air movement, bringing in fresh air only when it is cooler than the building.

THERMAL MASS

Control of thermal mass was the sixth planning tool. The climate of hot arid regions being characterized by large diurnalt emperature variations, damping and time-lag were achieved by use of massive construction in some areas whereas other areas were deliberately kept light-weight. A massive structure that takes time to warm up will also take time to cool down. A light weight structure, on the other hand, warms up and cools down quickly. The massive structure is therefore cool in the day but warm at night. Shahjahanabad houses, therefore, usually have a light airy structure ('SAIWAAN') (Fig. 16) at the roof level which can be used in the evenings. Wind pavilions are used for the same purpose in the *havelis* of Jaisalmer.

According to one theory the great pyramid at Gizeh (Fig. 17) was built to house the standard Egyptian measure of 'cubit' and to preserve the special proportion of *if*. The great mass of this naturally air-conditioned structure, maintains the king's and queen's chamber at 23°C throughout the year. Ventilation air also enters the chambers at the same temperature.*

Night Radiation Cooling

In some areas of northern India, such as Delhi, in summer the air is uncomfortably hot even at night. In such places night ventilation is not very effective for cooling and night sky radiation is the only answer. The roof surfaces exposed to the night sky, cool down by radiation and the air immediately in contact with the roof also begins to cool down. The buildings in Shahjahanabad (Fig. 3) were designed to permit the heavier cool air to enter the building. There are no parapets towards the courtyard, whereas there are always solid parapets towards the street. Furthermore most rooms have large openings towards the courtyard, so that the cool air can enter the livings paces.

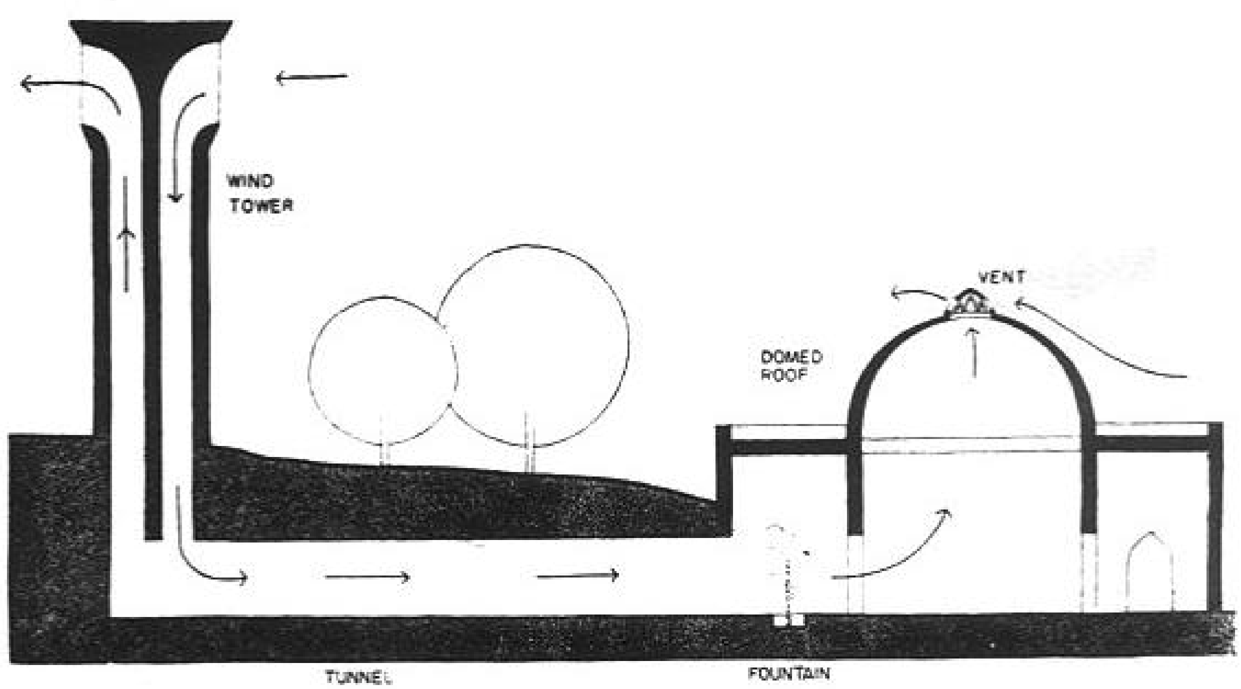


Fig. 13 Iranian cooling system using wind tower, underground funnel evaporative cooling and natural ventilation.

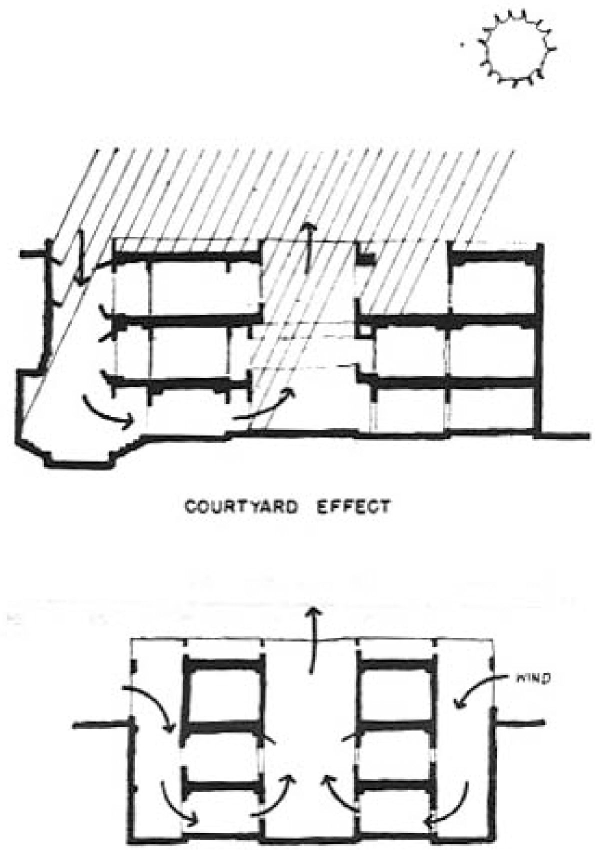


Fig. 14 Air-shafts of Nathmalji's Haveli

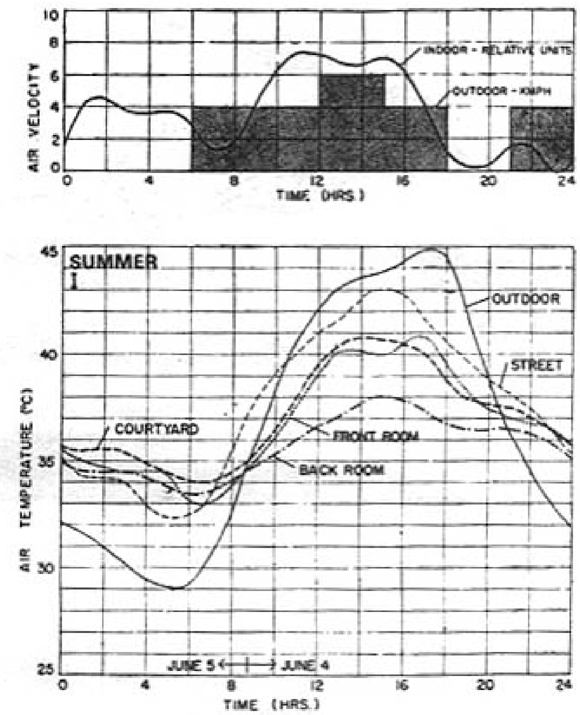


Fig. 15 Measured temperatures and airflow in a house at Jaisalmer. During the calm periods, the courtyard effect brings cool air into the building

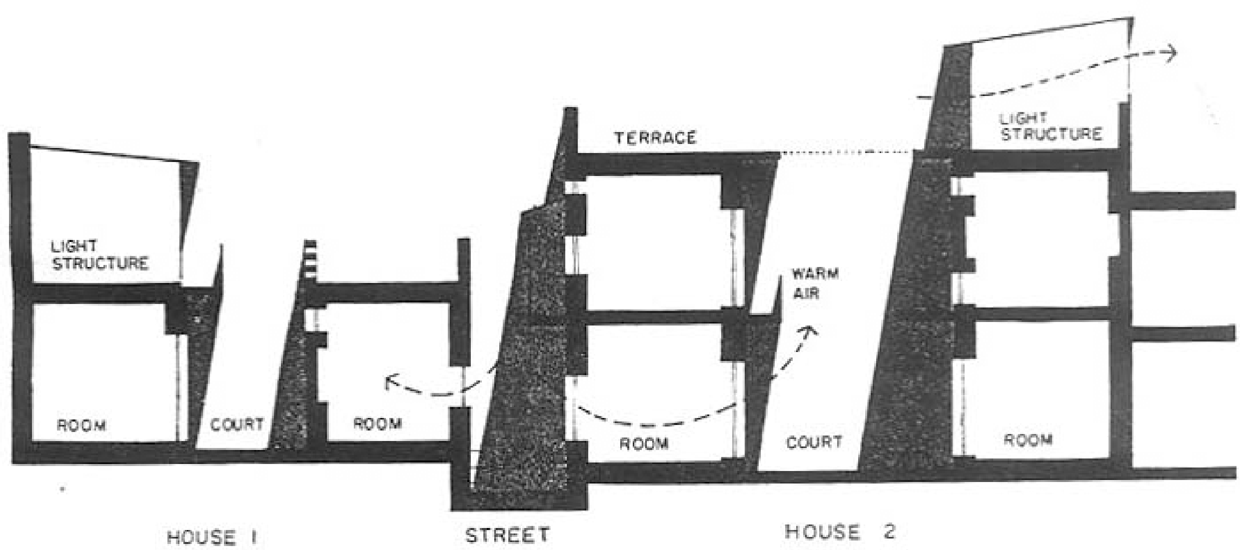


Fig. 16 Typical section through Shahjahanabad houses. The main building is massive while a light-weight structure is built above it

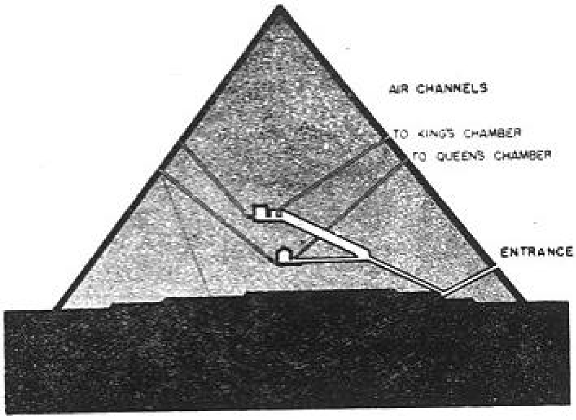


Fig. 17 Section through the pyramid of Cheops at Gizeh. Channels were provided for ventilation with cooled air

CONCLUSION

Every properly designed indigenous builiding uses more than one of the cooling methods to achieve satisfactory thermal conditions. It would be unfair and wrong to judge thermal comfort level in such buildings by the same yardstick that we use for modern buildings. As has been said earlier, the important thing was to keep people cool but not necessarily the building. If they could be comfortably cool outdoors, people did not need and would not use the building.

The feeling of comfort is a subjective perception that varies from person to person and from one culture to another. Measurement of temperature, therefore, will not indicate how comfortable the users of a building might have been many years ago. The measurement of temperature will however say something about the effectiveness of a particular cooling method from which one may be able to judge how comfortable we might be in a similarly designed modern structure.

Measured temperatures (Fig. 18) in a well designed house in Jaisalmer showed that the indoor temperature in the day was 8°C lower than the outdoor temperature but even so, its magnitude was more than 35°C, 5° more than what is considered a comfortable temperature. Never having been exposed to mechanical air-conditioning, the users of this building did not show any signs of discomfort. There is perhaps more to comfort cooling than meets the thermometer.

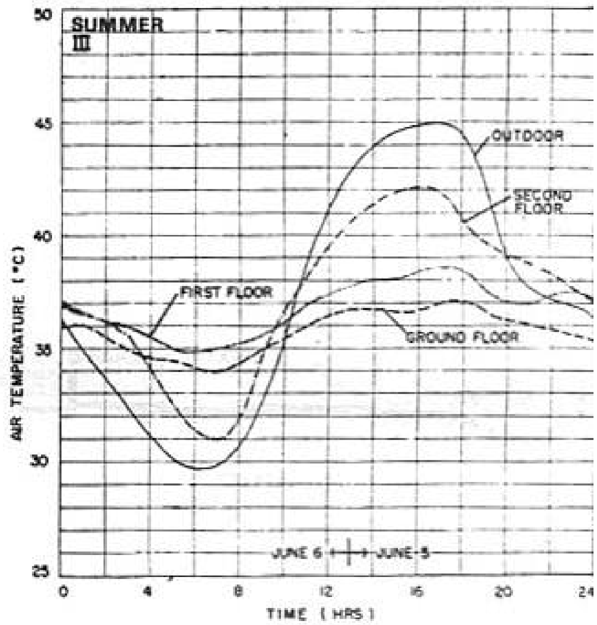


Fig. 18 measured temperatures in a three-storey house

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