(1)

PASSIVE COOLING SYSTEMS IN TRADITIONAL IRANIAN ARCHITECTURE

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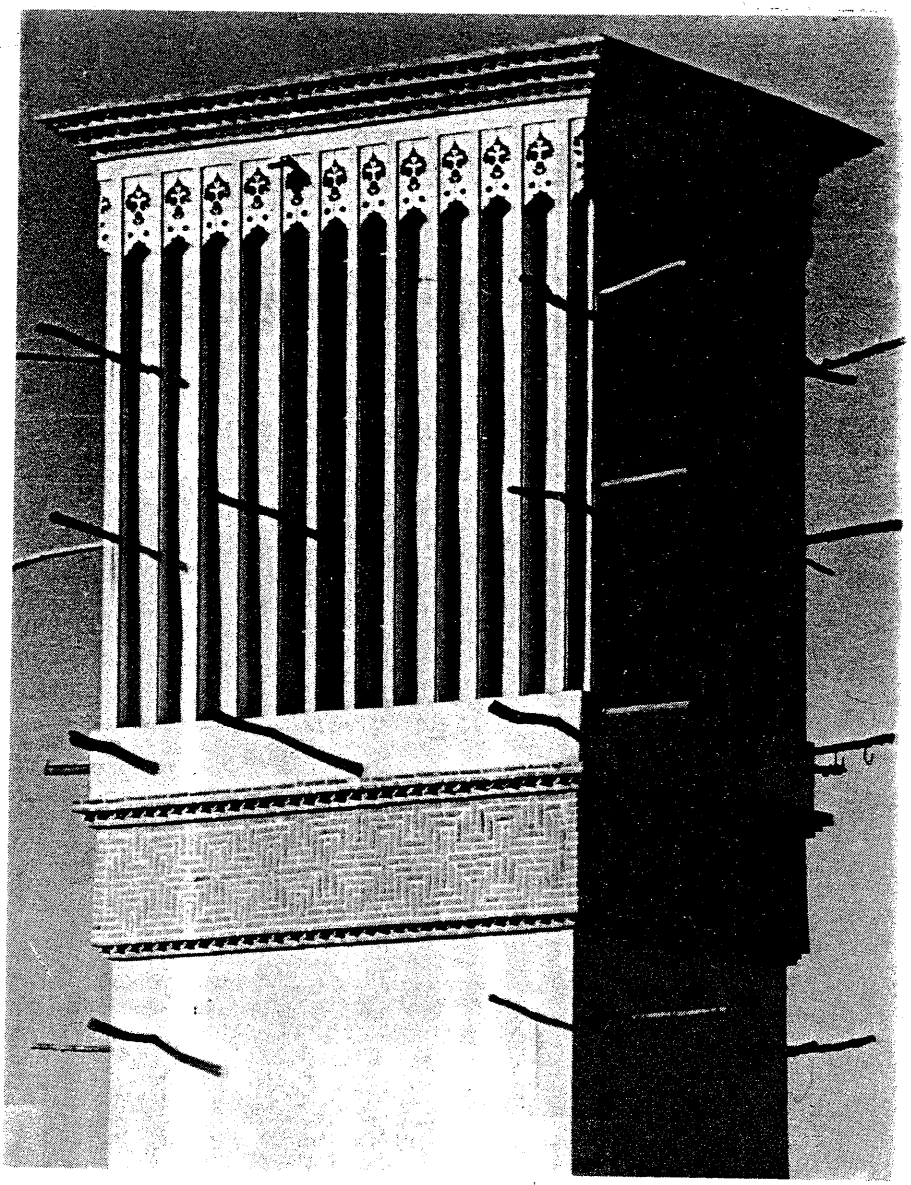
In Iran certain traditional building designs achieve more than a flattening of the temperature curve; they circulate cool air through the building and can even keep water cold and ice frozen from the winter until the height of the long, hot summer of the country's arid central and eastern plains. They do so without any input of energy other than that of the natural environment; hence they can be characterized as passive cooling systems.

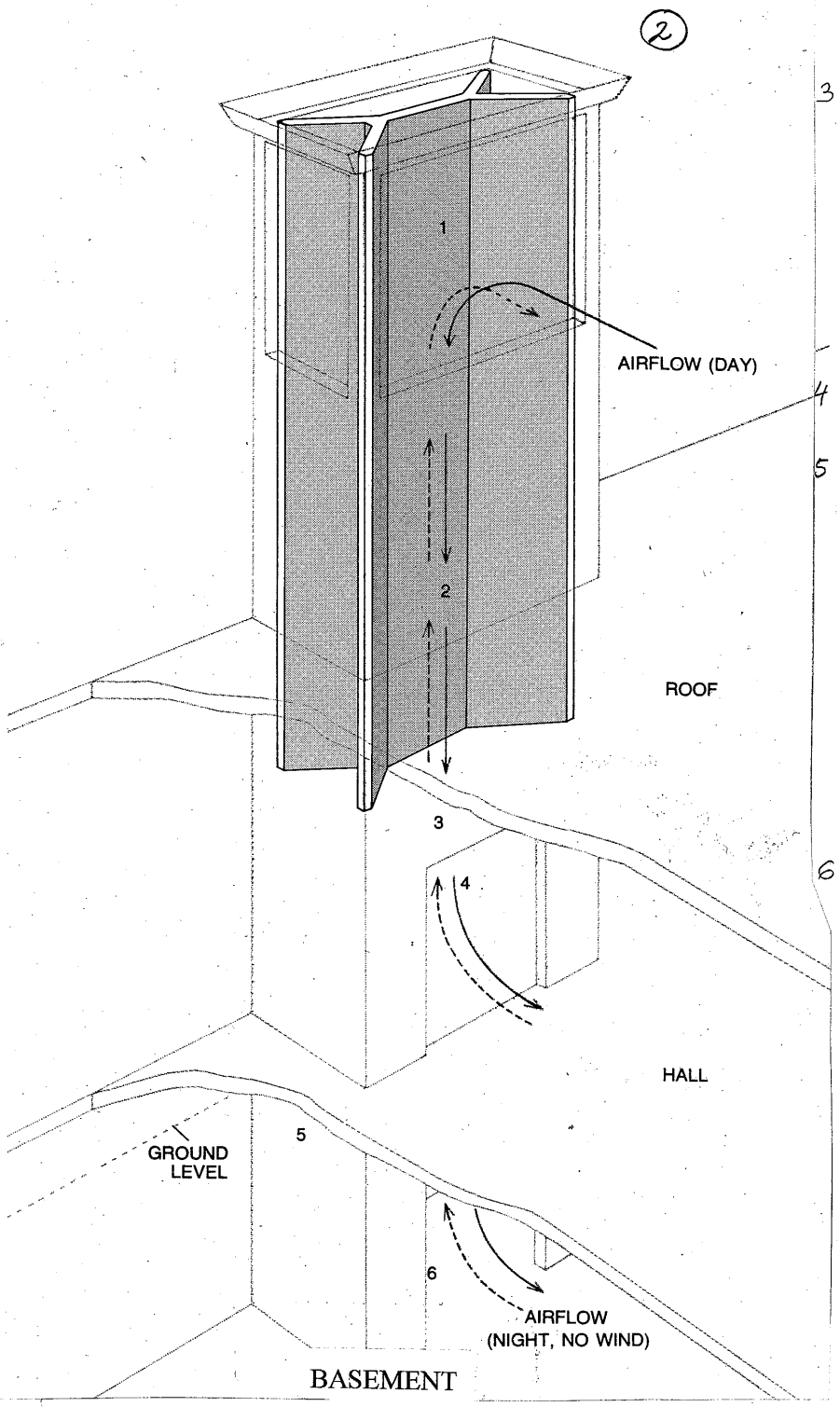
Although the summer days in the arid regions are extremely hot, the summer nights are cool. Several features of traditional Iranian architecture are designed to take advantage of this wide daily temperature range.

The "wind catcher," or wind tower, harnesses the prevailing summer winds to cool the air and circulate it through a building. A typical wind tower resembles a chimney, with one end in the basement of the building and the other end rising from the roof. The upper part of the tower is divided into several vertical air passages that terminate in openings in the sides of the tower.

The wind tower operates by changing the temperature and thus the density of the air in and around the tower. The difference in density creates a draft, pulling air either up or down through the tower. Doors in the lower part of the tower open into the basement and the central hall of the main floor of the building. The flow of air through different parts of the building can be controlled by opening or closing the doors from the tower and the doors of the rooms off the central hall.



CLOSEUP VIEW OF THE TOP OF A WIND TOWER



A WIND TOWER OPERATES in various ways according to the time of day and the presence or absence of wind. The walls and airflow passages of the tower (*2*) absorb heat during the day and release it to the cool air at night. The next day the walls are cool. When there is no wind, hot ambient air (*solid arrows*) enters the tower through the openings in the sides (*1*) and is cooled when it comes in contact with the tower. Since the cooler air is denser than the warmer air, it sinks down through the tower, creating a downdraft (*2, 3, 5*). When there is a wind, the air is cooled more effectively and flows faster. Doors in the lower part of the tower (*4, 6*) open into the central hall and basement of the building. When these doors are open, the cooled air from the tower is pushed through the building and out the windows and other doors, entraining room air with it. The cooled air's path of circulation depends on the arrangement of doors in the tower and the building.

When there is no wind at night (*broken arrows*), the tower operates like a chimney. Heat that has been stored in walls during the day warms the cool night air in the tower. Since the warmer air is less dense than the cooler air, the pressure at the top of the tower is reduced, creating an updraft. Air in building is entrained up through the tower and cool night air is pulled into building through the doors and windows. When there is wind at night, air flows down tower and through building. Since tower walls warm night air before it enters building, rate of cooling can be lower.

The operation of the tower depends on wind conditions and the time of day. When there is no wind at night, the tower operates like a chimney, circulating air by pulling it upward and out through the tower openings. It works as follows. The tower walls (including the internal walls that separate the air passages) have absorbed heat during the day. Since heat flows in the direction of decreasing temperature, the walls transfer heat to the cool night air in and around the tower. The configuration of the upper part of the tower, namely the thickness of the walls and the cross section of the air passages, is designed to provide sufficient heat-storage capacity and heat-transfer area for the task. Since the warmer air is less dense, the air pressure at the top of the tower is reduced, creating an upward draft. The air in the building is drawn up through the tower, and cool ambient air is pulled into the building through the doors and windows. The process continues during the night, so that cool air is kept circulating through the building.

When there is a wind at night, the air is forced to circulate in the opposite direction; the rooms are cooled by night air coming down the tower rather than through the doors and windows. Here, although the night air is warmed by the tower walls before it enters the building, the cooling can still be sufficiently effective to bring the temperature in the building close to that of the ambient air. The external walls and the roof of the building radiate stored solar heat to the night sky, which further cools the building. Since the desert sky tends to be very clear at night, the radiative heat transfer to it is extremely effective.

When there is no wind during the day, the operation of the tower is the reverse of a chimney. The walls of the upper part of the tower have been cooled during the previous night. Hot ambient air comes in contact with them and is cooled. Being denser than the hot air, the cooled air sinks down through the tower, creating a downdraft. The cooled air is pushed through the building and eventually out through the doors and windows, entraining room air with it.

When there is a wind during the day, the rate of circulation is increased. The cool air can be circulated through any room in the building by the appropriate arrangement of doors in the tower and the rooms. If there is no wind during the day, when the temperature of the tower reaches that of the ambient air, the circulation of air down through the tower and into the building ceases and the tower begins to operate like a chimney. (Of course, the operation of the tower is not constant throughout the day and night; the cooling effect and the duration of each phase of tower operation change according to fluctuations in the air temperature, the intensity of solar radiation, the wind velocity and so on.)

So far I have discussed only those temperature changes in wind towers that are due to what is known as sensible cooling. Sensible cooling occurs when there is a change in the temperature of air without a change in its humidity, or water-vapor content. Evaporative cooling occurs when there is a change in the temperature and the humidity, and it can play an important role in the operation of wind towers. For example, when the basement wall of a tower is damp, as is often the case, the air coming down the tower is cooled both sensibly and evaporatively. In other words, water on the wall absorbs enough heat to be vaporized. Since vaporization requires relatively large amounts of heat, wind towers that incorporate evaporative processes can cool the air quite effectively. In fact, before refrigerators came into wide use in Iran, the damp basements of wind towers served as cold-storage areas. Moreover, the humidifying of the air that accompanies evaporative processes is an important contribution to comfort at lower temperatures.

Another way of exploiting evaporative cooling is to place a small pool with a fountain at the bottom of the wind tower. Wind can be sensibly and evaporatively cooled coming down the tower and then evaporatively cooled by the pool and the fountain before it enters the rooms of the building. There are many buildings with towers of this type in the Iranian city of Yazd.

A wind tower in the city of Bam is employed in a different way. The tower is placed about 50 meters from the building it serves, and an underground tunnel runs from the bottom of the tower to the basement of the building. The ground over the tunnel is planted with trees, shrubs and grass. When the ground is watered, the water diffuses through the soil so that the tunnel walls are kept damp, and air coming down the tower and through the tunnel is sensibly and evaporatively cooled. A pool and fountain where the cooled air enters the basement furnish further cooling.

Vocabulaire

to flatten = to make flat
frozen ← to freeze
the height of the summer = the hottest part of the summer
to take advantage of : tirer parti de
daily : adj ← day
range : gamme, écart
to catch : attraper

to harness : exploiter
prevailing = most common
basement = floor (étage) built below ground level
rooms off the hall = rooms opening into the hall
namely = i.e.
further (adv.) = still more
to sink down = to fall down
according to : selon
velocity = speed
solid / broken arrow : flèche en trait plein / en pointillés
damp = moist, slightly wet
pool = small area of water
trees, shrubs, grass = vegetation
soil = ground