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Vernacular Climate Control in Desert Architecture

AHMET VEFIK ALP

College of Environmental Design, University of Petroleum and Minerals, Dhahran (Saudi Arabia) and Alp & Alp Architects, Istanbul (Turkey)

ABSTRACT

Architects today have at their disposal a rich variety of mechanical means to control the climatic environment in buildings they design. Consequently, it has become a common tendency to rely entirely on engineers and their equipment to achieve comfortable climatic conditions in building spaces. Yet, this attitude appears to carry along unwelcome side-effects: not only has a building's initial cost risen considerably, but smooth functioning of artificial systems requires periodical and costly maintenance, in addition to the need for energy over the life of the building, and all this accompanied by other environmental drawbacks such as noise, pollution and various hazards.

It is an unrealistic standpoint to reject what modern technology can provide to ensure a better building climatic environment. However, instead of relying wholly on mechanical means, the architect should, through a meaningful design, direct his efforts to achieve the best possible natural climatic control which, then, may be supplemented by artificial processes.

The paper discusses how vernacular architecture, sited in the extremely harsh conditions of the desert context, has tackled the issue of climatic regulation and efficiency relying only on natural means.

INTRODUCTION

In desert climates in the past, builders had to rely on a number of imaginative techniques to optimize people's comfort in buildings' internal spaces. Such strategems have even kept a winter's water cold and ice frozen through the subsequent hot summer. Ancient creative solutions for better human comfort in harsh climates enjoy a number of undebatable positive aspects:

— they use no energy other than nature's forces;
— they are basically maintenance-free;
— they do not pollute the environment;
— they are noise and vibration-free;
— they are economical to build.

What makes it sad today is that architects, even the most celebrated ones, bypass the sensitive issue of climatic control through relying on engineers' proposals for sophisticated systems. Yet, engineers, educated on different grounds, are inclined in most cases to conceive buildings as pieces of machinery rather than spaces to live, experience and remember, and their sophisticated mechanical systems inherently possess a number of negative faces, some fundamental:

— they require specialized design and computation services;
— they need continuous energy which is in short supply in some instances, or very expensive in others;
— they need constant maintenance which, in turn, demands experts and spare parts;
— they, on most occasions, pollute the environment through their refuse or deposits;
— they are potential sources of noise and vibration in buildings;
— they are expensive to build;
— they increasingly require larger spaces in buildings' floors and roofs, and they may cause unaesthetic views about and atop of buildings;
— they are potential causes of hazards;
— they occasionally interfere with a building's spatial system and structural layout, which then is endangered of becoming subordinate to mechanical systems;
— they conflict in nature with visually warmer and friendlier building finishes and need to be hidden by false ceilings or partitions.

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Having established this, let us make it clear, however, that the author does not take an extreme standpoint which blindly rejects any sort of inclusion of mechanical systems in contemporary building design and construction processes. Rather, the paper intends to emphasize that architects and designers in hot and arid lands have available a multitude of ways of using nature's help to achieve an acceptable climatic ambience through sensible and wise architectural design. What modern technology and materials offer us today may then be heartfully used to augment and complement the climatization effected through climate-sensible spatial design.

PASSIVE CLIMATIZATION TECHNIQUES IN DESERT LANDS

What vernacular and traditional architecture has achieved through trial and error through the years inherently provides the aesthetic qualities, the climatic adaptability and the economic feasibility that today's sensitive architects search for. Indigenous urban and rural fabric and individual building structures demonstrate endlessly such ingenuities of past architecture. Climatic control commences with community planning on the urban scale. It initiates through the way buildings agglomerate and shelter each other from the heat, the way serpentine-like streets denounce the harsh sun and pull the cool breeze through while keeping dust and sand out.

The interest of this paper, however, focuses on the individual building scale. Therefore, let us visit and review various techniques developed to naturally climatize habitable spaces.

Massive walls

Cultures in climates where the temperatures are disturbingly hot during the day and cool at night exhibit buildings with thick walls of brick or stone which, in addition to their insulating properties, function as heat reservoirs: during the hot day, the heat flow from exterior to interior is retarded and during cooler hours a given part of the heat imprisoned in the walls is released towards internal spaces. The consequence is a minimization of temperature change inside the building. Sun-dried brick used in the traditional adobe building appears superior in that respect. Its low heat conductivity and high energy storage capacity allows as much as 80% of the outside heat to be absorbed and only 20% transmitted inside.

Provided that the wall thickness is accurately selected, the coolness stored in a summer night will provide for comfortable temperatures for a long part of the following day. Likewise, heating in winter will not be required due to the heat stored in walls and radiated during the night. Today, baked bricks (cond. coeff < 0.66 W/mK) of 30-cm minimum thickness successfully replace adobe of vernacular building. Few Saudi Najd villages are still intact in the Central Arabian plateau to offer valuable examples in this respect.

Courtyards

In courtyards the cool night air is stored until the mid-hours of the following day while plants shield the court walls from direct solar heat gain.

The internal patio environment is a cooler private area suitable for many uses. It has proven most responsive to the rigorous conditions of hot-arid regions. It helps ventilation and filters dust, sand and noise. It moderates the climatic extremes in many ways: here, the cool air of the summer night is kept for many hours undisturbed by hot and dusty winds provided that the surrounding walls are as tall as the yard is wide (Fig. 1). The rooms draw daylight and cool air from the courtyard. During pleasant morning and evening hours, the household gathers in the courtyard safeguarded from curious eyes. Arcades at the perimeter (iwans) are indispensable to shade the overhead midday sun. In dry, dusty climates, running water is imperative to cool the air by evaporation and absorb the airborne sand.

Wind towers

The wind tower, or "wind catcher" harnesses the prevailing summer wind to cool it down and circulate it through the building. While one end of the tower rises from the roof the other end goes down to the basement. The upper part of the catcher is divided into several vertical air passages that terminate in openings at the top. Local designs exhibit variations in the height, the air-passages division, location and number of openings, the placement of the tower in relation to the building, and finally the material.

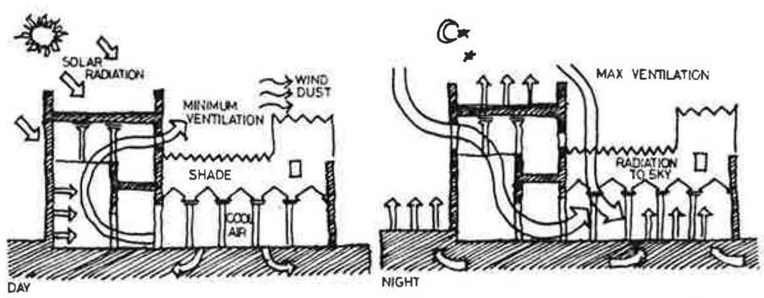

Fig. 1. Effective ventilation of an internal patio during day and nighttime.

The wind tower functions by altering the temperature and, thereby, the density of the air in and around the tower. The lower part of the tower opens into the basement and to the main level of the structure. The flow of the air is manipulated by opening or shutting the air access panels in the tower and the doors of the rooms off the central space where the tower opens normally on the main level of the structure.

The wind tower operates in different ways according to the time of the day and wind conditions. Practically, it remains functional both in the presence and absence of wind. It uses changes in air temperature without change in relative humidity. This process is referred to as "sensible cooling". The intriguing wood sticks that project from the exterior of wind towers are the uncut ends of wood reinforcement beams. The portion jutting out is kept in place to act as a support for scaffolding for prospective maintenance of the external surface of the tower (Fig. 2).

"Evaporative cooling" occurs with the addition of water to the system. Such cooling involves a change in the relative humidity of the air. When the unsaturated air is in contact with water the latter partially evaporates and the temperature of the air is lowered as its vapor content is increased. In most cases, the water seeps through to the inside of the lower part of the wind tower at the basement level which, naturally, causes the air to be evaporatively cooled before entering the building's internal spaces. In other cases, the tower is built far from the structure and is connected to it by an underground tunnel. Through irrigation, water is present at the surfaces of the tunnel and this allows the air to cool down along the way. A small pond and fountain at the entry point to the building further reinforces evaporative cooling (Fig. 3).

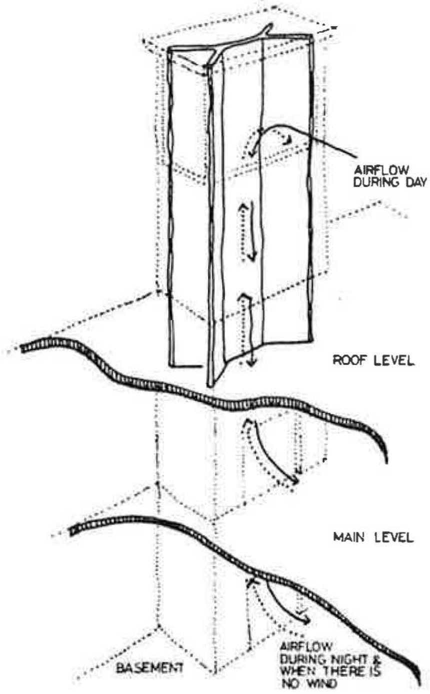

Fig. 2. Ventilation by means of a wind tower.

A wind tower operating both sensibly and evaporatively is particularly effective. Wind towers may even be made more effective if there exists an underground stream. The basement of the building is then connected by a vertical well with the stream. The sensibly cooled air descending from the tower runs over the opening of the shaft. The result is that air from the shaft is pulled upwards due to the fact that the pressure of the air from the tower is decreased as it blows over the shaft at high velocity. Other vertical drills from the ground surface provide an air supply to the underground stream which is cooled down and then diffused into the building (Fig. 4).

A common issue with wind towers is that they obviously allow dust and other organisms into the building. Screens have helped to

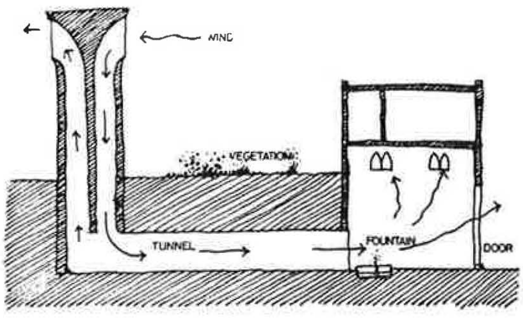

Fig. 3. Evaporative cooling using a tunnel from a displaced wind tower and a fountain in the house.

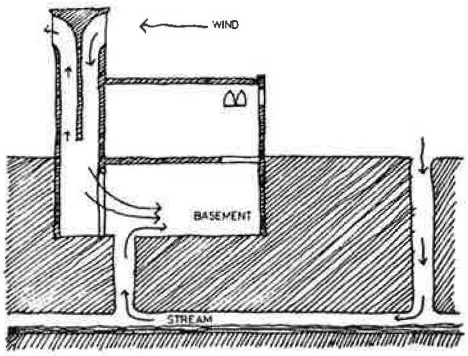

Fig. 4. Evaporative cooling by means of a wind tower attached to the house and a shaft away from the house but connected to the basement via a tunnel above an adjacent stream.

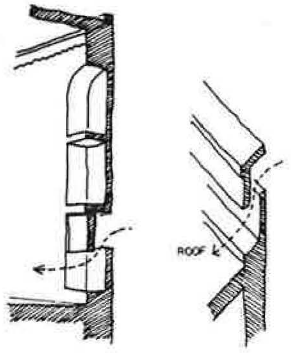

Fig. 5. Variations of badgeers to assist ventilation.

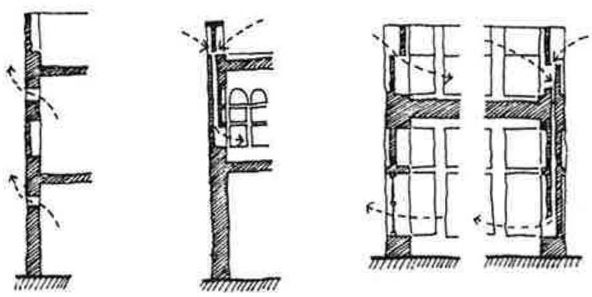

Fig. 6. External wall devices to encourage ventilation.

solve insect admission and taller towers let less dust enter the habitable spaces. An alternative way of keeping the dust out of a structure is to build the base of the tower larger than its top. An increase in the airflow section diminishes the velocity of the wind at the base of the tower. The dust will be deposited here in shelves named "dust pockets". Another measure is to orient the tower-top opening towards directions with dust-free winds.

Wind catchers have been traditionally made use of in hot–humid climatic regions in Iran, Pakistan, Arab Emirates, Bahrain and Kuwait with stylistics variations in each case. In addition to the most conventional one where intake and exhaust shafts are integrated into a single tower, one distinguishes types facing into the prevailing wind and away from the wind, acting as supply only and exhaust only, respectively. Each exhibits a different horizontal section in the turret. The oldest wind catchement tower is documented in ancient Egypt (2100 BC). Later, around 700 BC, wind towers were referred to in the inscription from Saigon II of Mesopotamia.

Badgeers

Badgeers are structurally integrated horizontal wind scoops. A recessed niche on the external wall suffices to create a badgeer which runs uninterrupted between two vertical posts. These mid-wall wind intakes may cool down the internal spaces in humid weather. Bahrain, Kuwait and Eastern Province of Saudi Arabia still exhibit genuine badgeer applications. Variations of the same theme are recessed parapet openings along the roof terrace to breeze the roof space which proves to be favourable to spend evenings. Other badgeer types derive from combinations (Figs. 5 and 6).

Domes and air vents

A curved roof has a larger convection heat-transfer surface, whereby it is more easily cooled. When an air vent is added to the top of a curved ceiling, the latter is rendered more effective. When air flows over a cylindrical or spherical object, the velocity of the air at the apex is increased and as a consequence, the pressure at the apex is lowered. The pressure

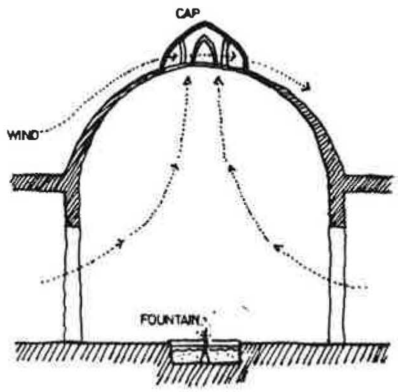

Fig. 7. Curved room with air vent above fountain to promote ventilation and cooling.

difference induces the internal hot air to be discharged out through the air vent. In regions where the prevailing wind is multidirectional, semi-spherical roofs are most common. Otherwise, when the wind direction is stable, a vaulted roof with its axis perpendicular to wind blow would be as effective. When dust makes a wind tower unusable, air vents become practical. A pool and fountain below the dome further cools the air moving through the room (Fig. 7).

Public baths "hammam" in Turkey, Egypt and the Middle East make use of domed roofs with capped air vents. Monitors, funnels and turbines are roof-vent variations used to let the heated interior air to the outside. They are further effective when supplemented by screening and insulated closure panels (Fig. 8).

Planting

Vegetation may be effectively used to act as a climatic moderator. It shelters from unpleasant winds, filters sand and dust, regulates air temperature through evaporation, reduces glare, and minimizes the heat reflection from ground surfaces. Above all, it shades and thereby cuts down solar heat gain.

Roof planting is beneficial in many instances. In dry areas the irrigation of the roof will cool down the structure through evaporation. A moist roof loses the heat it absorbed during the day to the night sky.

Cooling towers

Cooling towers are mostly seen in Iran and Egypt. Wind-scoop towers catch the wind, the air drops through the cool shaft, it passes through porous clay water containers which sweat moisture. The passing air is cooled down and its heat-carrying capacity is increased. In most cases, charcoal on a grille is hung in the shaft past the clay jars. The charcoal absorbs the water dripping from the containers above and as the air circulates through it dust particles are caught and the air is cooled once more. A pond of water and possibly a fountain at the base further cool down the air by evaporation as the latter enters the building spaces (Fig. 9).

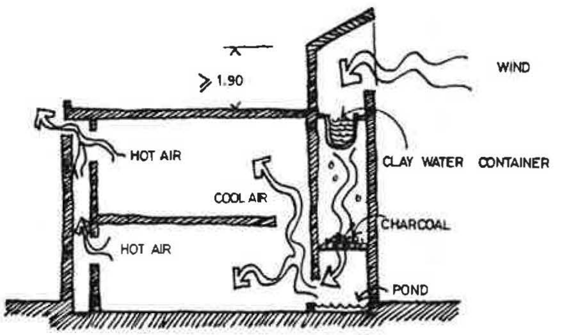

Fig. 9. A cooling tower with water and charcoal containers arranged to ensure a cool, moist and filtered air supply to the adjacent building.

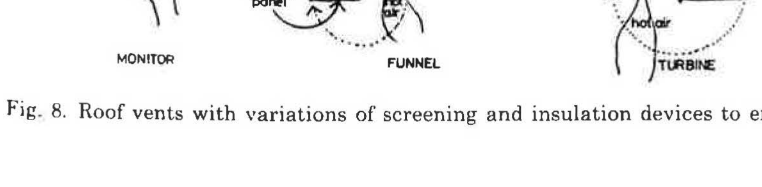

Fig. 8. Roof vents with variations of screening and insulation devices to ensure effective ventilation.

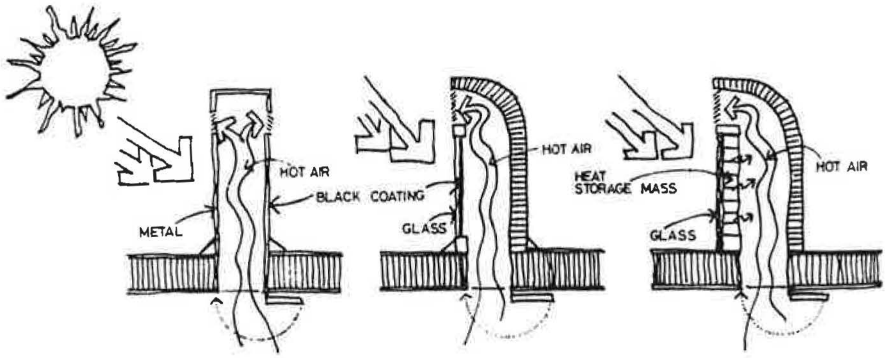

Fig. 10. Types of solar chimney to assist ventilation.

Roof ponds and water walls

Bags containing water are placed on the roof terrace and screened by a movable light insulation layer during the hot day. This set-up keeps the roof-generated heat off during the day. When night comes, the insulation is removed or slid aside and the water mass is permitted to lose its heat inertia to the night sky, cooling down the structure underneath. Approximately 15 - 20 cm deep water and a 4 - 8 cm foam insulation appear to regulate the internal temperature between 18 - 21 °C most of the time. "Drum walls, mass walls", and "water walls" use the same concept on perimeter walls.

Solar chimneys and induction vents

Solar chimneys make use of solar heat to reinforce natural air convection. The black-coated chimney is heated during the day and so is the air inside. The latter then expands and rises, tracking the interior air up and out. This is a self-regulating system: the hotter the day, the faster the air motion.

A variation is "glazed solar chimney". Such chimneys when facing west are favourable for venting during the hot afternoon part of the day. If a thermal storage mass is added behind the glazing, the system will store heat and keep on exhausting air after sunset (Fig. 10).

Induction vents are a "solar air ramp", "windows with radiant barrier curtains", or "solar mass wall". The sunlight is trapped behind south or west glazing, the heated air rises and is allowed to escape outside. This causes the internal air to be pulled in the heated space and exhausted. North-side shaded air may be used to replace the lost quantity inside the building. A mass-wall will serve as a heater during colder times by shutting the exhaust and letting the heated air return back into the space through an air filter (Fig. 11).

Rowshans or mushrabiyahs

"Mushrabiyahs", or projecting screened bay windows are common in Hejaz, the Western province of Saudi Arabia. They have orig-

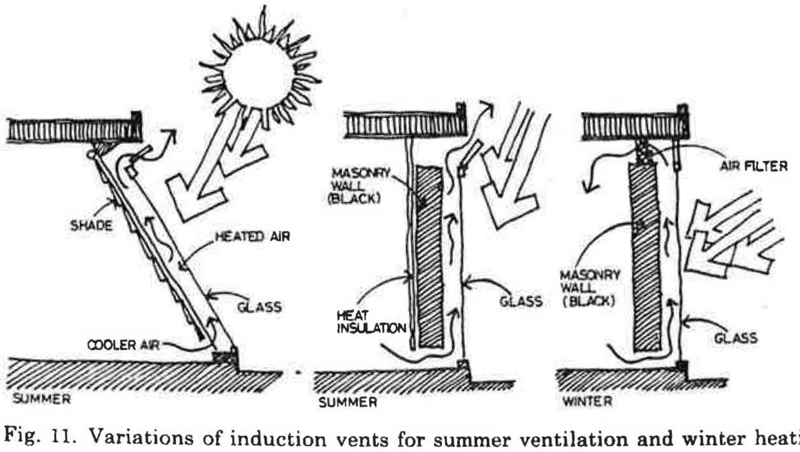

Fig. 11. Variations of induction vents for summer ventilation and winter heating.

inated from Egypt. These transparent wooden screens allow cross-ventilation while preserving the family privacy. Some are designed to allow a earthenware water container to sit to initiate evaporative cooling in dry climates. Cool water is obtained at the same time. Mushrabiyahs exhibit delicate carpentry craftsmanship and the timber is said to be imported from the Far East.

CONCLUSIONS

The master builder or the architect has always had available a multitude of natural ways and means to offer the users acceptable climatic comfort regardless how severe desert zones conditions are. There also exist many other parameters, such as building orientation and configuration which assist the designer in his endeavor to attain climatic adaptability. The lessons we are given by traditional and vernacular architecture sited in harsh conditions of deserts' hot-arid-humid zones are of the utmost value in this respect. Nowadays, the builder additionally enjoys the availability of diverse new building-oriented products such as weatherproofing, insulation, glazing, finish materials and a rich variety of shading, louvering and screening devices and the like to enhance the climatic comfort in internal and semi-internal building environments.

With the pros and cons of natural versus artificial climatic regulation in mind, it becomes apparent that a complete subordination to engineers' mechanical devices today to positively modify the building climatic comfort is not to be considered as a valid design attitude. Architects can and ought to attain climatic comfort by skilfully manipulating architectural design parameters and make wise use of what nature generously provides us. The sophisticated contemporary climatic control systems are to be also used, however, to augment and supplement what has been achieved through imaginative and climate-responsive architectural design.

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