Architectural Design Intervention as a Solution to Hot and Dry Climate of Jodhpur, Rajasthan

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ABSTRACT:
The technique used for building construction and its utilization leads to significant environmental issues due to their overuse of energy and other natural resources. Building energy usage and environmental harm are closely related since energy-intensive solutions were developed to meet the demands of heating, cooling, ventilation, and lighting, which severely depletes valuable natural resources. Nonetheless, structures may be made to provide thermal and visual comfort for occupants while consuming less energy and resources. Using an integrated approach to building design can have an impact on the energy resource efficiency of new construction. This article presents energy-efficient building solutions that optimize the use of renewable energy sources, energy-efficient equipment, and passive solar design techniques to balance energy consumption across building systems, including lighting, air conditioning, and ventilation. Architects can achieve energy-efficient buildings by researching the site's macro- and microclimate, utilizing bioclimatic principles to mitigate unfavorable circumstances, and capitalizing on favourable variables. This article discusses several typical design features that either directly or indirectly impact thermal comfort levels and, consequently, the building's energy usage.

Keywords: Energy Efficiency; Ventilation; Macro and Microclimate; Passive design strategies
DOI Number: 10.48047/nq.2022.20.8.nq221170 **NeuroQuantology 2022;20(8):11322-11336**

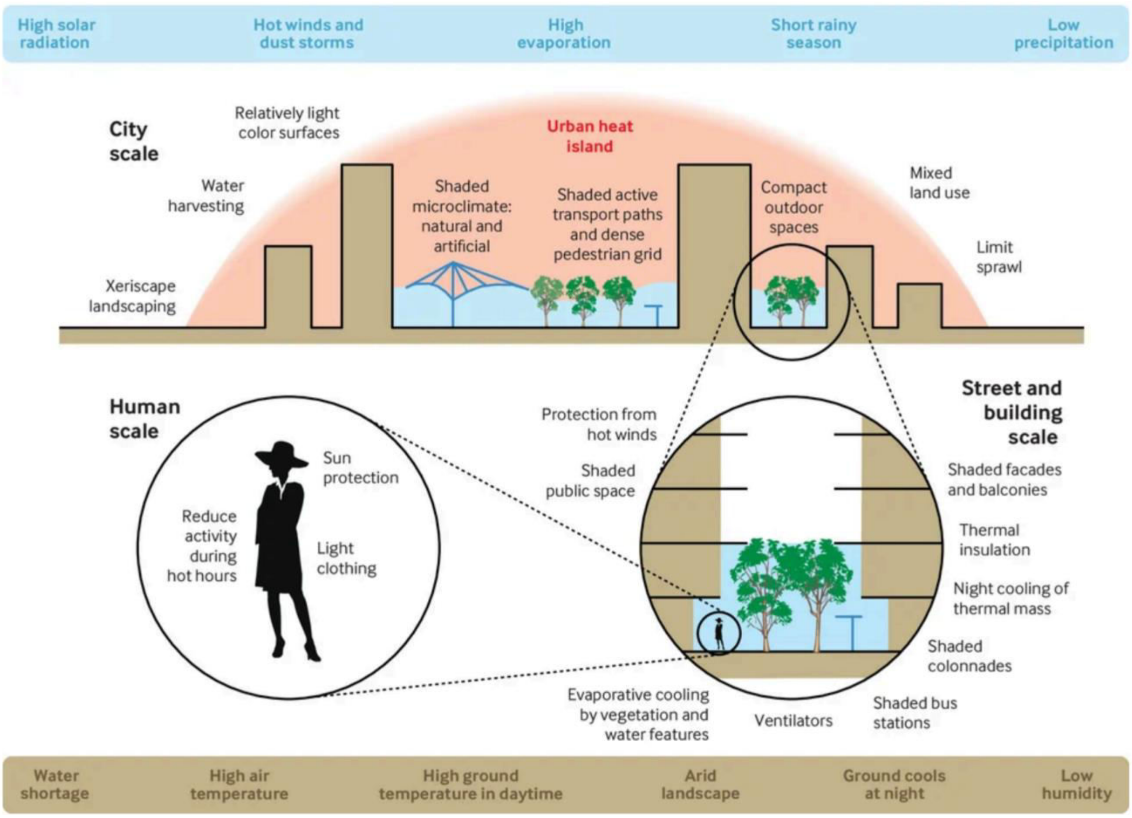
1. INTRODUCTION

The building's energy usage and performance are significantly impacted by the climate. The objectives of a climatically responsive sustainable building design are to use natural resources more efficiently, reduce energy consumption, and provide comfortable, healthy, and sustainable living places (Hui 2000). These days, sustainable construction and design techniques are crucial. It may be argued that sustainability was already a motivating factor in the past, as seen by the various approaches and forms that were employed. Thus, despite several advancements in materials and technology, issues and safety measures in design and construction have not changed significantly since the time of Vitruvius. Furthermore, these advancements might have had unfavourable consequences. For this reason, a comprehensive discussion of the building process is necessary.Put another way, building methods, material selection, and climate-responsive design must all be considered in concert, and the finished product must function well over the duration of its useful life. Although sustainability is portrayed as a 21st-century idea, it has really been used since the time of Vitruvius' writings and has emerged naturally in traditional architecture (Vitruvius 1969). Examining the sustainable design and construction methods used in Jodhpur's traditional architecture, one can see how the area's traditional settlements and buildings were created to blend in with the topography, culture, and climate of the area, as well as how their design and construction could be incorporated into contemporary design techniques.

The research program on building methods utilized in Iran's hot, arid regions served as the foundation for this study. The study's initial goal is to compare and contrast traditional housing concepts from the perspective of climate-responsive architecture. Second, it seeks to present the fundamental ideas and significant modifications in application that can be applied to future sustainable home designs. This study looked at design solutions for hot,and dry climates and compared modern and traditional homes based on design parameters such as building orientation, building envelope, building form, and living space choices.

2. BUILDING DESIGN LIMITATIONS IN HOT AND DRY CLIMATE:

The main challenge in designing for hot, dry climates is minimizing energy use, and from this perspective, older structures can offer the answer. In hot climates, the historic dwellings were designed to adjust to the natural temperature. Utilizing these antiquated construction methods, wind towers, inner courtyards, latticed screens, or "mashrabiya," can all effectively block sunlight and improve ventilation. These days, it is essential to use climate-sensitive building techniques, which can also be quite successful in reducing energy usage.



Since the weather can restrict outdoor activities, socializing with others outside, and active transportation, some of these elements can be especially challenging to implement when creating a healthy atmosphere in hot, dry regions like the Middle East. A few significant obstacles are as follows:

- Prolonged hot summers, severe water shortages, and even excessive evaporation all work against green places.
- High temperatures and strong sun radiation result in thermal discomfort and heat stress.
- The urban heat island effect at night is more pronounced in dry-climate cities than in temperate and tropical ones.

A prime example of sustainable building design is Masdar City in Abu Dhabi, where the use of technology is crucial to the execution of passive design principles. In Masdar City, technology is being utilized to improve passive design techniques in several ways:

*a). **Smart building controls**:*
Masdar City buildings use smart building controls to regulate lighting and temperature based on outdoor circumstances.

*b). **Automated Shading Devices**:*
Masdar City's shade systems have automatic controls that change the shading according to the sun's position, lowering heat gain and boosting energy efficiency.

*c). **Use of Advanced Insulation materials**:*
Modern insulation materials are used in building design to decrease heat transfer and lower the requirement for air conditioning.

3. CHARACTERISTICS OF HOT AND DRY CLIMATE OF JODHPUR

Jodhpur experiences short, hot, humid summers, short, cold winters, and year-round dry, mainly clear weather. Less rainfall due to low humidity lowers the number of plants in the area. Due to the intense heat and dryness of the air, there is little precipitation in this type of climate, often between 50 and 150 mm annually. The sky in this kind of environment is usually blue and clear. Nevertheless, now and again, dust storms cover the whole sky, creating an intolerable glare. The highly loose and sandy soil, little humidity, and infrequent rainfall may make it easy for only prickly plants and thick leaves to survive here.The average annual temperature fluctuates between 51°F and 105°F; it is rarely lower or higher than 46°F or 110°F.

3.1 Average Temperature of Jodhpur:

The average daily maximum temperature during the 2.7-month hot season, which runs from April 12 to July 3, is above 99°F. May is the hottest month in Jodhpur with an average high temperature of 104°F and low temperature of 83°F.The average daily maximum temperature during the 2.2-month mild season, which runs from December 6 to February 14, is below 81°F. With an average low temperature of 51°F and high temperature of 76°F, January is the coldest month of the year in Jodhpur. You can see a concise characterization of the hourly average temperatures for the full year in the figure below. The year is represented by the horizontal axis, the hour of the day by the vertical axis, and the average temperature for that hour and day is shown by the hue.

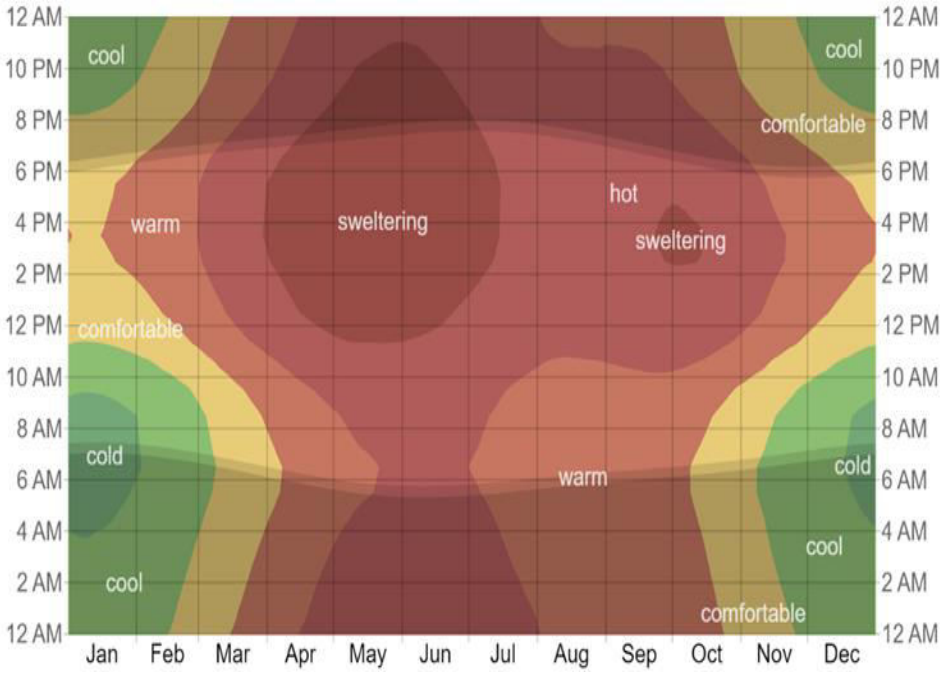


Figure 2: The average hourly temperature, color-coded into bands. The shaded overlays indicate night and civil twilight.

4. DESIGN PRINCIPLES FOR ACHIEVING ENERGY EFFICIENCY

Architects can design buildings that are energy-efficient by researching the site's macro- and microclimate, utilizing bioclimatic principles to mitigate unfavourable conditions, and capitalizing on favourable variables. Several typical design components that influence thermal comfort levels and, consequently, a building's energy usage, either directly or indirectly, are as follows:

(a) landscaping,
(b) ratio of built form to open spaces,
(c) location of water bodies,
(d) orientation,
(e) planform, and
(f) building envelope and fenestration.

However, these design principles alone are insufficient to produce acceptable interior conditions in harsh climates. When used in a design under such climatic circumstances, a few tried-and-true ideas can mainly meet the requirements for thermal comfort.

5. ARCHITECTURAL INTERVENTIONS FOR ACHIEVING ENERGY EFFICIENCY IN HOT AND DRY CLIMATE AREAS

5.1 Site and Building Form Interventions:

Buildings may be constructed with far less energy than is often used now. The primary goal of this research is to develop techniques for lowering building energy use in hot, dry locations. In this situation, energy-efficient design options are evaluated. They are primarily dependent on optimal building form, material selection, and orientation, as well as the use of passive cooling and ventilation. This blog explains how principles give rise to the notions of harnessing natural energy and passive cooling strategies for hot and dry areas.

5.1.1 Building Orientation:

Building orientation is an important architectural factor, mostly concerning wind and solar radiation. Buildings should be angled to enhance sun gain in mostly cold locations; the opposite is advised for warmer ones. Both of these circumstances may occasionally occur in areas with highly noticeable seasonal variations. An orientation that is slightly east of the south is preferred in cold climates, particularly one that is 15° east of the south, as this exposes the unit to more morning sun than afternoon solar and allows the house to start heating during the day. The MLA hostel building in Shimla is a prime example of this. In a similar vein, wind might be welcomed or unwanted. A compromise between the orientations of the sun and wind is frequently necessary. With careful design, shadingand deflecting devices can be incorporated to exclude the sun or redirect itinto the building, just as the wind can be diverted or directed to the extentdesired.

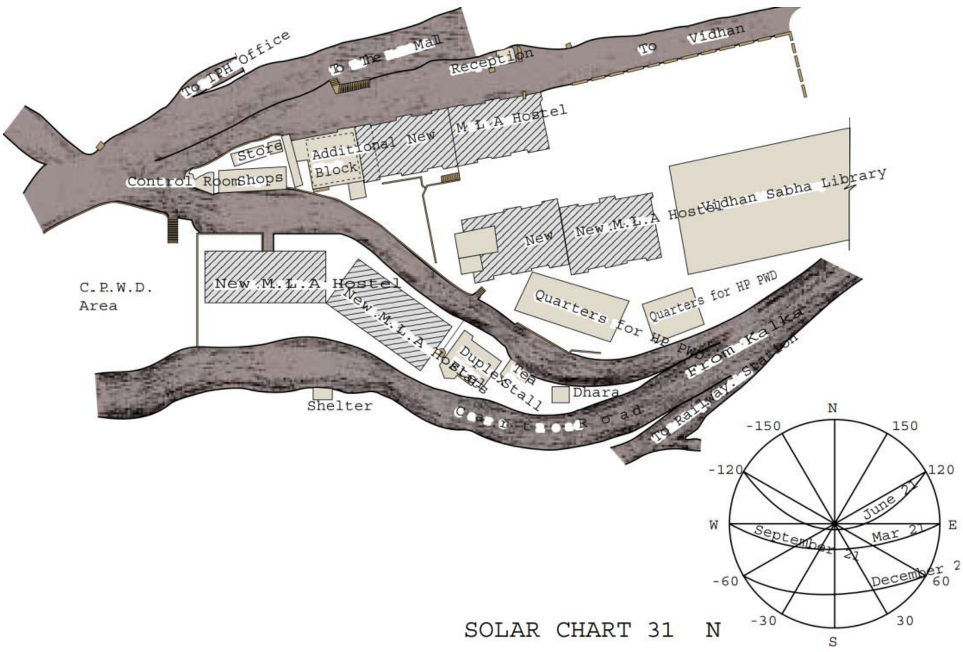


Figure 3: The building blocks in the MLA hostel, Shimla, located in the cold and cloudy zone, are oriented due south ±15° for direct solar gain. They are positioned so that, even in the longer winter shadows, there are no shadows from one structure over the other. To benefit from south exposure, it was suggested that all bedrooms face south.

5.1.2 Building Form/ Surface to Volume Ratio

The amount of space inside a building that requires cooling and how much of the envelope surrounds that space determines the building's thermal performance. The surface-to-volume ratio, or S/V ratio, is a parameter that is derived from the building shape. The more compact the shape, for a given building volume, the less wasteful the heat gain/loss. Buildings are therefore compact in shape and have a low S/V ratio in hot, dry regions and cold climates, respectively, to decrease heat gain and losses. Additionally, the airflow pattern surrounding the building is determined by the building form, which has a direct impact on ventilation. The depth of a building also affects how much artificial lighting is needed; the deeper the building, the more artificial lighting is required.

5.1.3 Landscaping

One of the key components in changing a location's microclimate is landscaping. Well-designed landscaping lessens the amount of direct sunlight that strikes and warms building surfaces. It stops heat from the ground or other surfaces from entering a structure by reflected light. By generating a pressure differential, landscaping alters airflow patterns and can be utilized to strategically direct or redirect the wind. Furthermore, the evaporative cooling provided by grass and shrubs, as well as the shade cast by nearby trees, lower ambient temperatures. Well-planned roof gardens can lower a building's heat burdens. A study shows that the ambient air under a tree adjacentto the wall is about 2 °C to 2.5 °C lower than that for unshaded areas, whichreduces heat gain by conduction (www.greenbuilder.com).

The main components of an energy-conserving landscape are trees. What kind of trees should be planted depends on the climate. In a mixed climate, planting deciduous trees on a building's southern side is useful. The summer sun is blocked by deciduous plants like Champa or mulberry, and when these trees lose their leaves in the winter, the sun may still heat the structures. This landscaping plan has been implemented to provide shade for TERI's RETREAT building, which is located on the southern side.

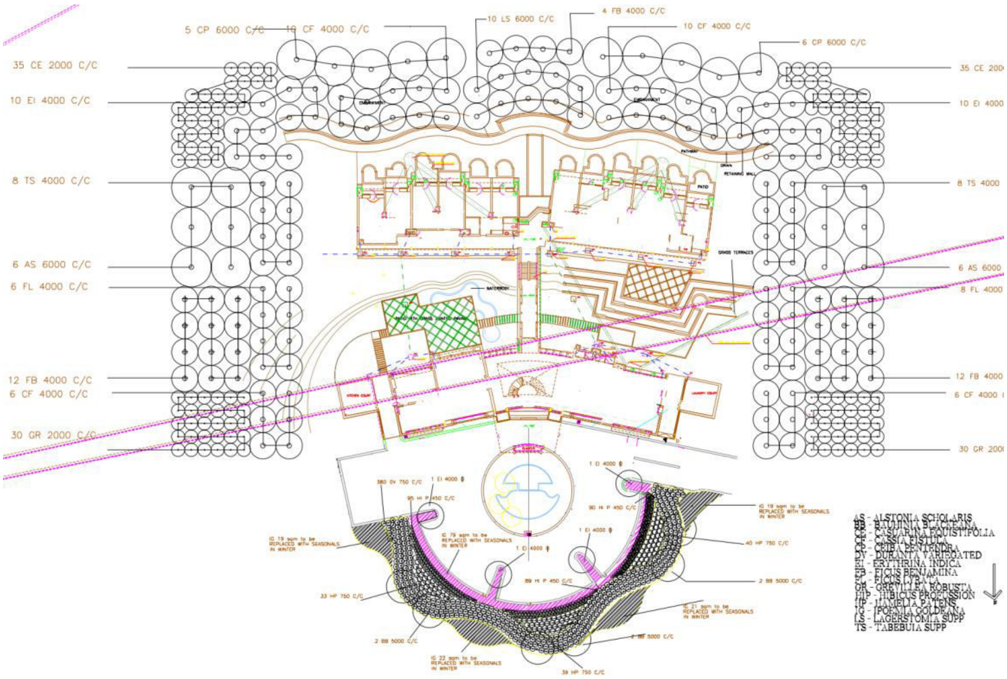


Figure 4: The RETREAT building has deciduous trees on the south side to cut off summer gains. These trees shed their leaves during the winter to avoid losing solar gain. Windbreaks are installed in the north and northeast to guard against winter winds.

5.1.4 Location of Water Bodies

Water is an excellent microclimate modifier. It significantly reduces temperature and absorbs a lot of heat through evaporation, particularly in hot, dry climates. However, as water increases humidity, it is best to avoid it in humid climates. Water has been employed in the WALMI building complex at Bhopal to modify the microclimate with great success.

5.2 Building Envelope

5.2.1 Materials

Selecting the right building materials is crucial to lowering a structure's energy content. Low-energy structures made of low-energy materials, effective structural design, a decrease in the amount of high-energy building materials, and less energy-intensive transportation can all help to lessen the burden on conventional energy. Optimizing indoor comfort is also aided by material selection. Several structures in the Pondicherry area's Aurovilleneighbourhood have exhibited the use of materials and components with minimal embodied energy. The Auroville visitor center employs cutting-edge building materials and construction methods to lower the building's embodied energy and achieve the ideal comfort levels appropriate for Pondicherry's warm, humid climate.

Building	**Elements/Materials**	**KWh/cum (in situ)**
Cement Concrete	1:5:10	402
Lime Concrete with brick ballast	1:4:8	1522 (80% in brick)
Brick Masonry	1:5	676
Brick Masonry	1:4	709
Random Rubble Masonry	1:4	267

Stabilized Mud with 6% lime		197
RCC Roof (10cm)		174/m²
Cement Plaster	1:4	20.65/m²
Cement Plaster	1:6	15.09/m²
Lime Surkhi	1:4	11.05/m²
Source: Energy contents of building materials for India: paper by Dr C L Gupta. Green Architecture festival, Nasik, February 1994; data Courtesy Sanjay P, RakeshAhuja. Geeta V		

5.2.2 Thermal Insulation

When a building requires mechanical heating or cooling, insulation is extremely useful since it reduces the space-conditioning demands. The right location for insulation and the appropriate thickness are critical. In hotter climates, insulation is applied to the wall's outer face, which faces the outside, to form a thermal mass that is strongly coupled to the interior but weakly coupled to the outside. The RETREAT building's space-conditioning loads have been lowered by about 15% thanks to the use of vermiculite concrete insulation on the roof and 40mm thick expanded polystyrene insulation in the walls.

5.2.3 Roof

In addition to receiving a lot of solar radiation, the roof is crucial for ventilation, daylighting, and heat gain/loss. Adequate roof treatment is crucial, contingent on the climate. The roof should have adequate insulating qualities in a hot climate to reduce heat gain. Here are a few techniques for protecting roofs:

- Deciduous plants or creepers might be used to cover the area. Rooms will remain cold due to evaporation from leaf surfaces.
- Cover the entire roof surface with inverted earthen pots. It also provides an insulating layer of still air above the roof.
- A detachable cover is a useful tool for shading the roof. During the day, this can be positioned near the ceiling, and at night, it can be rolled up to allow for radiative cooling. To reduce the amount of radiation the canvas absorbs and the resulting conductive heat absorption through it, paint the upper surface of the canvas white.
- Vermiculite concrete provides effective roof insulation. This has been employed at the RETREAT building in GualPahari (near New Delhi) to reduce roof conduction by 60%.

By adding skylights and vents, the roof can also be effectively utilized for daylighting and ventilation. The newly built office building of the West Bengal Renewable Energy Development Agency (WBREDA) in Calcutta serves as an excellent example of this.

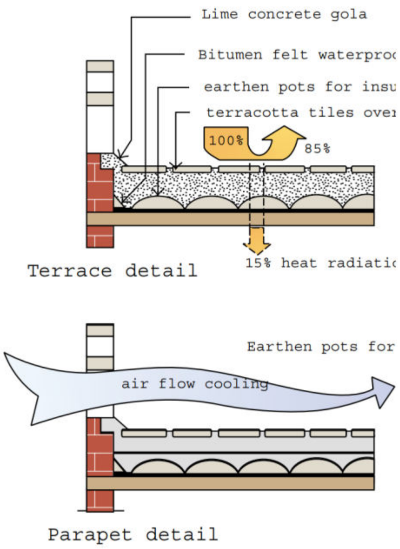


Fig 5. Roof details showing the use of earthen pots Fig 6. Broken China mosaic can be used onthe rooftop for reflection of incident radiation.

5.3 Fenestrations and Shadings:

Windows and other glazed sections are the most susceptible to heat gain or loss among all the components in the building envelope. An essential component of bioclimatic design is the placement, size, and details of windows and shading, which help to block out the light and wind from entering a structure or let them in when necessary. The direction of the predominant wind determines where ventilation apertures should be placed. Naturally, openings at higher elevations help to expel heated air. A small inlet and a big outlet increase the velocity and distribution of airflow through the room; the size, shape, and orientation of the apertures control the air velocity and flow throughout the space.Whenever feasible, the house should be positioned on the lot to benefit from the predominant breezes. In the summer, the predominant wind direction is from the south or southeast. Windows should be designed with both lighting and ventilation in mind, adhering to the guidelines in the first revision of the IS:3362-1977 Code of Practice for natural ventilation of residential structures. A substantial amount of air motion is necessary in warm and humid climates. Fans are necessary in these places to create comfortable indoor air movement. In hot and dry as well as hot and humid locations, it has been shown that windows occupying 15 to 20% of the floor surface are sufficient for both ventilation and daylighting.Glazed openings allow natural light to enter a building as well. Therefore, heat input and loss, ventilation, and daylighting requirements are the main factors that influence fenestration design. The glazing systems and shading devices are crucial window components that control these.

5.3.1 Glazing Systems

Roughly 75–85% of the solar radiation could enter a building through a conventional residential window with one or two layers of glazing before recent advancements in glass, films, and coatings. Certain interior shading elements, such as blinds or drapes, may reflect some of that energy outside the structure. Most of the energy—heat, in particular—stayed inside, which had an impact on thermal comfort. To regulate a building's interior temperature, research and development have focused heavily on windows' poor thermal properties.

Windows allow in direct sunlight, which increases heat input. In colder climates, this is ideal, but in hotter ones, it is essential. In hot, arid climates, windows should have the smallest possible dimensions. For instance, in Ahmedabad, the number of uncomfortable hours per year can be lowered by as much as 35% if glazing is accounted for at 10% rather than 20% of the floor surface (J K Nayak, et al).

5.3.2 Shading Devices

The amount of heat gain through windows is significantly higher than that through solid walls and is based on the solar energy gain factor and the total heat loss coefficient U-value (W/m2K). Thus, window and wall shading systems reduce the amount of heat that enters the structure. In a hot and dry low-rise residential structure in Ahmedabad, the maximum room temperature can be lowered by up to 4.6 °C (from 47.7 to 43.1 °C) by covering a window with a horizontal 0.76 m deep chhaja. Furthermore, it is possible to cut the number of uncomfortable hours with temperatures above 30 °C in a year by 14% (J K Nayak, et al).

Shading devices are of various types:

- Moveable opaque (roller blind, curtains, etc): These can be highly effective in reducing solar gains but eliminate view and impede air movement.
- Louvers: These may be adjustable or fixed. These affect the view and air movement to some degree.
- Fixed overhangs.

Fig 7. The office building for the West Bengal Pollution Control Board is a landmark of energy and resource-conscious architecture in this region. Efficient planning and carefully designed shading devices, fenestration design and efficient lighting design have brought about 40% energy savings over a conventional building of similar size and function. This picture shows the east facade with inclined louvers to cut off solar gains.

5.4 Advanced Passive Cooling Techniques:

Buildings were planned to benefit from daily temperature changes, convective breezes, shading, evaporative cooling, and radiation cooling before the turn of the century. But these ideas were neglected in favor of mindless Western imitations, which turned buildings into energy-guzzlers. With today's rising energy costs and growing environmental concerns, several of these older, less sophisticated methods are starting to gain popularity again. Natural heatsinks are the means by which passive cooling systems extract heat from a structure. They do not require any intermediary electrical equipment; instead, they cool directly by radiation, convection, and evaporation. Every passive cooling approach is dependent on daily fluctuations in relative humidity and temperature. Each system's applicability is weather-dependent.

By using these design techniques, interior rooms receive less heat gain. This section provides a brief explanation of the passive strategies that help a building lose heat by radiation, convection, evaporation, or by utilizing the surrounding spaces' storage capacity, such as earth berms.

5.4.1 Ventilation

Outdoor breezes circulate air through the house's interior via the push-pull effect of positive air pressure on the windward side and negative pressure (suction) on the leeward side. To get good natural ventilation, apertures must be located in opposite pressure zones. Designers frequently choose to promote natural ventilation in buildings by incorporating towering spaces known as stacks. Warm air can escape through vents near the top of stacks, while cooler air enters the building through openings near the bottom. The WBREDA office building in Calcutta uses stack ventilation to great effect. In this structure, which is located in a warm, humid climate, induced ventilation was a key design technique.

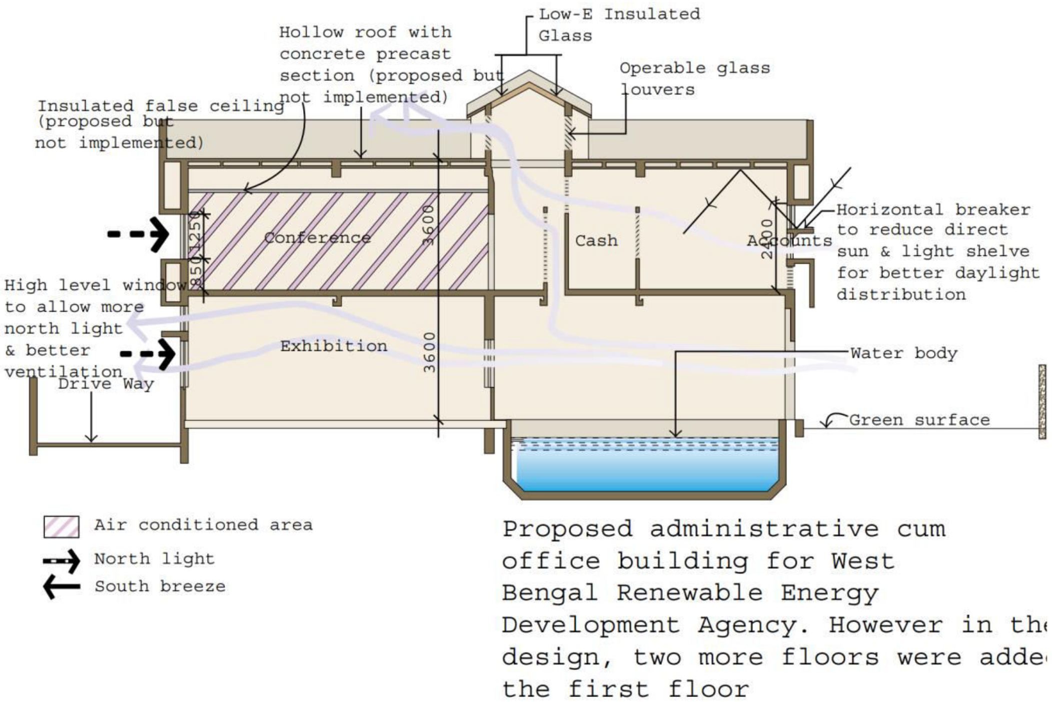


Fig 8. Section of the W BREDA office building showing ventilation strategies

Sudha and Atam Kumar's home in New Delhi's composite climate employs innovative ventilation solutions that include the construction of integrated solar chimneys. As previously noted, windows play an important function in causing indoor ventilation due to wind forces. Other passive cooling approaches that induce indoor natural ventilation and are employed by architects to accomplish passive cooling are detailed below.

Fig 8. Picture showing buildingintegrated solarchimney inSudha and Atam Kumar'sresidence atNew Delhiforeffective ventilation, especiallyduring the humid season.

5.4.2 Wind Catcher

Traditional architects were compelled to depend on natural ventilation to improve the indoor air quality of their buildings. The use of arching towers became common 3000 years before Christ's birth and is the best illustration of the successful application of natural forces. The air trap was a frequent architectural feature seen in most warm climate locations. Airtraps were typically placed in appropriate locations around the house based on the size of the structure and the number of air traps required to cool the summer apartment. In cities where the appropriate wind blows from a specified direction, the air trap is open in one direction and closed to the other three directions.

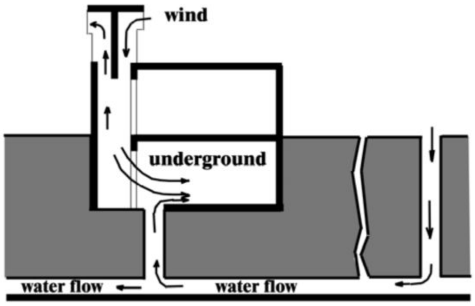


Figure 9.The function of a wind catcher.

In past centuries, traditional structures in arid and dry locations used air traps similar to modern air conditioners. An air trap is similar to a chimney, with one end below and the other elevated above a certain height on the roof. Numerous little openers or ducts can be installed at the higher output. At the end of the air trap at the bottom of the door, a pool is frequently built, with water supplied by qanats. The height of the air trap, the number of openers, and the location of the air traps are determined by the building's location within the city.

The air trap operates based on temperature and density differences between within and outside the trap. The difference in density of the air generates positive or negative buoyancy, causing the air to flow to the bottom or to the top. Air circulation in various parts of the building is controlled by opening and closing the numerous openers or ducts at the bottom of the air trap.

The air trap responds to the wind and solar radiation conditions in the region. During the day, both the inner and outside walls absorb a significant amount of heat. As a result, they maintain a temperature equilibrium at night and transfer the drawn warmth to the cold night air. The thickness of the air trap walls and the dimensions of the openings inside them are designed to transfer enough heat for optimal comfort. The light warm air inside the air trap rises and is sucked out at the top elevation. As a result, cool air enters the house through the windows and doors and continues throughout the night.

The wind catcher works on a few different concepts. They are constructed with long ventilation shafts positioned to capture any hint of a passing breeze and convey it down into the house. The interconnecting chambers of old buildings were intended to circulate the air that flowed down the wind catchers.

The sun-dried mud bricks used to construct the dwellings maintained their coolness in the summer and warmth in the harsh winters. The air traversed all the way down to the gathering spaces constructed in the basement, where the family would largely reside during the sweltering summers.

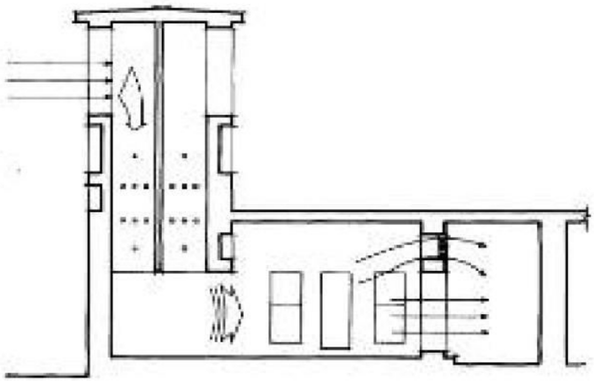


Figure 10.Cross Section of a wind catcher.

Finally, in a windless or waterless environment, a wind catcher acts as a stack effect aggregator of hot air. It generates a pressure gradient, allowing less dense hot air to rise and escape from the top. This is exacerbated greatly by the aforementioned day-night cycle, which traps chilly air below. The temperature in such an atmosphere cannot go below the overnight low. These last two purposes started to gain momentum in Western design, and various commercial items bear the name wind catcher

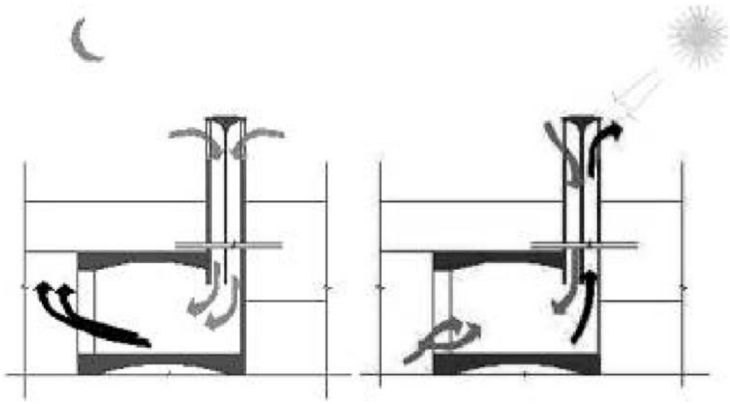


Figure 11. Wind catcher function during day and night (Azami, 2005).

The wind catcher might cool lower-level areas to freezing temperatures in the middle of the day when combined with thick adobe, which has high heat transmission resistance properties. We can further our goal of sustainability in modern construction by using this traditional Iranian aspect.

The air trap walls' thickness and the internal dimensions of holes were planned in a manner to allow in adequate heat. Ascent and suction from higher altitudes cause the bright, warm air within the air trap. Consequently, cool air enters the house through the doors and windows and stays there all night long.

If the wind blows at night, the air will flow in the opposite direction in the airtrap. In other words, the chilly air is drawn inside the home. Of course, in such a case, the cold air going from the air trap duct, which was heated over the day, will slightly warm the inlet air. nevertheless, air circulation refreshes the indoor temperature. During the day, the air trap operates differently than a chimney. In other words, the upper parts of the air trap were cooled the night before, and when the heated air comes into touch with the air trap's walls, it cools and goes to the bottom, finally circulating throughout the home and exiting through doors and windows.The movement of air during the daytime increases the ventilation process.

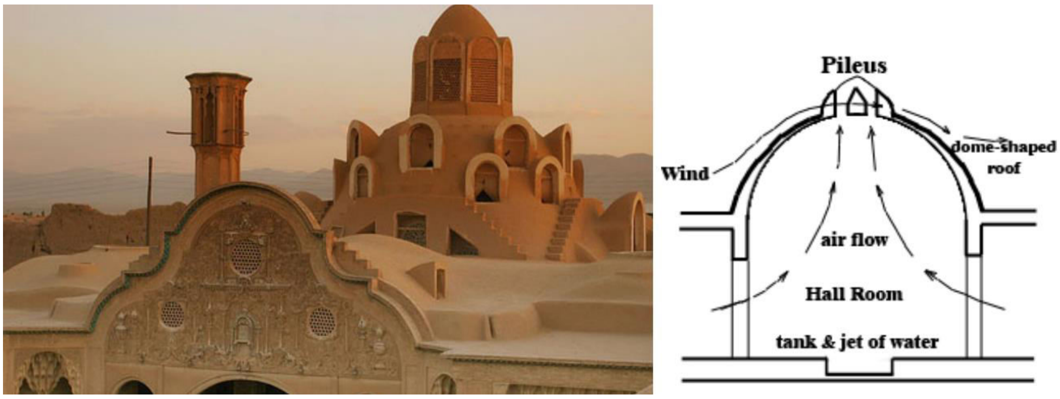


Figure 12. Schematic figure of natural ventilation in Broojerdi ha House.

5.4.3 Courtyard Effect

In a courtyard, incident sun radiation causes the air to warm up and ascend. Cool air from the ground level travels through the louvred openings of rooms surrounding a courtyard, resulting in air flow. Nighttime convection and radiation cool the warm roof surfaces. If the heat exchange drops the roof surface temperature to WBT of air, condensation of atmospheric moisture occurs, which restricts further cooling. If the roof surfaces slope towards the internal courtyard, the cool air sinks into the courtyard, enters the living space through low-level openings, warms up, and exits through higher-level openings.
However, it should be ensured that the courtyard does not receive excessive sun radiation, which could result in conduction and radiation heat gains in the structure. The courtyard's intense sun radiation causes significant glare.

5.4.4 Earth Air Tunnels

The daily and annual temperature changes lessen as depth below the ground surface increases. At a depth of roughly 4 m below ground, the temperature inside the earth remains practically constant throughout the year and is nearly equivalent to the local annual average temperature. A tunnel in the shape of a pipe or otherwise embedded at a depth of about 4 m below the ground will acquire the same temperature as the surrounding earth at its surface, so the ambient air ventilated through this tunnel will be cooled in summer and warmed in winter, and this air can be used to cool in summer and heat in winter.

The RETREAT building in Gurgaon's composite climate makes use of an earth air tunnel. The earth air tunnel system keeps the living quarters (the south block of the RETREAT) at comfortable temperatures (approximately between 20 °C and 30 °C) throughout the year, supplemented as needed with a system of absorption chillers powered by LPG during the monsoons and an air washer during the dry summer. However, the cooler subsurface air must be pumped throughout the dwelling space. Each room in the South Block has a'solar chimney'; warm air rises and leaves via the chimney, creating an air current that allows cooler air from the underground tunnels to replace it. Two blowers installed in the tunnels expedite the procedure. The same system supplies warm air, from the tunnel to the dwelling space, throughout the winter.

5.4.5 Evaporative Cooling

Evaporative cooling works by evaporating water to reduce the temperature of the interior air. It works well in hot, dry conditions with little air humidity. Evaporative cooling uses air's sensible heat to evaporate water, cooling the air and hence cooling the building's living area. The rate of evaporation rises when there is more interaction between water and air. A nearby water feature, such as a pond, lake, sea, or fountain in a courtyard, might offer cooling. The most common technology is a desert cooler, which is made up of water, evaporative pads, a fan, and a pump. In Gurgaon, evaporative cooling was used to create a roof-top solar energy hub. However, the system is currently inaccessible due to insufficient water supply in the area.

5.4.6 Passive Downdraught Cooling

It is an evaporative cooling method that has been utilized for millennia in regions of the Middle East, including Iran and Turkey. In this system, wind catchers direct outside air over water-filled pots, generating evaporation and a substantial temperature reduction before the air enters the inside. Passive downdraught evaporative cooling is very useful in hot, dry areas. It has been used to effectively cool the Torrent Research Centre in Ahmedabad.

Figure 12. Passive downdraught cooling has been successfully used at Torrent Research Centre, Ahmedabad. The wind catchers for the system are the predominant architectural elements in this building.

6. CONCLUSION

Passive design strategies in architecture are both environmentally responsible as well aseconomically beneficial. As we know, the impact of climate is adverse and requires immediateattention for sustainable living. That's why architects are considering passive design strategies tocombat rising temperatures. To deal with the extreme heat in hot, dry locations, a variety of strategies can be used, including blocking direct sunlight, using cooling equipment, increasing ventilation and circulation, and adding moisture to dry air.

Traditional architects have used a variety of scientific methodologies in the design of hot, dry locations to ensure thermal comfort. These strategies may be investigated and implemented in current designs to minimize the cost of energy while also maintaining a clean environment. If traditional methods are inadequate, they can be accomplished with the least amount of technology.

This research discusses climate-responsive design methods in a hot and arid area of Jodhpur on three levels.

- In the first level, macro strategies included factors like the distance between buildings, the enclosed urban environment, and narrow, irregular roadways. In hot and dry cities, review and development of these historic urban patterns should be taken into account.
- In this research, we address medium-scale methods, including building form, building envelope, self-efficiency in materials, and optical and thermophysical aspects of the building envelope. Rethinking our practices and coordinating the use of locally sourced materials with conventional building techniques are imperatives of sustainable design.
- Finally, micro-scale strategies demonstrate some more relevant architectural design methods that are the same as contemporary passive

systems. As an illustration, old wind-catchers have been developed into advanced passive cooling systems in recent years.

Consequently, consideration and development of the above strategies allow contemporary architects and designers to build contemporary architecture in a more sustainable, comfortable self-sufficientway.

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