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**Research Paper**

# Architecture before Air Conditioning in India

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***ABSTRACT:*** *The energy consumption in building sector is very high and is likely to increase further because of increasing living standards and thermal comfort of people. There has been extreme growth in the use of conventional cooling system in the buildings all around the world. Today, the architecture is completely isolated from the nature outside and is dependent on artificial means for cooling of the indoor spaces. Therefore, it is very important to recognize the passive techniques and its application in today's buildings for energy conservation. Traditional buildings were especially known for providing comfortable indoor climatic conditions to its occupants. Various passive cooling techniques, local building materials and construction techniques are incorporated in havelis and dwellings of Rajasthan, their application in the buildings and their respective impact have been reviewed and summarized. This paper, thus makes an effort to analyze and investigate several passive cooling techniques, eco-friendly building materials and construction techniques and their role in providing thermal comfort and its significance in energy conservation.*

***KEYWORDS:*** *Conventional Cooling, Passive Cooling techniques, Air conditioning, Courtyard, Ventilation.*

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## I. INTRODUCTION

Before air conditioner people built their dwellings which were more comfortable and reliant on passive techniques. Residence and lifestyle were evolved to make best possible use of these sources of cooling. Moreover, there was willingness and desire in the society to initiate such advantageous techniques in traditional building and organize spaces. But now the scenario is completely different from the past, people started neglecting natural source of ventilation and passive means which were used extensively in the past. People are relying on earth's resource at rapid pace to satisfy their needs and comfort. Society shifted away from traditional methods when mechanical cooling became available in the early 1900s. There has been then extreme increase in the use of mechanical refrigeration system for cooling the buildings. Increasing energy consumption has led to environmental pollution such as global warming and ozone layer depletion.

Our past actions had made inevitable changes in climatic conditions over last few years. A report by United Nations, cities consume two thirds of worlds energy use. Several studies have revealed that buildings and construction going-on uses 40% energy of the world's resources and releasing 40% $CO_2$ emissions, 30% solid wastes, and 20% water pollution in the world. With the upcoming energy calamity there is need of adopting alternative techniques from the past that could provide required thermal comfort of human well-being, but at an expense of conventional means which are environmentally and socially acceptable. As per estimate, about 35% of the buildings requirement can be satisfied by integrating passive techniques with modern buildings whereas, world's total energy consumption can be cut down by 2.35%.

Thus, passive cooling technique and natural ventilation offers this opportunity to connect human's comfort and building with the nature's rhythm. Basically, modern buildings can integrate the approaches employed in traditional buildings to attain thermal comfort in a passive way. The combination of various passive cooling techniques and sustainable construction material has always been perceptible on traditional architecture of Rajasthan. Traditional building of Rajasthan reflects such practices which were highly influenced during the period in which they were built. Elements such as courtyards, terraces, otalas and balconies or chhajjas were evolved from human efforts to full-fill the needs.

## II. PASSIVE COOLING TECHNIQUE

Passive design involves the use of natural processes for cooling to procure balanced thermal conditions. Energy flow in a building through passive system is achieved by natural means: radiation, conduction, or convection without using any mechanized device. In a hot-dry climate; indoor temperature in a building depends on reducing the rate of heat gained and elimination of excess heat from the building. Cities in hot-dry climate such as Jaipur, Udaipur, Jaisalmer, etc.; solar radiation and radiative cooling process are used in winters as well as in summers and saves up to 1-5% of energy. The theory of passive cooling practices and eco-friendly material of a region is very well developed. Principal behind such methods are to make efficient use of cost and resource by linking a natural harmony between building, people and climate.

Passive design strategies are predominantly reliant on various planning and designing characteristics (building orientation, shape, form, layout, size, aspect ratio, daylight and natural ventilation) of building. Some of the passive techniques suggested for environmental control in modern building described below reduces the heat gain into internal spaces.

(a) Shading Devices - shade and shadow of building surfaces
(b) Thermal Mass - damping of temperature
(c) Ventilation
(d) Radiation to night sky
(e) Evaporation Cooling

All these planning and deigning aspects were widely used in ancient buildings of Rajasthan for the purpose of thermal comfort and ventilation. This paper further describes about the several techniques and design elements which play significant role for passive strategies.

## III. PLANNING AND DESIGNING CHARACTERSTICS

### 3.1 Orientation

The orientation of buildings should be in such a way that it allows minimum solar radiation in summer and maximum in winter. Ideal orientation for any building can be determined by using sun path diagram. In state like Rajasthan, optimum orientation of building is North-South direction since west and east side receives the maximum heat gain.

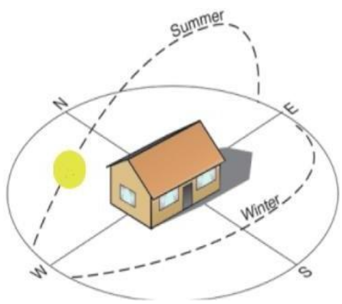


**Figure 1**: Orientation (Source: data: image/png; base64)

In Rajasthan most of the havelis and dwellings are oriented in such a way that it receives maximum solar in winters and minimum in summers. Bagore ki Haveli in Udaipur and Samode haveli in Jaipur are two such examples of North-South orientation. In both the buildings most of the openings are provided in north and south side to prevent excess heat entering into the building. The N-S orientation facing in the direction of prevailing cool wind direction endorses maximum nocturnal cross ventilation and prevent hot dusty winds throughout day. Whereas, in Roopsi house West-East orientation gained the maximum heat and thus a front yard is made in the entrance which acts as a thermal barrier. It is therefore desirable that long walls in hot-dry climate are exposed in North-South direction and short walls towards East-West side which due to the fact it is less exposed and gains less heat.

### 3.2 Shape and Built Form

Shape and built form of building affects the heat transfer in a building. Amount of energy exchange in and out of the building is directly linked with the surface area to volume of building. In hot-dry climate, buildings are compact in form with narrow rectangular or square face towards the street to reduce the heat gain and heat loss.

In Jaisalmer most of the dwelling like Roopsi house has an uneven compact form planning. The uneven building form with wide wall area helps in maintaining the indoor temperature. Similarly, in Samode Haveli it has more compact floor plan with less peripheral wall area to minimize the length of eastern and western wall. Apart from these, urban fabric of the region has densely clustered layout; ensuring the building is not directly exposed to sun.

### 3.3 Landscaping (Shading by Trees, Parks, and Vegetation)

Controlling of the microclimate around the structure was always significant in indigenous design. Shading by trees, vegetation and open parks is a very effective method of cooling the ambient hot air and protecting the building from solar radiation. It helps in reducing direct solar radiation from heating building surfaces. Tree shade helps in dropping air temperature about 2 to 2.5°C and provides evaporative cooling. Plantation of deciduous trees on south and south west direction are beneficial in courtyard or parks.

The courtyard of havelis in Rajasthan are named on the trees planted such as Tulsi Chowk. For example, in Bagore ki Haveli there is courtyard has a Tulsi plant and a deciduous tree which reduces the temperature of surrounding space. Similarly, Samode Haveli has series of courtyards and in every courtyard it comprises of deciduous tree planted on southern side. Also, the fountain court there is surrounded by trees and vegetation. Beside all this, Samode Haveli has various open spaces in the form of parks, gardens and courtyards which lowers the wind speed and surrounding temperature and increases humidity of air.

### 3.4 Presence of Water Bodies

In hot & dry regions, presence of water bodies are very substantial passive ways in cooling by evaporating a large amount of heat. Water acts as a modifier of climate; artificial ponds, small streams, waterfalls, fountains or mist sprays are used as air cooling sources. All these elements mentioned above mostly perform multiple functions. For example, water body and fountains acts like aesthetical feature in the building as well as a source of thermal cooling comfort.

Samode Haveli has small streams in courtyard and large swimming pools which increases the humidity and lowers the temperature by evaporative cooling. Whereas, in Bagore ki Haveli located beside Pichola Lake has a comparatively high latent heat of evaporation, it absorbs a great amount of heat from the surrounding air for evaporation. The cooled air is then introduced in the building. Large water bodies such as Pichola Lake reduces the difference between diurnal variations because they act as heat sinks. Thus, Bagore ki Haveli have less temperature variation between day and night, as well as between summer and winter. Also, the peak temperaturein summer is less near water than on inland sites.

### 3.5 Natural Ventilation

The movement of air from outdoor to indoor spaces of building is through 'push-pull' effect of positive air pressure on the upwind side and negative pressure (suction) on the sheltered side. Good ventilation requires location of openings in opposed pressure zone. Before air enters into the building and heats up, it is essential to treat air. We often choose to promote natural ventilation using double height spaces which is also known as stack effect.

Bagore ki Haveli included small windows (Figure 2) just above the floor level to let the cool breeze in and large arched openings or jharokha to let the hot air eliminate out. Maximum of the openings had jaali form to ensure privacy and let diffused light air move in. Similarly in Samode Haveli air vents (Figure 3) are used above door for induced ventilation by generating temperature difference. For controlled light and ventilation opening oriented in east-west direction had a set of three roll up screens and curtains; set of two grass mats used in summer by sprinkling water and one bamboo screen for controlled light. With this technique more the 30% energy can be saved for thermal comfort and recommended value for air movement in havelis of 0.2m/s to 0.4m/s was achieved.

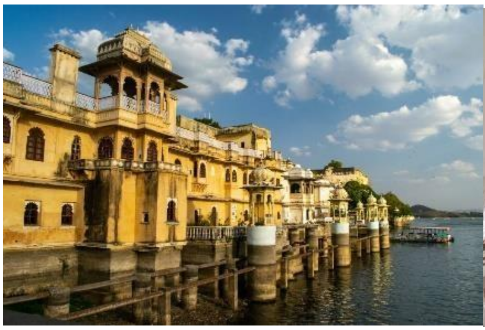


**Figure 2**: Openings in Bagore ki Haveli **Figure 3**: Openings in Samode Haveli (**Source**: https://goo.gl/maps/cdPrt3LQSZ1qMSR3A) (**Source**: https://www.samode.com/samodehaveli/)

### 3.6 Evaporative Cooling

The temperature of air in indoor spaces are cooled by evaporating water. Hot ambient air is passed over damped surface to cool the breeze before inducing inside the building. It is more effective when the contact between water and air increases, it increases the rate of evaporation. It's based on the principle the fact that the heat of air is used to evaporate water, thus cooling the air, which in turn refrigerates the space. Evaporative cooling could be direct or indirect. For example, grass mats used in havelis were sprinkled with water evaporates water and thus cools air stream. In hot-dry climate this technique is very effective and decrease of 9.6°c then the outside temperature was observed.

In Bagore ki Haveli, Pichola Lake (Figure 4) endeavors on the same phenomena. Haveli being situated adjacent to lake has more effect as waterbody is found to be more effective in hot-dry climate. Another technique used is a lotus fountain (Figure 5) which cools down indoor air breeze by the direct contact of water with lime deposition on the surface of fountain in green sandstone. In addition to this a well is located centrally in a courtyard (also known as Kuan Chowk) which indirectly reduces the ambient temperature. In comparison to Bagore ki Haveli, Samode Haveli also acquires evaporative cooling techniques but in different forms – fountain, artificial pond (Figure 6) and swimming pool. Fountain court and artificial pond drops the ambient temperature of surrounding space. In fountain court water comes in direct contact with the air absorbing the high temperature of vaporization from hot air and making it cool and moist. Cool air stream is then directly induced inside the spaces. Also the presence of swimming pool along with the building can offer a cooling effect.



**Figure 4**: Pichola Lake **Figure 5**: Lotus Fountain **Figure 6**: Artificial Pond(**Source**: https://goo.gl/maps/cdPrt3LQSZ1qMSR3) (**Source**: https://www.tripzuki.com/hotels/samode haveli)

### 3.7 Courtyard Effect

Courtyards are very significant for daylighting and ventilation. Earlier it was used as traditional designing element for dwellings and havelis but in present it is known among one of the best passive strategies used today. Solar radiation incident on the courtyard surface warms the air and light weighted warm air rises up, allowing cool breeze to settle down and enter the secondary spaces around through openings. During the night the process is reversed. Warm surface gets cooled by convection and radiation methods and a stage is reached when its surface temperature equals the dry bulb temperature of the ambient air.

In Rajasthan courtyard is the primary design element used. Entrance to havelis and dwellings is through large courtyard with all the secondary spaces organized adjacent to it. These were generally combined with water bodies, plants, trees and are usually open to sky to improve evaporative cooling, providing of shade and infuse maximum daylight in the buildings.

For instance, Bagore ki Haveli, Samode Haveli and Roopsi House has entrance through main courtyard (Figure 7) further followed by series of courtyards. All these courtyards are made more effective by integrating with vegetation and fountains. In Bagore ki Haveli, entrance courtyard has a well and fountain both and other two courtyards have deciduous tree planted (Figure 8) with wide arched opening in corridors. Similarly in Samode Haveli all the courtyard are in combination either with vegetation or small artificial pond. Whereas, in Roopsi House courtyard is combined with front yard (Figure 9) to reduce direct solar radiation. Courtyard in havelis are found to save up to 25% of power consumption. Also, when incorporated with vegetation, fountains and parks or gardens temperature is reduced by 2°-5°C. Thus, in Bagore ki Haveli and Samode haveli the inner temperature is found to be 12-15°c less than the outside and in Roopsi House there is very slight variation in temperature that is by 2-3°c.



**Figure 7**: Courtyard, Bagore Haveli **Figure 8**: Courtyard, Samode Haveli **Figure 9**: Courtyard, Roopsi House
(**Source**: https://goo.gl/maps/) (**Source**: https://www.samode.com /) (**Source**: https://issuu.com/prabhat.chhirolya)

## 3.8 Jharokha

Jharokhas are the enclosed projected openings or balconies overhanging from the wall usually in the upper stories. These are mainly found in palaces, havelis and temples of Rajasthan due to its aesthetic appearance, environmental aspects, facade treatment, and privacy to allow royal ladies to see in the street below without being perceived. Jharokhas in hot-dry region provide effective shading and cooling. Repetitive pattern of Jharokha covers the outer layer of the building facade with these kind of projecting overhangs, jaalis and small openings in it works for ventilation purpose.

Bagore ki Haveli had all the Jharokha (Figure 10) in the upper stories with height ranging from 1.8-3.5m. They are used to minimize area of building surface exposed to sun and form outer layer protecting from direct radiation and induce filtered light along with channeled cool air through the front façade of haveli which futher circulates inside the room and then eliminate through the courtyards taking out the hot air. Similar design elements can be seen in Samode Haveli with arched shaped opening (Figure 11) but differs in shape and type. They have large openings with perforated jaali on upper stories resulting in larger air mass movement to reduce temperature. Air movement in havelis of Rajasthan appears to have intensified indoor thermal comfort with wind speed of 2-3m/s whereas wind speed in Jaipur and Udaipur are 0.8-1.5m/s respectively.


**Figure 10**: Jharokha, Bagore ki Haveli **Figure 11**: Jharokha, Samode Haveli (**Source**: https://goo.gl/maps/cdPrt3LQSZ1qMSR3A) (**Source**: https://www.samode.com/samodehaveli/)

## 3.9 Lattice Screen or Jaali

Lattice screen are carved or perforated shading device in jharokhas, windows or balconies to obstruct solar gain and administer cool air during night by convective method. These are often used in the façade facing towards street and are effective for East-West oriented façade enclosed with engraved latticework positioned on the upper floors of a building. At some places lattice screen have been used to maintain privacy, let the air and light enter the building and also allow the visual connectivity from inside to the outside surroundings.

In Bagore ki Haveli wooden carved perforated lattice screen (Figure 12) can be seen in large openings to block direct sun rays and allow cooled air. Perforated screen permits diffused light and ventilation also maintains the privacy. Wooden screen absorbs the extra humidity from the air if it presents in it and if sometime humidity is reduced and air is dry then wood from this lattice humidify the air. In Samode Haveli small air vents (Figure 13) used above the door are covered with lattice screen which works with the stack effect phenomena by providing nocturnal convective cooling and induced ventilation during day. Lattice screens with small openings at low level are usually to protect from sandstorms whereas it has large opening in top floors. Lattice screen is very effective as the temperature inside room was less by 1.4°c. Screen decreases the heat gain percentage of the wall by 10-18% than the normal walls.

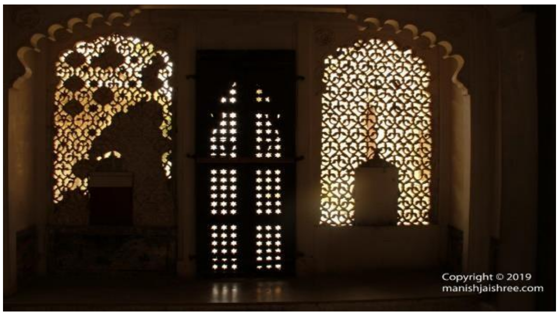


**Figure 12**: Jaali, Bagore ki Haveli **Figure 13**: Jaali-air vents, Samode Haveli(**Source**: https://manishjaishree.com/bagor-ki-haveli-udaipur/) (**Source**: https://www.samode.com/samodehaveli/)

## 3.10 Wind Tower and Air

A wind tower is a vertical ventilating design element which works on the principle of differential wind pressure and temperature by projecting above the terrace level of a building with openings on top towards the favorable prevailing winds. Its prime function is to induce air from above and transmit it inside the building. Wind towers come in various designs: uni-directional, bi-directional, and multi-directional but in hot-dry climate uni- directional and bi-directional are the most preferred where the diurnal variations are high. It works well for single units whereas ineffective for multi storeyed buildings.

Wind towers are effective in hot-dry climate, its existence can be perceived in traditional buildings of Rajasthan. In Samode Haveli wind tower lacking but air vents above the roof can be perceived but has negligible effect in temperature. Whereas, in Bagore ki Haveli; wind tower with domical air vents on top to prevent from dusty winds which makes tower impractical. Generally, hot air enters through these air vents and gets cooled throughout the day this mechanism make tower warmer. During night the tower releases its heat and balances the thermal comfort inside a building. Its diurnal function feasibility makes this system effective by reducing temperature up to 12-15°c in hot-dry climate.

**Figure 14**: Wind Tower, Bagore ki Haveli

## IV. BUILDING MATERIALS AND CONSTRUCTION TECHNIQUES

Building elements such as walls, roofs and floor can be used for thermal mass storage. Forming air flow through the storage media increases the competence of thermal mass capacity. Thermal capacity has adverse effects of solar radiation during day and nocturnal cooling at night which results in time delay in energy exchange as well as restraining of the parameters in the environment. As a result diurnal temperature variations exist between the materials and the environment around them. Traditional architecture is the result of centuries of optimization of climate reflection, material use and construction techniques. For example, most of the traditional buildings in Rajasthan are built in with different types of stone depending on local availability of material.

Rajasthan being the largest producer of sandstone in India is an excellent building material and is extensively used in state as they can be easily engraved and easy to use in smooth surfaces in various shapes and patterns. Traditional use of materials can be recognized in Bagore ki Haveli, Samode Haveli and Roopsi house in diverse ways.

Bagore ki Haveli, Udaipur; is one of the perfect example to understand and explore local materials of Rajasthan. Common building material used in haveli is locally available 0.35m thick yellowish sandstone, mud mortar and finished with mud plaster (Figure 15). Since sandstones are easy to carve, these walls are engraved in different shapes and patterns. Carved patterns and projected elements are used for aesthetic as well as these uneven surface have minor effect in reducing heat transfer from environment to building. Beside this, height of rooms are double to provide cool shaded environment. Even the parapet and railing in corridor have voids which helps in reducing the temperature and enhances wind flow between the spaces. Traditional roof with closely placed timber beams (Figure 16) are used and reed matting is used to shelter along with 0.45m thick earth layer such as terracotta tile on top.

**Figure 15**: Yellowish Sandstone, Bagore ki Haveli (**Source**: https://goo.gl/maps/cdPrt3LQSZ1qMSR3) **Figure 16**: Timber Beams, Bagore ki Haveli(**Source**: https://goo.gl/maps/cdPrt3LQSZ1qMSR3)

Samode Haveli, Jaipur; also has materials similar to those used in Bagore ki Haveli in the exterior but differs in interior, they have locally available marble and traditionally used mosaic floorings, double height ceilings, woven cotton mats or "dhurries", and traditional furniture. Most of the colors are in light shade with natural finishes. Walls of 0.4-0.6m thick and concrete floor were used for thermal mass storage and to promote thermal comfort height of the ceilings are up to 4.6m. Like in Bagore ki Haveli had voids in parapet to reduce temperature; here roofing is self-ventilated and roofing material with high thermal value is used.

In Roopsi House, Jaisalmer; most of the traditional house were made up of this building is usually made of three building materials lakhauri bricks, lime crushed brick aggregates, surkhi mortar, wood, cast iron, and cast iron bars. Lakhauri bricks are flat, rectangular burnt clay bricks with typical sizes of 0.1m × 0.15 m × 0.2 m. Rubble masonry construction is used and stone and wooden rafters are used to support roof and lintel whereas, for vertical support stone pillars are used. All the houses have a common sharing compound wall which are taller than other walls.

Therefore, providing a roof cover from locally available materials indoor temperature can be reduced since roof has the maximum uncovered area for solar gains. The careful selection of the material helps in reducing the thermal ingress inside the building. The same envelope formation acts as a thermal mass storage as it becomes difficult for the interior space heated during the day to eliminate its stored heat at night when the external air is cooled down. As observed earlier that the night temperature drops significantly, this thermal insulation provides ambient condition indoor when the outside temperature falls.

**Figure 17**: Lakhauri Bricks, Roopsi House
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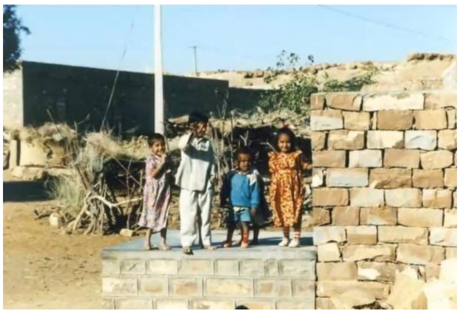

**Figure 18**: Rubble Masonry, Roopsi House(**Source**:
(**Source**: https://issuu.com/prabhat.chhirolya)

## V. RESULT AND DISCUSSION

The literature review and case study of various planning and designing principles of the three case studies reveals that evaporative cooling reduces the temperature by 9.6°c inside the building but when incorporated with water bodies such as lake, fountains, artificial pond etc. it is the most effective as it can reduce the temperature by 20 °C. Another important passive technique is natural ventilation, this should be the prime focus in any building as it reduces the dependence on artificial methods. These may be through window opening, jharokhas, jaalis etc.; Jharokhas window on the south also cuts out the east-west sun and in normal windows set of roll up screens, curtains and jaalis can be used to control light. Natural ventilation through these techniques improves the air movement up to 0.2m/s to 0.4m/s within building and save energy up to 30%. Jaalis increases the humidity when air enters into the building and allows diffuse light to enter the building.

Wind tower and air vents are very effective in hot-dry climate because of its diurnal functionality. Mostly, they are uni-directional or bi-directional in hot-dry climate. This passive technique as seen in above case studies can reduce the temperature up to 12-15 °C. Today in modern buildings we come across various open spaces in the form of parks, porches, gardens, and courtyards. These open spaces can be utilized for various purpose, but traditionally were provided for aesthetic and more as of passive technique as it reduces the temperature by 2 °c of the surrounding space. Like deciduous trees allows summer shading and natural daylight in winter months by shedding their leaves and thus should be planted in south and south-west of the building façade.

Courtyard planning is the most common and most effective passive technique practiced in Rajasthan. It is the oldest technique which can be perceived in traditional buildings as well as modern buildings. Integrating courtyard in haveli reduced power consumption by 25% which could be very effective and also if combined with other evaporative techniques such as fountain court, ponds, or vegetation it reduces up to 2-5 °c. Therefore, all these passive techniques results in reduction of mean temperature of building. It can reduce from 12 °c up to 20°c depending on type passive technique and its various combination.

**Table 1:** Passive Cooling Techniques – Description

| | |
|---|---|
| **Evaporative cooling** | • In hot-dry climate it decrease of 9.6°c then the outside temperature.<br>• Using fountain courtyards, indoor temperature was found to fall 20 °C.<br>• Indirect evaporative cooling may lead to a reduction of 1 ˚C in mean temperature. |
| **Natural ventilation** | • More the 30% energy can be saved for thermal comfort and recommended value forair movement of 0.2m/s to 0.4m/s can be achieved. |
| **Wind tower** | • This system is very effective as it reduces temperature up to 12-15°c |
| **Solar shading techniques** | • By providing a roof cover from locally available materials, indoor temperature maybe reduced since roof has the maximum exposed area for solar gains. |
| **Landscaping** | • Existence of a garden and trees can reduces surrounding temperature by nearly 2 °C |
| **Courtyard planning** | • Courtyard in havelis are found to save up to 25% of power consumption.<br>• When incorporated with vegetation, fountains and parks or gardens temperature isreduced by 2°-5°C. |
| **Jharokha & LatticeScreen** | • Energy consumption for south exposing facades can be reduced by about 9 % withproper use of shading techniques such as jharokha and lattice screens which can reduce up to 4° c. |

## VI. CONCLUSION

The purpose of this study was to explore the various designed indigenous building which uses one or more than one of the cooling approaches to achieve thermal comfort in a building. Traditional buildings were more sustainable, with use of climate responsive building material, eco-friendly construction techniques, natural ventilation and advantages of solar radiation was taken in those buildings. Therefore, several passive cooling practices were reviewed with reference to their design inferences and architectural interventions.

The study of these havelis and dwellings aids to the advancement of these techniques and promotes sustainability. It recommends to focus towards climate responsive building and using lower the carbon footprint of building which will have direct impact on regulating global warming and ozone layer depletion. Incorporating these passive techniques would certainly reduce our dependency on mechanical and conventional means for thermal comfort and minimize the environmental problems caused by extreme consumption of energy and other natural resources. Generally, concern for energy consumption is only an effort in the most of architectural design practices but passive cooling techniques and energy-efficient building design should be the primary goal because in majority of the cases it is a relatively low-cost exercise that will advance to savings in the wealth and operating costs of the refrigerating plants.

In developing countries, the continuous increase of energy consumption of conventional cooling suggests a more thoughtful examination of the urban environment and the impact on buildings as well as to an extended application of passive cooling techniques. Therefore, in contemporary architecture, it is now essential for builders, architects and engineers to integrate traditional passive cooling techniques in modern way in contemporary buildings as an integral part of design and architectural expression and they should be encompassed conceptually from the outset. Also, the recent concept of energy efficient Green buildings attracted all the architects, engineers and builders to shift over from the present practice of mechanical cooling to ancient methods of passive cooling methods in an efficient modern way and hence evolve a built form, which will be more climate responsive, sustainable and environmental friendly for tomorrow.

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