Energy efficiency & sustainable design strategies in Nahargarh fort, Jaipur

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Abstract:

Now that the current grey ages are forecasting the miserable future, as an outcome of prolonged & dubious exploitation of environment, man is crawling back to history to borrow the past age practices of sustaining in optimum resources. Mechanical manipulation of ill-designed built envelopes is bleeding the resources. Peeping into the past, crops up many sustainable architecture solutions, which are standing dynamic through the centuries. One such example stands on the ridges of Aravalis in Jaipur, Rajasthan- Nahargarh Fort, roaring its smart and sensitive design volumes. Madhavendra Palace, a royal summer palace to the primacy of Jaipur, overlooks the pink city from Nahargarh Fort. This palace exhibits, its proficient design strategies of flushing the zoetic volumes, with daylight and sufficient air changes. Tracing the general concepts of its space designing and keen habits of day lighting and ventilating the spaces, shows that the complex was not only drafted in track with the nature, but also the nature flowing in the royal volumes was at times synthetically pivoted. These editorial intents to showcase few of the ancestral sustainable building design solutions from Nahargarh palace, which could be implemented in today's world, thus fabricating more efficient awake spaces and retain the natural resources.

Keywords: Energy Efficiency, Nahargarh Fort, Sustainable Design, Daylight, Ventilation.

1. Introduction:

Amidst the royal architectural fabric of Rajasthan, stands one more efficient past age Indo-European sustainable superstructure, which roars over the city of Jaipur, designated as Nahargarh Fort. At approximate height of 700 feet, built in 1734, by Maharaja Sawai Jai Singh II, Nahargarh is one of the three forts (Amber fort, Jaigarh fort, Nahargarh fort) along with the connecting fortification wall running over the crest of Aravalis hill ranges, protecting the pink city, since past ages.

Fig 1.1 Madhavendra Bhavan, Nahargarh Fort

The fort was formerly known as Sudarshangarh Fort. Later, it was given a new name, Nahargarh which means 'abode of tigers'. It is am maze of terraces, gardens and courtyards, and it is blessed with breathtaking view of scenic surroundings. It was never intended to be a permanently occupied residence, but was a retreat place for the regal families of that era. Nahargarh's water reservoir is a deep one cut out of the rock, which is supplemented by additional water storage tanks and canals.

Fig 1.2 Nahargarh Fort site plan

Another attraction in the fort is the 'Madhavendra Bhawan'- a royal residential complex. Other structures inside the palace include Diwan-I-Aam, an open air enclosure where the king met the common men and listened to their problems and complaints. This article focuses on Madhavendra Bhawan, in addition to brief study of the entire Nahargarh fort.

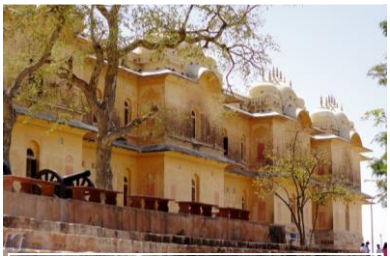


Fig 1.3 Madhavendra Bhawan

2. Site & orientation- Madhavendra Bhawan:

Sustainability started from the point the past age planners located the Royal complex on its site, because locating a site for a building is as important as its design brief. In climatic extremities of Rajasthan, the outdoor climatic conditions are constantly changing. Its effect on any built form depends upon the location and orientation of that complex.

Fig 2.1: The yellow arrows demarcate the prominent WNW winds on site, which rush upon the Aravalis and over the step wells before flooding into the built complexes. The blue arrows demarcate the secondary winds.

For proper and economic functioning of any building, the factors like daylighting, rate of heat absorption, in-ward and out-ward heat transfer, heat islands, cross ventilation, play major role. The royal complex is aptly designed in pace with its surrounding nature, as built forms has major share in manipulating its interior and exterior environment. Being located on the ridges of mountain range, the fort gets an added advantage of abundant natural air flow.

The Palace is blessed with views and vistas, ventilation and daylight from all sides. The residential complex is designed in tune with nature, to increase its efficiency and comfort level. Also, the design is such that even nature is manipulated at times in Bhawan and its surrounding envelope. Also, its location being at height, the fort is secured from direct and sudden attacks of enemies.

Fig 2.2: Openings in Madhavendra Palace

Madhavendra Bhavan being residential volume, demands continuous high comfort levels in terms of temperature and ventilation, unlike limited comfort demanding hours in formal spaces. The residential complex is orientation at an angle over the north-east and south-west axis, which naturally prevents the striking of true south and west sun on the residential facades. The respective placement of various structures on fort site and their orientation, play major role in daylighting, physiography and ventilation of built and unbuilt dimensions. Same and this very basic concept of rational orientation of building on site, in modern architecture, can develop conscious and sound spaces and save the non-renewable energy, which is nowadays heavily drained in thermally and visually manipulating the poorly designed volumes.

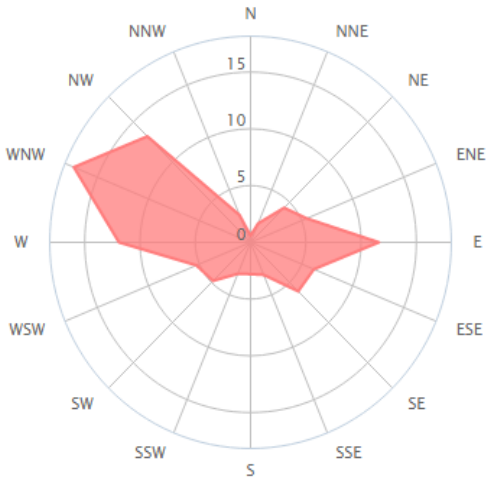


Fig 2.4:Wind rose diagram

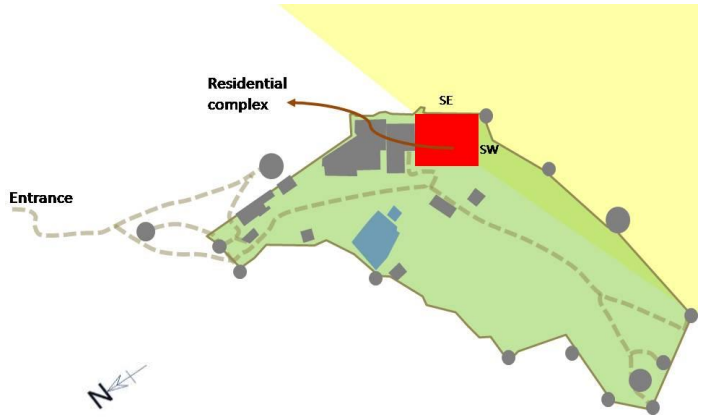


Fig 2.3: Schematic plan shows the south east and south west faces of the royal complex exposed to angled sun, which is consciously or unconsciously the direct outcome of its

3. Planning of Madhavendra Bhawan:

The main residential palace inside Nahargarh Fort is Madhavendra Bhawan built by Maharaja Sawai Madho Singh II (1880-1922 A.D.).

The entrance of the fort leads into spacious courtyard, with large 'dwars' on both sides embellished with decorative motifs of elephants, warriors on horseback, flowers and birds. There are also weather-worn cannon carriages. The complete Royal residential complex- Madhavendra Bhavan, highlights the design elements like symmetry, ratio and hierarchy, rhythm, which makes its functionally and visually pleasant. This palace was designed by Ar. Vidyadhar Bhattacharya. There are two floors, first on the ground floor meant for summer and the first floor for winter residence. The floor has nine suites, one for each of the nine queens of the maharajah. There are bathrooms, toilets, and kitchens, all well-lit and ventilated. An interesting feature is the long but narrow, corridors, some with windows overlooking the main courtyard. It is believed that these corridors were used by the maharajah to access each queen independently without the others having knowledge of his whereabouts, but hopeful of a visit nevertheless. Its nine identical apartments are Suraj Prakash, Chand Prakash, Khushal Prakash, Anand Prakash, Jawahar Prakash, Laxmi Prakash, Ratna Prakash, Lalit Prakash and Basant Prakash.

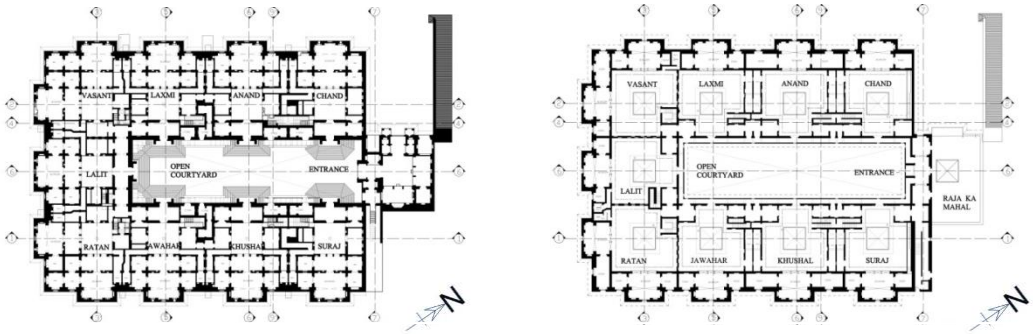


Fig 3.1 & 3.2: Madhavendra Palace- Ground floor plan & First floor plan

3.1 Plinth

There is a gradual and prominent lift of the plinth as we move towards the more private sections of the palace, which demarcates the area function superiority, natural drainage created in plan, visual hindrances for outsiders and extended vision for the end user royal families. As outsiders cannot peep into the interiors of palace, due to its plinth height, the designers placed the windows at lower height, which also helped in efficient ventilation of inner residential chambers and courts. The rain water is drained off into the step wells, due to the site topography as well as the raised built form.

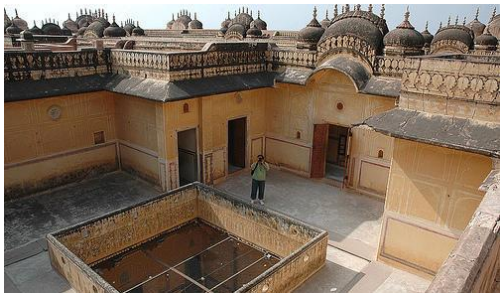
Fig 3.1.1: Madhavendra Palace

The space under raised plinth acts as hidden service areas for the palace.

3.2 Design elements:

Madhavendra Palace holds multiple design elements throughout its extent. Datum, symmetry, ratio, hierarchy, rhythm, flow, harmony and so on.

The intensity of few of these elements increase and decrease with the succession of the spaces and its activities, like the plinth level increases as we move towards the more private areas, the intricacy of decorative art increases on the path to the royal private chambers.



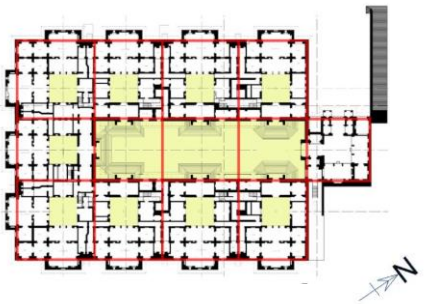


Fig 3.2.1: Madhavendra Palace- Central chief courtyard.
(Madhavendra Bhavan central courtyard depicting symmetry and hierarchy along both the axis.)
Fig 3.2.2: Madhavendra Palace- Individual residential suite courtyard
Madhavendra Bhavan- Courtyard inside courtyard concept of individual residential suites, which helps in creating thermal and daylighting comforts.

Fig 3.2.3: Madhavendra Palace plan showing symmetrical and rhythmic layout

Entire royal palace highlights symmetry chiefly in its plan, holding nine identical residential apartment suites. This element of symmetry runs from plan to elevations and sections. Hierarchy is seen in plan, expressing the flow pattern of privacy, air and light.

Courtyard inside courtyard is a beautiful example of hierarchy, ratio and rhythm, which is highly efficient climate responsive building element. Ratio running across voids and solids on walls i.e. window: wall ratio play a major part in creating thermal and visual comfort.

The hierarchy in designs and scales of doors, arches, windows, domes and chatris, create exquisite pictures in the palace. The amalgamation of such elements willfully helps in creating elegant play of daylight and wind flow. Besides aesthetics, these features help in filtering and manipulating the micro-climate on site.

Micro-climate of the site is a direct outcome of the combination and synchronization of all these design elements and passive techniques.

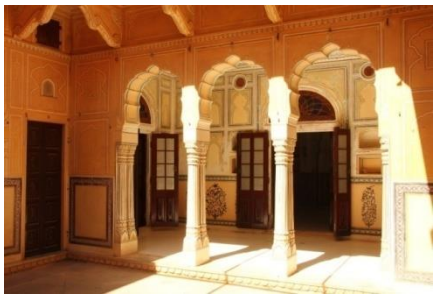


Fig 3.2.4: Madhavendra Palace exterior view.
(The above photograph shows window: wall ratio, and also the apparent windows painted on facades for retention of rhythm in view)
Fig 3.2.5: Madhavendra Palace interior view.
(The above photograph shows the play of daylight, as a result of beautiful overhangs,

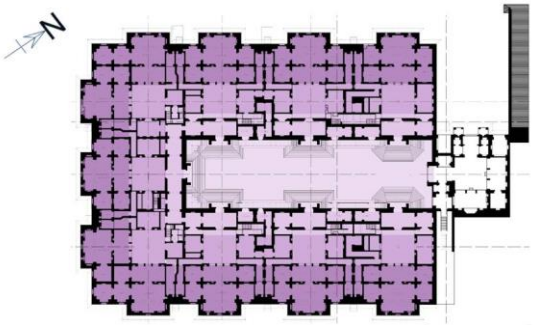


Fig 3.2.6: Madhavendra Bhavan- Ground floor plan
(Ground floor plan of Madhavendra Bhavan depicting hierarchy of privacy, and art intricacy)

The courtyards act as light wells and helps in out-ward movement of air. The architectural setting of palace shows hierarchy in transition of spaces i.e. courtyards, series of verandas and fenestrations. The central open court enveloped by verandas (semi-covered front passage) helps in filtering of human circulation, air flow and daylight, thus initiating the physical and thermal comfort.

Also, the ratio of courtyard plan to its height is higher, which directly helps in shading the inner open court area, and also initiates upwards vortice effect of exiting air, thus flushing the volumes with active air changes. These air changes take place because of temperature differences inside and outside the enclosed volumes.

3.3 Site drainage:

The climatic zone being hot and dry, site drainage and rain water harvesting are given prime importance.

The fort complex has two Baolis, catching the surface run-off water of the site, located on natural slope lower levels.

These step wells (baolis) have organic curvy steps, which donot make these step wells look out of context on site. The curvy steps makes step well appear as a part of the site contour itself.

Proper provision was made in the palace, to harvest the maximum possible rain water, from its built and open surfaces. Each single residential apartment in Madhavendra palace is provided with rain water chamber in the center of its courtyard. Roof terraces where given gentle slope and where provided with ducts to catch rain water at regular intervals over each dwelling unit.

All the rain water, from roof terraces and courtyards, was harvested into the step wells, through hidden underground ducts. The ducts joining water from terrace and courtyard of each unit where further opened into single bigger duct, which lead to first smaller well and further to the larger step well.

Also the entire fort complex holds natural and also planned landscaping, which survives best in minimum available water. Softscaping also helps infiltration of air flow, and also sometimes slower the sand-storm winds. The trees help in lowering the outer temperature around the residential complex, thus comforting the open envelope around. At times the hot air rising from the pink city, located at foot hills, is cooled due to the green fabric of the fort site. Facades of Madhavendra Bhavan have windows on all faces, providing views of elegant vistas on all sides.

Fig 3.3.1: Nahargarh Fort Site drainage view (Aerial view of Nahargarh fort, depicting the slope of site and the location of Step wells on lower levels)

Fig 3.3.2: Step well at Nahargarh fort

Fig 3.3.3: Rain water harvesting on site

4. Design elements and their role in daylighting and ventilation:

4.1 Courtyards:

Madhavendra Bhavan is aligned along NE-SW oriented central major rectangular courtyard. This major courtyard transits into nine smaller courtyards of individual residential unit. In hot and dry climate of Rajasthan, rather than designing a single solid volume that would entrap heat inside, planning around open courts (angans) is recommended. These courtyards helps in lowering the temperature, by creating buffer, and also helps in continuous air movement, thus creating thermal comfort.

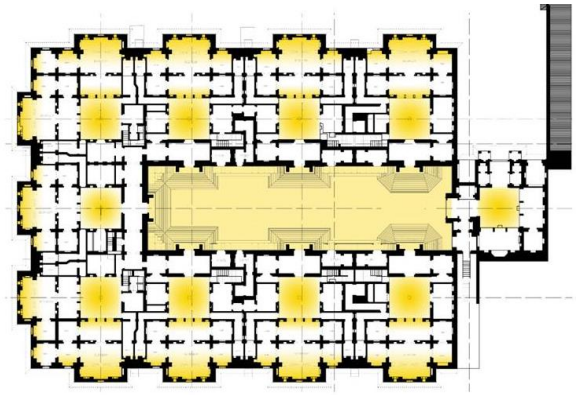


Fig 4.1.1: Madhavendra Bhavan plan depicting light wells and daylighting.

Fig 4.1.2: Madhavendra Bhavan residential courtyard

The forced air entering through smaller and smarter openings, rushes through the series of spaces, and flows out through the courtyards, thus ventilating the closed, semi-open and open spaces in the palace. The courtyards act as light wells for illumination of spaces on inner face of palace.

Thus courtyard is one such climate responsive architectural design element, which takes the built-form towards sustainability.

4.2 Openings:

The royal residential complex shows smart and optimum fenestration locations of just appropriate sizes and shapes. Thick stone walls of palace holds smaller windows, to limit the inwards transfer of heat, while daylighting and ventilating the interiors. Jallis on openings let air and light flow into the interiors, and control the inside view, sand cyclones, and glare into the enclosed volumes.

The windows are placed at lower height, as it helps in ventilating the interiors with fresh cool breezes, raising the warmer air up, which leave the interiors through very small openings (Jharokas) at upper levels. The higher plinth of the palace donot allow the view outside to inside. Smaller window to wall ratio, thicker walls, jallis, courtyards, verandas etc. helps in keeping the age old interiors cooler in summerss and warmer in winters, through the centuries. Toilets have angled openings, along the wall thickness, to create visual hindrance and ventilate the space simultaneously. The decorative rajputana style overhangs (chajjas) over the windows, provide protection from harsh sun and rain. Windows also play a very vital role in creating a play of daylight in the enclosed volumes, besides illuminating the habitable spaces. In few areas, portholes in walls break monotony of darkness, creating spotlight effect. Smaller openings also forces air inside the built forms creating air tunnels, thus ventilating the interiors. The larger cross openings make way for air to leave the volumes, rushing through verandas and out form the courtyard. Domes and Chatris added on the terraces, not only demarcate the reign superiority, but practically also shades the open courts inside, to some extent.

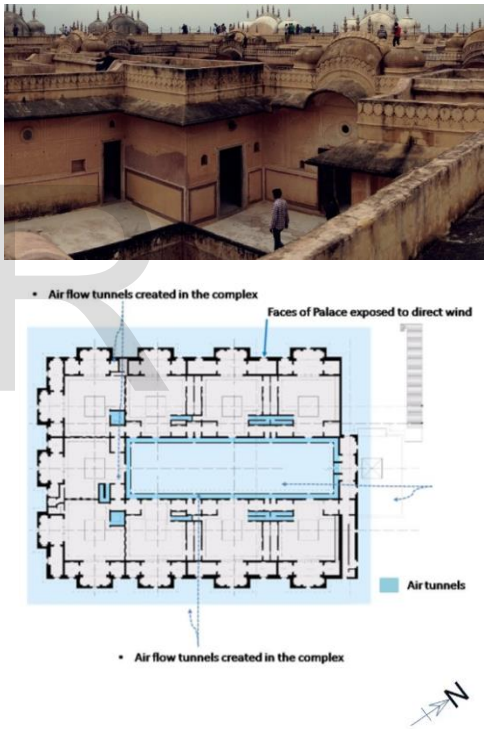


Fig 4.2.1: Madhavendra Bhavan- Ground floor plan (Plan of Madhavendra Bhavan depicting the air movement, on facades and air tunnels effect created in narrow passages and staircases)

4.3 Air Tunnels:

The palace has many hidden air tunnels, sometimes ventilating the interiors most efficiently and sustainably. These air tunnels run through the section of walls, few of them diverted outside sideways and few upwards.

Few air tunnels open out at the top of domes. Kitchen air vents are smartly manipulated in the interiors and diverted out. Presence of hidden air tunnels helped in proper air flow, thus increasing comfort conditions in the spaces.

4.4 Interiors:

The royal palace being residential by activity, special attention was given to interior decoration. It shows intricate floral paintings (Arish work) in the interiors, on walls, nisches, ceilings, floorings etc. The colour theme of the interiors was kept a bit lighter, as the inner spaces could be illuminated by reflecting the daylight, thus making the spaces look more spacious.

Use of mirrors on walls, columns and ceilings of the interiors reflect light, thus awakening the interior dimensions the doors and windows show traditional wood art, with Belgium glass.

The play of light, through the various sizes and shapes of windows, arches, cut-outs, doors, jallis and colored glasses, enhance the royal interior volumes and moods, at different times of the day.The interiors remained cooler, as a result of smart design strategies. In past ages, they also used draperies, which also played role as buffer for temperature, besides for aesthetics and privacy reasons. Also the intricate carvings in sandstone on outer facades help in keeping the building cooler, than the plain facades.

Fig 4.3.1: Kitchen vent

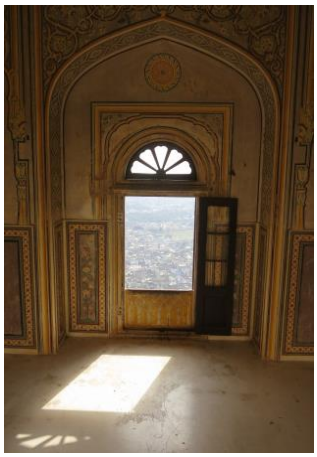


Fig 4.4.2: Daylighting in Palace

Fig 4.4.3: Intricate carvings on outer surfaces of the palace

4.5 Staircases and passages:

Narrow passages and staircases don't serve only the purpose of transition, but also act as air tunnels enforcing the air changes in the interiors. The narrow low height continuous passages encircling the larger central courtyard, on first floor, were hidden transiting spaces for the royal kings and queens.

The setting of staircases and passage ways and cut off areas are such as to segregate and overlap the activities and movements of kings and queens, supporting staff, and visitors, at times. The passages have small multiple low height windows for view and ventilation. These small windows and Jharokas lit the passage way in minimal comfortable fashion. Winds when passed through narrow spaces form forced wind streams, thus flooding the interior rooms.

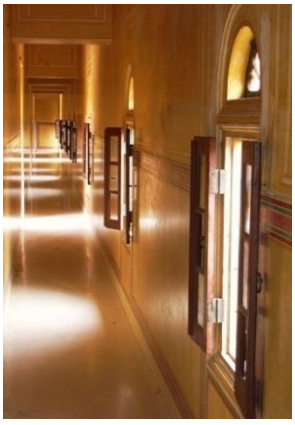


Fig 4.5.1 & 4.5.2: Passage for kings and passage for queens respectively

5. Construction materials:

Construction of the fort offered a safe sanctuary from marauding bandits and invading armies and also offered employment to the people. The heavy walls and narrow staircases where designed for security purpose of the residence. Constructed from red sandstone to limestone, the materials used help to give this majestic abode an impression of being incredibly defensive and a solid stronghold.

The walls are clad with colorful murals and frescoes. Red sand stone is widely used in the exteriors and the interior is done with Arish work finishing, consisting of lime which helps in absorbing the moisture content present in the air due to its exothermic properties. Arish work finishing is done on the interior walls, ceiling and floors as it provides a smooth finishing surface which is then beautifully painted in light, natural color, thus it enhance the interiors and add moods to it. Not only the strong structural material like stone stood through the test of time but the intricate and delicate paintings too, are embellishing the regal envelope till date. The intricate carvings on the external facades, besides the aesthetic reason played a major role in reduced the heat gain by creating multiple miniature shadings. Red sand stone in the exterior reduces the solar gain thus creating the thermal comfort inwards due to its thermal resistant properties.

Belgium glass is beautifully used as transom which creates an elegant light effect as well as protect from scorching sun. The tinted unglazed glass also helps in reducing the U-value, thus enhancing the thermal comfort.

Fig 5.1 & Fig 5.1: Frescos in the interiors & Painted walls and ceiling- Arish work

Fig 5.3: Sand stone is widely used in the exteriors

Fig 5.4: Wooden doors & windows with Belgium glass

6. Application of ancient sustainable design strategies in modern designs:

In today's world, where humans are draining the natural resources rapidly and environment is degrading blunderingly, there is rising an urgent need to take our lifestyle and settlement fabric towards green future. Inspiration from elderly traditional and vernacular architecture lend us many passive design strategies, which work best in optimum resources and with greater comfort, unlike some modern ill-designed buildings requiring pumping of cooled air to create temporary comfort conditions.

7. Conclusions

- Inspired from past age structures, live planning helps the building to work in minimal artificial resources (e.g.: electricity), thus cutting down the pollution around the built envelope.
- The traditional buildings set an example of sustainable architecture, by lowered energy consumption, through application of the passive design strategies, and developing its own micro-climate.
- Any and every type of building affects its surrounding environment and vice versa. Micro-climate of any site is the outcome of the site planning, landscaping, design of built forms, construction materials and techniques etc.
- Conscious design strategies like designing in tune with site topography, orientation, courtyards, optimum windows with smart locations and shading devices, thermal insulation, water harvesting etc. can be used in modern buildings, which can lower the energy consumption and increase the functional lifespan of habitable spaces.

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Source: http://www.jaipurweddings.com/images/nahargarh/3.jpg
Fig 1.2: Madhavendra Bhawan
Source: http://karuneshjohri.com/wp-content/uploads/2012/03/madhavendra-bhawan-nahargarh-fort-jaipur.jpg
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http://www.windfinder.com/windstatistics/jaipur_airport
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