Shekhawati: urbanism in the semi-desert of India A climatic study

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ABSTRACT: The architecture of any place and time is an outcome of many factors- religious doctrines, ritual focus, social set-up, resource availability, climatic impact and economic constraint. India offers a great variety in each of the above-mentioned factor. Yet if we closely analyse, more or less the social set-up is similar in all regions in a particular time period. The variation occurred due to the climate, resource availability and economics. If we analyse the traditional residences of various regions, we find similarities in their spatial hierarchy and arrangement, but each presents before us a unique example responding most innovatively to the local climate. In this paper we have tried to bring forth the climate responsiveness and appropriateness of the Havelis of Shekhawati, Rajasthan, India.

Keywords: Climate responsiveness, Passive architecture

1. INTRODUCTION

Nestled in the dusty and semi-desert part of Rajasthan (a western state of India, which is called to be the abode of the sons of kings, the *Rajas*, thus Rajasthan) Fig. 1 is a group of towns that constitute the colourful region of Shekhawati. Here the streets are lined with 'Havelis' painted in nature of an open-air art gallery. Shekhawati meaning the land of Shekha's clan derive its name from Rao Shekha (1422 AD – 1488 AD, a king). [1]

Figure 1: Location of case study in India

The case study for this paper covers Havelis or the elaborate courtyard houses in Shekhawati region. Most of these were created 75-200 years back but they present before us the most appropriate of the solutions to the climatic constraints even today.

The analyses of the passive design features used to control the indoor environment inside the Havelis present a surprising fact that most of the passive design measures prescribed by the modern designers, energy conservationists, environmentalists and climatologists are already incorporated in these age old structures. It is a very distressing fact that while evolving new environmental friendly techniques and construction practices, we are ignoring the already existing legacy, which presents before us the most suitable of measures, perfected over the centuries of trial and error.

Hence this paper brings out the relevance of these passive design features and construction methodologies in the wake of increasing energy demands and least energy consumed by these strategies.

2. A PROBE INTO THE PAST

2.1 Society

It was a male dominated society where women were restricted inside the house. The men performed the outside activities and women took care of all the household matters. It was a clear-cut demarcation between the activities, thus the workspaces and there was hardly any visible interaction between the two genders. This demanded a segregation of space as we find in terms of minimum of two courtyards.

2.2 Religious and ritual set-up

The owners of most of these Havelis were Hindus belonging to different castes- traders, Brahmins, warriors etc. the rituals for all of them were more or less the same. Most of the rituals were performed around fire- the rituals of birth, marriage, death, festivals etc. Other than climatic suitability, courtyard appropriately served the purpose. The courtyards came alive during extended celebrations of marriage/festival. [2]

2.3 Economy

There was economic stratification prevalent. But in Shekhawati, majority of the community comprised of rich traders who were endowed with all wealth and comforts but were helpless in the hands of nature. The availability of resources and lack of fenestration resulting in monotonous flat facades, called for the painting of flat walls to make interesting facades.

Thus came into picture, the rich and brightly coloured, worldwide acclaimed murals of Shekhawati Fig 2. The economy was visible from the size of Haveli, number of courtyards, use of rich colours like gold and silver in paintings and carving of doors and window shutters.

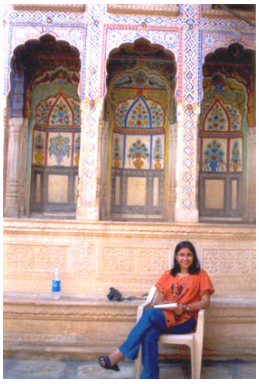

Figure 2: An elaborately painted and carved courtyard in Murarka Haveli, Navalgarh, Rajasthan

2.4 **Resources available**

Stone was locally available in abundance. Sand was there all over. Mud and clay were scarce and were preciously used for agriculture. Lime quarries were not very near but an easy access to them was secured. The use of stone was economical and climatically appropriate, thus we find all buildings unanimously in stone constructed with lime mortar Fig 3.

Figure 3: Typical settlement in Shekhawati region

2.5 **Climate** [3]

2.5.1 **Temperature**- Maximum temperature in summers rises up to 45°C while night temperatures fall to 20°C. winter days are temperate around 8°C while night temperatures reduce to just above freezing.

2.5.2 **Rainfall-** Annual rainfall is 600mm falling largely in the months of July-October.

2.5.3 **Humidity-** Apart from monsoon season, RH is terribly low- categorising the climate as Hot Dry.

2.5.4 **Wind-** Throughout the year dominant wind comes from NW quadrant and late in the monsoon SW winds are experienced. The winds temperature is hot in summers while very cold in winters. The only times when winds are preferred inside the building are summer nights and monsoon days.

2.5.5 **Sandstorms-** Dust storms and sandstorms are very common both during day and night.

2.5.6 **Solar radiation-** the solar radiation in intense around 700-800 Kcal/Sqm with sky being clear almost throughout the year.

3. COMPARISON OF PAST AND PRESENT

3.1 **Society**

The interaction between men and women has greatly enhanced due to the outdoor working of women and women empowerment activities taken up by socialists. This calls for unification of spaces. Still the formal and informal spaces need to be provided in Indian society, as the social interaction is still a common feature. Thus the spaces that were earlier divided as masculine and feminine are now to be called formal and informal, both of which are accessible to both the genders. Also since families are nuclear, the spaces required are smaller. [4]

3.2 **Religious and ritual set-up**

The society is less religious but the festivals still play an important role. The rituals are not performed that frequently but the occurrence is still there. Also with coming up of the spaces such as banquet halls, marriage halls and other public gathering spaces, the need for a common gathering place inside house has reduced.

3.3 **Economy**

The economy has equalised and gone up. It is easier for people to procure land and make houses with the housing and land loans easily available. But the land costs are shooting very high in urban areas. This makes it very difficult to procure large land plots (large in present scenario was the minimum in earlier times as we see from the street plans of Jaisalmer and Jodhpur and other urban settlements of Rajasthan)[5]

3.4 **Resources available**

The stone is still the cheapest building material available but it implies thick walls and wastage of usable space. The labour for the work of stone is also not available at cheaper costs. This has reduced the use of stone. Since stone is less used, the parallel use of lime mortar has also gone down. Another reason for not using lime mortar is the time consumption, low strength and less variety offered in use of lime mortar, and its comparison with readily available cement mortar. The cement concrete allows for more flexibility of form and larger spans. Despite its poor performance in hot dry climatic conditions, concrete is the most preferred building material.

3.5 **Climate**

Not much change in the climate is noticed. Only because of the global warming and reckless use of resources like water and vegetation, the temperatures have gone up by approximately 5°C in last 200 years. The ground water table has gone down and monsoon rainfall is less. This requires greater attention to passive cooling design features and rainwater harvesting techniques.

4. PHYSIOLOGICAL OBJECTIVES [6]

a. Reduction of intense radiation falling on external surfaces from direct sun, ground and surrounding constructions.
b. Lowering down of internal temperatures during day and sufficient time lag to allow comfortable conditions inside during day.
c. Sufficient air ventilation during night and spatial arrangement to allow for controlled ventilation during daytime.

5. PASSIVE COOLING DESIGN STRATEGY SUGGESTED BY MODERN DESIGNERS AND ENERGY CONSERVATIONISTS [7,8]

1. Compact settlement plan, introvert buildings (in case the heat production of buildings is low as in traditional buildings)
2. Narrow north-south streets with tall buildings on both sides to cut off sun Fig 4.

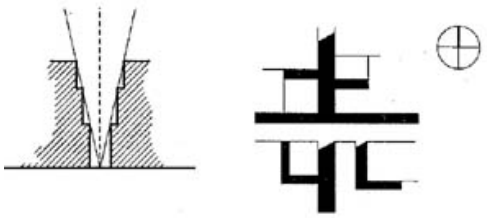

Figure 4: Narrow north south streets cutting off the sun.

3. Plantation of deciduous trees near or inside the building.
4. Ground surface should preferably be green and soft, but in case of hard surfaces, rough and light colored paving shall be used.
5. Perimeter/Area ratio shall be less.
6. Shaded courtyards to facilitate ventilation and lower daytime temperatures inside.
7. Reduction of exposed surfaces and shading of all the exposed surfaces, thus common walls between houses.
8. Least exposure to east and west orientation.
9. Minimal surface area to volume ratio thus resulting in taller buildings with shared wall surfaces Fig 5.

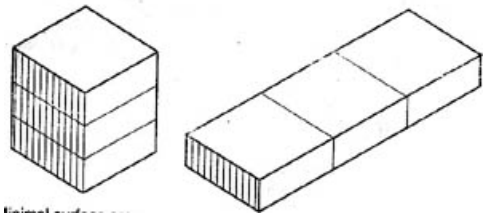

Figure 5: Effect of Surface area to volume ratio

10. Flat or Domical roof forms
11. Appropriate shading to openings using thick wooden shutters or materials with low thermal capacity.
12. Bottle neck openings or *Jalis* to enhance ventilation and reduce temperatures.
13. Fenestration shall be oriented north
14. Shading devices such as louvers or *Jharookhas* to shade openings from sun.
15. Materials having high thermal capacity and low conductivity for structure.
16. Heavy thermal mass of structure.
17. Insulation layer not directly exposed to the sun.
18. Light colours on exterior.
19. Smooth reflective surface on roof to reduce direct heat gain.

6. PASSIVE COOLING FEATURES IDENTIFIED IN SHEKHAWATI HAVELIS

For the study and analyses purpose one of the case studies is documented here. It is a small scale Haveli having only two courtyards that according to the yardsticks of Shekhawati is the minimum number of courtyards.

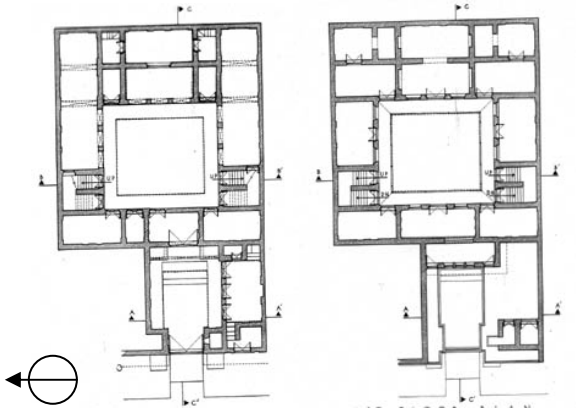

Figure 6: Ground Floor Plan and First Floor Plan of a Small Haveli, Dundlod, Shekhawati, Rajasthan

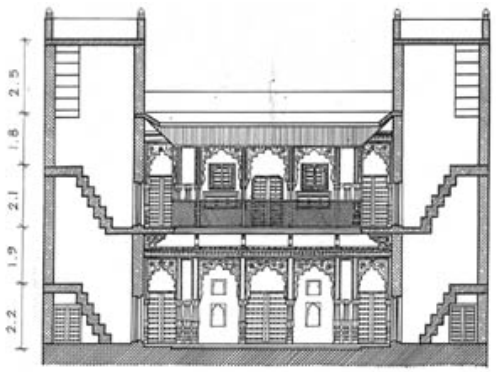

Figure 7: Transverse Section Through Internal courtyard

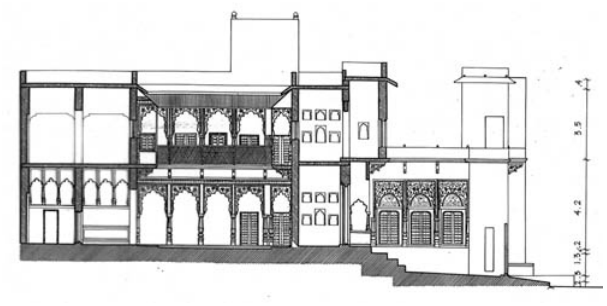

Figure 8: Longitudinal Section Through Both Courtyards

Following are the passive features identified in Shekhawati Havelis-

1. **Compact settlement plan**- the heat production from the buildings is very low thus a compact planning helps in reducing heat gain. It also allows mutual shading by buildings. It reduces the area of exposed surfaces Fig 9.

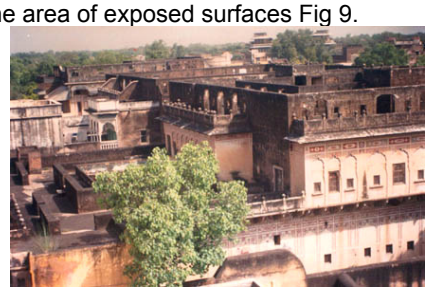

Figure 9: compact settlement allowing for mutual shading

2. **Narrow streets with tall buildings around-** it helps in shading the streets thus allowing less of direct sunlight during daytime and makes the movement easy for people. It also helps in lowering the ambient air temperature surrounding the building envelope by shading.

3. **Courtyard planning-** internal courtyard with high building mass all around it leads to induced ventilation, lowering of temperatures by convective cooling and natural lighting Fig 10.

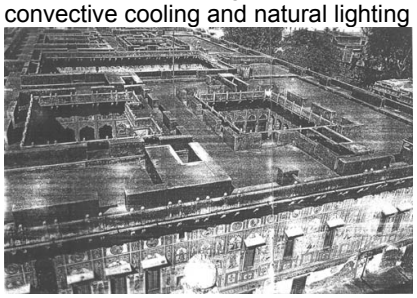

Figure 10: Photograph from roof level showing compact courtyard planning

4. **Heavy structure-** heavy building envelope stores larger amount of heat due to large heat capacities and creates a larger time lag Fig 11. This helps in keeping the inside cool during daytime when it is most inconvenient outside.

Figure 11: Inner room showing heavy construction

5. **Ceiling heights-** The habitable rooms were found to have ceiling height larger than 3.5 m while the other spaces like the ones made as viewing gallery for women which were to be used temporarily and occasionally, were only 2.5 – 1.8 m high. This meant a larger air mass resulting in lower temperatures Fig 11.

6. **Shaded colonnades and semi open areas-** All buildings are planned with some areas being semi open Fig 12. These spaces are used during the daytime and in rains. Such areas received fairly good light and natural ventilation induced by combination of courtyards and wind towers.

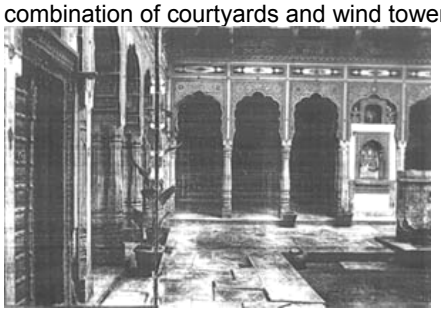

Figure 12: Arrangement of semi open areas around courtyard

7. **Flat roofs with insulation layer-** the roofs are constructed flat with stone slabs jointed with lime mortar. Above that a layer of inverted earthen pots to create an air layer for insulation. On the top of it again a layer of lime mortar finished with reflective smooth material like broken pieces of porcelain pots of white wash to reflect most of the sunlight falling on it.

8. **Small openings with thick shutters, jali screens and *Jharookhas*-** due to hot and dusty winds, natural ventilation inside the building during day is not desirable. Thus small openings are provided. These openings are opened during nighttime to allow convective cooling. During daytime the thick wooden shutters having low thermal capacity are closed. All the openings are shaded with projections covered all around with perforated stone screens known as Jharookhas Fig 13. This allows cooling of air by *venturi effect* phenomenon.

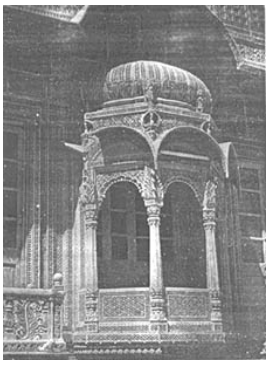

Figure 13: photograph showing Jharookha.

9. **Wind towers –** The staircase mumty was taken higher and each room was provided an opening from it to allow forced ventilation. This allowed convective cooling during night and induced ventilation during day.

10. **Materials for construction-** The stone was used along with lime mortar. Lime mortar allowed keeping lower temperatures inside the building. Stone helped in creating time lag due to high thermal capacities.

11. **External smooth surface painted in light colours-** Carving was not possible on the local stone available around Shekhawati. Thus instead of providing a rough surface, which would also have allowed inter granular shading, a smooth surface was created. To break the monotony of the flat white surfaces, painting was done with variety of colours all obtained from natural stones or vegetables Fig 14.

Figure 14: Street façade showing elaborate painting on walls

12. **Difference in the paving of inner and outer courtyard –** inner courtyard was generally kept soft with some vegetation (generally *Tulsi*) in the centre while the outer courtyard was paved with stones. In between the two was a transitory space with deferred entry and a small opening Fig 15. All activities of washing, bathing etc were performed in the inner court and also since it was more shaded, it remained cooler than the outer hard one. This heated the air in the outer courtyard and the lighter air rose up. This induced draft of cooler air from the inner courtyard. Thus the transition space always received cool air draft and was generally called the *Barsati* and was the favourite place to sit during day and rainy season.

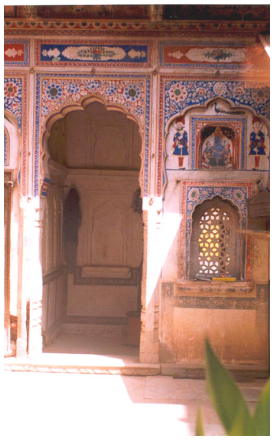

Figure 15: From inner courtyard to the outer courtyard through transition space

Note: Authors visited the case study during different times of the year in different seasons. The findings presented in the nest section are based on the total observations during all visits.

7. OBSERVATIONS

The following observations were made -

a. In each of the season (summer, rains and winter) at different times of the day, there are many comfortable spaces available in the houses that allow different kinds of activities.

In **summers** during daytime, till noon, the courtyard is the most preferred activity space. In after noon, the semi open spaces around the courtyard and the enclosed rooms for relaxing are preferred where the temperatures are the coolest during day. For working, the transition space between inner and outer courtyard is used because of cool airflow in that space which keeps body cool with the airflow thus taking away the heat from body. During nighttime, terraces are used after spraying of water.

In **winters**, during daytime, forenoon and afternoon both, courtyard is more preferred. For relaxing even the terraces are used. During night, the enclosed rooms are preferred as they have higher temperature than the ambient air outside due to time lag.

During rains the semi open spaces and the transition space is used because of the air movement available in these areas.

b. The temperature difference created due to heavy thermal mass and many other passive features is most effective in summers and winters. The time lag of the whole system is around 10 hrs. This allows comfort at all times of the day. The temperature difference created was almost around 12°C. This meant when the temperature on summer noon outside is around 45°C, the inside temperatures would be around 35°C. The proof of it was that the residents were able to stay comfortable inside the house at peak noon in summers without the use of any artificial means of cooling and ventilation.

Similarly in winters no artificial heating was used to achieve comfortable temperatures inside.

c. Heat gain and heat loss was greatly minimised due to the sharing of walls between the houses. This sharing was there immaterial of the economic status of the two neighbours. Generally the streets had residents belonging to a community rather than economic status.

d. The lighting levels were very low inside the enclosed areas. This helped in reducing the heat gain but the working environment inside the house was not comfortable as far as lighting levels are concerned. With a change in work culture, the artificial means of lighting were introduced.

CONCLUSION

After studying the Havelis of Shekhawati in detail, following conclusion can be made-

1. The Havelis respond most appropriately to the climate and society of the place in terms of material selection, spatial organization, construction techniques and use of passive design features.
2. With the combined effect of all features, the inside of the building always provided a comfortable environment when the environment outside was uncomfortable (throughout the year)
3. The same space could not provide the desired comfort in all seasons. Thus there were a variety of spaces (open, semi open and enclosed), which were used, in different seasons and times of day.
4. the incorporation of passive design features needs a comprehensive approach to design right from the inception of the building. This implies that the construction techniques to be adopted, the planning at cluster level and building level, the materials to be used and all other issues needed to be addressed simultaneously to solve the problem in an ecologically, socially, climatically and economically efficient manner.

Thus it is clear from the study that an appropriate use of materials, construction techniques and passive design features could bring about the much-desired comfortable environment inside the house. Hence incorporation of such techniques would certainly enhance the energy efficiency and reduce our dependency on artificial means for comfort. This would help us in reducing the energy consumption level at national and global level.

Note: The case study analysed did not have many artificial gadgets and the energy production of the building itself was very low. While in case of modern buildings where use of artificial gadgets is frequent, the performance of these passive-cooling techniques would be affected adversely. So while incorporating these measures in modern buildings, care has to taken to anticipate their actual performance.

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REFERENCES

[1] Urvashi Shrivastava, “Shekhawati-Hues and Rues”, *A+D*, Nov-Dec 2003, 114-115

[2] T S Randhawa , *The Indian Courtyard House*, New Delhi: Prakash Books, 1999

[3] CBRI, *Climatological and Solar Data for India,* Meerut: sarita Prakashan, Second rev. ed. 1969

[4] Shikha Khanna Jain, “Haveli Spaces- an anthropological interpretation”, *A+D*, May-Jun 2003, 100-106

[5] Kulbhushan Jain and Minakshi Jain, *Architecture of the Indian Desert* , Ahmedabad: AADI Center, 2000

[6] Koenigsberger, Ingersoll, Mayhew and Szokolay, Manual *of Tropical Housing and Building*, Madras: Orient Longman Ltd. , 6th ed. 1994, pp. 203-220

[7] *ibid*

[8] Arvind Krishan, Nick Baker, Simos Yannas and S V Szokolay, *Climatic Responsive Architecture* , New Delhi: Tata McGraw Hill Publication Company Ltd. , 2001, pp. 22-46

[9] Raj Rewal, Jean Louis Veret and Ram Sharma, *Architecture in India*, Paris: Electa France Milan, 1985, pp. 12-29

[10] Avlokita Agrawal, “Architecture of Shekhawati- Aesthetic prevails”, National symposium on Aesthetics in Indian Architecture, at MES School of Architecture, Kuttipuram, Kerala, India.

[10] Giles Tillotson, *Paradigms of Indian Architecture* , New Delhi: Oxford University Press, 1998, pp. 159-175

[11] Vibhuti Sachdev, “Mandala by Design- The courtyard of a Haveli temple in Jaipur”, *Marg*, (Vol 52, No 4).

[12] Giles Tillotson , “Palaces of Rajput Kings”, *Marg*, (Vol 52, No 4).