Rediscovering Traditional Mughal Fenestrations (16th to 17th Century) in India for Sustainable Architecture

Hemal Lotankar, Srinivas Daketi

Abstract- Fenestration is an interface between the exterior and interior. The complexities of functions of fenestrations have increased over the period of time. Traditional culture, art and knowledge find no place in this globalized world. As we embrace new materials and techniques, achieving thermal and visual comfort has become challenging. There is a missing link between the traditional and contemporary architecture of which fenestrations stand as evidence. Energy consumption for air conditioning and lighting can be reduced significantly through appropriate design of fenestrations. There is a need to understand the proper day lighting and natural ventilation and its impact on saving energy in buildings. Therefore, it is necessary to scientifically understand the techniques evolved in the past. The study focuses on understanding and analyzing traditional building fenestrations, which will help in determining the feasibility for its application in contemporary projects. The research highlights fenestrations of 16th-17th century Mughal buildings through literature review and case studies. It explores examples of fenestration designs responsive to the culture of the place and climate thereby achieving thermal comfort. The study provides guidelines to incorporate traditional fenestration designs with a modern approach to overcome the environmental disturbances and retain the cultural identity of the place.

Keywords: Fenestrations, Mughal Architecture,Climate, Culture

I. INTRODUCTION

Massive constructions evolved from completely enclosed structures to structures with different sizes of openings for ventilation andlighting. At first this was achieved by using thinly cut marble panels, which were later replaced with glass. The use of glass offered an opportunity to develop inside-outside interaction and transparency. (Bilow M,2012) Various individuals and government agencies have not only expressed concern about learning from past experiments and achievements in construction but also preservation of historic architecture. Buildings provide shelter and comfort to the user by offering protection from extreme external climatic conditions like solar radiations, temperature, precipitation and wind. With time lifestyle of the people as well as architecture advanced and aesthetics gained importance. Originally, the function of dwelling was providing shelter to man. It is now transformed into providing efficient, comfortable and healthy environment (Raval P, 2011). The comfort requirements of the users is influenced and regulated by the building fenestrations. Fenestrations allow a building to breath.

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It fulfills numerous functions such as glare protection, ventilation and the visual contact between inside and outside of a building. Microclimate, size and proportion of windows, orientation with respect to wind direction etc. are the factors which affects the air flow within the buildings. This paper brings out the relevance of the climate responsive fenestration designs in the wake of increasing energy demands.

II. FENESTRATIONS

2.1 Types of Fenestrations

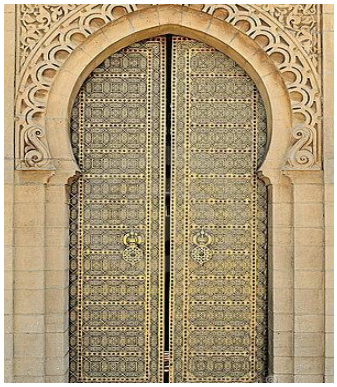


Figure1. Door

Figure 2. Jaali

Figure 3. Window Figure 4. Skylight Figure 5. Ventilator

(Image courtesy: www.dreamstime.com, architecturephotobook.earthitecture.in, www.icra.it)

2.2. Functions

The fenestration patterns and configuration affects the air movement, daylight and glare. It depends on size, location and area of the opening and also affects the solar heat gain. Ventilation is affected by location of openings defined by sill and lintel. Openings at higher level allow air flow and promote stack effect. Position of fenestrations also affects internal reflection of natural light and therefore openings of the same size located at floor level or window level or ceiling level distributes light in different

directions. Subdivision of window can be done to allow for lighting in the upper area, and for ventilation as well as rain tightness in the lower part, sometimes with the help of folding shutters. (Nijse, 2008).

Daylight- Natural lighting is a very important factor for visual comfort. Sun protection facilities are needed in order to avoid overheating and glare.

Natural ventilation- Natural ventilation means ventilating a space through apertures in the exterior envelope of a building. Differences in pressure, wind direction and the orientation of a building will cause the outside air to be blown or sucked into the building naturally. With natural ventilation, the outside air is not filtered or otherwise conditioned. In addition to manually operable windows, natural ventilation can be achieved with motor-driven flaps or window sashes.

Building orientation plays a significant role with regards to solar radiation and winds. The amount of radiation incident on the opening is determined by orientation of the building. The size and area of the opening varies with its use. Fenestrations used for escape of hot air are usually located high near the ceiling and elongated. The inlet and outlet of the building should not be of the same size so as to achieve good distribution of airflow. Screens are used to allow transmission of diffused light with the obstruction of solar radiation. It adds to the indoor visual comfort-preventing glare. Fenestrations reflect the art and culture of the place through carvings, moldings, paintings, etc. (Krishna A,2001)

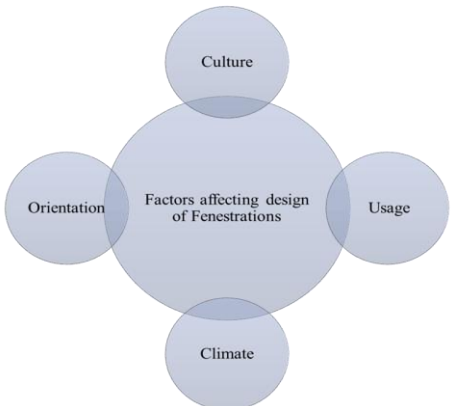


Figure 6. Factors Affecting Design of Fenestrations (Source: Author)

III. MUGHAL ARCHITECTURE

Indian architecture reached the zenith of its glory during Mughal era. It was age of innovation and renaissance, which flourished in Northern part of India from 16th to 17th century. Mughals made a remarkable contribution to Indian culture in the domain of architecture and is considered as a golden period of Indian architecture. It is a synthesis of Hindu-Muslim art tradition, which made use of red stone or marble and local art dominantly.

"With its own constructional and ornamental techniques, norms and concepts, grown from a sound historico-cultural and geophysical background, and a transparent evolutionary process, Mughal Architecture was a fully developed style and a perfect discipline, as none was prior to it in medieval India."(Source:www.indarchaeology.org)

IV. SCOPE

Considering the architectural diversity of India, the study is restricted to 16th-17th century Mughal architecture.

V. METHODOLOGY

Buildings with influence of Mughal architecture and purely Mughal buildings from 16th-17th century are documented and analyzed on different parameters of fenestration design by reviewing literature. Post 16th-17th century influence of Mughal architecture is also documented to show the change in design and technology. The parameters considered for fenestration design are aesthetics, climate, cultural impact and orientation of building.

VI. CASE STUDIES

1.1 Fatehpur Sikri

Climate: Composite

Buildings in Fatehpur Sikri were built with trabeate system using local red stone procured from nearby site. Cooling is predominantly a necessity in composite climate. The Panch Mahal at Fatehpur Sikri was built for Akbar's wives to enjoy their summer evenings (Ashar, 2003).Colonnaded façade with large openings allow ingress of cool breeze into the space in the evening. Sometimes the openings were also covered with roll up bamboo screens to protect the interior from easterly and westerly low inclination sun. These screens could be easily adjusted to control the sun's penetration. (Ali A, 2012)

Figure7.Arched openings in PanchMahal

Figure8.Small windows of Diwan-e-Khas

Figure9. Jharookas at Jodha Bai's palace
(Image courtesy: Author)

Figure10. Facade Openings

6.1.1 Shading Devices

Natural cooling was achieved by using inclined chajjas, which helped in cutting off the sun's radiations, reducing the absorption and slowing down the transmission of heat.The sunshades protect windows and walls from sun's radiations. Deep and inclined sunshades were used in buildings during Mughal period as they covered more surface area. Deep carving on building opening causes mutual shading in the day and in the evening. Differential wind forces on various building surfaces and temperature difference between outside and inside air results in cooling (Ali A, 2012).Wind movement with a greater force inside the building is enhanced by small windows on a huge wall.The velocity of the air entering the building was increased with tapered windows and smaller sections inside. The temperature of inside spaces of the buildings was lowered down by greater velocity of the air entering into a wider space. The hot air rises up in the dome space and escapes through the vents near the ceiling. (Sofla&Shokouhian, 2005). Jharokhas were incorporated in Jodhabai Palace as a viewing gallery for women.

6.1.2.Lattice Screen (Jaali)

Another strong feature of architecture of FatehpurSikri is lattice screen or *jaali* which keeps the internal spaces cool.Jaali provides privacy, as internal spaces are not visible from outside. It lowers down the temperature of internal spaces by regulating the airflow. Diffused light is spread throughout the interiors when there are harsh solar radiations outside .A cutout in the jaali provided at eye level for the viewer sitting on the floor gives clear view of the outside surrounding. *Jaali* in Mughal buildings mostly have a low sill or sometimes they are without a sill so that the air could move near the floor. (Ali A, 2012).

1.2 Haveli of Shekhawati Region of Rajashthan

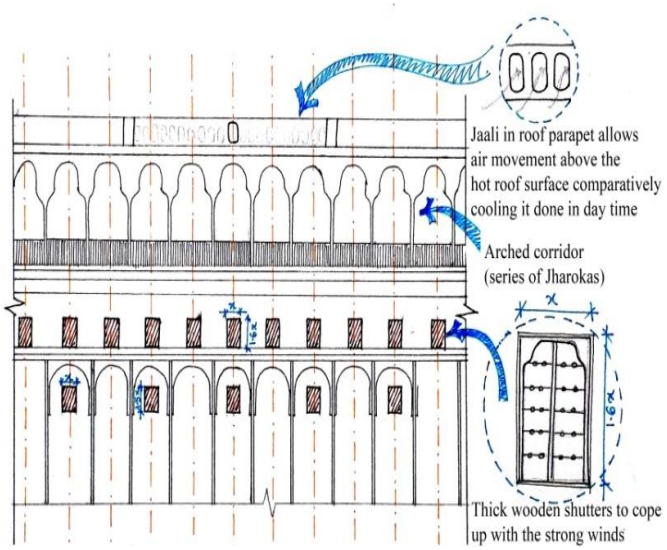


Figure11.Geometry of Openings

(Image courtesy: www.beyondlust.in)(Source: Author)

The Rajputana architecture is influenced by Mughal architecture of 16th century. Shekhawati is in dusty semi desert part of Rajasthan. The case study focuses on the climate responsive fenestration designs of the Havelis. These Havelis were lined around the street, painted in different hues and looked like an open-air art gallery. Created 75-200 years back, they present the most appropriate of the solutions to the climatic constraints even today.(Agarwal A, 2006).The climate of Shekhawati region is hot dry. At times in summer, temperatures rise upto 45°C during the day and fall to 20°C at night. The winters are temperate having temperature around 8°C and night temperatures are just above freezing point. The rainfall is around 600 mm in the months of July to October with a relatively low humidity. The dominant wind direction is north -west while the Southwest winds are experienced in the monsoons. The region has hot winds during summer where as cold winds during winter and is preferred inside the building only at night in summer and on some monsoon days. Solar radiations are very intense around 700-800 Kcal/sqm with clear sky throughout the year. (Agarwal A, 2006)

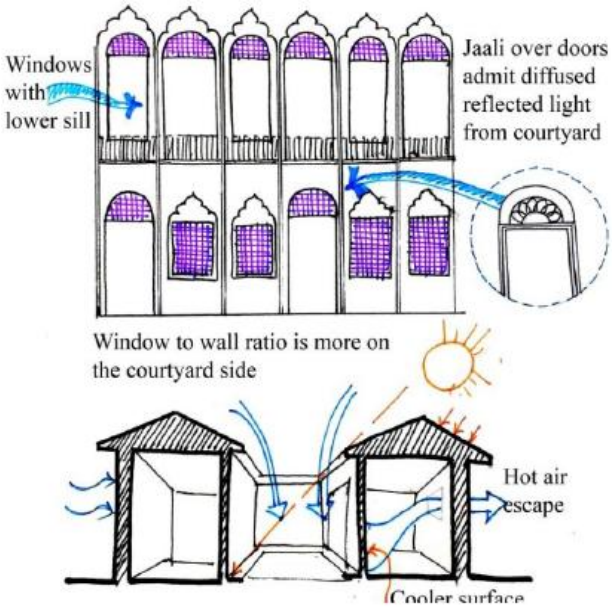


Figure12.Courtyard side Openings

Figure12.Arched Openings

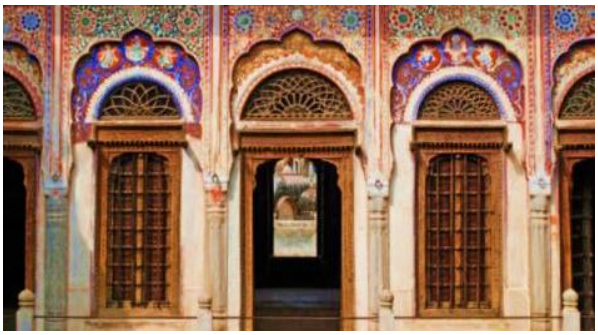


Figure 13.Carved Door Frames and Low Sill Windows

(Source: Author) (Image courtesy: www.beyondlust.in)

Due to the hot and dusty winds prevalent in this area, small and less number of opening are seen, as natural ventilation is not desirable inside the building during the day. During nighttime to allow convective cooling, these opening are opened. During daytime the thick shutters made of wood having low thermal capacity are closed. All the openings are shaded with projections known as Jharookhas covered all around. Window jaaliallows cooling of air by *venturi effect* phenomenon enhancing the natural ventilation with reduction in temperature. Wooden shutters were used to cope up with the strong winds. More number of fenestrations was oriented on the northern side for diffused light.

1.3 Hawa Mahal, Jaipur

Figure14.Variations in Fenestrations

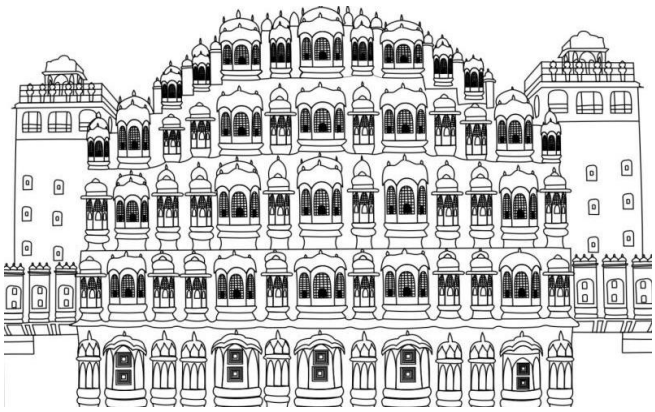


Figure15.Sketch Showing Windows to Wall Ratio

(Image courtesy: Kamath L)(Image Courtesy: Kumar S)

Hawa Mahal is one of the best examples of passive cooling techniques in hot dry climate. Air circulation is achieved through 953 types of fenestrations with lattice work differing on each floor, which helps air to pass through the building at a constant rate. Cool air enters the building due to the venture effect through lattice work and small windows thus creating temperature difference and air conditioning it during high temperatures. The windows were provided to enable the ladies to watch everyday life and processions from inside .It is intricately carved and bordered with white motif and each peephole like window has arched roof with hanging cornices. It has a beautifully carved door, which opens out, into the courtyard.

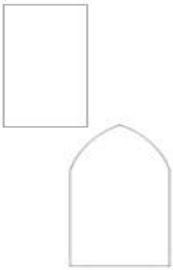
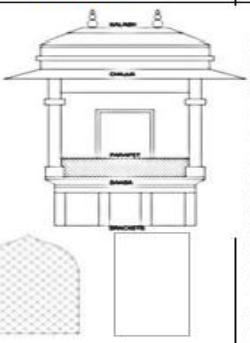
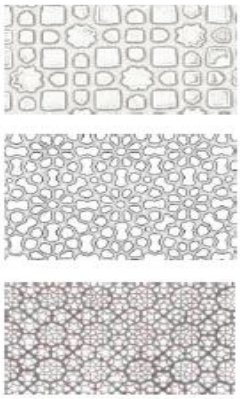
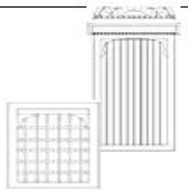
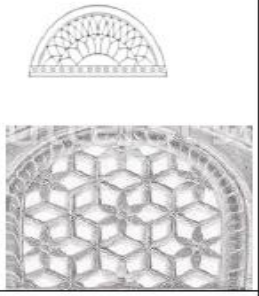
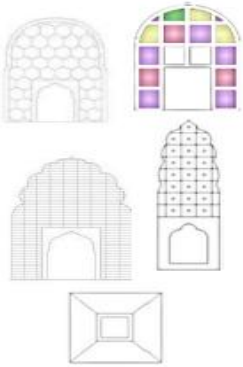
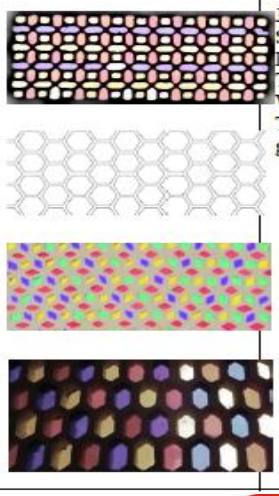
Figure16. Viewing gallery, Figure 17. Door

Figure18.Windows overlooking the courtyar

Figure19.Stain glass in Jaali

(Image Courtesy: Kamath L)

VII. OBSERVATIONS

Buildings	Doors/Opening	Windows	Jaali patterns	Materials
1.Fatehpur Sikri (16th-17th century)				Jaali-Stone Door/Window-Thick, Timber
2.Shekhawati Haveli (Nawalgar) (Influence of Mughal Architecture 16th-17th century)				Jaali-Marble or red sandstone Door-Timber Windows-Timber Door frame-Carvings in Timber
3.Hawa Mahal, Jaipur (Post 16th-17th century Mughal influence)				Jaalis-Pink Sandstone Doors-Timber Windows-Timber, Stain glass

VIII. ANALYSIS

8.1.1. Comparative Analysis of Fenestration Profiles

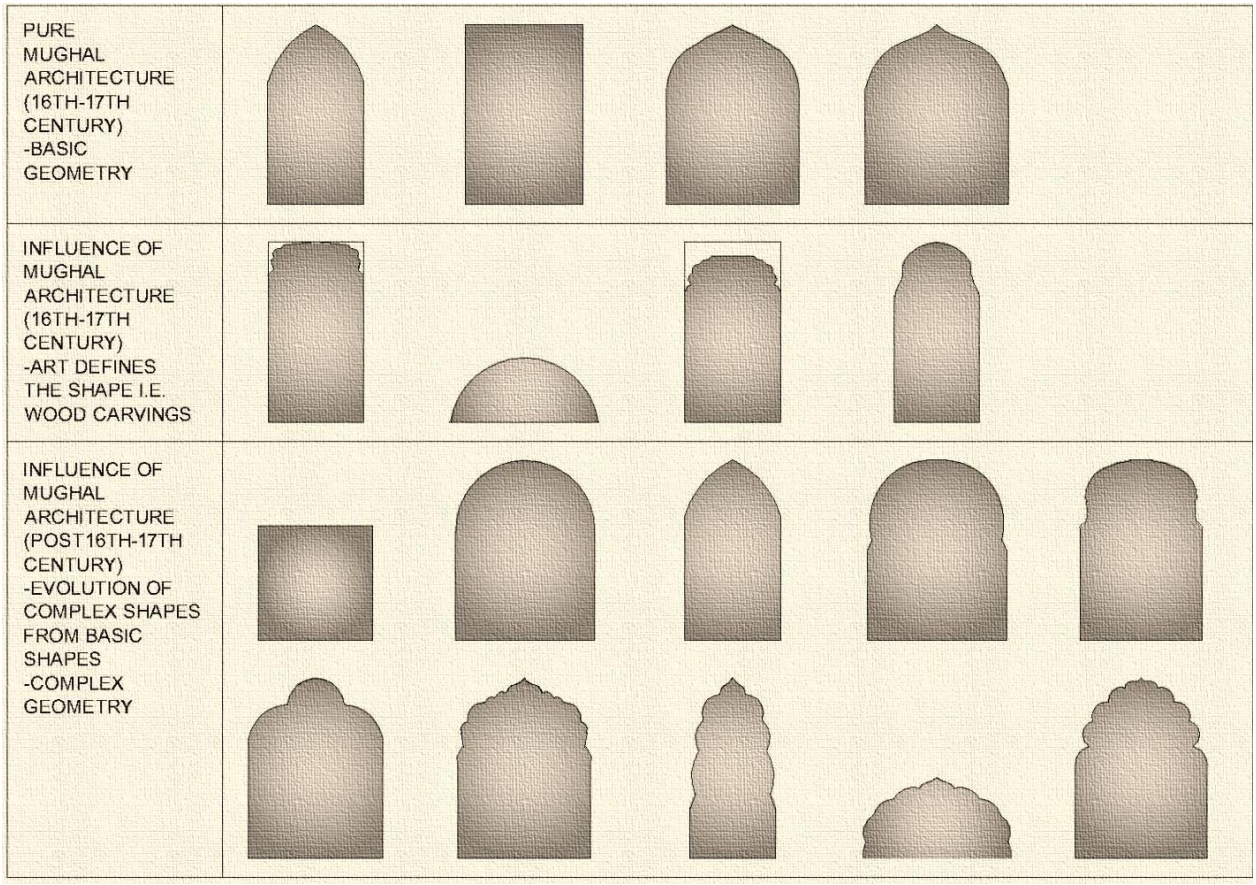


Figure20.Transformation of Fenestration Profiles

8.1.2 Comparative Analysis of Jaali Patterns

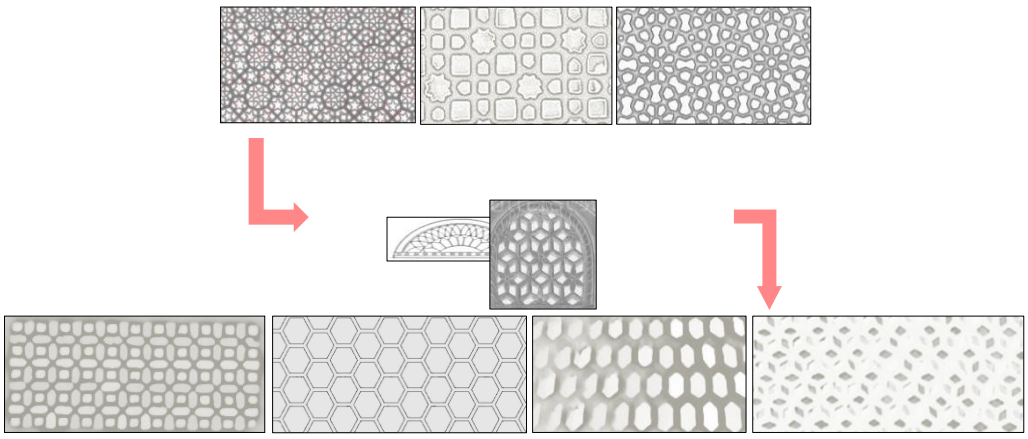


Figure20.Transformation of Jaali pattern from floral to simple geometrical shapes

8.2 Sustainable concepts

- Passive cooling and day lighting techniques incorporated in Mughal buildings made the buildings harmonious with nature.
- The fenestrations of the buildings were designed on the basis of culture and suitability to climate. The parameters of variation in fenestration design are orientation, response to climate, material, construction method, techniques, art and culture and change as per the function.
- Small openings on the façade were compensated with large and number of fenestrations on the side overlooking the courtyard to benefit the diffused light.
- In case of Panch Mahal, Fatehpur Sikri which has a composite climate, the openings had to be protected with large overhangs to avert harsh solar radiations falling inside. During summer, grass mats with water sprinkled on it were used to cover the openings to cool down the hot breezes. Heavy quilts were suspended during winters. This was done to further improve the internal

environment and prevent direct solar radiations to enter the space.

- The most common passive cooling technique adopted in all the buildings is venturi effect through Jaalis, which enhances velocity of air entering the space.
- The comparative analysis of all the case studies show that Jaalis were prominent whereas windows were less in number and smaller in size. The velocity of air increases as it passes through the Jaali due to the driving pressure attempting to push the air inside.
- It also shows the transformation of shapes from basic to complex geometry and Jaali patterns from floral to simple geometrical patterns from evolved over a period of time.
- The people of Shekhawati focused more on culture and the art molded the fenestrations. The Jharokhas, which were extensively used in Mughal Architecture, were modified into a series forming a corridor overlooking the courtyard.

IX. CONCLUSION

The research chronologically traced the evolution of Mughal fenestrations and reveals that how climate, regional influence and prevailing lifestyle determined the shape and profile of the fenestrations. Traditional methods offer thermally comfortable indoor environment by giving deliberate climatic conditions. Losing traditional knowledge is losing identity that makes a place unique and stands out and thus proper interventions are required to preserve traditional wisdom, sustainability concepts and culture of India. Tradition and culture can reform from time to time but should not lose originality. The work has examined passive design of fenestrations in Mughal buildings with locally available materials with response to climate. These findings provide guidelines to architects for energy efficient design of buildings. The principles can be used and amalgamated with advanced technology to promote harmony between indoor and outdoor environment. Further studies can be carried out in order to determine the exact geometry of fenestrations and examine its efficiency for a given climateto incorporate the same in modern context.

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