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Geometrical pattern designs used in mughal architecture in India during the period of 1526-1737

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Abstract
The Indian architecture is world famous for its decoration. The credit goes to Mughal to brought new geometrical architectural approach, techniques coupled with colours schemes. The geometrical pattern art flourished in India during Mughal period and is evident from their buildings which are influenced by local culture, climate, tradition, material and technology. Pattern decoration techniques and designs, originated during the Mughal period, and are now being practiced in contemporary building as part of the interior as well as exterior walls and floors. The geometrical, arabesques, floral, fruits and abstract forms used in contemporary buildings really connect us with Mughal period. This paper attempts to find rationale (i.e., aesthetic, cultural and other) for using technique and designs for wall and floor decoration in contemporary period and explores its impact on culture. The study infers that the pattern decoration in present time relate to the Mughal as well as to Hindu culture.

Keywords: pattern designs, mughal, architecture, geometrical

Introduction
India possesses a rich heritage, involving two great religions, Hinduism and Buddhism. These two religions along with their political patronization developed an architectural vocabulary expressing their spiritual desire and aspirations. Later when Muslims invaded India, they introduced a new architectural approach, evident in their secular and religious structures all over the Indian subcontinent.

The Muslim rulers constructed a number of majestic buildings with the use of important features influenced by local culture, climate, tradition, material and technology. India is known for diverse traditions, cultures and versatile art. The art is a strong tool to reflect the culture and living style of any society. This study will show the pattern designs, theme and many aspects which belong to the great Mughal rulers and now in contemporary period. The Mughal are known for their glory, living style, and attractive architecture with its unique decoration and not needed to any introduction. Akbar was the first emperor who promotes Indian as well as Mughal art and culture in Mughal dynasty. They made much beautiful architecture in India and their architectural decoration reflects their taste, interest, living style and culture. It shows that architecture and its decoration speaks their living and traditional language. This study presents a tangible evidence of the use of geometrical pattern designs in the Mughal architecture of India.

Observations
Mughal architecture
Late Mughal (1526 to 1737 CE) kings were grate patrons of architecture and some splendid buildings were constructed by their order and supervision. Their architecture is a mixture of local Islamic and Hindu style with heavy influence of Persian architecture (Asher, 1992). Early surviving Mughal buildings such as Sher-Shah Mausoleum (1540-5 CE) are decorated with paintings and tiles of floral motifs. Mausoleum of Humayun in Delhi (1556-66 CE) is complex consisting of great Persian style garden. The building is decorated with white marble frames surrounding arches and white marble tablets as frieze and cornices, making beautiful contrast with red coloured sandstone structure. Some very adorable samples of 6 and 8-point geometrical patterns can be found through marble floorings, window grilles and balcony railings (Figure 1).

Mathematics and art

Geometry of architecture

Geometry is one the most important elements of Islamic art. "Star shapes and polygons appear in all the arts and provide a source of much architectural decoration. Geometric shapes are highly versatile and can be extremely complicated." From the simple polygons and rectangles used as framing devices to the highly complex interlaces of stars and irregular polygons. The four basic shapes, or "repeat units," from which the more complicated patterns are constructed are: circles and interlaced circles; squares or four-sided polygons; the star pattern, ultimately derived from squares and triangles inscribed in a circle; multisided polygons.

How is geometry seen to be spiritual?

Because circles have no end they are infinite and so they remind Muslims that Allah is infinite. Complex geometric designs create the impression of unending repetition, and this also helps a person get an idea of the infinite nature of Allah. The repeating patterns also demonstrate that in the small single element of the pattern implies the infinite total. The repeated geometric patterns often make use of plant motifs, and these are called arabesques. Stylised Arabic lettering is also common

1. The Circle and it is centre at which all Islamic patterns begin. It emphasizes one god. The triangle symbolises human and the principles of harmony. The square is the symbol of physical experience and the physical world or materiality. The hexagon symbolises heaven. The star symbolises the spread of Islam.

2. Basis of geometry: The basic methods by which 3, 4, 5, 6, 8 and 10 point patterns can be constructed using only a straight edge and compass. Constructions of 7 and 9 point patterns can be approximated. From the geometrical constructions mentioned above generally, patterns with a greater complexity can be constructed. Patterns with12, 14, 15, 16, 18 and 20 are readily established.

Three point geometry: Three points geometry can be constructed from six point geometry. Discussed in six point geometry.

3. Four point geometry Four point geometry is one of the easiest geometries to set out. It is often used in counter point with circular geometries. It is constructed by raising a perpendicular from the centre point of a horizontal line to the point where it cuts a circle described from that point, and joining the four points of intersection. Further sub-divisions into eight point geometry can be constructed by sub-dividing the sides of the square.

4. Five point geometry: Five point geometries are slightly more difficult to construct, but can be relatively easily developed. They have an additional interest in that they are similar in proportion to the geometry derived from the Golden Section, having proportions between the minor and major chords of the five points circumscribed by a circle, of1:1.618. From the five point geometry, ten point geometries are easily developed and form the basis for many of the more attractive patterns in Islamic decoration.

5. Six point geometry: Six point geometry is by far the easiest geometry to construct, requiring only a simple form of compass to create the basis for accurate three-, six- and twelve-pointed forms. In this, seven-circle from the six-point geometry construction and shown how the basic pattern lines evolve. The first illustration shows, in first figure, the basic circle rose with, in second figure, the addition of lines joining the intersections of the surrounding circles with the basic circle to create a regular hexagon.

6. By joining different points different patterns are found as shown above

7. Dividing of a single circle, the more common basis for a pattern is a simple grid, here the development of the circle suited to six-point geometrical patterning. Even in this the eye finds it difficult to rest, but is continually moving around the circles. The addition of straight lines just develops and guides this movement. A slightly different development of diagram and is repeated here to show how a relatively simple pattern based on six-pointed geometry might be developed. The basic grid shown in the six-point, has been turned 30 counter-clockwise and a number of straight construction lines selected on which the pattern has been produced.

8. Taj mahal Called a monument to love, the Taj Mahal has also been called "Indias most famous and finest example of architecture. We could call it a monument to symmetry. From the formal gardens divided into four sections, to the tomb 900 feet from the entrance, the four minarets continue this symmetrical theme. The minarets next to the Taj Mahal are 41.1 meters or 137 feet high and are cylindrical columns with angles. Located at each of the corners of the raised marble plinth the minarets repeat the right angles that are an obvious part of the Taj Mahal. The main structure is cubical. The windows have arches which comes to a point.

9. Painted geometry in the ceiling: The complex is set around a large 300 meters square charbagh, a Mughal garden. Interior of dome, showing in laid geometric decoration

10. The central circle at the base arches upward to create the famous onion dome. The Taj Mahal is a fine example of geometry. The rectangular reflecting pool mirrors the pools in each of the four gardens and makes your eyes follow along parallel lines to the tombs entrance. The intersecting perpendicular lines continue to create right angles in each of the four sections which are subdivided into another four squares. The doorways are rectangular in design with semi-octagonal angles. The room that the tombs are placed is octagonal. As we look at the Taj Mahal, there are multiple lines of symmetry. The total effect combines to make one of rhythm and harmony.

11. Tomb of Itmad-Ud-Daulah (Eyteymaaduddowlah) Decagonal and Quasi-Crystalline Tiling in Medieval Islamic Architecture,, Islamic mathematicians had made a breakthrough in the geometry that made it possible to create this extraordinary complex with patterns having a 12-foldrotational symmetry. A set of five tile types, now called "girih tiles", in any combinations serve as templates for incorporating with the existing decagonal symmetry.

13. A modest attempt to draw manually a pattern with 10-fold rotational symmetry using in combination decagonal, hexagonal and bow girih tiles

Many Islamic designs are built on squares and circles, typically repeated, overlapped and interlaced to form intricate

and complex patterns. A recurring motif is the 8-pointed star, often seen in Islamic tile work; it is made of two squares, one rotated 45 degrees with respect to the other. The fourth basic shape is the polygon, including pentagons and octagons. All of these can be combined and reworked to form complicated patterns with a variety of symmetries including reflections and rotations. Such patterns can be seen as mathematical tessellations, which can extend indefinitely and thus suggest infinity. They are constructed on grids that require only ruler and compass to draw. Artist and educator Roman Vero stko argues that such constructions are in effect algorithms, making.

One of the early Western students of Islamic patterns, Ernest Hanbury Hankin, defined a "geometrical arabesque" as a pattern formed "with the help of construction lines consisting of polygons in contact. He observed that many different combinations of polygons can be used as long as the residual spaces between the polygons are reasonably symmetrical. For example, a grid of octagons in contact has squares (of the same side as the octagons) as the residual spaces. Every octagon is the basis for an 8-point star, as seen at Akbar's tomb, Sikandra (1605–1613). Hankin considered the "skill of the Arabian artists in discovering suitable combinations of polygons almost astounding He further records that if a star occurs in a corner, exactly one quarter of it should be shown; if along an edge, exactly one half of it.

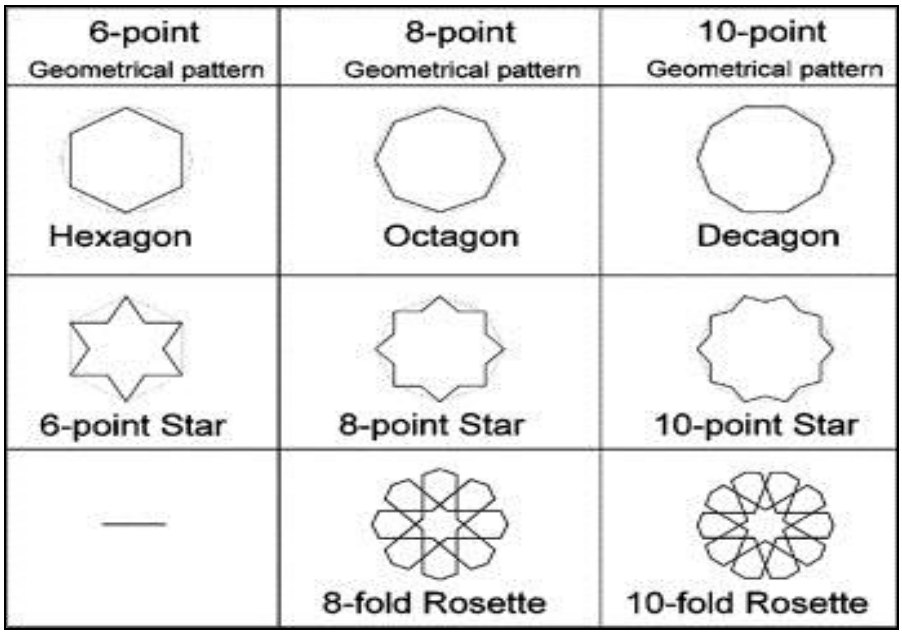

Fig 1: Samples of 6 to 10 point geometrical patterns

Dominant 6 and 8-point geometrical pattern is also repeated in Red Fort of Agra (1564-80 CE). Its buildings are harmoniously decorated with carved red sand stone and white marble with floral and geometrical patterns. However some examples of 12-point and very few and simple form of 10-point geometrical patterns can be found in this complex (Figure 2).

Fig 2: From left: Humayun Tomb in Delhi; Red Fort in Agra; Friday Mosque of Fatehpur-Sikri; Etimad-ud-Daulah tomb.

By the end of 16th century Mughal architects began to use more 10-point geometrical patterns. Friday mosque of Fatehpur-Sikri (1571-96 CE) is an example of this era. Apart from various elegant types of 6, 8 and 10-point patterns of this building, the example of 14-point geometrical pattern has been applied over piers of its main dome (Figure 3).

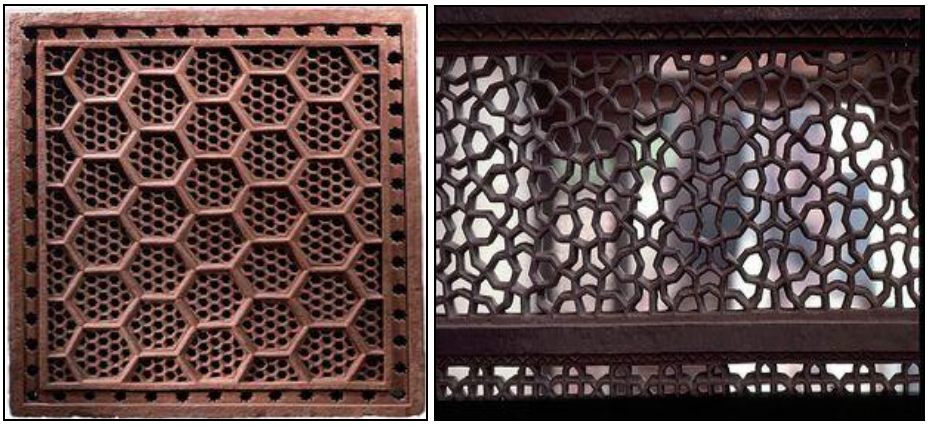

Fig 3: Friday mosque of Fatehpur-Sikri and Salim-Chishti tomb (inside the mosque), various 6,8,10 and rare 14-point stargeometrical pattern

Through the next decades, geometric ornament became an essential decorative element in Mughal architecture which in some cases made vegetal motifs as subsidiary and filler decorative. Tomb of Akbar The-Great (1602-12 CE) and Etimad-ud-Daulah Tomb (1622-28) are examples of this era (Figure 4). Both are completely covered with inlay marble and sandstone with 6,8,10 and 12-point geometrical pattern. Another remarkable Mughal building in terms of geometric ornaments is Lahore Fort complex built during 16th and 17th centuries. There are adorable samples of geometrical patterns through stone floor finishing of sheesh-mahal, fountain courtyard and mosaics of surrounding wall

Fig 4: Etimad-ud-Daulah tomb in Agra, 1628 CE, celebration of 6 and 10 point geometrical patterns by inlay and carved marble through the facade of tomb

In Mughal architecture, red sandstone, white marble and polychromic tiles are main cladding and decorative materials. Islamic geometrical patterns are key decorative elements of both secular and religious buildings. Unlike their predecessors and specially Mamluks, Mughal architects and craftsmen, avoided complicated geometric patterns such as 12 or 16 points geometrical patterns and instead, they made lots of effort for right and perfect proportions in shapes and angles of patterns. However, the most rare 14-point geometrical pattern can be found in some Mughal buildings. Another distinguishable feature is that Mughal architects used geometrical patterns in floor finishing designs and carved window grilles and railings more than other geometric architectural styles. (Figure 5)

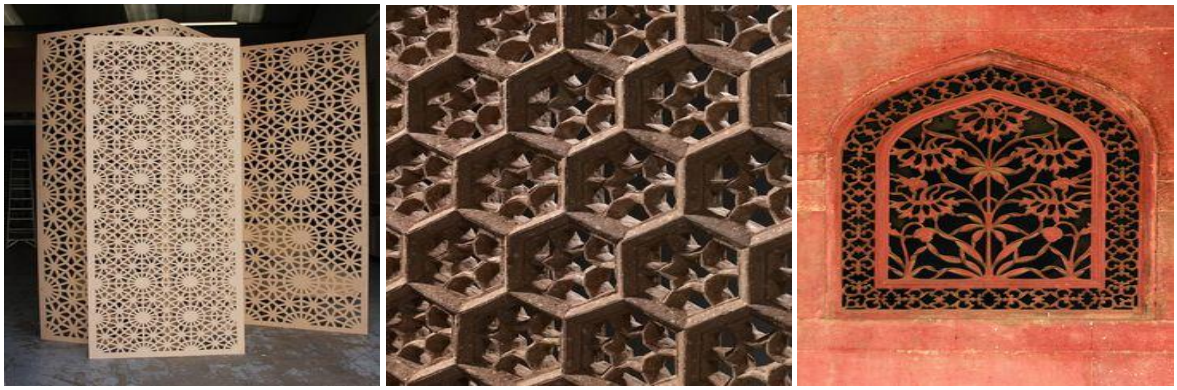

Fig 5: Jali from Fatehpur Sikri

Recently I visited Qutub Minar in Delhi. There also I could capture different patterns of Mughal Architecture. Sharing about some the major patterns used in Mughal Architecture in India.

1. Jali patterns

Jaali means net. Jaalis are carved on red stone or white marbles. Jaalis are extensively used in Mughal Architecture for windows, edges of the platforms and terraces (Figure 6)

Fig 6: Jali Window from Qutub minar Delhi and Dargah of Khwaj, Ajmer

2. Geometrical patterns

Another design pattern used in mughal architecture is repeated geometric pattern. Even Jaalis have geometric patterns (Figure 7).

Fig 7: Repeated geometrical pattern

3. Arabesque

Arabesque are the patterns made by interlacing lines and curves. Arabesque is another major design used in mughal architecture. These looks quite complicated designs (Figure 8).

Fig 8: Arabesque patterns

4. Calligraphy Designs

Calligraphy is another defining charecteristic of Mughal architecture. The Qutub Minar has the calligraphy designs running around the Minar. These are in the form of bands. This has the text from Quran (Figure 9).

Fig 9: Calligraphic designs

5. Floral Designs

Floral designs are major patterns in almost all the art and architecture. Mughal Arts and Architecture is not an exclusion. The floral designs are includes mainly lotus, rose, buds and plants (Figure 10).

Fig 10: Floral design

Conclusion

This research tries to find the earliest examples of the most prominent types of geometrical pattern of Mughal architecture. Survey of Agra and Delhi famous buildings, has been concluded in Table 1-10, which shows different geometrical pattern design. Along the survey of patterns from buildings, great Mughal dynasties and patrons have also been studied, which reveals the design variations and impact of regionalism and period-styles. Concluding time-chart sketches the geometrical patterns from early stages to late 18th Century. In this context, for building inspired from a particular era, this study has the answer of suitable pattern in terms of relevant.

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