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EVOLUTION OF GEOMETRIC PATTERNS IN ISLAMIC WORLD AND A CASE ON THE JALIS OF THE NAULAKHA PAVILION IN THE LAHORE FORT

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Abstract

The geometric patterns in the Islamic 83World have evolved with the time, the empire and the region. These patterns not only show the aesthetics of the craftsmen, but the extraordinary skills and understanding of geometry in Islam as well. This paper examines and maps the Islamic geometric patterns evolution through different dynasties. In this study, one of the milestones of buildings in Islamic dynasties was selected and the pattern tessellations belong to the particular building is reproduced. It is assumed that selected building represents all characteristics of that period. Examined as a case, The Jalis of the Naulakha Pavillion in The Lahore Fort, shows that how a basic hexagonal pattern is used in different layouts. The complexity of the grid and the simplicity of the patterns are highlighted and understood in these examples.

1. INTRODUCTION

Everything that is made beautiful and fair and lovely is made for the eye of one who sees.
- Rumi, Mathnawi I:2383

Geometry in Islam plays a significant role, as geometric pattern was turned to an art form and ornamentation purposes due to some constraints of using human or natural figures. İt is considered as one of the three types of ornamentations in Islamic art, which are nonfigural, the other two include, calliagraphy and vegetal patterns. Geometry is considered as a sacred art form and calliagraphy is the most fundamental element of Islamic ornamentation and art. Calliagraphys significance is due to the fact it is in Arabic script, the script the Holy Book of Muslims, the Quran is written in. The calliagraphic ornamentation has not only been used to beautify the written verses on paper, but also used as a major ornamentation art form in architectural exterior and interiors, where the verses of Quran are beautifully composed and written on the domes and walls of the mosques or other religious significant architectiral buildings. Calligraphic ornamentation in architecture and on scroll usually appears in conjunction with geometric and vegetal patterns.

For centuries the geometric patterns have been used and have evolved according to the time and the region. These patterns not only show the aesthetics of the craftsmen, but also the extraordinary skills and understanding of geometry in Islam as well. They provide the evidence of no matter how elaborate and complex these patterns are they are based on simple grids. Created by using only a pair of compasses and a ruler, these mathematical complex frameworks are examples of the scientific advances and inventions of the Islamic Golden Age. This paper

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investigates the evolution of Islamic geometrical patterns from the surviving buildings of the different regions. The study examines how these patterns evolved over the time and how the great Mughals, who were originally from Central Asia, descended from the ethnic Turks of Mongol, adopted and adapted these patterns in the Indian subcontinents art and architecture. This paper also attempts to document the historical significance of the patterns, focusing on the patterns used by the artists and craftsmen in making of jali in Mughal art and architecture.

Jalis (meaning fine net/web) or screens have been a significant architectural feature of many decades. These ornamental perforated screens, in earlier times did not only play aesthetic role in a building design but also played major role in tackling the natural conditions in buildings ventilation and lighting. These passive cooling and lighting screens have been part of many different regions design and architectural techniques which results in different use of materials and designs. The major focus of the study is on the importance of the jalis (screens), as decorative architectural elements along with their functional significance.

2. GEOMETRİC PATTERNS

2.1 Geometry in Islamic World

In Islamic geometric figures, circle is the ultimate base of all creation and represents the symbol of unity. The expansion and natural division of this important figure into regular divisions is the starting point for many patterns and it also originates three most essential figures, the triangle, the square and the hexagon. When the circle is expanded from one circle into three circles the first and the simplest figure originates a triangle. As per Critchlow's (1976) cosmological analysis of geometrical patterns in Islamic art and architecture, a triangle represents "human consciousness and the three basic biological functions: ingestion, digestion, and excretion".(Oweis, n.d) Expanding the circle further gives us a square, symbolizing earth and materiality, also representing the universe's four main elements: water, earth, fire and air, where as a hexagon symbolizes the heaven.

In Islamic geometrical patterns, most of them are based on polygons and when the vertexes of these constructive polygons are connected, they give birth to the fundamental Islamic patterns, the star-polygons. This fact forms the base for the classification of the patterns, for example all patterns which are generated from an octagon, transforms to an octagon star and are classified under 8-point geometrical patterns and the pattern will be called as an 8-point star and where the two adjacent rays of the star are parallel, resulting in a shape representing rosette leaves, is classified under 8-fold rosette. (Abdullah and Embi, 2012) As shown in Figure 1, the illustration shows how to generate 6-8- and 10 fold complex shapes deriving from single polygons.

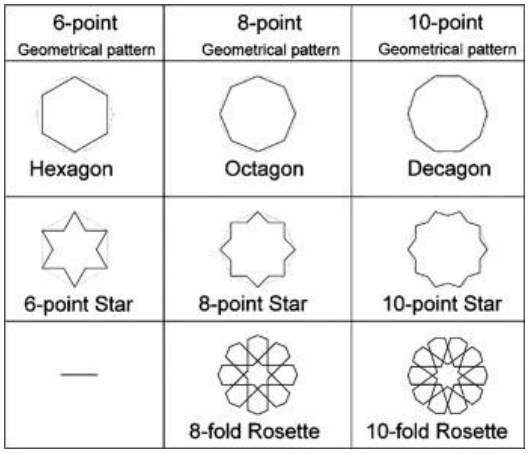


Figure 1. Geometrical patterns classification (Abdullah and Embi, 2012)

The geometric patterns in the Islamic World have been used and have evolved with the time, the empire and the region. These patterns don't just show the aesthetics of the craftsmen, but the extraordinary skills and understanding of geometry in Islam as well. They provide the evidence of no matter how elaborate and complex these patterns are they are based on simple grids. Created using only a pair of compasses and a ruler, these mathematical elegant frameworks are an amazing example of the scientific advances and inventions of the Islamic Golden Age. From the rise of Islam in the 7th century till the 9th century not many original contributions have been made by the Muslims in the field of geometry. But it wasn't as if they weren't progressing, it was during the 8th and 9th century that the Muslims significantly progressed in scientific innovations by translating ancient texts into Arabic and learning different philosophies which undoubtedly increased their knowledge and broadened their visions.

By the 8th and 9th century Muslims scientific and technological knowledge had grown in Middle East, Central Asia and Iran and on the basis of that the expansion of geometry in Islamic art and architecture is also observed. (Abdullah and Embi, 2012) It was during the 10th century that Muslims original contributions in the field of sciences became significant which was also observed in the complex field of geometry.

The natural division of the circle into regular divisions is the ritual starting point for many traditional Islamic patterns, as demonstrated in the drawings by Henry, shown in Figure 02 and Reeves drawings that are presented in Table 01.

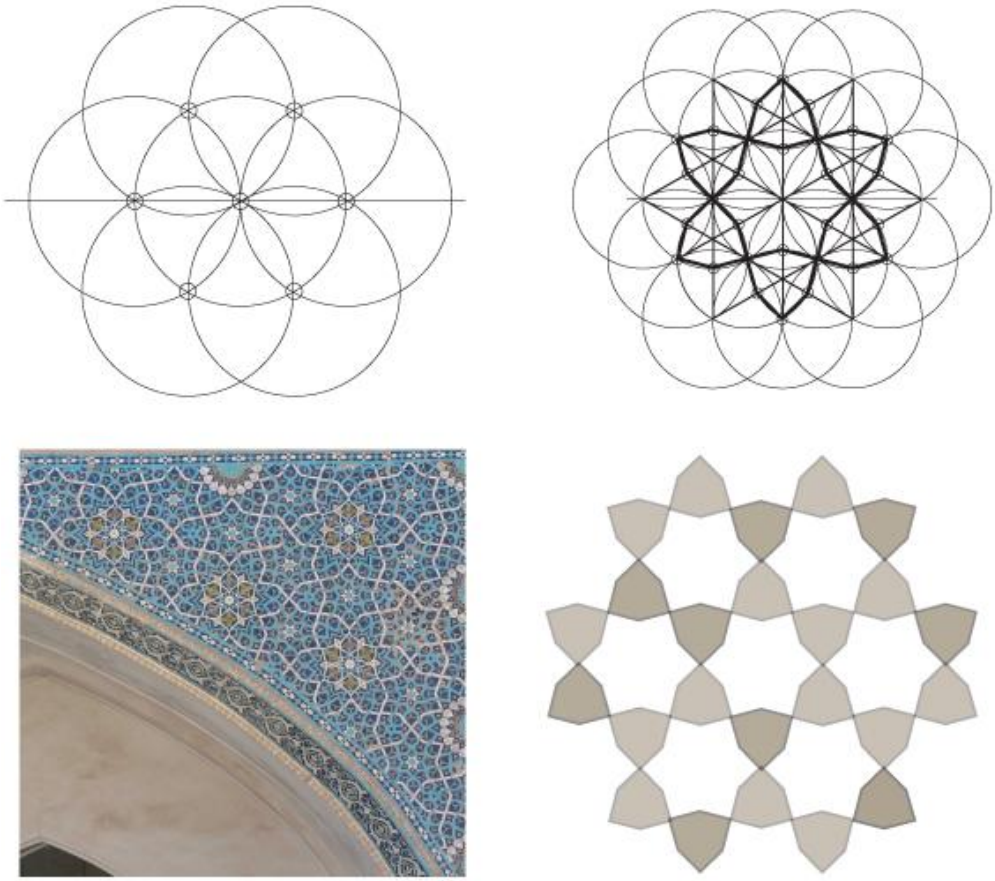
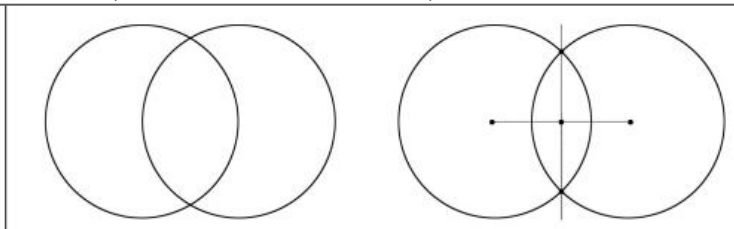
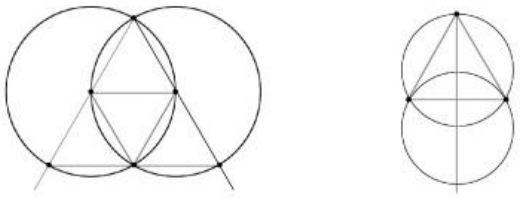
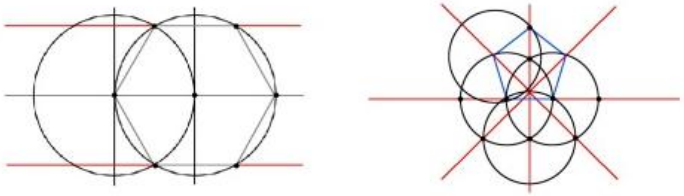


Figure 2. Geometrical patterns designed from division of circle (Henry, 2007)

The pattern (15th century) from Yazd in Iran, in Figure 02, is derived from six regular divisions of the circle. From this a regular grid of triangles is established, on top of which the design is elaborated. Note how the complex tracery of pattern interweaves with the basic design which appears in white outline. (Henry, 2007)

Table 1. Significance of Circle (McMillan-Reeves, 2010).

Vesica piscis	
The in-triangle	
The in-square and rectangle	
The hexagon and pentagon	

2.2 Evolution of Geometric Patterns through the Islamic Dynasties

The evolution of the Islamic geometric patterns has been studied and understood by the surviving architectural buildings of the Muslim dynasties. The dynasties that made a major contribution in the development and shaping of Islamic art and architecture can be as follows:

- Umayyad Dynasty (661 to 750 CE)
- Abbasid Dynasty (750 to 1258 CE)
- Seljuk Dynasty (1038 to 1194 CE)
- Fatimid Dynasty (909 - 1171 CE)
- Mamluk Dynasty (1250 to 1517 CE)
- Ottoman Empire (1290 to 1923 CE)
- Safavid Empire (1501 to 1736 CE)
- Mughal Empire (1526 to 1858 CE)

The first Arab monarchy based in present day Syria was established by the Umayyad Caliphs. The Umayyad architecture was based on the mosques and palaces, which reflects the influences and inspirations drawn from the Byzantines and Sassanian empires construction techniques and ornamentation. By the end of 7th century the floral patterns from and ornamentation was common in the Islamic architecture (Yalman, 2000). One of the first and iconic surviving buildings of their empire can be mentioned as The Dome of the Rock, Jerusalem (late 600s CE). The façade and the exterior are ornamented with mosaics, the interior surfaces gives the hint of swirling designs with vegetal motifs with gold tesserae (small blocks used for the

construction of mosaics) (Botchkavera, 2012). Another example can be mentioned as The Great Mosque of Damascus in which floral ornamentation inspired by the landscape of Damascus (Labatt, 2012).

After the Umayyad Empire, the Abbasid Empire took forward. The works of ornamentation in architecture gained popularity and new techniques and more abstract styles were adopted. Frescos, wood and stone carvings, brick works, stucco and terracotta were extensively used (Blair 2011). The Great Mosque of Kairouan in Tunisia (built in 670 CE, rebuilt in 836 CE) has elementary geometrical patterns with the floral and vegetal motifs on the building, making it one of the earliest examples of use of geometrical patterns in Islamic architecture (Apelian, 2014). (Figure 3). Abbasid Palace of Baghdad (1179-1230 CE) is also a building belonging to this period (Figure 4).

Figure 3: The Great Mosque of Kairouan. The examples of the geometric patterns on the wall (Mortel, 2012). The pattern drawn by authors.

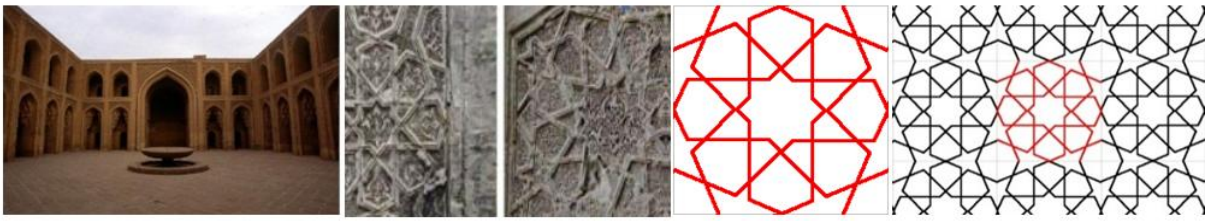


Figure 4: (Left) Abbasid Palace, courtyard in the House of Wisdom, known as the Bait al-Hikma. The second image is the original decorations before restoration. The basic 8-folf rosette pattern, found in the ornamentation. (right) (Paolino 2012, Abdullah and Embi 2012). The pattern tessellation drawn by authors

The Madrasa of Mustansiriyeh (1233 CE) has highly ornamented and detailed muqarnas. The entrances exhibit arabesque-sculpted terracotta and geometric patterned brickwork. The earliest examples of six-point geometry, eight and twelve-point geometrical patterns, rosette pattern and eight-point star were observed (Abdullah and Embi, 2012) (Figure 5).

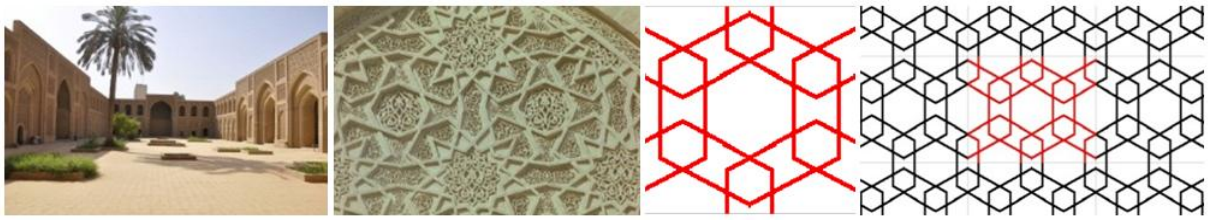


Figure 5. The Madrassa of Mustansiriyeh's courtyard. The 12-point geometrical pattern on the arch (Ministry of culture-Iraq, 2013) The pattern tessellation drawn by authors

It was by the late 8th century that the geometrical shapes were introduced on surfaces but only as individual elements for ornamentation. During the Seljuk Empire, the focus of the Islamic world was more on tombs and madrasas The Seljuk's artistic movement brought transformation in geometric motifs and introduced complex patterns. The use of 10-point

geometrical patterns, abstract 6- point and 8-point patterns and unusual patterns made of non-constructible polygons such as 7, 9, 11 and 13-point geometrical patterns was all observed during the Seljuk's era. Among the Early Seljuk architectural examples of tombs Iran's province, Qazvin, tomb towers of Kharaqan (1067-93) can be mentioned. It has an octagonal plan, with double crusted domes and brick walls along highly ornamented panels with different abstract and star geometrical patterns on the façade (Hatim, 2000) (Figure 6). Additionally, the Friday Mosque of Isfahan is the absolute example of Seljuk style, highly detailed and decorated geometrical motifs, made of brickworks, over a plan of four-Iwan style, with earliest examples of heptagon and geometrical patterns used in the decoration of the walls (Dalal, 2014) incorporating geometrical patterns (mostly 5 and 8-point star patterns) with the structural elements (Henry, 2007).

Figure 6. The tomb towers of Kharaqan (right) and the brick wall and arch detail (Zereshk, 2008) The pattern tessellation drawn by authors

The Fatimid Dynasty (like the Seljuk's) six-point stars have also been very popular in their works of architecture, but it was more isolated or sculptural as they didn't cover entire form or surface and always directed towards a focal point (Mazot, 2012). One of the Fatimid's remarkable works known till date is The Al-Azhar Mosque and madrasa (970-2 CE and later), decorated with stuccowork floral and geometrical patterns. Ornamentation is on panels and windows along with Arabic inscriptions in six point star designed in the interior apex of the dome. Later addition of a mihrab with detailed ornamentation has been made by the Ottomons restoration (Abouseif, 2011). (Figure 7). Also, The Al-Aqmar Mosque (1125 CE), can be mentioned as one of the finest example with fluted domes, arches, Maqarnas and highly carved facades with Arabic calliagraphic, geometric and floral ornamentation (Mazot, 2012).

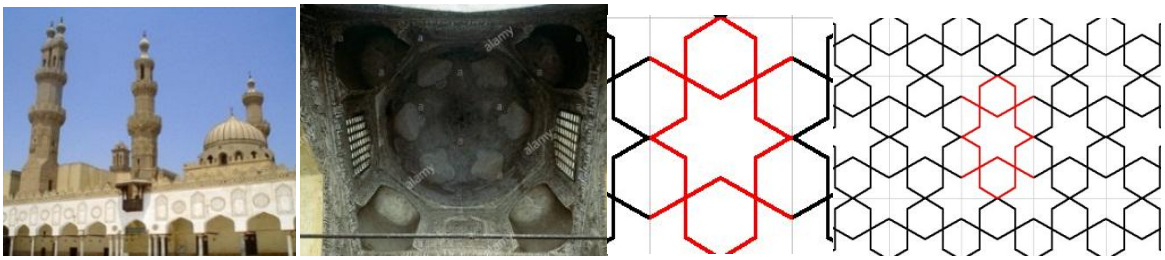


Figure 7: Al-Azhar Mosque and the detail of the dorm showing a six point geometrical pattern (Tentoila, 2006) The pattern tessellation drawn by authors

Following, Mosque of Al-Salih-Tala'i (1160 CE) in Cairo like the Al-Aqmar Mosque, the use of six and eight-point star is used in the bas-relief sculptural ornamentation on the walls. (Figure 8). During the Mamluks a 12-point geometrical pattern was carved over the Minbar adding to the significance of the mosque and a decorated carved wooden door is also added which shows a fine example of 8 and 12-fold rosette pattern. (Jarrar, Riedlmayer and Spurr, 1994, Abdullah and Embi, 2012).

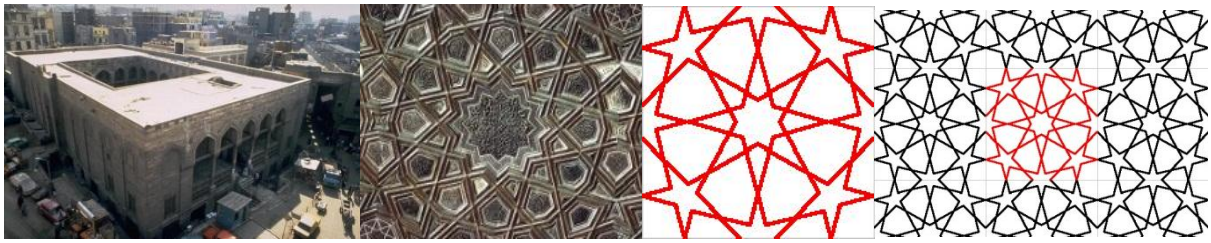


Figure 8: Mosque of Al-Salih Tala'i the fold rosette pattern detail in the mosques interior. Rabbat n.d, Wade 2017) The pattern tessellation drawn by authors

After the Seljuk's, the Mamluks period is considered as the second artistic movement. Their architectural ornamentation geometrical motifs were designed more as main focal motifs and less interwoven (Bloom, 1999). 16-point geometrical patterns were an extraordinary feature of the ornamentation of their time. One of the most remarkable works of the Mamluks can be considered as Mosque of Baybar's (1260 CE). Its interior ornamentation has scripts carved in stucco and it has geometrical ornamentation on windows (similar to the 12-point pattern in Kharaqan tombs, Qazvin, Iran). (Abdullah and Embi, 2012) The facade of the mosque has Ablaq (ornamentation using dark and light-colored stones).

Secondly, in the Qalawun Complex of Cairo (1283-5 CE) the surfaces have remarkable geometrical motifs in different techniques such as stucco and marble carvings, wooden inlays and paintings (Flood, 1997). The patterns used majorly in the interior, for the ornamentation over the ceiling, doors, windows and walls are the 6, 8 and 12-point geometrical motifs. (Figure 9) The most extraordinary element of the mausoleum is the Mihrab with the 10-point geometrical motif which is considered as the earliest of its type (Abdullah and Embi, 2012).

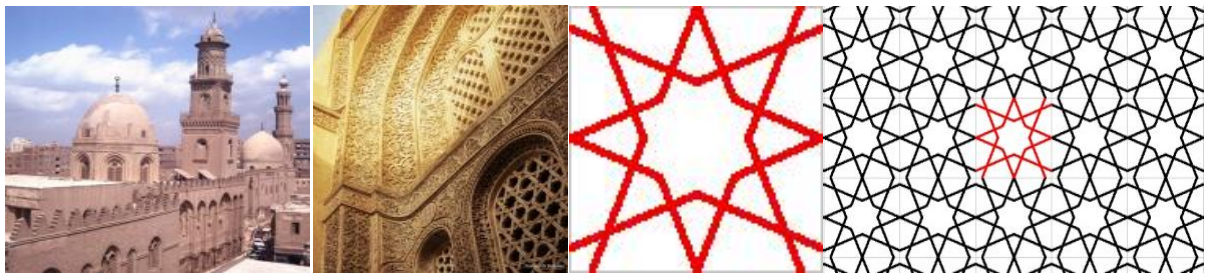


Figure 9: Qalawun Complex (A. Badaway 2010, O'Kane 1995) The pattern tessellation drawn by authors

Sultan Qaybtay Mosque and Mausoleum (1472-75 CE) is the ultimate achievement of architectural development in Cairo (Fletcher and Cruickshank, 1996). The remarkable carved geometrical motifs on the dome's exterior (with 10 and 9 and 16-point geometric patterns) and the wooden Mimbar with 10 and 16-point geometrical pattern are the most important achievement of that period (Abdullah and Embi, 2012), (Figure 10).

Figure 10: Sultan Qaybtay complex (left), the interior of the dome showing the geometric pattern using 8-point star, (middle) the exterior of the dome showing the remarkable use of 9, 10 and 16-point pattern (right)(Torky 2017)

Later, the Ottoman Empire, considered as the master builders. Their work was influenced by the Seljuk's style, with some inspirations from Mamluks (Yalman, 2000). The Ottoman artisans used various materials for ornamentation but majorly wood, marble and glass (colored). The use of polychromic tiles with floral and geometrical patterns known as Iznik has been the most distinctive element that has been widely used in their buildings. In the Ottomans works more floral and vegetal patterns are observed and the geometrical ornamentation was limited to doors and Minbar panels only. 8 and 16 point geometrical patterns, 5, 6, 10 and 12-point geometrical patterns were more popular amongst the artisans and architects of the Ottoman Empire (Abdullah and Embi, 2012). The most remarkable architectural works of the Ottoman's is in the present day cultural capital of Turkey, Istanbul, which was then the capital of the Ottoman Empire.

Sehzade Complex (1544-8 CE) has 6 and 10-point geometric motifs over the doors, portals and on the stone minbar 9, 10 and 12-point geometric motifs are carved. It is one of the most significant architectural masterpiece of the era designed by the Master Architect of the Ottoman Empire, Mimar Sinan (Yalman, 2000), (Figure 11). Suleymaniye Complex (1551-8 CE), Haseki-Hurrem Baths (1556 CE) and Selimiye Complex (1568-75) in Edirne. All these buildings main ornamentation focus has been on floral motifs designed on Iznik tiles with few geometric patterns on doors, window crowns and carved marble mimbars (Yalman 2000).

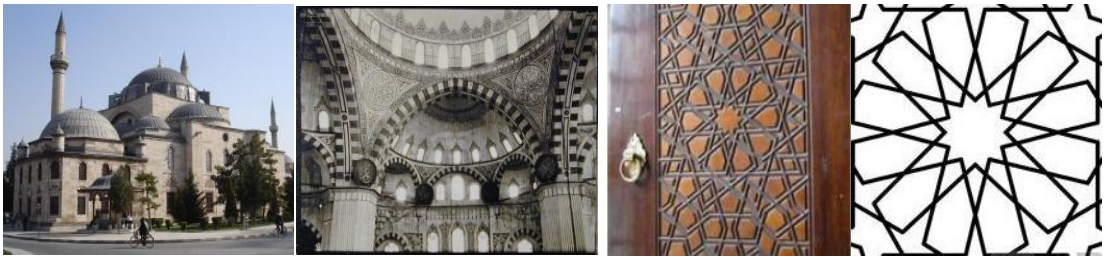


Figure 11. Sehzade Complex, Istanbul (Millett 2008, Kocaman 3013, Kose 2012)

It was during the Safavid period when there was a significant growth in art and science. They got the rich architectural traditions and techniques in the legacy (Yalman, 2000). They used geometrical (fusion of floral) ornamentation on all building types. In Isfahan there are two important examples; Ali-Qapu Palace (1598 CE) and Chehel Sutun Palace (1645-47), both the buildings are secular and show extensive use of geometrical ornamentation (8 and 10-point geometrical patterns) on balconies and ceilings along with decorated muqarnas, carved stuccos and paintings with floral and figural motifs. Figural paintings narrating historical events were also common in palaces of Safavid era. (Abdullah and Embi, 2012). In religious building these geometrical patterns were fused with calligraphic inscriptions. In the Safavid architecture the use of combined patterns was less.

Then came the Great Mughals contribution to geometric patterns, they ruled as a multi-cultural empire and drew inspirations from all great works of art and architecture (early Islamic, Hindu and Persian style) expressing their multi- cultural perspective. This enriched their aesthetics, teaching them the significance of geometry in architecture as a universal language of unity and symmetry (Dadlani, 2016).

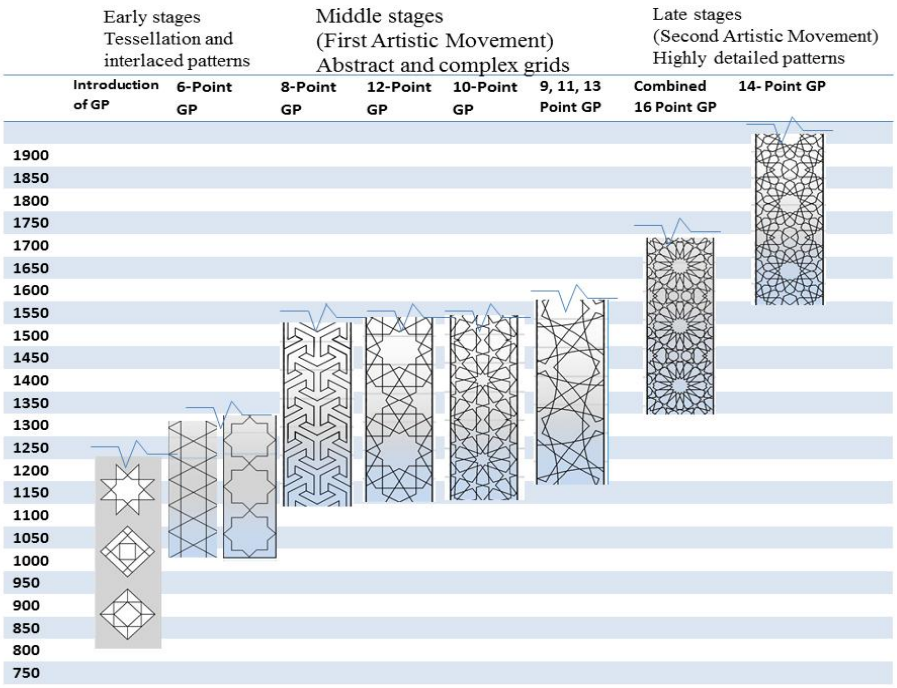
Their early architectural example with floral ornamentation (tiles and paintings) is found in Sher- Shah Mausoleum (1540-5 CE). Later, in Delhi, the Mausoleum of Humayun displays the use of different materials and techniques, the use of white marble frames over a contrasting red sandstone structure makes this building one of its kinds. The use of 6 point and 8 point geometrical motifs are used in floor patterns and are gracefully designed and carved in the window grills (screens or jali) and balcony railings. (Figure 12) The same use of materials and patterns are also found in Agra's Red Fort (1564-80 CE), along with few 10 and 12-point

geometrical patterns. By the end of this era more examples of 10-point geometric motifs are observed, such as in Fatehpur Sikri's Friday Mosque (1571-96 CE), where one of the earliest examples of 14-point pattern over the main dome's piers is also found (Abdullah and Embi, 2012).

Figure 12. Humayun's tomb, Lahore Fort, Taj Mahal, (Remsberg 2017, Nawaz 2013, Asitjain 2009) The pattern tessellation drawn by authors

They avoided complex geometrical patterns in their designs and focused more on proportions and angles while designing the patterns. Finest examples of this period which display the designs with 6, 8, 10 and 12-point patterns over sandstone and marble inlay work are, Akbar The-Great's Tomb (1602-12 CE) and the Tomb of Etimad-ud-Daulah, in Agra. The most extraordinary Mughal Complex that represents geometric patterns and ornamentation at its best are found in the Great Taj Mahal and Lahore Fort. (Figure 12) Remarkable work of craftsmanship is seen in the screens, windows, floor finishing, courtyard's fountains, mosaics and railings.

Table 02: The Table represents the era when a geometric pattern was introduced and how they co-existed in certain eras. The influence and the development of the patterns are visible in this table. Table drawn by the authors.



To sum up, tracing back the formation of the geometric patterns and its evolution over the time shows the strong impact all the empires had over the following one. The artisans and craftsmen of each era tried to make the pattern one of its own kind, more symbolic and more complex. The use of materials and experimentation of different techniques shows that with the

passage of time they mastered this art of composing and repeating in any possible area. The dome, walls, floors, minarets, mihrabs, windows and balconies, all elements were used as the artisans' canvas for ornamentation.

3. GEOMETRİC PATTERNS İN JALİ DESİGN

Jali (Urdu word) means a net or a fine web. It is an ornamental perforated screen found in Indian, Indo-Islamic and Islamic architecture. As a shading device it is an egg crate, a combination of horizontal and vertical shading device at a minuscule scale. It appears to be 2-dimensional, but the thickness along with the interlinked balusters forms many small devices equivalent to a large overhang or a vertical fin (Kamath and Daketi, 2016).

Jalis or screens have been a significant architectural feature of many decades. In earlier times these structures did not only play aesthetic role in a building design but also played major role in tackling the natural conditions in buildings ventilation and lighting. (Figure 14) These passive cooling and lighting screens have been part of many different regions design and architectural techniques which results in different use of materials and designs. Most of the regions with hot climatic conditions have been using the screens efficiently and has been a part of their building practices for years (Kamath and Daketi, 2016).

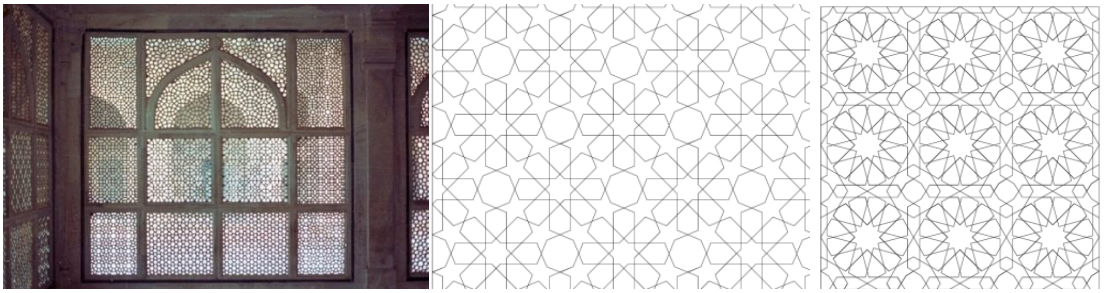


Figure 14. Jali at Tomb of Salim Chishti, Fatehpur Sikri (Godel, 2011) Patterns tessellation (Broug, 2006).

Characteristics of a Jali can be mentioned as repetition, infinity and symmetry. Furthermore, Kamath and Daketi (2016) lists the main properties of a jali as follows,

- The jalis are mostly in geometric form which means the module is repeated. Complex patterns are usually made on grids. The composition of the modules usually consists of squares, triangles or hexagons.
- Since the patterns are constantly repeating itself they create the illusion of continuity beyond the frames physical boundary, thus making it challenging to identify the overall patterns starting and ending points.
- This intentional repetition is symbolic of infinite nature of God. It is so because Muslims believe that human cannot imagine a stable palace for God. (Kamath and Daketi, 2016)
- The jalis are usually in symmetrical form made by mirroring of the pattern or unit on the selected stone

3.1. Mughal screens as a medium to analyze geometric patterns.

The screens or jalis have been a major architectural element in the Mughal architecture and the use of geometrical patterns and different layouts have been observed in most of their works. The most extraordinary Mughal Complex that represents geometric patterns and ornamentation at its best are found in the Great Taj Mahal and Lahore Fort. Remarkable work of craftsmanship is seen in the screens, windows, floor finishing, courtyard's fountains, mosaics and railings. Geometry has been important in planning as well as designing. The Mughal artisans and

architects focused more on proportions and angles while designing the patterns. Finest examples of this period which display the designs with 6, 8, 10 and 12-point patterns over sandstone and marble inlay work.

Case Study: The Jalis of The Naulakha Pavilion in The Lahore Fort

The case study focuses on a pavilion located in the northern section of Lahore Fort, the Naulakha Pavilion. This pavilion and the compound holds a great significance in the entire fort due to the uniqueness of the structure and highly ornamented walls, floors and ceilings. Naulakha is derived from nau meaning nine and lakha meaning lakhs, it is believed that the pavilion which is a summer house, was constructed expensive, costing 9 lakh rupees, which is a great amount at that time, due to its unique curvilinear roof and semi-precious stones inlay work, making it an icon. Not only the structure is extraordinary but its placement with its west facing façade giving the view of the entire old city (walled city) made it more special.

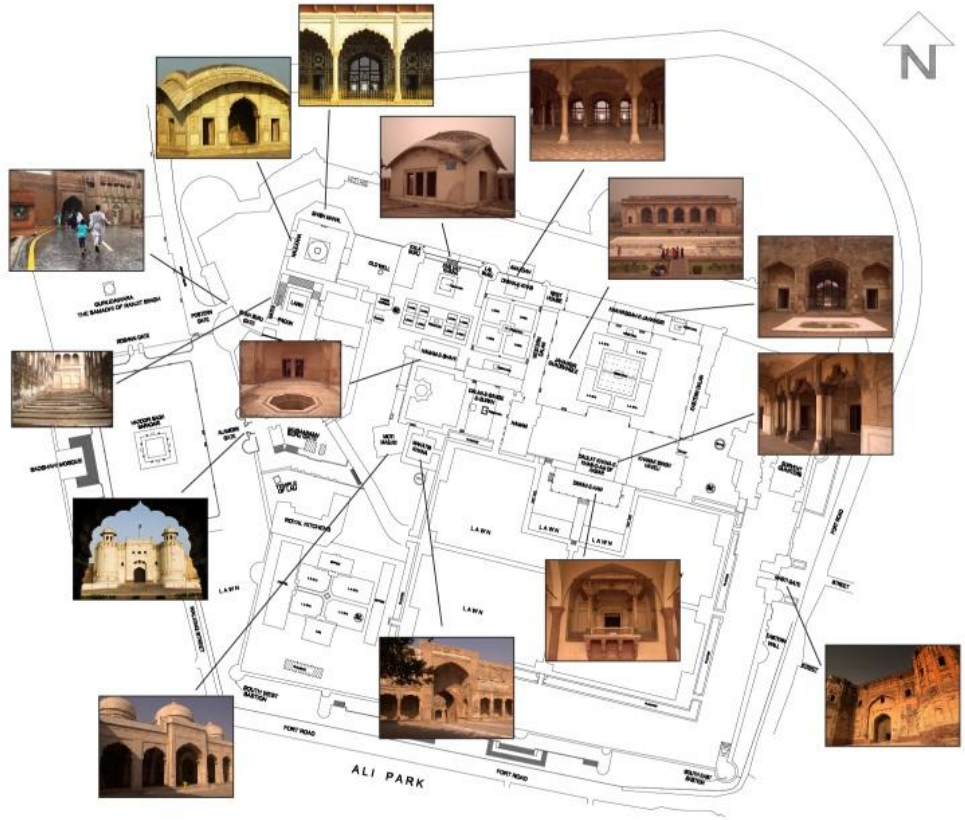


Figure 15. The Lahore Fort Complex plan showing the buildings place (Saqib, n.d)

Lahore, the city that was once the historic capital of Punjab and it was the Great Mughal Empire's thriving cultural hub, due to which it holds a very important historical and cultural significance for Pakistan. The Walled City Lahore is amongst the most remarkable example of planning and architecture during the era of the Great Mughals. The Lahore Fort, situated in the Walled City Lahore is one of the great architectural legacy left by the Mughals. It not only tells us tales of how the common people and the royals lived there but also about the highly skilled artisans who ornamented every space with detail and finesse.

The Lahore Fort has numerous fine examples of jalis which is not only used for ornamentation purposes but also plays significant role in the different spaces architectural requirements. When the fort was designed and built, the river Ravi flowed along the north of the fortification wall. The cusped arched openings with marble geometric jalis, integrating viewing windows not only provided a delightful scene from the fort but also made the pavilions more comfortable during the hot summer days, by allowing more air movement and diffused light only. The fort complex is humongous therefore only few parts of the widely spread complex are discussed regarding the main aspect that is the jali work.

***The Naulakha Pavillion*:** Located in the northern section of the complex this pavilion is a personal chamber built im 1633 by the Mughal ruler Shahjehan as a summer pavilion. It is constructed in white marble and is considered remarkable due to the thinness of its curvilinear roof and the jali inside. Its considered as a masterpiece due to the fact that no joints exist and is perfectly balanced to equalise the strains and stresses of each piece of pure white marble used. To hide from view from the ground, the joints had 'merlons' capped at the edges (Sheikh, 2015). The center of the pavilion has intricately carved marble jali, which was descirbied to be ornamented in delicate 'parchin kari' (pietra dura) covered with a silver lining, which is considered amongst the finest in the world evn today. The rest of the walls are ornamented with semi-precious stones inlay work in floral patterns and geometric ornamentation on floor and roof of the pavilion. (Figure 16)

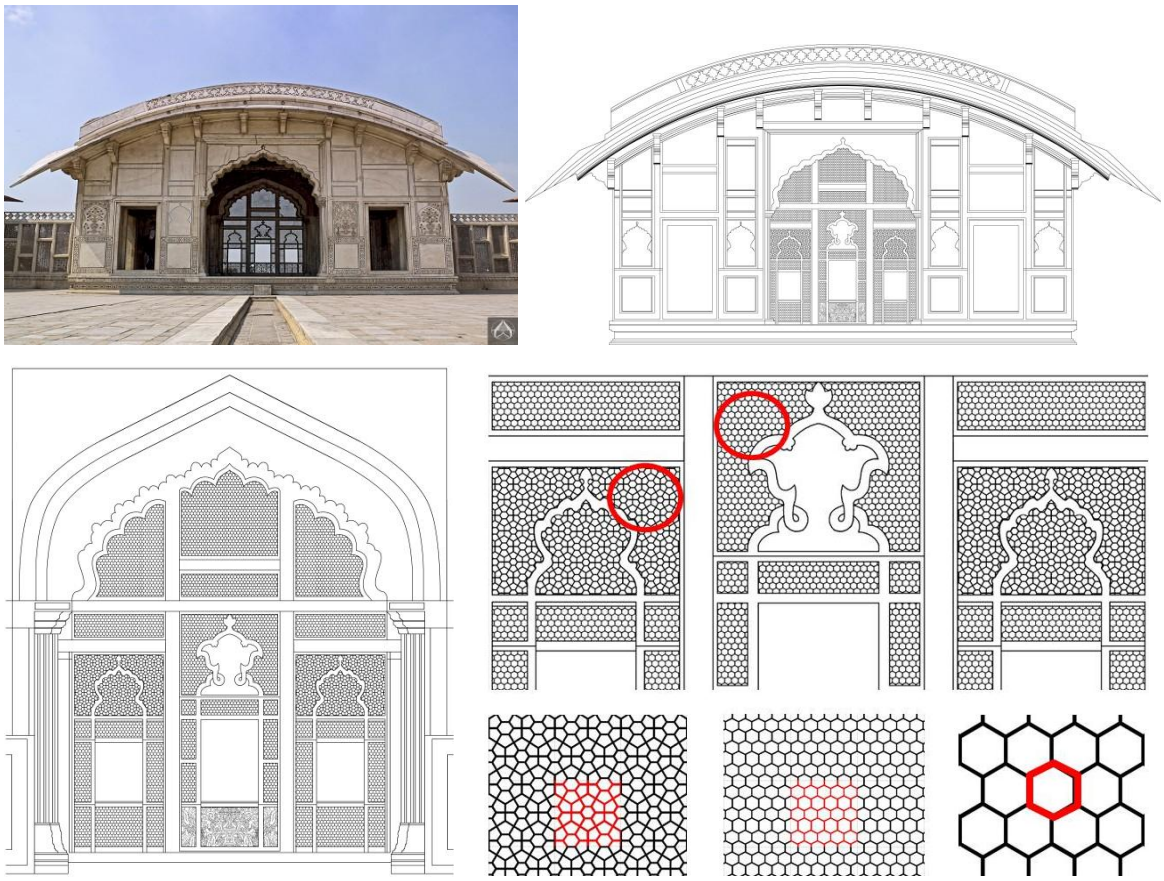


Figure 16. The Naulakha Pavilion. (Mir, 2011). Drawings of the pavilion. The central arch of Naulakha Pavilion, with intricate patterns carved out from marble. The screens on the central window are different compared to the side panels windows frame, but the basic pattern is same, the hexagon. The pattern tessellation drawn by authors

The interior of the pavilion, stone inlay on the floor and glass work on the roof show the intricate use of pattern by the artisans. The 8-pointed star pattern and 8-fold rosettes is observed on the floor and the roof layout. The jali of the pavilion is not very complex, it's a honeycomb pattern carved out from the while marble. The central panel is a classic example of the use of hexagon in jalis, whereas the two side panels of the pavilions screen wall show a different layout using the same basic hexagonal pattern. (Figure 16-17)

Figure 17. The interior of Naulakha Pavilion, The Sheesh Mahal (Malik 2015, Shah 2011)

These exquisite jali windows allow cool breeze and a view of the city streets. The same jali design is observed in the Sheesh Mahal (The Palace of Mirrors), which is also in the same compound.(Figure 17 centre and right) The finely carved jali isn't only a part of these marvelous pavilions but also repeated throughout in the surrounding walls of this complex.(Figure 18) Again, as observed in the earlier jalis, it is a honeycomb pattern using the hexagons (six point geometrical patterns) and on few of the panels, octagons (eight point geometrical patterns) are used in a fairly complex tessellation.

Figure 18. The walls and balcony railings are also carved jalis, with six and 8-point geometrical patterns. (Markcareaga, 2004)

4. Conclusion

Throughout the history of the Muslim Art and Architecture one can observe that all the empires focused on the architecture and its ornamentation. Art and architecture are always considered as major elements in each empire, as it reflects the strength, wealth and success of that era. It not only marks their rule in that region but also leaves an everlasting impression, telling the tales of their golden era to the generations to come.

This study is an attempt to map the styles of ornamentation in different Islamic empires and the evolution of the Islamic geometric patterns. The research focuses on few major empires and their contribution in the development of the patterns, in the light of the examples found in the existing architectural marvels of that dynasty. One thing that remains constant in all these

empires is their passion and focus on the ornamentation and glorification of religious and important buildings, to mark their eras own significant style. Table 2 gives a basic information about few commonly used geometric patterns, their introduced time period and how they co-existed in certain eras. The influence and the development of the patterns on the later empires are visible in this table. This table gives us a clear image of how complex and detailed the patterns became over time.

The timeline shows how the Muslims took inspiration from the existing cultures and with the passage of time they successfully developed their own artistic style and language. Experimentation with different materials and application on different architectural elements, the complexity of the geometric patterns and its tessellation is observed. Concluding example from the Mughal architectural marvel shows how these various patterns are used differently, along with the significance of jali, as intricate finely designed and crafted screens for ornamentation purposes along with its major role in the passive cooling and tackling the natural conditions in buildings ventilation and lighting.

After years of evolution and complexity of the Islamic geometric patterns, the Naulakha Pavilion shows us how the geometric pattern used in the screens and flooring, retains its basic form, as seen in the earlier example of the Abbasid Dynasty's, Ibn Tulun Mosque in Cairo, where the six point geometrical pattern, hexagons and eight point geometrical patterns were introduced, as shown in Table 2, the early stages of the artistic development in the history of Muslim art and architecture. As shown in Table 2, the basic pattern forms originate from the simple layouts. The basic elements of the pattern and its formation remained intact and in between new compositions and tessellations took birth, giving each tessellation an identity of its own and each pattern a new life, on a different material with a different technique.

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