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Evolution of Islamic Geometrical Patterns

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Abstract

Although Islam gives function and not form, Islam as a context has affects on forms and ornaments in somewhat. The great role of geometry in Islamic architecture due to restriction of using natural figures is an example. In this research, the application of Islamic geometrical patterns (IGPs), and suitability of their usage over architectural elements in terms of time-scale accuracy and architectural-style matching is studied. A detailed survey of hundred well-surviving buildings throughout the Muslim world of architecture has been conducted for this purpose and as a result, not only origin of patterns identified, but also radical artistic movements throughout the history of Islamic geometric ornaments revealed. Finally, this study sketches the evolution of IGPs through history, while regional diversities are also taken into account.

Keywords: Islamic; Decorative; Geometrical; Patterns; Art; Architectural decoration

Introduction

For centuries, Islamic geometrical patterns (IGPs) are used as decorative elements over walls, ceilings, grilles, doors and openings, dome, minarets, to name a few. However, having no guideline and code for these adorable ornaments, has often caused inappropriate use, in terms of time-scale accuracy, architectural-style matching and even identity. An example of misunderstanding of historical roots and origins of IGPs is the decorative pattern of Enghelab (Revolution) Square in Tehran, Iran. The six-point geometrical pattern, which has been used in that square, is one of the earliest types of IGPs and can be found in Ibn-Tulun mosque in Cairo, which has existed since the late Ninth Century. However, lack of knowledge about the history of IGPs and their evolution among Iranians Media and authorities, made a confusion of using Zionist sign over one of the main squares of the capital, which is supposed to be a reminder of the Islamic revolution in Iran. This incident ended up by demolishing the square. Figure 1 shows the response of the municipal authorities to media criticism.

Figure 1: Demolishing Enghelab Square in Tehran

In terms of timescale accuracy, architectural style and property, Great Mosque of Tehran is an interesting example. Its design is inspired by the distinctive Seljuk architecture (1037-1194 CE). However, patterns designed for decorating exterior surfaces of its main courtyard is a type ten-point geometrical pattern, which were not common during Seljuks and was not in favor of Seljuk architects and artisans. The research aims to investigate IGPs historically and draw a time-

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chart of evolution of IGPs to answer questions regarding the suitability and appropriate use of these patterns as buildings decorative elements in terms of both "time-scale accuracy" and "architectural-style properties and order".

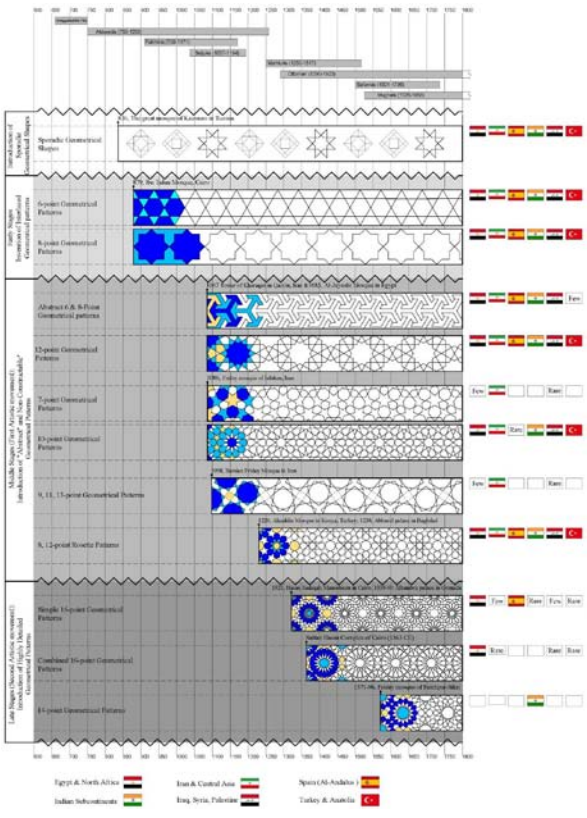
Period of Geometry Infiltration into Islamic Architecture

"For without symmetry and proportion no temple can have a regular plan," ancient Roman architect, Marcus Vitruvius Pollio (80 BC to 15 BC) wrote in his famous treatise *De Architectura. "Twenty years were spent in erecting the pyramid itself: of this, which is square, each face is eight plethora, and the height is the same..."* – father of History, Heroditus (484 BC-425 BC). With these mentioned examples, it can be stated that the integration of geometry and architecture has been existed and understood long before the birth of Islam. Nevertheless, we cannot dismiss the importance of geometry through the history of Islamic architecture. Hence, the question is when and how did geometry infiltrate into the Islamic architecture. The expansion and development of geometry through Islamic art and architecture can be related to the significant growth of the scientific and technological innovations of Eighth and Ninth centuries in the Middle East, Iran and Central Asia by translations of ancient texts from languages such as Greek and Sanskrit into Arabic (Turner, 1997).

By the 10th century, original Muslim contributions to the sciences became significant; in this context, important developments in the field of geometry resulted from the work of, among others, Umar-al-Khayyam, Abu'l Wafa al-Buzjani, Abu Mansur al-Khwarizmi and Ibn-al-Haytham (Özdural, 1995; Mohamed, 2000). It is believed that the earliest written documents on geometry through the Islamic history of science, is Khwarizmi's mathematical book; The Compendious Book on Calculation by Completion and Balancing, written in early Ninth Century (Mohamed, 2000). Hence, it is not surprising to see a gap of nearly three centuries from the rise of Islam in the early Seventh Century (Berkey, 2003) to late Ninth Century. Hence, the earliest example of decorative geometrical patterns can be traced over surviving buildings of the Muslim world (Table 1).

By detailing the survey of surviving monuments, evolution of IGPs through history of Islamic architecture has been studied. Some minor dynasties, in terms of their impact, such as Buyid, Ayubids, Ilkhanid and Timurid have been neglected and would be studied in detail in other research. Patterns are evoked and their tracks have been traced to find earliest surviving examples. Concluding time-chart (Table 1) sketches the evolution of Islamic 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 architectural-style and time-scale accuracy.

Table 1 : Time chart of evolution of IGPs through the history



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Types of IGPs

Definitions and classifications of IGPs are not in the scope of this research. However, it is required to provide sketchy description about the types of Islamic architectural patterns. Most of IGPs are based on constructive polygons such as hexagon and octagon. By connecting vertexes of these shapes, star-polygons will appear which are considered as fundamental element of Islamic geometrical patterns. It is from this fact, which the very first level of IGPs' classification starts (El-Said, 1993; Broug, 2008). For instance, all patterns in which their main elements are from hexagon or hexagon-star come under 6-point geometrical patterns and the star is called as 6-point star (Figure 2). Accordingly, patterns are further called as 8, 10, 12, 14, 16…-point geometrical patterns. As can be seen in Figure 2, in certain level, the sides of two adjacent rays of star become parallel which will form a deformed hexagon.

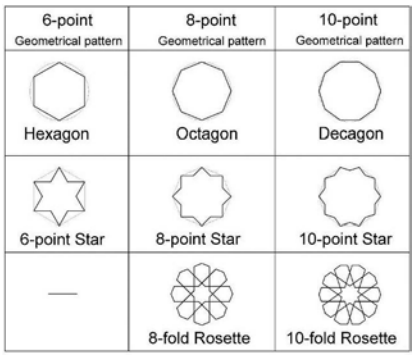

Figure 2: First level of IGPs classification

These shapes represent rosette leaves; hence, the patterns containing such elements will come under "n-ford rosette", such as eight or 10-fold rosette. In the following pages whenever a pattern is called "n-point geometrical pattern" it means that it falls under relevant type of polygon, which it is constructed from. It is interesting to say that as a result of following study, we can observe that the evolution of Islamic geometrical patterns follow the difficulty-path of construction of the above mentioned polygons from the easiest (in other words hexagon) to more complicated types of polygons and stars.

Umayyad Architecture

Umayyad Caliphs (660 to 750 CE) and their dynasty established the first Muslim Arab monarchy and were based in a region where nowadays is called Syria. They start to import and adopt the construction techniques form Sassanians and Byzantine empires where they have already conquered (Fletcher and Cruickshank, 1996; Petersen, 1996). In terms of building and architecture, the focus of Umayyads was on mosques and palaces. By the end of the Seventh and early Eighth Centuries, vegetal and floral patterns derived from Sassanid and byzantine architecture was common in the Islamic world. A great surviving building of this period is Dome of Rock (Figure 3) which began construction in 688-691 CE. The external surfaces and facades are covered by glittering mosaics which, if it followed the surviving internal surfaces, were from the Hellenistic composition of vegetal motifs and swirling patterns with plenty of gold tesserae admixtures among the predominant tiles of green colour (Grube, 1995 and Michell). Throughout the 16th Century and under Ottoman rulers, the outer mosaics repaired and replaced by new façade of tile and marble with geometrical design from Damascus.

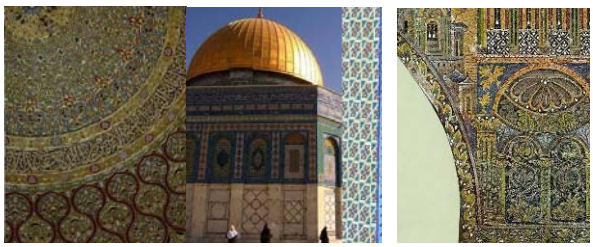

Figure 3: Dome of Rock, original ornaments of interior with floral motifs (Left) - New façade with geometrical design, date back to 16th century (Center) - Facades mosaics of Great mosque of Damascus (Right)

By 705 CE, grate parts of Damascus Christian temple, converted to the Great Mosque of Damascus (Flood, 2001). The original decorative patterns are floral resembling the rich gardens and natural landscape of Damascus. The floor finishing of the Sahn repaired and renewed numbers of times, therefore its geometrical

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designs are later additions and not original. Another well-surviving building of Umayyad period is Qasr-al-Mshatta (743-744), in Jordan. The surviving decorative carved stonework of its façade, represents a significant step to real art and architecture of Islam. The carved patterns are full of woven vegetal designs along with animal and human figures (Fletcher and Cruickshank, 1996; Baer, 1999).

Survey Umayyad surviving buildings, shows that vegetal ornaments remained common features of their architecture. Finishing surfaces and facades are mostly covered with carved molded stucco, mosaic and wall painting, with figural and floral motifs. However, it seems that it was by end of the Umayyad era, that the use of figural patterns in mosques becomes limited.

Abbasids Architecture

Abbasid caliphs (750 to 1258 CE) were wealthier than their descendent and they start to trade over much wider regions from east of Persia to west coast of Africa. These active trades imposed Muslims to wide range of traditions and cultures where Persian culture became more predominant in their era and made Abbasid a "Perso-Arab" dynasty (Fletcher and Cruickshank, 1996; Petersen, 1996). By first two centuries of Abbasid, the new concept of Islamic art and architecture started to shape and by end of their era, the Islamic art and architecture were almost introduced and recognized by architects and artisans.

The Great Mosque of Kairouan (Tunisia) originally constructed in 670 CE, and rebuilt in 836 onward is a great example of Abbasid-Aghlabid buildings. Ornaments of this building are mainly designed with vegetal and floral motifs; however, some elementary geometrical shapes can be noticed. These geometric ornaments are designed more as individuals and unit shapes rather than a woven and interlaced geometrical pattern (Figure 4). It shows the earliest stage of application of geometrical ornaments in Islamic architecture.

Figure 4: The Great Mosque of Kairouan in Tunisia

Decorative patterns of interior arcades (left) and finishing surface of the original Mihrab (Right), show the individual geometric shapes of the mosque. The Mosque of Ibn Tulun (876-9 CE) was built by the order of Ahmad Ibn Tulun, the Abbasid governor of Egypt. In general, the layout and decorations follows the Samarra-Iraqi style where Ahmad Ibn-Tulun came from (Antoniou, 1998; D'Avennes, 2008 and Scanlon). The simple geometrical patterns used in this mosque are among earliest examples of geometrical motifs of Muslim decorative arts.

Figure 5 : Ibn-Tulun Mosque in Egypt

Figure 5 illustrates the early example of eight-pin star geometrical pattern (first two from left) and six point geometry (third and fourth). Abbasid Palace of Baghdad (1179-1230 CE) and The Madrasa of Mustansiriyeh (1233 CE) have almost the same plan and structure (Grube, 1995). With muqarnas decoration and detailed geometrical patterns of carved brickwork and terracotta, they are great examples of architectural tradition and techniques of late Abbasid and early Seljuk's era. Here we can find one of the earliest examples of additional rosette leaves to star elements of eight and 12-point geometrical patterns (Figure 6).

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Figure 6 : Abbasid palace in Baghdad, original geometric decorations before restoration

Architectural decoration and ornaments such as wall painting, carved wood, stone, stucco, terracotta and brick works, were popular during the Abbasid era. By the late 8th and early 9th Century, geometrical shapes, in the form of individual and sporadic elements, were introduced in surface decoration. However, it was not until late Ninth Century that woven geometrical shapes in the form of geometrical patterns adopted by artisans and become predominant in Islamic empire.

Seljuk Architecture (First Artistic Movement)

Seljuks were Turko-persian Dynasty (1038 to 1194 CE) which ruled much of Islamic world from Anatoly to central Asia to south coast of Iran. The first buildings constructed by Seljuks were in Iran, and in terms of architecture, they followed the construction techniques of Iranian architects and artisans (Hillenbrand, 1999; Clévenot, 2000). During the Seljuks, construction of Madrasas and tombs become very popular in Islamic world and Iwan become the principal element of structures for both religious and secular buildings (Ettinghausen, et al., 2001). Seljuks took great steps in transformation of ornaments and decorative patterns from floral and figural to geometrical, and their architecture is more characterized by geometrical pattern. Seljuk architects and artisans, designed more sophisticated interlace geometrical patterns and the earliest example of abstract 6 and 8-point geometrical patterns can be seen throughout this era in Table 1 before.

Tomb Towers of Kharaqan (Figure 7) with 15 m heights and diameter of 4 m, built during 1067-93 in Qazvin province of Iran, are examples of early Seljuk architecture. Towers are octagonal in plan with brick walls and double layer domes. Facades are elaborated with very fine decorative panels while each panel has different pattern including stars and abstract geometrical motifs.

Almost concurrent to Abbasid palace in Baghdad, signs of additional rosette leaves to star patterns can be found over Mihrab's crown of Madrasa al-Firdaws (1235- 6 CE) at Aleppo, Syria. The marble Mihrab is decorated with geometrical patterns, which has remarkable detailed eight-point rosette pattern.

Figure 7 : Tower of Kharaqan in Qazvin, 1093, 12-point, abstract 6 and 8-point geometrical patterns

Friday Mosque of Isfahan has much of its development through the Seljuk era. The two main domes are constructed in 1086 and 1089 and it was in the early 12th Century that the plan of mosque changed to four-Iwan Style. It is a perfect example of Seljuk detailed decorative patterns, made of brickworks (Grube, 1995). Figure 8 shows that through late 11th and early 12th Centuries, five and eighth-point star concepts were not only popular in decorative elements, but also the techniques of integrating these decorative concepts with structural elements had already been invented. Apart from common six and eight-point geometrical patterns of Seljuk era, amazing patterns can be found over the walls of southern domed-area of Friday mosque of Isfahan, which dates back to 1086 CE. One is the rarest example of pattern containing heptagon and another might be one of the earliest examples of 10-point geometrical patterns.

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Figure 8 : Great Mosque of Isfahan in Iran, northeast dome and its interior design (Left and Center) - roof of praying hall dates back to twelfth century (Right)

During the Seljuks, geometrical patterns developed significantly. Surveying decorative patterns of their era from early stages to Friday mosque of Isfahan, reveals an artistic movement, which resulted in a radical change in conventional geometric patterns (for example, introducing very complex and sophisticated 10-point geometrical patterns as well as abstract 6 and 8-point geometrical patterns). This movement continued to Barsian Friday Mosque (1098) to early 13th century where the most unique and unusual 7, 9, 11 and 13-point (patterns made of non-constructible polygons) has been applied (Figure 9).

Figure 9 : Friday Mosque of Barsian in Iran, Mihrab is decorated by the rarest Islamic geometrical patterns

Fatimid's Architecture

Fatimid Caliphs (909 - 1171 CE) and their dynasty lived in North Africa. It was during Caliph al-Muizz, that Egypt become under control of Fatimids in 969 CE (Behrens, 1992; Petersen, 1996). Al-Azhar Mosque (970-2 CE and later) was the first mosque and Madrasa built by Fatimids in Cairo. Still parts of original stucco panels (with vegetal motifs) and window screens (with geometric designs) are surviving. However, stuccoworks above the windows and over the walls (with abstract 6-point geometrical design), have been added during Caliph al-Hafiz (1129-49). There is another Mihrab with significant geometrical decorations, which was built during the Ottoman restoration in 18th Century (Behrens, 1992; Rabbat, 1996). Meanwhile, the Al-Juyushi Mosque (1085 CE) in Cairo is a relatively small mosque, with domed prayer hall. The most significant surviving element of this building is lavish carved stucco of its Mihrab (Figure 10) with floral and geometrical patterns (Behrens, 1992). Abstract six-point geometrical patterns over spandrel of Mihrab are similar to Seljuk style. Interior apex of dome is also designed with six-point star with Arabic inscriptions.

On the other hands, the Al-Aqmar Mosque (1125 CE) in Cairo is a great example of mature Fatimid's architecture, with keel-arches, fluted domes, rich carved façade, Muqarnas pendentives and the layout which covers the difference of Qibla and main street directions (Yeomans, 2006). The façade is elaborated with calligraphic, vegetal and geometric decorations, however motifs are replication of previously introduced designs.

Another remarkable Fatimid building is Mosque of Al-Salih-Tala'i (1160 CE). In terms of structure and decorative techniques, it is so close to Al-Aqmar mosque (Spurr and Riedlmayer, 1994). Same as Al-Aqmar mosque, six and eight-point star geometrical shapes can be found in form of projected sculptural decoration over the walls. However, a perfect proportioned 12-point geometrical pattern is carved over the Minbar, which was added during Mamluks in 1300 CE. It is considered as the second Minbar in Cairo. The carved wooden door is also dated back to 1303, which is decorated with 8 and 12-fold geometrical rosette pattern.

Early Fatimid Decorative pattern were more in the form of isolated projected elements or sculpture, rather than being an entire surface-covering pattern. Although they could be found in the form of interlaced geometric pattern in limited areas such as window screens, they were more in the form of focal points in decorations and not as woven geometrical pattern.

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Mamluks Architecture (Second Artistic Movement)

Mamluk Sultans and their dynasty ruled most parts of Syria and Egypt for more than two and half century during 1250 to 1517 CE (Petersen, 1996). The relatively stable government backed by their professional army structure and flourished economy on both in trading and agricultural aspects. Hence their wealth made their cities and Cairo as capital the center of intellectual and artistic activities. Mamluks architecture influenced by their predecessor Ayyubids, as well as Italian and Andalusia styles. By the 13th Century, most cities had congregational mosques, therefore Mamluks made their effort in construction of madrasas, tombs, bazaar (souq), hospitals and caravanserais (Behrens, 2007). Vegetal, geometrical patterns and calligraphy were so popular in design of carved wood, stone and brickworks. Like the Fatimids, geometrical patterns remained less interlaced and used more as focal elements of decorations or adopted in limited areas.

Mosque of Baybar (1260 CE) in Cairo's has façades, made of alternative dark and light stone (i.e. Ablaq) , and indoor decoration is carved stucco scripts and window grilles with same 12-point geometrical patterns of Kharaqan tombs in Qazvin, Iran. On the other hand, the Qalawun Complex of Cairo (1283-5 CE) has significant and adorable finishing surfaces of paintings, rich carved marble and stucco and gilded wooden inlays with geometrical motifs. 6, 8 and 12 point geometries are repeated all over window grilles, doors, walls and ceilings. But it is 10-point geometrical pattern of mausoleum's Mihrab (Figure 11), which might be the earliest of its own type, made this monument as one of the most outstanding Mamluk heritage.

Zigzag and Ablaq textures are used as external decoration of Mosque of Al-Nasir Mohammad (1318-34 CE) which is similar to the Qalawun Mosque, very advanced type of 6 and 8-point geometrical patterns have been adopted in the decoration. Almost the same 10-point geometrical pattern is also used in the hood of Mihrab (Figure 11).

Figure 11: Qalawun complex , 6 and 8 point geometrical patterns over entrance door (Left) and ten-point Star pattern in Mihrab (Center) - Hood of Mihrab in Mosque of Al-Nasir Mohammad (Right)

Despite all brilliant floral decorative patterns of Sultan Hassan Complex (1356-61 CE), not only the most advanced type of 6, 8, 10 and 12-pointed geometrical patterns are used, but one of earliest examples of 16-point geometrical patterns can also be found in panels of its wooden Mimbar (Figure 12). Although 16-point star appeared earlier over dome of Hasan Sadaqah Mausoleum (1321 CE in Cairo), but 16-point geometrical patterns in Sultan Hassan complex are astonishingly complex and mixed with 9, 10 and 12-point star and rosette. Surprisingly, even signs of 20-point star geometrical pattern can be found on the suspended grand bronze lantern of sanctuary.

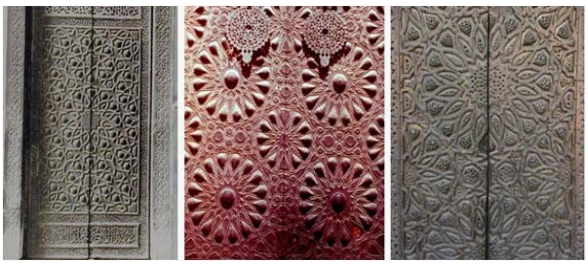

Figure 12 : Sultan Hassan complex in Cairo

Sultan Hassan complex is in the early stages of second artistic movement in the history of Islamic geometrical patterns, when the Muslim architects and artisans, started to combine multi types geometric patterns (such as 6, 8, 9, 10-point… geometrical patterns) in a single decorative pattern (See Time-chart in Table 1).

Similar samples of 6, 8, 10, 12 and 16-point

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geometrical pattern can be found through the decorative elements of Khanqah of Sultan Faraj-ibn-Barquq (1399-1411 CE) and Muayyad mosque (1415-21 CE) both in Cairo. Sultan Qaybtay Mosque and Mausoleum (1472-75 CE) "is the ultimate achievement of architectural development in Cairo" (Fletcher and Cruickshank, 1996). All the interior and exterior façades are elaborated with complex floral and geometrical patterns. The dome external decoration is carved geometrical pattern, which is the one of earliest examples of its own type in Cairo (Yeomans, 2006). Combined and complex geometrical patterns are also applied in this building, whereas combination of 10 and 9 and 16-point (over the apex) geometry can be found in carved patterns of dome. The other is combination of 10 and 16-point geometrical pattern over carved vertical panels of its wooden Mimbar (Figure 13).

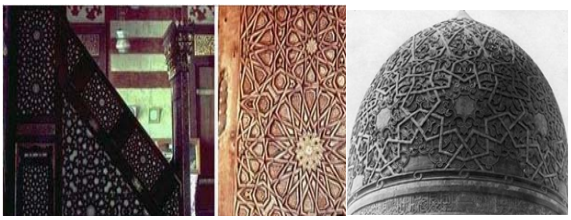

Figure 13 : Sultan Qaybtay Mosque, Carved wooden mimbar (Left, Center) - pattern of dome (Right)

The same styles repeated in buildings of next decades, such as Amir Qijmas Al-Ishaqi Mosque (1480-1 CE), Sultan Qansuh al-Ghuri Complex and Wikala of al-Ghori (1505-15 CE). This shows that through late 15th and early 16th Century, 16-point and combined geometrical pattern were so popular among Mamluk architects and craftsmen. However, a few examples of 10-point geometrical patterns can also be found in Amir Qijmas Al-Ishaqi Mosque and Wikala of al-Ghori.

Ottoman Architecture

Ottoman Emperors (1290 to 1923 CE) architecture developed under heavily influence of Seljuk style with background of Persian and Byzantine architecture and minor impression of Mamluks style. They were master builders and achieved high advanced techniques of proportioning inner and outer scales, using light, huge domes and semi domes, vaults and roofing elements (Kuban and Emden, 2010; Freely, 2011). Survey of early Ottoman buildings such as Yesil Mosque of Iznik (1378-92) and Ulu-Cami or the Great Mosque of Bursa (1396-1400) shows that early ottoman building were not rich in decorative pattern and even by end of 14th century, geometrical pattern were not so popular among ottomans architects and craftsmen.

Instead, in Yesil Mosque of Bursa (1421), geometric ornaments used extensively and samples of 6, 8 and 10-point geometrical patterns are all over the walls, ceilings and doors (Figure 14). The building restored in 19th Century, has some original polychromic tiles with floral and geometric patterns surviving.

Figure 14 : Yesil Mosque in Bursa, samples of 6, 8, and 10 point geometrical patterns

The Bayezid II Complex (1501-8 CE) is the earliest imperial mosque that surviving in Istanbul as capital of Ottomans. In general, geometric ornaments are not the main decorative elements in this mosque but there are few adorable 6 and 10-point geometrical pattern over main entrance doors and portals. There is also a remarkable combination of 9, 10 and 12 point geometrical pattern over the carved stone Minbar (Figure 15). Hoever, the Shezade Complex (1544-8 CE) in Istanbul, designed by Ottoman Master Architect Mimar-Sinan, has simple but elegant interior decorative. Although this mosque is one of the most ambitious architectural masterpiece of Ottoman Empire, but application of decorative geometrical patterns are limited to its stone Minbar and wooden doors which for the most only 10-point

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geometrical pattern is used (Figure 15).

Figure 15 : Bayezid Complex, ten and nine-point geometrical patterns (First two from left)Shezade Complex, different type of Ten-point pattern (last two pictures)

Some other adorable buildings such as Suleymaniye Complex (1551-8 CE), Sokollu-Mehmet-Pasha (1560-5 CE) in Luleburgaz, Haseki-Hurrem Baths (1556 CE) and Sokollu-Mehmet-Pasha in Istanbul (1571-4 CE) were constructed by the Ottomans during mid-16th Century onward. However, geometrical patterns were not the main decorative feature in all of them and instead it was Iznik tiles with floral motif designs that formed the essential decorative element of those buildings. Among those mentioned buildings, Rustam Pasha Mosque (1560-3 CE) in Istanbul is most famous for its exquisite Iznik tile works with floral patterns which covered most of finishing surfaces. However, few 10 and 12-point geometrical patterns can be found in design of wooden doors and Mimbar and wooden ceiling of right gallery of main praying hall which are replica of styles that has been used in earlier buildings. Meanwhile, the Selimiye Complex (1568-75) in Edirne is the culminated and the most exquisite building designed by architects Sinan (Freely, 2011). The mosque is heavily covered with Iznik tiles with floral motifs. However, few geometrical patterns can be found through its carved marble mimbar and window crowns (Figure 16).

Figure 16: Selimiye Complex, Few six and ten-point patterns over Minbar and window crowns

Marble, wood, and colored glass were main decorative materials used by Ottoman builders and the most distinctive decorative element of Ottoman architecture is their massive use of glazed polychromic (Iznik) Tiles with floral and vegetal motifs. In generals, Ottomans were in favor of floral and vegetal patterns and geometrical patterns have been limited to door and Minbar panels. Ottomans architects and artisans appreciate more 6, 5 and eventually 10 and 12-point geometrical pattern rather than 8 and 16-point geometrical pattern, which were so popular by Mamluks artisans.

Safavid Architecture

Boosting economy of Safavids (1501 to 1736 CE) along with relatively stable government caused a significant growth in science, art and particularly in architecture. They were heirs of rich architectural legacy of their predecessors such as Seljuks, Ilkhanids and Timurids (Blair and Bloom, 1995, 183-198; Fletcher and Cruickshank, 1996). Safavid architects used geometric ornaments in both religious and secular buildings. For example Ali-Qapu (1598 CE) is an eight storey palace in Shah Square of Isfahan. It is highly decorated by Muqarnas, carved and painted stucco. Although floral and figural motifs are dominant decorations but ceiling of its high columned balcony is covered with different types of 8 and 10-point geometrical patterns (Figure 17).

Figure 17: Ali-Qapu Palace in Isfahan (first two from left) Chehel-Sutun Palace (last two pictures)

Another secular building with extensive use of geometrical patterns is Chehel Sutun Palace (1645-47 CE) in Isfahan. Interior spaces are decorated with prorate and miniature paintings

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of some historical events along with highly detailed carved stucco and paintings with floral motifs. Wooden ceiling of entrance balcony is designed with variety of geometrical patterns consisting different types of 8 and 10 point geometrical patterns (Figure 17). While in secular buildings, inside elements of geometrical patterns are filled with vegetal motifs, in many surviving religious buildings of this period, geometric ornaments and calligraphic inscriptions are mixed. A remarkable example of this style is Hakim Mosque of Isfahan (1656-62 CE). Safavids baked brick is the main construction materials and external surfaces are highly decorated with tiles and brickworks of geometric motifs and inscriptions of Nastaliq calligraphy. As is in other buildings of this period, 8 and 10-point geometrical patterns are dominant and signs of other type of patterns are limited, more so in either grilles or furniture.

Figure 18 : Hakim Mosque of Isfahan, samples of 8 and 10-point patterns over Iwans and vaults spandrels

In comparison with Mamluks, less combined patterns are used in Safavid architecture, however, these complex types of patterns were common throughout the 16th and 17th Centuries in Iran and central Asia. Highly detailed and sophisticated examples can be found in Friday Mosque of Isfahan which faced massive restoration during Safavid era (Figure 19).

Figure 19 : Friday Mosque of Isfahan, Combination of 8 and 0-point pattern (Left)Combination of 8 and 12-point geometrical pattern (Right)

Decorative patterns with geometrical and floral motifs were common through both secular and religious Safavid buildings. These patterns were applied all over the internal and external surfaces using carved stucco, wood, colored glasses, polychromic tiles, lattice and stone. Figural paintings have also been used widely through imperial pavilions and palaces for which portraits and demonstration of historical events were more common. Processing detail of surviving Safavid decorative patterns shows that they were more in favor of 8 and 10-point geometrical patterns.

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 colored 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 20).

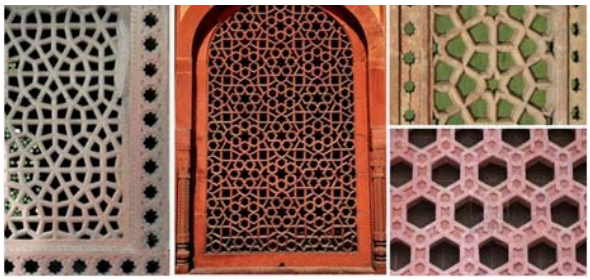

Figure 20 : Humayun Tomb in Delhi, 1566 CE, Samples of 6 and 8-point geometrical patterns

Dominant 6 and 8-point geometrical pattern is also repeated in Red Fort of Agra (1564-80 CE). Its buildings are harmoniously decorated

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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 21).

Figure 21 : Red For in Agra, showing geometrical patterns used in its Aamar-Singh Gate (First two from right) and lattice marble railing of Shish-Mahal (Right)

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 rarest example of 14-point geometrical pattern has been applied over piers of its main dome (Figure 22).

Figure 22 : Friday mosque of Fatehpur-Sikri and Salim-Chishti tomb (inside the mosque), various 6,8,10 and rare 14-point star geometrical 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. 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

Figure 23: 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

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.

Figure 24 : Lahore Fort in Pakistan, 17th century

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 Islamic architectural styles.

Muslims of Spain

From the middle of Eighth Century, when the Umayyads strengthened their rule over Iberian Peninsula to the Nasrid Dynasty who were the last Muslim rulers of Spain until 1492 CE, some notable structures have been either

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constructed or converted and modified by Muslims. The important surviving examples are Great Mosque of Cordoba (785-987 CE), The Aljaferia Palace in Zaragoza (Mid of 11th Century) and Great Mosque of Seville (1172-82 CE) (Goodwin, 1991; Lapunzina, 2005). Alhambra Palace (1338-90 CE) in Granada is considered as one of the most splendid palaces made by Muslims. Almost all surfaces are richly decorated with the finest interwoven carved or lattice stucco, stone, polychromic glazed tiles, calligraphic inscription, beautiful wooden works, muqarnas and cornices with both floral and geometrical motifs. Although geometric ornaments used extensively with profusion colored and intricate renders, highly complex 7, 9, 14 types of patterns are missed. Even 10-point geometrical pattern is not used and the simplest type of 16-point has been applied.

Figure 25 : Alhambra Palace in Spain, showing details of 6, 8, 12 and 16-point geometrical patterns of tile and carved stucco decorative works

Conclusion

This research tries to find the earliest examples of the most prominent types of IGPs through history of Islamic architecture. Survey of hundred well-surviving and famous buildings, has been concluded in Table 1, which shows evolution and origins of IGPs. Along the survey of patterns from buildings, great Muslim dynasties and patrons have also been studied, which reveals the design variations and impact of regionalism and period-styles. Concluding time-chart sketches the evolution of Islamic 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 time and time-scale accuracy and architectural-style matching.

References

Antoniou, J. (1998). Historic Cairo: A walk through the Islamic city: The American University in Cairo Press, Cairo, Egypt.

Asher, C.E.B. (1992). Architecture of Mughal India. Cambridge University Press, Cambridge, United Kingdom.

Baer, E., (1999). The Human Figure in Early Islamic Art: Some Preliminary Remarks. pp. 32-41

Behrens-Abouseif, D. (1992). Islamic Architecture in Cairo: An Introduction. Brill, Leiden, New York, USA.

Behrens-Abouseif, D. (2007). Cairo of the Mamluks: A History of the Architecture and its Culture, I.B. Tauris & Co. Ltd, Salem Road, London.

Berkey, J. P. (2003). The Formation of Islam: Religion and Society in the Near East, 600-1800. Cambridge University Press, Cambridge, United Kingdom.

Blair, S. & Bloom, J. M. (1995). The Art and Architecture of Islam, 1250-1800. Yale University Press, New Haven, USA.

D'Avennes, P. & Scanlon, G. T. (2008). Islamic Art in Cairo: From the Seventh to the Eighteenth Centuries. American University in Cairo Press, Cairo, Egypt.

El-Said. (1993). Islamic Art and Architecture: The System of Geometric Design. Garnet Publishing, Southern Court, United Kingdom.

Ettinghausen, R., Grabar, O., & Jenkins, M. (2001). Islamic Art and Architecture, 650-1250. Yale University Press, New Haven, USA.

ISSN : 2232-0474 | E-ISSN : 2232-0482
www.gjat.my

Fletcher, B. & Cruickshank, D. (1996). Sir Banister Fletcher's a History of Architecture. 20 ed. Architectural Press, Jordan Hill, Oxford, London.

Flood, F.B. (2001). The Great Mosque of Damascus: Studies on the Makings of an Umayyad Visual Culture. Brill, Leiden, New York, USA.

Freely, J. (2011). History of Ottoman Architecture. WIT Press, Southampton, United Kingdom.

Goodwin, G. (1991). Islamic Spain. Penguin, London, United Kingdom.

Grube, E.J. & Michell, G. (1995). Architecture of the Islamic World: Its history and Social Meaning : With a Complete Survey of Key Monuments and 758 Illustrations, 112 in Colour. Thames and Hudson, United Kingdom, London, United Kingdom.

Hillenbrand, R. (1999). Islamic Art and Architecture. Thames and Hudson, London, United Kingdom.

Kuban, D. (1974). Iconography of Religions: Islam. Muslim Religious Architecture. The Mosque and its Early Development. Brill, Leiden, New York, USA.

Kuban, D. & Emden, C. (2010). Ottoman Architecture. Antique Collectors' Club, Woodbridge, England.

Lapunzina, A. (2005). Architecture of Spain. Greenwood Press, Westport, London.

Mohamed, M. (2000). Great Muslim Mathematicians. Universiti Teknologi Malaysia, Skudai, Malaysia.

Özdural, A., & Omar, K. (1995). Mathematicians, and "Conversazioni" with Artisans. Journal of the Society of Architectural Historians, 54(1): 54-71.

Petersen, A. (1996). Dictionary of Islamic architecture. Routledge, New Fetter Lane, London.

Rabbat, N. (1996). Al-Azhar Mosque: An Architectural Chronicle of Cairo's History. In Muqarnas Volume XIII: An Annual on the Visual Culture of the Islamic World. Gülru Necipoglu (ed.) Leiden: E.J. Brill. pp. 45-67.

Spurr, J. B. & Riedlmayer, A. (1994). Resources for the Study of Islamic Architecture. Cairo: The Aga Khan Program for Islamic Architecture.

Turner, H. R. (1997). Science in medieval Islam: An Illustrated Introduction. University of Texas Press, Texas, USA.

Yeomans, R. (2006). The Art and Architecture of Islamic Cairo. Garnet Pub. Ltd., South Street, United Kingdom.