Wisdom in Art: Mathematics in Islamic Architecture in Iran

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Abstract

Architecture through the ages, has embraced a wide variety of arts and sciences. By using mathematics, Iranian architecture has achieved a high level of beauty and perfection. It is evident that advanced geometry was used by the prominent architects at that time. Geometry was used not only to solve structural problems, but also in the details of the designs of various structures. These range from the immense high entrances of Friday Mosques in important cities, to entrances of ordinary homes. 1By reviewing examples of medieval Iranian architecture, one becomes aware of its close relationship to scientific fields such as mathematics, geometry, cosmology, and astrology. This Relationship made it possible to achieve perfection, monumentality and poetic beauty. **It is wisdom within art.**

"This high dome is simple, yet complexly designed,
No sage ever knows the secrets behind the gate"- Hafiz (14th century)

Architecture through the ages, has embraced a wide variety of arts and sciences. By using mathematics, Iranian architecture has achieved a high level of beauty and perfection. This is especially evident in the Islamic Iranian architecture of the Middle Ages (10th to 14th century). During this period there were astonishing and glorious achievements of this endeavor – that is – the application of mathematics in architecture.

Many researches show the close relationship between mathematics and Islamic Iranian architecture. "The Study of mathematics had long been an area of original and fruitful research in Islam. Arabic translations of Euclid were of course already available in the Abbasid (early Islamic) period. While the scientists of Saljuq and Mongol Iran (early 10th century) were the best of their age, it has been estimated that it was the Timurid (14th century) period which saw the apogee of Islamic work in computational mathematics."[1]

The transition of a square into a circle by using triangles is one of the characteristics of Iranian architecture from the pre-Islamic period. Later, Iranian architects used this process to create more complicated and elaborate forms in the design of their buildings. The center point of the square, marked by the intersection of two diagonals, is the most important point in the transition to a circle process. This called for a further geometrical solution in the corners in order to create the desired forms and volumes. In order to create the vast varieties of forms which were achieved by the turning, rotating, and twisting of a simple square, the usage of circles and triangles was common and widely used in much of the medieval Islamic Iranian architecture.

It is evident that advanced Geometry was used by the prominent architects at that time. "The techniques of tower construction established in earlier centuries continued and spread under the Saljuq Sultan, their governors, and their neighbors. The cylindrical brick shaft of a variable taper was decorated with brick patterns and inscriptions of varied quality and complexity." [2]

Usage of advanced mathematics continued into the Il Khanids period. “Its apparent feature was a more immense scale. The structural load-bearing components of monuments were concentrated. A large ratio of height to the interior width of the chamber was displayed.” For example: “ the weight of the double shelled dome of the mausoleum of Uljayto in Sultanieya central Iran (45 meter high with a diameter of 24.5 meter) is concentrated on a small number of supporters, without the use of any shoulder or buttress.”[3] So it needed to be calculated prior to its construction.

Geometry was used not only to solve structural problems, but also in the details of the designs of various structures. These range from the immense high entrances of Friday Mosques in important cities, to entrances of ordinary homes. The more modest residential architecture conceals private and common-use areas of the houses. The layout of such houses varied according climate, culture, tradition, and aesthetic tastes. In order to satisfy these demands, and the placement of these structures within an urban setting, the architects had to rely on mathematics in order to achieve the best results.

The mastery of advanced mathematics among the architects, and the application of this knowledge in the various aspects of design led to the creation of amazing and admirable architecture[1]. There is no doubt that only those architects who were acquainted with an advanced knowledge of geometry, algebra and astrology, as well as, poetry and philosophy, could design such architectural elements that protected the structural stability while achieving perfection of beauty -- characteristic of medieval Iranian architecture in Iran. This level of balance and elegance would not have been attained without the mastery of mathematics by the creators of the work[2].

The ratio of height to the diameter of the towers or minarets in medieval Iranian architecture shows another aspect of the use of mathematics in architecture. The Tower of Gonbad-I-Qabus near Gorgan (in northern Iran), is a unique example of such a case. While this tower “reaches the amazing height of sixty-one meters, its diameter is only seventeen meters.” [5] This mathematical relationship helped the architect to create the sense of “the ascension from earth toward heaven.” This effect is achieved by narrowing the diameter of the tower where the entrance is placed, in comparison to the height of the structure.[*Ibid.*]

An additional example is the Gonbad-i- Ali Tower at Abarquh, in central Iran. This octagonal tomb consists of a tower of rubble masonry, rather than the traditional brick, and features a “bold three-tiered muqarnas[3] cornice, also of rubble, [that] once probably supported a pyramid roof.”[6]

Further use of advanced mathematics is evident in medieval Islamic architecture of Iran, especially the period between the Seljuk and the Timur dynasties, in the height of the towers and entrances, and the two shelled domes, used in the mosques of various cities. The “lofty minarets, with their ambitious construction and rich geometric and epigraphic decorations were designed and constructed with immense skill.”[7] “Construction techniques have not been studied thoroughly, but the continued ability of these slender towers to resist earthquakes suggests that their builders employed some sophisticated method, perhaps wooden tie beams, to give tensile strength to the structure.” [8]
Other examples are the Masjid-i-Jameh at Tabriz and Masjid-i-Jameh at Varamine. The first one “consisted of a single immense Iwan[4]of brick 99 feet wide, about 213 feet deep, to the springing of now collapsed vault, about 82 feet tall, shows an immense sahn[5] with centre pool and single-aisled porticoes,”

[1] “The astronomical tables of Ulugh Beg represent an advance on previous work, and the most important mathematician of his court, Ghiyath sl-Din Kashi, included in one of his many treatises, the Miftah al hisab, a table for the setting up of arches, domes and stalactite systems of different profiles” [1].

[2] “The poet Nezami, writing in the twelfth century, describes the talent of mythical architect, Shida, who designed and erected a fabulous seven-domed palace for Bahram Gur. Shida was of honorable birth, a master in drawing, a famed geometer in surveying, a finished worker in the building art and artist skilled in sculpture and painting” [4].

[3] “In Iran stalactite systems have been designated by Arabic word muqarnas or “joined” which also has the broader meaning of vaulted and by the Persian word “khonj whose basic meaning is ” corner” or ” solid angle” [4].

[*6*] while the latter had "a small dome behind the main portal completes the portal iwan, … the dome chamber is articulated, as is all else, by squinch filled with muqarnas in brick, which signal the transition from the square to the octagon" [*Ibid*.]

Among the large number of examples of the close relationship between Iranian medieval architecture and geometry, I would like to review a magnificent example – which is worth researching more thoroughly in the future – that is the entrance of the Friday mosque, Masjid-I-Jame, at Yazd, situated near the centre of this large city.

This Friday Mosque (Figures 1, 2, & 3) is notable for "its exceptionally narrow pishtaq[4] surmounted [by] twin minarets. The interior of the dome has an almost complete tile revetment, and the elimination of the rear wall of the iwan in the qibla[7] side ensured, for first time, that congregation in the court yard could see it. The upper galleries produce a considerable lightening of the dome chamber, both visually and structurally, and more complex succession of solids and voids. The same considerations are found in the transverse vaulting of the prayer hall." [10]

Figure 1: *View from central courtyard (Hayedeh Mashayekh, 2004)*

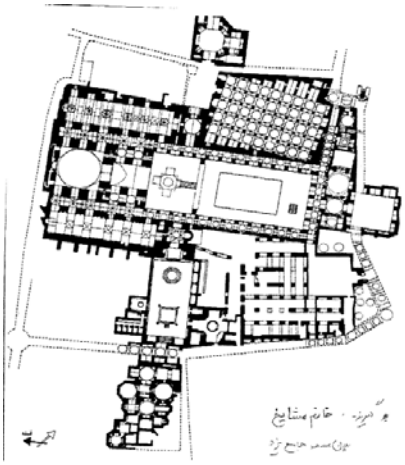

Figure 2: *Floor Plan (Reproduced from documents published by the Iranian cultural Heritage Organization, n.d.)*

[4] "Iranian architecture developed an interpretation of enclosed exterior space; indeed, the essence of the Iranian aesthetic can be said to lie in the organization of the courtyard. Here the simple motifs of iwan and the arcaded courtyard are combined, with the added emphasis of the sanctuary domed and sometimes of the minarets above the sanctuary iwan, all organized in relation to the overarching sky, their volumes immaterialized by the attenuation of their masses and by a pervasive ceramic vesture basically the color of the sky. Iranian architecture also initiated the expression of the aesthetic of the façade in its portal." [9]

[5] Sahn is the main salon where worshippers stand to the Ghiblea in the direction of Mecca and is the biggest and main parish salon.

[6] Main iwan or pishtagh (the first arch of iwan) gives access to the Principle part of mosque especially to the mihrab. Meanwhile regular iwan is the covered area for worshippers facing the main court. There could be one two or four iwan courts or iwan domed as well.

[7] Ghebla is the Mecca direction towards which worshippers face.

Figure 3: *detail of entrance (Hayedeh Mashayekh, 2004)*

The principal entrance to the mosque, which is composed of an iwan and the minarets from the 14th century, is exceptional in that it is the tallest entrance in Islamic architecture of Iran. The height achieved in this part of the structure would not have been possible without structural mathematical analyses. The height is stressed further by the ascending line molding of the minarets. (Figures 4, 5, and 6.)

Figure 4: *Entrance (Reproduced from documents published by the Iranian Cultural Heritage Organization, n. d.)*

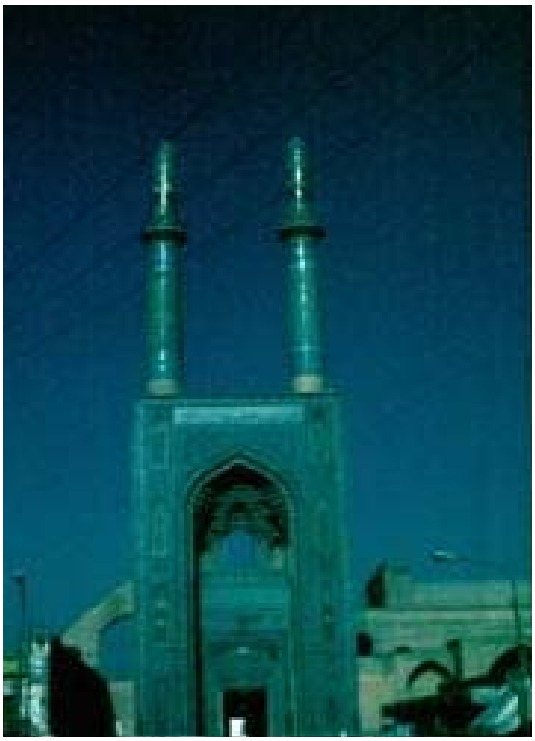

Figure 5: *Entrance (Hayedeh Mashayekh, 2004)*

Figure 6: *Entrance (Hayedeh Mashayekh, 2004)*

As mentioned before the purpose of the tall towers or minarets was to create the sense of reaching to God. This sense could be embodied in the structure by narrowing the entrance as much as possible, and by making it as tall as possible, with the help of mathematical calculations. (Sketches 1 and 2)

Sketch 1

Sketch 2

Masjid-I-Jame, Yazd, Iran

(Sketches were created by the author.)

By reviewing examples of medieval Iranian architecture, one becomes aware of its close relationship to scientific fields such as mathematics, geometry, cosmology, and astrology. This relationship made it possible to achieve perfection, monumentality and poetic beauty. **It is wisdom within art[8, 9].**

Acknowledgment

I wish to thank Mehdi Nasrin and Hagit Hadaya for their comment and assistance.

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[8] "The distinctive Saljuq contribution lies rather in the final establishment of several of the classic forms of Iranian architecture and in the capacity of Saljuq architects to draw out the utmost variety from these types. Mosques with one, two, three or four iwans are known, and the 4 iwan plan receives its classic formulation in association with an open courtyard and a monumental domed chamber: a hierarchy of size distinguished major iwans from minor ones…The pishtagh was developed from a simple salient porch to a great screen which conferred a grandiose façade on the building behind it" [11].

[9] "The double-shell dome of the mausoleum of Uljaitu in Sultaniya (1350-13 A.D.) 54 m. high with a diameter of 24.5 m. is the largest existing dome in Iran … Its section is a void. The thickness of the dome shell is respectively 0.6 m. and 0.4 m. thick near the base "structurally the building is a masterpiece". In a detailed study of the building in 1883, Dieulafoy found the use of geometry in the design on the interior and exterior elevation" [3].