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Reflection of the Role of Geometry in Design of the Aghabozorg School-Mosque in Kashan

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Abstract

Aghabozorg Mosque with massive brick dome and the tiled minaret is one of the most magnificent Islamic buildings in Kashan in the Qajar period. The unique features of the architecture suggest the architects of this building, in terms of the nature of architecture in designing the form and architectural space, have considered principles that are based on geometric shapes and proportions between them. Regarding the importance of the issue, the authors, with the approach of geometric proportional analysis, seek to answer this question: what is the role of geometry and golden proportion in the construction and shaping of the elements of Aghabozorg School-Mosque? For this purpose, the descriptive-analytic research method has been used in this study. In order to retrieve geometric and proportional data, plan, elevations, and sections of the building were investigated and analyzed accurately. The results of this research indicate that the architects had the necessary knowledge about the systems of equations and geometric drawings and used golden proportions and circle divisions to design plan, elevations, and sections and also applied geometrical knowledge in the direction practical and qualitative for creating the building.

Keywords: Geometry, traditional architecture, golden proportions, Aghabozorg School-Mosque.

2010 Mathematics Subject Classification: $00A67$.

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1. Preliminaries

In introducing the architecture of the Aghabozorg School-Mosque spaces, after entering the school grounds, the two upper and lower courtyards and the courtyards of the residence and magnificent brick dome of the two sidescan be seen. In addition, there are two backyards, a large warehouse, the Mosque building next to the dome, and a tiling altar located next to the dome. Tiling, gilding, inscriptions, mogharnas and painting are belongings of this great building [14]. The Aghabozorg Mosque in terms of the plan is a Mosque with three parts and the important point of attention is the combination of the Mosque and school. All of the building is made of brick and has a beautiful patio with its ceiling decorated including gypsum cornices and painted. The walls of the forehand are covered with tiles of Alwan from above the inscription to the bottom of the beds on the both sides of the port. The main boards of the building are the dome and the pavilion with its glory due to the greatness of the building and the excellent and unique design, especially the techniques of the original Persian architecture which have been used in it, make this Mosque one of the most important buildings of the Islamic Iran. All of this, including the dome, which is one of the largest brick domes and the decorations in this building are tiling, brickwork, exquisite gypsum and tile inscriptions, mogharnas, calligraphy and painting which was painted by Professor Mohammad Bagher Qamsari. Inscriptions of the lines of the Mosque were written by famous professors of Kashan's Calligraphy, including Mohammad Ibrahim (the grandfather of Ma'arefi), Mohammad Hussein (the grandfather of the Adib family) and Toghri Baslameha written by Seyyed Sadegh Kashan [12]. The beginning of a geometric structure of architectural designs should be sought in the history of the past, which, despite several thousand years of history and the emergence of school desks throughout the centuries, this structure has always existed [11]. The basic element of art and engineering, including the art of architectural engineering, is "geometry". Each building has its own special design and architecture, and the geometric position of architecture as a fundamental knowledge plays a significant role in design. Therefore, in this study, the architecture of the Aghabozorg School-Mosque has been tried and analyzed for geometry.

The research of this study is based on the analysis of literary sources and observation. Analytical descriptive method has been used to analyze extraction data. AutoCAD and Photoshop software were used for drawings in this study and some parts were drawn manually by using ruler and file. In this regard, geometry and proportions related to the architecture are extracted from books. Then, considering the identified geometric systems, the proportions in the architecture of the Aghabozorg School-Mosque were tested and analyzed experimentally. The geometry of arches as well as golden ratios were identified in the plan, section, and elevation and then draw.

2. Background Review

Cultural heritage is considered as the identity of a nation and its identification document among other nations. In the architecture of buildings, geometry tools are used in accordance with the temporal and spatial conditions and needs of each building. Several studies have been done on how to use this knowledge in architecture. In the context of this article, we will consider some issues. Karimnezhad and Abdi has been analyzed the architecture of the Mosque of Aghabozorg Kashan in terms of golden proportions in an article titled "Golden Approaches in Historical Architecture: A Case Study of the Mosque of Aghabozorg Kashan" and has been introduced golden proportions and some examples of its application in various historical buildings of the world. Bomanian et al. in an article entitled "Comparative Study of the Architectural Design of the Masjid-Schools of the Qajar and Safavie Schools", evaluated and reviewed the innovations and changes from the general scheme of the Mosque-Schools of the Qajar period in comparison with the schools in Safavie period which have studied the case of the Aghabozorg School- Mosque. In the article "The Characteristics of the School Mosque in the Islamic Architecture of Iran, the Study of the Relationship between the Educational Environment and the Nudity" by Hooshyar et al., they examined the relationship between educational and religious spaces in different periods of Islamic architecture of Iran. The Aghabozorg School-Mosque is one of the examples of the Qajar period in this research. In the article titled "The history of map drawing and application of geometry and account in Islamic architecture" Neyestani explored the history of using effective factors involved in the construction of a building, in particular, the use of map drawing, geometry, and calculus in the architecture of the period Islam has been paid [15]. Sharbaf in a book entitled "Knot and Handling" describes various types of methods and rules of geometric drawings under arches and decorations of different levels of Iranian architecture with the related Figures [18]. In a paper titled "Geometric Analysis of the Mosque of Sheikh Lotfollah of Isfahan in order to determine the geometric relationship of the prayer hall with the entrance to the building", based on the research hypothesis, the existence of a certain geometric relationship between the prayer room and the entrance to the building, a geometric model was first designed and then, with its adaptation to the Mosque's plan, the hypothesis is proved and part of the logic of the formation of the effect becomes evident. The result of the research indicates that the size of the chamber space is proportional to the dimensions of the entrance gate and the location of this space is related to the location of the input of the building in the body of the minefield, and a geometric process is interconnected. Hejazi, in a paper titled "Sacred Geometry in Iranian Nature and Architecture" has proved the application of geometric knowledge in many Iranian monuments, which in Iranian architecture have a broader knowledge of the proportions, especially the golden ratio widely. This is the basis of Iranian aesthetics. In many Iranian buildings, planes and vertical sections were designed in the framework of squares and triangles of equilibrium that their constituents featured all the important points, such as the width and height of the doors, the width, length and height of the halls, location of inscriptions, etc. As a result, a building was not a set of non-conforming components, but a combination of components with appropriate proportions that moved into space and made us feel relax [3]. In his article "Geometry in pre-Islamic Iranian architecture and its manifestation of contemporary Iran's architecture" Silvaie et al., while fully understanding the geometric principles of traditional architecture and the intellectual roots and its theoretical foundations, manifests itself in the works contemporary architecture has been analyzed [17]. In this article, the paper tries to identify and analyze the geometry used in the construction of the Aghabozorg School-Mosque in Kashan, with the definition of geometry and the recognition of the geometric principles in traditional architecture. The geometry is a word of size and refers to knowledge that determines the mathematical relation between points, lengths, surfaces, and volumes, and shows the ratios of them and their derivatives and functions.

3. The Place of Geometry in the Quran and its Application in Architecture

In the Quran, the most original and original source of Islamic thought, the physical and structural form of the universe is expressed in the form of one of the keywords of the Islamic worldview, namely "magnanimity" [4]. The word "magnanimity" in the Holy Quran has been used in terms of power, tightness, fate, and dignity. Of this, the divine (3), the moon (49), and the moon (12) are interpreted in size and measure and have a close connection with geometry as the science of determining the sizes. Imam Reza (AS) says in an adequate scripture to Younis bin Abdul Rahman: "The magnitude is geometry and boundary, like the amount of survival and the time of mortal" [16].

Traditional mystery shows the cosmos in its terrestrial dimension. In an architectural building, all dimensions, both in its entirety (height, length, and width), and in its components (including geometric surface patterns), are interconnected and never separate with geometry. Since human beings share commonalities with nature. The traditional architect uses geometry to explore more of the phenomena of nature in order to direct the discursive mind from a sensible world to a sensible world. In terms of external performance, the use of geometry as art to create the shapes, patterns, and proportions of the great architect of the world recalls and calls for specific forms. Therefore, the art of geometry is a key element in building relationships between buildings and ideas that the maker has in mind. In terms of internal function, geometry as a science is used to select structural dimensions such as height, length and width of the building and its structural components on the structural behavior of the building, a behavior that follows geometry. Proper geometry makes the building have a static and balanced behavior [5]. In Iran's architecture, special proportions have always been used, and it may be argued that the oldest proportions are found in the remnants of the Iranian architecture, for example, in the Ilam architecture and Choghaznbil's ziggurat, and in the medieval architectures Particularly Achaemenid examples of proportions are found. Examples of nominative proportions that have been used in both Iranian architecture and European architecture include: "The golden ratio shown as the number of 1.618 is the most prominent of the proportions of the world architecture" and "Proportion the Iranian gold which master Pirnia defined along the length and width of a rectangle within a regular hexagon is 1.73" [13]. In general, in designing and evaluating each architecture, two points should be not: one structure, the principles of the structure of the main building and the bone structure of the building, and narrates the correct implementation of these principles of a building can be centuries and the other, in which geometry is considered as the position and appearance of the building. An inseparable principle of structure and posture has always been considered, which ultimately creates the necessary coordination between structure and view [4]. Research has so far focused on architectural works to prove the existence of geometry and the relationships between geometric shapes and architectural elements in historical monuments. In this paper, in addition to this, we will analyze the influence of geometry and geometric proportions on the plan, views, and section of the Aghabozorg School-Mosque (according to Figures 1 and 2 in this regard).

Figure 1: The picture of the Aghabozorg School-Mosque.

Figure 2: The image of the mosque of Aghabozorg.

The beauty of traditional Iranian architecture is based on the balance between the elements in the building and the decorations have been used in it geometrically and logically [2]. Geometry is evident in any one viewer in two-dimensional design, a Kokabi arch, Mogharnas, Rasmibandi, and decorative Nimkar, but it is more difficult to see the geometric alignment. Some relationships cannot be properly identified because they are not within a field of view or on another level of the building that needs to know or know the design process [4].

Pythagoras and his followers acknowledged the existence of links between numbers, forms, and music. Islamic philosophers such as Ekhvan al-Safa also believed in the emergence of the world based on mathematics. In their opinion, the pivotal basis of this universe is number and geometry, which in fact should be considered as pure quantity. But in this thesis, the meaning of a number is not the values used to measure physical quantities. Two, the digit is not one after one, and it is not obtained from the sum of two, but one with its division into two transforms. In this thinking, numbers start from one, and each number has its own position. The number one can determine the quantity, but in other words, it can provide the principle of absolute unity, thus often being presented as the symbol of God [16]. From the words of the brotherhood, it turns out that the account and geometry are like a ladder that human beings thereby achieve the world of reasoning, divine, and theology, and the account and geometry is the preamble of the movement towards God. "The surface of the ultimate is the object, and it is at the very end of the line, and it is the end point of the line". So "nothing is at par with nothing and no more than the object". Robert Lawler calls geometry a factor in order and unity of the universe, and states: "In geometric designs, we can be seen as constant and constructive patterns of the constant, timeless world." Geometry is the spatial order by measuring the relations of forms of geometry and astronomy account, which is the science of ordering time by observing the circular motion. Thus, Lawler determines the order for geometry [9].

4. Golden Proportions

About three hundred years BC, the prominent Greek mathematician Euclid, in the fourth chapter of the book "Principles", which was the most readable book of the Western world after the Bible before the century, wrote : "A straight line can be divided into two small and large parts so that the ratio of the length of the particle to the large component is equal to the length of the large component to the small one." By solving the algebraic problem, he realized that the ratio of such always Equivalent to 1.6180339887; a dumb 5 is a pixel, and this dumb figure was later called the "Phi number" [13].

Based on golden proportions, a single segment can be divided into two parts, in which the proportion of the smaller part of the larger part is equal to the proportion of the larger part of the whole segment (according to Figure 3 in this regard).

$\frac{A+B}{A} = 1.618$ $\frac{A}{B} = 1.618$

Figure 3: Golden proportions in algebra.

A rectangle whose alignment is aligned in golden rectangles. As a rectangle, if a square is constructed on a smaller side, the remainder of the original rectangle will again be the same golden rectangle, but with a smaller scale. This action can be repeated infinitely and produce a progressive form of squares and golden rectangles [13]. To draw a golden rectangle with a golden ratio, first draw a square to the side of the unit, then find the square in the middle of the lower side, and draw an arc with a radial midpoint of the lower side of the square up to the upper right corner (according to Figure 4 in this regard). These indicate the length of the rectangle [13].

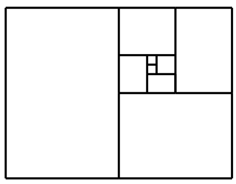

Figure 4: Golden proportion in geometry and the golden rectangle.

To draw a Golden rectangle with a golden ratio, first draw a square to the side of the unit, then find the square in the middle of the lower side, and draw an arc with a radial midpoint of the lower side of the square to the upper right corner (according to Figure 5 in this regard). These indicate the length of the rectangle.

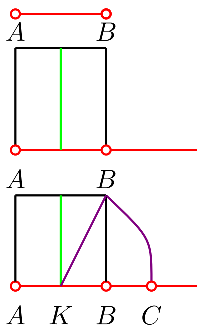

Figure 5: How to draw a golden rectangle.

The golden proportions are giggly mysteriously tied to all of the finer and finer effects of nature, and all aspects of the uncensored universe. In Figures 6 and 7, a few examples of the presence of a golden helical and a longitudinal golden ratio of nature is shown. Figure 8 also shows the golden proportions of the human body. In Figure 9, a man is standing in the form of a pentagon. From the drawing of the pentagon diameters, the star becomes five. It should be not that the ratio of the diameter of each regular pentagon to its sides is equal to the golden ratio [8].

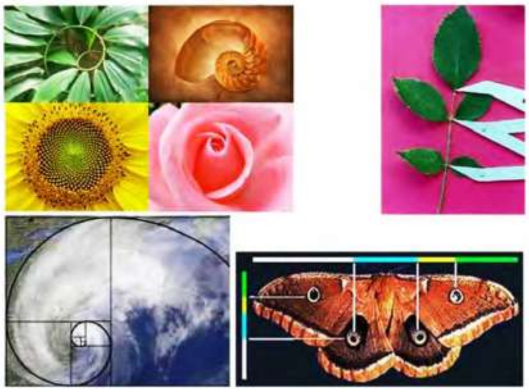

Figure 6: Examples of golden proportions in nature [8].

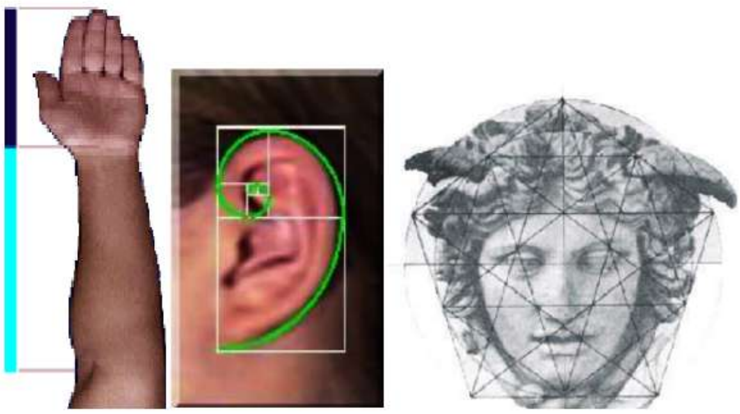

Figure 7: Examples of golden and pentagonal proportions in human body [8].

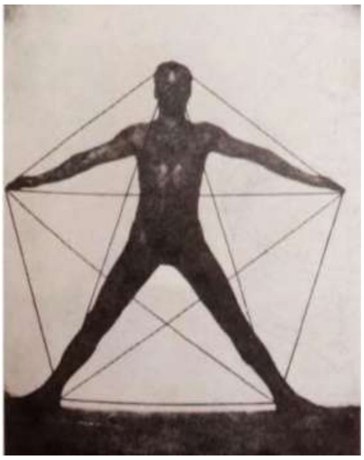

Figure 8: Man in the form of a pentagon and five full star [8].

5. Aghabozorg School-Mosque and its Architectural Features

Aghabozorg School-Mosque located in Kashan, Kamalol-Molk Square, Mullah Habibullah Sharif Street, belongs to the second phase of the Qajar dynasty. In terms of stylistics, Dr. Pirnia is one of the second stages of the Isfahan style. The year of construction of this building is 1268 AH. The building of this building is based on the personal wealth of Haj Mohammad Taghi Khanban to use the prayers of the congregation, the lesson, and discussion of his bridegroom, Mullah Mehdi Naraghi II, the brother of Mullah Ahmad Narag Hi, known as Aghabozorg. At the beginning of the building, this building has a large octagonal chamber, chest, and chrysalis. Upon entering the Mosque-School area, the two upper and lower courtyards and the courtyards of the residence and the magnificent boulder dome of the two sides. In addition, there are two backyards, a large warehouse, another nave behind the dome, a Mosque building next to the dome. Mosque courtyard - The school is made in two floors, the ground floor is grounded with a garden and garden, and on the three sides there are twelve chambers with a hallway and hallways separate with a larger teacher than the cellars in the middle and several warehouses Made at angles. On the north side of the school is a large school with two high air vents, but the second floor is on either side of the eastern and western hemisphere, at the bottom of the wide corridors located on the upper part of the school's cellar. According to the plan, this is a Mosque with three nurseries. The original design and construction of the Gonbad-khane were open to the four sides, but later on, on the west side, Haji Mullah Mohammad Ali, son of the great, built a vast winter nursery. Also, in the lower part of the southeastern corner of the dome is a building with a dock, anchorage, water storage and wells [1].

Figure 9: The Aghabozorg School-Mosque.

The School-Mosque is a compilation utility that, with elegance, places school and Mosque together without interrupting each other. This functional separation has been created due to the level difference. Thus, the Mosque, school, and cellar spaces are located in three different levels. The entrance Mosque is intact. The lower floor semicircular school is located and the chambers are located in the courtyard of the garden and one mezzanine below the Mosque. The garden or pit gardens is a climatic climate that is hot and dry to reduce the thermal exchange of the building with the surrounding area. Also, creating a garden pit with appropriate ponds and trees would create a climate that would stylize the interior of the building (according to Figures 10, 11 and 12 in this regard). Usually, the soil needed for the brick and mortar of the building was excavated from the same pits. This dome, unlike the conventional way, is located on a column (pillar space) and the space dome is open. This issue, as well as the location of a small yard behind the dome space of the house, create a sense of suspense in the dome space of the house [10].

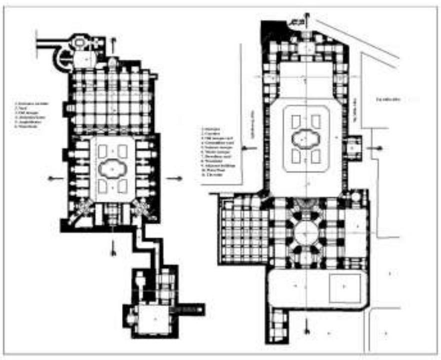

Figure 10: The ground floor and basement plan of the Aghabozorg School-Mosque.

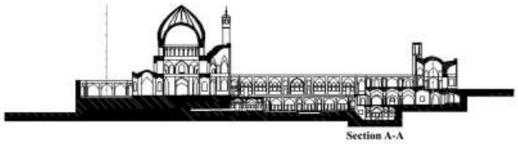

Figure 11: Section A-A, Aghabozorg School-Mosque.

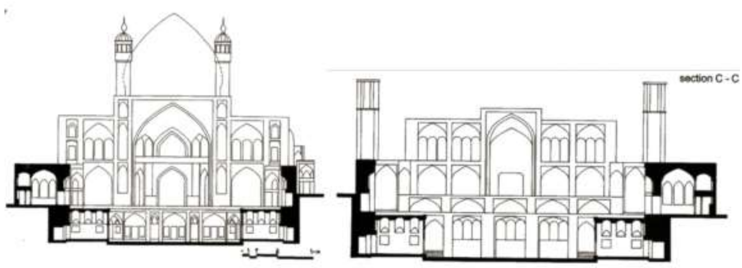

Figure 12: North and south view of Aghabozorg School-Mosque.

6. Geometry on the Plan, Elevation and Section of the Aghabozorg School-Mosque

The application of geometry in design can be considered at two levels. The first level involves the appearance of geometry in the design. Like squares, octagons and regular polygons visible in plan, elevation, and details. The second level analyzes the layout of geometric patterns that determine the dimensions, orientation, and association of shapes of the former level and are not visible at first sight. Hence, first, the first level identifies the geometric shapes. Consider the square to the side of a unit and we will arrange it as far as the diameter of the array. The larger side of the rectangle obtained is equal to the square diameter of 2, and the approximate value is 1.4142. With a rectangular diameter, a rectangle $3O$ can be drawn with a rectangular diameter of 3μ, and this process can continue (according to Figure 13 in this regard). These rectangles are a dynamic rectangle (dynamic) [7].

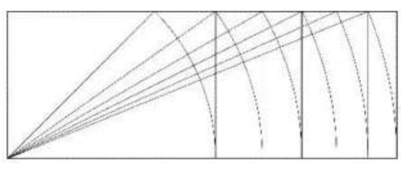

Figure 13: Drawing the rectangle radical 2 and extending it.

Elevation and plan proportions of building complex by using the golden rectangle are based on two radicals. It can be seen that the ratio of the length of the various spaces that are separated from each other in the Mosque courtyard is equal to the golden number. The plan for the architect's complete knowledge of the proportions Iranian gold is drawn. Golden rectangles are shown in the plan. The ratio of the length of the width of these rectangles is equal to the golden number. Each rectangle corresponds to a completely distinct space from other spaces (according to Figures 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31 and 32 in this regard).

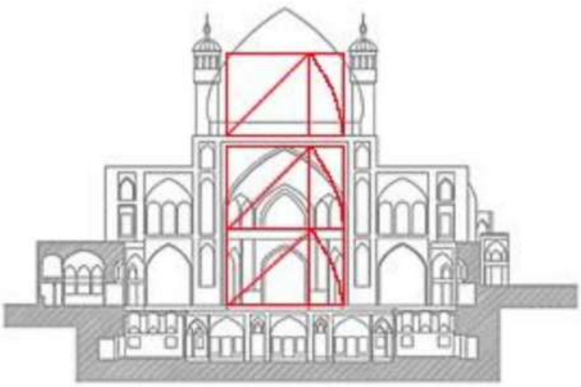

Figure 14: Golden rectangular position with radical 2 in elevation.

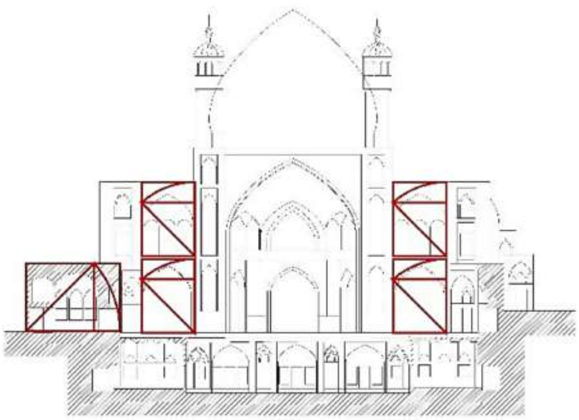

Figure 15: Golden rectangular position with radical 2 in elevation.

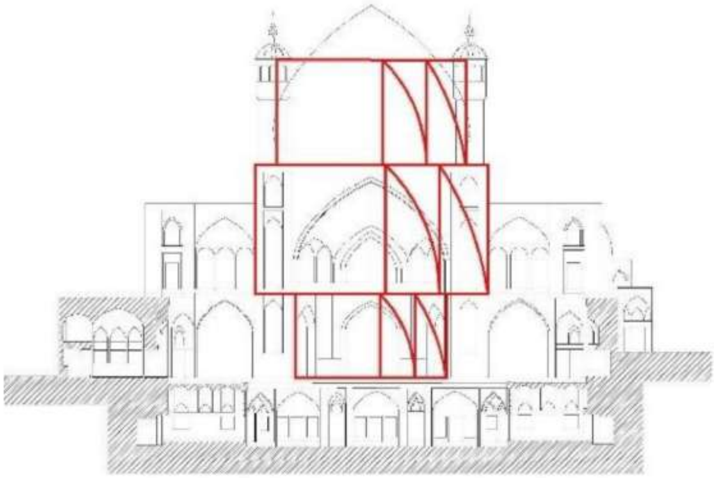

Figure 16: The golden rectangle with radical 3 in elevation.

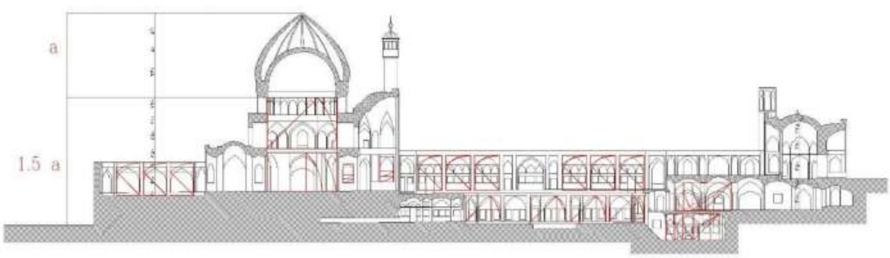

Figure 17: Radical 2, radical 3, and radical 4 in section of rectangle.

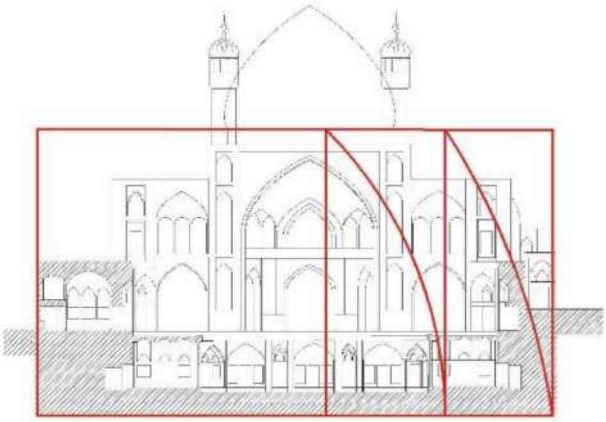

Figure 18: Golden rectangular position with radical 3 in elevation.

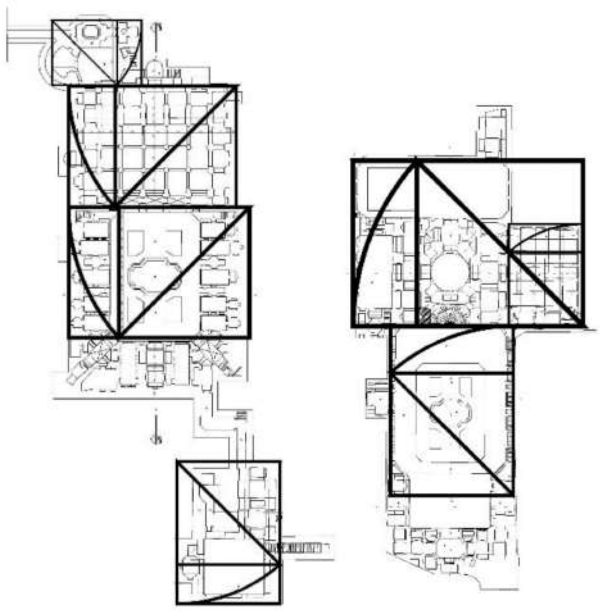

Figure 19: Golden rectangular position with radical 2 in plan.

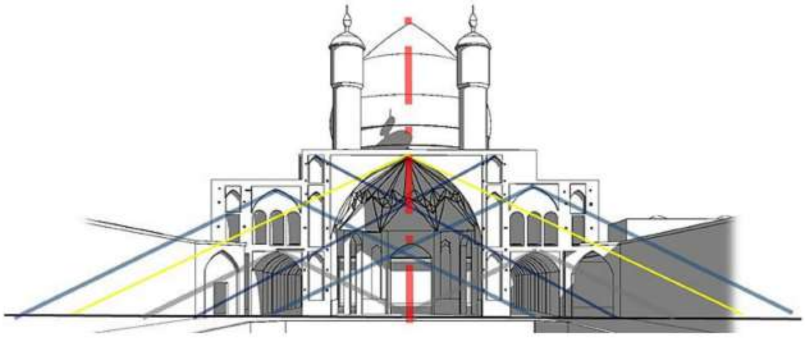

Figure 20: Elevation geometry in the Aghabozorg Mosque.

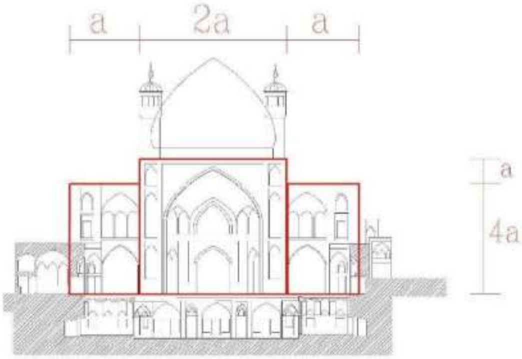

Figure 21: Elevation geometry in the Aghabozorg Mosque.

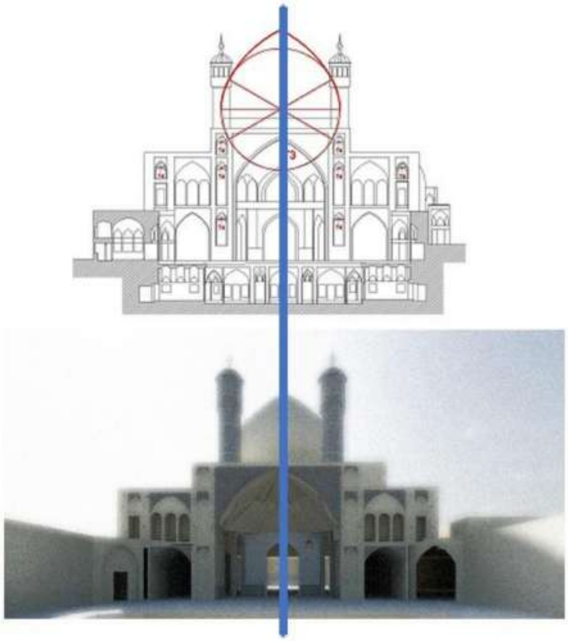

Figure 22: Elevation symmetry, Aghabozorg Mosque.

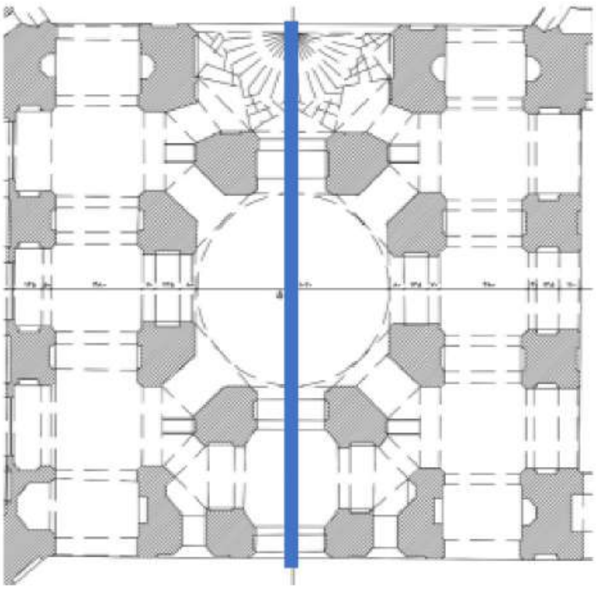

Figure 23: Symmetry in the dome of the Aghabozorg Mosque.

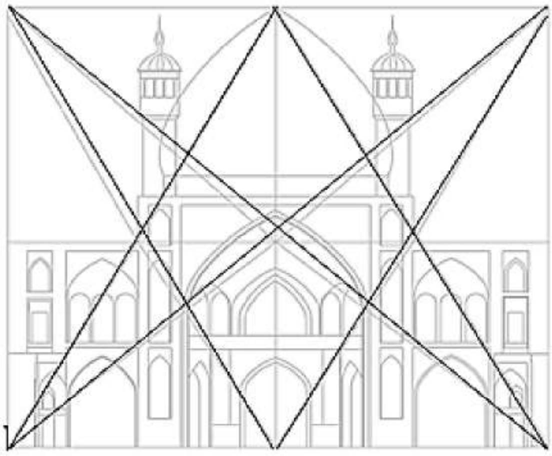

Figure 24: Elevation geometry in the Aghabozorg Mosque.

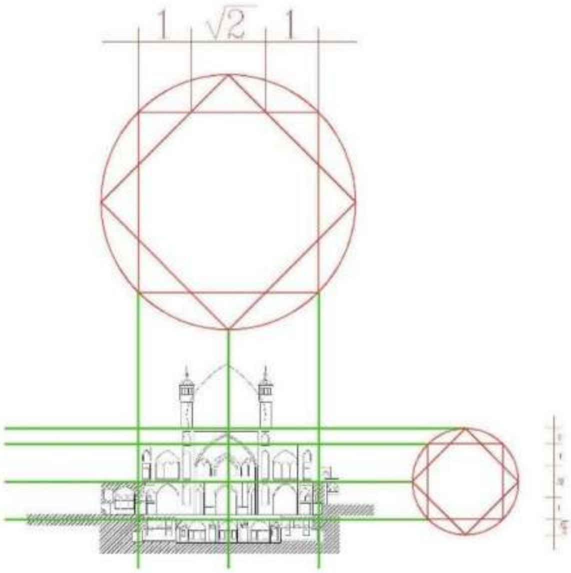

Figure 25: Elevation geometry in the Aghabozorg Mosque.

Figure 26: Elevation geometry in the Aghabozorg Mosque.

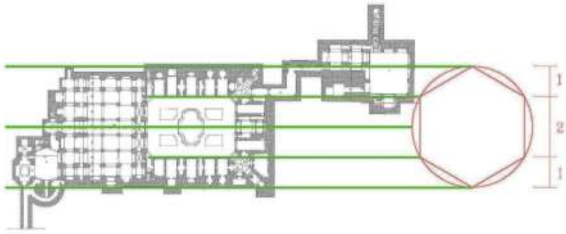

Figure 27: Circle divisions and geometry proportions in the yard and plan of Aghabozorg School-Mosque.

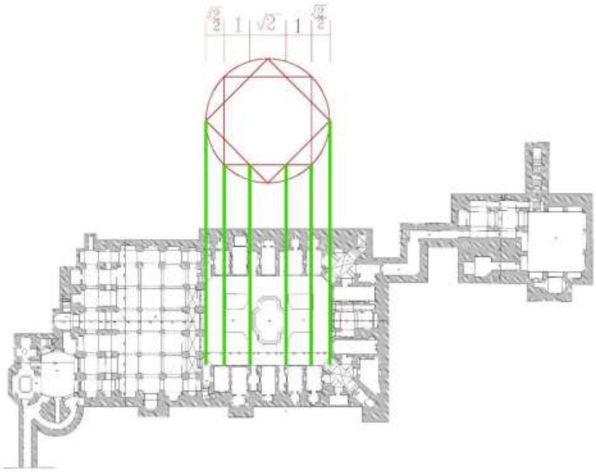

Figure 28: Circle divisions and geometry parameters in the yard, gardens and watercourses of Aghabozorg School-Mosque.

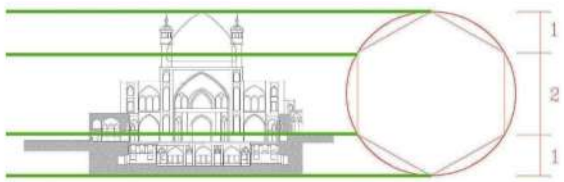

Figure 29: Elevation geometry in the Aghabozorg Mosque.

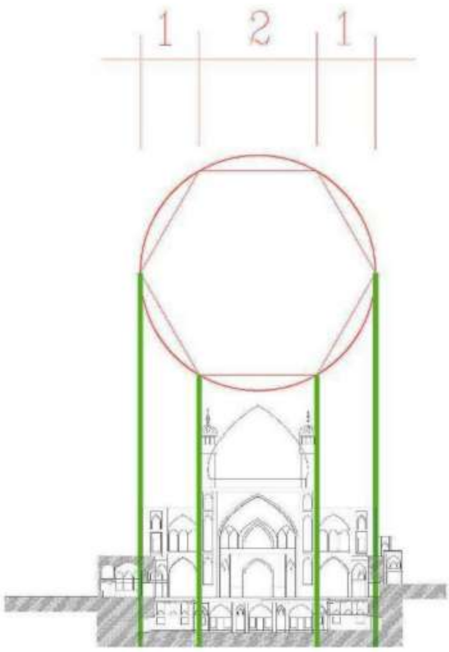

Figure 30: Elevation geometry in the Aghabozorg Mosque.

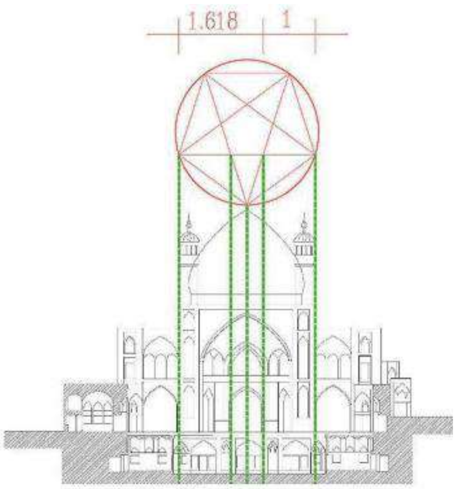

Figure 31: Elevation geometry in the Aghabozorg Mosque.

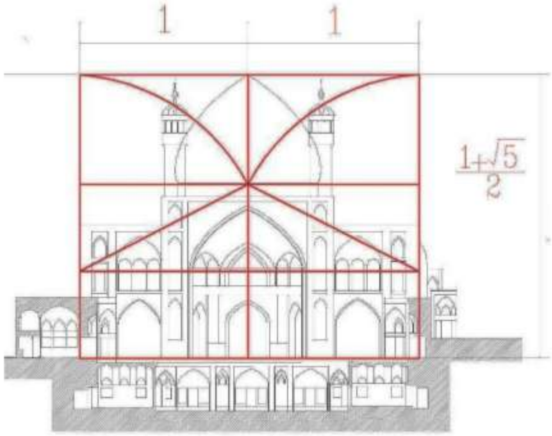

Figure 32: Elevation geometry the Aghabozorg Mosque, composed of two rectangles with a golden ratio of 1.618.

7. Identification of Arches in the Aghabozorg School-Mosque

In the old days, roofs were covered with wood. It is certain that these ceilings did not have significant strength and disappeared over time, so the architects realized that if the ceilings and enclosures were covered with clay and brick, but with curvature, resistance and life Building will be a hundred. Hence, different roofs of different strengths have come into the realm of architecture [6]. Therefore, based on the geometric formation of the arches, in this paper, recognition of the types of arches in the building of Aghabozorg School-Mosque has taken. The arches used to consist of five and seven steep, five and seven steep, sparrow shoals, and medium shoals on the map 10, 11, 12, and 13 these arches are visible and the method of drawing them in the table number one is briefly explained (according to Figures 33, 34 and 35 in this regard).

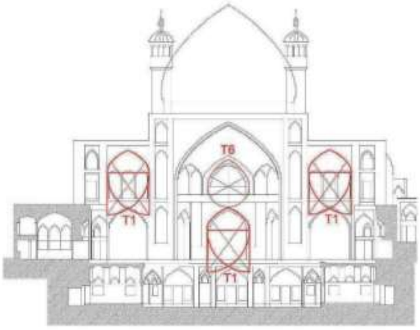

Figure 33: 5 & 7 sharp arch type 1 and Shabdari sharp arch type 6.

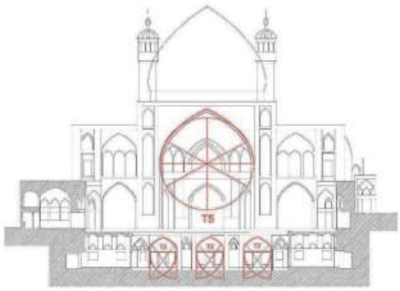

Figure 34: Shabdari middle arch type 5 and 5&7 low slope arch type 2.

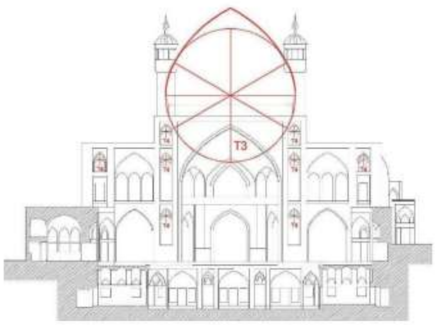

Figure 35: Shabdari sharp arch type 3 and Shabdari middle arch type 4.

According to Table 1, the height of all arches is between 0.4 and 0.6. This elevation due to the load is proportional to the aesthetic and structural, because the transfer of force from the top of the arch to the tangent to the tangent to the arc moves, and at the end, the vector of tangential force at the foot of the arch is close to the perpendicular line and this feature makes the thrust driven to be minimized and maximizes the compressive force that is in harmony with the characteristics of the traditional structures.

Table 1: Typing the arches used in the Aghabozorg Mosque.

Type	Slope	Height	Width	Number	Location	Name
1	0.52	1.73	3.29	3	South view	5 and 7 sharp arch
2	0.43	1.10	2.54	3	South view	5 and 7 low slope arch
3	0.76	8.08	10.62	1	South view	Shabdari sharp arch
4	0.64	6.21	9.65	8	South view	Shabdari middle arch
5	0.53	4.69	8.77	1	South view	Shabdari middle arch
6	0.61	2.09	3.42	3	South view	Shabdari sharp arch

Considering the survey done at the main dome of the building, its height is 0.76. This high rise is due to the creation of a city symbol of the city.

8. Conclusion

Geometry and proportions are powerful tools in architecture and in order to create architectural proportions. An overview of geometric analyzes carried out on numerous historical buildings in different parts of the world shows that golden ratios are widely used in the architecture of these buildings. An architectural work without regular and regulated geometry is lacking in quality and beauty, and what distinguishes a building is how to arrange geometric shapes. The ultimate goal of art and architecture is to create the proper field for the growth and emergence of the highest mental and intellectual talents of man, found in many forms into the life of nature. Geometry can be considered as a very important factor of shaping the works of Iranian contemporary architecture, which has a decisive role and is recognized as a sacred indicator in the works of architects, both in the past and today. This science is mastered by the traditional Iranian architect, indicating engineering to design methods. Despite the observation of geometry indicators in past buildings, it can be said that for Iranian architects, geometry has a high degree of credibility because, being acquainted with the knowledge of geometry and the ability to implement geometric relations, it seeks to reconcile methods of geometry theoretically, they did not use it clearly, but they have always been involved in the architectural thinking of this geometry. Our goal is to choose the Aghabozorg School-Mosque to study the role of geometry in the building the way it is arranged in its architectural space because it attracts the audience at first sight. So it should be a building with distinctive and special features what we found out that the architect was based on the necessary knowledge because in the place. The identification of architectural elements in the plan, the balance between spaces, and the creation of decorations of geometric principles and excellent proportions. As indicated in the research process, the most geometric proportions are based on the divisions of the circle and golden proportions in the vast spaces of the Aghabozorg Mosque.

The architect of this building has been very successful in putting the human in a proportionally balanced space, creating a sense of relaxed spiritual environment. The Mosque and school performance have been very successful, especially in the garden courtyard of the school of the seminary. Combination of two functions, use of the garden pit, precise use geometric systems, circular divisions, geometric arcs, and the geometric layout of materials at all levels could be attributed us to the existence of the necessary knowledge of the architect in the design of the complex.

9. Notes

1. Kokabi arch: A vault in which the crossover is seen from the arches and several forms of the star.
2. Mogharnas: A type of Rasmibandi, consisting of three-dimensional articulated riders and sometimes discrete instruments with a particular geometric order.
3. Rasmibandi: A type of Karbandi, consisting of a geometric grid of crossed arches, which some of them carry weight and some are merely decorative.
4. Decorative Nimkar: The Nimkar is the half of vault that has been placed underneath the geometric design. The types of halves are named after the depth and the span.
5. Dumb numbers: Dumb numbers are numbers that do not end in their decimal fractions, and form a unidimensional and infinite look. A pixel is a dummy number.
6. Fi: In Persian alphabet, the first word of the name of Phidias that is the ancient Greek Zeb had, which most likely would have included this numerical ratio decade before Euclid in his artistic style.

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