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Geometric Patterns Used in the Architecture of Kaboud Mosque in Tabriz, Iran

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Highlights

- The geometric principles used in the architecture of Kaboud Mosque in Tabriz have been studied.
- The construction of the Kaboud Mosque has been created based on the Iranian engineering style.
- The architectural style of Kaboud Mosque created a new technique in Iranian architecture.

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Abstract

Doubts about the architectural style of the Kaboud Mosque in Tabriz are related to the geometry of the plan and its special volumetric composition, which has made this building different from other examples of mosque architecture in Iran. For this reason, some scholars, following the formal origins of this mosque, have traced its roots in the art of the Ottoman region and, as a result, have introduced the architecture of the Kaboud Mosque as an imitation of Ottoman architecture. In the present study, using a descriptive-analytical method, the form of the construction of the Kaboud Mosque of Tabriz and its comparison with the Ottoman mosques have been studied and recognized. Then, the geometry used in the Kaboud Mosque of Tabriz has been analyzed by measuring its degree of compatibility with the resulting rectangles of regular pentagons and hexagons. The results show that the construction of the Kaboud Mosque is similar in form to some Ottoman architectural works. However, structurally, it has been created entirely based on the Iranian engineering style. The architectural style of this building, although it opened a new chapter in the design of the mosque in Iranian architecture, could not arouse the desire of later architects to repeat its form.

1. INTRODUCTION

Geometry is a suitable tool for arranging architecture and establishing conscious relationships between building components each other, to be integrated, and to enable the integration of space as a creative and purposeful combination [1]. The architect's mastery of geometry and its creative use facilitates the transformation of the concept into space and form in the design process and minimizes the erosion of the concept in this process. The result of such a process is a kind of architecture that, far from the perceptions of taste, is understandable in terms of order and proportions. Architectural design is expressed in the form of geometry [2]. It is in the lawful space of geometry that anything, including the components of a house or even a city, can step into the realm of existence and find its identity in a space of multiplicity and diversity [3]. The fundamental factor in creating unity among the components of the universe, including the components of the body of each architectural culture, can be nothing but geometry [4].

The architecture of the past periods of Iran has always included the use of geometry and precise drawing. To the extent that knowledge of mathematical rules and geometry was the duty of every architect, the distinction between architects and their competition with each other has been based on this axis [5]. Therefore, it is clear that geometry is important in Iranian architecture, and understanding how this index is important and necessary. In this way, geometry can be considered a hidden aspect of Iranian architecture in different periods [6]. To identify an architectural work, in addition to the formal aspect, the role of

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building geometry must also be considered. Just as the symbols used in a city become the identity of that city, so the identity of a building can be identified when the form of the building can interact with the geometry. The mosque, as a place for one-sided worship of God, is the most appropriate type of architecture to objectify the concept of plurality in unity, and perhaps, for this reason, the most enduring architectural works of the Islamic period in Iran are mosques [7]. In the architecture of Iranian mosques, geometry tools appropriate to the temporal and spatial conditions and needs of each building have been used well, and despite the almost similar pattern of mosques in each historical period of Iran, each building has its unique architecture.

In this research, one of the magnificent works of Iranian architectural heritage, namely the Kaboud Mosque of Tabriz, has been discussed in terms of geometry. The characteristic of the present article in comparison with other works that have been done about this mosque so far is the omission of aesthetic discussions to pay more attention to the issue of geometry in the architectural structure of this building. The reason for adopting this approach is to create the necessary focus to address the issue of geometric proportions of this mosque. Doubts about the architectural identity of Kaboud Mosque in Tabriz, the form of the plan, and its specific volume, which has made this building different from other examples of mosque architecture in Iran. For this reason, some scholars, after recognizing the formal origin of this mosque, have sought its roots in the art of the Ottoman region and, as a result, have introduced the architecture of the Kaboud Mosque as an imitation of Ottoman architecture [8]. The reason for the claim of these researchers is the similarity of the shape of the Kaboud Mosque with the Ottoman mosques of the same period, which were built as double-domed mosques and had a clear background in the historical architecture of the Ottoman region [9].

The present study hypothesizes that the architecture of the Kaboud Mosque, despite having some similarities to the form of mosques in the Ottoman region, has been built according to the geometric principles of Persian architecture. Although many interventions have been made in the renovations over the last eighty years [10], the manifestations of its Persian originality are still understandable. Now, based on the issue, this study intends to answer the question that the geometric principles used in the architecture of the Kaboud Mosque of Tabriz are consistent with the principles of Iranian architecture. And it analyzes the ambiguities that arise in the stylistic discussions about this building.

2. LITERATURE REVIEW

To study and know the Kaboud Mosque of Tabriz, one can obtain various information from written sources, sources in each of which is a special way, about the artistic and architectural wonders of this work have been commented. "Zaka" a researcher of Iranian history and civilization, had a good knowledge of the history of art and architecture in Tabriz and Azerbaijan. Regarding the originality of the style of the Kaboud Mosque in Tabriz, he believed that the architectural form of this building is derived from cultural and social relations between Iran and the Ottoman Empire in the ninth century AH (Anno Hegirae). He writes: It seems that the architectural plan of "Yeşil" in Turkey is an adaptation of this mosque [11]. Of course, this section has its drawbacks, because the Yeşil Grand Mosque in the current Turkish city of Bursa was built and completed in 822 AH, i.e. 48 years before the Kaboud Mosque [12].

Blair and Bloom are two other scholars who have commented on the architectural style of this mosque. By understanding the common formal relations between the Kaboud Mosque of Tabriz and the mosques of the Ottoman region and by acknowledging the defensible architectural commonalities, they have proposed the influence of another architectural flow in the structure and volumetric composition of the Kaboud Mosque. The mentioned architecture is the brilliant architecture of the Timurid era, which at that time was widespread in parts of Iran, especially in the Greater Khorasan region. By quoting an example from the tomb of Amir Shah Malek (known as the Shah Mosque of Mashhad), which is one of the valuable buildings of the Timurid period, Blair and Bloom suggest that: The architect of the Imam Mosque in Mashhad is the same person who designed and mapped the Kaboud Mosque and was familiar with the architecture and design of the Green Mosque in the Borseh [13].

This opinion has been repeated by Hillenbrand. The difference is that he does not emphasize the similarity of the Kaboud Mosque with the mosques of the Ottoman region and he argues is that the architectural form of the Kaboud Mosque is the evolution of the architectural experiences of the Timurid period and the result of the continuation of architectural experiences in Khorasan region. When discussing the works of Timurid architecture, after describing the plan and architectural form of the tomb of Amir Shah Malek, he writes: The most magnificent is the Kaboud Mosque of Tabriz, in which an idea similar to the Shah Mosque and with a more complete expression due to the open-space Central has been presented [14]. However, in the face of such views, Pirnia has expressed a completely different view of the Kaboud Mosque and believes: The plan of this mosque, which has no central courtyard, was taken from the Shah Vali Taft Mosque. Then the Sheikh Lotf-Allah Mosque in Isfahan has been used [7].

What was said was a selection of the most popular views that have been put forward about this building and shows the diversity of views that exist in this field. The science of geometry in architecture has always been an interesting research subject. The development of geometry and other branches of knowledge in the Islamic world began during the eighth and ninth centuries AD with translations of ancient texts from languages such as Greek and Sanskrit into Arabic [15]. In the field of geometry, important developments were the result of the efforts of scientists such as Khayyam, Abolfafuzjani, Abu Mansour Kharazmi, and Ibn Meysam [16]. Persian architects considered geometry to be an important science. Geometric analysis of many Persian historical monuments has proven that in Persian architecture, complete knowledge of proportions, especially the golden ratio, has been widely used and this has been the aesthetic basis of Persian mosques [17].

In the past, the implementation of building shapes and sizes was done using the knowledge of geometry, which was the basis of controlling the building in terms of aesthetics and statics. Past Iranian architects with familiarity with the knowledge of geometry and the ability to implement geometrical relationships sought to match theoretical geometrical methods with their tools [18]. Published research in geometry and proportions can include the work of former Soviet scholars, such as geometric analyzes of "Bolatov" on the tomb of the "Ghatlagh Agha" in Samarkand, "Man Kufskaya" on the tomb of "Khajeh Ahmad Yasavi", and "Donald Wilber" on the school "Goharshad' pointed to Herat in Central Asia (which was specifically focused on the Timurid and Ilkhanid periods) [19].

In the present study, an attempt is made to reveal the decisions of the architect in creating this beautiful and lasting work by the geometric analysis of the architecture of the Kaboud Mosque in Tabriz and to determine the origin and roots of the design of this building.

3. RESEARCH METHOD

This research has been done with the help of formal systems and is largely dependent on regular and analogical propositions, so the research method of this research is logical and descriptive-analytical reasoning. First, the initial pictures and plans of the building were taken from the Tabriz Cultural Heritage Office and completed based on field observations and perceptions by the authors. Then, the form analysis is performed by referring to the firsthand documents and sources in the writings related to the geometric reading of architecture, using manual drawing and the simplest tools such as a ruler and compass. The purpose of the formal or geometric analysis is to study the planar structure by dividing the space into simple geometric shapes and measuring its degree of compatibility with the resulting rectangles of regular pentagons and hexagons. It should be noted that in the regular pentagonal and hexagonal form, due to the possibility of simple and low error drawing on the one hand, and also due to the special ratios that exist between the side and the diameters of each of these shapes (golden ratio), to The title of the basic form of analysis is considered. Finally, final drawings and geometric analyzes were drawn in AutoCAD software to increase the accuracy of the analysis.

4. GEOMETRY IN IRANIAN-ISLAMIC ARCHITECTURE

The Iranian architect has always paid the most attention to the positive aspects of architecture (such as logic, static principles, technical and scientific issues of the building, human scale, use of local materials,

etc.). The basis for achieving the correct type and shape of coatings and load-bearing parts and their location and dimensions was unique, in which the architect had complete control over its quality [5]. Calculations and geometry were so important that only first-class and famous architects were called engineers [4]. This type of application of geometry in the design of coatings and dimensions and fit of full and empty parts of the building is the structural application of geometry in architectural design. Sometimes, to create harmony and create reasonable proportions in the building, the dimensions were determined and all parts were subordinated to it. Networking in Iranian architecture and modular in European architecture has been such an indicator. In this architecture, networking, according to the intended spaces is a means of adjusting the dimensions and sizes, and geometry of the architectural guide in providing proportions and principled coordination [20].

The results of many scientific and psychological types of research show that the most beautiful surfaces and shapes from the point of view of human beings are those that have a golden ratio in their dimensions [21]. Renaissance writers called this proportion the celestial relation and the followers of Euclid called it the essence of the middle and the sides, and from the 19th century onwards this proportion became known among artists as the Golden Division. During the Renaissance, the study of this ratio was common among mathematicians [22]. As Cockster writes in the first part of his paper, quoting Kepler: Geometry has two great treasures, one is the Pythagorean theorem and the other is the division of the line relative to the middle and sides, the former with gold and the latter with a precious gem can be compared [23]. The Greeks showed their perfectionism by realizing the golden ratio and using it in their temples, using it in columns, statues, facades, and plans. Leonardo Da Vinci and Kepler, who used the golden divisions, can be mentioned as the continuation of this method. Recently, Le Corbusier based his modular system on the golden ratio.

When a line segment is divided in such a way that the ratio of the whole segment of the divided part is greater than, equal to the ratio of the larger to the smaller divided part, then this ratio will be approximately equal to 1.618, which is the golden ratio [24]. In other words, the golden ratio is a fixed number that if we add a unit to it, we will reach the second power of that number. These proportions are obtained by developing a proportional set of coordinate exponential integers such as 1, 1, 2, 3, 5, 8, 13, etc. and its characteristic is that the sum of both consecutive numbers is equal to the next number. The logarithmic curve and ratio of numbers in a golden rectangle are shown in Figure 1.

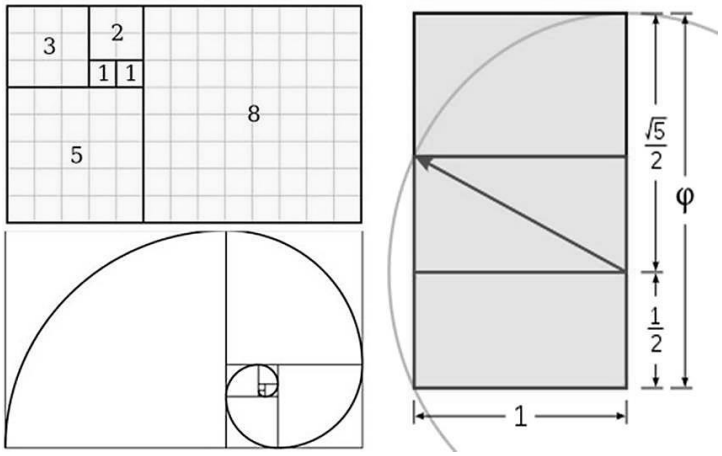

Figure 1. *Logarithmic curve and ratio of numbers in a golden rectangle [25]*

In other words, geometry has been part of the manifestation of the concept of beauty in Iranian architecture. Golden proportions have long been considered by architects in Iran and the Islamic era, and have been widely used in the design and construction of historic buildings, and in most of the historical monuments of Iran, these proportions have been used [26]. The selection of regular pentagons and hexagons by Iranian artists and their use in architecture (especially covering domes) draws their attention and accuracy in selecting and obtaining the best proportions in lines and surfaces. Because in regular pentagons and hexagons, the ratio of radius to side length is the same golden ratio that has been used in the original Iranian-

Islamic architecture [27]. Also, the isosceles triangle, which Abu al-Wafa Buzjani used to draw a pentagon and called a pentagonal triangle, is a triangle that has this golden ratio between its leg and its base [28].

In the study of the application of geometry in architecture, whether its mystic meanings, structural application, or modular dimensions are considered until geometry cannot be shown in the plan and facade, it cannot be claimed that such knowledge has been obtained [19]. At a higher stage, the researcher must be able to design based on this knowledge. The design here does not mean changing countless design elements. This design requires accurate identification of geometric elements at different levels and the position of each element in the design, understanding of the relationships between them, composition techniques, and their meanings [29]. Although today the mystical principles, geometry, and networking of geometry have been replaced by new principles, it is necessary to know those principles in the study of traditional architectural works and gain a comprehensive understanding of their design.

5. RECOGNIZING THE FORM OF KABOUD MOSQUE IN TABRIZ

Kaboud Mosque is one of the unique examples of ancient Iranian architecture and the only building that has survived the reign of the "Qaraquyunlus" in their capital, Tabriz [11]. The architectural beauties of this mosque are so interesting and attractive that even now, after centuries and damage to its structural integrity, it amazes every human being. Kaboud Mosque was originally a member of a larger architectural complex called the "Mozaffariyeh Complex". Unfortunately, over time, the glory and development of the Mozaffariyeh complex do not last long and are damaged and destroyed by repeated earthquakes in Tabriz. However, what is now in front of our eyes from the most important member of the Mozaffariyeh complex, the Kaboud Mosque, is a building that is the result of renovations and interventions in the last eighty years (from the first Pahlavi period, until now) [10]. The plan, Facade, Section, and pictures of the Kaboud Mosque in Tabriz are shown in Figure 2.

Figure 2. *Plan, Facade, Section, and pictures of Kaboud Mosque in Tabriz*

According to Blair and Bloom, the Kaboud Mosque in Tabriz has always been unique in Iran in terms of architecture and decorations [13]. Pirnia also introduces this mosque (Azari style swan song) in the discussion of Persian architectural stylistics and says: Unlike most mosques, Kaboud Mosque has no middle courtyard and has been built extroverted due to the cold weather in Tabriz [7]. To complete Pirnia's speech, it should be said that in the ninth century AH, when the main foundation of the Kaboud Mosque was formed, according to the tradition of Persian architecture, mosques were usually built introverted and with a middle courtyard [5]. However, Kaboud Mosque, unlike its contemporary mosques, does not have a central courtyard (so-called mass architecture).

The important point in the architectural typology of the Kaboud Mosque is its function, which means that it is not just a mosque and has a dual-purpose function, namely a mosque-tomb. In other words, the southern part of the building is the mausoleum, and in terms of hierarchy, access to the mausoleum is possible only by passing through the mosque, and two accesses are located on both sides of the mosque altar. Relationships between spaces and micro-spaces in the plan of Kaboud Mosque in Tabriz are shown in Figure 3.

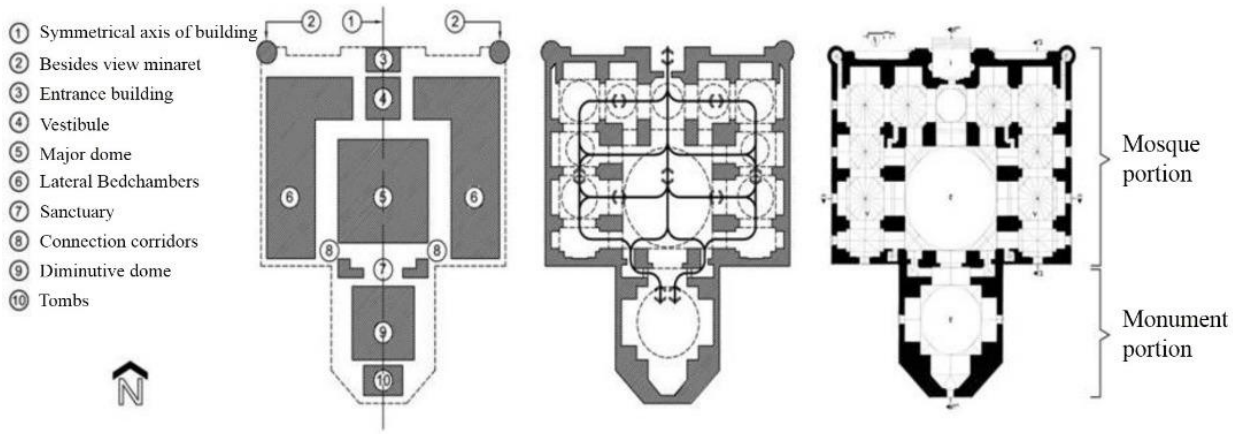

Figure 3. *Relationships between spaces and micro-spaces in the plan of Kaboud Mosque in Tabriz [11]*

Another important point of the architecture of the Kaboud Mosque is that there are similarities between this mosque and some Ottoman mosques. Because the Kaboud Mosque, like them, is a building with two domes and no central courtyard [15]. Much of the Anatolian region was under the political and military control of the Ottoman dynasty at a time when the Kaboud Mosque in Tabriz was under construction. Two-domed buildings in the Ottoman Empire include the first buildings built in the city of Bursa (the first real capital of the Ottoman Turks) and then examples of this type appeared in other cities in the Anatolian region [12]. According to Hillenbrand, the design of mosques of this period, based on the logic used in the early Ottoman mosques (the design of a single central dome dominating the building) in broad dimensions and at different scales took firm steps [14].

When the Turkmen of "Qaraqoyunlu" and "Aq Quyunlu" took control of the northwestern parts of Iran, power was in the hands of the Timurids in eastern Iran, and cities such as Samarkand, Bukhara, and Herat were the ruling centers of the dynasty [13]. Contrary to what has been said about the architecture of the two-domed buildings in the Anatolian region, this type of architecture was not the common style of the Timurid era. However, in the architecture of the Timurid period, buildings with two domes and even more have been designed and executed [5]. Of course, it should be noted that in Timurid architecture, the authority of two domes in a building was never by the principles seen in Ottoman architecture. Sample plans of two domes. A: Ottoman and B: Teymouri is shown in Figure 4.

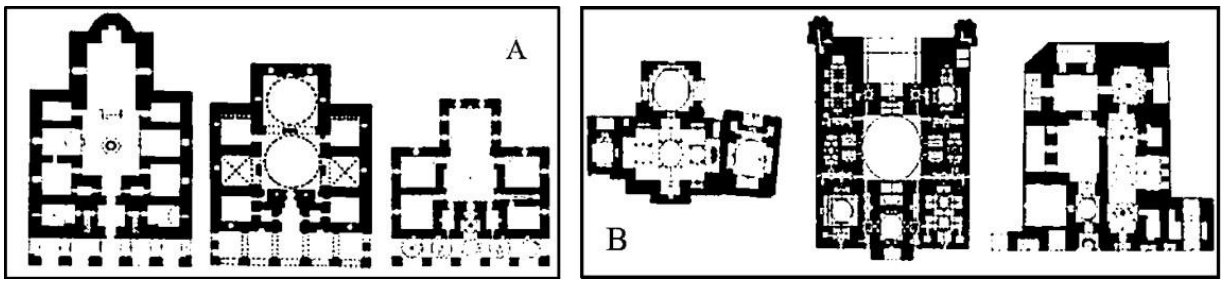

Figure 4. *Sample plans of two domes. A: Ottoman (Bayazid Pasha Mosque, Ildirim Bayazid Mosque, Godfather Mosque in Bursa). B: Teymouri (Shrine of Darb Imam in Isfahan, Tomb of Khajeh Ahmad Yasavi in Turkestan, Tomb and Mosque of Toman-Agha) [13]*

The common architecture of the Timurid era (regardless of the number of domes) is a type of building with a central courtyard design and in terms of facade features, an asymmetrical body with a high porch and minarets in each corner is the dominant type of Timurid buildings [7]. In summarizing what has been discussed so far, the commonalities and differences between the architecture of the Kaboud Mosque and similar Ottoman and Timurid examples can be deduced, which can be classified as follows:

- Materials: In terms of materials, Anatolian mosques are generally stone buildings, while in the structure of the Blue Mosque, the predominant use is brick, which is a native and common material of the city.

- Decorating the outer walls: In the architecture of Ottoman mosques, there is a kind of indifference to decorating the exterior. Their exterior decorations are inefficient and focused on the interior [14]. Meanwhile, in the architectural system of the Kaboud Mosque, according to the tradition of Timurid architecture, in addition, to decorating the interior, attention has been paid to decorating its exterior.

- Interior relations: In Ottoman examples, the spatial continuity and sequence of relations between the two domes are easier and smoother than in the Kaboud Mosque. In the Kaboud Mosque, the space of the two domes is separated, although there is a connection between the space of the two domes (which is due to the difference in their function). A comparison of relations between two domes in samples of the Anatolia region and Kaboud Mosque is shown in Figure 5.

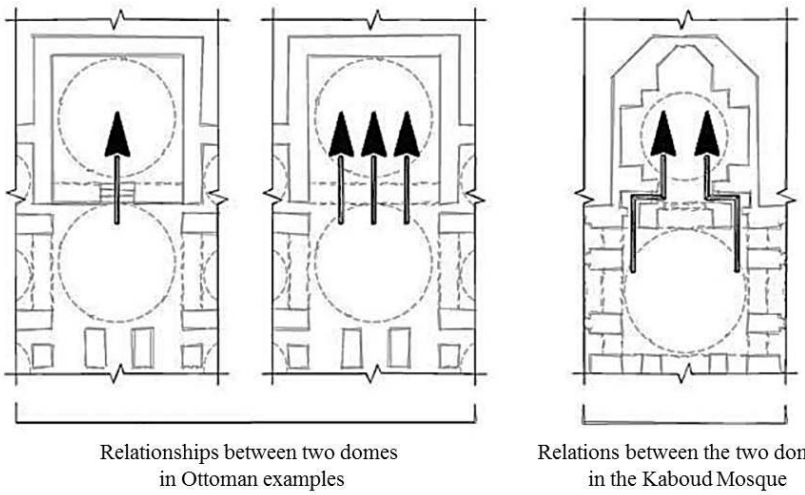

Figure 5. *Comparison of relations between two domes in samples of the Anatolia region and Kaboud Mosque [8]*

- Plan design: The plan of the Kaboud Mosque in terms of design is similar to the plan of Ottoman mosques and even in terms of the number of domes, and the locations of large and small domes are similar.

- Facade: In the facade of Ottoman mosques, no element is more prominent than the other element, but in the Kaboud Mosque in the context of Iranian architecture, in the middle of the entrance facade of the

mosque (northern facade) a large porch, two panels of the entrance element and has been distinguished from other parts of the facade. The similarity of the plan and facade of the Kaboud Mosque to the dominant type of Ottoman and Timurid examples is shown in Figure 6.

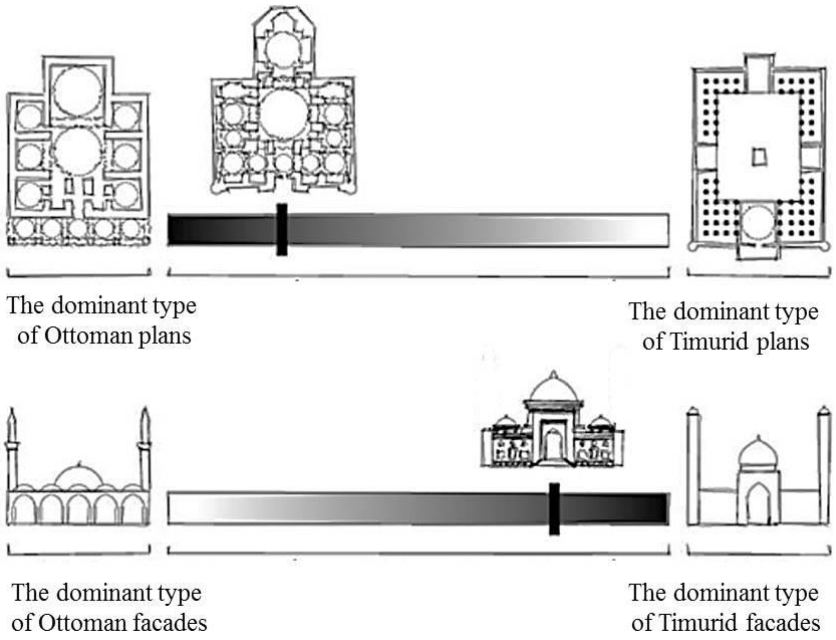

Figure 6. *The similarity of the plan and facade of Kaboud Mosque to the dominant type of Ottoman and Timurid examples [8]*

6. GEOMETRICAL ANALYSIS OF KABOUD MOSQUE IN TABRIZ

We know that Kaboud Mosque in Tabriz is a building that was built in one stage and was not developed later and only renovated [10]. Therefore, it can be considered as a whole unit and expect significant relationships between the components and the building as a whole. This confirms the possibility of designing it based on a predetermined geometrical pattern. In addition, assuming that the building is a tomb, which was examined in the previous sections (it is a kind of religious architecture), it can be expected that the designer wanted to perfect his design using geometrical drawings. The use of geometry in design can be considered in two ways [19]:

1) Finding important points and places in a design using geometrical drawings, which is the main subject of analysis of this article. These geometrical drawings can generally be examined on two levels. The first level contains the geometric shapes of the appearance in the design. Such as squares, octagons, and regular polygons visible in the plan, façade, and details. The second level analyzes the geometric designs that determine the dimensions, direction, and accompaniment of the shapes of the previous level and are not visible at first glance.

2) Using geometrical drawings to obtain values and proportions that determine the dimensions and proportions of different parts of the building and its components. As seen in the architectural works of Egypt and Greece, these geometrical drawings generally turn into numeric results such as $\sqrt{2}$ and $\sqrt{3}$, golden ratio, and so on. Then these numeric ratios appear in the dimensions of the shapes. In this article, we will address this type of analysis as a sub-topic.

The first shape that catches the eye in the facade has a straight fit. The length of the side of this square, as explained in the geometry of the plan, is based on the drawing of several hexagons of the dimensions of the plot. One side of this square coincides with the ground line of the building and in the most basic, stage determines the diameter and the average height of the volume. The middle discontinuous seam in the form of an octagon also exactly matches this square. The placement of the main square in the facade is shown in Figure 7.

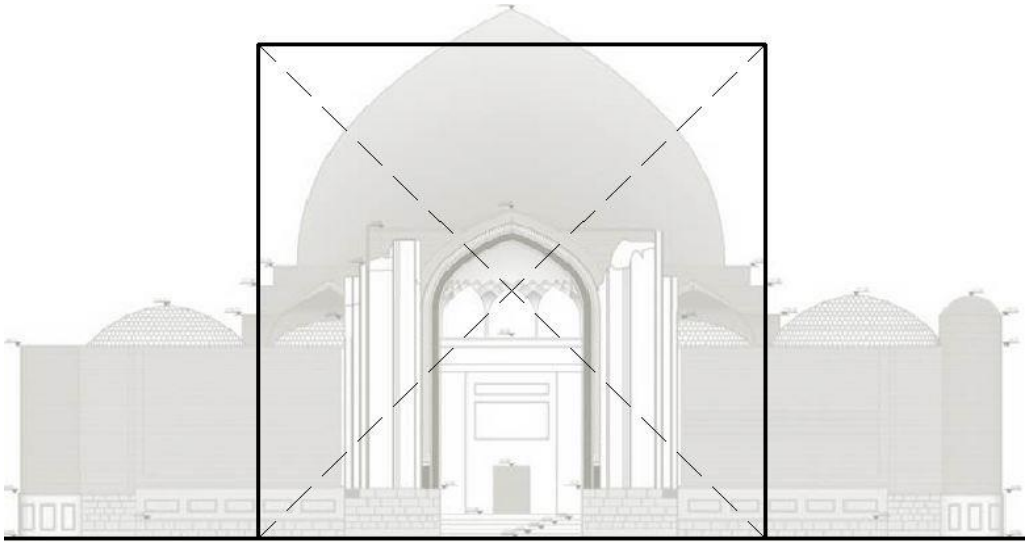

Figure 7. *Placement of the main square in the facade*

Before obtaining the second group of important points of the building, it is necessary to make preliminary drawings. The first is to draw the hexagon ABCDEF inside the square as shown in Figure 8. The vertex A of this hexagon coincides with the vertex of the dome. Hexagonal drawing with this orientation is very common in traditional Persian architecture. For example, a hexagon is used to find the optimal orientation of the building and to draw a sharp clover arch in Persian architecture [30]. The hexagon is also the basis for drawing a golden rectangle (1: $\sqrt{3}$). Draw a circle to the center O (the intersection of the square diameters) in the hexagon ABCDEF. Drawing a hexagon of a square is shown in Figure 8.

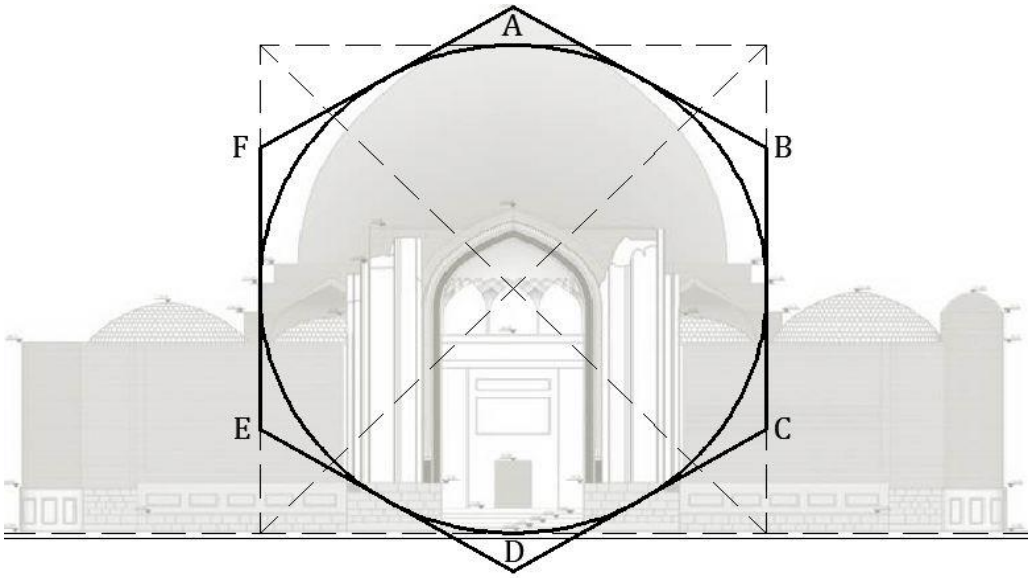

Figure 8. *Drawing a hexagon on a square*

The points of intersection of segment BF with the circle are called G and H. We find points I and J similar. The quadrilateral GHIJ is a rectangle $\sqrt{2}$. We get the rectangle G'H'I'J' by rotating 90 degrees of the rectangle GHIJ. The H'I' side coincides with the top of the plinth and the GH line segment coincides with the middle of the dome height. The sides G'H' and I'J' also show the protrusion of the mosque entrance. Drawing a rectangle $\sqrt{2}$ is shown in Figure 9.

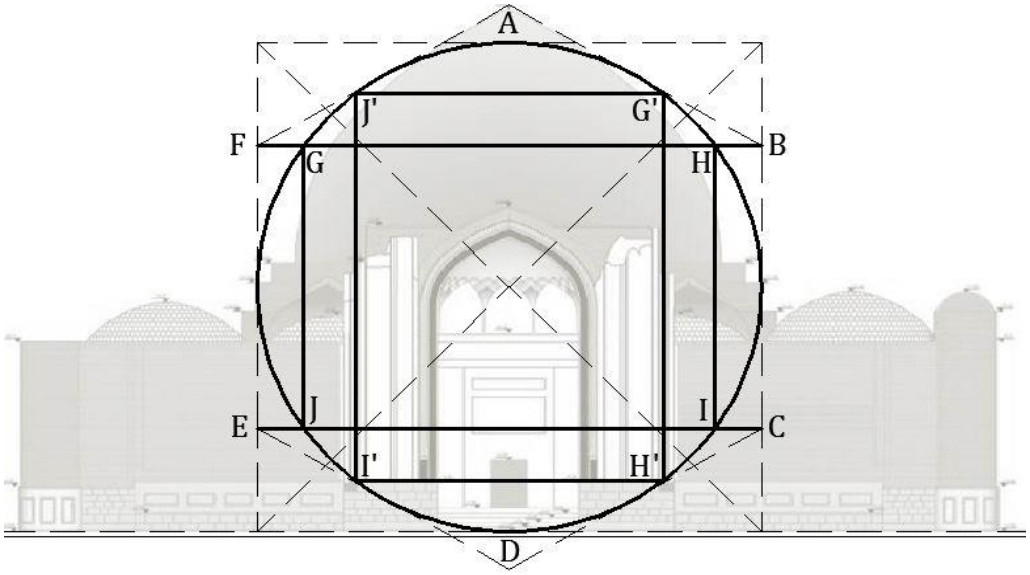

Figure 9. *Drawing a rectangle* $\sqrt{2}$

Draw from point J vertical to FC. We call the foot of this vertical K. Draw an arc to the center J and to the radius JK to intersect the length IJ at L. The perpendicular foot along the H'I' (above the plinth) of J and L is called J_1 and L_1. Finding the side edge of curved coverings (small domes) is shown in Figure 10.

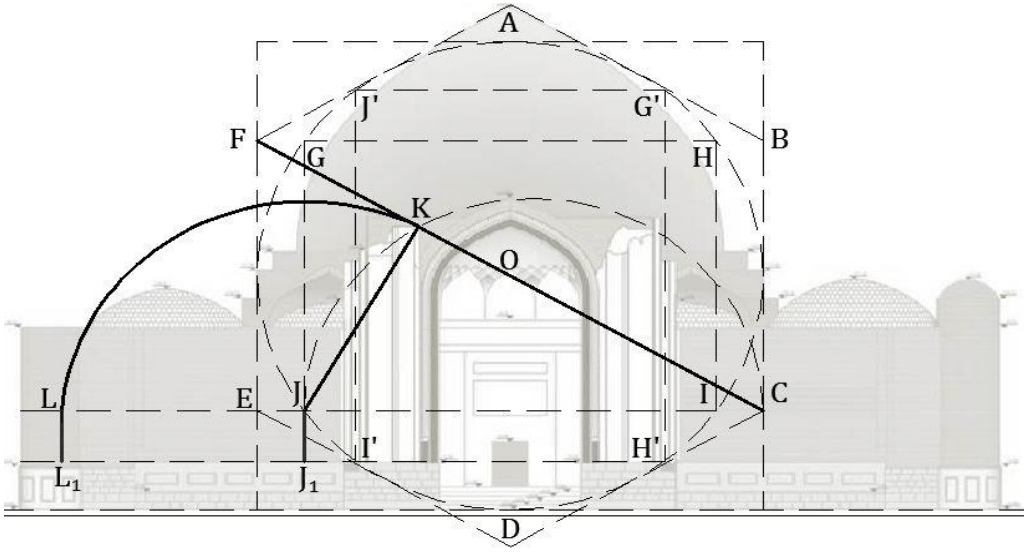

Figure 10. *Finding the side edge of curved coverings (small domes)*

The middle of J_1L_1 is called M and the line segment MN is vertical to the length ML_1 on J_1L_1. Then draw an arc to the center L_1 with radius L_1N to intersect the vertical line passing from L to P. The points J_1, L_1, and P are the three vertices of another rectangle $\sqrt{2}$, the fourth vertex of which is called Q. The PQ line segment touches the roof (flat surface) of the mosque and the PL line segment shows the edge of the side towers. Finding the roof surface is shown in Figure 11.

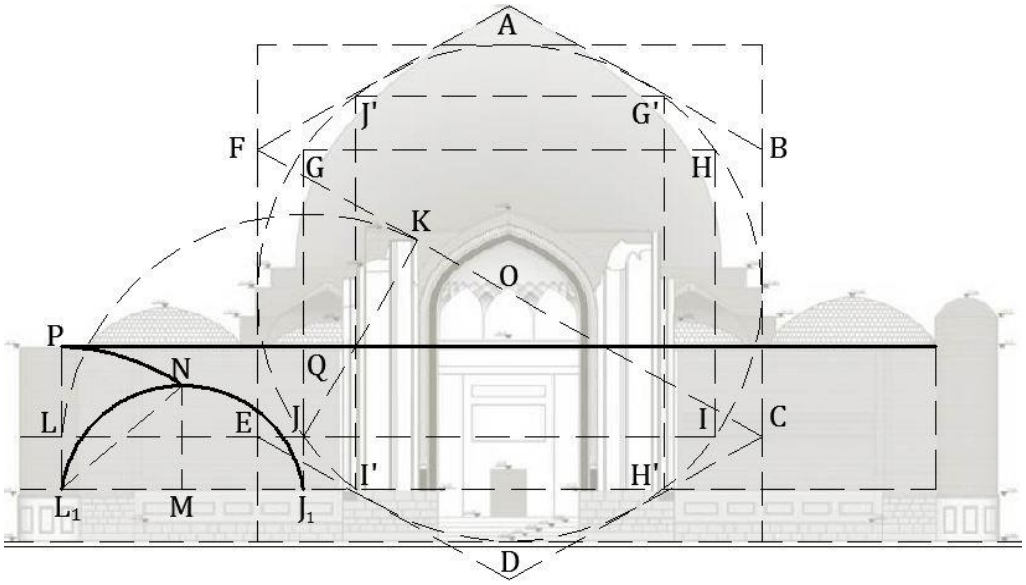

Figure 11. *Finding the roof surface*

To find the edge of the facade, it is enough to extend the lower side of the main square of half of it. Finding the edge of the façade is shown in Figure 12.

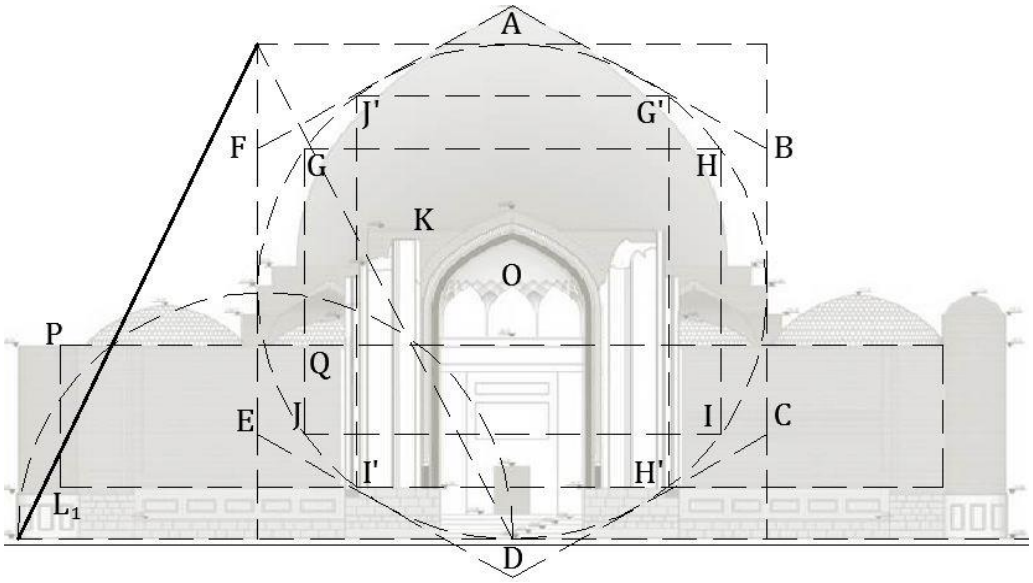

Figure 12. *Finding the edge of the façade*

Converting a square plan to a circular plan (dome) is one of the innovations of Persian architecture. Using this technique, Persian architects could cover a larger area with curved ceilings [5]. To find the central square of the dome, it is enough to draw a golden rectangle (Φ: 1) whose small side is equal to PL_1. For this purpose, we call the intersection of the vertical symmetry axis with the two lines of the upper facade (roof surface) and the lower facade (above the plinth) U and V and draw the square UVWX. Then we call Y the middle of UX and draw an arc to its center and to the radius YW to intersect the lower edge of the facade (above the plinth) at Z. The Z point represents the central square corner of the dome. Finding the central square of the dome is shown in Figure 13.

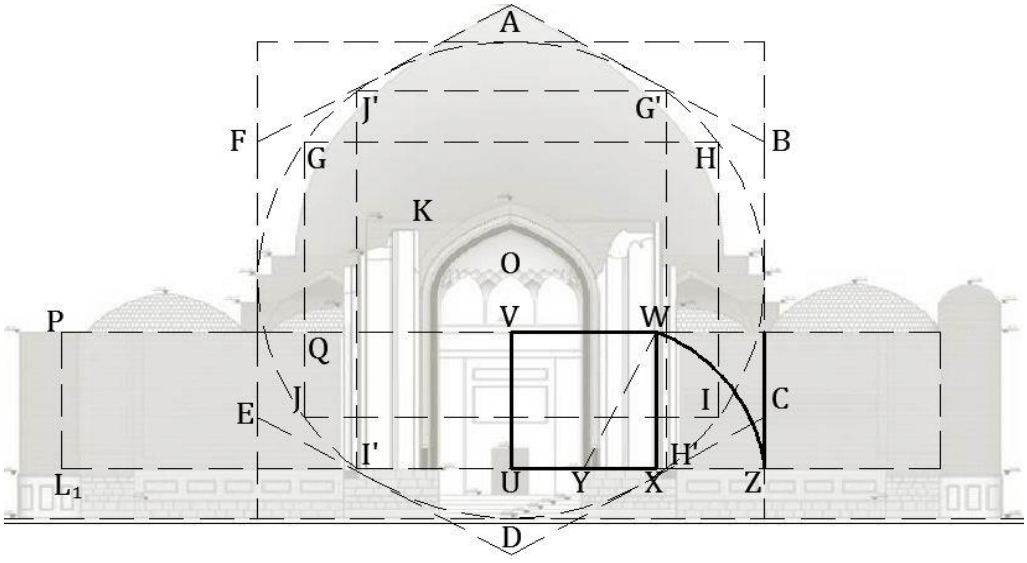

Figure 13. *Finding the central square of the dome*

On the other hand, the golden proportion Φ can be followed in the Kaboud Mosque of Tabriz. We know that in a rectangle drawn with proportion Φ if a square is subtracted from one side, the remainder is a new rectangle with the same proportion. By continuing this process, a logarithmic spiral can be obtained that corresponds to many natural shapes. This spiral inclines to point E. To find this point; you can draw the diameter of the AC and insert it vertically from vertex B. By symmetry of this point of the axes of symmetry of the rectangle; a new rectangle will be obtained, which has a golden ratio. As seen, these drawings can also be accurately adapted to the layout of the mosque. The resulting golden rectangle coincides with the central square corner of the dome. Also in the negative space on both sides of the dome, two other golden rectangles can be seen. Golden proportions in the facade of the mosque are shown in Figure 14.

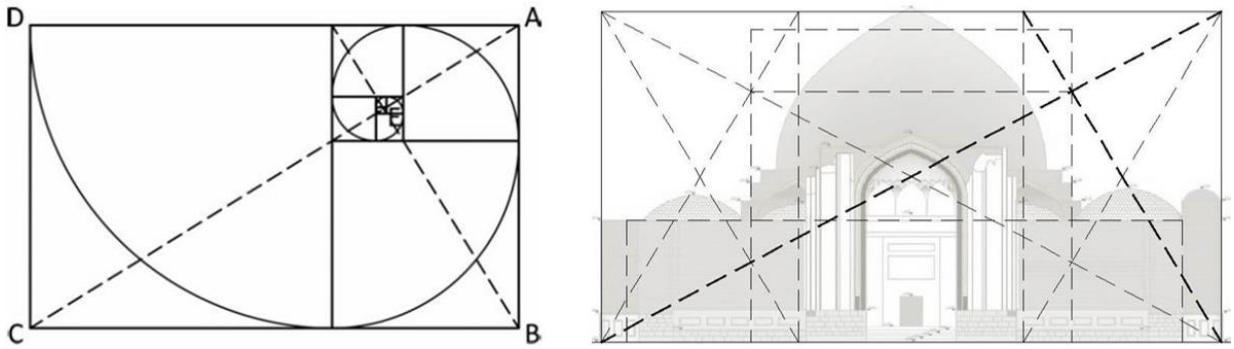

Figure 14. *Golden proportions in the facade of the mosque*

A similar geometry can be found in the plan of the Kaboud Mosque in Tabriz. To draw a plan, first draw a square, a circle, and a hexagon ABCDEF like its facade. The dimensions of these shapes are also equal to the dimensions of the facade shapes. Clearly that the hexagonal circle coincides with the central square of the dome. Draw the hexagon A'B'C'D'E'F' in the circle enclosing the hexagon ABCDEF. Extend the two sides B'C' and E'D' to intersect at point G. Point G is located in the middle of the entrance of the mosque. Extend the two sides B'A' and E'F' to intersect at point G'. Point G' is located in the middle of the second dome (tomb dome). Matching the hexagon geometry of the facade with the plan is shown in Figure 15.

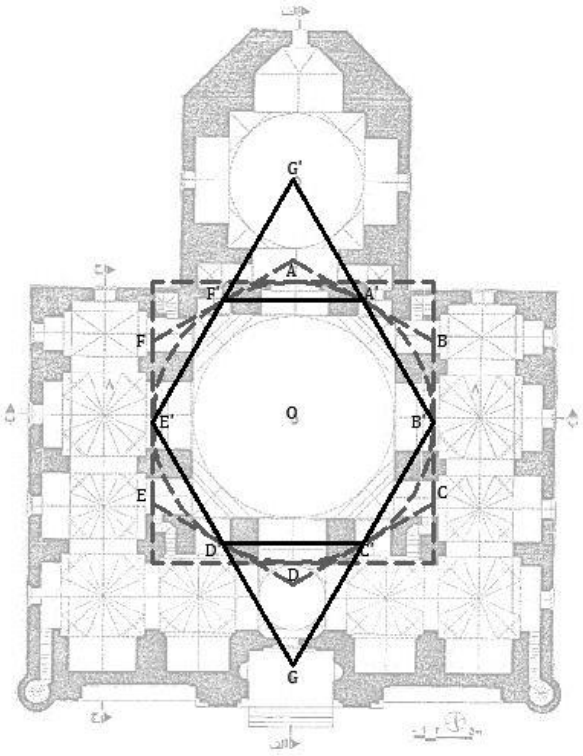

Figure 15. *Matching the hexagon geometry of the facade with the plan*

Hexagonal geometry can also be found in building details. The tiling patterns of the interior of the mosque are placed in hexagons. Furthermore, the plan of Mogharnas at the entrance of the mosque is based on dividing the semicircle into six parts. Hexagonal geometry in mosque decorations is shown in Figure 16.

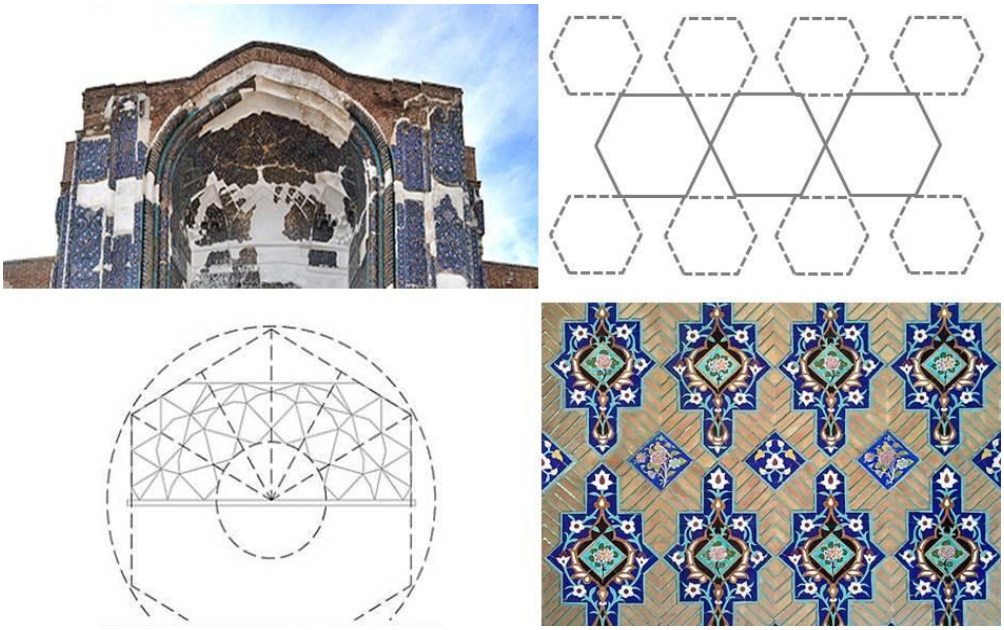

Figure 16. *Hexagonal geometry in mosque decorations*

The presented geometrical drawings showed that there are coordination and certain principles in the decision of the architect of this building in the design and construction of each part of the mosque. The use of the hexagonal geometrical system indicates the necessary knowledge and knowledge of the architect of this monument from the geometric proportion system of Iranian architecture [6]. This choice was not made by default and was imposed on the building. Rather, the sizes and proportions of length, width, and height of the geometrical shapes used in the building contributed to this decision. Using a hexagonal geometrical

shape, the architect has created a special beauty between the depth, the opening, and the height of the entrance facade.

On the other hand, the architect was fully aware of the golden proportions and how to use and influence them creating a visual balance in the eyes of the audience. Choosing the height of the main entrance of the mosque has created the most beautiful proportions in the building according to the porch and dome. Despite the accuracy of the research and the comprehensiveness of the research, the geometric drawings presented in this article have only a suggested aspect and do not claim proof. Such a claim would require documentation from the builders, which unfortunately does not exist.

7. CONCLUSION

In this article, an attempt was made to recover the hidden geometry of this building after the introduction of the Kaboud Mosque in Tabriz. Furthermore, in the case of land use based on the evidence provided, it was concluded that this mosque was built as a tomb. The geometry found in the plan, facade, and cross-section (coordinated together) is based on regular hexagons. Previously, analyses have been performed on ancient Persian buildings based on squares, regular pentagons, regular octagons, etc. The achievement of the present article based on hexagons can be considered unique, at least in Persian architectural works. Furthermore, the proposed method for drawings has the property that it finds the important points of the building step by step and reaches the details of the general dimensions. The drawings presented in this article are presented on the facade, cross-section, and plan side by side and in harmony with each other.

At first glance, the Kaboud Mosque of Tabriz is strongly influenced by the effects of Ottoman architecture. The materials used in the facade and the carvings done on them have made the appearance of the building look like Ottoman architecture. However, as mentioned in the text of the article, this work is completely Iranian at its heart. One of the hidden features of the building, which was examined in detail, is its geometry. This feature, along with other features, has made its design one of the valuable examples of Persian architecture. Furthermore, the special geometrical method used in the building distinguishes it from similar examples and has given it a Persian identity. Realizing the geometrical feature of the work and its creative application along with other features and concepts can help to revive the original Iranian identity in architectural works.

Although the architectural style of this building opened a new chapter in the design of mosque Iranian architecture, it could not arouse the desire of later architects to repeat and complete its form. Therefore, the idea used in the creation of the architecture of the Kaboud Mosque in Tabriz was like a single star that shone once and then turned off. Meanwhile, the architecture of the two Ottoman domes in the mainland (i.e. the Anatolian region, which was the origin of its form), successfully continued its evolution and finally manifested distinctive works in Istanbul.

CONFLICTS OF INTEREST

No conflict of interest was declared by the authors.

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