TRADITIONAL COMPLEX MODULARITY IN ISLAMIC AND PERSIAN ARCHITECTURE: INTERPRETATIONS IN MUQARNAS AND PATKÂNÉ CRAFTS, FOCUSING ON THEIR PREFABRICATED ESSENCE

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INTRODUCTION

Prefabricated architecture has been a subject of fascination for architects since World War I. It started gaining popularity early in the 20th century in the western world. In the history of architecture prefabrication and modular construction are perceived as the result of modernism, effecting massive increases in construction programs in the public sector. Thinking of prefabrication and modularization carries one towards the Islamic world of architecture in the eastern world rather than early western modernism. This work focuses on *Muqarnas*, a special three-dimensional ornamentation with complex modularity, which was a common vaulting in Islamic Architecture. This paper introduces this craft as an example of modular construction and an early prefabrication method.

The intention here is to find a new starting point for ideas of modularization, question the history of modern architecture and trace its routes through traditional Islamic Architecture. When is the actual starting point of ideas of prefabrication? Post war era in the early 20th century in the western world, or hundreds of years prior to that in the eastern world?

To find the answer, the authors will attempt to discover the essence of the Muqarnas. First, the preliminary definitions of this craft will be outlined, after which its development will be traced. Thereafter, a new discourse on the Islamic Architecture parallel to the studies of Muqarnas will be initiated. At this point, *Patkâné* will be presented as an early origin of the Muqarnas. Comparing these two crafts leads to the early ideas of prefabrication and modularization. Specific studies on the proposed hypothesis are based on recognition of the traditional methods in areas of design, calculation and construction of the Muqarnas in Persian and Islamic Architecture.

Analytical resources in this study have led to deducting components and parameters of prefabrication in both areas of design and construction of the Muqarnas. This leads to the paper's hypothesis. This traditional craft from Persian and Islamic architecture, with its significant morphologic and spatial varieties, will be introduced as one of the oldest movements of the prefabrication and modularization in history of architecture.

RESEARCH METHODS

The primary data resources in this study are documented drawings and literature, which provide theoretical geometry[1] of Muqarnas and Patkâné. These data are derived from analysis and interpretations of manuscripts left from the 15th century Muslim mathematician *Ghiyathe al-din jamshid Kashani*.

Parallel to the above-mentioned documented data from preceding times, there are two sources of complementary information, Oral Research and Field Research, which provide data for practical geometry in this study.

Verbal information in this study is gathered from in-depth interviews and participant observations with Mimars[2] Our verbal data is gathered from experts such as *Asghar Sh'arbaf, Heidar Eshgh-Abadi and Hamid-Reza Kazempour* (Sharbaf's apprentice). The second source is the surveying of preceding architectural pieces from which were produced 2D and 3D line drawings. This has been classified as field research.

The aforementioned collected data represents a network of comprehensive information, both theoretical and practical aspects of the Muqarnas. This analysis will eventually reflect the proposed hypothesis on the course of prefabrication in this area of Islamic architecture.

ESSENCE OF MUQARNAS

Muqarnas are a traditional architectural embellishment of Islamic and Persian architecture, which resemble stalactite rock formations. Among the most characteristic artifacts and original inventions of medieval Islamic Architecture, they are structures formed out of small pointed niches with rhythmic modularity and infinite compositions. They were built to break down vaults and domes into multiple facets with the purpose of unifying a dome's transitional zone into a compositional unity.[3]

There is a description of this craft in the book of Ghiyathe al-din Jamshid Kashani, "Key of Arithmetic". The Muqarnas is a vaulting like a staircase with facets and a flat plates. Every facet intersects the adjacent piece at a right angle, half a right angle, their sum, or another combination of these. The two facets can be thought of as standing on a plane parallel to the horizon. Above them is built either a flat surface not parallel to the horizon or two surfaces, either flat or curved that constitute their roof. Both facets together with their roof are called one cell. Adjacent cells, which have their bases on the same level, parallel to the horizon, are called one tier. The measure of the base of the largest facet is called the module of the Muqarnas."[4]

Muqarnas are sometimes regarded as a sort of wall sculpture, which is usually adorned with painting or tile mosaics. It is an ornamented ornament, which in its most basic form, is beautiful enough that it does not need more decoration.

A historic survey of the evolution of Muqarnas shows early "Muqarnas-like" elements have been found in both North-Eastern Iran and Central North Africa. Specialists in Iranian Architecture have developed a continuous line of progression in this craft, which starts from the 10th century.[5]

To gain a better understanding of the design and construction of the Muqarnas, one should search through more bygone data and older architectural elements and pieces. Among vaultings in traditional Persain and Islamic Architecture, there are structures called Patkâné, which have configurations similar to the Muqarnas. Studying those configurations along with historical records will provide a context for a comprehensive understanding of Muqarnas in both aspects of design and construction.

PATKANÉ IN PERSIAN AND ISLAMIC ARCHITECTURE

Mohammad Karim Pirnia, a prominent architectural historian and architect (1923-1998), has pioneered many new phrases, which have since been appended to the common vocabulary of traditional Persian architecture. He suggests the most appropriate explanation for the Patkâné: "Individual cell or small niche resting over other niche. Patkâné are formed out of tiers of niche. Each tier is projected and extended farther out from the course bellow. This structure was used to complete transitional zones at the corners of domes chamber." This looks at the essence of the Patkâné. Below is a closer look at this topic.

Formation of Patkâné

Historically, spatial transitions from a rectangular base to a dome used to be problematic. Iranian architects and mathematicians solved the problem by inventing a transition form as a segue between shapes. This came about during the *Ashkanid* dynasty in Iran. This evolution continued to the *Sasanids* and expanded in the Islamic era. One of the architectural solutions for the transitional zone was creation of squinch. The invention of squinch was the context for development of the Patkâné. Squinch consists of two diagonal arches, which meet each other at a point or in a line across the angle of two walls.[6] Two curved triangular plates named *Tassé* form the squinch. The preliminary samples of this technique can be found in the Sarvestan Palace.

An early example of the transitional zone is at the tomb of Amir Ismael Samani, which is an upgraded version of the Sasanid style, using rib vaults. In this example the ribs are exposed and the squinch zone is filled with two Tassé. This is the first step of developing the Patkâné. Another example is Jourjir Mosque, currently Hakim Mosque, in Esfahan 10th centry. Unlike the previous example, the transitional zone here is located inside of the half dome's portal rather than inside of the dome chamber. The Great Mosque of Naein, 10-11th centry is the next architecture piece, which demonstrates the preliminary transformations in application of the Patkâné. Here, for the fisrt time, Patkâné is represented as a shell for the whole vault rather than just sitting in one corner of the space as a complementary.[7](Fig.1)

PATKANÉ AND MUQARNAS

Due to equivocality in Islamic arts, the initial interpretations of resemblances and dissimilarities of the structure and configuration of Patkâné and Muqarnas are difficult to recognize. In the field of architecture, the problem begins with ambiguities in characteristics of the components, where it becomes difficult to understand whether a form was meant to be absolutely decorative or genuinely architectonic. Historically, a Muslim architect would think of both statics and aesthetic as separate entities.

The relation between Patkâné and Muqarnas can be understood in the same way. The Patkâné was first used as a solution for transitional zones. It then became useful in both small and large openings of the vaults. Since then, this vault was not only an architectonic[8] part of the design but it was also considered a decorative form. Transitional zones in dome chambers, column heads, cornices of minarets, *Mihrab*[9] and dropped ceilings in closed or semi-closed spaces are examples of Patkâné as a decorative craft as well as an architectonic element.[10]

Consequently, creation of Muqarnas can be translated as a branch of the evolution process of Patkâné. Hence, basic morphology of the Muqarnas is adopted from stacking of Tassé in the Patkâné design. In the meantime, what distinguishes Muqarnas as a separate craft from Patkâné, are the differences and contradictions in their geometry, structure and construction. Understanding these characteristics creates a line between these two styles.

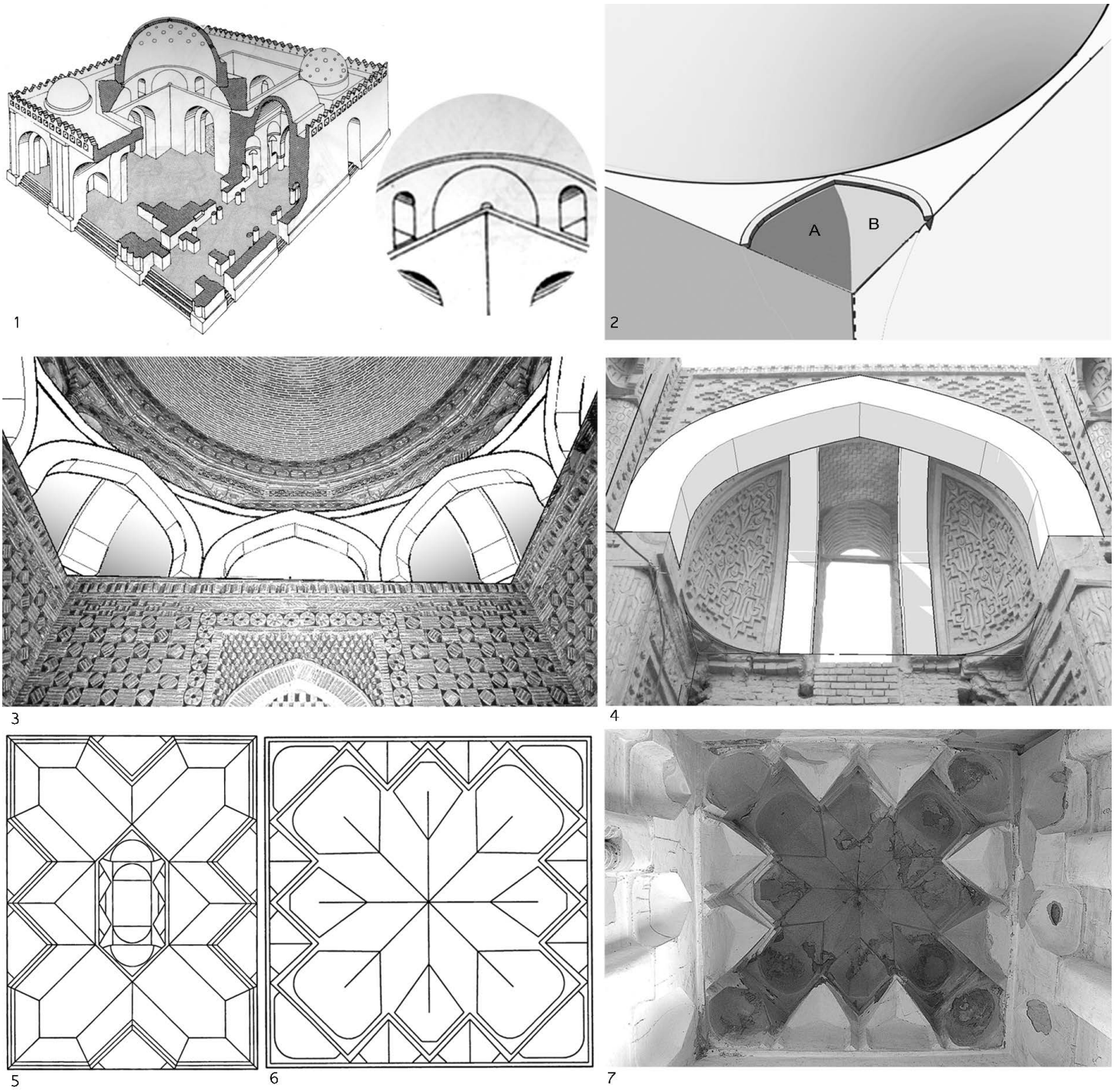


Figure 1.
1. Transitional zone in Sarvestan Palace. [Besenval, R, *technologie de la voûte dans l'Orient ancien*, 2 vols. (Paris: Éditions Recherche sur les Civilisations, 1984), 440.]
2. A squinch and its two constitutive Tassé, a & b. [Authors]
3. The Squinch transitional zone and ribs in the tomb of Amir Ismael Samani, Bokhara. [Authors]
4. The transitional zone in the portal of Jourjir Mosque, Esfahan. [Gholamhossein Memarian, ed. Hadi Safaeipour, *Mermarie Irani, Niaresh (Iranian Architecture, Structure*), (Under Publication)]
5. Plan of Patkâné vaulting in the Great Mosque of Naein. [Mohammad Karim Pirnia, ed. Gholamhossein Memarian, *Sabkshenasie memarie Irani (Stylistics Of Iranian Architecture)*, (Tehran, Iran, Pazhoohande Mimar, 2003), 148]
6. Plan of Patkâné vaulting in northen Iwan og the Great Mosque of Naein. [Mohammad Karim Pirnia, ed. Gholamhossein Memarian, *Sabkshenasie memarie Irani (stylistics of Iranian Architecture)*, (Tehran, Iran, Pazhoohande Mimar, 2003), 148]
7. Patkâné vaulting in northen Iwan og the Great Mosque of Naein. [Authors]

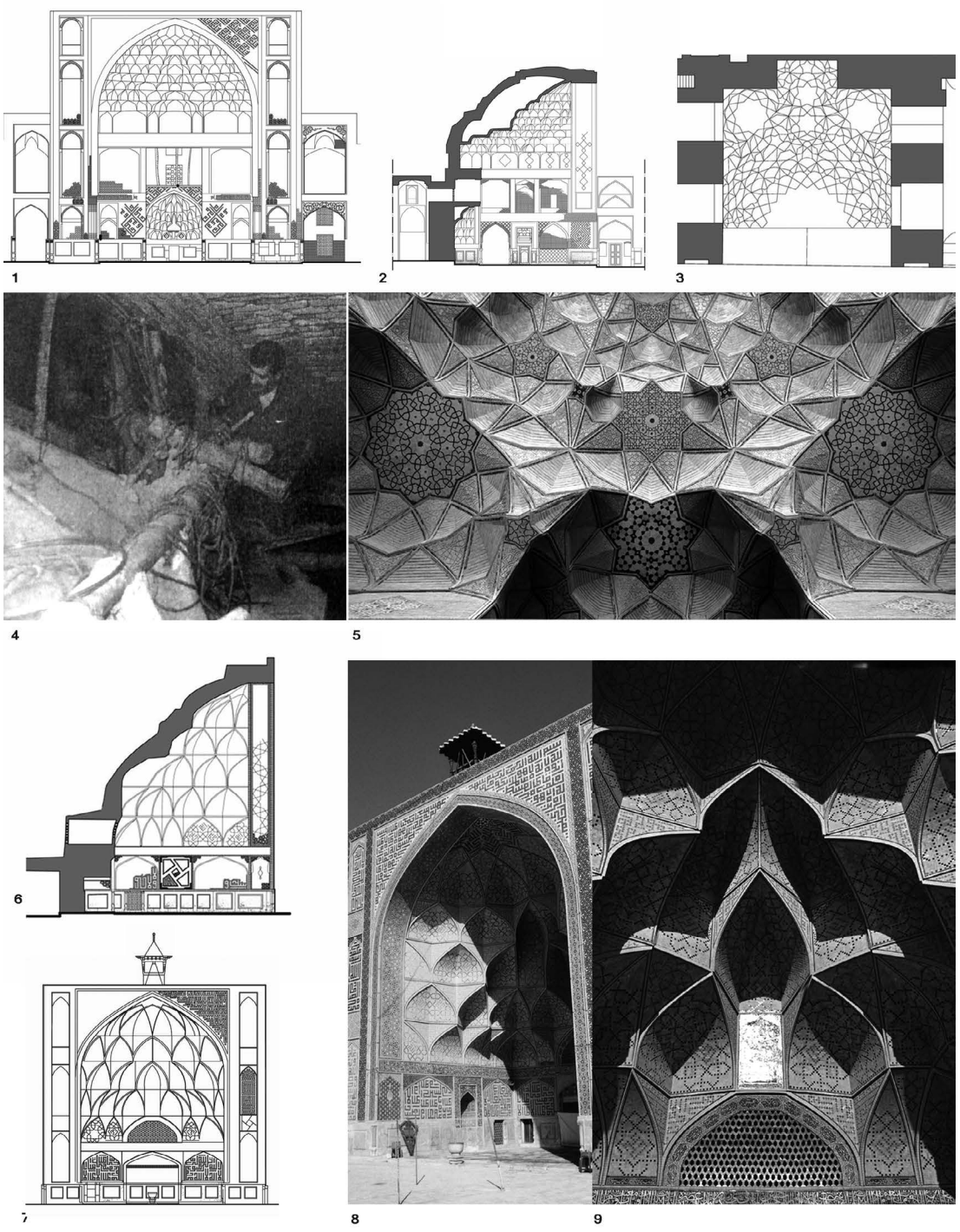


Figure 2. Comparing two vaultings in west and east iwan of the Great Mosque of Esfahan.
1,2,3. Plan, Elevation and Section of Muqarnas in the East Iwan of the Great Mosque of Esfahan. [Gholamhossein Memarian, *Masjed Jame Esfahan (The Great Mosque of Esfahan*) with the efforts of *Mohammad-Ali Tabarsa*, (Tehran, IRAN, The Center for Architectural and Urban Studies and Research, 2011), 198-199]
4. Tensile elements for bonding the Muqarnas in intershell of the vault of the East Iwan. [Esfahan Institute of Cultural Heritage, *Restoration Report of the Great Mosque of Esfahan*, 2006]
5. Takht in the Muqarnas of the East Iwan. [[Gholamhossein Memarian, *Masjed Jame Esfahan (The Great Mosque of Esfahan*) with the efforts of *Mohammad-Ali Tabarsa*, (Tehran, IRAN, The Center for Architectural and Urban Studies and Research, 2011),197]
6,7,8. Plan, Elevation and Section of Muqarnas in the West Iwan of the Great Mosque of Esfahan. [Ibid, 167]
9. Details of Tassé in the Patkâné of the West iwan of the Great Mosque of Esfahan. [Henri Stierlin, *Islamic Art and Architecture*, (N.Y, Thames & Hudson Inc, 2002), 218]

1. Structural Boundaries: Muqarnas is dropped from ceiling, while Patkâné is self-supported.[11] Although this is not the case in those decorative Patkânés, which act in the same way as the Muqarnas that they are dropped from ceiling as well.
2. Constructional Boundaries: The major difference is here in the construction phase. In Patkâné, each tier and niche rests over the course bellow and the hierarchy starts from the lowest level. In the Muqarnas, this is reversed so the construction process starts from the highest point of the vault.
3. Morphological Boundaries: The main morphological difference between the two is that Muqarnas has horizontal elements in addition to the stalactite niches. These elements have significant impact on geometry of Muqarnas; they are focal points of the geometry.

The intention here is to focus on the ornamented vaults, which are made out of consecutive courses of Tassé. This means Muqarnas and only those types of Patkâné, which are identical to Muqarnas in their structural behavior and construction methods

DESIGN AND CALCULATION METHODS OF MUQARNAS

Architect-Artisans of Islamic Architecture were not only masters in their own crafts but also in geometry. These architect-artisans were concerned with the practical and immediate consequences of their work rather than its theoretical qualities. One of the practical consequences of their mathematical and geometric effort was creating infinite compositions and highly sophisticated configurations of Muqarnas, which cleverly interlocked with each other to decorate Islamic Architecture.[12]

One way to achieve a firm grasp of design methods of Muqarnas is to read and understand its traditional visual language. Preceding Muqarnas drawings were the best demonstrations of practical and theoretical aspects of Persian and Islamic Architecture.[13] These drawings are called Toomar[14] and represent Muqarnas works in plane projection.

Two-dimensional representations of the complex three-dimensional Muqarnas form were abbreviated and shortened. The reason this could be done is that in the plane projection, elements did not overlap. This is one of the elements and modules in the design of Muqarnas, which let them interlock with each other on a two-dimensional plane without any overlaps. Nevertheless, the explicit three-dimensional projection is not included in the plane projection.

Although one can distinguish different shapes from each other in plane projections, understanding which element belongs to which tier is not part of the information included in plane projections. This is the part of their design which needs to be decoded.[15]

A closer look into these representations shows us two fixed rules in the projection methods:
1. Utilizing a limited number of simple and uncompounded geometric elements.
2. A geometric system of conformity in every Muqarnas projection, which determines the links between its elements.

In order to determine the role of the first category, take a look at the definition proposed by Kashani. His theory decomposes Muqarnas to its basic building blocks, and then proposes two subsets for the primary elements. First are the primary building blocks, which he calls Khané[16] or cells. There are subsidiary elements as well which are needed between the cells to complete the geometric network. We call them intermediate elements.[17]

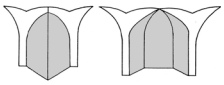
As previously mentioned, there are limited numbers of the main elements. The proposed definition by Kashani is then expanded to include specific elements such as Thakht, Pabarik, Tass(Tassé), Shaparak, Shamssé.[18,19] The following table gives a thorough explanation and translation of each term.[20]

The primary requirement of prefabrication is that the whole complex has to be decomposed to specific forms with limited variety and quantity. Presence of this matter in Muqarnas enables the creation of a variety of projections out of specific and almost invariable elements. The significant feature of these elements is that they are recognized as three-dimensional units from the beginning of the projection. This means that there is a predetermined three-dimensional element per each two-dimensional element in the main two-dimensional projection. Since mimar were conversant with how each element would affect the space, they were able to design the whole space based on a two-dimensional plan.

Here is a quick glance through the projection of one simple Muqarnas to help understand the spatial influence of each three-dimensional element on the whole design.

1. Designating geometric Axes: There are two types of axes, radial and orbital. In order to designate the location of the axes, first a half-circle centered on the mid span of the opening with arbitrary radius is determined. Radial axes are designated by dividing the half-circle into eight equal sectors. The most effective spot of the plane of projection is the center of the half-circle which connects every element to each other and eventually to a unique center.
2. Locating Takht in the first tier: Size, type and the number of Takht are based on size of the span, height of its arch and also style of the mimar. For instance, assume four star-shaped Takht at the intersection of four radial axes with four orbital axes. At this point, the centers of all four Takht are new focal points in the plane projection of the plan.
3. Locating Shaparak and Pabarik: These elements are located centered within the center of each Takht.

The last two steps are attributed to the number of tiers of Muqarnas. The more the tiers repeat the more the new focal points are created according to the number of Takht. Moreover, edges of tiers are convergent to the center of Muqarnas. It means they are designed in a

	Building Blocks	Explanation	Orientation	Location
1	Regular Polygons 	Triangle, square, pentagon, hexagon, etc...	Completely Horizontal	Locations of Takht are the designer's choice. They should be projected in specific spots in order to facilitate synchronization of the Muqarnas on a hypothetical circle.
2		Multi sided Stars (Three Sided, Four Sided, Five Sided, etc…)		
3	Thakht[i] Non-Regular Polygons 	Knotted shape (triangle and other repeated elements in Islamic patterns)	Almost Inclined	
4	Rhomboid 	This specific Thakht is not as horizontal as others. Usually it is folded on either its short or long axis.	Inclined	
5	Pābārik	A parallelogram in which two sides are equal and the axial symmetry is based on its long axis.	Inclined	Around Takht. Around *Shamssé.*
6	Shāparak 	A three-sided element, which connects other Muqarnas components to each other. Angles between the sides of this form are highly flexible, depending on project needs.	Inclined	Between various elements.
7	Tāss (Tāssé) 	Tāss are curved triangular pieces or niche shape elements, which generate concaved spaces of Muqarnas.	Vertical at first and terminating into inclined surface.	Mostly between two Shāparak or two Pābārik. It can be found in all tiers but the last tier.
8	Shamssé[ii]	Either one or one half of a multi sided star, however its sides and axes has to be more than those in Thakht.	Inclined at first and terminating into a flat or horizontal plane.	Always in the last (highest) tier. In the center of the Muqarnas when it is complete or tangent to the boundry (When it's a half projection)

[i] Persain word for "Flat"
[ii] Abstract Persian metaphor for "Sun"

way, which gradually transforms the rectangular base to one unique point or the focal point of the geometry.

4. Designing the tier of Shamssé: As the opening of the vault is converging to the center, Tassé of the last (highest) level become aligned with the axes of the Shamssé. At this point, the vault is completed and the Shamssé and its belonging Shaparak sit on the final level of the projection. It should be noted that the size of the radius of the Shamssé depends on the mimar's design and style.

The above-mentioned process demonstrates the role of each element in a Muqarnas projection. This study led to the realization that the most effective element in the geometric system of the whole projection is the Shamssé, which is often a great star at the center. The whole projection is formulated based on the geometry of the mentioned star. Afterwards, orbital and radial axes of Takht (which are multi sided stars) complete this geometry. The last factor is the edge of the first tier, which with its own geometric pattern fades into the whole complexity of the Muqarnas geometry.

MUQARNAS CONSTRUCTION METHOD

Here is a brief description of the construction process of plaster Muqarnas.

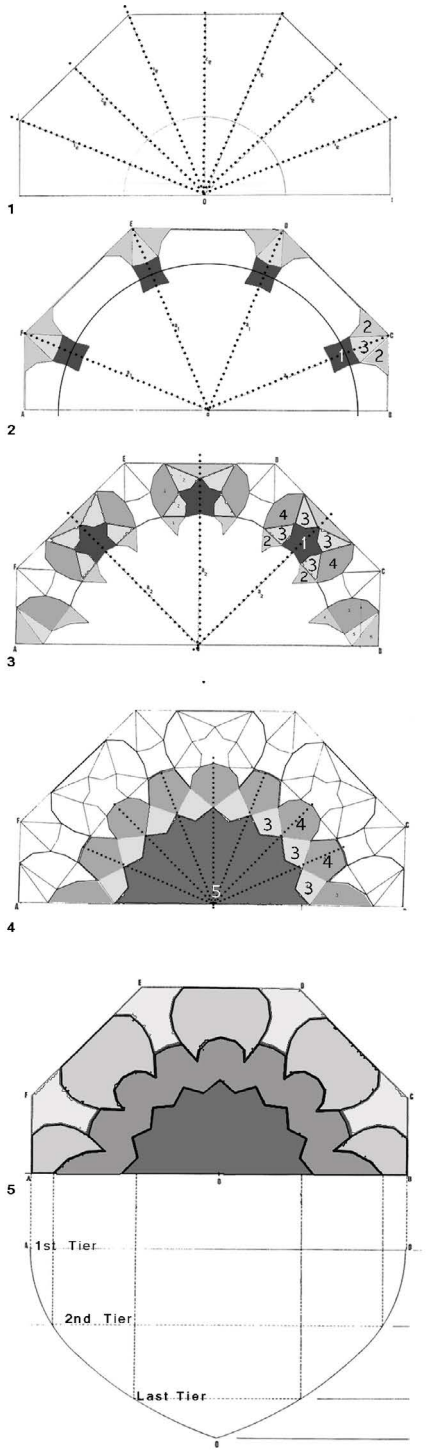


Figure 3:
1,2,3,4. Formation stages of Muqarnas in context of half an octagon. [Authors]
5. Representation of tiers in plan and elevation. [Authors]

1. A full-scale working sketch of the two-dimensional plan was scratched on a plaster or a wooden slab under the prospective Muqarnas vault. This full-scaled plane projection was called Takhmir.[23,24]
2. Each row of tiers of the vault was then determined with ceramic bars or lumps of clay on this two-dimensional pattern. After that, plaster or wooden plates of alternating 2-3 centimeters (1-2 inches) thickness were cast for all the tiers of the vault.
3. The next step was to bond these plates to the vault and to the wall with Sazoo.[25] The plates are all loaded on the dome structure above the Muqarnas. Plumb line was used as correspondence to the full-scale sketch on the floor.
4. Molding and installation of each tier from the base row to the central Shamssé is the next step. Plaster molds for main elements of each tier are built. In most cases these molds are created in such a way so that they can be used for as many as elements that architect-artisan (mimar) wishes to produce. Afterwards, overlaying plaster, tile work (either tile or mirror) or bricks[26] are built in respect to the designated molds. Eventually, a quick drying plaster as liquid grout on the back of the tile work executes the cells.[27,28]
5. The mimar bonds these rendered Muqarnas cells to the vault and fits them into the spatial grid of the horizontal and vertical openings, forming a unified whole.[29]

CONCLUDING THE STUDY

The two recent chapters of this study are explicit expressions of fundamental components of prefabrication. This final chapter is a complete collection of those components with exactitude in two aspects. The aspects of design and construction. Some of these factors correspond to predetermined elements of the projection and some are dependent on the geometric system of the whole.

Prefabrication Components Corresponding to Design

1. Predetermined Three-Dimensional Elements: It is perfectly conceivable that this has a significant impact on achieving the concept of prefabrication. Determinant of this character is having distinctive three-dimensional forms with limited diversity while the mimar is projecting his ideas. So his only task is to create a perfect composition of the determinate elements, applicable to the size and type of the associated vault.
2. Low Diversity in Elements while High Composition Feasibility: The fewer elements the more creativity in geometric compositions. This is due to years of experience and expertise of Iranian architects and mimars who have simplified the projection of Muqarnas to the least possible complexity.
3. Variety of Composition Methods: The complexity of the design despite the limited diversity of the components enriches this style. The result of this is the compatibility of Muqarnas to every kind of vault. Consequently there are hundreds of pieces of work, spread across geographic borders of Islam, which never look the same.
4. Replication of Elements: The prosperity in Muqarnas projection is the fact that its elements appear in replication. For instance, by mutating interior angles of a hypothetical Shaparak it can either fit into the geometric system of a Shamssé with five sides or into one with four, six, eight, etc..

5. Designated Leveling Methodology in Both Horizontal (Plan) and Vertical (Elevation) Planes: Although Muqarnas has a highly complicated projection, the presence of fixed levels of heights along the tiers except the first and the last one facilitates the idea of prefabrication.[30]
6. Distinction of Tiers in Plan: As mentioned before, tiers do not overlap in the plan. The plane projection of Muqarnas embodies all of the required information.
7. Rigid and Determinant Geometry Rules: The location of the center of the Shamssé and its radial axes assigns a rigid geometric system to the projection. So, the mimar figures out the final composition by having an approximate estimation of desired number for Thakht and the best spots for them.
8. Rigid and Determinant Geometry Rules in Vertical Plane (Elevation) Based on the Plan: Except the first and the last tier (Shamssé), which the mimar determines, the height differentiation between all other tiers is the same.[31] So, vertical projection proceeds simultaneously with the horizontal plane projection.
9. Axial and Central Symmetries in the Plan: In most cases, the projection is symmetrical based on its center. Based on the vault and its geometry the Muqarnas would have axial symmetry as well. In partially open spaces, portals and iwan there is central symmetry; closed spaces such as dome chambers can have both axial and central symmetries. The symmetrical geometry makes the job less labor-intensive. It reduces the job to only a fraction of the projection. These fractions are varied from one half to one thirty-second of the whole vault span.
10. Extensibility: The highly efficient geometric system allows the projection to expand along its axes as far as it needs to grow.

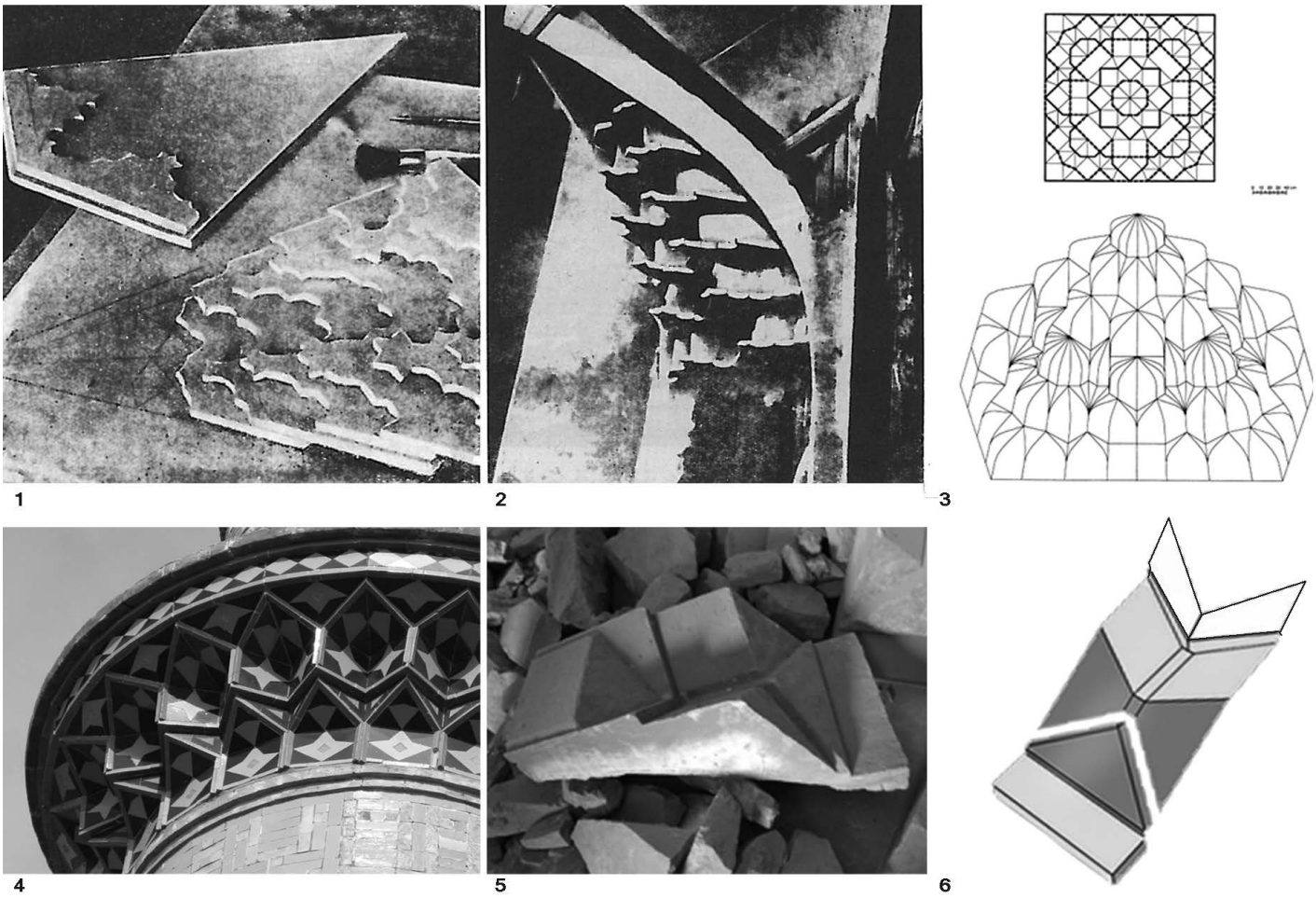


Figure 4. Ilustration of Muqarnas construction
1. Physical model of the horizontal tiers. [Gülru Necipoalu, The Topkapi Scroll Geometry and Ornament in Islamic Architecture; with an essay on the geometry of the Muqarnas by Mohammad al-Asad. (Canta Monica, CA, Getty Center for the History of Art and the Humanities, 1995), 65]
2. Full scale construction of tiers. [Ibid]
3. Reconstruction of the muqarnas of the southern vault of Takht-e-Sulayman. [Mohammas Ali Jalal Yaghan, "Decoding the Two-Dimensional Pattern Found at Takht-i Sulayman into Three-Dimensional Muqarnas Form" , Iran 38 (2000): 80]
4. Patkâné in the cornices of minaret of tomb of *Sultan Bokht Agha, Esfahan*. [Authors]

5,6. Continues plaster mold and its computer 3D model of a Patkâné element for preservation of a minaret. [Authors]

Prefabrication Components Corresponding to Construction

1. Application of Prefabricated Plaster Templates: The explicit geometry of Muqarnas allows for the creation of a desired number of plaster templates. This is the most important property of Muqarnas in terms of construction methods and prefabrication.
2. Diversity of Components Formed Out of One Specific Template: One interesting feature of the Mugarnas construction method is that each mold is considered larger than the actual size of a hypothetical desired Tassé. Hence, it makes it possible to build a variety of Tassé by applying specific sections of its surface to each type. Consequently, it creates fewer templates, faster construction and fewer costs.
3. Fabricating on the Ground and Assembling at Each Spatial Coordinates: The explicit and predetermined geometry, clear coordinates for each element and the identical leveling between each two tiers, makes it possible to fabricate all the elements off-site and then assemble them on the site. Hence, scaffolding is only in need for the assembling phase not during the fabrication. This means quicker pace during construction.

These noted features provide a general understanding of the prefabricated aspect of Muqarnas projections. So far this study has provided a satisfying response to the proposed hypothesis. One remarkable matter is the dynamic, attractive, multifarious and imaginative figure of this craft. Despite the rigid rules of construction, this craft has never been limited or restricted in its creative expression. Because of this, it has the potential to be ranked higher in comparison to more recent pieces of architecture. In conclusion, it has to be noted that this study was an introductory chapter to a small part of a much larger style of design in the world of Persian and Islamic Architecture. The world of anonymous architects and artisans, whose works, must be introduced to the contemporary world of architecture. Hopefully, contemporary science and technology will support this amazing culture of design and construction so it will be able to find its way out of the darkness and will no longer be hidden and forgotten in history.

ENDNOTES

1. Abu Nasr Muhammad Farabi, Ihsa Al-AUlam (on the *Introduction of Knowledge*), trans. Hossein Khadiv-Jam (Tehran, IRAN, Elmi Farhangi Publishing Co., 2002), 77
2. Arabic word for "Architect" here means traditional craftsman or rchitect-artisan.
3. Yasser Tabbaa, "The Muqarnas Dome: Its Origin and Meaning", *Muqarnas 3* (1985): 61-74.
4. Ghyâth al-Din Jamshîd Al-Kashi, Miftâh al-Hisâb (*Key of Arithmetic*), ed. Nader Nabulsi, (Damascus: Damascus Society, 1977) 387.
5. Yasser Tabbaa, "The Muqarnas Dome: Its Origin and Meaning", *Muqarnas 3* (1985): 61-74.
6. Mohammad Karim Pirnia, "*Gonbad dar memarie Iran (Dome in Persian Architectrue*)", ed. Zohreh Bozorgmehri, Asar, no. 20 (1991) 22
7. Safaeipour, Hadi. *Interpretations in Morphologic Development: Focusing on Patkâné*; MA Thesis, Tarbiat Modares University. Mohammad-Reza Bemanian. Ph.D. 2009: 113-121
8. David and Camilla Edwards,"the Evolution of the shouldered arch in medieval Islamic architecture", *Architectural History* 42 (1999): 68-95.
9. Arabic word for "Sanctuary".
10. Safaeipour, Hadi. *Interpretations in Morphologic Development: Focusing on Patkâné* . MA Thesis, Tarbiat Modares University. Mohammad-Reza Bemanian. Ph.D. 2009: 123-126
11. Mohammad Karim Pirnia, "Dome in Persian Architectrue", ed. Zohreh Bozorgmehri, *Asar*, no. 20 (1991) 38
12. Alpay Ozdural, Omar Khayyam, "Mathematicians, and Conversazioni with Artisans", *Journal of the Society of Architectural Historians* 54, No.1 (1995): 54-71
13. Gülru Necipoalu, The Topkapi Scroll Geometry and Ornament in Islamic Architecture; with an essay on the geometry of the Muqarnas by Mohammad al-Asad. (Canta Monica, CA, Getty Center for the History of Art and the Humanities, 1995), 11
14. Persian word for "Scroll"
15. Silvia Harmsen, *Algorithmic Computer Reconstructions of Stalactite Vaults - Muqarnas - in Islamic Architecture*; Ph.D. Diss. Ruprecht-Karls-Universität Heidelberg; 2006
16. Persain word for "House" here means cell.
17. Ghyâth al-Din Jamshîd Al-Kashi, *Miftâh al-Hisâb (Key of Arithmetic)*, ed. Nader Nabulsi, (Damascus: Damascus Society, 1977)
18. Asghar Sha'rbaf, *Géréh & Karbandi* (Tehran, IRAN, Iranian Cultural Heritage Organization, 2006), 10-11
19. Mahnaz Raeiszadeh and Hossein Mofid, *Mabanie memarie sonnati dar Iran be ravayate Prfo. Lorzadeh (Fundamentals of Traditional Architecture in Iran*, Narrated by Prof. Lorzadeh), (Tehran, IRAN, Mola, 1995), 86-87
20. Appellation of Muqarnas elements is based on the narratives of Asghar Sha'rbaf and Hossein Lorzadeh. They are both pioneers in Iranian architecture.
21. Persain word for "Flat"
22. Abstract Persian metaphor for "Sun"
23. Hossein Pournader, *Sha'rbaf va asarash (Sha'rbaf and his pieces of work*), (Tehran, IRAN, Iranian Cultural Heritage Organization, 2000), 60
24. Persian word for "Fermentation" Decomposing of organic matter. This is based on Pournader's book of *Sha'rbaf va asarash (Sha'rbaf and his pieces of work*). He means a plan which is drawn on the ground plane and it is prepared for construction of elements on the ground before assembling the in their spatial coordinates. It has to be noted that this word was used as *Takhmin* (Arabic word for Approximation) in the precious study by I. I. Notkin; *Decoding Sixteenth-Century Muqarnas Drawings; Muqarnas*; 1995; Vol. 12; pp. 148-171.
25. Woven from plant fibers such as palm tree of horsehair that has high tensile strength. Finished and lined with plaster.
26. Those Patkâné projections which their Tassé were big enough that could be filled with brick are not considered as samples of prefabrication. Since the brick work were all on-site and using scaffolding.
27. Overlaying materials were placed in such a way that they were facing the mold.
28. Mahnaz Raeiszadeh and Hossein Mofid, *Mabanie memarie sonnati dar Iran be ravayate Prfo. Lorzadeh (Fundamentals of Traditional Architecture in Iran*, Narrated by Prof. Lorzadeh), (Tehran, IRAN, Mola, 1995), 87
29. I. I. Notkin, "Decoding Sixteenth-Century Muqarnas Drawings" *Muqarnas* 12 (1995): 148-171
30. *Muqarnas:My Heavenly Rrchways*, dir. Kashi. Sabereh, 16 min, DVD.
31. Asghar Sha'rbaf, *Géréh & Karbandi* (Tehran, IRAN, Iranian Cultural Heritage Organization, 2006), 146