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Traditional Modularity System in Uzbek and Persian Mimars: Construction of Muqarnas

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Abstract: The aim of this study is based on knowledge of mimars to explain and show of fundamental components of muqarnas, creation method, and methodology. Furthermore, to better explain the process of muqarnas creation the author analyzed some of the historical scrolls from Tashkent and demonstrated how to rebuild the 3D design of muqarnas based on 2D planes.
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 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.

Key words: Muqarnas, stalactite, shamseh, toranj, taseh, parak, shaparak, tee, espar, takht, toomar, Tashkent scroll, Bukhara scroll, mihrab, mimar, sazu (sazoo), shoul.

Introduction.

The primary data resources in this study are documented drawings and literature, which provide theoretical geometry [9] of Muqarnas and *Patkâné* [8]. These data are derived from analysis and interpretations of manuscripts left from the 15th-century Muslim mathematician *Ghiyathe al-din Jamshid Kashani*[12].

Verbal information in this study is gathered from in-depth interviews of *N.Dadkhan, H. Safaeipour, G. Memarian*, which had been participant observations with *Mimars*[6] Our verbal data is gathered from experts such as *Asghar Sh'arba*, *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.

According to *Akram, Ismail, and Franco (2016)*[2], Muqarnas are usually used in undersides of domes, cornices, pendentives, arches, vaults, and squinches **(Fig.1.).** As they can show a downward-facing shape, so, one can trace a line between the floor and any point on the Muqarnas surface. One can design Muqarnas geometrically so that a unique visual form can be obtained**.**

Sakkal (1988)[18], declares that Blocks of Muqarnas have been arranged in many compositions in the way that they can enclose partially or completely space, in doing so, there must be a connection between them in the horizontal direction, and also, a connection between on top of each Muqarnas in the vertical direction. In both cases, the first state (horizontal layering called "combination") and the second state (which is called "juxtaposition", the final arrangement is called "cluster".

The essence of muqarnas.

Patkâné, which has 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.[6]

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Fig.1.1. Sassanian (Palace at Sarvistan) - interior of the main dome, Palace at Sarvistan, 420-438 AD, by Bahram V, Iran. Squinches were used to support the round domes, in addition to the use of columns as supports for the vaulting in the side rooms.

Fig 1.2. Ismail Samani Mausoleum at Bukhara, Uzbekistan (914-943.).

Historically, spatial transitions from a rectangular base to a dome used to be problematic. Central Asian architects and mathematicians solved the problem by inventing a transition form as a segue between shapes. This came about during the Samanids dynasty in Uzbekistan. This evolution continued and expanded in the Islamic era. One of the architectural solutions for the transitional zone was the creation of a squinch. The invention of squinch was the context for the 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. [11] Two curved triangular plates named Tassé form the squinch. The preliminary samples of this technique can be found in the Sarvestan Palace ***(Fig. 2.).***

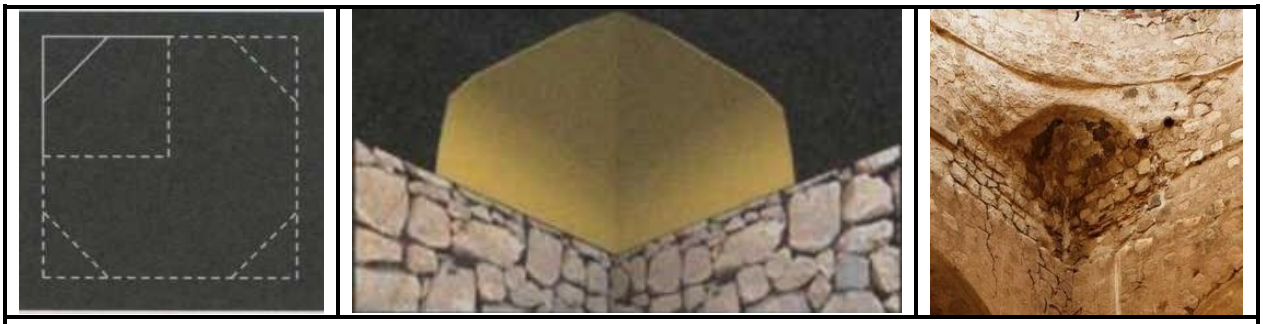

Fig.2. View of squinch in Sarvestan Palace (Source: Hamidreza Kazempour).

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 *Tässé* ***(Fig.3.)***.

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 part of the design but was also considered a decorative form. Transitional zones in dome chambers, column heads, cornices of minarets, *Mihrab*[26], and dropped ceilings in closed or semi-closed spaces are examples of *Patkâné* as a decorative craft as well as an architectonic element.[17]

Consequently, the creation of Muqarnas can be translated as a branch of the evolution process of *Patkâné*. Hence, the basic morphology of the Muqarnas is adopted from stacking of *Tässé* 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.

1. Structural Boundaries: Muqarnas is dropped from the ceiling, while Patkâné is self-supported. [26] Although this is not the case in those decorative Patkânés, which act in the same way as the Muqarnas that they are dropped from the ceiling as well.

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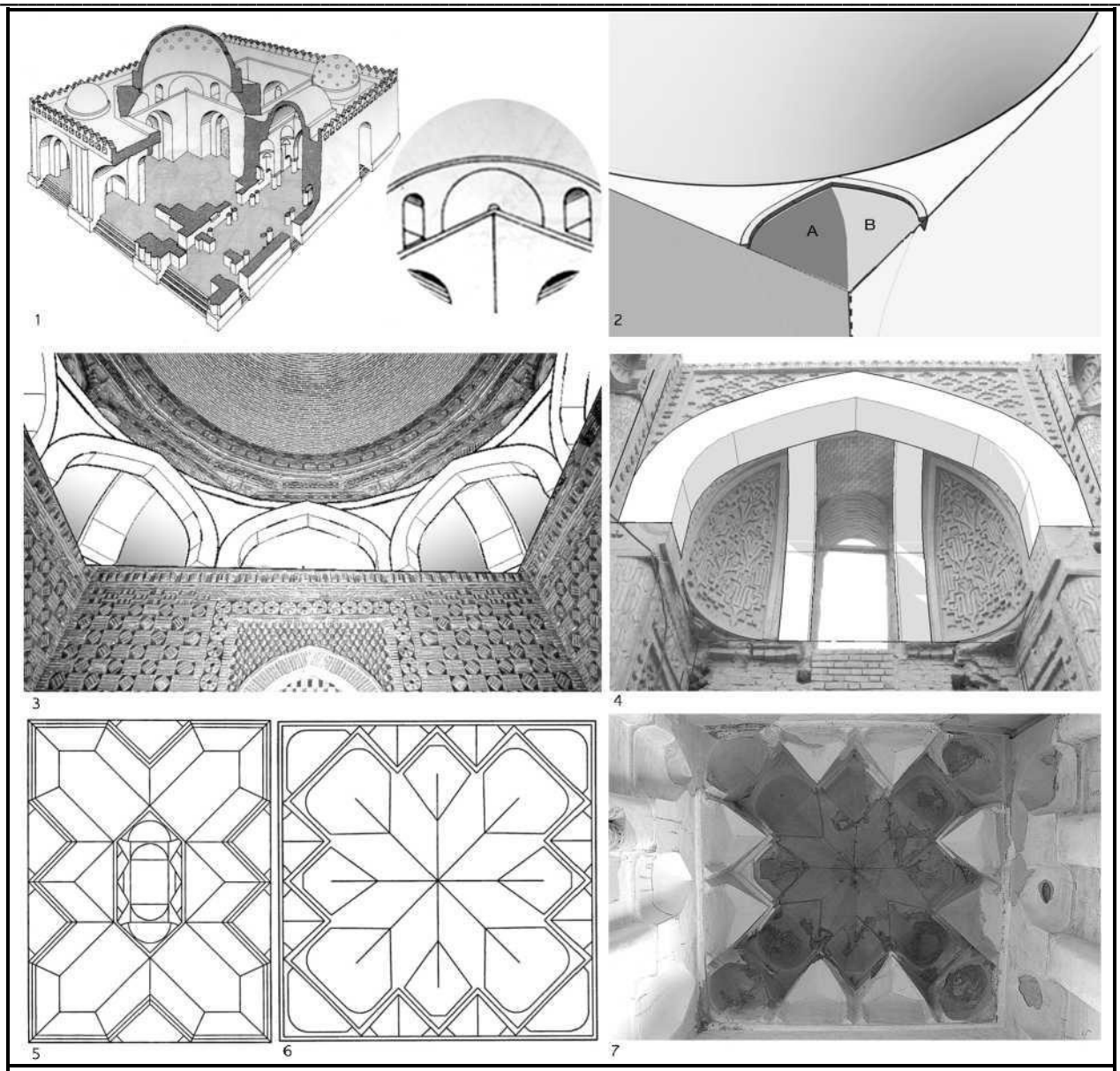

Fig. 3. (Source: Dadkhah, N., Safaeipour, H., Memarian, G.).

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 Tasse, 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 Safaepour, Met^mafie Irani, Niaresh (Iranian Architecture, structure), (Under Publican)]*
5. *Plan of Patkâne 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 Patkâne 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. *Patkâne vaulting in northen iwan og the Great Mosque of Naein. [Authors]*

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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 a significant impact on the 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 Process of Muqarnas construction.

Architect-Artisans of Islamic Architecture were not only masters in their own crafts but also in geometry. [3] One way to achieve a firm grasp of the 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. [14] These drawings are called *Toomar* [6] (or *Daftar-i girih* [5]) and represent Muqarnas works in-plane projection **(Fig. 4.)**.

1.

3.

2.

Fig. 4. (Source and Photo by Shakhboz Mustafoev).
1. Bukhara Scrolls. Foundation of the Bukhara reserve "Ark". inv. № 4429/16,
2. Bukhara Scrolls. Foundation of the Bukhara reserve "Ark". inv. № 4429/16,
3. Tashkent Scrolls. Fund of the Tashkent Institute of Oriental Studies named after Abu Raykhon Beruni. Documents with architectural drawings. Document №2.

Two-dimensional representations of the complex three-dimensional Muqarnas form were abbreviated and shortened. Since the constituent elements do not overlap in muqarnas, one can project the three-dimensional structure to a plane surface, making a pattern plan. A plan defines the procedures and design methods adopted by the builder, especially when the building tradition under discussion lacks theoretical frameworks for construction. Yet under Middle Eastern traditions, plans appeared in very minimal and simple forms, with the builders zealously guarding them as trade secrets. Here it was rather the verbal traditions that transferred the knowledge from one generation to the next. [13]

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With the advent of the Renaissance, scaled plans and measured drawings became the norm in European architecture, widening the gap with the traditions in the East that relied greatly on abstract geometrical motifs. Therefore, the remaining muqarnas patterns from the Middle East, that do not obey conventional drawing rules, were first suggested by Yaghan [21] to be termed as two-dimensional pattern plans for muqarnas, abbreviated as 2DPP, in many recent publications [23].

The remarkable point that is nobody knows the way these 2DPPs of muqarnas creation and the fact that no one knows exactly how these two-dimensional pattern plans were transferred to three-dimensional structures, except those who were builders, the masons, and artisans. During the middle ages, artisan kept in strong secret the methods of transformation of the 2DPPs into three-dimensional models, who had the responsibility to guard these methods and have them learned by the next generations of the guild. [16]

Necipoğlu[14] further points to the dimensional ratios of the designs, elaborating that in order for the patterns to match the actual dimensions on-site, the easiest solution was to adhere as much as possible to rectangular frames the dimensions and scales of which were not so much important as the fixed ratios of length to width.

It is worth noting that Central Asian builders and a member of the guild had a tradition in which the secrets of the traditional method of designing stalactites were passed on from ancestors to students (or sons in top secret). According to tradition, the master blessed the student when he was fully ready for independent work. The student had to have and interpret the existing old patterns, have a sharp eye, capable of quickly catching plans with precision, and transform the three-dimensional plan of the stalactite to the plans, which was done in our study. [25]

A short description of the construction process of plaster Muqarnas has been presented by Dadkhah Safaeipour & Memarian (2012) [6], which can be summarized as below:

Firstly, a two-dimensional (Takhmin or Takhmir Fig. 6.3.)[15] pattern plan of working sketch with full-scale should be scratched on plaster or on a wooden slab. Then, tiers rows should be identified by ceramic bars or clay lumps on these plans. And after that, for each, all tiers of the vault, alternative plates of plaster or wood (1-2 inches) should be cast and prepared. Then, the plates must be connected to the vault and wall by Sazu (or Sazoo) [10] **(Fig. 5.).** All plates are loaded on the dome, above the Muqarnas. A Plumb line [1] is used as correspondence to the full-scale sketch on the floor **(Fig. 6.).**

Fig. 5.1. Sazu, the traditional rope used for hanging layers of muqarnas (Source: Shakouiri Saeid)

Fig. 5.2 Sazu, the traditional rope used for hanging layers of muqarnas (Source: Hamidreza Kazempour)

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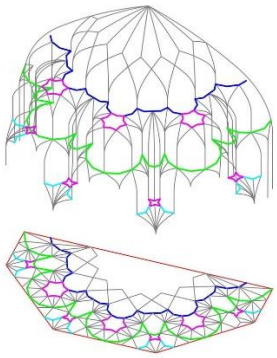

Fig. 6.1. 2D and a 3D (isometric) sketch of muqarnas (Source: Tayyaba Sarwar)

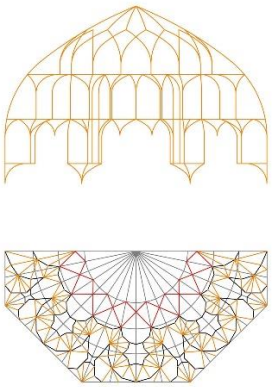

Fig. 6.2. 2D and frontal plane sketch of muqarnas (Source: Tayyaba Sarwar)

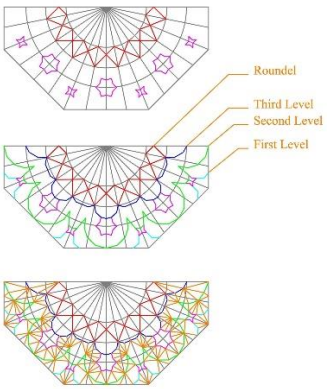

Fig. 6.3. Takhmin or Takhmir is used as correspondence to the full-scale sketch on the floor(Source: Tayyaba Sarwar)

In the next step, Molding and installation of each tier should be done from the base row to the central *Shamseh* [8], and molds of plaster should be constructed as the main elements of each tier. These molds sometimes are developed in a way that can be used in the number of elements that architect-artisan (*mimar*) [7] has intended to produce. Then, an overlaying plaster, tile work (either tile or mirror), or bricks should be constructed with these molds. Finally, a plaster that can be dried quickly is used between the cells, as a liquid grout on the back of the tile work. Finally, these cells should be connected to the vault, and they should be fitted to a spatial grid of the horizontal and vertical openings, in order to form a whole work **(Fig. 7.).**

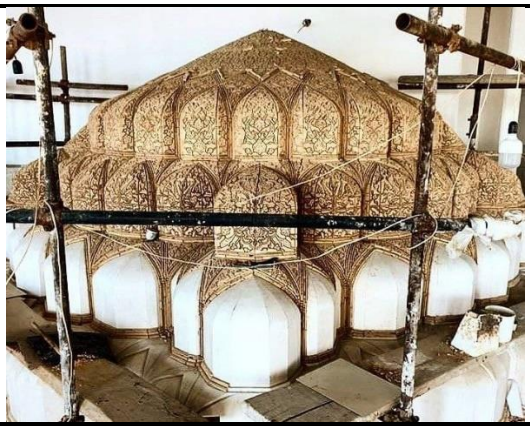

Fig.7.1. Construction of muqarnas in Iran (Source: Shakouri Saeid.).

Fig. 7.2. Construction of muqarnas in Bukhara (Source: Bakhtiyor Babamurodov.).

Yaghan (2001) [22] has stated that Muqarnas consists of orderly horizontal layers with small 'unit surfaces', these layers have been accumulated on each other and have been connected by their layer lines in base and top. This layer - lines (top and base) are integrated or have been separated by joints. All horizontal gaps between lines with the same height (like stars), have been filled by roof patches, which are along with units faces and layers, constructed according to 2DPP and their boundaries have been defined clearly. Muqarnas, depending on their 2DPPs that are created upon them have certain degrees of complexity. Sometimes it needs a great deal of skill and experience to decode Muqarnas drawings into three-dimensional forms **(Fig. 8.).**

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	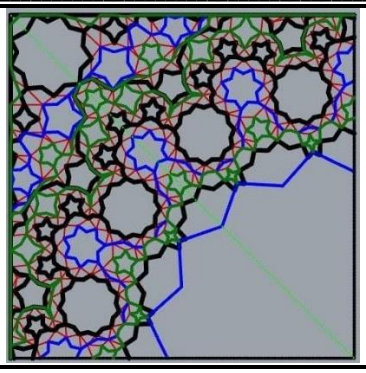	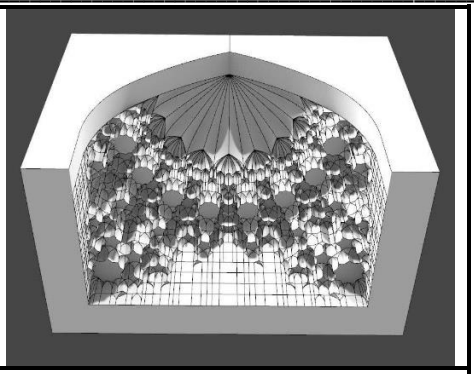
Fig. 8.1. Tashkent scroll. № 2/1, (Photo by Shakhboz Mustafoev).	*Fig. 8.2. Geometric analysis of Tashkent scroll. № 2/1, (Source: Shakhboz Mustafoev).*	*Fig. 8.3. Isometric view of Tashkent scroll. № 2/1, (Source: Shakhboz Mustafoev).*

Conclusion.

Based on our researches we could claim that to create muqarnas artisans needed only 2D sketches of muqarnas. All types of muqarnases consist of layers (*Takhts*) which placed radial system around of shamseh. To connect layers masters used different types of *Toranj*, *Taseh*, and *Parak* in a zigzag way, which fills empty spaces. The heights of the layers depended on dividing the place of mihrab into equal parts and rarely skillful master choose proportion based on his compositional imagination. It usually becomes when the proportion of mihrab had been violated (Ideal mihrabs proportion should be 2x1).

References.

1. A plumb line (Persian: [شاقول] - Shoul), is an instrument that has been used in ancient Islamic architecture to ensure that constructions are "plumb", or vertical.
2. Akram, O. K., Ismail, S., & Franco, D. J. (2019). The Significant of Islamic Architecture Heritage at Baghdad City, Iraq-Case Studies of Shrine of Lady Zumurrud Khatun and Omar Al-Sahrawardi. International Journal of Engineering Technology, Management and Applied Sciences, 4, 133-138.
3. Alpay Ozdural. (1995). Omar Khayyam, “Mathematicians, and Conversazioni with Artisans”, Journal of the Society of Architectural Historians 54, No.1. pp. 54-71.
4. Arabic word for “Architect” here means traditional craftsman or architect-artisan.
5. Bukhara Scrolls. Foundation of the Bukhara reserve "Ark". inv. № 4429/16, № 4430/16, № 4174, № 4176, № 4177, № 4178, № 4179, № 4180.
6. Dadkhah, N., Safaeipour, H., & Memarian, G. (2012). Traditional complex modularity in Islamic and Persian architecture: Interpretations in muqarnas and Patkané crafts, focusing on their prefabricated essence. In proceedings of 2012. ACSA fall conference—Offsite: Theory and practice of architectural production.
7. Elena Imani. (2017). Historical and geometrical analysis of muqarnas and prospect of its reflection on today’s architecture. A thesis submitted to the graduate school of natural and applied sciences of Middle East technical university.
   Elena Imani. (2017). Historical and geometrical analysis of muqarnas and prospect of its reflection on today’s architecture. A thesis submitted to the graduate school of natural and applied sciences of Middle East technical university.
8. Hamidreza Kazempour. (2016). The Evolution of Muqarnas in Iran. Supreme Century. ISBN-10: 1939123526.
9. Hossein Khadiv- Jam (2002). Abu Nasr Muhammad Farabi, Ihsa' Al- ‘Ulum (on the Introduction of Knowledge), trans. Tehran, IRAN, Elmi Farhangi Publishing Co. 77.
10. In order to construct a Muqarnas vault, for standing each tier of the vault on two-dimensional plane projection, designers used a suspended column called *Sazoo*, on the back of Muqarnas, which itself was made of animal fur like horsehair and lined with plaster. See also:
11. Mohammad Karim Pirnia. (1991). “Gonbad dar memarie Iran (Dome in Persian Architectrue)”, ed. Zohreh

ISSN NO: 2770-0003
Date of Publication: 29-12-2021

Bozorgmehri, Asar, no. 20.
12. Nader Nabulsi. (1977). Ghyâth al-Din Jamshîd Al-Kashi, Miftâh al-Hisâb (Key of Arithmetic), ed., (Damascus: Damascus Society.).
13. Necipoglu, G. (2005). Muqarnas: An Annual on the Visual Cultures of the Islamic World, Volume 22. Harvard University. Print.
14. Necipoğlu, G., & Al-Asad, M. (1995). The Topkapı Scroll: Geometry and Ornament in Islamic Architecture: Topkapı Palace Museum Library MS. Getty Center for the History of Art and the Humanities. Discovered Scroll and Its Late Gothic Parallels.
15. Notkin I.I. (1961).Bukhara ganch carving in the works of Ust Shirin Muradov. State Publishing House of Fiction Uz SSR. Tashkent.
16. Notkin I.I. (1995). Decoding sixteenth-century Muqarnas drawings. // Muqarnas. An Annual on Islamic Art and Architecture. Volume 12.
17. Safaeipour, Hadi. (2009). Interpretations in Morphologic Development: Focusing on Patkâné. MA Thesis, Tarbiat Modares University. Mohammad-Reza Bemanian. Ph.D.
18. Sakkal, M. (1988). An introduction to Muqarnas domes Geometry. Structural Topology 1988 num 14, 21-34.
19. Tashkent Scrolls. Fund of the Tashkent Institute of Oriental Studies named after Abu Raykhon Beruni. Documents with architectural drawings. Document №1, №2, №3, №4, №5, №6, №7.
20. The Mirza Akbar Architectural Scrolls. (1876). South Kensington Museum (the precursor of the Victoria & Albert Museum) by Sir Caspar Purdon Clarke in Tehran.
21. Yaghan, M. A. (1998). Structural Genuine Muqarnas Dome: Definition, Unit Analysis, and a Computer Generation System. Journal of King Saud University (Architecture and Planning), 10, 17-52.
22. Yaghan, M. A. (2000). Decoding the two-dimensional pattern found at Takht-i Sulayman into three-dimensional muqarnas forms. Iran, 77-95.
23. Yaghan, M. A. (2003). Teaching Architectural-Visual-Experience through Virtual Reality Using Vrml: Muqarnas Example. Journal of King Abdulaziz University, Environmental Design, 1, 27-42.
24. Yaghan, M. A. (2010, July). The evolution of architectural forms through computer visualisation: muqarnas example. Proceedings of Electronic Visualisation and the Arts, 113-120.
25. Андреев М.С. (1956). Старинные свитки альбомы из Бухары с образцами архитектурного орнамента. - «Изв. Отд. общ. наук АН Тадж. ССР», вып. 10— II. Сталинабад. стр. 121 — 136; там же: Свиток А (инвент. № 4174)., Свиток В (инв. № 4176)., Свиток Д (инв. № 4177)., Свиток З (инв. № 4178)., Свиток Е (инв. № 4179)., Свиток Б (инв. № 4180)., Свиток Г (инв. № не указан)., Свиток Ж (инв. № не указан).
26. Захидов П.Ш. (1996). Меьмор олами. Қомуслар бош тахририяти. Т.
27. Мустафоев Ш.Ш. (2020). Архитектура. Самарқанд, Шохи-Зинда мажмуасидаги “Номаълум” ёхуд Қутлуқ оқа мақбараси муқарнасини таъмирлаш муаммолари ва унинг геометрик таҳлили. // Архитектура, қурилиш ва дизайн илмий-амалий техник журнали., №4. Тошкент архитектура-қурилиш институти. Тошкент.
28. Мустафоев Ш.Ш. (2020). Ўзбекистон меъморий ёдгорликлари безагида муқарнаслар ва уларни тузиш муаммолари.//Меъморчилик ва қурилиш муаммолари (илмий-техник журнал), №4. Мирзо Улуғбек номидаги Самарқанд давлат Архитектура-қурилиш институти. Самарқанд.
29. Юсупова М.А. (1997). Медресе Хивы и Бухары: эволюция, общности и особенности архитектурных школ // ОНУ, Ташкент. № 7-8. С. 57-64
30. Юсупова М.А. (1997). Эволюция зодчества Бухары XVI-XVII вв. // ОНУ, № 9-11. Ташкент. С. 97-109.
31. Юсупова М.А. (1998). Архитектура (Средней Азии IX-XII вв.). // Свет из глубины веков. Имам ал-Бухари. - Ташкент: Шарк. С.103-116.