

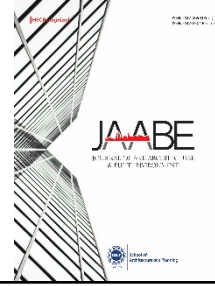
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- Author (s):** Farhana Naz
- Affiliation (s)** Lahore College for Women University, Lahore, Pakistan
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# Muqarnas in Islamic Architecture: Development, Materials, and Techniques

Farhana Naz\*

Lahore College for Women University, Pakistan

## Abstract

Muqarnas was first created during the first millennium AD and became a defining feature of Islamic architecture during the second millennium, specifically between the 11<sup>th</sup> and 16<sup>th</sup> centuries, both in religious and secular contexts. Although largely abandoned by the 17<sup>th</sup> century, the use of muqarnas decoration reached its peak during the above period. This study examines muqarnas, its three-dimensional architectural embellishment, as well as its development and influence on modern architecture. For this purpose, the descriptive analytical approach was employed. Architectural surveys were carried out at the local level, while textual analysis was done to analyze the historical development. The history of muqarnas was traced from Islamic religious buildings to modern architecture. It was found that digital technologies including Computer Aided Design (CAD) and computer numerical control (CNC) have influenced muqarnas pattern design and rebirth in the 20<sup>th</sup> and 21<sup>st</sup> centuries. Both ancient and modern muqarnas use isometries and symmetry, although their design procedures are different. Parametric design and CAD tools allow the current muqarnas to be dynamic and flexible, unlike the traditional ones. The current research underlines that regionally available materials and pattern availability affect the design of muqarnas. Early manifestations of muqarnas were used to fragment squinches, which ultimately led to the creation of an aesthetically pleasing formal mechanism and a system of three-dimensional decoration. In the middle period, muqarnas was also used as decorative carvings on structural member. At present, lightweight materials such as fiberglass and pre-fabricated muqarnas are preferred in contemporary architecture, although the details of muqarnas are still maintained for their aesthetic value. The geometry used to calculate muqarnas has remained the same since its development, regardless of the materials used. This research stimulates the design of new muqarnas patterns for aesthetic purposes and building performance optimization. Modern architecture uses muqarnas

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\*Corresponding Author: [Farhana.naz@lcwu.edu.pk](mailto:Farhana.naz@lcwu.edu.pk)

compositions and digital technologies to reflect the traditional cultural and historical patterns, creating a developing trend.

**Keywords:** aesthetics, building material, decoration, digital technologies, geometry, Islamic architecture, muqarnas

## Introduction

Muqarnas is a prominent feature of Islamic architecture, particularly in three-dimensional geometry. Islamic geometric patterns can be divided into two categories, that is, two-dimensional and three-dimensional patterns. The former refers to the ornamentation used to decorate flat or curved surfaces, such as walls. The latter includes muqarnas, which is a three-dimensional ornamental structure developed using different materials and techniques in different regions. The word ‘muqarna’ has roots in both Arabic and Greek languages. Goodwin (1996) cites Muhammad Al-asad, to prove that the Arabic word ‘muqarna’ descends from the word ‘qurnas,’ which refers to a decorated ceiling with three-dimensional components. On the other hand, mathematician Dold-Samplonius (1992) cites Behrens-Abouseif and emphasizes that the term ‘muqarna’ has origins in Greek (κορῳνίς) and Latin (coronis), among other languages. According to Moussavi (2009), muqarnas is a three-dimensional decorative element used in the Iwans and domes of traditional Islamic architecture. Architectural dictionaries provide various definitions of the term ‘muqarnas’ based on different perspectives. However, mathematicians, architects, and researchers commonly describe it as a three-dimensional architectural composition constructed in tiers with overlaid levels of small niches, often interspersed with pendant parts (Esposito, 2004; Goodwin, 1996, p.196; Peterson, 1996, p.206).

Muqarnas is a form of decorative art in Islamic architecture, consisting of geometric forms used at transition points in spaces with different surface features, from the rectangular basis of the building to the vaulted ceiling. In Islamic architecture, muqarnas is typically utilized on domes, vaults, niches, squinches, and pendentives (under domes). The aim is to offer a common manner of transition to overcome the distinction between vertical, curved, and horizontal domes and to produce a smooth transition from the building's rectangular form to the vaulted ceiling (Palmer, 2008). There are three types of muqarnas, namely corbeling, superimposed, and suspended muqarnas (Fig. 1) (Harris, 2006). A corbeled muqarnas involves carving outwards from the

middle of a thick block of stone or wood, either before or after its assembling (Fig. 1a). In contrast, a superimposed muqarnas is built up against a concave surface of a supporting structure, such as a dome or a vault, leaving no hollow space between the muqarnas and the supporting surface (Fig. 1b). Lastly, a suspended muqarnas (Fig. 1c) is made up of surface-decorated panels produced on the ground and attached to the architectural structure using attachment ribs, leaving an empty space between the muqarnas shell and the structure (Hamekasi et al., [2011](#)).

**Figure 1**

*Muqarnas Construction in Three Different Ways: (a) Corbelled Muqarnas; (b) Superimposed Muqarnas; and (c) Suspended Muqarnas*










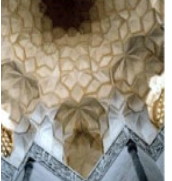

*Note.* Source: (Hamekasi et al., [2011](#))

Muqarnas have been used in different parts of buildings, as shown in Table 1, such as in large domes, cupolas, niches, on arches, and as a virtually flat decorative frieze. The material used in the construction of muqarnas varies according to the region and includes bricks, stucco, stones, ceramic tiles, plaster panels, mirror glasses, wood, and paint, as shown in Table 2. Although the view of muqarnas may appear as intricate, its plan form is comparatively straightforward. Figure 2 shows two images of the same arch in Isfahan: The first is the direct upward view, while the second is the external view, demonstrating that this particular muqarnas has a fairly uncomplicated design.

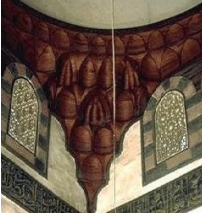
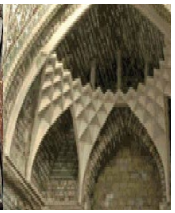


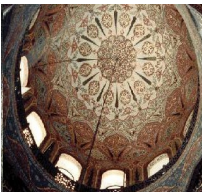



**Table 1**

*Use of Muqarnas in Different Applications*

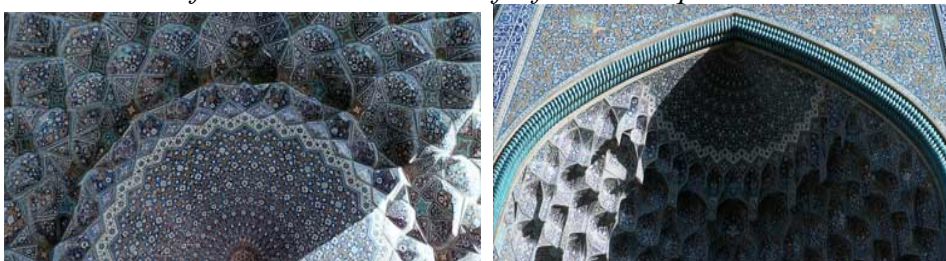
Muqarnas	Application	Muqarnas	Application	Muqarnas	Application
	Portal		Flat Ceiling		Minaret

Muqarnas	Application	Muqarnas	Application	Muqarnas	Application
	Wall		Mihrab		Niche
	Corner		Dome		Base of a dome

**Table 2**  
*Muqarnas Depicting Different Types of Building Materials*

Muqarnas				
Material	Wood	Ceramic	Mirror Glass	Paint
Muqarnas				
Material	Stucco	Stone	Plaster Panel	Brick

**Figure 2**  
*View of Arch in Isfahan: (a) Upward View in the Iwan of Isfahan; (b), Outside View of the Arch in the Iwan of Isfahan Mosque*



*Note.* Source: (Lockerbie, [n.d.](#))

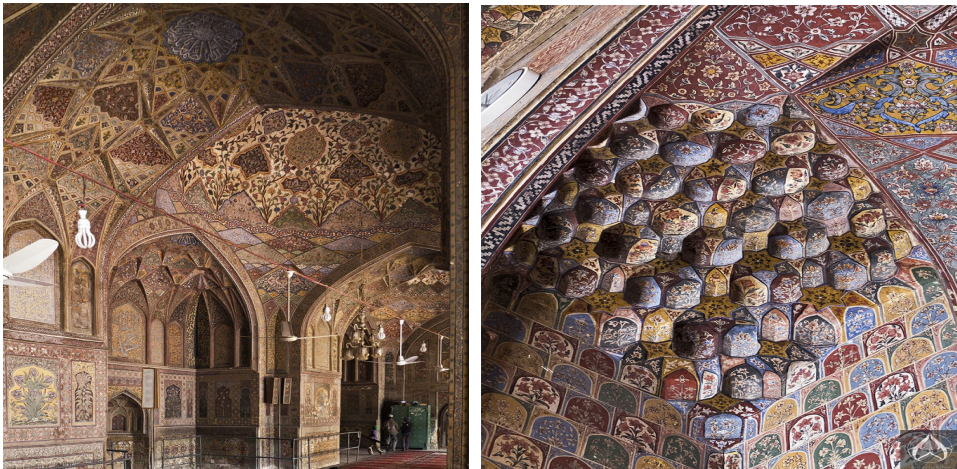
### Research Methodology

The study includes a historical perspective aimed to the evolutionary stages of muqarnas. The study also utilize the analytical descriptive method to examine the principles underlying muqarnas design and its aesthetics, as well as, to compare the development of various types of muqarnas and their techniques. For this purpose, data was collected through architectural surveys of traditional and contemporary buildings at the local level. Furthermore, textual analysis was employed to analyze the architectural projects containing muqarnas built from the 10<sup>th</sup> to the 16<sup>th</sup> century. All the examples included in the study are of historical significance.

Apart from the historical examples, the current research culminates by incorporating the 21<sup>st</sup> century compositions, inspired by shapes that seemingly share similarities with historical muqarnas patterns, along with modification techniques using modern materials. The examples of contemporary architecture help to elaborate the analytical approach by comparing between the traditional and the contemporary styles of muqarnas. These examples highlight the evolution of muqarnas from its origin to its contemporary development keeping in view the context of usage, building materials, and techniques.

### Figure 3

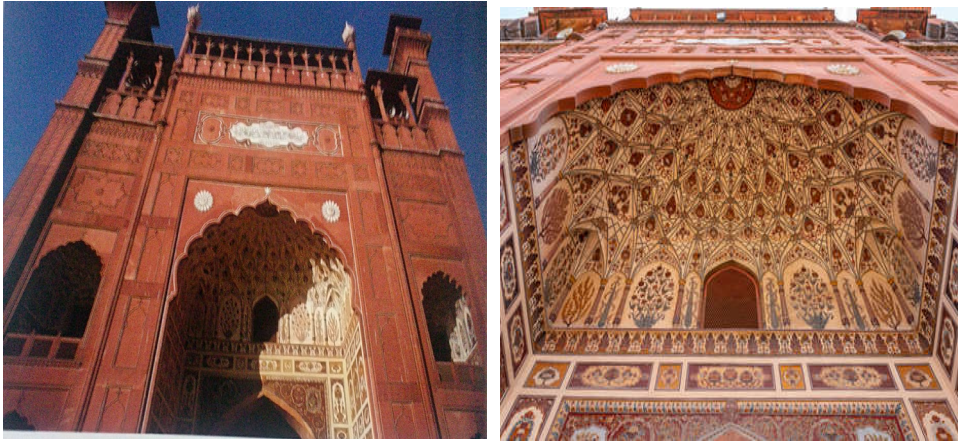
(a) *Archway and Niches Decorated with Muqarnas*; (b) *Muqarnas Decoration in Wazir Khan Mosque, Lahore*



*Note.* Source: (Archnet, [n.d.](#))

## Figure 4

(a) *Entrance to Badshahi Mosque, Lahore Decorated with Muqarnas*; (b) *Closer View of Muqarnas*



Following the decline of the Mughal dynasty and the end of the Safavid dynasty, traditional muqarnas culture experienced a period of stagnation due to modernization. From the widespread use of muqarnas in medieval Islamic architecture, it is evident that this decorative element was highly valued and widely employed in religious buildings (Clevenot, [2000](#)).

### Impact of Technology on Contemporary Development of Muqarnas

Modern Islamic architecture continues to use muqarnas as a decorative element, both in the exterior and interior of buildings. Several techniques are used to incorporate this ornamentation into contemporary design (Sennott, [2004](#)). One approach is the use of computer-aided design (CAD) software and computer numerical control (CNC) machines to create precise and intricate muqarnas patterns. This allows architects and designers to experiment with new forms and styles of muqarnas, as well as to quickly produce complex designs that would be difficult to achieve by hand (Al-Rawi, [2020](#)). International Medical Center in Jeddah was constructed in 2005. This project includes a significant use of custom-designed muqarnas for both the interior and exterior of the building. The muqarnas used under the base and the shade of balconies depicts the continuation of its historical usage (Figs. 5a and 5b).

**Figure 5**

(a) *Muqarnas Details of International Medical Center Jeddah, Saudi Arabia*; (b) *Muqarnas Details on the Balcony of International Medical Center, Jeddah*



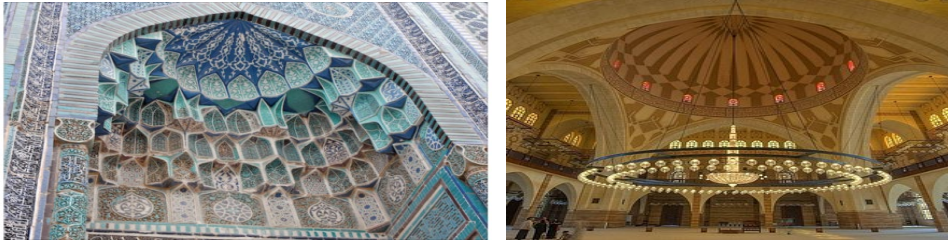
**Note.** Source: (International Medical Center, [n.d.](#))

A modern mosque that employs the latest techniques of muqarnas is the Sheikh Zayed Grand Mosque in Abu Dhabi, UAE. This particular mosque was completed in 2007. The mosque features a massive dome covered in muqarnas. It was designed using 3D modeling software and fabricated with a combination of traditional and modern techniques, using fiber-reinforced plastic (FRP), instead of traditional materials such as stone or stucco (Sheikh Zayed Grand Mosque Center, [2023](#)). The result is a stunning example of the combination between traditional Islamic art and modern technology (Fig. 6a). Another technique used in modern Islamic architecture is the application of muqarnas patterns using prefabricated units made from materials such as fiberglass, plaster, and concrete. These units can be mass-produced and assembled on site, allowing for greater efficiency and cost-effectiveness. An example of this technique is the Al-Fateh Grand Mosque in Bahrain. The mosque was completed in 1988, and it features a dome covered in white fiberglass muqarnas (Edwards, [2023](#)). The use of fiberglass allowed for the creation of large, lightweight elements that could be easily installed on site, while still maintaining the intricate geometries of traditional muqarnas (Fig. 6b).



## Figure 6

(a) *Muqarnas Details of Sheikh Zayed Grand Mosque Center, Abu Dhabi;*  
 (b) *Muqarnas Details on the Interior of the Dome of Al-Fateh Grand Mosque Manama, Bahrain*

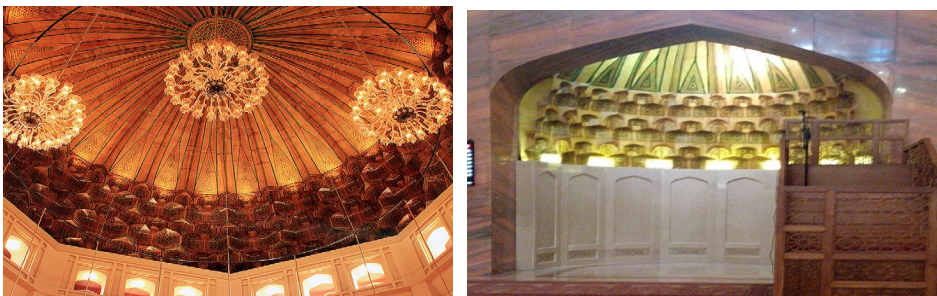


**Note.** Source: (a) (Sheikh Zayed Grand Mosque Center, [2023](#)) (b) Alamy ([n.d.](#))

Another example of the use of this technique is the Grand Mosque Bahria Town in Lahore, Pakistan. The mosque opened for public in 2014. Its dome and mihrab are adorned with muqarnas decoration, with the dome featuring fiber glass muqarnas descending into the mihrab showcasing elegantly detailed muqarnas (Figs. 7a and 7b). These modern applications of muqarnas showcase the adaptability and versatility of this ancient architectural form in contemporary design.

## Figure 7

(a) *Muqarnas Details on the Dome of Bahria Town Mosque, Lahore;* (b) *Muqarnas Details on the Mihrab of Bahria Town Mosque, Lahore*

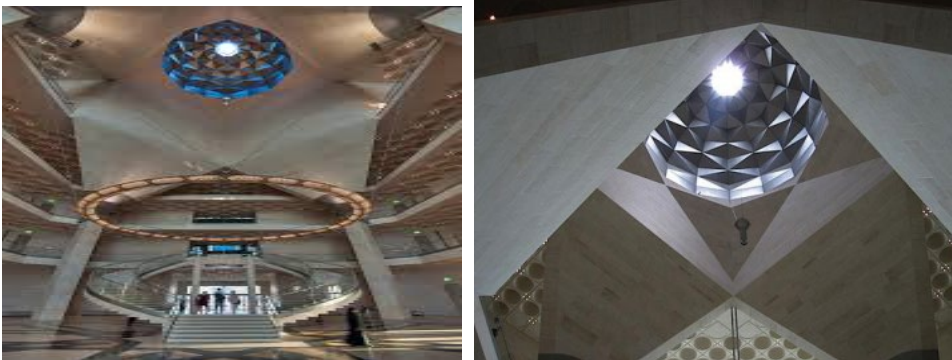


The Doha Museum of Islamic Art was built in 2008 in Doha, Qatar (Figs. 8a and 8b). The design of the museum's atrium dome draws inspiration from Islamic architectural principles of light, geometry, and water. With its symmetrical design, the primary purpose of this dome is to reflect sunlight within the main atrium (Pratomo & Provoost, [2017](#)). The

muqarnas dome in traditional architecture was also used to reflect sunlight and bring it into the buildings. Similarly, Miyahata Ruins Museum at Fukushima, Japan was built in 2015 (Figs. 9a and 9b). The museum has spectacular roof structures that depict the qualities of muqarnas in its architectural form (Cardenas, [2016](#)). These formations' geometrical arrangements and plane projections resemble several historical muqarnas instances. The two-dimensional patterns follow the geometric rules of the historical examples of muqarnas.

**Figure 8**

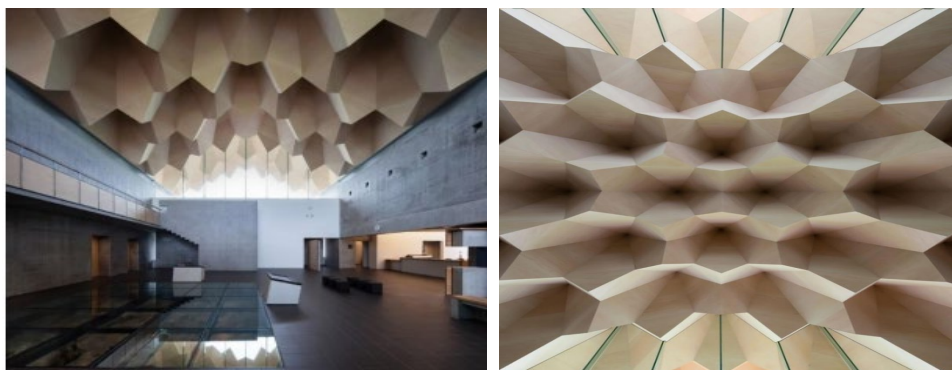
(a) *Atrium of the Museum of Islamic Art, Qatar;* (b) *Closer View of the Dome in the Atrium*



*Note.* Source: (Cardenas, [2016](#))

**Figure 9**

(a), *Gallery of the Miyahata Ruins Museum at Fukushima, Japan;* (b), *Closer View of the Roof of the Gallery.*



*Note.* Source: (Cardenas, [2016](#))

Muqarnas Tower is a commercial office building built for King Abdullah in 2013 and located in Riyadh, Saudi Arabia (ArchDaily, [2023](#)). The building's facade is influenced by muqarnas vaulting techniques and provides shade in view of Saudi Arabia's climate. Its geometry of constructed façade reflects ancient isometry and geometrical restrictions. Apparently, the front of Muqarnas Tower does not depict the previous muqarnas compositions. Rather, the Tower's symmetrical design differs from earlier designs in a way that it includes triangles with varying scales and forms, although this pattern has the simplest plan (Figs. 10a and 10b).

### Figure 10

(a) *Façade of Muqarnas Tower, Riyadh, Saudi Arabia;* (b) *View of Entrance*



*Note.* Source: (ArchDaily, [2023](#))

The primary components of both ancient and current patterns are regular geometric forms. Historical patterns generally employed squares and rhombuses, whereas modern designs mostly use triangles and rhombuses. As a result, using regular shapes as basic elements is a feature of muqarnas patterns, along with the techniques and materials available in the specific region. However, certain essential pieces of current forms have irregular shapes, though the idea behind them is based on a regular shape, or they have been changed into irregular shapes using CAD systems and generative design techniques.

### Discussion

Muqarnas, a form of architectural ornamentation, has been developing since the 10<sup>th</sup> century. Its actual style was born in the late 12<sup>th</sup> century in North-

western Iran. This style went on influencing the muqarnas construction in Iran during the Safavid dynasty and in South Asia during the Mughal period. Originally, muqarnas was one among the many architectural decorations in use. Later on, it turned out to be an essential part for defining and separating architectural elements including walls, ceilings, shafts, and balconies. The buildings, with their uniquely muqarnas style, dating from the late 12<sup>th</sup> century, have brilliant-colored tile work reflecting the rich creative heritage of the region. As an example, the Al-Jame Mosque in Isfahan shows muqarnas made of glazed tile, testament to Persian knowledge in relation to the tile work of geometric patterns.

Muqarnas was constructed using a variety of materials, including bricks, stone, glazed tile, and timber. The technique of building with muqarnas was likely spread through trade and pilgrimage routes, allowing for the emergence of regional variations. The drawings for muqarnas primarily comprised templates for skilled artisans already familiar with the construction process. The appeal of muqarnas lies in its geometric foundations, which engage the mind, as well as its visually stunning appearance, which is an illustration of the Islamic world's sophisticated understanding of mathematics, geometry, and design, inspiring the soul. It is an integral part of Islamic art and architecture, and its development and usage had a significant impact on the architectural traditions of the Islamic world and beyond. The Mughals included muqarnas in major architectural projects, as is also seen in the Taj Mahal with muqarnas adorning the entrance gateways and the main tomb, showing a synthesis of Perso-Indian architectural elements. Muqarnas depicted purity and grandeur, represented by the local marble that was in plentiful supply.

Muqarnas, a decorative architectural element in Islamic religious buildings, initially served a functional purpose but evolved over time to become an important decorative feature. It reflects the style of Maghreb and Andalusian architecture, inspired by local traditions combined with Islamic and North-African impact. The stucco and wood in muqarnas, such as in the Alhambra Palace, reveal Moorish craftsmen's perfection in adapting to local materials. Another example, in this respect, is the Ottoman-style Süleymaniye Mosque which combines muqarnas with the idea of synthesis, representing Byzantine and Islamic architectural traditions. The Ottomans made use of casting stone and marble because of its bulk presence in the region.

The materials used to create muqarnas varied significantly based on local availability. Especially in the Middle East, muqarnas was made from stone and bricks in most countries, considering the environment. On the other hand, timber and stucco were very commonly used in North Africa and Andalusia, both of which allowed a very different and distinguished style and technique. These differences in muqarnas, manifestly of regional character, reflected local architectural traditions, cultural influences, and, of course, the material. The distinctive look and utility of muqarnas linked to these amalgamated influences. This is the reason that inclusive variation of designs and styles are appreciated still today and also practiced.

The study of these variants' sheds light on the historical architectural tradition, while providing the richness of source and giving inspiration to modern architects and designers aiming to use old features in modern structures in an inspiring way. At present, muqarnas continues to be used for decoration in modern buildings, with designers using CAD systems to create alternative patterns inspired by various compositions of traditional muqarnas. This growing trend in architecture aims to preserve the traditional culture and utilizes historical patterns of muqarnas in modern building designs, showcasing its enduring influence on contemporary architects and designers.

## **Conclusion**

The results from the textual analysis revealed that the development of muqarnas in Islamic architecture has its roots in northeastern Iran, most likely during the Abbasid caliphate in Iraq during the 10<sup>th</sup> century. Muqarnas evolved from a simple ornamental piece into a sophisticated structural component. It was employed primarily on vaults, domes, and later on as a transitional feature, highlighting its aesthetic and practical value in architecture. According to the findings, in the past different regions preferred the materials available in their locality and distinct approaches were adopted to construct the buildings. For instance, stone is an easily available material in North-African countries including Morocco, Egypt, and Tunisia. So, architects in these countries preferred stone muqarnas in their buildings, historically. While architects in Middle-Eastern countries including Iran, Iraq, and Syria chose plaster for the building of muqarnas. Later, muqarnas was also used as structural member along with its decorative purpose in various areas. The creation of architectural transitional features and providing support to the roof were among the main

structural uses of muqarnas. The muqarnas was not only culturally important but also had artistic significance as well. Mamluk, Timurid, and Safavid architecture showed the mastery of architecture through muqarnas, with its elaborate patterns. Apart from structural purposes, muqarnas also performed decorative and symbolic functions, indicating Islamic cosmology and the cosmic canopy. It was a testament to the high quality of craftsmanship and aesthetic refinement of its era.

At present, advancements and innovations in the design of muqarnas and its efficient preparation are achieved using CAD and CNC technology. At the same time, the use of advanced materials has made it possible for the construction of large, lightweight elements that could be easily installed on the site, while maintaining the intricate geometry of traditional muqarnas. This innovation in technology has combined traditional styles with smart materials such as fiber glass, providing the muqarnas with enduring relevance.

### **Conflict of Interest**

The author of the manuscript has no financial or non-financial conflict of interest in the subject matter or materials discussed in this manuscript.

### **Data Availability Statement**

The data associated with this study will be provided by the corresponding author upon request.

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