

A study of the design characteristics and construction techniques of discontinuous double-shell masonry domes in holy shrines in Iraq and Iran

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Abstract:

The architecture of holy shrines is an Islamic architectural style prevalent in many countries of the Islamic world. This style possesses distinct characteristics that distinguish it from other Islamic architectural styles, due to its uniqueness and function as the shrine of an important Islamic figure, which carries many symbolic and moral aspects. Domes are one of the most prominent architectural elements in these shrines, and they come in various shapes and classifications across the Islamic world.

The research aims to study the design characteristics and construction techniques of the discontinuous double-shell domes in holy shrines, most of which date back to the Jalayirid period in Iraq and the Timurid period in Iran, with the aim of developing a framework to distinguish these domes. After studying the main components of the selected models, the research arrived at a framework through which we can distinguish these domes on the formal, structural, and decorative levels. The results also showed that the dome of Imam Reza was distinguished by its design and construction characteristics from the domes of Iraq due to the difference in its location.

Keywords: *Domes of the holy shrines, Double-shell domes, Design characteristics, Construction techniques*

1. introduction:

The dome is an architectural structural element used in various civilizations due to its significant role in covering vast spaces and its profound symbolism. Domes developed significantly during the Islamic civilization and were used to roof palaces, mosques, shrines, inns, and other diverse Islamic architectural structures. Therefore, the dome is considered one of the most important elements of Islamic architecture, requiring detailed study.

Dome architecture in holy shrines began to develop during the Mongol rule in Iraq and continued to flourish under the Safavid and Ottoman periods until the present day. Due to the paucity of studies on the historical domes in holy shrines in Iraq, particularly discontinuous double-shell domes, this study focuses on this type of dome, examining its design characteristics and construction techniques with the aim of developing a framework for distinguishing them.

The research followed the comparative analytical approach in studying the main parts of the dome, which are: the dome shell, the drum, the transition zone, and the structural supports for each of the domes of (Imam Ali, Imam Hussein, Domes of Al-Kadhimiya, and Abbas ibn Ali, peace be upon them) in Iraq and the dome of (Imam Reza, peace be upon him) in Iran. The research tools used to collect and analyze the required information were books, articles, field visits, interviews, and Architectural programs.

2. literature review:

Studies that have addressed the architecture of the holy shrines can be classified into two groups, as follows:

2.1. Historical and archaeological studies:

These studies, in a descriptive and general style, addressed historical aspects related to the holy shrines, with a brief description of their general plans and most prominent elements. Such as the proposals of (Al-Sharifi and Mahdi, 2022), which addressed the most important developments witnessed by the Husseini shrine, including the dome element during the rule of the Abbasid Caliphs and those who came after them, using a descriptive historical approach. The study of (Al-Mosuei, 2019) addressed the emergence of religious shrine cities and referred, in a concise descriptive style, to the architecture of religious shrines and their architectural elements, including the dome.

Meanwhile, the study of (Suad, 1958), which is an archaeological study, addressed the history of the Imam Ali shrine and its architectural description, indicating the date of the first building erected over the tomb of Imam Ali, the stages of development of the current dome, and the external and internal finishes of the dome body.

One of the important historical studies that dealt with masonry domes and classified them according to their shapes, number of shells, and construction methods is the study (Memarian, 2018), but it did not refer to Iraqi domes, and was limited to studying Iranian domes.

2.2. Analytical Studies:

Some studies that have addressed domes have focused on classifying them according to the arches that comprise them, as in the study by Al-Kaflawi (2014), which used a comparative engineering analytical approach to examine the types of arches that comprise the domes of holy shrines. This study concluded that all the arches of the domes of holy shrines in Iraq are contiguous pointed arches.

The study by Jaafar (2012) examined the formal aspects of the domes of holy shrines in Iraq using an investigative approach. It indicated that all the domes of holy shrines in Iraq are bulbous in shape, but not identical, and that there are differences in proportions on the one hand and the nature of the dome's curve on the other. The study arrived at a dome model that represents the general average for such domes. The study addressed only the external shape of the dome's body (the outer shell) and did not examine the other components of the dome and their design and structural characteristics. While some studies focused on the supporting elements (Khashkhashis) used in supporting double-shell domes, as in the study (Safaeipour & others, 2012), and briefly referred to some domes of holy shrines. A study (Hejazi & Pourabedin, 2020) examined the structural performance of discontinuous double domes made of Persian brick against earthquakes. Different upper and lower dome configurations were studied. The study focused on Iranian domes and was limited to structural aspects only.

In light of the above-mentioned epistemological issues and proposals, the research problem was defined:

The need to develop a comprehensive theoretical conception of the domes of the holy shrines in Iraq to distinguish them and identify the differences between them and the dome of Imam Reza (peace be upon him) in Iran.

To achieve a comprehensive study of these domes, the following questions must be answered:

- What are double domes and what is their historical background in the holy shrines in Iraq?
- What are the design characteristics of these domes?
- What are the construction techniques used in their construction?
- What are the similarities and differences between the domes of the holy shrines in Iraq and the Dome of Imam Reza (peace be upon him) in Iran?

3. Methodology

After conducting library studies and reviewing numerous books and articles on domes, detailed field studies were conducted, and geographical areas were identified according to the research topic, which focuses on double (discontinuous) masonry domes in holy shrines. The following samples were selected for study: The Dome of Imam Ali in Najaf, the Domes of Imam Hussein and Abbas ibn Ali in Karbala, the Dome of the Two Imams al-Kadhimiya in Baghdad, Iraq, and the Dome of Imam Reza (peace be upon them) in the holy city of Mashhad.

Several interviews were conducted with specialized builders and relevant authorities, such as the Engineering Projects Department at the Holy Shrines and the Shiite Endowment Department. During the field studies, the dimensions of the domes and their component parts (dome span, height, and thickness of the supports) were measured using measuring tools such as laser meters. Numerous photographs of the dome were also taken from the inside and outside to study the shapes of the domes (interior and exterior), the construction and finishing materials used, the methods of transforming the square to the circular shape upon which the dome rests, and the structural elements used in these domes, such as drums and Khashkhashis (Stiffeners). All results were documented and simulated using architectural software (AutoCAD, 3D Max). Based on the comparison and analysis of the obtained data, a framework was developed to distinguish the domes of the holy shrines in Iraq and to identify the similarities and differences between them and the Imam Reza (peace be upon him) Dome in Iran in terms of design characteristics and construction techniques.

4. Classification of Domes

In previous studies, researchers have classified domes into several categories based on their shapes and the number of shells. Domes consist of two aspects: formal and structural, and take an arched shape in space when viewed from the perspective of the domes. Domes can be classified based on the type and shape of this arch. However, the problem with classifying domes according to the type of arch lies in the fact that there are domes that contain more than one shell, and the outer shell differs from the inner shell. Therefore, domes must be classified based on the shape of the inner and outer shells (Mamarian, 2018, p. 375).

Dr. Pernia divides domes into three types based on the type of shell:

- Domes with two fully connected shells
- Domes with two connected shells between spaces
- Domes with two completely separate shells (Pernia, 1992, p. 79).

This classification provides a suitable basis for the architectural distinction of domes and can be used, with some modifications, to enhance their structural roles.

Domes with two shells that are not completely connected are divided into two groups: (Nar) domes and (Rak) domes, according to the Persian language. Rak domes have an inner shell in the form of a curved arch, while the outer shell is conical or pyramidal. The construction of the inner and outer shells is completely different. Nar domes have two separate shells with curved shapes. The inner shell has its own construction method, and the outer shell has its own function (Figure 1).

The research focuses on the study of the discontinuous double-shell domes (nar) in the holy shrines of Iraq and Iran in the following paragraphs.

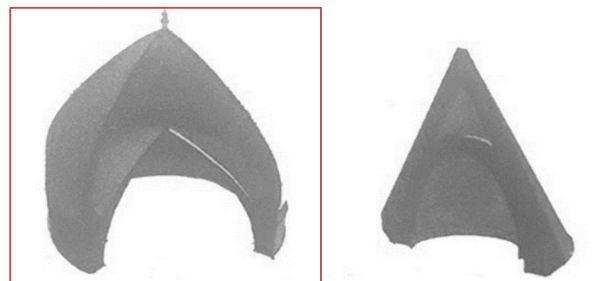


Figure 1. Shows the double-shelled domes, from the right the (RK) domes, from the left the (NAR) domes (Memarian, 2018)

5. Components of domes and their structural elements

Through a formal analysis of the dome, we can distinguish a group of its main components, like other vertically oriented architectural elements (Figure.2). These components are: (Pernia, 1992, p. 145), (Al-Haddad, p. 148), (Michell, p. 124)

- **The basic plan of the dome**, called (tahrung) in Persian
- **The walls or columns supporting the dome**, called (pishn) in Persian: their shape depends on the (tahrung). If they are square, they will form a cube extending below the octagonal ring.
- **The transition zone**, called (chapireh) in Persian: represents the transition from the usual square shape to the circular shape for the dome to sit upon. It is an important structural component widely used in the Islamic world and has several forms or methods, including: pendentive and squinches, the origins of which date back to Sassanian architecture, which reached its greatest stage of development in architecture. Islamic, muqarnas, and some of them mix more than one type.
- **Drum**: The drum is the supporting part of the shells, following the base area (Janbara) to be connected to the body of the dome. The drum may be omitted in many models so that the body is connected directly to the base, or its height may be exaggerated to form a large proportion of the body of the dome, as in the Dome of Imam Reza (peace be upon him). Drums often contain openings, which range between 8, 10, 12, or 16. The thickness

and height of the drum are important factors in choosing the type of shell, and affect the building's ability to bear upper loads. (Pirnia 1991: 86)

- **The dome's body:** Every architectural element has a main part, and the dome's body is considered its main part. The dome's body (Nar) is curved in various shapes depending on the number of curve centers, which vary from one country to another and from one style to another, depending on the functional type. The dome's body in the separate double-shell domes under study consists of two shells:

(1) The inner shell of the dome, whose upper face is usually stepped and rough. It is called (Ahianeh) in Persian. The inner shell has a structural behavior similar to that of single-shell domes. Due to the increased stresses in double-shell domes, it is necessary to use more resistant arches to construct this shell. Elliptical arches are recommended. The inner shell may start from the bottom, middle, or top of the drum, resulting in a variety of structural details (Figure.3) (Safaeipour & others, 2012, p. 4)

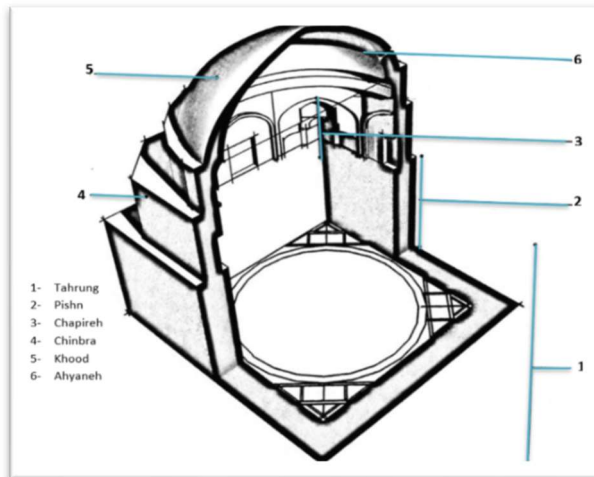


Figure 2. Components of domes and their structural elements (Source: authors;

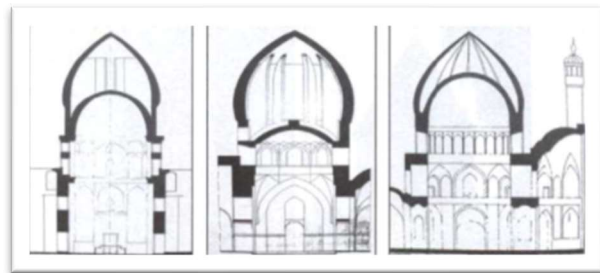


Figure 3. Different combination of drum and inner shell. (left to Right:) Inner shell under the drum, Inner shell between the Drum, Inner shell top of the drum

(2) The outer shell of the dome, which is placed on the (ahianeh), is called (khud) in Persian. It plays an important role in the urban landscape. This shell can be constructed from different types of load-bearing arches. The diameter of the dome at its maximum expansion can sometimes be larger than the diameter of the (drum), as in the dome of Imam Hussein (peace be upon him). This part is called (avgoun) in Iranian architecture. Domes that do not protrude from the drum are called (shelal) in Iranian architecture, as in the dome of Imam Reza (peace be upon him) (Pirnia, 1991:86) (fig. 4).

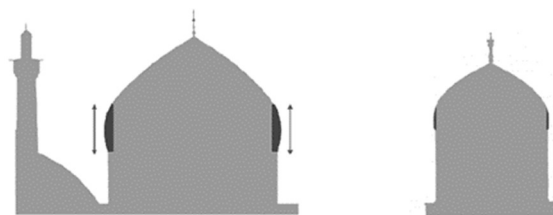


Figure 4. Avgoun part in Imam Hussein Dome (left)- Shellal part in the shrine of Imam Reza (Safaeipour & others,2012)

- **Khashkhashis (Stiffeners):** Stiffeners are thin brick walls which are used between the two shells of double shell domes (Pirnia,1991:86). Its Persian name, Khashkhashi, refers to poppy plant. Shape of khashkhash flower (poppy) and its structure can be seen in the section of the plant itself (fig. 5). Stiffeners are built simultaneously with the outer shell and are connected to it with in-and -out joint. This brings more stability for the stiffeners while the outer shell is under bending stress; it does not let them separate from the shell. Section of the shell is

bigger at the spots where stiffeners are connected to it which prevents outward movements in the shell as well as the drum. Moreover, vertical forces formed by weight of stiffener results in higher slope in the diagram of tensional stresses passing through the middle one third of the shell (fig.6). (Safaeipour & other, 2012)

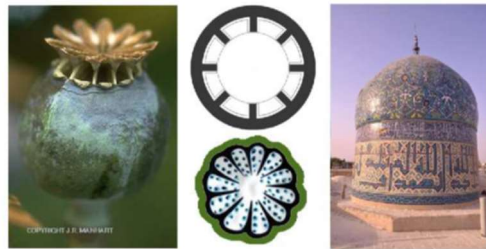


Figure 5. the root of the word Khashkhashis in Persian is 'Khashkhash' which means the poppy. Similar to double shell domes, the poppy planet is made of a thin outer shell which is supported by several internal buttresses (see section of the poppy). This Structural and conceptual similarity may introduce the natural concept of Iraqi and Iranian double domes. (Safaeipour & other, 2012)

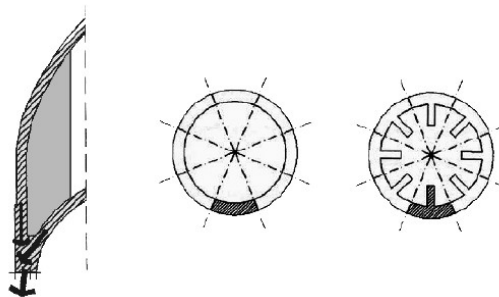


Figure 6. Structural role of stiffeners in discontinuous double shell domes (Baluchestani, 2008).

6. Domes of the holy shrines

This section discusses the unreinforced double domes of the holy shrines in Iraq, and the Imam Reza Dome in Iran, with an architectural description of the main components of these domes:

6.1 Dome of Imam Ali (PBUH)

Sources indicate that the first building constructed for the shrine of Imam Ali (PBUH) was by Harun al-Rashid, who erected a prominent structure over the tomb around 170 AH (786 AD). Subsequent additions and renovations followed, and interest in the shrine continued, even though its important architectural elements date back to the late first half of the eleventh century AH (17th century AD) (Al-Kaflawi, p. 98).

The sanctuary is crowned by a double-shelled dome supported by four pillars enclosing four large, high arches that surround the holy shrine on all four sides (Al-Gharifi, 2007). The outer golden, onion-shaped dome is magnificent and is considered the highest dome of the holy shrines in Iraq, as its height above the shrine ground reaches (30) meters to the point of the building's knot, while its diameter is 16.6 meters and its circumference is 51.85 meters. The arch used in forming the dome consists of 6 centers (Al-Kaflawi, p. 100). As for the inner dome that crowns the holy shrine, it is convex in shape, almost a circular hemisphere, and its height above the ground of the sanctuary is 23.50 meters and its diameter is 13.5 meters. The interior of the dome can be seen embroidered with mosaics, beautiful Qashani tiles, and wonderful geometric decorations. The dome's pillars and the arches separating it are covered with reflective mirrors (Niebuhr, 1955). The dome features a tall drum measuring 5.60 m (Al-Gharifi, 2007). The dome has 12 windows, the number of which symbolizes the Twelve Infallible Imams (peace be upon them). (Guide to the Holy Shrine of Imam Ali, 2011). Both the outer and inner shells are located above the drum, and the distance between the tops of the two domes is estimated at 5.5 m. The dome contains 16 main retaining walls (Khashkhashis) and 16 subsidiary ones. The sections of these Khashkhashis are graded and their depths are

uneven, acting as radial supports in the lower part to resist the erosion of the inner shell. The width of these supports decreases in the upper part to strengthen the upper outer shell (Safaeipour, 2012, p. 13) (Fig. 7). The transition area from the square to the circle, on which the drum is based, consists of three muqarnas. The middle one, which is located in the corner of the square, has its base at the bottom and its head at the top, while the bases of the two lateral muqarnas, which are located in the corner of the lateral arches, are at the top and their heads are at the bottom (Table 4). Such a style did not appear in Islamic architecture until the tenth century AH (Maher, 1983).

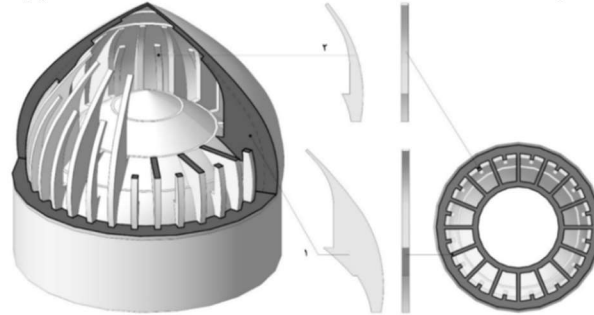
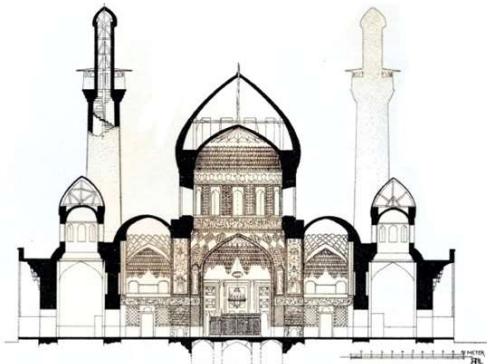


Figure 7. 3D and horizontal section showing details of the supporting elements (khashkhashi) and the inner and outer shell of the dome of Imam Ali (peace be upon him) (Safaeipour, 2022)

6.2 The Dome of Imam Hussein (PBUH)

Sources confirm that the current architecture of the shrine of Imam Hussein (peace be upon him) dates back to the renovation ordered by Sultan Uwais bin Sheikh al-Jala'iri. A towering dome was erected over the tomb, made of brick and plaster, flanked by two minarets at the front of the shrine in 767 AH (1366 AD). His sons, Sultan Ahmed and Sultan Hussein, later completed their father's construction in 786 AH (1384 AD). Developments and additions have continued throughout various historical periods, up to the present day. (Al-Kaflawi, 104)

The al-Hussain shrine is crowned by a double-shelled, pointed dome resting on four massive pillars with rectangular sections (Fig. 8-A). The dome rises approximately 29.36 m above the ground level of the shrine, and its diameter is 12.22 m from the inside. The dome rests on a drum 6 m high, interspersed with (12) windows with pointed arches, decorated with geometric and plant motifs. The drum is crowned at the top by a Qashani ring on which verses from the Holy Qur'an are inscribed, written in white on a dark blue background. The dome is decorated from the outside with square-shaped bricks plated with gold. (Engineering Projects Department of the al-Hussain Holy Shrine, 2025). The six-centered pointed arch was used to form the dome, similar to the arch used in the dome of the shrine of Imam Ali (PBUH) (al-Kaflawi, p. 104). There are (12) walls built of bricks (Khashkhashis) in the form of supporting columns between the two layers, and each one of them is located between two of its twelve windows from the inside (Engineering Projects Department of the Holy Shrine of Imam Hussain, 2025). (Figure. 8-B)



(A)

(B)

Figure 8. (A) Section of the Imam Hussein shrine showing details of the dome and its components (Nöldeke, 2024), (B) Images of the brick supporting columns between the two shells (researcher)

6.3 Dome of Abbas ibn Ali (PBUH)

The shrine of Abbas (peace be upon him) is the second most important Islamic architectural landmark in the holy city of Karbala. Sources indicate that the first building erected over the holy tomb dates back to 372 AH (983 AD) during the Buyid era. During this period, a building was erected over the holy tomb, topped by a high dome of brick and plaster.

Successive additions to the holy tomb followed from 740 AH to 790 AH by the Jalayirids, beginning with the founder of the state, Sheikh Hassan, followed by Sultan Uwais, then Sultan Hussein, and finally Sultan Ahmed Bahadur Khan, son of Uwais, who completed the current structure. The Qajars, Safavids, and Ottomans also worked on decorations and additions to the Abbasid shrine (Al-Kafeel Global Network, 2020). The shrine of al-Abbas (peace be upon him) is crowned by a high dome with a circumference of 46.5 meters and a diameter of 15 meters. Other sources indicate that its diameter is 16 meters at its widest points from the inside, and it is located between the two minarets. This dome rests on four massive walls inside the shrine. The dome's height above the roof of the shrine is approximately 19 meters, while its height above the floor of the shrine is approximately 32.7 meters (Engineering Projects Department of the Holy Abbasid Shrine). The type of arch used to form the outer dome is pointed, consisting of seven centers at different coordinates (Al-Kaflawi, p. 108).

The dome from inside the sanctuary contains two panels of tiles, the lower one is (90 cm) wide and Surah (Al-Munafiqun) is written on it, and above it there are (12) windows, each one is (2.10 m) apart from the other, and its sides are covered from the outside with Karbala tiles, where the width of each window is (1.80 m) and its height is (3.25 m). Above the windows from the inside there is the other panel, (75 cm) wide, on which are written verses from the Holy Qur'an, and above it is a wonderful artistic panel of mirrors that were cut and shaped using traditional methods, forming Islamic inscriptions, where the names of the twelve imams are written at the top of the inner dome in prominent black script. The dome is made up of two shells, the outer dome is covered with gold, with a total of 6418 gilded plates. The inner dome is smaller and only the interior is visible, representing the interior of the ceiling above the holy shrine, covered with mirrors. The distance between the tops of the two domes is 9.25 m. There are (12) walls built of bricks (Khashkhashis) in the form of columns supporting the outer dome, and each one is located between two of its twelve windows from the inside. (Figure 9)

These windows are located within the base of the dome, which rises 7.55 meters above the surface of the sanctuary. It consists of two parts: the lower part, the octagon, is 1.2 meters high above the surface of the sanctuary and 16.90 meters wide between each of its two opposite sides. The upper part rests above the octagon, which is the circular neck of the dome. Its diameter is 14.90 meters and its height is 6.35 meters above the surface of the octagon. This part includes a Qur'anic inscription at the top, made of enamel and 1 meter high. Below it is a band of engraved tiles 1.35 meters high. The height of the top of the outer dome is 13.15 meters above the top of the drum (Engineering Projects Department of the Holy Abbasid Shrine, 2025), (researcher).

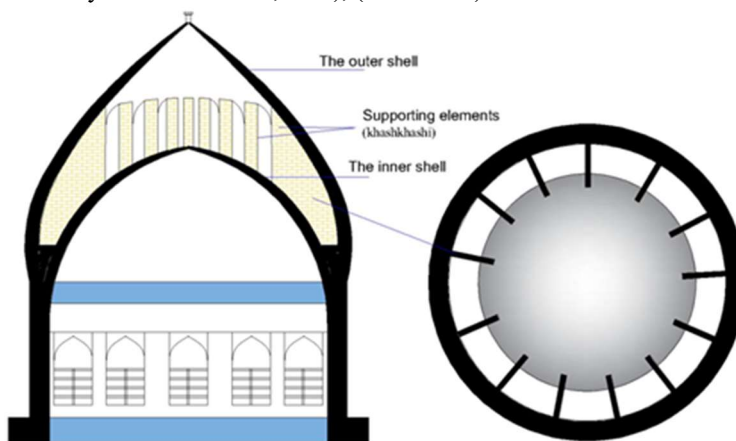


Figure 9. A vertical and horizontal section showing the outer and inner shell and the supporting elements of the Dome of Al-Abbas (PBUH) (Researcher)

6.4 Domes of the Two Imams al-Kadhimiya (PBUH)

The shrine's architecture reached a state of meticulous attention to detail in terms of its decorative beauty and construction at the beginning of the eighth century AH. In 769 AH, Sultan Uwais al-Jala'iri renovated the shrine, constructing two domes and two minarets. He ordered the placement of two fine marble chests over the two graves and decorated the sanctuary with Qashani bricks on which verses from the Holy Quran were inscribed. Upon Shah Ismail's entry into Baghdad, he ordered the sanctuary to be renovated, the arcades to be paved with marble, the sanctuary to be decorated with Qashani tiles, and four minarets to be erected instead of two. A mosque was added to the shrine's northern side in 914 AH (1508 AD).

The sanctuary houses the two holy shrines and is surrounded by a portico on all four sides. Three canopies overlook the courtyard on the southern, western, and eastern sides. This hall is covered by two domes with a tall drum, devoid of windows, plated in gold, and the interior is decorated with beautiful mirror engravings (Al-Kaflawi, pp. 110-111). The domes of the two holy shrines are similar in shape and structure. The shoulders of the arch used to form the dome are defined by five centers (Al-Kaflawi, p. 112). The dome's inner span is approximately 6.5 meters, and its outer span is approximately 10.5 meters. The distance between the tops of the two shells is estimated at 14.1 meters. The drum is 5 meters high and is located between the two shells (Engineering Projects Department of the Al-Kadhimiya Shrine, 2025), (Haji Ibrahim Zargar 2009). Four main retaining walls (Khashkhashis) were constructed with dimensions of (1200 cm Width, 26 cm Depth, 410 cm Height), and 12 secondary walls with dimensions of (1200 cm Width, 26 cm Depth, 135 cm Height) located in the space between the two shells. One of the distinctive features of the Khashkhashis used in constructing the Kadhimiya domes is that the four main ones extend to the center of the dome's base diameter and are connected to each other. To form a hyperbolic structure in the middle of the dome, which increases the rigidity of the dome and its ability to resist lateral loads and prevents deformation of the dome's shape (Safaeipour & others, 2012, p14) (Fig. 10)

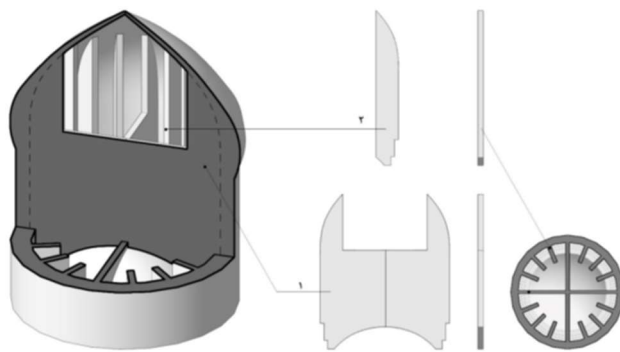


Figure 10. D3 model, horizontal and vertical section showing details of the supporting elements (khashkhashi) and the inner and outer shell of the dome of the two Imams al-Kadhimiya (PBUH) (Safaeipour, 2022)

6.5 Dome of Imam Reza (PBUH)

The dome of Imam Reza, which dates back to the Timurid era, consists of two shells, similar to the domes of the holy shrines in Iraq. The dome's outer shell rises approximately 30 meters above the floor of the shrine, and its thickness at the base is approximately 70 cm, tapering to 50 cm at the top. The span of the outer dome is approximately 11.28 meters, and the distance between the top of the outer dome and the inner dome is approximately 11.7 meters.

The inner dome's height from its top to the floor of the shrine is approximately 19 meters. The dome's thickness at its base is also 70 cm, tapering to 30 cm at the top. The structure of the inner shell consists of seven narrow ribs connected by eight large retaining walls (Khashkhashis) (Figure 11). The inner diameter of the drum is 11.6 meters, its height is 8.7 meters, and the thickness of the cylinder is about 60 cm (Memarian 1988:250) (Golombek & Wilber, 1995:259-263)

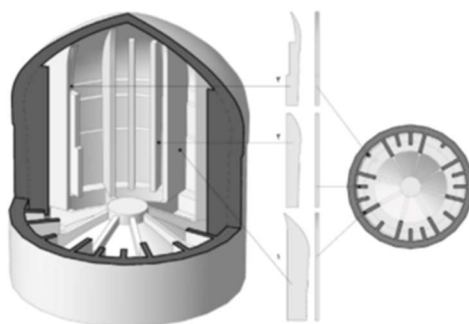


Figure 11. 3D model and horizontal and vertical sections showing details of the supporting elements (khashkhashi) and the inner and outer shell of the dome of Imam Reza (PBUH) (Safaeipour, Taken from: Saadat, 1976)

7. Discussion and results

After discussing in the previous paragraphs the concept of double domes and their main components, and providing a brief overview of the historical background, design, and structural characteristics of the domes of holy shrines, this paragraph will analyze and discuss the following terms in the models selected for the study: (dome shell, drum, transition zone, supporting elements "khashkhashi" to distinguish them and find the most prominent differences between them, as shown in the following tables:

7.1. Dome Shell:

Table.1 compares the characteristics of the dome shell in the selected models according to a set of indicators, including: shape, arch type, construction and finishing materials, and dimensions.

The results of the dome shell revealed that the domes of the holy shrines in Iraq are similar in shape due to the use of the pointed arch in their formation, but differ in the number of centers that make up the arch, as shown in the table.2. The results also showed that the building materials used to construct the shells of all domes were brick and plaster. The finishing of the inner shell varied between reflective mirrors and linear decorations, as in the domes of Imam Hussein and Abbas (peace be upon them), and tiles only in the domes of Imam Ali and Kadhimiya (peace be upon them). The outer shell was finished with gilded panels in all domes. The results showed that the domes of the holy shrines in Iraq contain an "Avgoun", the area protruding from the drum, while the dome of Imam Reza (peace be upon him) lacks it. The dome of Abbas (peace be upon him) is the tallest among the domes of the holy shrines in Iraq and Iran, at 32.7 meters. The domes of Imam Ali and Imam Reza (peace be upon them) come in second place, at approximately 30 meters above the ground of the shrine, as shown in Table.1.

7.2. The drum

Table 3 compares the drum characteristics of the selected models according to a set of indicators, including dimensions, drum openings, and the materials used in construction and finishing.

The results showed that the diameter of the drum of the Imam Ali dome, about 16.6, is the largest among the drums of other domes, and that the drum of the domes of Imam Ali, Imam Hussein, and Imam Abbas (peace be upon them) contain 12 openings, while the domes of Imams Kadhimiya and Imam Reza (peace be upon them) lack openings. The finishing materials used on the outside varied between gold sheets and linear decorations in the domes of Imam Hussein, Imam Ali, and Imam Reza (peace be upon them), and Qashani decorated with Islamic motifs in the drum of the Abbas dome (peace be upon them), as shown in Table 3.

7.3. Transition Zone

Table 4 compares the characteristics of the transition zone in the selected models according to a set of indicators: the type of transition zone, and the materials used in construction and finishing.

The results showed that the transition zones in the domes of the holy shrines in Iraq were all of the pendentive (Karbandi) type, but differed in detail, as shown in Table 4. The transition zone in the dome of Imam Reza was

different, as the Muqarnas arch was used to transition from square to circular. Reflective mirrors were used to complete all transition zones in the models selected for study.

7.4. Stiffeners (Khashkhashis)

Table 4 compares the characteristics of the stiffeners in the selected models according to a set of indicators: type, number, dimensions (length, width, height), and location.

The supports used to support the two shells of the dome in the selected models were classified into main and subsidiary supports. The results showed the diversity of these divisions in the selected models. Only 12 main supports were used in the domes of Imam Hussein and Abbas (peace be upon them), while 16 main supports and 16 subsidiary supports were used in the dome of Imam Ali, and 4 main supports and 12 subsidiary supports were used in the domes of Al-Kadhimiya (peace be upon them). The dome of Imam Al-Rida was distinguished from the domes of Iraq by the use of 8 main supports and 9 subsidiary supports with a depth of 1.15 m, and 3 other subsidiary supports with a depth of 0.6 m, as shown in Table 5.

Table 1. (Source: Researcher)

Dome shells									
	shells	shape	type of arch	Materials		Dimensions (m)		view	Profile Shape (Section)
				building	finishing	Width	Height		
Imam Ali	outer shell	Bulbous	juxtaposed pointed arch	brick & plaster	gold sheets	16.6	30		
	inner shell	semicircular	semicircular arch	brick & plaster	Qishani + Geometric decorations	13.5	23.5		
Imam Hussein	outer shell	Bulbous	juxtaposed pointed arch	brick & plaster	gold sheets	12.22	29.36		
	inner shell	semicircular	semicircular arch	brick & plaster	reflective mirrors, calligraphic decoration				
Imam Abbas	outer shell	Bulbous	juxtaposed pointed arch	brick & plaster	gold sheets	16	32.70 (20.7 roof)		
	inner shell	semicircular	semicircular arch	brick & plaster	reflective mirrors				
Al-Kadhmain	outer shell	Bulbous	juxtaposed pointed arch	brick & plaster	gold sheets	Out 10.5			
	inner shell	semicircular	semicircular arch	brick & plaster	reflective mirrors	6.5			
Imam al-Rida	outer shell	Bulbous	juxtaposed pointed arch	brick & plaster	gold sheets	11.28	30		
	inner shell	semicircular	semicircular arch	brick & plaster	reflective mirrors		19		

Table 2. shows the number of centers in the arches that make up the domes of the holy shrines
(Source: Researcher, adapted from: Al-Kaflawi)

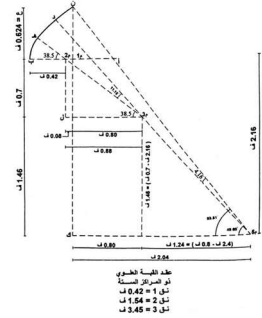
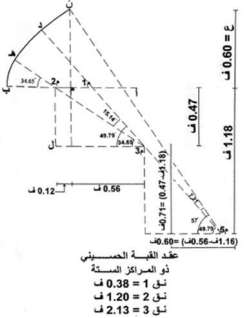
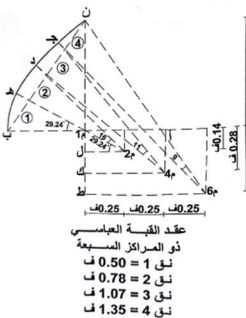
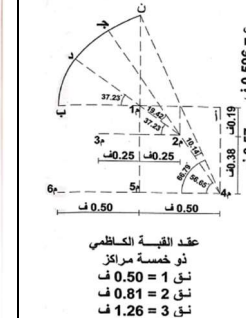
	Imam Ali	Imam Hussein	Imam Abbas	Al-Kadhmain
Nu .of centers	6	6	7	5
	 عدد القبة الخديوية أو خمسة مراكز نق 0.42 = 1 نق 1.54 = 2 نق 3.45 = 3	 عدد القبة الحسينية أو المراكز الستة نق 0.38 = 1 نق 1.20 = 2 نق 2.13 = 3	 عدد القبة العباسية أو المراكز السبعة نق 0.50 = 1 نق 0.78 = 2 نق 1.07 = 3 نق 1.35 = 4	 عدد القبة الكاظمي أو خمسة مراكز نق 0.50 = 1 نق 0.81 = 2 نق 1.26 = 3

Table 3. (Source: Researcher)

Drum							
	Materials			Dimensions (m)		Number of holes in the drum	picture
	building	finishing		Width	Height		
		outside	inside				
Imam Ali	brick & plaster	gold sheets + calligraphic decoration	Qi Shani + Epigraphic & Geometric decorations	16.6	5.6	12	
Imam Hussein	brick & plaster	gold sheets + calligraphic decoration	Reflective mirrors + calligraphic decorations	12.22	6	12	
Imam Abbas	brick & plaster	Qashani + calligraphic decoration	Reflective mirrors + calligraphic decorations	14.90	6.35	12	
Al-Kadhimain	brick & plaster	gold sheets + calligraphic decoration	-	10.5	5	-	
Imam al-Rida	brick & plaster	gold sheets + calligraphic decoration	-	11.6	8.7	-	

Table 4. (Source: Researcher)

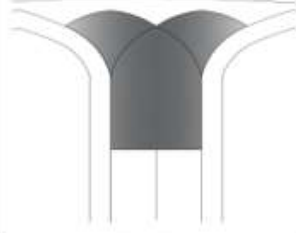
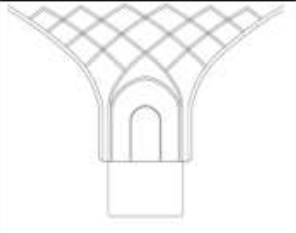
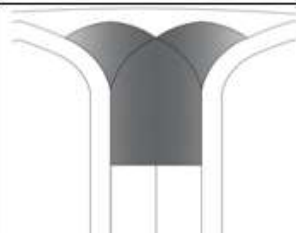
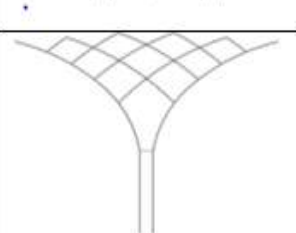
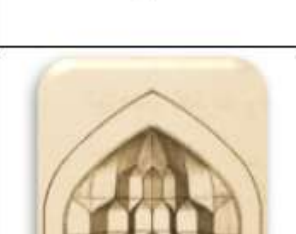
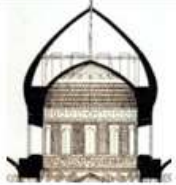
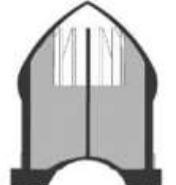
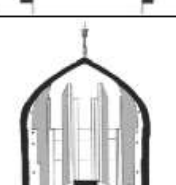
Transition Zone					
	Materials		type	Geometry (Elevation)	picture
	building	Finishing			
Imam Ali	brick and plaster	Reflective mirrors	Pendentive (Karbandi)		
Imam Hussein	brick and plaster	Reflective mirrors	Pendentive (Karbandi)		
Imam Abbas	brick and plaster	Reflective mirrors	Pendentive (Karbandi) + Muqarnas		
Al-Kadhimain	brick and plaster	Reflective mirrors	Pendentive (Karbandi)		
Imam al-Rida	brick and plaster	Reflective mirrors	Muqarnas arch		

Table 5. (Source: Researcher)

Khashkhashis (stiffeners)									
			Dimensions (m)			Position		Geometry (plan)	(Section)
			Width	Depth	Height	Start	End		
Imam Ali	main	16	2 bricks	3-4	7.5	Over the drum and the inner shell	Above the Upper breaking point		
	Sub	16	2 bricks	1-1.5	5.5	Over the drum and the inner shell	Above the Lower breaking point		
Imam Hussein	main	12	0.36	1.2-1.45	7.2	Over the drum and the inner shell	Above the Upper breaking point		
Imam Abbas	main	12				Over the drum and the inner shell	Above the Upper breaking point		
Al-Kadhimain	main	4	0.26	4.10	12	Over the drum and the inner shell	At the upper breaking point		
	Sub	12	0.26	1.35	12	Over the drum and the inner shell	At the upper breaking point		
Imam al-Rida	main	8	0.45	1.75	13	Drum bottom-over the inner shell	Above the upper breaking point		
	Sub 1	9	43	1.15	10	Drum bottom-over the inner shell	At the upper breaking point		
	Sub 2	3	0.43	0.6	10	Drum bottom-over the inner shell	At the upper breaking point		

8. Conclusion

The dome is a structural element with symbolic and aesthetic characteristics in Islamic architecture, particularly in the architecture of holy shrines. The research focused on the study of the unreinforced double-shell domes in the shrines of Imam Ali, Hussein, Abbas, and Kadhimiya (peace be upon them) in Iraq, and the dome of Imam Reza in Iran. This type of dome appeared and spread during the Jalayirid and Qajar periods in Iraq and the Timurid period in Iran. The results showed a great similarity between the domes of the holy shrines in Iraq and Iran, and that the type of arch used in forming all the domes was pointed. However, the number of centers varied from one dome to another, as shown in Table (2). A study of the height of the domes relative to their diameter revealed that the domes of the two Imams, Kadhimiya, were the highest among the other domes, as shown in Table.6. The study concluded that the dome of Imam Reza was distinguished from the domes of Iraq by the length of the drum, the absence of

openings, and the fact that the arch of the dome does not extend beyond the drum (Shelal). Three types of supports were used to support the outer shell (main, sub1, sub2), which is not found in the domes of Iraq. It was distinguished by the use of the muqarnas arch in the transition area from the square to the circle. The research was able to reach a framework that distinguishes these domes to serve as a knowledge base to support researchers in in-depth study of domes in Iraq, given the lack of such studies in Iraq.

**Table 6. shows the ratio of the height of the domes of the holy shrines in Iraq in relation to their diameters.
(Source: Researcher)**

Dome	Total height of the dome	Notes
Imam Ali	1.03D , D=16.5	Lowest percentage of increase
Imam Hussein	1.23D, D= 12.22	
Imam Abbas	1.27D, D= 15	
Al-Kadhimain	1.35D, D= 10.5	Highest percentage of increase
Imam al-Rida	1.06, D= 11.28	

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