

Revisiting the Geometry of the Transition Zone Using Filposh Squinches in Ardeshir Palace

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ABSTRACT

Iranians invented squinches to cover a square-plan space with a dome. Filposh, a type of squinch first found in Sasanian architecture, is a conical vault constructed in the transition zone's corners to transmit the dome's forces and weight. This technique can be seen in three halls of the Sasanian palace of Ardeshir. In this paper, the geometry of the transition zone using filposh squinches between a spherical dome and the square supporting walls in Ardeshir Palace was re-examined. A historical descriptive method was employed to analyse the main drawings of the halls from the nineteenth century to the present, and two hypotheses concerning the geometry of the transition zone were modelled and evaluated. As a result, the hypothesis that the dome's cross-section intersects the chamber's square plan is rejected. Furthermore, the claim that the transition zone's square plan circumscribes the dome's cross-section was discussed and proven.

KEYWORDS

Filposh, transition zone, squinches, Ardeshir Palace, Iran

INTRODUCTION

In ancient architecture, covering a square-plan chamber with a dome was an advanced architectural achievement. Because the dome's circular cross-section cannot be directly positioned on the square space, interface elements must be employed to bring the square shape closer to the circle (Golzari–Rabb 2022). Without these elements, there are four voids between the dome and

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the walls of the cuboid space (Elkhateeb 2012. 156), causing structural and formal issues (Memarian–Safaeipour 2018. 382). *Figure 1* illustrates these four voids in plan and perspective. The Iranians invented squinches to address this architectural challenge and played a key role in the development of domed structures (Creswell 1914. 683). Although the precise date of this invention is unknown, several surviving squinches in structures from the second and third centuries are highly advanced, reflecting that this level of architectural development is the result of decades of experience (Memarian–Safaeipour 2018. 385). The Sasanian era (224–651 CE) was one of the most prominent historical periods for square spaces with domes (Namjoo 2014), and the oldest existing squinches can be found in Sasanian architecture (O’Kane 1996).

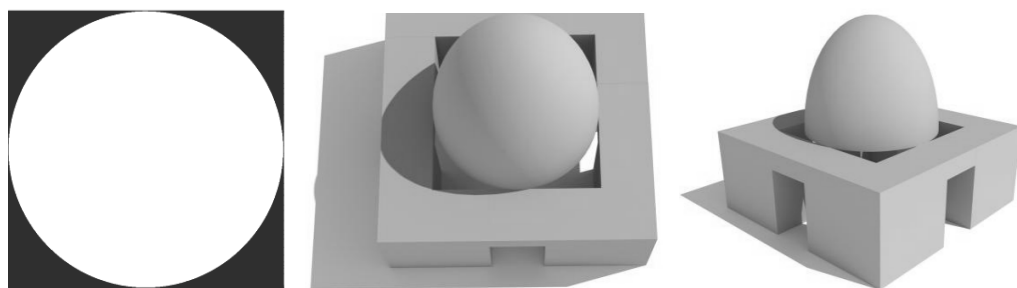


Figure 1. Voids between the squared structure and the dome, by authors

During the Sasanian period, four different types of squinches were developed, namely, Filposh, Patkin, Sekonj, and Shouldered arches (Golzari–Rabb 2022). The oldest surviving squinches may be seen in Dokhtar Castle (Schippmann 1990; Hosseini 1999), which is filposh. This architectural element was found in other Sasanian buildings, such as the Ardeshir Palace and fire temples like Siyahgol Ivan. Hence, filposh was the first type of squinch used in Iranian architecture, and it further evolved in Iranian-Islamic architecture. This study aims to re-examine the geometry of the transition zone with four filposh in a hall of the palace of Ardeshir. The main drawings of the palace from the nineteenth century until the present were gathered and investigated, and the two hypotheses regarding the transition zone in the hall were modelled and discussed.

ARDESHIR PALACE

Ardeshir Papakan defeated the last Parthian king, Artabanus IV (216–224 AD) (Gholikhani et al. 2020; Daryae 2013; Pope 1965), and established the Sasanian Empire in 224 AD (Pourshariati 2008; Zouberi 2017). Ardeshir found several spectacular buildings, including the Palace of Ardeshir (Huff 1986). Ardeshir Palace¹ (also called Ātaškada) is the Sasanian’s second monumental structure (after the first fortified monumental complex at Qale Dokhtar) and contains significant architectural novelties (Huff 2014). This structure is situated in the Firuzabad Plain’s northwestern outskirts (Askari Chaverdi–Djamali 2020. 25). The Palace’s construction dates back to the second half of the third century AD (Djamali et al. 2017). The entire structure was

¹ It is also known as Firouzabad palace.



made of broken stone or rubble, bonded together with a good lime-sand mortar, and the walls of the domed halls are 4.7 meters thick (Perrot–Chipiez 1994. 165). Plaster was used to cover the walls (Pope 1965. 540). Elliptical domes cover (Creswell 1914. 683) three square halls in this palace, and the middle dome room, which is located on the main axis of the building and behind Ivan, is the most important space of this palace (Muhammadi et al. 2017. 93). *Figure 2* displays the present situation of the palace.



Figure 2. Ardeshir Palace, https://madainproject.com/palace_of_ardashir (Accessed 02 June 2022)

FILPOSH TECHNIQUE

Filposh is a conical vault to facilitate the transformation of the square plan to a circle shape to place a dome (Godard et al. 1992. 11). The Sasanian filposh was constructed of stones and rubble, but in the following periods, adobes and bricks were used as the main building materials to build this structure (Golzari–Rabb 2022). Choisy and Creswell claim that the Iranians' conical vaults in four corners transform the square plan into an octagon plan (Choisy 1899. 125; Creswell 1914. 683), making it easier to set a dome. Godard, on the other hand, rejects the notion of the octagonal cross-section beneath the dome and claims that the dome's cross-section is not circular at the top of the squinches (Godard et al. 1992. 20). Conical squinches in Ardeshir Palace and Qal'a-ye Dokhtar, according to O'Kane, are crude in design and execution (O'Kane 1996). Creswell describes squinches in the palace of Ardeshir, which are filposh, as "a series of concentric arches, thrown across the angles and advancing one over the other" (Creswell 1914. 683). Filposh in this palace, according to Memarian and Safaeipour, is a half cone that starts from a corner and continues inclined until it becomes a vertical arch in its final layer (Memarian–Safaeipour 2018. 399). *Figure 3* portrays Choisy's drawings of the squinches in the hall of the palace.



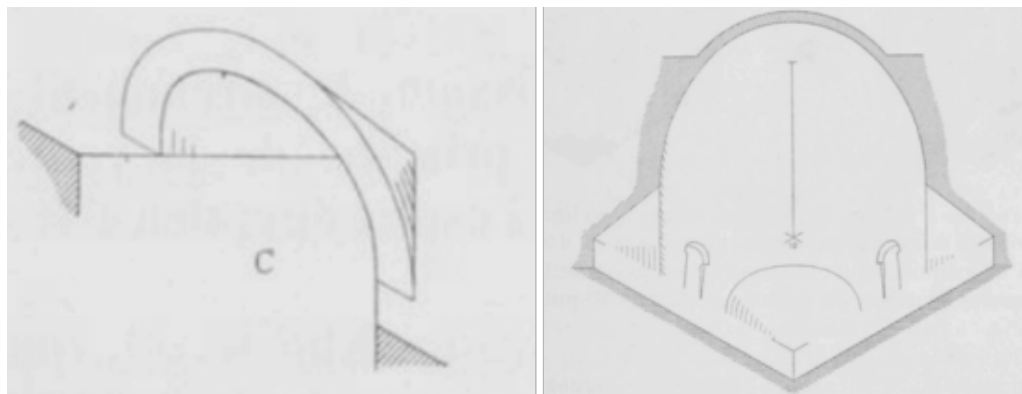


Figure 3. Conical vaults under a dome (Choisy 1899. 124–125)

In addition, O’Kane indicates that “the rubble masonry was so haphazardly applied that it is difficult to distinguish the outer edges of the squinches from the corbeled walls between them” (O’Kane 1996) in the palace of Ardeshir. The transition zone is employed to change the walls of a square chamber to a base to set a dome (Moradi 2019. 24) and in this palace, the transition zone is a special drum composed of squinches and near vertical or curved walls. As will be discussed in the next part of the paper, the masonry materials were not placed in the Sasanian fil-posh by accident, and the transition zone follows a specific geometry. Figure 4 shows the transition zone in a dome chamber of this building.



Figure 4. The transition zone in a dome chamber, the palace of Ardašir I (O’Kane 1995)

TRANSITION ZONE IN ARDESHIR PALACE

Since the nineteenth century, different scholars, for instance, Eugène Flandin, Pascal-Xavier Coste, George Rawlinson, John Mansbridge, Richard Phené Spiers, F.S.A. Friha, Gholamhossein Memarian, and Hadi Safaeipour, have documented and studied the palace of Ardeshir. Their drawings were reviewed to determine their views on the geometry of the transition zone in the palace's square halls. A square circumscribes a circle, and a circle intersects a square; these are the two main hypotheses for the transition zone in the square hall of this palace. Each of them is discussed in the following sections.

A: A SQUARE CIRCUMSCRIBES A CIRCLE

The palace was first illustrated in the book “Voyage en Perse” by Eugène Flandin, a painter, and Pascal-Xavier Coste, an architect, during the years 1840 and 1841, by order of the French Minister of Foreign Affairs and under the authority of the French Embassy in Iran (Flandin–Coste 1851). *Figure 5* shows the earliest document of the palace's plan, sections, and façade. Three dome-roofed chambers feature squinches with concentric semi-circular lines. The dome's cross-section is encircled in a chamber's square plan and reaches one point on each side of the chamber's interior walls. Several scholars used these drawings in their studies later on. For example, Pope adopted the plan in his book “Persian Architecture: The Triumph of Form and Color” (Pope 1965. 55).

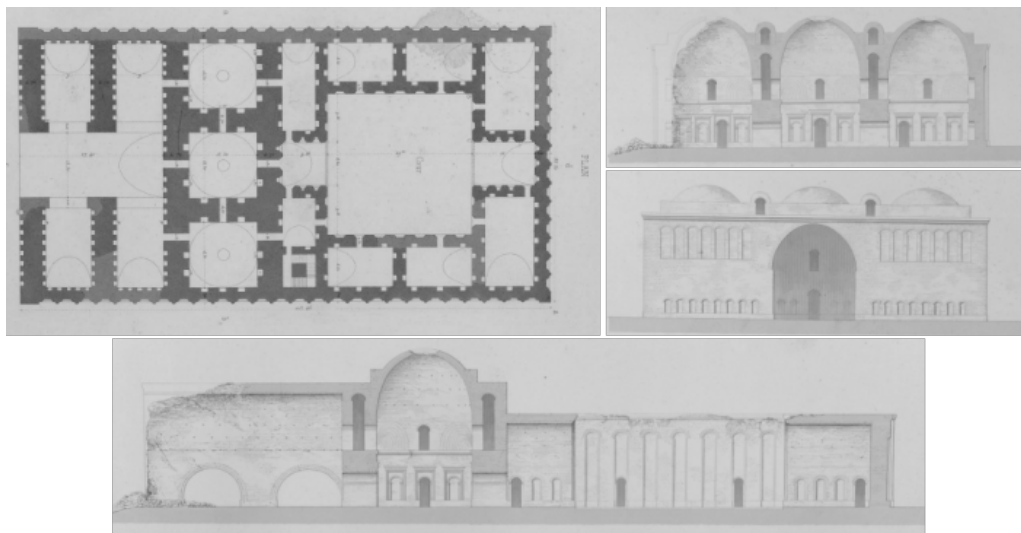


Figure 5. Firouzabad palace (Flandin–Coste 1851)

George Rawlinson (1812–1902) indicates that one of the main features of Sasanian buildings is square chambers that are covered with domes that are circular at their base and elliptical in section, and they rest on unusual pendentives, not on drums (Rawlinson 2005). Rawlinson was



one of the first researchers to notice the uncommon characteristics of pendentives in Sasanian architecture; these elements were eventually referred as squinches by other scholars.

The square is converted into a circular shape by building a series of semi-circular arches at the angles of the chamber, each one projecting more into it than the one before it, thus eliminating the corners (Rawlinson 2005). He described the structure of the filposh technique in the square halls of the palace. A cornice ran around the pendentives² as well, either above or below them or both above and below, and windows were also made through the upper part of the walls between the squinches (Rawlinson 2005). In this building, cornices were built above and below the squinches of three halls. In Rawlinson's book, entitled "The Seven Great Monarchies of the Ancient Eastern World, Vol 7: The Sasanian or New Persian Empire", Flandin and Coste's drawings were used as shown in *Figure 6*.

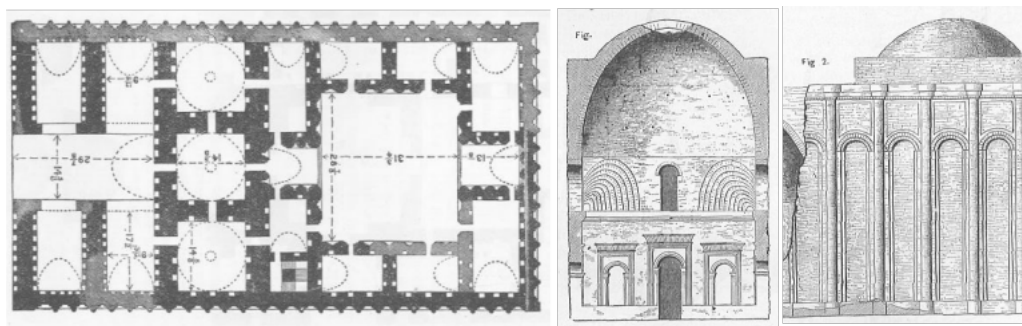


Figure 6. Plan, section, and façade of Ardeshir Palace, by Flandin (Rawlinson n.d.)

In "L'Art antique de la Perse: Achéménides, Parthes, Sassanides", Marcel Dieulafoy illustrates the plan of the structure and a perspective of the great square hall. He referred to the elements beneath the dome as pendentives (Dieulafoy 1885). *Figure 7* demonstrates the cross-section of the dome circumscribed by the walls between squinches.

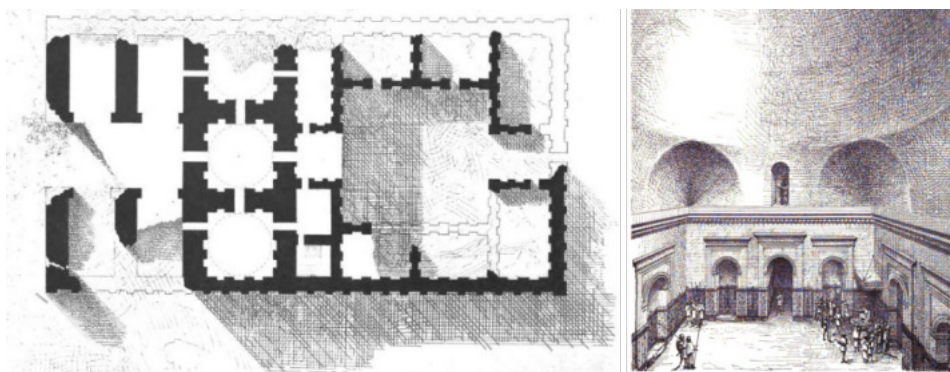


Figure 7. Ardeshir Palace (Dieulafoy 1885), <https://catalog.hathitrust.org/Record/000601500> (Accessed 27 May 2022)

² Rawlinson describes them as pendentives of a curious character, but these are squinches.

Choisy illustrates in his book “Histoire de l’architecture” a section perspective of this building. The structure’s plan is presented in the book “Architecture East and West” by Richard Phené Spiers and F.S.A Friiba. *Figure 8* displays illustrations in both sources, which are based on the drawing by Flandin and Coste.

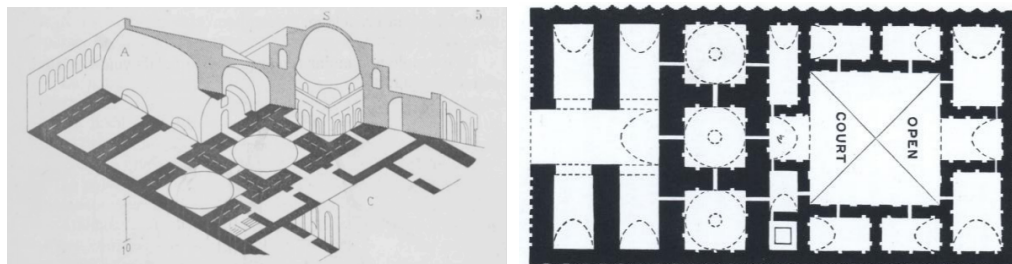


Figure 8. A section perspective (left) (Choisy 1899. 143), plan (right) (Phené Spiers–Friiba 1905)

The Persians were the first to build circular domes with four angular corbelled semi-domes³ over square plan spaces, according to John Mansbridge’s book “Historia Gráfica De La Arquitectura” (Mansbridge 1977. 28). In *Figure 9*, the dome’s cross-section is tangential to four of the square space’s walls in the chambers.

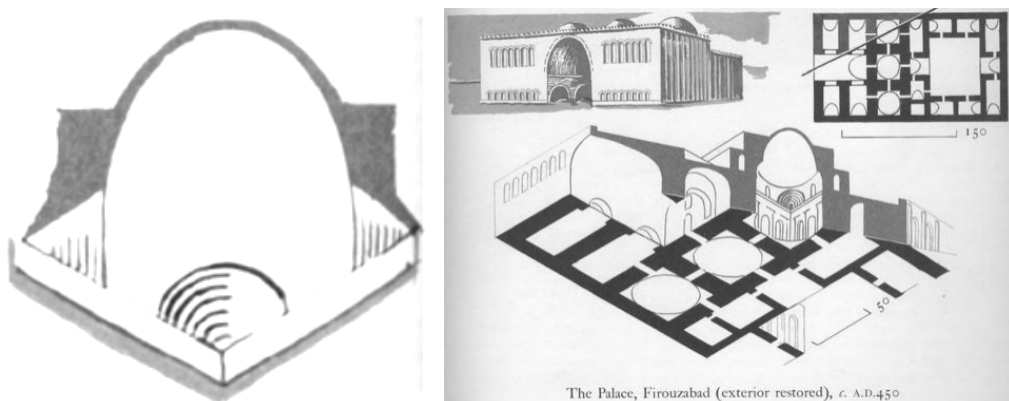


Figure 9. Squinches in corners (left), Firouzabad palace (right) (Mansbridge 1999)

Hans Hugi represents the plan of this building with oval sections of the domes in three halls (Hugi 1977). Although this is the only design that shows the domes have an oval cross-section, the rectangular spaces circumscribe them, as shown in *Figure 10*.

³ trompas

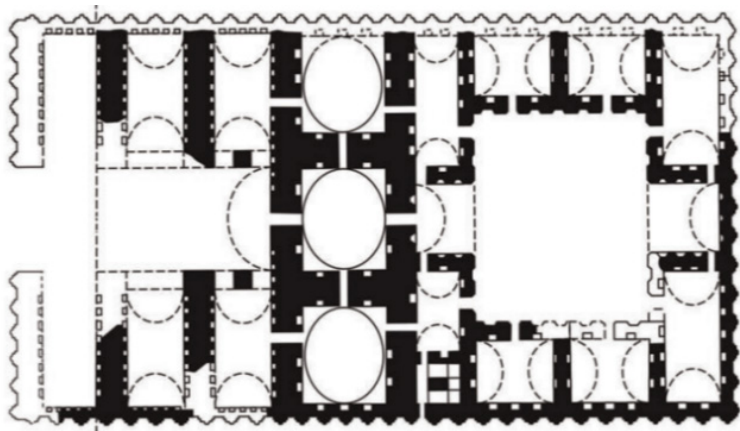


Figure 10. Plan of the Ardeshir palace (Hugi 1977)

The squinch in the palace is described by Elkhateeb as a niche with a half-dome that is formed by the intersection of the corner block and the positive form of the niche with its half-dome (Elkhateeb 2012. 160). As it is demonstrated in Figure 11, the transition zone served as a circular base for placing the dome, and four walls of the cube circumscribed the dome’s interior cross-section.

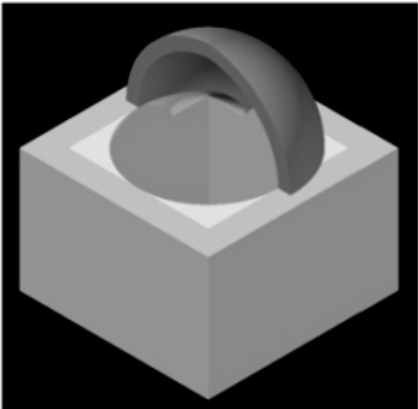


Figure 11. The transition zone in the palace of Ardeshir (Elkhateeb 2012. 160)

B: A CIRCLE INTERSECTS A SQUARE

Ernst Herzfeld was the first researcher to demonstrate that the diameter of the dome’s cross-section of the hall of Ardeshir Palace is larger than the side of the hall’s square plan. As seen in Figure 12, a portion of the dome’s cross-section rests directly on the walls between squinches, while the remainder rests on the rest of the transition zone.



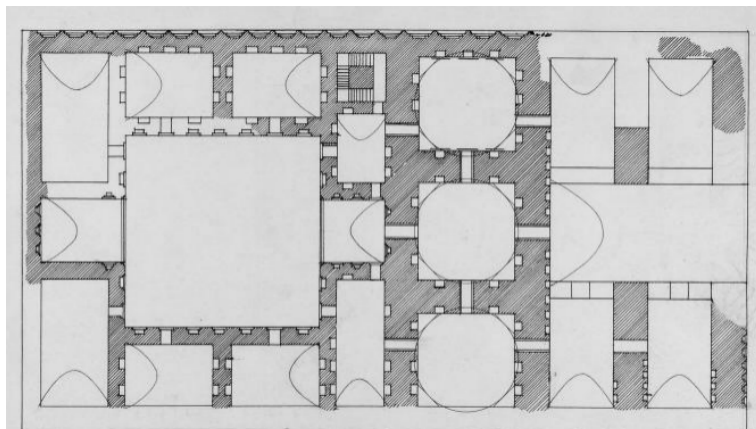


Figure 12. Unfinished ground plan (by Ernst Herzfeld 1934),
<https://sova.si.edu/details/FSA.A.06?s=144&n=12&t=D&q=Plans+%28drawings%29&i=146#ref24782>
 (Accessed 27 May 2022)

The most recent illustration of the square hall in the palace was drawn by Gholamhossein Memarian and Hadi Safaeipour in the book “Memari Irani: Niyaresh” (Memarian–Safaeipour 2018. 394). Figure 13 displays that eight frames are placed on top of the walls and the squinch’s last arch is situated in the frame at each corner. In other words, the square plan was transformed into an octagonal shape, and a dome was placed on top of it. Even though this type of transition zone is common in Iranian-Islamic architecture, it was not used in this Sasanian structure. It is important to point out that according to the authors, filoposh in Sasanian buildings is not pointed, and the octagonal cross-section beneath the dome is yet unformed (Memarian–Safaeipour 2018. 399). Therefore, the theoretical argument and the 3D modelling of this hall’s transition zone do not support each other in this book. In addition, the dome’s diameter is slightly larger than the square plan, and the four little walls between squinches support a portion of the dome.

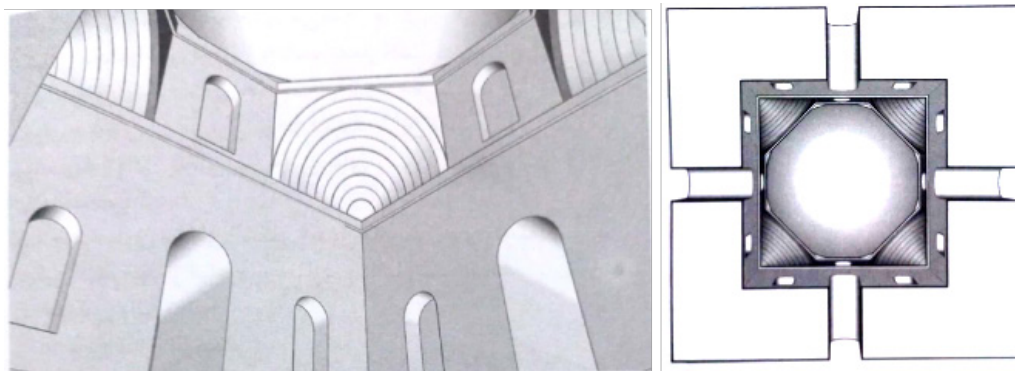


Figure 13. The transition zone in a hall, Ardeshir Palace (Memarian–Safaeipour 2018. 394)

Table 1 summarizes the two main hypotheses for the geometry of the transition zone in the square halls of the Ardeshir palace. According to most scholars’ drawings, the square plan circumscribes the circle section of the dome, and the interior layer of the dome is placed on top of the squinches and the walls between the squinches. The second idea is that the dome’s cross-section diameter is larger than the square side, and the dome’s base part intersects the square chamber’s top part, which can be seen in two documents. In Herzfeld’s plan, the last arch of the squinch is tangential to the dome’s base circle, however, Memarian and Safaeipour show that this arch intersects the dome’s cross-section.

Table 1. The geometry of the transition zone in a square hall of Ardeshir palace, by authors

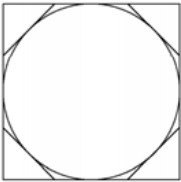
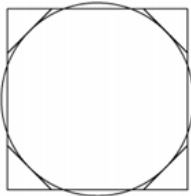
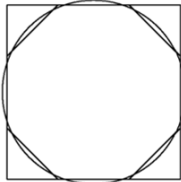
Transition zone	Scholars	Geometry
A square circumscribes a circle	Flandin and Coste, Rawlinson, Pope, Dieulafoy, Choisy, Phené Spiers and Friba, Mansbridge, Hugi ⁴ , Elkhateeb	
A circle intersects a square	Herzfeld	
	Memarian and Safaeipour	

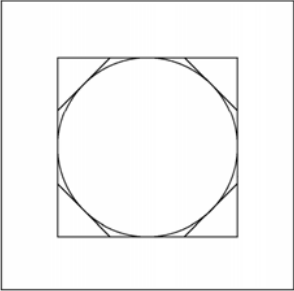
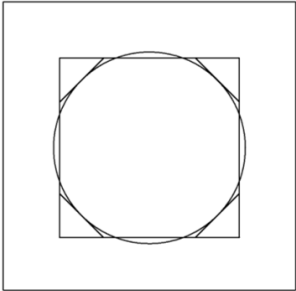
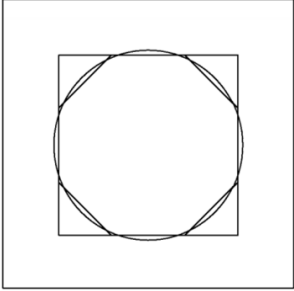
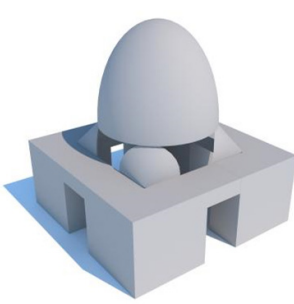
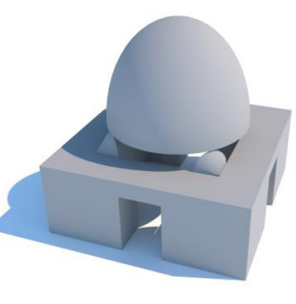
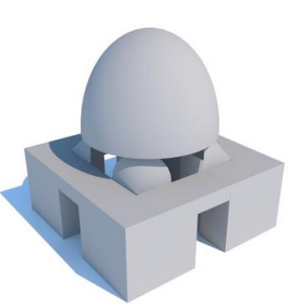
Table 2 presents the 3D models of the hypotheses. As seen in the models of the second hypothesis, there is a formal issue because the base layer of the dome intersects the walls between squinches. Therefore, this hypothesis is rejected.

There are eight small voids between the dome, four squinches, and walls between the squinches, as shown in Figure 14, the first hypothesis’ plan and 3D model. The question that has arisen here is how these gaps in the transition zone were filled.

⁴ In his drawing, the oval shape is surrounded by a rectangular shape.



Table 2. 3D models and plans of the transition zone, by authors

The geometry of the transition zone		
A square circumscribes a circle	A circle intersects a square	
		
		

Except for Elkhateeb, none of the researchers have defined the form of this filling in their drawings. Elkhateeb's model demonstrates that there are two small pendentives in each corner for filling these vacant spaces. *Figure 15* shows that constructing eight pendentives between squinches and vertical walls between them is one option for completing this transition zone, while building near curved walls between squinches to provide a circular base for the dome is another. A scan under the dome of this palace's hall will be required to determine the technique employed for filling these voids, which will be done in the next research.

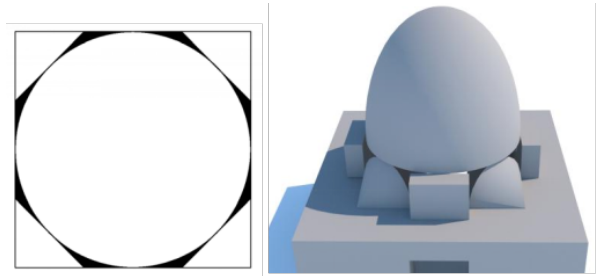


Figure 14. Eight voids in the transition zone, by authors



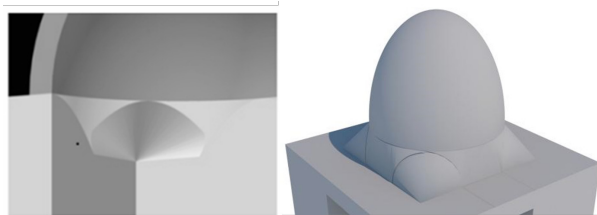


Figure 15. Two pendentives and the squinch (left) (Elkhateeb 2012. 160), curved walls between squinches (right), by authors

CONCLUSION

In the three halls of the palace of Ardeshir, domes with ovoid shapes were built above square-plan chambers. Four filposh, a type of squinch, were built at the hall's upper angles to transform the quadrangular chamber into a circular one as a base for the dome. There are two main hypotheses about the geometry of the transition zone in these halls based on drawings of this palace from the nineteenth century. As a result of this research, the transition zone's geometry in these halls is a square that circumscribes the dome's circular cross-section, and the squinches' edge lines are tangent to this circle.

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A kupola és a kupoladob geometriájának vizsgálata az Ardesir palotában

ÖSSZEFOGLALÓ

Iránban a négyzet alakú tér kupolával való lefedéséhez egy speciális megoldást fejlesztettek ki. Ez az ún. filposh, a sarokterek egy fajtája, amelyet először a szászánida építészetben alkalmaztak. Ez nem más, mint egy kúpos boltozat, amelyet – hasonlóan a csegelyhez – a kupoladob sarkaiban építettek a kupola erőinek és súlyának átvitelére. Ez a technika az ardeshiri szászánida palota három termében látható. Ebben a cikkben az Ardeshir palota gömbkupola és a négyzet alakú tartófalak közötti átmeneti zóna geometriáját vizsgáltuk meg. A történeti források segítségével megvizsgáltuk a palota főbb rajzait a 19. századtól napjainkig, és az átmeneti zóna geometriájára vonatkozó két hipotézist modelleztünk és értékeltünk.

KULCSSZAVAK

Filposh, kupoladob, csegely, Ardeshir palota, Irán

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