Feasibility Study of Existence of a Dome over the Cruciform Palace of Bishapur in Sasanian Times

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Abstract

Problem statement: Some architectural and artistic monuments have been preserved from the city of Bishapur, which was founded in the early Sasanian era by Shapur I. One of them is the remains of a building called the Cruciform Palace. The cruciform plan of the construction is surrounded by huge piers of stone and gypsum, about six meters thick, and its central square is over twenty-two meters long. There are currently no signs of ceiling or roof in situ.

Hypothesis: The previous theories about the possible ceiling form of the Cruciform Palace of Bishapur are not based on documentation. The imagined dome over the central square of the Cruciform Plan would be the largest stone dome of that period in Iran. The existence of a dome above this building and its compliance with the conventional dome form of Sasanian architecture is the hypothesis of this research.

Research objective: The purpose of this research is to find indications that demonstrate the possibility of the existence of the dome and then illustrate the possible authentic form of its structure based on the reliable evidences.

Research Method: To achieve these goals, a comparative study method was utilized and the samples that were similar in structure, architecture, and historical style were studied. Their dimensions and proportions were examined to obtain a model for the size of piers and spans in the Sasanian domes.

Conclusion: According to the obtained results, the thickness for piers of the palace is consistent with the average size of the selected samples of the Four-Arches constructions in Iran and potentially confirms the existence of a dome over the square section of the cruciform plan. About the height of the dome, the range of results is various and the hypothetical height can be estimated based on the mean measurements.

Keywords: Sasanian Architecture, Dome, Virtual Re-Creating, Cruciform Palace, Ceremonial Hall.

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Introduction and statement of problem
The Sasanian dynasty began in Iran with the defeat of the Parthians in 224 A.D. (Daryaee, 2014). The urban remains and architectural relics of the Sasanian period are significantly more than the works of the five-century Parthian period that ruled the land of Iran, and the Sasanian kings have been recognized as the founders of many Iranian cities (Karimian, 2010). This is more pronounced in the time of the two first kings, Ardeshir and Shapur. Their newfound cities are concentrated in the southwestern part of the country, between the southern slopes of the Zagros and the northern margin of the Persian Gulf, extending further into the Mesopotamian region. Shapur followed his father’s manner in establishing new cities after coronation in 241 A.D. (Pigulevskaiā, 1963). Of all the cities related to him, Bishapur was his favorite one (Ghirshman, 1971). The city was at the crossroad of two major ancient routs, one connecting the city of Gur with Ctesiphon, and the other between northern cities such as Istakhr, the ancestral home of the Sasanian kings and the Persian Gulf. The ruin of Bishapur which is currently between the cities of Kazeroon and Qaemiyah is in the west of Fars province. The city is built at the outlet of a gorge and on the southern edge of a river. There are a wide variety of religious, military and memorial monuments and also royal residences, some of which include rock reliefs, memorial pillars, statues, fire temple, water temple, military fort and palaces. What sets Bishapur apart in Iranian urban development is the use of some non-Iranian architectural elements, such as Corinthian style Capitals and mosaic floorings. The use of these elements of Roman art was influenced by Shapur’s conquest of Antioch (Canepa, 2017), which, of course, was designed to create a symbol of the greatness and splendor of Shapur in order to compete with Antioch (Sarfaraz & Teymouri, 2007).

Among the complex of royal residences in Bishapur, the remains of a huge structure attract attention. The central part of its plan consists of the intersection of a square and a cross, which is surrounded by a corridor. This building that is called the Cruciform Palace or Ceremonial Hall (Mehryar, 1999), is located in the vicinity of Anahitha Temple, Mosaic Iwan and Mosaic Court (Fig. 1). The building is severely damaged and only evidences of the roof can be distinguished in the northeast corridor. One of the features of this structure is the thickness of its walls extend for about 6 meters. This is one of the signs that reinforce the idea of a dome on the square central section with a span of 22.8m. The interior wall surfaces contain 64 niches with plaster decorations. The palace was discovered during archaeological excavations that began in 1936 (Ghirshman, 1938). The large volume of ancient hill that covered the structure attracted the attention of Ghirshman and Salles who worked for the Louvre (Ghirshman, 1956). The remains of plasters were discovered during the archaeological excavations, and they transferred the least damaged parts to the Louvre and reconstructed a specimen of the niche. The rest of these ornaments were exposed to erosion and were severely damaged. In recent years, conservation operations have been carried out on these remains.

The original shape of the palace is not recognizable at first glance, and this is a fundamental problem. What a visitor sees in the interior of this ancient structure is an open yard with a cruciform plan that has four doorways and its interior surfaces contain several damaged niches. The intense destruction of this monument in an obscure date makes it impossible for an untrained observer to have an idea of a huge dome on the remains. The few pieces of plasters that remain in some parts do not present the beauty of the niches in their original form, while plaster
decorations could enhance the sense of being in an interior space. There is no consensus on the existence and type of roof, which could have been the largest stone dome in Iran. The size of the span makes it difficult to imagine a dome on it, so the cover of the central part of the building is sometimes questioned (Fig. 2). The purpose of this article is first to find the signs that can prove the existence of a dome cover on this cruciform plan. Experts who agree on the dome structure at this location have depicted different drawings of its type and shape, largely based on the personal experiences. The next goal of this research is to find indications that illustrate the original form of the palace structure based on the sound evidences. In other words, understanding the type of vault or dome that covers this space is the key question. To answer this question, it is necessary to take a look at these kinds of structures in the same historical period that they are similar in map and contain identical materials. This research seeks to find a hypothesis that is consistent with the architectural style of this historical period in this part of the world. Sasanian architectural style is a unique type for the construction of a dome made of stone and gypsum. How valid could a
hypothetical form be? Despite the fact that the formation of a dome on the four piers in Sasanian architecture uses a nearly identical style, there are differences in their proportions in the case studies. Since no visible signs of squinches, pendentives or springer of arches are visible in the area, its exact shape cannot be determined; however, its general form can be estimated.

What can be added to complement the research hypothesis is that the Cruciform Palace had a dome that complied with the other domes of the contemporaneous Four-Arches buildings. Due to the oval form of the most arches in Sasanian architecture, the hypothesis of existence a dome with oval cross section comes to mind. If such a hypothesis is proved, the height of the palace dome from its base, unlike the half sphere domes, would be more than half of its span in plan.

Theoretical foundations and background research
James Justinian Morier visited Bishapur in 1808 and 1809. His journey reports are the first documentation by Western researchers to describe this ancient site (Morier, 1818). Unfortunately, the Cruciform Palace was buried beneath the mound during his visit, and this was not changed during Rice’s visit in 1931. Talbot Rice published his report 4 years later (Rice, 1935), which drew the Louvre’s attention to archaeological excavations. In 1935, the fieldwork requirements were laid out by George Salles, who was in charge by the Louvre Museum’s Asian Art department. The excavations were carried out between 1938 and 1941 by Roman Ghirshman (Ghirshman, 1956). He succeeded in identifying an important part of the Sasanian palaces in Bishapur. Ghirshman published the results of his work in some articles and two books. Reviewing his findings and writings and local documentation, revealed that he did not pursue a specific conservation plan in the area and believed only in collecting and transmitting artifacts. Some immovable objects, such as plaster ornamentation and mosaic flooring, were not exceptional, and two important examples were transferred to the Louvre in France, which included a plaster niche and some facial images made with mosaics.

During his excavations at the Cruciform Palace, 64 niches were discovered (Ghirshman, 1938). Comparison of the current situation and photos of excavation operations is the best evidence that conservation and restoration could be effective in preserving gypsum decorations. What are nowadays found on the site are 64 cavities on the interior surfaces that had been originally niches with decorations. There are three niches on each segment, but there are four niches on the sides of the entrances, with two niches on each side of the doorways (Fig. 3). The average height level of the niches is 110cm above the ground and their width is between 72 and 75cm and the...
distance between them is 115 to 119cm. The plan shape of the niches is parabolic and has a depth between 44 and 45cm. Its inner surface consists of a 150cm high cylinder and a spherical ceiling, of which there is no indication except the sample in Louvre. The height of the reconstructed arch is 350cm high, probably based on evidence that no longer exists. The plaster half sphere ceiling was installed under the arch (Fig. 4). The plaster decorations seem to have been better preserved before the archaeological excavations, based on the figures that Ghirshman published in his articles (ibid). In the 64 niches of the palace, only small fragments of plaster are visible in situ that are damaged by natural erosion and they do not convey the whole plot to the viewer. The niche function might have been to hold a statue, because researchers have found examples of this type of work in the Sasanian site of Hajiabad (Azarnoush, 1994). Although no statues have ever been found inside these cavities, however, fragments of gypsum sculptures have been found in the forms of human figures in the area that could have been located in the niches. The starting point of the archaeological excavations at the palace was the interior part of it, which extended to the outer area (Ghirshman, 1938).

Because of the halt to operations, there are many ambiguities about the exterior part of the area. The interior map of the palace is entirely symmetrical in two axes and its main hall is a square measuring 22.80 meters, that the research hypothesis is based on the existence of a dome above it at the time of construction. There is a 6.90 in 8.90m Iwan on each side of the interior square that each contains a doorway at the end. The arched lintel in the northeastern side is the only remaining specimen among the four doorways. The elevation below the lintel arch to the gypsum floor is 5.5 meters. The spans of the doorways are equal to an average of 1.70 meters.

Although there is no sign of the ceiling, these decorations induce the characteristics of an interior space. The high thickness of the piers is also effective in reinforcing the dome probability hypothesis but requires more precise reasons, so that structural proofing and comparative studies will be considered to prove or disprove the dome hypothesis.

Based on the background information, it can be said that the theoretical foundations of this research are based on the existence and quality of domes covering the Four-Arches construction of the Sasanian era. The first monuments attributed to the Sasanian began with the large stone domes that showed kind of historical support in earlier periods, but no trace of them has remained. The most prominent surviving examples of these domes, which were built before Cruciform Palace of Bishapur, are the domes of the Firuz-Abad Castle and the Ardezhir Palace. The Sasanian architects’ desire for covering the main square plan spaces led to the construction of several domed buildings used to cover many of the Fire Temples. The probable dome of the Cruciform Palace had not been the first stone dome of the Sasanian period, but it had been the largest one.
Gypsum and uncut stones had been the main construction material of the Cruciform Palace. The stones were brought from the adjacent mountains (Rezaie & Ahmadi, 2017) and were placed in mortar without any particular order of arrangement. It seems that the outer lines of the piers were initially shaped like closed walls, which acted as molds for casting stones and mortar, resulting in large piers consisting of a combination of dense stone and gypsum. What attracts the attention at first glance is the thickness of the piers of this building. An average wall width of 585cm can be built to hold a heavy roof. On the other hand, the width of the span casts doubt on the existence of a roof over this space because there is no record of a Sasanian dome made of stone and gypsum with a diameter of 22.80 meters. A comparative study was used to reach the conclusion about the ambiguities raised. There is no sample that meets the structural dimension requirements of the study sample in Sasanian architecture, so other common points such as architectural form, historical period, materials and structural properties were considered. To achieve a criterion for the architectural form of the palace, the building was carefully documented by photogrammetric processing. The investigation of the ground plan shows that the basis of its structure is a form of Sasanian Four-Arches construction, which due to its large dimensions has found its own proportions. The Four-Arches structure had been a common ceiling system during the Sasanian period. It rests on four piers at the corners of a square plan, each with an arch attached to the side pier (Huff & O’Kane, 1990). Sasanian architects used squinches to convert
the square base to a circle, which was an arched element over the interior corner of the room to support a dome (Creswell 1914; Wright, 2009). So, those samples of Four-Arches constructions were selected that followed this form and were made of stone and gypsum during the Sasanian period (Fig. 5). The selection of the samples was based on the scattering throughout the country and structural independence on surrounding elements such as corridors. On the other hand, those were chosen that have evidences of domes to achieve information about the structural system of Four-Arches constructions. The selected Four-Arches buildings are Nakhlak, Konar-Siah, Newis, Tole-Jangi, Sarabe-Murt, Separu, Niasar, Khorram-Dasht, Shamshirbor, Bazeh-Hur and Jarreh. As already mentioned, what makes the existence of a dome in the Cruciform Palace structurally possible is the thickness of its piers, so the proportion between the width of the spans and the thickness of the piers are of significant importance. The parameters considered in this comparative study are the overall width of the structure and their proportions in the central square, so that a probable order can be found. The height of the springer level of domes has also been measured in order to find a possible logical relationship between the dimensions of the inner square and the height of the dome (Table 1 & Fig. 6).

Discussion

According to the results, the ratio between the outer dimensions of the square of the Four-Arches constructions and the interior spans on which the domes were built are between 1.96 and 1.53 with an average of 1.56. Interestingly, despite the much larger dimensions of the Cruciform Palace of Bishapur than the other Four-Arches buildings, this proportion is 1.51, which is very close to the average of the study samples. Therefore, the thickness of the piers is not inconsistent with the possibility of a dome like other Sasanian Four-Arches structures. In other words, based on the dimensions of the Four-Arches in Sasanian architecture, calculated for a construction of a dome above them, the piers thickness of the Palace of Bishapur could be suitable to support a dome. However, the spans of the four Iwans are considered smaller than the usual, which was a factor in reinforcing the structure.

The same method was used to estimate the height of the dome. For this purpose, the ratio between the height of the domes springers and their spans were calculated, which the lowest value was 0.77 and the highest value was 1.16 with the average rate of 0.98. However, this proportion cannot definitely be considered for the Cruciform Palace because the height level of the domes is highly correlated with their spans. For example, the dome height level is much lower than the average of the other samples in Jarreh, the closest case study to the Cruciform Palace. In other words, if it is intended to provide an average elevation, the dome of Cruciform Palace should begin at a height of more than 22m; however, the height of
Table 1. A comparative study of a number of Sasanian Four-Arches. The proportions between interior spaces, outer dimensions and the height of the springer of domes are considered. Source: authors.

<table>
<thead>
<tr>
<th>Name</th>
<th>a(cm)</th>
<th>b(cm)</th>
<th>c(cm)</th>
<th>a / b</th>
<th>c / b</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nakhlak</td>
<td>902</td>
<td>460</td>
<td>456</td>
<td>1.96</td>
<td>0.99</td>
</tr>
<tr>
<td>Konar-Siah</td>
<td>810</td>
<td>506</td>
<td>460</td>
<td>1.60</td>
<td>0.91</td>
</tr>
<tr>
<td>Newis</td>
<td>900</td>
<td>510</td>
<td>540</td>
<td>1.77</td>
<td>1.06</td>
</tr>
<tr>
<td>Tole Jangi</td>
<td>858</td>
<td>534</td>
<td>535</td>
<td>1.61</td>
<td>1.00</td>
</tr>
<tr>
<td>Sarabe Murt</td>
<td>989</td>
<td>536</td>
<td>...</td>
<td>1.85</td>
<td>...</td>
</tr>
<tr>
<td>Separoo</td>
<td>941</td>
<td>616</td>
<td>590</td>
<td>1.53</td>
<td>0.96</td>
</tr>
<tr>
<td>Niasar</td>
<td>1123</td>
<td>622</td>
<td>705</td>
<td>1.81</td>
<td>1.13</td>
</tr>
<tr>
<td>Khorram Dasht</td>
<td>1030</td>
<td>645</td>
<td>750</td>
<td>1.60</td>
<td>1.16</td>
</tr>
<tr>
<td>Shamshir Bor</td>
<td>1023</td>
<td>650</td>
<td>508</td>
<td>1.57</td>
<td>0.78</td>
</tr>
<tr>
<td>Bazeh Hur</td>
<td>1377</td>
<td>704</td>
<td>738</td>
<td>1.96</td>
<td>1.05</td>
</tr>
<tr>
<td>Jarreh</td>
<td>1494</td>
<td>893</td>
<td>689</td>
<td>1.67</td>
<td>0.77</td>
</tr>
<tr>
<td>Average</td>
<td>948</td>
<td>607</td>
<td>597</td>
<td>1.56</td>
<td>0.98</td>
</tr>
<tr>
<td>Bishapur</td>
<td>3450</td>
<td>2280</td>
<td>1.51</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Fig. 6. The Guide of Table 1

the dome of Jarreh Fire Temple, which spans 8.93 meters, is only 6.89 meters.

Attempting to imagine the original form of work is a topic that captures the minds of the experts. Ghirshman and his team also had imagined the original shape of the dome and its decoration and they also had made a small model based on it (Ghirshman, 1962). The problem with his reconstruction is that the dome structure was adapted from Roman architecture rather than
adhering to Sasanian architecture. In their design, the curvature of the dome starts from the springer of the arches and is supported by pendentives (Fig. 7), while different technics were used in Iranian domes during the Sasanian era.

The Sasanian architect first completed the four arches and then the spandrels on both sides of the arch were constructed vertically. A square support was thus obtained, which still shows no sign of the curvature of the dome. At this point, four squinches were built at the corners of the square and the curvature of the dome would begin (Fig. 8). Almost all the domes of the Sasanian era, which their original structural traces are still preserved, contain the same components in the same way with minor differences. This type of dome construction makes it taller than those used pendentives for building the corners. However, as shown in the table, there is no exact order in the proportion between the height and the width of the spans in these Sasanian buildings. In the Four-Arches of Jarreh, which is not so distant from Bishapur, the height of the dome is relatively low, though it has a rather wide span. Therefore, the exact height of Bishapur Dome cannot be determined on the basis of this evidence; However, according to the scale it appears to be less than the average of the other Four-Arches.

On the basis of the above, the height of the dome and its squinches in the Palace of Bishapur can only be estimated approximately (Fig. 9).

Conclusion

The plaster ornamentation of the niches in the Cruciform Palace or Ceremonial Hall, which adorned the interiors, increases the possibility of building to be covered; however, there was a need for other physical foundations to provide different options for the type of covering. Based on the findings of this study, which are based on the physical examination of the palace and the comparative studies with its contemporaneous Four-Arches, it was found that, according to the first part of the research hypothesis, the structure could potentially have had a dome cover in its original form. The unique dome structures of the Sasanian era, based on the creation of four squinches on a square formed by the construction of four arches on four piers, are applicable here, and the thickness of the piers is proportional to the span, makes it possible to imagine an initial dome. In order to alleviate the structural weakness that could have been caused by the large dome span, the spans of the arches have been considered relatively smaller and the central square sides have been covered with thick stone and gypsum walls. About the height of the arches and the geometry of the dome cross section, which was assumed to be elliptic, no definitive theory-based comment can be made. According to the mean elevation ratio of the studied to their dome spans, a value of about one is obtained, but in the samples with high dome
Fig. 8. Dome construction process based on the Sasanian architecture. Source: authors.
Fig. 9. A cross section of the initial hypothetical shape of the Cruciform Palace of Bishapur. Source: authors.

spacing, the height is usually lower. Therefore, the starting height of the dome of the palace can be equal to its span that is about 22m, but the lower height of the dome is also likely.

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