Sasanian Vaults

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I. Introduction

There is no information available on the history of architecture and construction of vaults in the structure of buildings: however with men leaving the caves and establishing buildings it should have some applications in the past. Among the primitive vaults in the Iranian architecture we can mention the mass grave of Teppe Ahar in Haft Tappeh within the ancient time of the art of the medieval Elam about 1400 B.C. and the temple (Ziggurat) of Choghazanbil in the town of Dor-Antash (12^{th}, 13^{th} centuries B.C.) in Khuzestan province. Meanwhile, a Median fortress has been discovered at the Noushijan valley, near Hamedan which has a fireplace with a veranda and oval and barrel vaults constructed on the basis of technical and mathematical principles (Zomarshidi, 1994: 3-4).

Among the factors affecting the Iranian architecture climatic conditions, weather and existing materials may be mentioned. That is why in ancient Iran barrel and cradle vaults were widely used in the warm and dry areas due to the shortage of wood and availability of cheap brick. In the Parthian age the plan of trilateral verandas, with the central veranda being usually wider than the lateral verandas, and crescent-shaped vaults spread (Girshman, 1971: 26). The Sassanid used vaults and arches for construction and decoration of the buildings so that this method of laying stones in the Sassanid vaults and its oval, semi-circular and crossing plan were passed over to the western or eastern regions who had just converted to Islam (fig.1-1). The wall of these buildings in the valleys of Tigris and Euphrates were made of brick and in the Iranian regions they were made of rubble stones and lime mortar. They were in fact intended to support and keep the horizontal pressure of the vaults. This type of wall served as an important origin of the spread of the construction elements to the extent projections, arches and decorative niches appeared in front of the huge buildings (Girshman, 1971: 290-291).

The Sassanid architecture was founded on the basis of the architecture in the central and eastern dry regions. Houses of these regions are made inwardly[1] which is proper response to the weather dryness, disturbing winds and hit sun. The dome-shaped cover is made of brick and stone pillars and columns made of stone and gypsum more often connected to the walls, also dome-shaped brick vaults over a square structure and establishment of big halls and terraces with barrel (cradle) vaults are evident characteristics of the Sassanid architecture (Nassiri Ansari, 1971: 121-122).

Fig. 1: Map of the Sassanid Empire
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The four-vault structures around the central four-vault whether in simple fireplaces or vestibule fireplaces formed the foundation of the Sassanid fireplaces. The Sassanid transferred the pressure of the load of the ceiling to the pillars by constructing crescent-shaped brick vaults thus making the halls needless of pillars and wooden covers. For instance, Taq-i Kisra in Ctesiphon with a length of 91 meters and a width of 26 meters, with an area as much as half of that of the 100-column hall in the Persepolis and a height as much as twice of that of the Apadana Palace was roofed without any column.

[1] Inward architecture: The Iranian architects organized building components around one or several middle places and isolated the building from the outside world. Only an octagonal structure connected them together.

II. Sassanid Vaults

From architectural point of view, a vault is made through sliding an arc along a straight line that stays vertical on a semi-circular plate. A vault is sometimes called a cradle or a vault (Farshad, 1362: 295-296). Availability of good quality soil in Iran allows it to be used both in the construction materials and other art disciplines. In addition to its abundance and simplicity of preparing raw material, the endurance of the materials made from soil such as tile and brick is another reason of using this material in the Iranian architecture. Mud brick and the brick itself are materials that are easy to make, cheap and are not labor-intensive. That is why most people could use it in construction works. Soil products are more durable than wood and would not wear out like wood. The mechanical resistance of brick is much higher than wood and it supports heavier loads in permanent structures such as bridges, dams and so on. Since Iran was an earthquake-prone territory and its buildings were subject to serious earthquake once every few years, this structural alteration boosted the resistance of the buildings against the quake pressures. In addition to the quake pressures ,the pillars of the buildings sometimes subsided, and the elastic characteristic of the brick buildings compensated for the subsidence by creating tropical cracks whereas if the buildings were stiff and unchangeable ,they were possibly destroyed (Farshad, 1362: 32, 34). Beside the above mentioned characteristics, the mud materials have other characteristics such as insulation against temperature changes, suitability for façade making, easy transportation and prompt construction. Due to these very specifications soil, materials had a wide-spread application in construction operations since the ancient time, and particularly the Sassanid era. In most cases lime grout was poured over the vaults after covering them to achieve a smooth surface. Clay mortar was usually used for covering the cradle and dome-shaped vaults (Zomarshidi, 1994: 77, 81).

It should be noted that stone materials were also used in the buildings of the Sassanid age. Buildings were usually made from stone chips mixed with lime, clay or gypsum mortars. Generally, when Iranians wanted to construct a permanent building, they used stone materials. The bridges and dams of the Sassanid era that were supposed to remain permanently as well as certain giant buildings such as the Firuzabad and Bishapur Palace were built from stone chips. Indeed, the middle part of the walls and rooms of the Sassanid buildings were sometimes filled with stone chips and mortar while the façade was made of shaped stone slabs. Application of lime mortar in the stone buildings, brick works, and the wall coverings in the Sassanid age

continued like the previous (Parthian) era. The cover lime (without sand) was used as mortar in the earlier buildings of this age, at the time of the rule of Ardashir I. Some transformations occurred in the construction techniques and styles at the time of the Shapur I and mortar of sand and lime were widely used ever since. These changes probably took place with the defeat of the Roman Valerian by the Shapur I. After this victory, the Roman prisoners of war who were brought to Iran used the Roman technique and materials including sand and gypsum, in construction of the cities such as the city of Shapur I (Bishapur).

The cradle vaults that were made during the Parthian and Sassanid rules in Iran were generally of two kinds. One was made with the help of formworking usually in a semi-circular shape and the other was built without form working. Taq-i Kisra, Ctesiphon, as one of the most magnificent and perfect Sassanid vaults was made without framework and is considered the biggest vault in the world made of non-reinforced construction materials. The vault's span is 25 meters and its height is about 34 meters. The vaults which were made with the help of annular method during the Sassanid dynasty are in the oval and parabolic shapes with a complete form static point of view. However, these considerations do not seem to be involved directly in the geometrical shape by the builders. It was most probably a construction method that resulted in the oval or parabolic shapes. One of the major issues which were involved in the form of the cradle vaults and affected their mechanical behavior was that the driving force, vault and vertical force of the vault should have been borne and neutralized with the help of thick support and walls. That is why establishment of a balance and firmness of the vault always required the construction of strong and consolidated walls and supports. Any weakening factor such as a hole, door and window in the supporting walls of the arch in either resulted in the destruction of the vault. For this very specific reason, the primary vaults and the corridors that were roofed by the arches mostly lack entrance and side window, thus they were lightless. The issue was resolved in the best possible way by invention of a modern method in the Sassanid age. Ordinary arches with low thickness covered the space between the transversal vaults. The load of these vaults was transferred to the arches instead of walls. Therefore, they could make the walls of the either side thinner of make door and wall in them (Farshad, 1382: 29, 39-40, 297-299). One of the Sassanid buildings that used this method is the Iwan-i Karkha near Susa. We need to refer to certain terminologies about vault and arch before discussing about the characteristics of vaults of the Sassanid era.

The summit of the arch is called “Tuft of the arch” from architectural point of view and a plaster mold by the name of “Toyzeh” is used between the two primary parts of the arch when constructing this arch. Toyzeh, which can be referred to as a type of mold or guide and a primer of a building’s curve is made after determination of the type, size and form of the arch and its drawing on the ground. Then a replica similar to the original arch is built by lime and reed. A plaster strip is made as a result with a relatively good endurance which may not be placed on the two heads of the wall. Its foot is attached to the wall with lime, so that if it is covered with brick and developed, it turns into a desirable arch in the building like a schablone. A big Toyzeh called “Shah Toyzeh” is usually placed in front of the vaults and verandas. This Shah Toyzeh consists of the main Toyzeh and brick whereby after consolidation of the initial Toyzeh by the name of “DOZ”, meaning covert, a “Chipleh” is made under it, that is, brick or mud brick is attached under it in a horizontal and blade form in order to cover the lower part of the Toyzeh. The external cover of the Toyzeh is called "Palaneh"; this combination with brick was aimed at achieving “Tabareh” meaning necessary thickness of the arch and vault so that it could serve as protector of panniers and cradle of the veranda. The series of Shah Toyzeh and its pillars was called “Hoo” or “Khoo” due to its similarity to shoulders and arms. The words mean scapula and shoulder in “Pahlavi” and “Dari” languages. Toyzeh was also used in construction of domes. The dome with Toyzeh was called Tarkin Dome, a dome in which a Tark has been used. Toyzehs are the ribs of the vault that were set up in specific spaces as the main supporters of the cover. The Toyzeh has two pairs in the big arches. That is, a half-arch was set up from each pillar and attached at the apex. Toyzeh was sometimes put under the vault as a formwork and removed after ensuring that the vault would stand without it: however, it often remained inside the work and distances between Toyzehs were filled with different vaults.

The oldest sample of vault and Toyzeh can be seen in the Karkheh Veranda. Different parts of an arch were names as follows. The part which is laid on the wall as the starting point of the arch was named as “Pakar;” the place over it and broke the arc of the semi-circle was called as “Shekargah” and the part over it up to the apex of the arch was named as “Avargah.” The tip of the arch was “Tiz” or “Calcan” (Fig. 1-2). The old masons sometimes called Pakar as “Balanj” and Shokrgah as "Shoulder of the arch". If bricks were laid together from width to make a vault, it would be called “horseshoe vault” or “Zakhm” or “Biz.” If bricks were put together from the narrower side in a vertical form, it would be called “Roman vault”. The third type of vault

making was blade “Chipleh” or “Lapoush” in which bricks were attached together in a horizontal position to act as a horizontal blade and the arc was both decorative and half-carrier (Mirlatifi, 2005: 77-78, 81, 94).

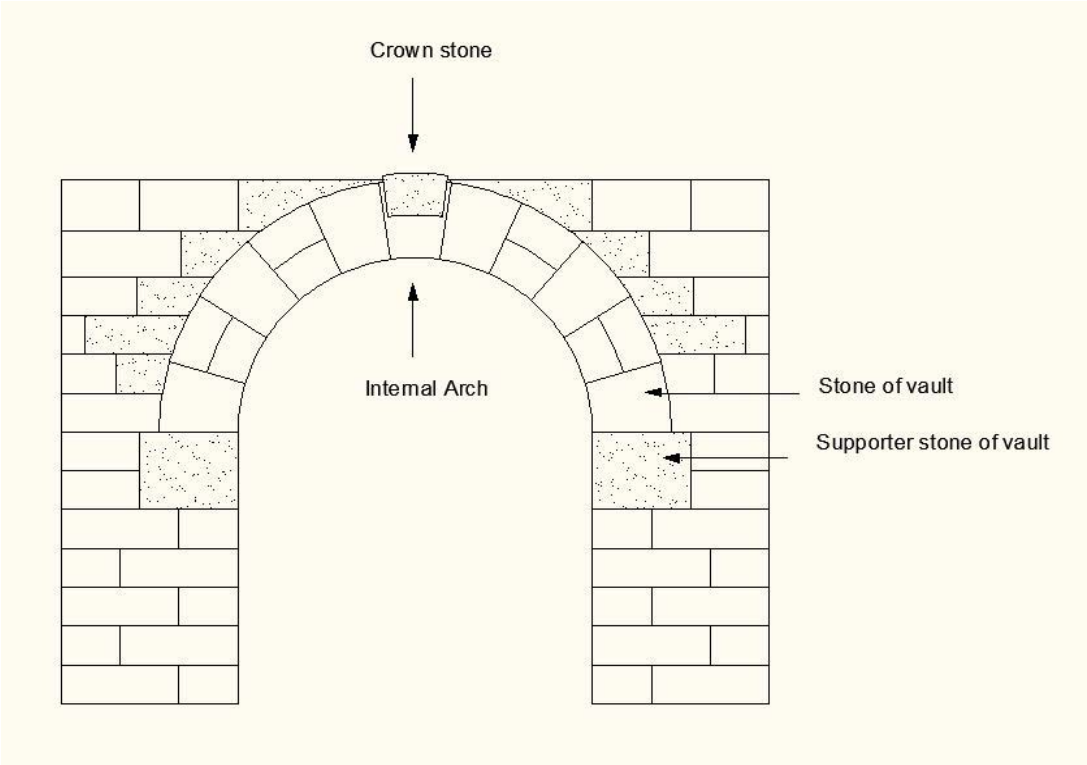

Fig. 1-2: Parts of the vault. Design by the author.

The Sassanid vaults generally included cradle, dome-shaped or conical vaults which facilitated the transition from the square structure under the roof and achievement of the annual plan of the dome. Individual vaults and cradle vaults in the small buildings of the Sassanid era were usually built without using of wooden skeleton. In this method after construction of the supporters, heads of the vaults, namely the diagonal surface on which the vaults should have been laid were prepared. As it was mentioned before method of arch building developed in the Sassanid era. The arches were constructed based on mathematical and geometrical regulations and in view of the tolerance of pressure forces. These arches were mostly circular, oval and “Holouchin” (a line drawn from the end of the small diagonal to the big one forming a 55-degree angle) or like “Chiar” arches (dust arches) and parabolic in shape. Annular arches or the like were used to bear the pressure and as decorative arches in some cases. Decorative arches as their

name shows were among the arches used for decoration of the facades. They were drawn in different shapes (Godard, 1979: 11, 15, pp 31-32).

Ahang or cylindrical (tubular, cradle, Kourehpoosh) vaults are among the famous and ancient vaults in Iran. In order to make this type of vault a starting point was needed. This point was always one side of the underlying square wall. At first a wall (the ending wall between two pillars) was built upwardly which was called “Spar.” Then the arcs of the vaults were drawn on this wall. The Spar wall and the main pillar were then made semi-conically on the straight angles like a spider web, something that was called “Borour Kardan.” The four-section vault was among other types of the vaults which were used in the Sassanid palaces. This vault is in fact the conjunction of two “Ahang” vaults that equally intersect each other and their common point is on a surface. This type of vaults was built on four pillars and columns. Moreover, they were used to make “Kol Afrang” (or “Kolah Farangi”) so that light could also reach the space under the vault. Kolah Farangi or Kol Afrang is a relatively smaller vault built over some vaults and domes. Other types of roofs were also built on four columns or pillars such as “Kolombe” or “Kolombo” and “Khanchepoosh.” Kolombo was a vault which was constructed between four columns or pillars whereby the four corners of the vault were made in an elephant shape. When the vault’s plan shaped like an octagon or a polygon brick were set in concentric circles and finished with a small rise. The apex was sometimes left as a hole for light entry and air escape (Mirlatifi, 2005: 95, 101).

Stone semi-circles were widely used in the ancient monuments in Iran with an application in construction of stone buildings and bridges (Fig. 2-2). Construction of stone arch is much different from the brick arch, with the only commonality of drawing rules and action and reaction of forces. Stone pieces had to be cut like a bow before the arch is constructed. If big pieces of stones were to be used for making the stone arch the internal and external curve should also have been cut however, small pieces did not need cutting. In any case the pieces of stones should have been cut in an integrated form with the same size because uneven and multi-sized stones created a driving line under the pressure forces (Zomarshidi, 1994:121-122). In this arch the Tizeh stone was higher than then ordinary pieces in order to ensure the tightening of the two shoulders. This piece of stone was called “crown stone.” In the earlier buildings dating back to the rule of the Sassanid Ardashir I (Ardashir I Palace, Qal’a-yi Dukhtar) barrel, cradle and horseshoe vaults were mostly used (Fig. 2-3, 2-4, 2-5).

Fig. 2-2. Application of semi-circle arch in Firuzabad Bridge, (Photo by the author).

Fig. 2-3. Barrel vault, cradle vault, horseshoe vault and arch Qal'a-yi Dukhtar, Firuzabad (3rd century AD), (Photo by the author).

Fig. 2-4. Various vaults and arches in Ardashir I, Palace (3rd century AD.), Barrel vault, Horseshoe arch, Firuzabad, Photo by the author.

Fig. 2-5. Arch, horseshoe arch in Ardashir I, Palace, Firuzabad, Photo by the author.

In the earlier buildings of this era, traditional and native techniques were employed however at the time of Shapur I, some developments took place in the construction techniques and styles. These developments probably occurred with the defeat of the Roman Valerian by Shapur I. After this victory, the Roman prisoners of war were brought to Iran (Farshad, 1982: 39-40). With their help a dam (the Keiser Dam) for water storage was built near Shushtar and the Roman skills, construction materials and engineers were exploited for construction of Shapur I palace. The Romans were also employed in construction of (Iran-Khuzeh- Shapur) at Shush during the rule of Shapur II, and Veh-Antiokh-Khusraw or Romgan which was part of the city of Ctesiphon during the rule of Khusraw I (Anushirvan) (Garsoian, 1983, p 79). Most of the vaults of the buildings in Bishapur were semi-circular and made in the Roman style. A total of 64 fine niches as decoration were built in the hall of the Bishapur Palace which had decorative plaster (Nassiri Ansari, 1971: 143). The arches and niches were built with Holouchin arcs. The roof of the daises served as the starting point of the dome, built in the form of “Ahang” or cylinder (Mirlatifi, 1384: 62). Other types of the vaults used in the buildings of this city were barrel vault of other monuments and cradle vault over the corridors of the “Anahita Temple” (Figs. 2-7, 2-8).

Fig. 2-6a. Bishapur Hall, Shapur I, Kazerun, 3rd century A.D Photo by the author.

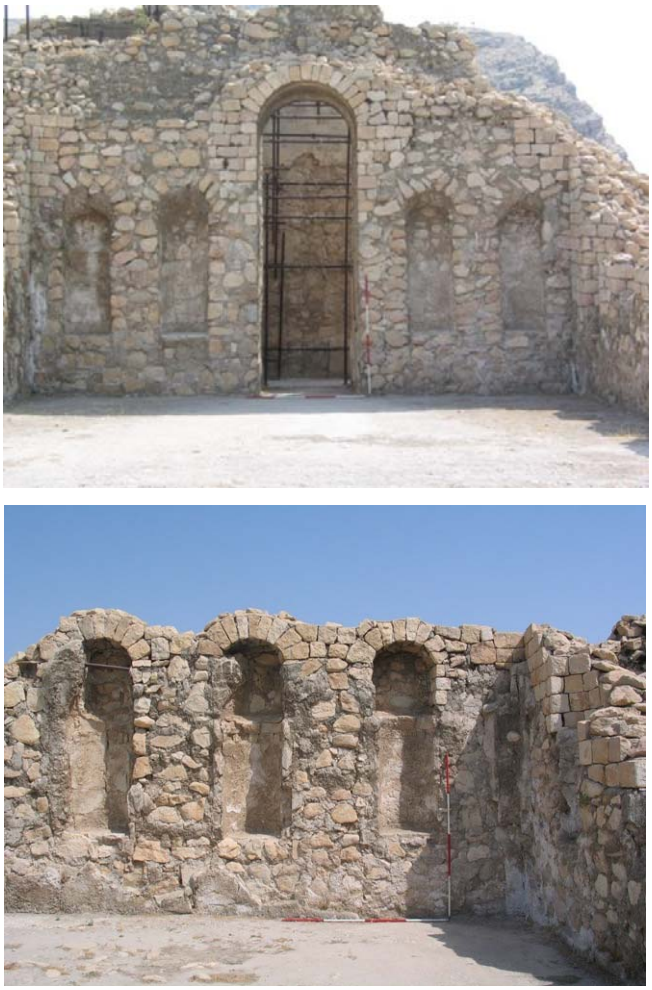

Fig. 2-6b. Bishapur Hall, Shapur I, Kazerun, 3rd century A.D Photo by the author.

Fig. 2-7. Semi-circular vault and arch on the wall of the city of Bishapur , Photo by the author.

Fig.2-8. Cradle vault in Anahita Temple, Photo by the author.

The Iranians learned a lot on urban engineering and designing, road building, military strongholds and mosaic arrays from the Romans. Architects sometimes came to Iran to help with implementation of these designs: however, there were prisoners of war or people of the conquered Roman cities who were employed in construction of the urban buildings, bridges, palaces and so on (Garsoian, 1983: 78). Meanwhile, during the Byzantine Empire skill workers who became unemployed and homeless as a result of the government monopoly under the rule of Justinian's migrated voluntarily to Iran in search of work. The Byzantine emperor too, dispatched other craftsmen to Iran to work in the Ctesiphon Palace (Garsoian 1983: 685). It is noteworthy that although the bridges of the Sassanid Age were constructed with Roman characteristics, this does not mean that the Sassanid depended only on the skill of the Roman engineers. Vaults were

built based on the mathematical and geometrical principles to the resist the forces. The façade of the buildings of the Sassanid age often had barrel vaults whether those that were made with stone rubbles based on the local and native skills or those that were built with brick in Khuzestan, Iraq or Sistan. Barrel vaults had similar shapes and they differed in terms of construction materials or style of construction. Various ways of vault making show that barrel brick-made vaults were newer than those made from rubbles although Sassanid architects could built the china stone barrel vaults in the form of barrel-cradle vaults if necessary (Reuther, 1983:499, 509).

III. Conclusion

Native or local architecture depends on the regional conditions which themselves follow various factors such as geographical features and environmental characteristics. This architecture comes into existence based on the climatic conditions and existing construction materials. The role and application of vault is of special importance for buildings and different nations and communities have created various styles for various usages. Vaults have been used in thresholds, verandas, domes, decorations of buildings and so on. The Sassanid architects used various versions of oval, circular and horseshoe vaults. The horseshoe vault is seen in the buildings of the Ardashir Palace (Firuzabad), Qal'a-yi Dukhtar and so on. Another type of the vaults which were common in this era was cradle vault for covering the corridors. When Shapur I, detained Valerian, the Roman Empire in 260 A.D., he brought a large number of the Roman workers to his service. That is why the bridges that were built in this age were similar to the Roman bridges to a large extent. Among the Roman prisoners there were engineers and craftsmen. In addition to these Roman craftsmen who were the prisoners of war, a considerable number of other craftsmen immigrated to Iran due to their low wages in their respective countries. The reason was that Iran attached much importance to them and gave them good wages. Although Iranian enjoyed the engineering skills of the Romans they did not use their designs and architectural elements on full scale. The Sassanid architects created developments in their work to make them suitable for the Iranian taste. The monuments remained in Bishapur convey the expansion of these techniques. Another reason why the buildings like the Anahita Temple, Shapur Palace and bridges were made from stone is perhaps the abundance of the manpower, suitable peaceful conditions or influence of the engineering principles and skills of the Roman buildings. Vaults have been constructed in these areas more carefully and resemble similar works in Roma in terms of technique. The niches (of

the central hall) were plastered. Within the architecture of this era vaults were not usually laid on the columns directly (with some exceptions indeed) but they generally appeared as half-columns. In some cases vaults were only used as decorative elements. Here the vault appeared as an arch. Execution technique and brick arrangement were among the most important differences between the Sassanid and Roman vaults whereby the Roman (Byzantine) vaults differed from the Sassanid ones in terms of brick (or stone) setting. The Iranian architects used cradle vaults to cover the corridors. Barrel vaults were also used in the main threshold of the building or in the verandas or around the building as a decoration. Annular, Holouchin, Chiar and oval arches were commonly used in buildings such as palaces, castles, bridges and so on. These arches were generally made from raw brick and mortar of mud, straw and stone or lime mortar (with due consideration to the joint). The frontage was often made from mud and straw and plastered with gypsum. Plaster works with wide branch and leaf designs decorated the arches. The vaults of this era were extended and high and belong to the families of annual or oval arches of the Sassanid age.

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