

POL-E-DOKHTAR BRIDGE, GREAT MASONRY STRUCTURE OF THE SASSANID ERA

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Keywords: Iranian bridge Structures, Bridge, Sassanid era, Traditional Structures.

Abstract. *The vast land of Iran is an elevated plateau desert and high mountains. However many permanent and temporary rivers are found in Iran which were the great barriers on the way of travelers. Therefore, road building necessitated the construction of bridges. The pre-Islamic styles of Iranian Bridges draw on 2500 years of architectural development from various.*

Pol-e-dokhtar Bridge is one of the bridges over Sassanid era which is located in the Khoramabad city in western part of Iran. The bridge concerning the measure, size, shape and architectural features are unique in Iran, Asia, and even the whole world.

This paper featuring a description of bridge structural styles, information on traditional bridge materials such as unburnt brick, mortar, mud, lime stone and gypsum, as well as an analysis of Pol-e-dokhtar bridge structure, over the Sassanid era.

The method of research was descriptive-analytical. Conventional methods of data collection such as field research and documentary methods have been used.

This interest and informative text will be of importance to anyone with a technical interest in structural history and presents a general overview of the structural and architectural characteristics of Iranian historical bridges structures and investigates historical buildings of Iran through a structural engineering approach.

1. INTRODUCTION

The Sassanid Empire or Sassanid Persian Empire was the last pre-Islamic Persian Empire, ruled by the Sassanid Dynasty from 224 CE to 651 CE [1]. The Sassanid Empire, during Late Antiquity, is considered to have been one of Persia's/Iran's most important and influential historical periods, and constituted the last great Iranian empire before the Muslim conquest and the adoption of Islam [2].

In many ways, the Sassanid period witnessed the peak of ancient Persian civilization. Iranian architecture displays great variety, both structural and aesthetic, developing gradually and coherently out of earlier traditions and experience [3]. Sassanid critical condition required that the bridge should be considered as other architectural structures to ease the traffic. This need was significantly more in the Khuzestan and West region of Iran where more rivers flew and also because one of Sassanid governmental centers was located in Ctesiphon and other one in the Pool City, therefore a smooth way must connect those two centers to each other [4]. This article reviews history of bridges in Iran, ancient Iranian masonry bridge structural styles, traditional bridge materials, tradition methods of bridge constructing and Shape of piers and hydraulic effect of water on them over Sassanid Era. Furthermore, this paper featuring descriptions of some famous bridges structures through a table. The method of research was descriptive-analytical. Conventional methods of data collection such as field research and documentary methods have been used.

2 HISTORY OF BRIDGES IN IRAN

The vast land of Iran is an elevated plateau desert and high mountains. However many permanent and temporary rivers are found in Iran which were the great barriers on the way of travelers. Therefore, road building necessitated the construction of bridges. The pre-Islamic styles of Iranian Bridges draw on 2500 years of architectural development from various.

Bridges may have existed in the Iranian highlands as monuments of vernacular architecture since prehistoric times; they were probably constructed, as they still are today, of timber girders or even suspended between abutments consisting of piled-up stones [5]. There is no clear information about the history of Iranian bridge constructing, the only source which give us limited but useful information about this mentions that there was bridge on the Karkhe River made by the second king of Abarati Dynasty (1700-1800 BC) to connect his palace to the Susa City [4].

In Sassanid Dynasty, Ardašīr I (a.d. 224-41) was renowned for his irrigation and drainage projects [6]. Bahrām V Gōr (420-38) is reported to have used the building material from churches destroyed during his persecution of Christians in the construction of aqueducts and bridges over canals [7], and Kōsrow I (531-79) to have repaired every bridge of wood or stone that had been damaged during the Mazdakite revolution [6]. After the emperor Valerian's army was defeated and captured by Šāpūr I in 260, Roman prisoners of war were employed for construction work in Kūzestān and had an influence on Iranian civil-engineering techniques that was unparalleled in any other branch of architecture [6].

A group of bridges titled *Pol-e-dokhtar* which means the bridge of daughter. Archaeologists believe that these bridges are presented to the goddess of Venus who is the goddess of water and rain in Zoroastrianism, So that she protects these bridges. Building these bridges was considered as a religious act [4].

These Bridges featured in general:

1. These Bridges are Monuments of Sassanid
 2. They located in especially strategic mountainous areas
 3. Often located in the ancient important ways
 4. Besides these bridges usually there was a fort or castle that protects and controls the traffic.
- Bridges were made in many purposes; they were not only a connecting element. In brief it can be said the ancient bridges were serving following purposes:
1. Providing a road as a means of communication on the bank of a river
 2. To raise the water's level relative to the surrounding fields and irrigating vast agricultural areas about it by making bridge-dams such Shadorvan in Shuhtar
 3. Providing energy to actuate large water –mills
 4. Transferring water to the other side of river
 5. Providing a place of recreation

2.1. Traditional bridge materials

Iranian used different kinds of materials and mortars in bridges. These materials were chosen based on the condition and availability. Furthermore, where the necessity was forcing them to stop the creativity would solve the problem. One of these creativities was to use metal clamps to fasten the stones tight to each other.

Metal clamps seem to have been abandoned after the Sassanid period, but there is no certainty that they were obligatory even in Sassanid structures. As gypsum mortar, which was preferred in Iranian architecture, is soluble in water, lime mortar would normally be expected as the bonding agent in bridges, it is reported from Bīšāpūr and Kōrramābād, and chemical analysis of mortar from Mihr-Narseh's bridge at Fīrūzābād showed consistent use of lime with normal impurities for the piers, whereas gypsum was used for the causeway [8].

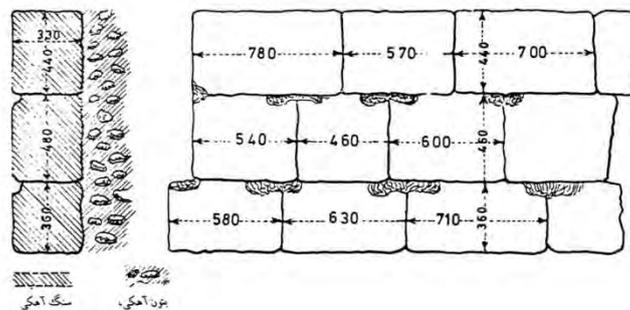


Figure1: Iron and Lead Clamps

Another point is that Iranian also acknowledged gypsum burning and plaster work very soon. Parthian time cornice clearly shows this matter. In Iran vaulting by bonding with big bolster technique was done by using quick setting gypsum mortar (like 26 meter bolster of Miyaneh, Pol Dokhtar). Using gypsum, lime mortar, cement grout, dressed stones and finally brick helped the durability of bridges in first periods of bridge construction. Therefore, the bridges with high durability and long life got a significant insolubility against different factors of destruction [9]. However they used cement grout was also used in foundation and walls. Apart from quick setting aerial mortar plaster mortar and lime cement mortar for humidity insulation, Iranians had also devised regulated set cement mortar as well. By using albumen and living lime powder (CaO) they made mortars which were more durable, quickly settled and stable in water. Because, living lime powder (CaO) with albumen gives slaked lime (Ca (OH)

2) and 275 calories of heat is freed from it. The freed heat cooks albumen and a very durable mortar is created; even now the mortar of living lime powder (CaO) and albumen is used for tinkering china portions [10].

Taking into account the scant supply of good timber in Iran, on one hand, and the knowledge of advanced vaulting techniques, on the other, it seems more probable that stone or brick vaults were commonly used to span the piers. An important aspect of early Iranian bridges in general is the part that barrages or weirs played, owing to the need for irrigation. The relative rarity of bridges designed solely for traffic may be explained by such interrelated factors as the almost exclusive use of pack animals, rather than carts, for transport and the formability of most rivers during most of the year [8].

Table1: Most important ancient bridge materials

Material	Type	Use	Part
1 Stone	Substance	Stonemason, Rubble, uncut stone	In piers
2 Lime	Mortar	Lime which is tight in water.	In piers and Foundations
3 Gypsum	Mortar	Pure or Mixed with soil	In arches
4 Sarouj	Mortar	A mixture of lime and ashes or sand in water	In piers and Foundations
5 Iron and Lead clamps	Holder	Lead Molten or leaden and ionic clamps	Integrating two different material types

2.2. Tradition methods of bridge constructing in Sassanid Era

From ancient times Iranian experts have used different methods for constructing foundation, arch span and determining location of bridges.

2.2.1. Foundation

Bridge constructors' main effort was to stabilize bridge bases where the river water was less. Since deepening water and as a result constructing foundation under water was not possible, the foundation were constructed in less deep but massive spaces to avoid the displacement of foundation by running water [4]. In constructing a bridge in Ghafghaz port (Babol Abvab) for not being able to restrain the power of surging water, they constructed the bridge base as explained: The skin of big beasts like cow, camel and donkey were blown with air and were bind beside each other; on the blown skins frame works of beam and wood are created and the skins are fastened under them. The framework, then, thrown into water and was carried where the bridge were to be constructed and it was restrained from river coast to prevent its moving by water waves The base of bridge were constructed on floating framework ;once the base of bridges became heavier the framework sank into water and the restraining thread loosened till the blown skins sat on river floor; the structure of bridge base were brought up the water as much as it was needed. The divers then were sent under the water to incise the skins and let the air out of them and the framework be set in river floor. This traditional method is a kind of foundation construction using compressed air which was matured in later periods [10].

2.2.2.Span Arches

Owing to the restoration of bridges in Sassanid period, the shape of arches is not clear. Undoubtedly, the arches were brought to a peak under the Sassanid. The arches of spans in Sassanid bridges indicate that architects were successful in constructing high segmental arches and especially in covering the spans with hard materials. Most of arches were horseshoe-shaped but they changed into ogival arches into Islamic period and kept unchanged until 10th century.

In constructing arch which were mainly four center arches uniform methods were used ;therefore, Iranian experts build the constructions without using framework. In contrast to Romans, they also did not use frame work in constructing bridge arches, but constructed them with plaster mortar and brick using bonding method and between multiple arches of the bridge bonded to each other with brick partitions [10].

2.2.3. Shape of piers and hydraulic effect of water

Some important structural factors concerning the resistance and sustainability of the bridge against water pressure include [11]:

- a) Considerable weight of bridge;
- b) Connection surface of the bridge to the riverbed;
- c) The shape of bridge pier which acts effectively in absorbing force .

Piers on a pentagonal or hexagonal plan, with triangular cutwaters pointing upstream and, in later examples, on both sides, seem to be typical of Sassanid bridges, though they can be found on later examples as well; on the other hand, rounded projections and buttresses on a semicircular plan seem to appear only in the Islamic period [8].

In general, the shape of the pier is in such a way that they are given a performance similar to breakwater. The form of cutwater causes a decrease in the dynamic force to the bridge preventing from water-flow turbulence (in lower parts of pier or foundation). The shape of frontal pier and foundation are divided in three groups with regard to the absorption amount of dynamic force of water [11].

1. The form where the frontal part or pier has no angle and the absorption of dynamic force of water is high

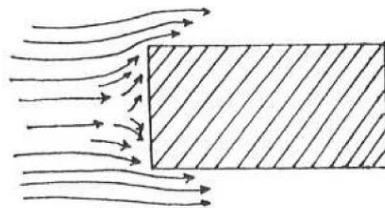


Figure 2: Pier without any angle

2. The form where frontal foundation or the pier itself is curved and dynamic-absorbing power is more or less low

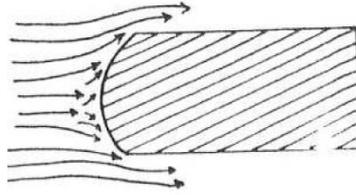


Figure 3: Pier with Curved form

3. The form where the frontal foundation or the pier itself has a sharp-point pier or foundation frontal and the absorption dynamic force of water gets low

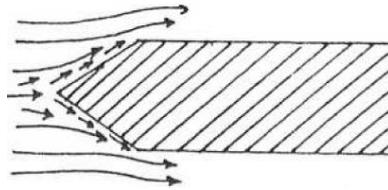


Figure 4: Pier with sharp-point form

2.3. Introducing famous Sassanid bridges

Here, some examples of Sassanid bridges are introduced and considered.

Table2: Famous Sassanid bridges

Bridge	Location	material	Mortar	Bridge length(m)	Number of spans	Pier type
1 Mihr-Narseh Bridge	Fīrūzābād	rubble concrete of stones	Lime	9.70	?	pentagonal
2 Pol-e Doḡtar at Kāšgān	Kāšgān River	Uncut and Stonemason	Lime and Saruj	270	12	
3 Shushtar Bridge(Valerian)	Shushtar	Stonemason	Clamps	500	44	pentagonal
4 Dezfūl Bridge	Dezfūl	Stonemason	Lime and Saruj and clamps	385	14	pentagonal
5 Kovar Bridge	Shiraz	Uncut and squared stones	Saruj	125	6	
6 Ghalatsian	Sardasht	Uncut stones	Saruj	55	3	

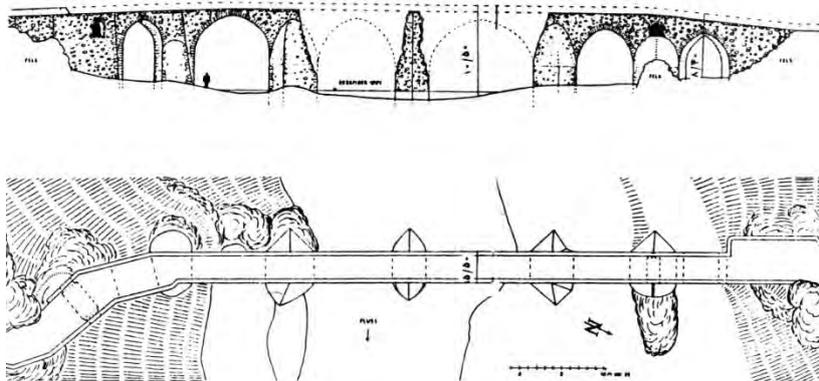


Figure5: Kovar Bridge-Sassanid era

3 CONCLUSION

In Sassanid bridges, usually, stone pieces were attached to each other by iron clamps, but this way was used to build important bridges made by government because of the high price of iron and lead. Water mortars such as lime and Saruj were used in bridge building. Bridges over Sassanid period were built by a combination of approaches and styles of Achaemenid period with the effects of Roman style. Roman style influenced bridges after that Shapur conquered the Roman Emperor Valerian and made Romans prisoners to build bridges. Usage of Roman style never was like copying, it was used as a combination to improve the Iranian style.

The result reveals that these bridges were built to make cultural, ethnic, economic, religious links as well as developing welfare, security and convenience in arduous mountainous area. Utilizing the most modern bridge constructing techniques of the time, a lot of magnificent bridges were built skillfully.

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