

## **RENOVATION AND REHABILITATION OF ANCIENT BAHMAN WEIR IN FARS, IRAN**

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### **ABSTRACT**

Bahman weir is one of the most famous ancient structures located in Fars province in southwest of Iran. The weir is a masonry rock structure with 7 meters height. The weir dates back to 2000 years ago. It is constructed on GhareAghaj River as a diversion structure to supply Kavar plain irrigation demands. The weir has undergone limited partial repairs several times. The weir has been studied completely in 2002 and its detailed rehabilitation plan has been developed. Site geology, main body geotechnical aspects, weir stabilities against sliding and overturning have been addressed with especial consideration to its age and historical value. The study also encompasses the weir appurtenance structures including its intake structure and downstream conveyance channel. Investigations show that the ancient Iranian had a deep knowledge on site selection, hydraulic structures, and construction materials.

### **INTRODUCTION**

In the ancient periods, when our ancestors understood the value of water for agriculture, they recognized the importance of water control and storage. Actually, the easily controlled water we have nowadays in our dams reservoirs is the pure fruit of an attempt began on those era. In this regard, the Iranian nation has contributed a lot to this issue. One may recognize and appreciate the Iranian approach, methodology, level of knowledge and experiences towards dam construction upon observing these historical workman pieces. Investigations show many similarities between modern and ancient hydraulic structures. Scrutinizing these valuable historical heritage would help us to resolve the complicated problems we encounter in water resources issue.

Iranian people whose lands are located in a semi-arid climate have prevailed on climatological constraints by incorporating several different techniques originated from their inherent intelligence. Construction of different structures for water control, storage and conveyance such as dams, barriers, water stores (known as "Ab-Anbar") and Qanats reveals their wise attention for optimum water resources exploitation. Most of these

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structures are considered among successful architectural structures, which draw applause and wonder of those who carefully observe them. This article intends to introduce one of these remarkable structures named “Bahman Weir”.

## HISTORICAL BACKGROUND AND LOCATION

Bahman weir is one the most ancient irrigation structures in Iran being still operational. Based on conducted scientific investigations, this structure is one of the historical proofs of comprehensive and deep understanding of its designers and constructors regarding geology, structural materials and river hydraulic behaviors.

Bahman weir is constructed on GhareAghaj River in Fars, Iran. It is located 10 kilometers from city of Kavar and 65 kilometers southeast of Shiraz. The weir has been constructed to divert river flow for Kavar plain agricultural lands irrigation purposes. Location of Bahman weir is shown in figure 1.



**Figure 1 - Location of Bahman Weir**

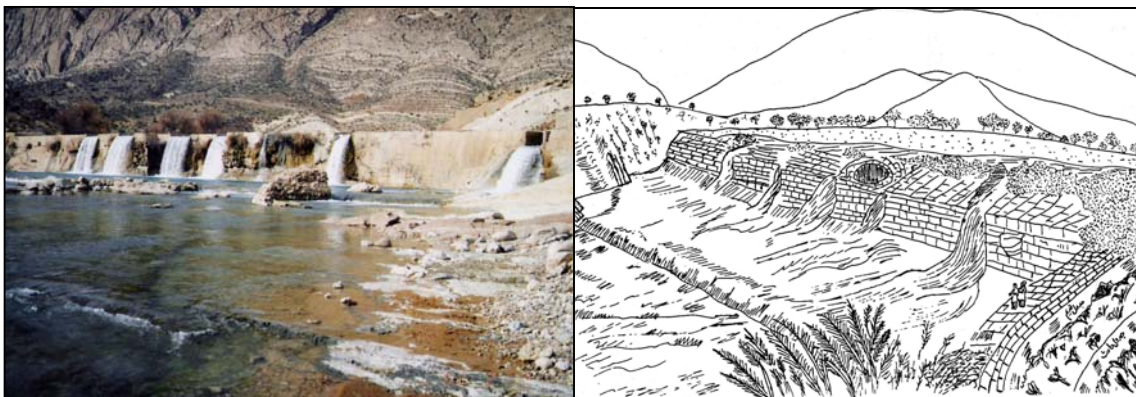
Date of Bahman weir construction is not known specifically. However, its age is estimated about 2000 years. In fifteenth century, Mostofi has referred to Bahman weir as “a historical barrier” in his book entitled “Nozhat Al-Gholoub”. Forsat Al-Doleh Shirazi has visited the weir about a century ago. He has described architectural and structural states of the weir and its quality at the time of his visit. He has also made a sketch of the weir that is considered as the most important visual reference for technical investigation of the structure. This sketch, which is the general view of the weir, helps us to understand the structural properties and shape of the weir. He has included this

weir in his book entitled "Asar-e Ajam". The status of the weir under present conditions and also its former condition in a century ago are shown in figure 2.

GhareAghaj River is one of the most important rivers in Fars province, Iran. The river, after conjunction with Firouzabad River, is called Mond River and runs up into Persian Golf. Length of the river upstream of the weir is about 130 kilometers. The weir basin is about 1600 square kilometers. The basin climate is semi-humid with a mean annual rainfall of 580 millimeters. Longterm river flow at weir site is 7.9 cms. River floods with different return periods at weir site are presented in table 1.

**Table 1 - GhareAghaj River Floods at Bahman Weir site**

Return Period (year)	2	10	50	100	1000
Flood Discharge (m <sup>3</sup> /s)	256	976	1354	2396	4144

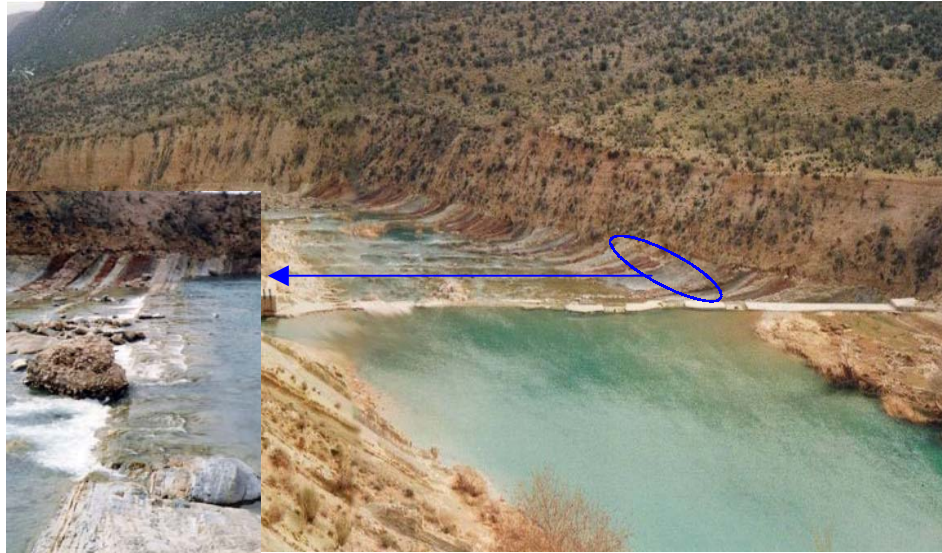


**Figure 2 – Bahman Weir “at present” and “a century ago”**

### **GEOLOGICAL AND ARCHITECTURAL ASPECTS**

One of the main features of Bahman weir is geology of its location site. In this area, GhareAghaj River passes through Razak formation. Razak formation consists of alternated marlstone and siltstone layers with sandstone slices. Hard sandstone layers are visible in a few 10 meters intervals in river bed and normal to flow line. Bahman weir is constructed over one of these veins, as shown in figure 3. Like other ancient barrages in Iran, Bahman weir is a masonry long crested weir made of large limestone rocks and Sarouj mortar. Length of the crest is 116 meters having 5 open conduits, 2.5-3 meters width each, to allow release of surplus water. However, all crest length is active during flood periods. The weir performance during low and high flows is depicted in figure 4. Width of weir body is not uniform along its length and it follows width of foundation sandstone. Accordingly, crest width varies between 5 to 10 metes.

Geophysical studies have been conducted on 6 positions on weir crest to better understand the conditions of weir body and foundation materials. Upon assessments of the results, 4 boreholes have been dig on crest followed by an experimental grouting. Depths of boreholes vary from 10 to 15 meters so that penetration into the bed rock is assured. Results of tests show that the weir body height varies from 5.4 to 13.2 meters.



**Figure 3** – Geological Condition of Bahman Weir Site



**Figure 4** – Performance of Bahman Weir under Low and High Flows

Conducted tests show that quality of weir body materials and foundation bed rock grows less from very good materials in right abutment to poor materials in left abutment. Henceforth, the weak part of the structure is located in its left abutment. Downstream of this weak part there is a mass of rock and Sarouj took out from the main body during floods. The damaged portion has been repaired.

Although there are evidences of many active faults around the weir site, field studies show that there is no fault crossing the site. The closest fault to the weir site is Sepidar

active fault located about one kilometer southeast of the site. Investigation of Iran Seismic Hazard Zonation Map prepared by International Institute of Earthquake Engineering and Seismology – IIEES (1999) shows that weir site is located in an area with high earthquake hazard. In this regard, the weir would experience accelerations as high as 0.3g (for a 75-year return period earthquake equal to 50% of occurrence in 50 years) and 0.37g (for a 475-year return period earthquake equal to 10% of occurrence in 50 years). Thereon, considering the 2000-year age of the weir, it is logic to conclude that the weir has experienced heavier earthquakes during its life.

Bahman weir is constructed to regulate water surface in river and to divert the flow to A'zam channel located on its left bank as shown in figure 5. In this area, there is remaining of an old channel that its elevation shows that the crest elevation was lower than where it currently is. Therefore, it would be concluded that the crest had been heightened by maximum 2 meters during its life. The matter is also obvious by observing the changes in body materials textures.

Nowadays, required water of some parts of Kavar plain is supplied by Bahman weir through river flow diversion and conveyance through A'zam channel. The conveyed water is distributed into seven portions irrigating agricultural lands of 16 villages measuring totally about 5000 hectares.

## HYDRAULIC CONDITIONS

Assessment of Bahman weir performance requires proper description of its existing conditions and other influencing factors. The right portion of the weir body has been remained unharmed through years of operation. But, the left portion has been damaged and repaired several times through its servicing stage.

Due to flow overfall downstream of weir the loose marlstone layer has been eroded gradually resulting in a natural stilling basin just downstream of the weir. The stilling basin has a depth of 10 meters. There is a hard sandstone layer just downstream of the stilling basin, similar to the vein where the weir is constructed on, forming a natural end sill providing stability of river bed and stilling basin hydraulic performance. The natural sill at the end of the natural stilling basin can be seen in figure 5.

Unfortunately, one of the most valuable and sophisticated structures of the weir has been destroyed under rehabilitation works conducted by farmers and local people in the far past. The structure was a bottom outlet, shaped like a well, having two gates. It was used for evacuation of sediments deposited behind the dam. Forsat Al-Doleh Shirazi has referred to this structure in his book and showed its position in the middle of the weir as shown in figure 2.

At present, sediments have been completely filled out the weir reservoir. Assessment of Bahman weir stability shows that overturning and sliding safety coefficients under flood conditions, with 2 meters head on the crest, are 1.82 and 1.2, respectively. These coefficients under normal conditions are 3.23 and 2.2, respectively.



**Figure 5** – Bahman Weir with Natural Stilling Basin and A'zam Channel

## CONCLUSION

With no doubt, technology development in the ancient civilizations was an answer to mankind needs for optimum exploitation of natural resources, safety towards natural hazards and improvement of individual and social life standards. Man intention to control the environment and exploit its natural resources has resulted in opportunities and challenges leading to increase of his understanding of natural resources and materials and construction of structures. Bahman weir is a significant proof to this claim. The 2000-year old Bahman weir takes us into deep thinking since durability concept of structures has just been taken into consideration in the past two decades. Let's hope that specialists and engineers take proper lessons for correct management of natural resources and environment upon observing and studying such cultural heritages of the world while endeavoring to protect them.

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