

Traditional Architecture of Iranian Water Mills in Reference to Historical Documents and the Case Studies

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Abstract

This article is a study of the artisanship involved in the construction of Iranian Watermills, and the cultural aspects of a traditional architecture that incorporates an understanding of constructions that date back centuries. Expanding the existing knowledge of these heritage properties and explaining their current condition in order to express the need for the preservation of ancient artisanship as part of a sustainable conservation future are the other prominent concerns of this work.

Herein, historical and contemporary documents and travel accounts concerning the traditional buildings of the Iranian water-mills are studied to achieve a better understanding of the buildings background in the region. In addition, depending on the information accessibility and the existence of the constructions' remains, the authors chose some historical sites to be aware of the buildings' current condition and their exact functions based on observational studies. The article discusses that Iranian traditional Water mills represent knowledge of a highly developed technology which makes such ingenious use of natural resources without the consumption of additional power. Among different Iranian Traditional constructions, water-mills are the subject of the main body of this article.

Keywords: Iran, Traditional architecture, Construction techniques, Water-Mills

1. Introduction

This article aims to make a better understanding of the effective construction techniques in Iranian water-mills and to present their efficient functions, which utilizes natural resources without the consumption of additional power. This is indeed important as energy saving and sustainability concealed in such constructions are significant issues in contemporary architecture (Mackintosh, 1997). Technological innovations of the first half of this century are the root cause of the buildings' redundancy as modern refrigeration, new sources of power and the internal combustion engine have overtaken such constructions as, mills (Hyde, 2000).

Few travellers, either today or in the past, have been sufficiently interested in recording traditional buildings; those that have (notably John Fryer in the seventeenth century, C. J. Wills in the nineteenth and Hans E. Wulff in the twentieth) have shown a general interest in both Persian buildings and customs. However, among all Iranian traditional constructions, water-mills are the subject of the main body of this article. Study of these buildings, motivates some instructive skills and cultural values in which the Iranians excel: 1) the Persian imagination and

ingenuity, which is unrivalled in making the best use of water. In this, the Iranian contribution to the world's technology is probably unique. 2) Iranian traditional building techniques show an ingenious use of natural resources without the consumption of additional power. 3) Employing local materials in construction and repair work has many advantages as the original materials are close to the site. 4) These buildings contribute significantly to the economy as key attractions for tourists.

The research method is divided into three sections: On the first step, historical and contemporary documents and travel accounts concerning the traditional buildings of the Iranian water-mills are studied to achieve a better understanding of the buildings background in the region. On the next step, depending on the information accessibility and the existence of the constructions' remains, the authors chose some historical sites (like Kashan, Band-e-Amir and Shushtar in which historical water-mills are still immune) to be aware of the buildings' current condition and their exact functions based on observational studies. Finally, to have a more comprehensive understanding of the Iranian cases, the consultancy of leading experts on traditional constructions (from the University of Tarbiat Modares in Tehran) is utilized to compare the similar constructions and their functions in other countries. As in most traditional buildings dating proves to be difficult, the considered buildings to which a period is even ascribed, are all thought to have been built before the reign of Shah Abbas (1587-1629); and the extent of decay of these buildings is estimated to be more than 60 percent in most cases.

2. Traditional Water-Mills

Before water became a prime mover, power traditionally relied upon humans and animals. Stone querns may still be used on a small scale domestically, and perhaps a camel mill survives deep in some bazaar. The majority of water-mills are now powered by oil-driven machinery, hardly surprising in a country where water is in places more precious than oil. Two types of water-mill survive in Iran: the Vitruvian mill, the type common throughout the Western world with its water-wheel set vertically on a horizontal axis; and the little-known Greek mill with its water-wheel set horizontally-the fore-runner of the turbine. We can only report two Vitruvian mills, both near Isfahan (at Lahijan and near Pir Bakran). Each has an exceptionally attractive site, the mill forming a small island in the mill-stream. Each was worked by two water-wheels, one on each side. The reasons for both the preference for the Greek mill and the lack of evidence of its existence became apparent as work proceeded.

Greek mills were first recorded during the first century B.C. in Thessalonica (whence their name) and in the Pontus, and it is probable that they came into wide use in the Eastern Mediterranean and Near Eastern countries from this time. By the fourth century A.D., they had spread to Ireland and China (Singer, 1975), although they very well have been invented spontaneously in different parts of the world (Ibid). The Greek mill, with its direct transference of power from a horizontally set water-wheel to a millstone fixed above it on the same axle, is only an extension of the idea of the rotary quern, using water power instead of human power. An abundance of slaves (6th-8th century A.D) made such development superfluous, and it was not until a labour shortage made the old system unworkable that the water-powered Greek mill, rotating its millstone once for each turn of the wheel, came into use (Ibid). However, such mills could only temporarily satisfy the increased demand and the Vitruvian mill was invented (8th century A.D). The simplest Vitruvian mill, with its vertically-set water wheel, turned its millstone five times for each revolution of the wheel. The persistence of the Greek mill seems to depend on a relatively small supply of grain to be milled by a small water supply, there being no real efficiency in the construction of the far more complicated machinery of the Vitruvian mill, unless there was sufficient grain to be ground (no Greek mill has been reported in the valleys of the Nile or Euphrates) (Beazley, 1963). Prof. E. Beazley has also suggested that in Europe the Greek mill was to some extent ousted by the introduction of the feudal system, in which the lord of the manor owned one central mill, to which the peasants brought their corn instead of milling it individually. (Ibid & Mirdanesh, 2007)

It is perhaps hardly surprising that the Persians, with their long tradition of efficient use of water, favour the Greek mill which is powered by a small quantity of water directed at high velocity to turn the horizontal water-wheel (Weaver & Pinder, 1963). As shown in (Figure 1), the water from the leet pours in a torrent down the vertical 'chimney' (a drop varying from 3. 20 to 7. 40 m. in those measured). Near the bottom of the chimney it rushes down a wooden tube of narrow bore which ends in a nozzle; this further constricts the jet which is directed to the water-wheel itself. The wheel is housed in a small space right under the heart of the mill. It is half-filled with rushing water if the mill is working, and is usually difficult to reach without a long, wet crawl in the dark. Therefore, few water wheels were actually examined as part of this research. Those at Band-e-Amir (Figs.2 and 3) is a shallow cone-shape, like an inverted conical hat, made up of timber blades set in a big timber axle (diameter 28 cm.). The jet of water is directed into the top. That at Doshmanziari is remarkably like those seen in the Shetland Isles; the blades or paddles are set in a massive hub, and these are struck tangentially by the stream of water. The vertical axle passes up through a fixed millstone set in the floor of the grinding room above

the wheel-house to turn the upper millstone which it supports. The iron tip of the axle rests on a timber sole-tree, which acts as a lever whose precise position can be varied by the fine adjustment of the lightning rod; thus the closeness of the millstones and the fineness of the flour can be controlled.

Millstones vary remarkably small in diameter. Those measured were 93, 96 and 103 cm. (in Shetland they varied from 68-91 cm.). The grain in Iran is fed from a plastered bin (or a separate store) integral with the building, not from a hopper as is common elsewhere. In both cases, however, the wheel itself is used to cause vibration in order to ensure a flow of grain. In Iran, a vertical stick, sprung in tension against the hole in the upper stone, vibrates the chute from the corn bin (taking the place of the clapper where a hopper supplies the grain). It is difficult to convey adequately the sculptural quality of the inside of an Iranian grinding room, particularly when it is cut into the rock face. The fine shapes of the plastered bins and other containers, the wheel housing, which curves round the millstone, the curve of the roof, whether vaulted or rock cut, and the walls, themselves are also often curved, are whitened with a fine coating of flour dust. This covers everything in a working mill (including the millers) except for the spinning focal point of the hard grey millstone and the dry yellow corn streaming into it (see figure 4) Investigating the Greek mill in Iran, it became apparent that there may have been many more on the Plateau than was suspected in previous researches. The necessity to get a sufficient fall of water in a relatively flat area means that some mills - perhaps many - are underground (Kiani, 2006). Sometimes the only sign of their existence may be a ventilator, and the jube which is in fact a mill leet, which runs at ground level and then drops in the 'chimney' down which the water pours in a torrent to the underground water-wheel. After turning the water-wheel, the water runs into a qanat system (The easiest way to construct a Qanat is to dig up an almost horizontal tunnel from the earth surface to the aquifer in order to drain the groundwater out) (Wulf, 1966). This may have given rise to the idea that some mills are positioned in qanats. This seems unlikely, since the all-important drop to the wheel would entail very deep excavation with the mill, say, 4.m. below the qanat. Whenever possible, the mill is constructed on a hillside to make the most of the natural fall. Then at least half the mill can be cut out of the ground like a cave and it can be conveniently reached from the lower level. There is considerable variety in the grouping of the mills, since this depends on the quantity of grain to be ground and on the water supply. By far the most spectacular are the groups of mills below great irrigation dams. The dam of Band-e-Amir in Fars was built in c. 960 A.D., possibly on Achaemenian foundations (Cultural research association, 2007). (Figs.5 and 6) The prime function of this great dam was to provide a reservoir for irrigation of the Marv-e Dasht (the plain to the east of Persepolis), but presumably it was also used to provide power for water-mills from an early date (800-850 A.D). (Ibid) The mills are grouped in three clusters fed by leets. Three main leets are led off from the side of the dam. From these a leet is taken for each mill, each controlled by its own sluice gate. The gate is simply constructed and operated; it is like a wooden, two-handled flat shovel and is positioned by a cross slab on the leet. Walls were of rubble masonry except for the wheel and mill houses, which were partly cut out of the rock. The flat roofs were of timber and mud, since the presence of water meant that trees flourish. In other places where timber was scarce, the roofs were of brick vaulting and walls often of unbaked brick. Another important group of mills that survives are below the huge Sasanian dam at Shushtar, which was illustrated by Madame J. Dieulafoy in the nineteenth century while some of these remained working up to 1970s (see Dieulafoy, 1887; figure 7). However, most groups of mills are on a much more modest scale than these. Above Estebanat (south-east of Shiraz) there is a series of six stone-built flour mills just above the town fed by a rushing mountain stream. It is bordered on one side by gardens and on the other by small bouldered mountains shaded by walnut and plane trees-an idyllic spot. It is told that there were mills in the town that produced 'oil for the face' (Kiani, 2006). North of Qutabad (near Jahrom) are the remains of another series, but these were built along a jube. The caravanserai at Aliabad, outside Pusht-e-dam (in the Dasht-e-Lut), had its own underground mill (and hammam [bath]). The single mills were the biggest. Of these, that at Ferouseh, seventeen kilometres south of Abdeh, has one of the most attractive settings. It is still working by water power, and this in itself may be considered to be a curiosity by the local inhabitants. Such mills also exist at a petrol station in Abdeh (a promising place-name for anyone in search of a water-mill). The mill is in a high walled enclosure, like that of a garden, on the outskirts of a village beside a poplar wood. The only visible building in the enclosure is a watch tower which could be reached from the underground mill. Only the domed roof of the mill, crowned by a ventilator, and the noise of the grinding, betrayed its existence. It was fed by a good jube with the usual arrangement of sluices. Other parts of the enclosure were walled off, partly as a garden and partly for animals.

The mills described so far have been recorded as part of a survey covering a wide area. A much more detailed account is given below of a grain mill in Fars, at Deh No, Doshmanziari. The mill was built c. 1940 by a group of men who pooled their funds (Cultural research association, 2007). The water-mill is some distance from the village, where it can be powered by the river and is less convenient. Payment is made in kind to the miller

(Lambton, 1953). A donkey-load of wheat is about 20 mans and of this the miller takes one man (6 1/2-7 kilos). The miller, who lives in a house in an orchard nearby, is a Sayyid; all the Sayyids living in the village take the proceeds from the mill for the twelve days after the New Year, as a customary right. The revenue of a mill might be set aside to defray the expenses of a mosque, and this may still hold true (Sani-o-doleh, 1948).

3. Inventory: Technical Details

The water-mill system in ancient Iran consists of the following parts. It is necessary to bring out this point that, the location of water mills selected somehow to have 5 to 6 meters head between up streams and down streams. Apparently higher pressure caused problem for turbine's wheel and wouldn't let it work properly.

3.1 Water Resources

The resources, which were generally used to operating the mills, were rivers, springs and qanats. And they got much benefit from these resources in Gargar and Amir weirs and many other places. But the case was different in Feen Garden, as a part of river discharge supplies water for operating almost 75 mills located between Feen and Kashan and the villages in nearby. (Fig. 8)

3.2 Water Tower

This tower was similar to an incomplete cone, and the cross-section decreased as it went down. In one of those towers in Kashan, the diameter was 2.5 meters at the top and 1.2 meters at the bottom. This tower led to a narrow channel with a wooden weir, which could be manoeuvred from inside the mill in order to open and close. As it was mentioned, the difference between water level in upstream canal and the exit channel was about 5 to 6 meters. When the mill was at rest, the tower was evacuated and water was diverted from behind of the mill.

3.3 Grain Storage and Wooden Hopper

Grain was stored in a small room just above the millstone. And from the bottom of the room there was a wooden hopper, which led the grain to the sole in the middle of the upper stone of the mill. When the mill was under operation, caused vibration, its vibration reflected.

3.4 Downstream Canal

When water passed through turbine, entered downstream canal and led to the river (Fig.9).

3.5 Upstream Canal

This canal directly related to water resources. It was often covered with bricks and lime concrete. Besides the main channel, there was a diversion one or a wooden weir before water entered the tower. This diversion channel was connected to downstream channel and it diverted water while the mill was at rest. It was possible some mills operated just by one canal (Fig. 10).

3.6 Wooden Turbine

This canal directly related to water resources. It was often covered with bricks and lime concrete. Besides the main channel, there was a diversion one or a wooden weir before water entered the tower. This diversion channel was connected to downstream channel and it diverted water while the mill was at rest. It was possible some mills operated just by one canal. Figure 11 shows a wooden turbine. It consisted of a wooden axle with a diameter, which gradually increased as it went down. The two ends of this axle are generally made of iron. The lower end of the axle was fixed to a stone, which was the support of the turbine. The upper end tightened to the upper millstone, rotated when the turbine was under operation. The lower end of the axle had some grooves with blades, made of wood. These blades were 40 to 60 cm. long and their free ends were connected to each other. The blades respect to main axle had a moderate slope (Fig. 11).

3.7 Millstones

The diameter of stones depended on water quantity and water head. For instance, the millstones of Feen Spring and Gargar Weir had a diameter of 1.6 meters and Amir Weir

about 1.3 meters. The lower millstone was very strong and unmovable, but the upper one, which was tightened to the axle of turbine, could rotate and it was generally lighter than the lower one. In the middle of upper stone, around the axle there was a hole, which led the grain to the space between two stones. The two stones were not completely horizontal; in fact they had a moderate slope. This simple technique caused flour jumped out from the highest point according to centrifugal force and collected in a shallow hole. Then the miller collected the flour in bags and delivered to the owners (Fig. 4).

4. Conclusion

The unique fabled artistic background of Persia makes up for the seemingly lack of natural resources and beauty (Kasmaie, 2006). Traditional constructions techniques are particularly important because they are the result of centuries of development and practice. The recording of artisanship is extremely vital, not only because it provides empirical evidence of original practice, but also because it can be directly applied to practical conservation (Murakami, 2008). Herein, the great Iranian tradition is as yet little known in the West and there is much to be learnt both from it and the building techniques which are integral with it. It is the fate of traditional constructions throughout the world to be neglected until they are nearly extinct. The Folk Museum and the Museum of Buildings are relatively new ideas in Europe, where they are thought of primarily in terms of conservation and education in history and the arts. In Iran, their value could be even greater since these functions could be combined with those of an institute of intermediate technology. Not only is the building tradition itself still alive, but there is much to be gained from a knowledge of a highly developed technology which makes such ingenious use of natural resources without the consumption of additional power. The Persian Water-mill could hardly be described as small, but the technology it represents is certainly beautiful in its simplicity. (Mahmoudi & Mofidi, 2008).

It is not wise to give up all modern technologies and revive tradition instead, but it is quite wise to adopt the sustainable relationship which has always existed between environment and the elements of the traditional production system. However, unless positive action is taken, most Iranian Traditional buildings will have crumbled. Thus, In the name of Iranian architectural heritage, it is hoped that any further decay of such historical constructions can be prevented by funding.

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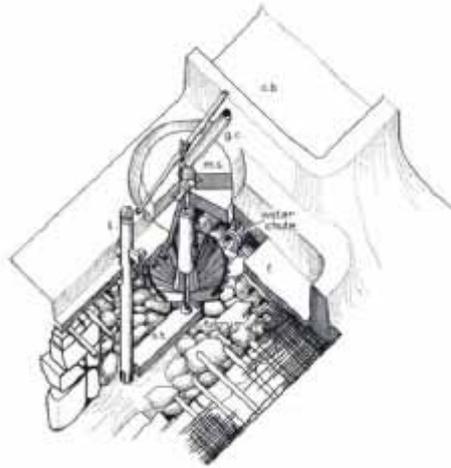


Figure 1. Sketch showing machinery of mills at Band-e-Amir; the floor of the grinding room has been cut away to show the water-wheel. [Authors]



Figure 2. Greek mills, Band-e-Amir: the water wheel. (Weaver & Pinder, 1963)



Figure 3. Greek mills, Band-e Amir: mill leets and chimneys. (Weaver & Pinder, 1963)

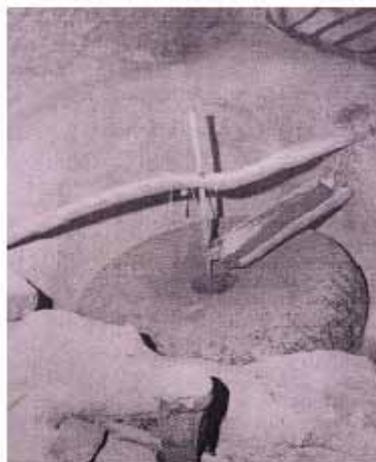


Figure 4. The mill wheel directly over the water wheel. [Authors]

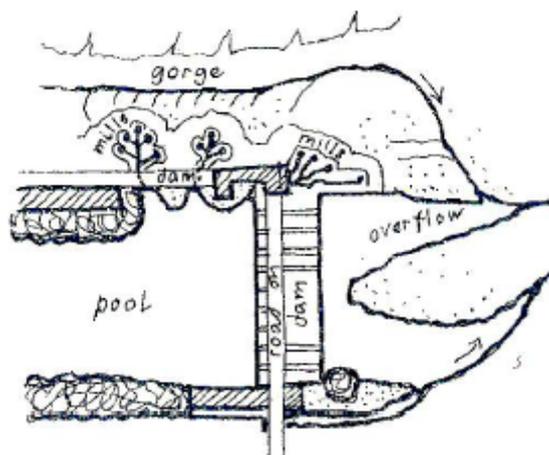


Figure 5. Lay out plan of mills at Band-e-Amir [Authors]

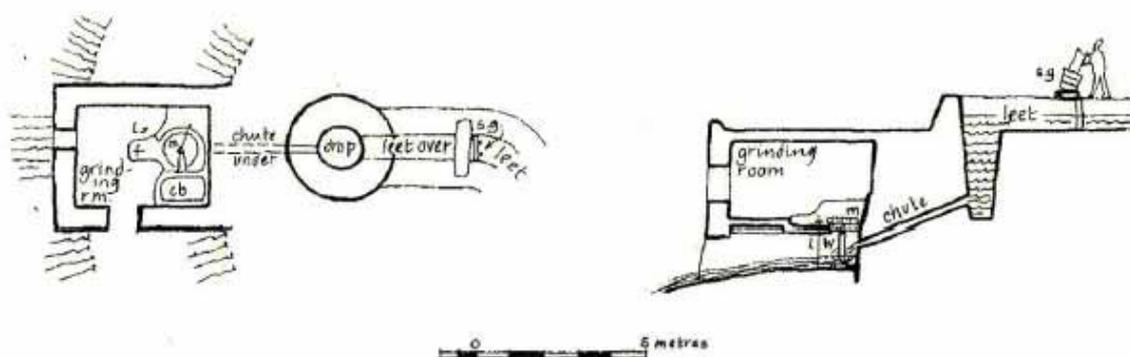


Figure 6. Plan and section of a typical mill at Band-e-Amir [Authors]

Note: The upper mill-stone rests on the axle. The iron tip of the axle rests on the sole plate; thus by slight adjustment of the position of the sole plate the precise clearance between the two will-stones can be controlled. A jet of water is directed by the wooden pipe into the water wheel. The peg driven into it prevents the water forcing out the lining which restricts its bore and thus increases the velocity of the water.



Figure 7. Remains of Sasanid mills at Shushtar. (Mirdanesh, 2007)

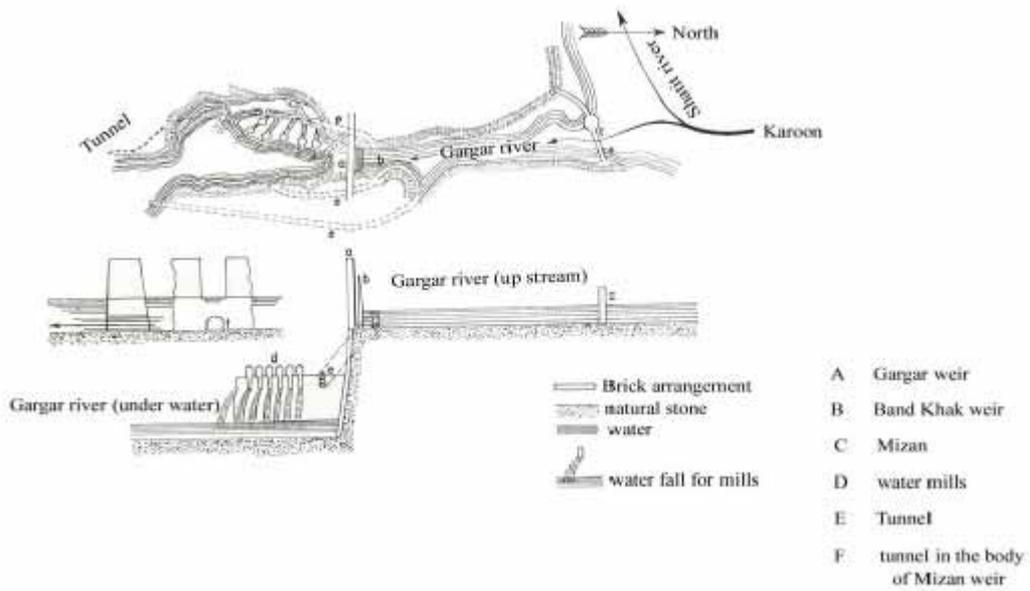


Figure 8. Some weirs in the eastern part of Shoshtar [Authors]

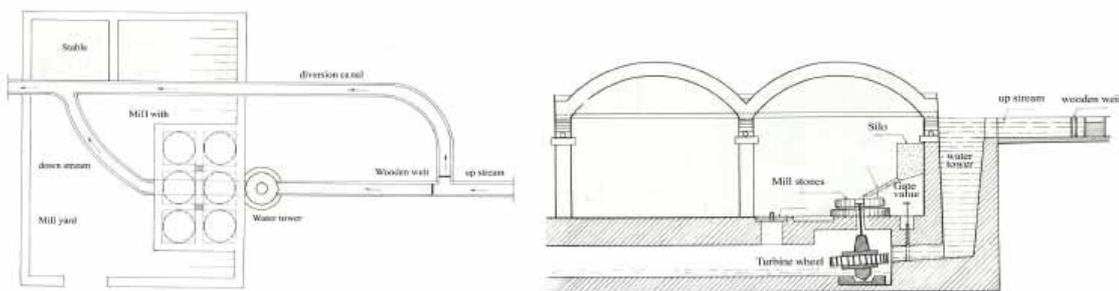


Figure 9. A brief map & Longitudinal of water-mill in ancient Iran [Authors]

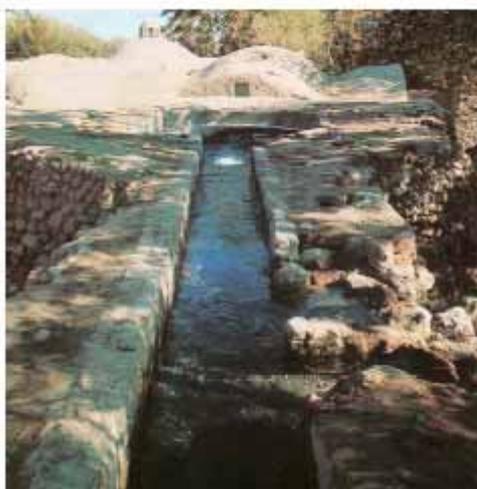


Figure 10. Here is Sohrab Canal which belongs to one of the mills in Feen Gardan in Kashan. The spillway and diverting channel are shown in the right side and the roof of the mill in the rear. [Authors]

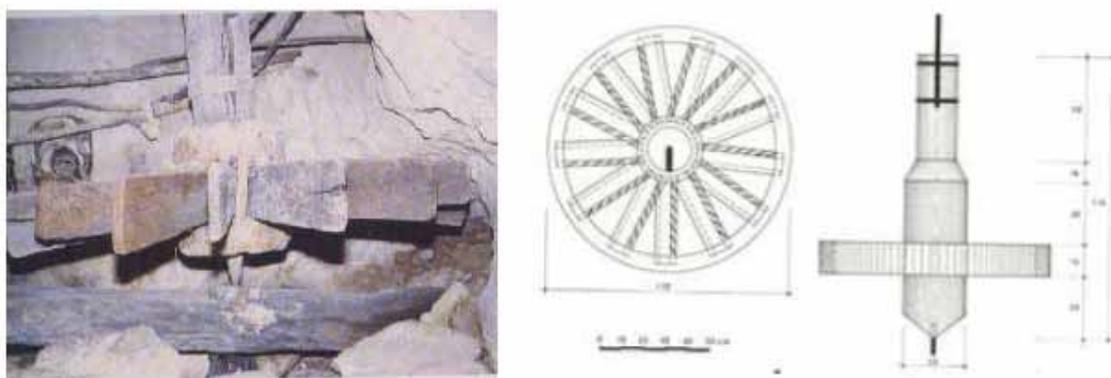


Figure 11. The turbine wheel of a water-mill in Iran [Authors]