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Being Green in Desert

Sustainability analysis of Mohammadabad double-stone watermill, central Iran, Safavid era (17-18th century)

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Abstract: In this paper; an ancient watermill in the central desert of Iran is described, and aspects of its sustainability are explained. In central and eastern areas of Iran, watermills are a part of a wonderful collection of structures based on Qanat technology (a three thousand-year-old passive irrigation system, comprised of a series of wells connected at the bottom by an underground channel). Mohammadabad double-stone watermill is representative of Qanat-fed watermills found in arid and semi-arid regions of Iran. It has some unique features that bold it among peers.
After a brief introduction of Qanat and Qanat-fed watermills, a detailed description of Mohammadabad double-stone watermill and its features is presented with illustrative images and drawings and different sustainability aspects of that have been discussed.

Key words: Watermill, Qanat, Water management, Sustainability, Traditional knowledge.

1. Introduction

Ancient civilizations and cultures possess plenty of valuable achievements and lessons gathered from thousands of years of experience and trial and error. A narrow and detailed observation of this precious legacy, with large parts already missing and other parts being forgotten, can give us new insights into solving modern society's problems.
Studying the ingenious approach of ancient Iranian architects and technicians; energy efficiency and optimal resource consumption is the main purpose of the author that can be considered a pattern in new urban planning, modern architecture and design.

2. Background

2.1 Qanat

A Qanat is a good example of this valuable treasure from ancient civilization, created and developed by traditional wisdom and thousands of years' experience to provide a reliable and permanent supply of water for irrigation and human settlements in arid and semi-arid areas. It can briefly be defined as a series of *well-like* vertical shafts connected together at the bottom by a slightly sloped canal. The water is drained naturally by its weight into vertical wells and then passes through the sloped canal to surface of lower level lands. The deepest well, named the mother well, could be located several kilometers from the Qanat's outlet, named Mazhar. (Figure.1) One of the longest Qanats in Iran, named Zarch, has a length of approximately 80 Km (with its three separated paths joining together) with more than 1000 vertical shafts. (Semsar Yazdi, 2014)

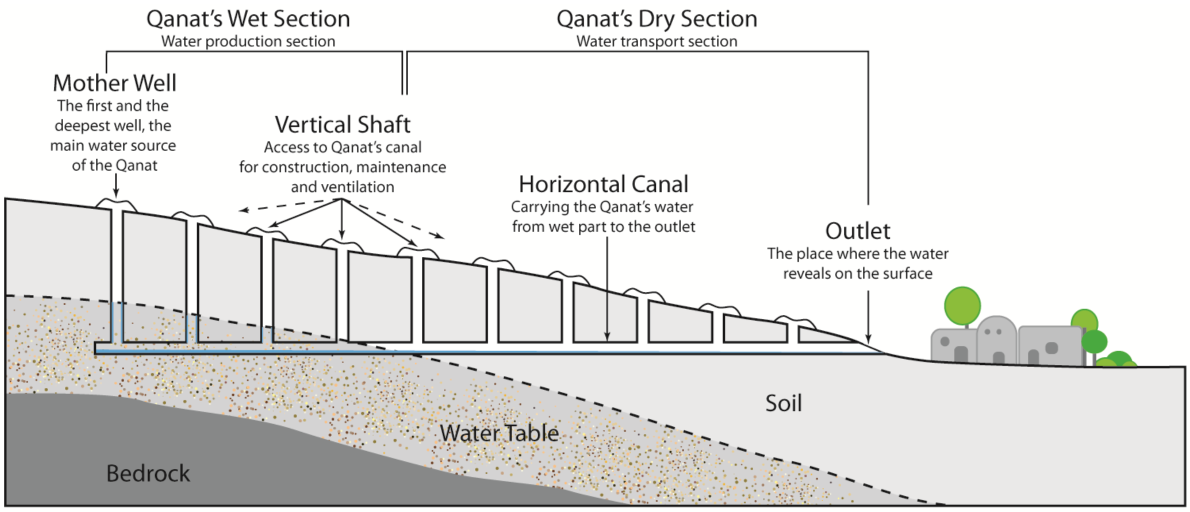

Figure.1 Schematic section of a Qanat (drawn by the author)

The main advantages of Qanat as an irrigation system are:

1- No energy sources are needed; all of the function is done by gravity.

2- Underground covered canals keep current water safe from evaporation in hot and dry conditions of desert areas.

3- The amount of water and the way it is drained from the groundwater is such that it cannot discharge the aquifer and its water quality maintains. (English, 1997)

Qanats in arid regions in the central and east of Iran are not only irrigation systems; they are a lifeline of regional societies that have shaped their own type of civilization. In addition to irrigation uses, Qanats have numerous applications in contribution of urban or rural facilities such as; water reservoirs (drinking water supply), ice pits (ice supply for the whole year), wind catchers (passive cooling system), and watermills.

2.2 Occasional patterns in Qanat canal

Locating the mother well, digging in the correct direction underground, creating the exact slope of the canal, and many other tiny key points in planning and making a Qanat need professional calculations and plenty of experiences. Generally, the slop of the canal must be kept the same along its length. But there are some occasions that cause placing a sharp slop or even a waterfall in the canal. It may have an unexpected reason, such as impenetrable rock in the path of canal, a need to move the original place of an outlet to a further place, some unrepairable damages in an old canal and be no other choice but to dig a new canal. (Semsar Yazdi, 2004) (Figure.2) It can also be deliberately designed to make a level difference to achieve the required energy for rotating the mill blades of a watermill. (Papoli Yazdi, 2000)

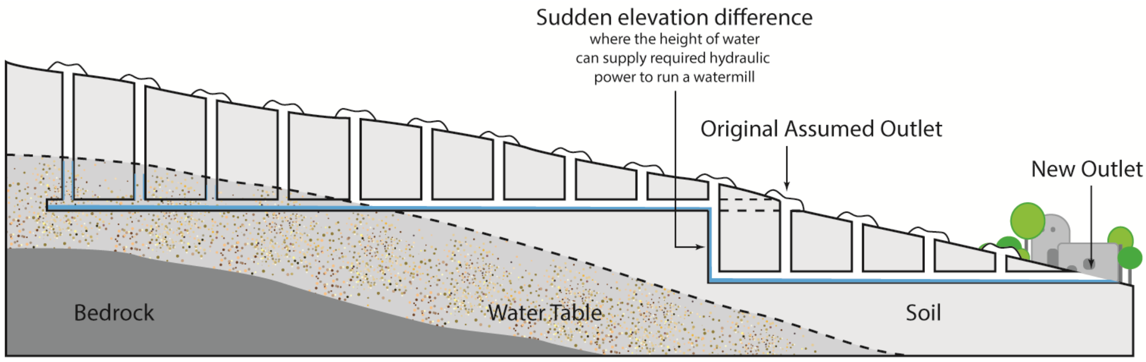

Figure.2 Schematic section of a sudden elevation difference (drawn by the author)

2.3 Qanat-fed watermill

Although Iran contains arid/semi-arid areas and faces lack of water in most regions, watermills were widely used in ancient Iran (Persia), even in the driest desert cities. According to evidence; watermills have a long history in Iran, at least 1,700 years, and a few of them have managed to operate continuously to the present day. (Saeidian, 2012) Watermills in humid areas or on hillsides are mostly stream-fed and use surface water flows such as rivers and springs as energy sources. However, watermills located in dry areas are generally Qanat-fed and use Qanat water flow to move millstones. (Harverson, 1993) Generally, the volume and speed of a Qanat’s water is not sufficient to turn the millstone directly. The common method used in Qanat-fed mills is to gather the water from the Qanat in a pool (*Tanoureh*) after the Qanat’s outlet point, then drain the water through a tiny nozzle in bottom of the pool. (Figure.3) The pressure of this flow was enough to move wooden blades attached to the upper millstone. Thus almost all Qanat-fed watermills are located a few meters underground, depending on the height of the pool. (Mahmoudian, 2012)

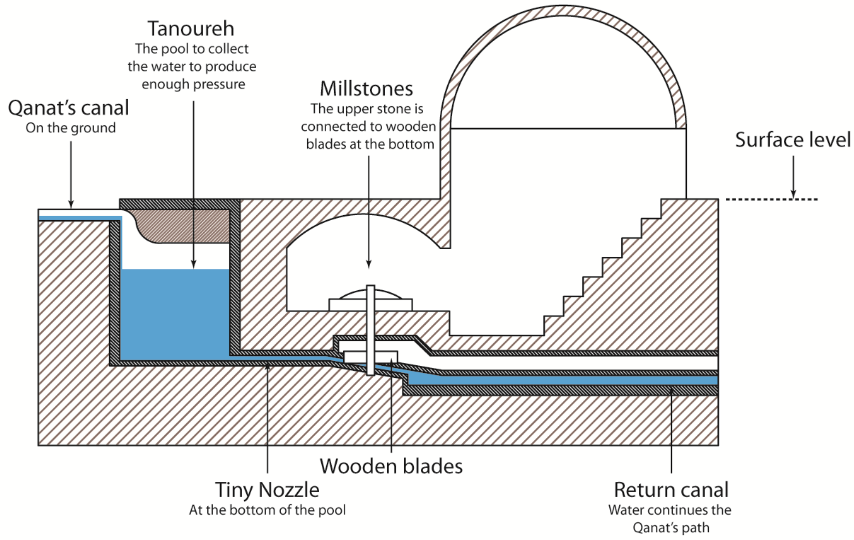

Figure.3 Section view of a general Qanat-fed watermill (drawn by the author)

3. Mohammadabad Double-stone watermill

Mohammadabad double-stone watermill is a brilliant representation of Qanat-fed watermills of Iranian arid regions. It has some special features that make it unique among similar structures; it is one of two known deep underground watermills, both near Meybod city. (Papoli Yazdi, 2000) As mentioned before, all Qanat-fed watermills are located a few meters underground to make use of water pressure, but these two watermills break that pattern of Qanat-fed mills by not waiting for the Qanat canal to spring above ground in order to use the water flow. Instead, they go deep and use the unwanted level shift of the Qanat canal as an opportunity to achieve the required energy to rotate the stones. Located so deep underground has caused some different needs and circumstances from other watermills in terms of construction, building material, ventilation, lighting, and operation of the mill. The solutions employed to meet these needs are very clever yet simple.

3.1 Geographical location and climate

The watermill is located in Mohammadabad village, a small village of Meybod county in Yazd province. Yazd province is located in the heart of the arid area of central Iran, at an oasis where Iran's two large deserts, Kavir and Lut, meet. Yazd city, the capital of Yazd province, is the driest major city in Iran with an average annual rainfall of only 60 millimeters, and it is also one of the hottest, with the temperatures frequently above 40 °C in summer. (Yazd …, 2012) This is a historical city with more than two thousand years of history. It was located on the path of Silk Road and is mentioned in Marco Polo's book as a noble city with a great amount of trade.

Meybod city, the capital of Meybod County, located in north-west of Yazd city, is a small historical city with a history longer than Yazd, even mentioned about 7000 years in some unofficial records. Because of its valuable historical fabric, the whole city is registered as a national cultural heritage site. (Official …, 2015) Meybod contains several ancient castles, caravansaries, water reservoirs and so on.

Mohammadabad double-stone watermill is located in west side of Mohammadabad village, in a semi-desert environment with little Tamarisk and Saxaul bushes, artificially planted to combat desertification. It is completely under the ground; with no significant sign above the ground. There is only a short hill around one of its five skylight holes. The hill is 2.5 meters in height and quite similar to many other small hills around the Qanat's vertical shaft outlets which are a general feature of the deserts around Yazd. Thus it's not easy to find the mill without a familiar guide.

3.2 History

Unfortunately there is very little information about exact history of this watermill. As to Iranian national cultural heritage organization's experts, the style of architecture of the lowest room of the mill, determines the construction date to the end of Safavid dynasty, about 1700 AD. The mill served the city of Meybod and several small towns and villages nearby. Because of its two separated millstones, the miller could adjust the capacity of the mill in different seasons according to quantity of orders. In 1963 after a huge flood, the mill stopped working and never reopened again. The gradual rise of industrial and electrical mills caused watermills to become obsolete. The mill was abandoned and has had no owner for long period. In the last years of the 20th century, "Water and wastewater Co." of Yazd province took over ownership and maintenance of this site. The mill was registered a national cultural heritage site in 2009, by Iran Cultural Heritage Organization. But even now, there is no barrier or special protection around the mill with heavy rains and floods threatening it every few years. Recently, the mill has been rented by a private tourism company who are now responsible for the maintenance and protection of the site. The last repairs and dredging were carried out in 2014. (Babaei Nodushan, 2009) Now the double-stone watermill of Mohammadabad has become a tourist spot for cultural and desert eco-tours in Yazd province.

3.3 Technical features

The main characteristic of the mill is its location; at a depth of approximately 40 meters underground. In fact, there was no construction above ground for this mill, it was all done by digging the earth. This means the technology used to build the mill is exactly the same as used to create a Qanat. Scratch markings made by digging axes can be seen clearly on the roof of the entrance corridor. During recent repair operations in 2009, the entrance of the mill was repaired with local bricks and cement, built in the same style of traditional construction in the region; it has lost its originality. At the same time, a series of 21 wooden frames have also been added to reinforce the flood damaged roof. The entrance to the mill is toward east. A 140 meters long corridor goes downward with a 25% slope and ends with an arced roof hall containing two millstones, hydraulic installations and two platforms for resting. The corridor's height ranges from 5.5 m at the beginning to 2.5 m at the end. Thus it was suitable for carrying grain and flour using livestock. This conical corridor supplies most of required light needed for milling during the day. There are also five vertical shafts running along the corridor that improve lighting to the mill and facilitate ventilation. The shafts have been dug in the same way as the Qanat's vertical shafts and have helped the construction team remove clod and mud easier.

Along the corridor, between the entrance and the mill's hall, there are 5 building elements with different applications used in the whole process of milling wheat and barley. From the entrance they are in order: (Figure.4)

1. Inspection room 2. Kitchen 3. Stable 4. Bascule steps 5. Garner

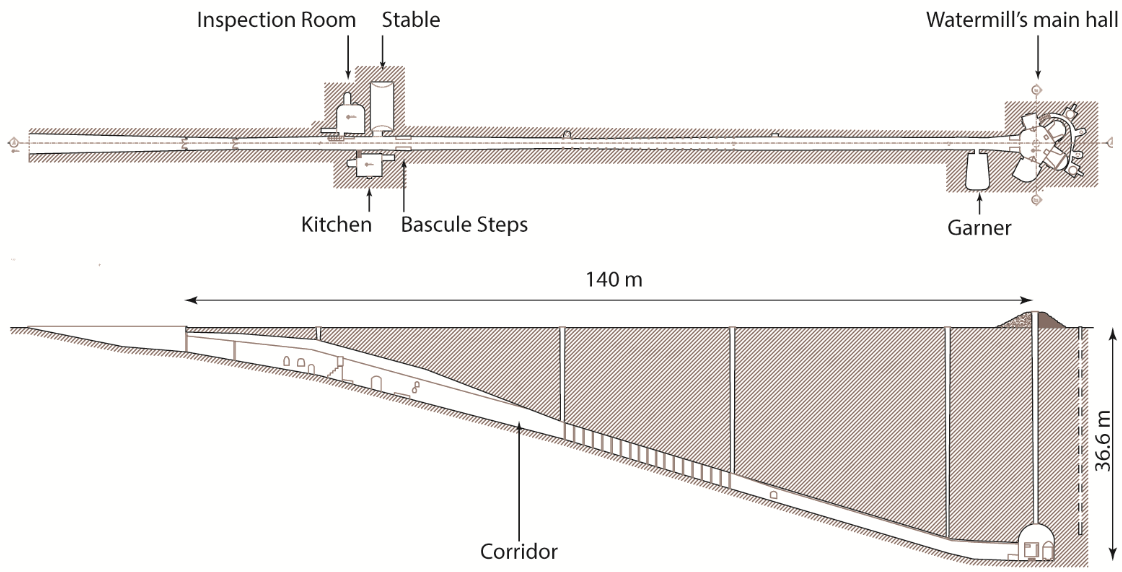

Figure.4 Plan and section view of Mohammadabad double-stone watermill (redrawn by the author)

The inspection room is a small room, dug in the left side of corridor. The room is about 180 cm higher than corridor's floor with five steps, all dug beside the wall and without using any other building material. The kitchen is located on the right side of corridor and about 190 cm above the floor, using six hand-dug steps. There are several niches and shelves dug in the walls around the kitchen. It seems that the height of the rooms has sanitary reasons, to be away from the direct touch of animals carrying grain and flour. The stable is the largest space with an area of nearly 30m2, at the same level as the floor. Bascule steps are two simple platforms, remaining from the original soil on two sides of the corridor, each has a 70 cm width, 170 cm length, and a 90 cm height. Their main function was to help with weighing the goods without releasing them from the back of the animals. The garner is the second largest space after the stable and has a different floor with a coating of lime, to protect the room against insects and vermin. (Babaei Nodushan, 2009)

In addition to these five main elements, there are also some niches in the walls of the corridor, to put small objects such as oil lamps for night lighting and a small platform in right side of the corridor for a short rest. The appendix includes several pictures from the present situation of the watermill, taken by the author.

4. Sustainability point of view

From the perspective of sustainability, Mohammadabad double-stone watermill is a collection of clever solutions to overcome environmental obstacles and achieve the most fully harmonized ways with nature and the environment. The sustainability aspects of the watermill can be listed as follows; some of these solutions are common in several other cases, and some are found to be unique in this watermill:

4.1 Definition of the mill

Watermills basically were a sustainability key for Qanats. Every Qanat needs continuous maintenance and periodic dredging that costs a lot during the year. One time investment to add a watermill on a Qanat, not only could cover the mill's and Qanat's regular and maintenance costs, but also made new revenue for Qanat owners. In some cases, earnings from a watermill was the investment in making a new Qanat. (Papoli Yazdi, 2000)

4.2 Water resource

As mentioned before, Qanats are a passive system and do not discharge underground aquifers. The water flow rate of a Qanat varies during the year and in different years. But can remain for hundreds and thousands of years, with good management and frequent maintenance.

4.3 Energy resource

All the required energy to move the millstones is supplied by water flow. A Qanat's water flow may vary during the year, but it remains continuous all year round. Thus the watermill can work nonstop. The operation of the watermill does not affect the Qanat's flow or output. In some cases, there is more than one watermill on the same Qanat. The most wonderful example of a Qanat is found in Boshruyeh, South Khorasan Province, which supports seven watermills along its 16 kilometers length. (Papoli Yazdi, 2000)

4.4 Construction and building material

The construction process of Mohammadabad double-stone watermill has used the same technologies and methods of construction as a Qanat. It's totally hand-dug, and mainly build without using any other building material. Rooms, platforms, and staircases are formed simply by removing unwanted parts of the original soil. The only element containing exterior material, is the mill's main hall and its hydro-mechanical installations.

4.5 Lighting

Although Mohammadabad double-stone watermill is located about 40 meters underground, it uses natural daylight as its main lighting source. Its conical sloped corridor directs daylight to the mill's main hall during the daytime. Besides their main role as ventilation, the four vertical shafts help with lighting as well. Oil lights were used at night, after working time.

5. Conclusion

As to the author's opinion; the most brilliant and wonderful sustainability key in many artificial phenomena remaining from traditional wisdom, including Mohammadabad double-stone watermill, is maximum efficiency and optimal use of natural characteristics of the environment and unwanted side effects.

A Qanat was originally an irrigation system and its role was for transferring water. In addition to agricultural use, this water was used for the charging of drinking water reservoirs, ice pits, and public bathrooms. But the Qanat's special characteristics; such as continuous water flow and relative lower temperature of the canals has attracted the attention of ancient technicians/scholars to find other applications to exploit these features as technical and economic opportunities.

Coolness of the current air in the Qanat canals is widely used to support the use of passive air conditioning systems, wind towers, to cool interior space of living areas, water reservoirs, and ice pits. It is also used directly to create private cool rooms, called Sardab, in the basements of larger houses.

The most wonderful peripheral use of a Qanat's water as a free and continual energy resource is watermill. There are several watermills located in Iran's arid areas, each with its own characteristics worth further study and investigation. Efficient use of the hydraulic power of a narrow stream of Qanat water in watermills is a brilliant idea by itself. But taking advantage of an unwanted elevation difference of water canal in depth of 40 meters underground presents a rare and unique masterpiece which reflects its creatures' deep insight, environmental wisdom and *Being Green in Desert*. This point of view and way of thinking can be the key milestone to define sustainability framework and guideline in contemporary design projects.

Appendix: Present situation pictures (The photos are taken by the author.)

Figure. 5 Outskirt environment of Mohammadabad Village

Figure. 6 Renovated entrance

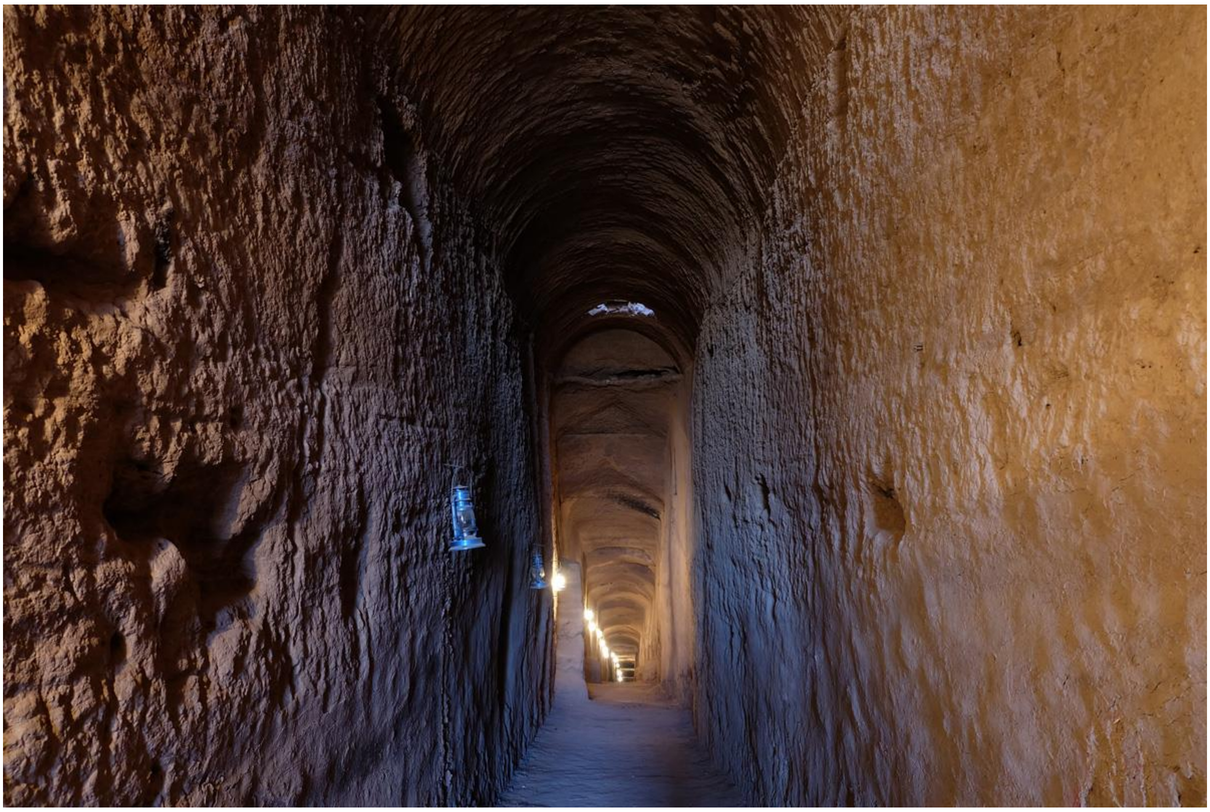

Figure. 7 The corridor’s view from the entrance

Figure. 8 Scratch markings made by digging axes on the roof of the corridor

Figure. 9 Hand-dug stairs to the inspection room

Figure. 10 Wooden frames added to reinforce the damaged roof of the corridor

Figure. 11 The main hall of the watermill and millstones’ original place

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