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The sustainable methods of producing, managing, preserving, and maintaining the water sources in the historical water monuments in ancient Iran

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ABSTRACT

This article aims to make a better understanding of the effective construction techniques in Iranian sustainable and historical water monuments 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. The present article targets at studying the Iranian artisanship involved in the construction of the structures which utilize the power of water as well as 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. Iran is located in an arid, semi-arid region. Due to the unfavorable distribution of surface water, to full water demands and fluctuation of yearly seasonal streams, Iranian people have tried to provide a better condition for utilization of water as a vital matter. This paper intends to acquaint the readers with some of the famous Iranian historical water monuments.

Introduction

All the ancient cultures were formed near the big rivers such as Nile, Dejle, Forat, Ganges, Huanghu, Yangtze, etc. The only culture which was not formed near any river was the qanat culture of Iran. The impressive development of Persian culture was due to its qanats and kareezes and the knowledge of hydraulics. In Acheamenian dynasty, the person who dug qanat in a barren land and water that land was exempted from paying taxes for 5 years. According to the historical documents remained, king Yasalar Parsi Skilasis Acheamenian, at the time of staying in Egypt, taught the techniques of digging qanats to Egyptian. At the time of the government of Sasanid dynasty, Hezar Dastan Madigan document described the way to construct qanat and its special techniques intelligently. Since, from the beginning of its history, Iran encountered several discontinuity of rainfall and the problem of supplying enough money to water the fields and to drink, constructing dams and water networks as well as qanats and kareezes was a normal and regular task to do. Thus, Iranian were the first to gain the knowledge of digging qanats and Iran was the first culture to use water agriculture and its techniques [5]. Also, they invented the most sustainable and useful way of using qanats. Then, the Iranian masters taught these techniques to the people of north of India, Africa, and Spain. In Iran, there were some very skillful dam builders who constructed the first arch dams like Izadkhast dam and Kerrit dam in Tabas Town which, with 60 meters height, was the tallest dam in the world before Hour Dam in the United States [4]. Iranian ancestors made many dams and hundreds of weir mills. They knew the evaporation of river flow in hot lands is high and, thus, the water loss is high. They, in addition, knew that if the river sediment is high in the river, the dam will be full of sediment and become useless. They knew that building excessive dams is a useless job, as it is an unsustainable, inefficient, and damaging tendency. They concerned about of the benefits of their own next generations not their pockets and welfare. Hence, they dropped out dam building as a technique of preserving water and continued to make use of sustainable techniques of preserving water such as digging qanats and weir mills as well as thoughtful water network [1].

Iran is located in an arid, semi-arid region. Due to the unfavorable distribution of surface water, to full water demands and fluctuation of yearly seasonal streams, Iranian people have tried to provide a better condition for utilization of water as a vital matter. Iran is located in the south of Asia between 44° 02` and 63 20 eastern longitude and 25 03 to 39 46 northern latitude. The country covers an area of about 1.648 million km^2.Iran is bordered on the north by Armenia, Azerbaijan, Caspian Sea and Turkmenistan; on the east by Afghanistan and Pakistan; on the south by Oman Sea, Strait of Hormuz and Persian Gulf; and on the west by Iraq and Turkey. Climatologically, Iran is situated in the arid and semi-arid regions of the world. Of the total area, 13% has a cold and mountainous weather, 14% has a moderate climate and the remaining 73% is covered by dry weather. The findings of archaeological surveys indicate that human being lived in various part of Iran as long as 15,000 years ago. Persia was a Cradle of Science in earlier times. The civilization in the western part of the Iranian plateau flourished 5000 years ago and they invented cuneiform writing. Discoveries prove that Iranians were peaceful and ingenious people in the second and third millennium BC who cultivated land and raised crops (Fig.1).

The first Iranian lived in meadows to feed their livestock. Some of them became familiar with techniques of irrigation and chose to be farmers. The importance of irrigation is pronounced in Iranian ceremonies, traditions and religious beliefs. Water has been depicted in many Zoroastrians and Anahit was believed as the Goddess of water. Lack of water in Iran affected the Iranian

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history and culture (Fig.2). Dam construction in Iran dates back to the ancient times. Iranians are credited for invention subterranean canals (Qanats) which is well-known in the world [2].

Fig.1. A historic picture remained from 1921 A.D of the watering network of Shah Abdo Al-Azim and Rey Town, between Tehran City and Rey Town.

Fig.2. Drawing watering from the hole in Isfahan City in about 1921 A.D.

Qanat (Kareez)

A traveler flying over Iran can see plainly that the country has an arid climate. The Iranian plateau is largely desert. Most of Iran (excepting areas in the northwestern provinces and along the southern shores of the Caspian Sea) receives only six to 10 inches of rainfall a year. Other regions of the world with so little rainfall (for example the dry heart of Australia) are barren of attempts at agriculture. Yet, Iran is a farming country that not only grows its own food but also manages to produce crops for export, such as cotton, dried fruits, oil seeds and so on. It has achieved this remarkable accomplishment by developing an ingenious system for tapping underground water. The system, called qanat (from a Semitic word meaning "to dig"), was invented in Iran thousands of years ago, and it is so simple and effective that it was adopted in many other and regions of the Middle East and around the Mediterranean [6].

The qanat system consists of underground channels that convey water from aquifers in highlands to the surface at lower levels by gravity. The qanat works of Iran were built on a scale that rivaled the great aqueducts of the Roman Empire. Whereas the Roman aqueducts now are only a historical curiosity, the Iranian system is still in use after 3,000 years and has continually been expanded. There are some 22,000 qanat units in Iran, comprising more than 170,000 miles of underground channels. The system supplies 75 percent of all the water used in that country, providing water not only for irrigation but also for house-hold consumption. Until recently (before the building of the Karaj Dam) the million inhabitants of the city of Tehran depended on a qanat system tapping the foothills of the Elburz Mountains for their entire water supply. In particular, the oldest and largest known qanat is located in the Iranian city of Gonabad which after 2700 years still provides drinking and agricultural water. Its main well depth is more than 360 meters and its length is 45 kilometers. Yazd and Kerman are also known zones for their dependence with an extensive system of qanats (Fig.3).

The main idea to construct the qanat was to access and transfer of groundwater by sinking a series of wells and linking them underground. Qanat or kareez is a technical method used to provide a reliable supply of water to human settlements or for irrigation in hot, arid and semi-arid climates [2]. The origin of this technology dates back to the ancient Persian Empire (Fig. 4).

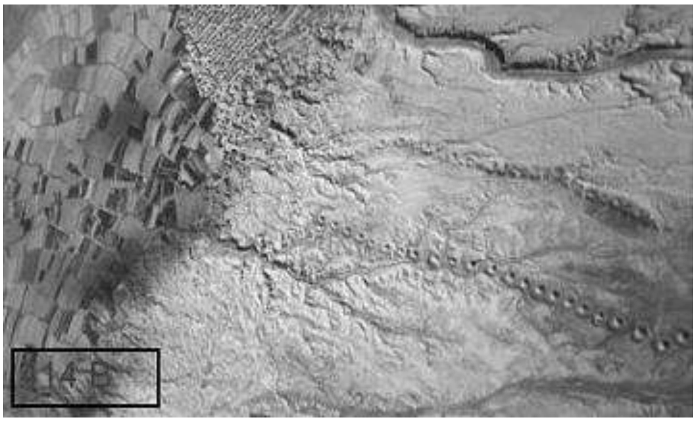

Fig.3. A historic picture of a qanat in 1971 A.D.

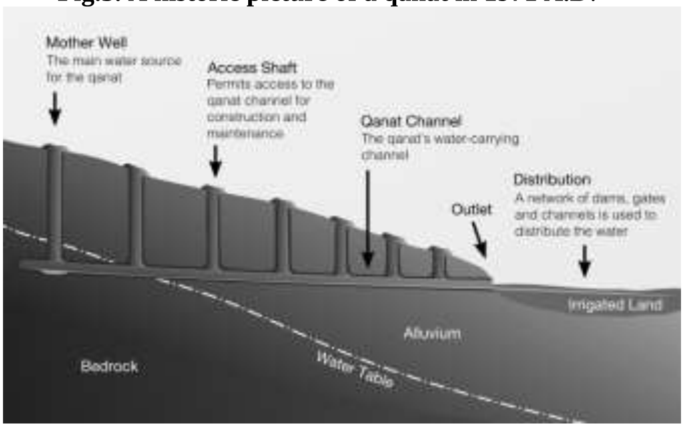

Fig.4. Qanat Construction.

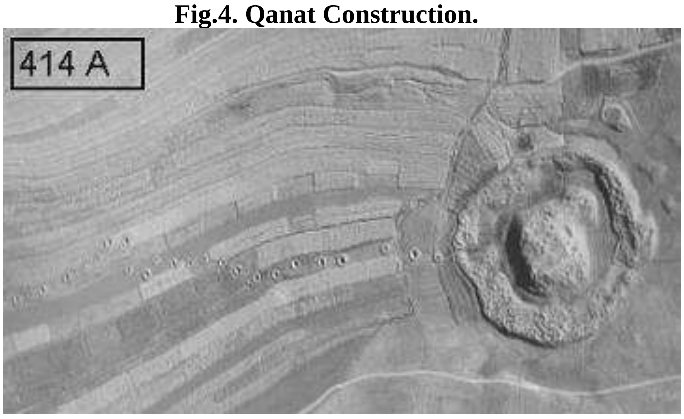

Fig.5. A view of qanats in Yazd Province

Persia is currently benefiting from 31000 active qanats (Fig.5) producing some 9 billion cubic meters of the ground water and forming some 15% of the aquifer discharge which is annually mined across the country. This huge amount of water is amazingly conveyed just by means of gravity. Since no electric or fossil energy is employed, this system is pollution free and bears no environmental contaminants. Qanat technology is not only an Iranian system of water mining, but also has overshadowed our economic, social and cultural outlooks since three thousand years ago. However due to the development of tube wells some of the qanats are going dry. Even then there are 50,000 qanats in Iran and nearly 75 % of them are still working [8].

Water Treatment System And Water Supply

No doubt, the initiative system of devising and constructing a potable water treatment in Chogha Zanbil, Khuzestan province is man's first invention for water treatment. The ziggurat of Choga Zanbil is one of the most impressive monuments of modern Khuzestan, and must have been one of the most impressive monuments of ancient Elam. Built by king Untaš-Napiriša (1275-1240) and named after him (*Dur Untaš*, "city of Untaš-Napiriša"), it measures 105x105 meters and was probably 52 meters high. It was to be the center of a new town, which was to become the king's residence, but was never quite finished. Still, the town survived its builder with more than two centuries, and there must have been people living in Dur Untaš well after 1000, because the Assyrian king Aššurbanipal was to claim in 646 BCE that he had destroyed the town, which suggests that there must have been something to destroy. The town measured about one square kilometer and was surrounded by a four kilometer wall. It was built on high ground, more than fifty meter above the nearby river Eulaeus (Dez), which made it difficult to bring water to the city. The solution Untaš-Napiriša found, betrays his ambitions: he ordered his people to build a canal to Susa, where fresh water was diverted from the Choaspes river (Karkheh). It passed along Haft Tepe, was diverted into nine branches, and finally reached the town. Unfortunately, the water of the Karkheh is full of mud and, because it was downstream from Susa, not very healthy. So it was necessary to clean it before it could be used in Dur Untaš. Therefore, refineries were built in which the water was conducted through several basins. Even by today's standards, this is a remarkable piece of engineering. The refinery that has been excavated, is the is oldest one known monument of this type in the world. Transfer and distribution of water in the past was performed using earthenware pipelines. This system was also used in the Takht-Jamshid Palace just to discharge the sewerage network and it can be seen that this method was not changed so much during the past 2500 years (Fig.6&7). The oldest physical water treatment system in the world named in Chogha Zanbil (Fig.8) was built approximately 3000 years ago that located next to the Ziggurat of Chogha Zanbil in city of Susa [7].

Water was transferred from Karkheh River (on the west of Susa) to a sedimentation basin and then the town over a distance of 45 kilometers via an open canal. The reservoir with dimensions of 70.1 m length, 7.25 m wide and 44.35m depth has a capacity of 350m^3. Materials such as tar and brick were used for building the structure. Once the reservoir was lled to maximum level, the physically treated and de-silted water owed in to the basin (located at a higher elevation) via the nine mentioned conduits.

Fig.6. The above hole, which is made of stone, is one of the solutions made by designers of Takht-e-Jamshid structure in order to direct the river outflows [author, 2012].

Fig.7. The general layout of the open air water ways in the Takht-Jamshid palace.

Fig.8. Physical water treatment basin, Chogha Zanbil temple [author, 2012].

Dam Building

Iran is located in an arid-semiarid region. Due to the unfavorable distribution of surface water, to full water demands and uctuation of yearly seasonal streams, people have never ceased their endeavors to provide a better condition for utilization of water as a vital matter. Dam construction in Iran dates back to the ancient times. Iranians carefully considered the three basic factors, site selection, and foundation condition and construction materials. In all cases, they fully observed all design and technical requirement and circumstances in the dam site and site selection. Topography and river diversion during reconstruction were also profoundly attended to dam [1].

a. Gheisar (Shadorvan) Weir mill in Shushtar

The construction of the weir mill is attributed to the Sasanid Era. It is the oldest bridge in the world, which has 44 gates and about 50 percent of it was reconstructed. According to the Eastern documents, Shapur I, Sasanid ruler, had Valerianus help in building the dam near Shushtar Town. The dam was built in about 1500 years ago and still is being used to return the Karun River flow to the agricultural fields. It is most likely that the Iranian rulers made Gondi Shapur and Shushtar areas the homelands of Roman captive soldiers. Iranian used to care much about the Roman knowledge about dam building. Thus, there is no doubt that the construction of this dam and bridges was done with a heavy reliance on Roman Engineers (Fig.9).

Fig.9. Shadorvan weir mill, the spatial situation of the structure near the northern and southern parts of Shatit River.

b. Mizan weir mill

Mizan weir mill is like a dam, which is located in Shushtar and was built manually by the residents of that area. It was originally constructed Sasanid Dynasty and is still survived. Some think that Mizan weir mill was constructed following the order of Shapur I of Sasanid. This weir mill divides the Karoun River into two and four branches between Gar Gar and Shatit. Gar Gar River is also called Dodange (two-gate) or Mosraghan and Shatit River is also called Chahardange (Four-gate). The weir mill was constructed by stone (made in Shushtar) mortar. By taking a review of shushtar history, the importance of this weir mill can be understood. On the one hand, breaking this weir mill was the messenger of poverty and destitution and, on the other hand, it was the means of watering about 40,000 hectares lands of Miyanab Town of Shushtar. The weir mill constitutes of many gates in a way that if the water flow of the river exceeds one third of the whole river flow, the river flow is partly transmitted to the adjacent branch and vice versa. This point makes the structure unique in the world's architecture (Fig.10).

Fig.10.This weir mill divides the Karoun River into two and four branches between Gar Gar and Shatit [author, 2012].

c. The amir weir mill

Amir Weir mill is located on the north of Takht-e-Gheisar Town and is attributed to the Sasanid Dynasty architecture. The weir mill with its valleys and holes on the west of the valleysand its near buckets has made a perfect system which surrounds the religious area of the land. The main role of the weir mill was to direct the river upsurges in order to be used in the farms. The weir mill was made of cube and carved stones, which are stuck together with mortar. Takht-e-Gheisar is considered as one the greatest ancient sites of Shushtar, though is still unknown for many (Fig.11).

Fig.11. Amir multipurpose dam (Dam, bridge and mill); Age:2000 years.

All Iranian ancient dams are masonry of the following types:

a. Gravity dams

Studies indicate that all the design criteria considered in the recent design of gravity dams were taken into the consideration in the design of Iranian ancient dams. Saveh and Sheshtaraz dams which are over 700 and 900 years old respectively are examples of this type.

b. Arch dams

Iranians perceived the high bearing of arches before Romans. Kebar (one of the oldest arch dams in the world has a height of 26m, a crest length of 55m and a thickness of 5m with an arch radius of 38m which proves the skills of Iranians in dam construction) and Kerrit dams over 700 and 400 years old respectively are both arch dams (Fig.12).

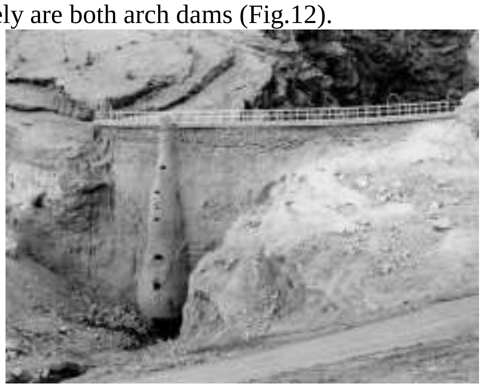

Fig.12. Kerrit Dam. Tabas, Iran [author, 2012].

c. Buttress dams

Akhlemad dam (Fig.13) with a crest length of 230m, height of 12 m and reservoir capacity of 3 million cubic meters and Fariman dam (Fig.14), 400 years old, are both buttress dams. Both dams are still under operation. A quick glimpse at what is the remains of the past, reveals ity of ancient Persians in water engineering and hydraulic works. Arch dams built from excellent materials, some of them 1000 years old, are still functioning here and there, each being a genuine masterpiece.

Fig.13. Akhlamad dam is one of historic structures of Iran in khorasan Rasavi province which has been built on Akhlamad River. In spite of 700 years old this ancient structure has been good resistance to failure.

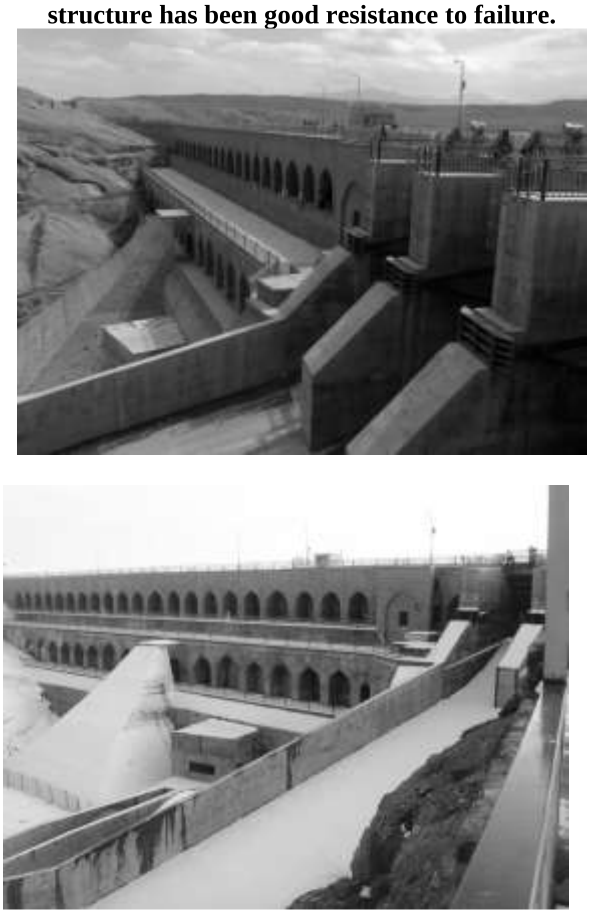

Fig.14. Fariman dam, khorasan Rasavi province, Iran. It has been built on Fariman River and belong to Teimorid dynasty.

Water Mills In Yazd (Middle Of Iran), Dezful And Shushtar (Southern Part Of Iran)

a. Sustainable architecture of the water mills in Yazd

One of the skills of ancient Iranians was to make use of the water s hidden power to rotate the stones of the watermills. The roof of a watermill building was usually a dome. Light and air were supplied through a door. The watermills were powered by the river currents, springs or qanats. Water mills were connected to the water sources by canals. A conduit just before the mill shaft would act as a bypass when the mill was not in operation. The mill shaft is semi conical in shape and its diameter reduces from top to bottom. This shaft can be plugged by a wooden device which is accessible through a narrow gallery from inside the mill [8].

The wooden turbine consists of a wooden axle, the diameter of which increases gradually from top to bottom. It has a lower iron tip housed in a pit in the lower millstone, acting as the turbine support. The upper iron tip of the axle is fixed in the upper millstone. This axle is surrounded by some paddles and the whole system is known as the turbine wheel. When a water jet impinges forcefully on the turbine wheel, it rotates, and this in turn causes the upper millstone to be turned. The lower millstone is stationary and the rotation of the upper stone on the lower grinds the grain. There is a hole in the middle of the upper stone, which discharges the grain into the space between the two stones. The two millstones are not truly horizontal, but are slightly inclined which helps the flour to be easily discharged into the flour bags (Fig.15).

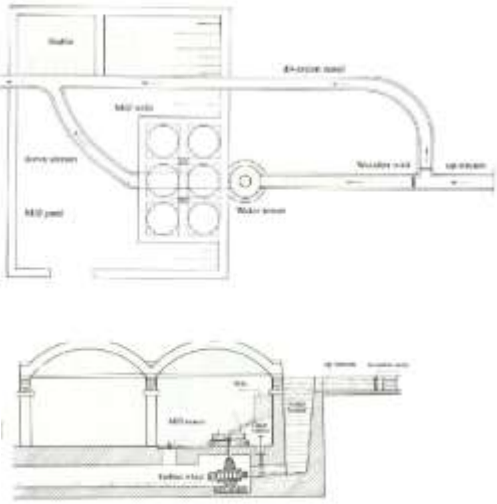

Fig.15. A brief map & Longitudinal of water-mill in ancient Iran [Authors]

The grains are stored in a silo located at the top of the watermill and are discharged through a wooden hopper into the hole dugout in the upper stone. By the rotation of the upper stone and the continuous strokes on the hopper, the grains in the silo discharge down. The water is guided out through a conduit built below the watermill (Fig.16).

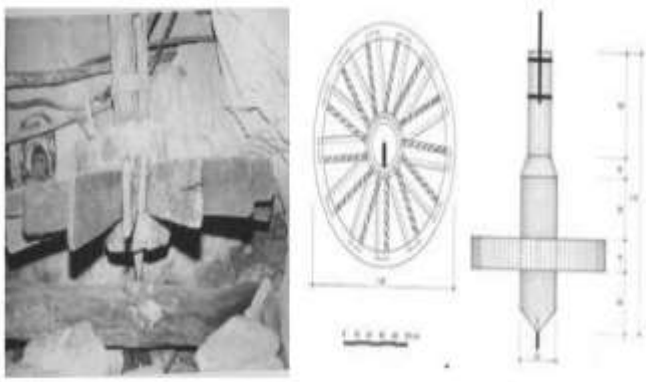

Fig.16. Water mill paddles in Taft in Yazd province. The turbine wheel of a water-mill in Iran [Authors]

Some parts of the roofed mill compound are designated for the cleaning and screening of the grains and our production. A space is also foreseen to lodge the animals, which are used to transport the flour bags. The Gar-Gar and Amir Weir mills were powered by the reservoir water. Kashan towns Fin-garden watermill was rotated by a spring, whereas Double Stone Water Mill of Mohammad Abbad Meybod (Fig.17), ancient watermill of Ashkezar, 15 km away from Yazd, and the two hundred year old Taft watermill were all, powered by the neighboring qanats.

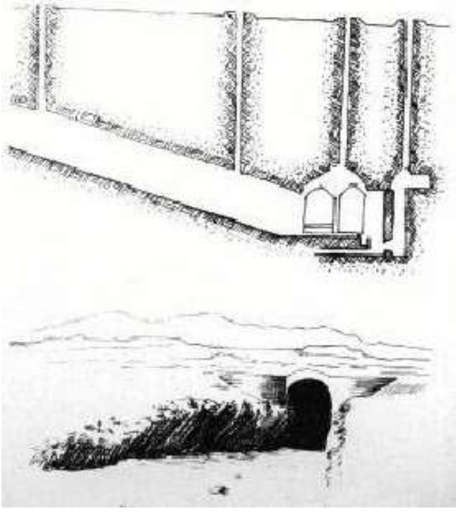

Fig.17. Entrance of double stone water mill of Mohammad Abbad in Meybod.

Double Stone Water Mill of Mohammad Abbad Meybod is an amazing hydraulic structure is absolutely unique. It has been created at the depth of 40 meters on qanat gallery in order to grind grains into flour (Fig.18). The neighbouring oases supplied their consuming flour from this 150 year old water driven structure. No construction materials had been used to establish this marvelous mill. The vestibule of the mill is so high that even camels could move back and forth easily and the lateral stables would room cows, donkeys or camels to carry flour. The mill is remotely situated in a deserted area some 8 km. out of Mohammad Abbad village which is 50 km. from Yazd. Dust and slime had led the mills long narrow passage gradually in the course of time due to flood waters which was unblocked by the regional water authorities who made a lot of endeavors to excavate it. This mill is open to visitors at present.

Fig.18. Double stone water mill of Mohammad Abbad in Meybod.

b. Sustainable architecture of the water mills in Dezful

Dezful watermills are built in two floors (Fig.19), of which the first floor was the place for the installation and the second floor was the place for grinding the wheat. The border between the two rooms was a roof, made of wood and covered by thatch. The design of the wall was in a form that wooden lumbers, with 10 to 15 centimeters width and 200 centimeters length, were put in the wall from the two ends to 20 centimeters deep in the wall. Then, it was covered by cane and the canes were covered by thatch and cane leaf. At the end, they were all incrusted by a layer of mortar or lime. The mortar was troweled so that it becomes smooth and uniform on surface. After drying the mortar, a smooth and nonporous surface was produced for the wheat to be collected on.

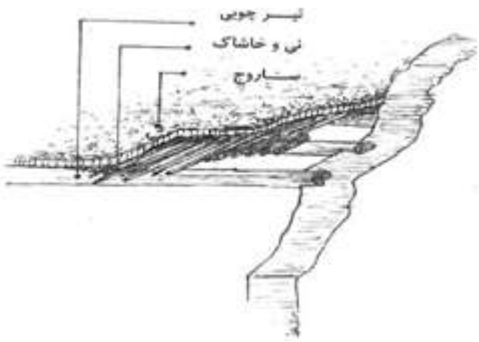

Fig. 19. Dezfoul watermills are built in two floors. In the lower floor, the installaions were located. The upper floor was the place that the grains were ground. [Author]

The wall façade, which formed the outer face of the structure, was made of brick, whose inside was filled with a mixture of mortar and bed river pebble which were abundantly available on the bed of the river. Sometimes, the outer façade was built with a blend of pebble and brick. This type of building administration was adopted from the style of Sasanid bridge construction in Dezful, which its remnants are visible under Dezful Bridge. Dezful watermills were designed in two forms: doublet (or single) watermill and pair watermills (Fig.20). Single watermills were the mills which had only one millstone to operate. That is, they had one single room, called single-stone. Pair watermills were the mills which had two rooms and were also called two-stone [11]. The two rooms were separated from each other by a blade of brick wall. The general aspects of all of these watermills are the same, a two-floor structure with a ship-like nose (Fig.20). All the watermills were connected to each other as well as the river bank by some bridges. With these bridges, people could carry their wheat, barley, or other grains by horse or other cattle to exchange with flour. The point is that the cattle were stopped near the bridges and, for the rest of the way, the packs of grains were carried by the workers, because the bridge paths were narrow and the cattle could not turn around on them. Dezful watermills were all constructed on the bed of Dez River, which has a conglomerate structure. The hydraulically powered structure on the Dez river bed is considered among the firmest conglomerate structure, which in rigidity is similar to concrete [12].

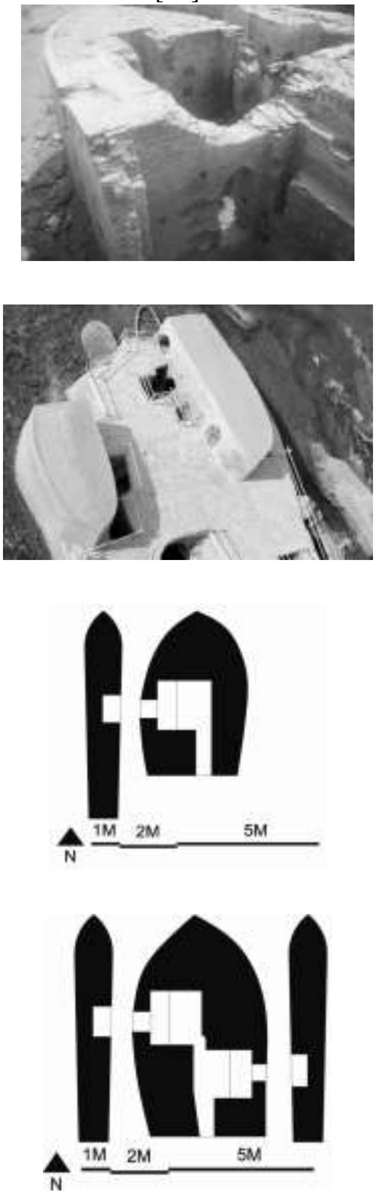

Fig.20. Dezfoul watermills were built in two forms, single watermills and coupled watermills. The nose of the wave breakers were likethe prow of a ship so that the watermills could resist against the powerful flow of the river [Author]

c. Shushtar water mills

Another important group of mills that survives are below the huge Sasanian dam at Shushtar, which was illustrated by Madame J. Dieuelafoy in the nineteenth century while some of these remained working up to 1970s (Fig.21). This weir-bridge located in the city of Shushtar, located 400 meters downstream of the Band-e-Mizan weir and upon the Gar Gar River is a weir-bridge which was built with the purpose of retaining water at a specific elevation. Three main canals and several ancillary canals have been excavated in the sandstone foundation of this structure in order to supply the water required to run at least 32 water mills. Currently the water once used for the running of the water mills flows unhindered in the form of striking waterfalls.

Fig.21. Remains of Sasanid mills at Shushtar (Mirdanesh, 2007).

Water Warehouse (Ab Anbar)

To withstand the pressure the water exerts on the containers of the storage tank, the storage itself was built below ground level. One important aspect to consider here is their resistance to earthquakes. Many cities in Iran lie in a region that have been struck with massive earthquakes. However, since almost all ab anbars are subterranean structures capped barely above ground level, they inherently possess stable structures.

The construction material used for ab anbars were very tough and extensively used a special mortar called sarooj made of sand, clay, egg whites, lime, goat hair, and ash in specific proportions, depending on location and climate of the city. This mixture was thought to be completely water impenetrable. The walls of the storage were often 2 meters thick, and special bricks had to be used. These bricks were especially baked for ab anbars and were called Ajor Ab anbari. Some ab anbars were so big that they would be built underneath caravanserais such as the ab anbar of Haj Agha Ali in Kerman. Sometimes they would also be built under mosques, such as the ab anbar of Vazir near Isfahan. The bottom of the storage tanks were often filled with heavy metals for various structural reasons. The 18th century monarch Agha Muhammad Khan, is said to have extracted the metals from the bottom of the Ganjali Khan public baths to make bullets for a battle. Subterranean water reservoirs (Ab Anbars) are historic hydraulic structure of Iran for drinking water supply that still persists in some regions of Iran [13]. The main purpose of this structure was supplying water demands of the passing caravans as well as people living close by.

Subterranean water reservoirs were cylindrical in shape (Fig.23) with arched ceiling and usually located in arid lands. In some regions, wind towers are also built for cooling and aerating water. Access to collect water was by a staircase going deep down to the lowest level of the reservoir. The storage capacities of these reservoirs vary from 300 to 3000 m (Fig. 22).

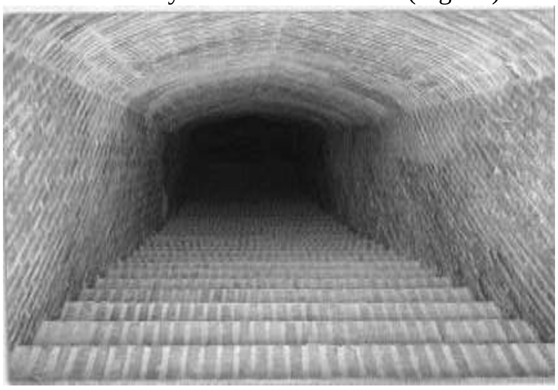

Fig. 22. The above water reservoir was considered as a water supplier for the residents of Lavarestan Town, Fars Province, Iran.

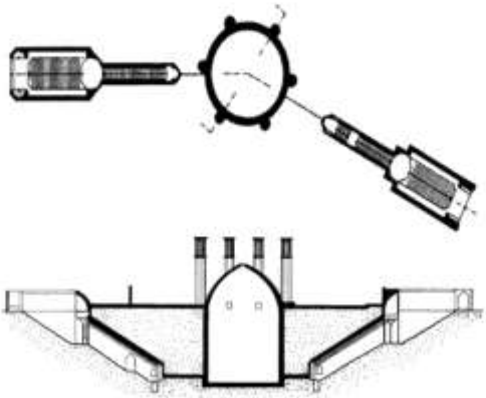

Fig.23. The plan and profile of a water reservoir in Sheshbadgire, Yazd, Iran. It has two stairways: one for the entrance of Moslems and the other for the Zoroasters. The adjacent land was considered as a backbone which resisted against the force of water flow toward the reservoir and its top dome

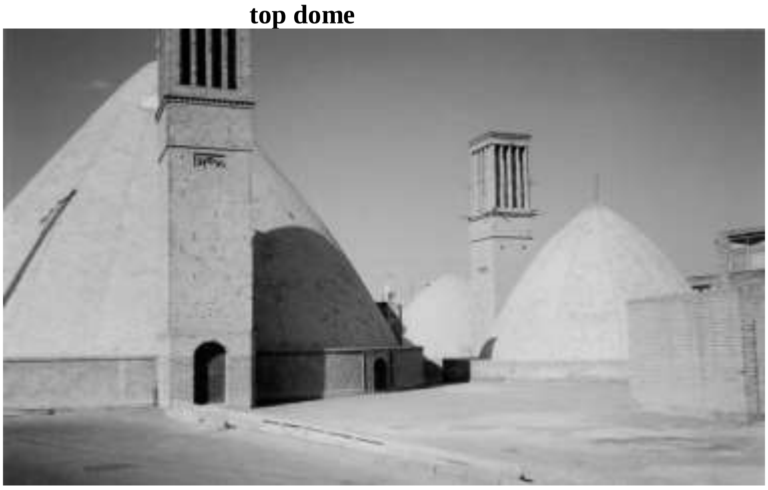

Fig.24. An ab anbar located in the Iranian desert city of Naeen.

Yakh-Chl (Ice-Houces)

Icehouses were buildings used to store ice throughout the year, prior to the invention of the refrigerator. The most common designs involved underground chambers, usually man-made, which were built close to natural sources of winter ice such as freshwater lakes. During the winter, ice and snow would be taken into the Icehouse and packed with insulation, often straw or sawdust. It would remain frozen for many months, often until the following winter, and could be used as a source of ice during summer months (Fig.25). This could be used simply to cool drinks, or allow ice-cream and sorbet desserts to be prepared [14]. The common use by the Persians of ice and snow for cooling drinks and food was reported by John Fryer in the late seventeenth century:

… They mightily covet cool things to the Palate. Wherefore they mix snow, or dissolve ice in their Water, Wine or Sherbets… [16].

he wrote (and of Isfahan):

... the Poor, have they but a Penny in the World, the one half will go for Bread, and dried Grapes, and the other for Snow and Tobacco...

This ice was from the ancient times used for the making of Faloudeh (the traditional Persian ice cream). In 400 BC Iran, Iranians had mastered the technique of storing ice in the middle of summer in the desert. Yakh-chl was a large underground space (up to 5000 m) that had thick walls (at least two meters at the base) made out of a special mortar called Sarooj, composed of sand, clay, egg whites, lime, goat hair, and ash in specie proportions, and which was resistant to heat transfer. This mixture was thought to be completely water impenetrable. The space often had access to a qanat, and often contained a system of wind catchers that could easily bring temperatures inside the space down to frigid levels in summer (Fig. 26).

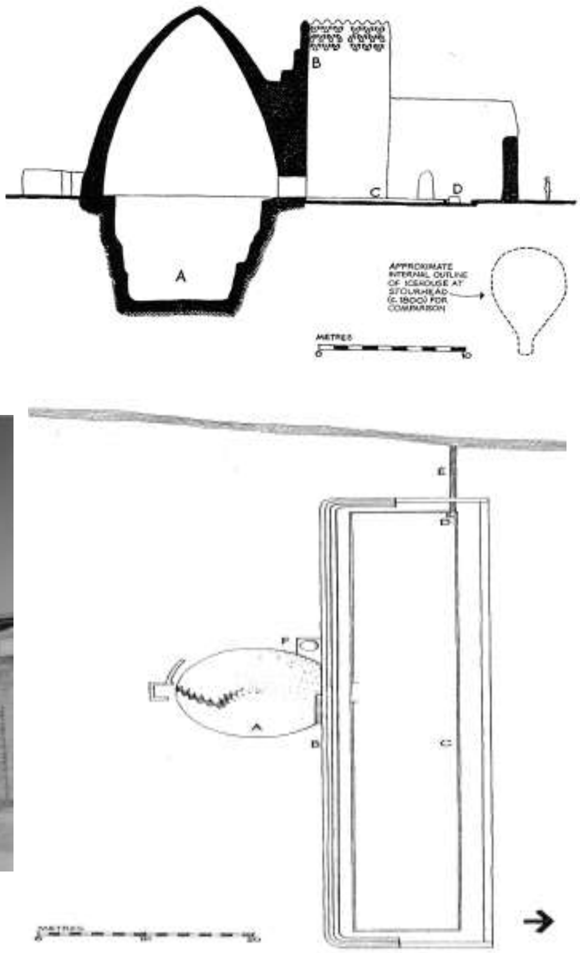

Fig. 25. Cross section of a Yakh-chl

Fig.26. Arg-E-Bam ice-chamber in Kerman province

The method of ice production is interesting. The long shallow channel to the north of the shade walls is poured with water during the winter nights, when the weather is very cold in Iranian desert (Fig.27). As the temperature of the earth and the water is higher than the sky during the night hours, the water will lose its heat and can easily freeze till next morning. The amount of water in the shallow channel depends mostly on the clouds. If the weather is very cloudy, the depth of the water in channel would be small so that it can freeze easier [15]. (Clouds act as an isolation layer for the exchange of cold and heat) .Before the sun rises, the ice made in channels is crashed into pieces as the smaller pieces lose heat faster than the bigger ones. They are moved to the vast domed wells afterwards. The depth of the wells stabilizes the temperature. So during the day, the changes of temperature would not affect the ice pieces. On the other hand, the height of the dome above the well lets the inner hot air stay at higher levels during the day while the lower parts are still cold. The material used to construct the building is from rammed earth with mud bricks which avoids the heat passes through the Icehouse easily during the day. Meanwhile it is made of the earth which was excavated to form the channel. So it is beneficial too. High mud brick walls to the north of the domes are used to spread a vast shaded area on the channel during the day. So it prevents the earth on the channel area from absorbing the heat as much as in the other parts. Therefore, the water could freeze sooner during the night. Here are diagrams analyzing the flow of hot and cold air in the building [17].

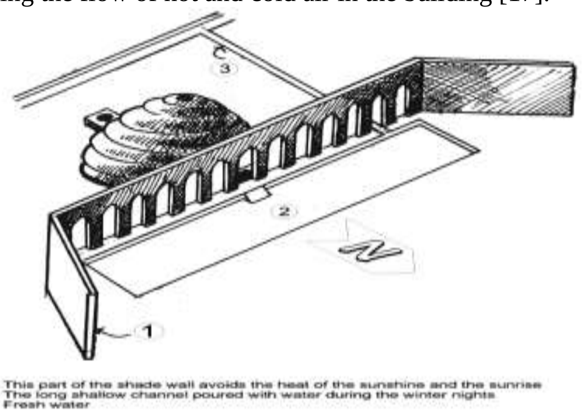

Fig.27. Perspective of an Icehouse with the shade wall and the shallow channel [author, 2012]

Conclusion

The unique fabled artistic background of Persia makes up for the seemingly lack of natural resources and beauty. 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. 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.

This paper intends to acquaint the readers with some of the famous Iranian historical water monuments. Observing the introduced structures reveals the deep insight of engineering sciences and making efficient employment of available regional materials in ancient time. Qanats, water mills and old dams have been utilized for centuries and compatible with the modern progresses of the engineering sciences. Yakh-chl (Ice-Chamber) does not have any application today but architectures can utilize some architectural principles and methods of exploitation for designing modern structures. Subterranean water reservoirs (Ab Anbars) can still be used in deserts and arid regions for supplying water demands. Due to the unfavorable distribution of surface water, to full water demands and fluctuation of yearly seasonal streams, people have never ceased their endeavors to provide a better condition for utilization of water as a vital matter. Dam building is a symbol of the widespread engineering methods, precision and accuracy of the past generations that their knowledge and experiences disclose to their modern age descendants. I hope that this paper can be a step forward to inform readers with a shortage review of water situation and some of the reputed historic hydraulic structures across the country of Iran.

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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