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APPLICATION OF TRADITIONAL ARCHITECTURAL STRUCTURE AS SUSTAINABLE APPROACH TO MITIGATION OF SHORTAGE WATER SUPPLY IN DESERT REGIONS

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Qanat is a traditional structure providing more than 15 percent water supply of Iran. In this research definition, history and structure of the Qanat were investigated and underground water management and community analysis of this structure were assessed. Results indicate Qanat is a vital lifeline of 75 percent of local people in dry regions that needs more research and awareness in contemporary issues. Architectural masterpiece of this structure demonstrated how indigenous knowledge of ancestors came over to effects of natural disasters such as severe droughts, water crisis, desertification, and soil and water sanitization as common subjects of these areas. Practical implication was proposed.

Keywords: Qanat, Architecture, Groundwater management, Community analysis.

1. Introduction

The Qanat technology was developed in Iran's arid regions to make use of groundwater resources for agriculture and habitation. Groundwater is brought to the surface without mechanical means, relying upon gravity alone. Water flows to the lowest levels and is then transferred to area where it is most needed, especially for agriculture. The techniques of Qanat construction were so widespread in Iran that they were included in the book later written on the science of hydrology. The antiquity of Qanats is not yet exactly established but the Qanat of Jopar near Kerman city (which is associated with the worship of Anahita the water goddess) is estimated to have existed as far back as 1200 BC. Studies in north-Western Iran, had established the presence of Qanat as far back as 800 BC. It is also estimated that in about 525 BC, Qanat exited in the coastal borders of the Persian Gulf including the Sultanate of Oman.

Historical evidence shows that Qanat were in use in Iran during the Achaemenian period (c.625 BC) and the technology was transferred to Egypt then. Historical records show that in the Parthian period (205-212 BC), Qanat were destroyed in strategic areas to hold back Roman occupation. Tabbari described Qanat in the Sassanid period though the actual location has not been mentioned. In the year 828 AD the Abbasiad caliph built a garden near Baghdad which was irrigated by Qanats. Karaji discussed the principles of the earth's gravity and flow of surface waters nearly a thousand year ago which shows that at that time Iran had knowledge of underground water. Inclined horizontal wells gradually replaced vertical wells for bringing water to the surface.

There are records that this technique later spread from Iran to other regions of the world such as North Africa, Spain, Cyprus, Sicily and other countries.

In 500 BC, Qanats were recorded in Egypt, in 750 AD in Madrid, in 850 AD in the south of Algeria, in the year 1520 AD in Los Angeles, in 1540 AD in Chile, in 1780 AD in Turkmenistan. Some of the archaic and reputed Qanat of Iran is as follows. The longest Qanat is mother well 400 m in depth. The oldest Qanat is believed to be of Sanabad in Mashhad dating back 1200 years. The Qanat of Ardestan is two stroyed and the Qanat of Vezvan has an underground dam.

The importance of Qanat to arid regions where annual rainfall does not exceed 150 mm has been well established and Qanat maintain their importance in these regions to date. Qanats were the only means of using water for several centuries and have contributed to the forming of civilizations manifests unique cultural, socio economic and political characteristics and the knowledge of how to live with deserts.

2. Methodology

The qualitative methodology has been used in this study. The secondary data was compiled from various sources including journals, books and websites regarding the Qanat structure around the world. In this study definition and history of the Qanat were provided and natural and community resources of Qanat were analyzed. According the results practical implication was proposed.

3. Results

3.1. Definition

Qanat is a system of water supply consisting of an underground tunnel connected to the surface by a series of shafts which uses gravity to bring water from the water table to the surface. Qanats are usually dug where there is no surface water and were originally invented by Iranians.

The main or mother well is generally excavated in the mountains penetrating deep into the water table. Water runs down a slightly slopping tunnel gradually increasing in volume until emerges near farms or communities. Water from Qanats is brought to the surface where the soil has been enriched by sediments from alluvial fans. Cultivated land and settlements sites are situated downwards from the point where the Water surfaces. The immediate outlet, Mazhar (emerging point of water) is the point where people take water and it is well kept and cemented and water use is monitored. A tunnel or Payab channels water under the residential area to the cultivated land. A sloping corridor with steps leads from the surfaces to the Payab. The first Payab is located in the main square and is used for taking drinking water. A network of smaller Payabs runs from the main Payab.

Qanats are also known as Karez (Afghanistan), Galeria (Spain), Khotara (Morocco), Aflaj (Arabian Peninsula), Foggara (North Africa), Kanerjing (China) reflecting the widespread dissemination of the technology across ancient trading routes and political maps.

3.2. Qanat in Iran and World

Qanat technology exist in more than 34 counties in the world but most are concentrated in present day iran, which has about 32164 active system with a total discharge of about nine billion cubic meters(m3). The first recorded Qanats were dug in the north-western areas of Iran and date back to 800 BC.

Science Iran has few perennial rivers and surface water resources many of its communities have depended on Qanats for thousands of year. This unique and environmentally sustainable system has created cultural and natural ecosystems that ideally addressed the specific needs of each community.

Digging Qanats involves a huge amount of work and engineering skills originally developed in Iran and exported across the world.

The Qanats of Iran have a special riche in the cultural social, economic, political and physical landscapes of the country. Without these kinds of hydraulic structures thousands of villages and towns would not have been them at all. Although life in Iran has changed radically over the centuries, Qanats have maintained their importance and significance at the heart of community well- being and survival of many communities in that country.

Qanats of Bam is one of convenient sample for demonstrating different aspects of this structure, which is explained as following.

On December 26, 2003 a powerful earthquake struck Kerman province in south- central Iran, killing 26,000 people, injuring many more and almost totally destroying the historical structure of Bam city. The earthquake also brought world attention on the wealth of that region's hydro geological, archaeological and geo historical culture, which had been well known to the ancient world but forgotten in the global rush towers modernity.

Within days after the disaster a huge international relief effort was launched. At first, efforts were focused on saving lives and providing emergency service but once the situation has stabilized, attention moved to broader interventions to strengthen traumatized communities cultural and social capacities to cope with the disaster and to rebuild infrastructure necessary for them to re establish their livelihoods and their lives.

Studies undertake soon after the earthquake revealed thousands of hectares of archaeological remains, these had not been disinterred by the violent actions of the earthquake but had been scattered across the surface abandoned for hundreds of years. Ongoing archaeological investigations reveal that the area is even more significant than had been believed when UNESCO was preparing the Bam dossier for submission to UNESCO's World Heritage Center. The Bam area seems to contain the oldest extant Qanats in Iran and perhaps in the world. The technical advantages of the natural setting of Bam which is located on a plain between two ranges of mountains , were progressively understood and exploited by men who played if not the leading role at least a significant part in the process of the invention and development of Qanats. Atmosphere.

3.3. Structure of Qanats

The structure of Qanat is simple. It consist of a tunnel running through an incline with many vertical wells that from air passages allowing for required operation such as excavation and dredging .this forms the basic pattern of Qanats, but from a structural point of view they can be divided into two main types.

- Mountain type: Qanat that use water resources from mountains regions.
- Plain type; Qanat that branch out from rivers.

Qanats are synchronized with the climatic conditions of the region. If average annual rainfall is heavy, the length of the Qanats is shorter and the mother wells are not deep. Where rainfall is scare the length of Qnanat increases and so does the depth of the mother well. In general, the depth of the mother well and the length of Qanats in mountain regions are less than those in the plains. The amount of water they provide is variable and depends on rainfall levels.

Qanat are categorized according to the flow, depth of the mother well, type of construction and geographical environment. Qanat in the plains and from mountain springs may be classified as those that: 1) run parallel or 2) run successively.

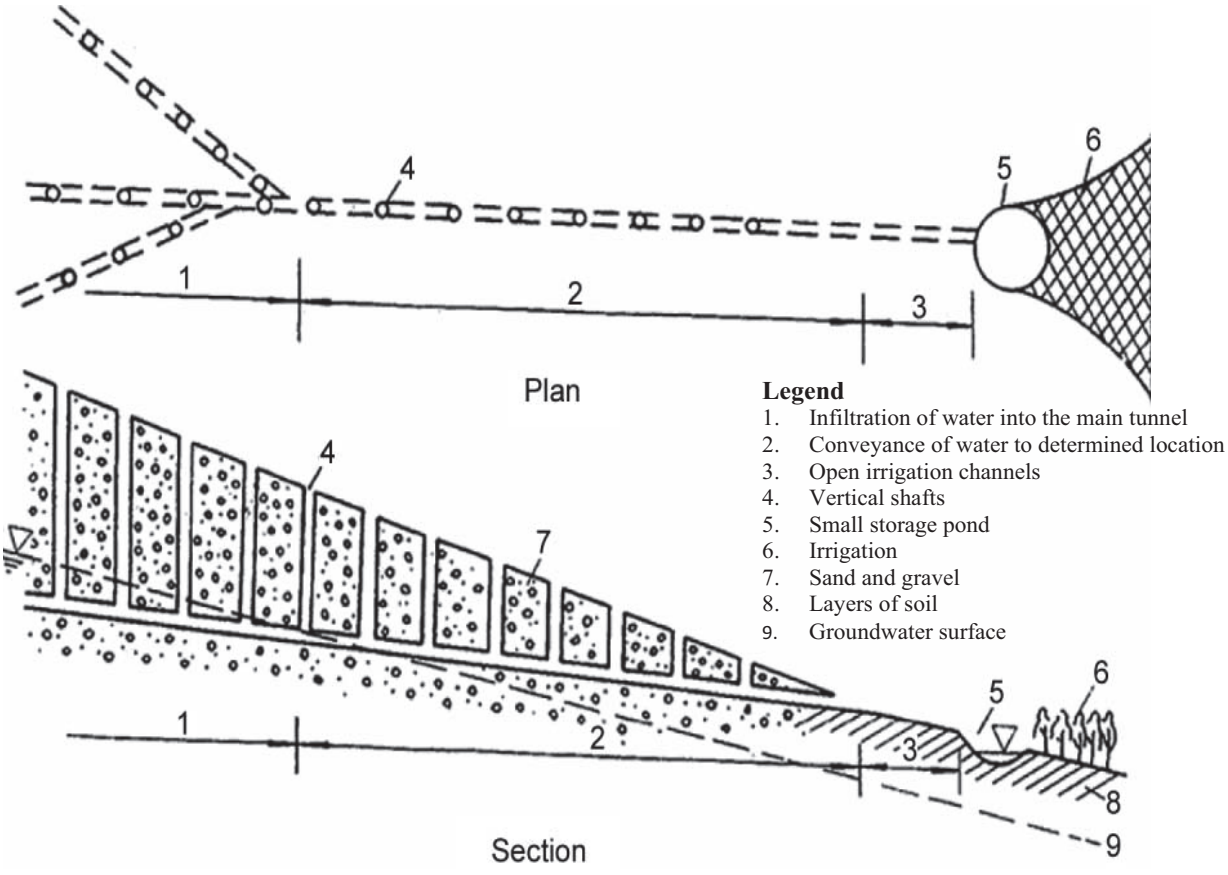

Figure 1. Plan of Qanat and its structure.

3.4. Groundwater Management

Qanats are mostly drug in places where there is no permanent and reliable water on the surface. Techniques for digging Qanats date back some 5000 years or more in Iran and the structure has tremendous social as well as practical significance. Comprehensive integrated and multi dimensional systems of water use were developed in many villages and town and were regulated by customary laws, some of which were written down. Different Qanats sometimes have different systems of water use for domestic consumption and for irrigation.

The following key issues are essential when using Qanats as a groundwater management tool;

1) It is important to make sure that the water table is adequate to ensure permanency and sustainability of water supply as the first step in the planning phase.
2) Practical knowledge of local groundwater should be secured among local Moghannis (Qanat digger). Although this is empirical and based on land formation, color and smell of the soil and mountain rocks, natural slope of the land and specific vegetation experience also plays an important role.
3) Modern geological techniques, Geographical information systems (GIS) and remote sensing (RS) instruments can contribute to the restoration and reconstruction of Qanats. To enable to incorporate modern scientific approaches in their traditional knowledge networks requires preparatory research, training and appropriate support.
4) The recharge process of the supplying aquifer should be known, conserved and continuously enhanced through artificial recharge if necessary. There are places where special dams were built in order to enrich the water table. The Iranian Qanats of Jandagh for example are fed by two

ancient dams one of which is claimed to be the second largest Underground Dam in the world, at 25m long, 1.5m wide and 7m deep.

5) In some areas of Central Iran, around Khoor, people dug wells 3-5 meters deep and 5-7m wide and filed them up with large stones found on flood beds. They directed the floodwater to these artificial pools to enrich the water table. This ancient recharging innovation can still be used replenish groundwater in many places.
6) Qanats can be used as an educational facility for students, technicians, professionals and researchers as well as the general public.

3.5. Community Management

The use of Qanat water was accompanied by a collective organization of production management, common in the central and eastern provinces in the Qanat regions. In the area around Tehran the typical Qanat based collective system is called Boneh. In Khorasan and the eastern part of Iran the system is called Sahra. The extent of development of the social and technical organization depends on production techniques.

Boneh developed out of the need for cooperation in constructing and maintaining Qanat and its water management extended to cover agriculture production and related socioeconomic system. In a typical Boneh the agricultural lands in a village are divided into several units, the Bonehs. Irrigation canals are built according to the size of each Boneh and the total number of Bonehs. To avoid wastage of water resulting from different frequencies in its passage through the irrigation canals, crops requiring the same amount of irrigation are cultivated on all Bonehs, and regular collective water divisions based on crop needs are made between the Bonehs.

Within the collective system, a social hierarchy defines roles and responsibilities. The owners of village, whether single or several and absentee, were at the top of the hierarchy. In the theory, the owner responsible for investing in the Qanat bringing water to the surface, providing short term credit for seeds and the cash needs of the peasants in winter and providing marketing facilities. The extent to which landlords fulfilled these responsibilities is debatable and there is ample evidence of abuse and neglect.

Division of Land and Water Distribution

Normally land belonging to a village was defined, and divided by features such as water canals, rivulets, trees boundaries and fences. The distance of these parcels of land from hilltops, Qantas, roads, amount of sunshine received (especially in hilly terrain), use of the land for keeping sheep (fertilization by sheep manure) determined the quality of the land parcel in terms of its level of soil fertility. Land was classified on the basis of soil quality or level of fertility, as say, good, average and bad. (These are not standard units but vary from village to village, based on the complexity of its production system and level of organization.

Only the principle applied is the same.) Each Boneh had several parcels of land scattered across the village lands. Allocation of land was through a system of draw .

Qanat water is used by a farmer based on his share of ownership. In general, the right to water varies from a few minutes to a few hours per year. Therefore every farmer only cultivates the area of land that he is able to irrigate with his share of water rights and the land area cultivated. With division of water shares from generation to generation, this balance has been preserved.

Contribution to Agricultural Biodiversity

Within each Boneh, land was divided into small allotments and each peasant had a share proportionate to his farm size. The peasant cultivated his own land and could choose, within set cultivated limitations, types of seeds and other inputs. The peasants' shares of the crops depended upon the small holdings and

maintained individual allotments. Thus the Boneh was based upon small holdings and maintained individual incentives. Based on the amount of water at his disposal, a farmer modified the area of land he was to calculate each year. Selected crops were diverse and complemented one another in terms of their requirements for water. To achieve the highest land fertility, cultivation number of years imposed by water limitation. Land left fallow was fertilized and used for crops requires less soil fertility, after these two rotations land was once more left fallow. This type of agricultural system is based on indigenous knowledge and is in perfect harmony with environmental conditions.

Seed Improvement

Every year the best crops are selected by farmers to extract the seeds. Seeds are collected as soon as the crop is harvested. Farmers believed that if the crops left or stored for more than two days, the seeds will lose their quality. In the selection of seeds for farming, species are examined and selected with a variety of factors, such as their requirement for water, cropping season, resistance to pests and quality of production. Selection of a diversity of species helps to reduce risks and enhances sustainability.

The Effect of Qanat Water on Crop Quality

1. Qanats normally never draw water from the bottom of aquifers, but from the top. Whereas deep wells with pumps are normally constructed to maximize water output from aquifers, and normally reach close to the bottom of aquifers. Force used in pumping water draws out sand and soil along with water.
2. Water flowing over long distance in Qanats, result in sedimentation of suspended matter, and therefore self-purification. It has been observed in the Zarech Qanat in Yazd that as distance increased from the pollution source, water quality in the Qanat improved, and also at the Mahzar, or spring(where water came out of the ground) and satisfied all the parameters required for irrigation, except chemical contamination.

Crops irrigated with Qanat water have been found to be of better quality and more resistant to drought. In addition, when using qanat water, Lower amounts of water are needed. For example, for cultivation of 625 (meter square) of hay, only 2 kg of seed is needed whereas if the same crop was to be irrigated using well water, 12 kg seed would be needed. Well water has higher salinity, which affects the quality and quantity of crops (especially those that are cultivated in spring), except for resistant crops such as hay, where well water has little impact on the quantity of crops, but significantly lowers quality.

3.6. Multi Functional Qanat System

The Southern, Eastern and Central part of Iran lie in the arid and semi zone , covering about 75% of the total land area, where shortage of water is the main obstacle to development . This has been overcome by the construction of Qanat systems. They are the main source of water for both rural and urban function, ranging from agriculture and production to household consumption. Intricate systems were developed for distribution of water from Qanats for cultivation of a variety of crops in the farms and orchards while sustaining the productivity of the land. Until about 40 years ago part or most of the water in larger cities, such as Yazd, Kazeroon, Esfahan, Tabriz, Shiraz, Ghazvin , Zanjan and Kashan was provided solely or significantly by Qanats thus demonstrating that they are not uniquely a rural phenomenon but have also had an important role in the formation of cities. Since Qanat water is available all year long with varying flow in different season's water reservoirs were built to store water for lean periods, suiting urban and rural needs. In rural areas, small natural and semi natural dams and pools called Ab Bandan were built for agricultural purposes and are still in use in the region. These small dams normally stored both Qanat water as well as surface and rain water. In urban area and along main communication routes, covered water reservoirs called Ab Anbar were in use to store and provide potable water.

Another Qanat related water structure is the water mill or Asiyab-Abi, for milling flour. The Qanats of Bagh e Fin or the Fin Garden in Kashan have 75% water mill distributed along the stretch of the Qanat when there is a total drop of about 5-6 m between the point of collection Sarab and the point of water discharge Zirab. A higher level difference was considered unsuitable for operating the water wheel which acted as a turbine. The wheel is undershot by the force of flowing water. The various functions of Qanats may be enumerated as follows:

- To secure water for irrigation in arid and semi arid zones with low precipitation in the rural areas around the great central desert covering the provinces of Isfahan, Yazd, Qom, Kerman and Khorassan.
- Securing water for household consumption in rural and urban areas, as is evident from the presence of Qanat in most of the larger and ancient cities of Iran.
- Use of energy produced by water current of which the finest example are the Qanats of Fin e Kashan which has seven mills, some of which are still working , Najaf Abad , where 17 water mills are present on the main Qanat.
- Qanat collect water from different layers of earth and keep the underground water level at a reasonable balance , never depleting its source (as a deep well using pumps can do). Therefore, depletion of underground water source is prevented even during worst drought situations.
- Qanats also play the role of a groundwater drainage system, especially during flash floods which are phenomenon specific to arid zones. Drainage of water through Qanats has prevented a rise in groundwater levels.
- Qanat play an important role in balancing the salinity of water and protecting Agriculture lands downstream. For example, in the Ghazi Qanat of Kashan, the water has become less salty over a 3o year period.
- Social systems in areas that rely on Qanats are related to ‘ownership rights’ to the amount of ‘water’, which is recognized as the most important resource for survival in the region. No matter how small a share, the owner of water is held in high esteem. The control of water rights determines the power hierarchy.
- Social hierarchy in cities was determined by the vicinity and location of a person’s house, as to whether it was upstream or downstream in relation to the Qanat.
- The legacy of Qanat is intertwined in the socio culture heritage of the region, bordering on spiritual and religious faith and beliefs. The waters of Qanats were held sacred as well as the protection and care of the system, and often involved ceremonial rites.

4. Conclusion

In conclusion, Qanat is a life-giving innovation that supplies both drinking and irrigation water of the people in arid and semi-arid regions and livelihood of these people rely on resistance of this resources

To sum up, most of Maghanni are died or have not ability to repair the cannel of the Qanat. On the other hand there is high cost and risk for establishment of the Caval (concreted cannel that water flows within that and protect the channel from collapse and so on), because Cavals under high pressures and chemical and physical weathering are depredated and after few years the owner should be repair the Qanat. Hence, In order to decrease risk of monitoring and digging procedure that was conducted by Moghanni, robots can be used, which are able to both monitor and dig the damaged area. Therefore, risk of restoring of Caval that was extracted from collapsing of Cavals will decrease. Owner of the Qanat and Organization should be replaced concreted Cavals with PVC pipe (Plastic pipes), which has high level of resistances and is able to bear under high pressure and weathering process. At the first may be this proposal seems with low degree of economical justification, but in the long time not only have econo,ical justification, but also will have technical justification. Because utilization of PVC pipe lead to decrease of leaching of mineral and sediment and the quality of the water remain unchanged to emerge from Mazhar.

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