SOME INCOMPARABLE ASPECTS OF IRRIGATION ART IN ANCIENT IRAN

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ABSTRACT

The ancient land of Iran, with its enduring civilization, is recognized by the world as a cradle of culture and civilization. Her intellectuals founded, over the centuries, great traditions of philosophy, science, art and craft, as well as establishing moral values that led to a long-lasting and harmonious relationship between the individual and society. It is self-evident that in the development of an ideology based on the three pillars of "auspicious thoughts, actions, and dialogues", there exists and implicit set of magnificent spiritual guidelines.

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Water mills, an Iranian architectural initiative in the expoitation of Hydropower.

- Water supply and physical water treatment in 3300 years old Choqa-Zanbil Ziggurat-A brilliant example the Iranian's ingenuity.

Ancient weirs in Iran.

Qanats (subterranean caral,an eternal saga of man defying aggressive elements, of nature in desert.

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The watermills were powered by the river currents, springs or Qanats. A conduit just before the mill shaft would act as a bypass when the mill was not in operation. The mill shaft 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.

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high mound on the bank of the river Dez, a tributary of the Karun, and was built in 1250 B.C. (ie. 3300 years ago) by the Elamite king Untash-Gal for the Elamite deity “Inshushinak”.

By the order of Dur-Untash Gal, the Elamite king (1245-1265 B.C.) a 50 km long canal was excavated to transfer water from the Karkheh River, on the west of Susa, to a sedimentation basin and then the town itself.

The remains of a large excavated reservoir and a basin can be seen outside the exterior walls of the Dur-Untash town. The water used to be de-silted in the reservoir and then transferred via a series of canals to the basin where it, could be taken by the people.

Ancient weirs in Iran, Scientific studies carried out have indicated that early Iranians were particularly concerned with three factors: dam location, characteristics of the dam foundation, and construction materials. In all the locations where ancient weirs were built, technical aspects including location and type have been well considered. Factors such as the nature of topography, river flows, availability of construction materials and the method of river diversion during weir construction were always taken into account.

Qanats, The Qanat, or chain-well, was a Persian hydraulic technique par excellence. It is a method for tapping deep groundwater without the use of lifting devices, by sinking a series of wells and linking them underground. The technique found widespread use in ancient times to serve urban water supply systems.

The Iranian artisan, by adapting himself to his surrounding environment, managed to obtain the water, he needed to have a prosperous life. Many villages were built because of the Qanat. The Qanat is thus a memento in the heart of the desert as a symbol of the eternal battle of Man with his harsh surrounding environment.

INTRODUCTION

The ancient land of Iran, with its enduring civilization, is recognized by the world as a cradle of culture and civilization. Her intellectuals founded, over the centuries, great traditions of philosophy, science, art and craft, as well as establishing moral values that led to a long-lasting and harmonious relationship between the individual and society. It is self-evident that in the development of an ideology based on the three pillars of “auspicious thoughts, actions, and dialogues”, there exists and implicit set of magnificent spiritual guidelines.

Throughout its long history, Iran has contributed its contribution to the world’s treasure-house of civilization, both at the material and spiritual levels. The country’s contribution to this treasure-house falls into two distinct pars, one being from its own people, and the other from the intermingling of these people with those of neighboring nations.

Ancient tradition rests on three pillars: ancient texts, contributions of scholars, and archaeological relics. These are essential for studying the culture and evaluating the birthplace of every nations.

The Goddess Mithra was the symbol of belief, honesty, affection and the Iranian psyche; in Avesta she is described as the mediator of darkness and light. The Goddess Nahid was the symbol of wind, clouds, and rain.

The study of the archeological relics is another source of judging the richness of any culture and civilization. Almost all of the archeologists after discovering and evaluating the relics of "Sialk of Kashan", the plain field in the south of Tehran, concluded that this location was the oldest place where man had lived as a community. Artefacts of the settlement of primitive man, such as demolished clay walls, food stores and the remains of the somke-coloured earthenware vessels and engraved jugs all are signs of this long lasting civilization.

Professor Ghrishman, in studying the remains of Sialk, has distinguished three stages of habitation: the cave-dwelling stage, the hut dwelling-stage (building houses with sun-dried bricks) and village and town dwelling stage using rectangular clay bricks and fabricating vessels. Iranian architecture was founded at that time and in such a way.

Iran is located in an arid, semi-arid region. Due to the unfavorable distribution of surface water, to fulfill 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.

The mean annual precipitation of our country is about 250mm which is less than the mean precipitation of Asia and about one third of that of the world. The different kinds of climates, topographic and geographic conditions, uneven distribution of surface streams, both in space and time are the hydrological features in many parts of the country.

The archaeological surveys suggest that Iranians enjoyed advanced culture and civilization some 7000 years ago. 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.

The value and credit of historical Iranian architecture is the variety, as well as its enriched spaces and at the same time its practicality of use, value of structural geometry and fascinating decoration. Based on such architecture, the hydro-architecture of Iran has a unique characteristic that makes it different from any other historical monuments, and this is especially attractive.

Civil works such as water mills, underground water reservoirs, ice ditches (chambers), Qanats (subterranean canals) and ancient dykes, all have logical, regular and simple function and at the same time demonstrate ingenuity and originality in every detail.

Dam construction in Iran dates back to the ancient times. Kebar Dam, one of the oldest arch dams in the world has a height of 26m, a crest length of 55m and a thickness 5m with an arch radius of 38m which proves the skills of Iranians in dam construction. Saveh arch dam and Durudzan fill dam are 2 modern structures that have been built very close to the old dam sites.

Iranian are credited for invention subterranean canals (Qanats) which is well-known in the world. According to Herodotus the Greek historian, Qanat digging technique was documented and practiced in the Achaemenids era (550-330 BC) 2500 years ago, Qanat was a characreristic Iranian initiative and the only means of water supply for agriculture and development, giving life to and quenching the thirsty plains, bringing into existence the villages, towns and eventually great civilization of this country.

Such construction master pieces, that is to say the excavation of tunnel-wells underground with a length of 10 times the equator were realized with the sacred aim of supplying the basic needs and more important, well being of the people.

Remains of reservoirs have been discovered along with water intakes, spillways and outlets and event the sewage systems belonging to pre-Achaemenids and Assyrians (600-1500 BC).

The dams made at the time of king Shapur I (Sassanian era) are 1300-1700 years old. A regulating dam and a bridge-diversion dam (500 meters long with 40 spans) in Shushtar are among these dams. Amir dam was constructed by Buyids dynasty 35km north of Shiraz is 1000 years old. This three-purpose dam (irrigation, bridge and mill) still exists and functions.

During the Safavids empire (1501-1739) water engineering developed significantly and many storage and diversion dams and bridges were constructed in Isfahan and Mashhad cities of which some still exist.

Irrigation principles have therefore been attended to, since the ancient times and viewed as “Irrigation Art”. The importance of irrigation is pronounced in Iranian ceremonies, traditions and religious beliefs. Water has been depicted in many Zoroasterian hymns and Anahit was believed as the Goddess of water.

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WATER MILLS, AN IRANIAN ARCHITECTURAL INITIATIVE

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 combination of roof’s geometry, along with the geometrical patterns of the decorated courtyard and the prevailing poetic atmosphere, in which only the sound of water flowing from the mill shaft onto the rotating paddles could be heard, gave this place a solemn atmosphere.

The watermills were powered by the river currents, springs or Qanats. The Gar-Gar and Amir Watermills were powered by the reservoir water. Kashan town's Fin-garden watermill was rotated by a spring, whereas the Du-Sangi watermill of Mohammed-Abad in Meibod, ancient watermill of Ashkezar, 15 km away from Yazd, and the two hundred year old Taft watermill were all, powered by the neighboring Qanats. These 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 I 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. 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 (Fig.1). 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 discharged into the flour bags.

Figure (1) : Watermill paddles , Taft – Yazd province

GRAIN SILOS AND THE WOODEN HOPPER

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.

THE ROOFED AREA OF THE MILL

Some parts of the roofed mill compound are designated for the cleaning and screening of the grains and flour production. A space is also foreseen to lodge the animals, which are used to transport the flour bags. The astonishing aspect of the operation of the watermills is their simplicity, which is the proof of ancient Iranian artisan's practicality.

DU-SANGI WATERMILL OF MOHAMMED-ABAD IN MEIBOD (IN YAZD PROVINCE)

This is a very rare example of watermill, which was constructed at a depth of 40 m on the water passage of Ghotb-Abad Qanat. No construction material was used to build it and the mill is excavated in a clay formation. Some well, also 40 m deep, supply light and air to it. Excavation of this mill dates back 150 years. It has supplied flour to numerous near and distant villages. The passageway to the mill has a high roof so that it was convenient for camels to pass through. A rest champer was also provided for the animals which were used to transport the grains or flour bags. This mill is located 50 km from Yazd city and 8 km from Mohammed-Abad village in Meibod (Fig.2).

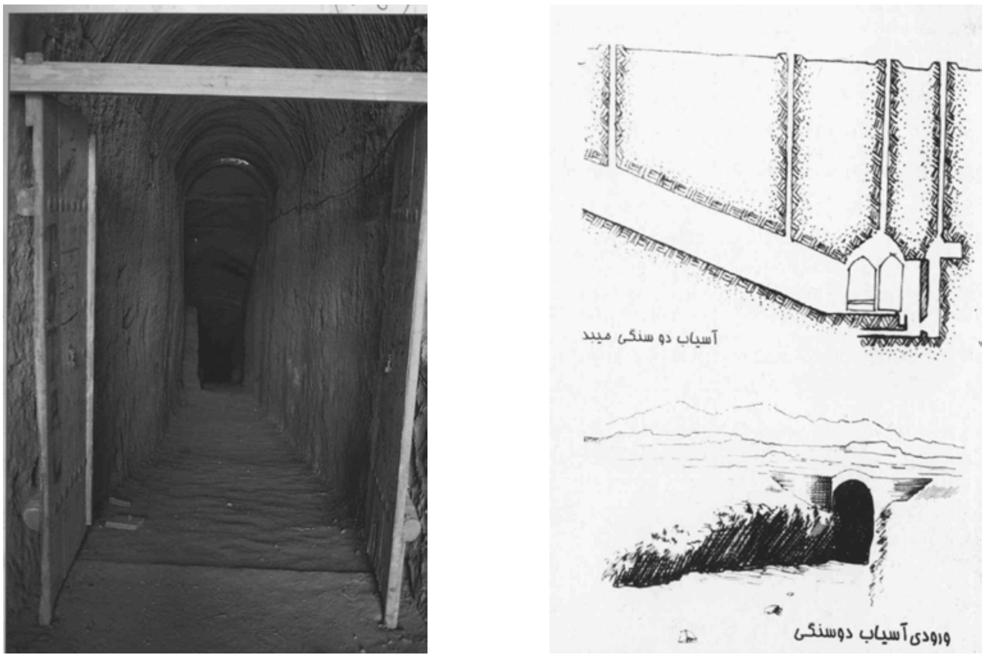

Figure (2) : Entrance of du sangi watermill at the depth of 40m, Meibod–Yazd province

WATER SUPPLY AND PHYSICAL WATER TREATMENT IN 3300 YEARS OLD IN CHOQAZANBIL ZIGGURAT

The Elamite temple of Choqa-Zanbil, otherwise known as Dur-Tash, is located on a Dur-un rash high mound on the bank of the river Dez, a tributary of the Karun, and was built in 1250 B.C. (ie. 3300 years ago) by the Elamite king Untash-Gal for the Elamite deity “Inshushinak”. It is about 25 m high and has an area of four square kilometers and consists of several storeys, made of mud brick and furnished with kiln fired bricks. The Ziggurat has a quadrangular base and its original height is believed to have been about 50m.

Choqa-Zanbil has three walls one inside the other, and the Ziggurat is located at its centre. It was a well known town, competing with Susa, and was the centre of political activities. Untash-Gal, with its numerous paved streets, palaces, and water supply installations was a symbol of Elamite civilization, culture and flourishing arts.

The water supply system to the palaces and the town of Dur-Untash was of equal importance to the construction of the temple and the palaces to its architect.

WATER SUPPLY SYSTEM

By the order of Dur-Untash Gal, the Elamite king (1245-1265 B.C.) a 50 km long canal was excavated to transfer water from the Karkheh River, on the west of Susa, to a sedimentation basin and then the town itself.

HYDRO-STRUCTURES

The remains of a large excavated reservoir and a basin can be seen outside the exterior walls of the Dur-Untash town. The water used to be de-silted in the reservoir and then transferred via a series of canals to the basin where it, could be taken by the people.

The reservoir with the dimensions of 70.10 m (length), 7.25m (width) and 44.35m (depth) has a volume of about 350m^3 and its base floor was made with kiln-fired bricks and lime mortar.

The two side walls were also made with the same materials and rest on the base floor. It seems that the water used to be conveyed via an open canal from one side. The wall, on the fourth side was also made with kiln-fired bricks and lime mortar. This wall at its lowest elevation, had nine openings (0.80m by 0.15m) which were spaced at 0.80m intervals from one another. These intakes were made with two layers of kiln-fired bricks and one layer of rubble masonry and all of the joints were sealed with bitumen.

The sharp inner corners of the reservoir were smoothed out by lime mortar.

Each one of the nine intake gates of the basin, situated under the ancient city's wall, were made of two oblique surfaces and a vertical part with the height of 1.60 m. The first oblique surface which starts at the reservoir floor level is 1.80 m in length, whereas the second surface has a length of 3.75m. The elevation difference between the bottoms of the reservoir and the basin is about 1.02 m. The basin with the dimensions of 9 m (length) × 7.6m (width) × 0.60m depth has a volume of about 4.30 m^3. The spaces behind the basin walls were filled with kiln-fired bricks and lime mortar which is 4 m thick on the northeastern side, 1.5m thick on the southern and 6m thick on other sides. This peripheral platform around the basin is rooted 2.5m deep into the ground.

From the existing evidence it could be concluded that, once the reservoir was filled to its maximum, the physically treated and de-silted water flowed in to the basin (located at a higher elevation), via the nine mentioned conduits, which then could be used by the people (Fig.3).

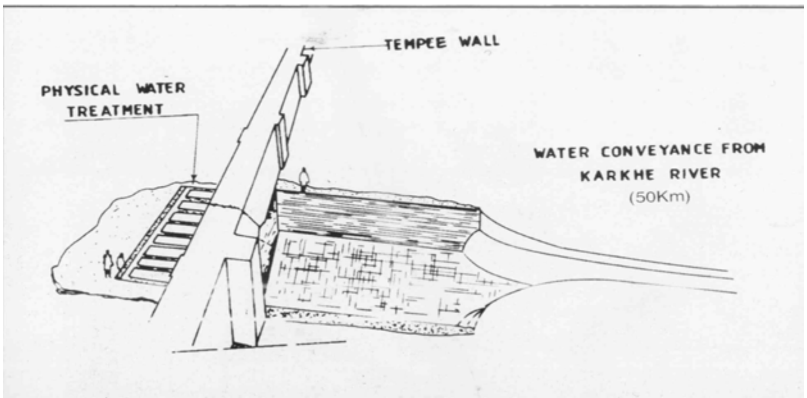

Figure (3) : Choqazanbil – physical water treatment basin (plan & section)

ANCIENT WEIRS IN IRAN

GENERAL CHARACTERISTICS OF THE ANCIENT WEIRS IN IRAN

Scientific studies carried out have indicated that early Iranians were particularly concerned with three factors: dam location, characteristics of the dam foundation, and construction materials. In all the locations where ancient weirs were built, technical aspects including location and type have been well considered. Factors such as the nature of topography, river flows, availability of construction materials and the method of river diversion during weir construction were always taken into account.

TYPE OF IRANIAN ANCIENT WEIRS

The ancient Iranian weirs which were made of masonry may be categorized as follows :

GRAVITY WEIRS

Studies have shown that all the major parameters which are nowadays taken into account for the design of such structures were well noted by the early Iranians, and this fact is evidenced by the construction of the 700 year old Saveh weir and the 900 year old Sheshteraz dam (Fig.4 & 5).

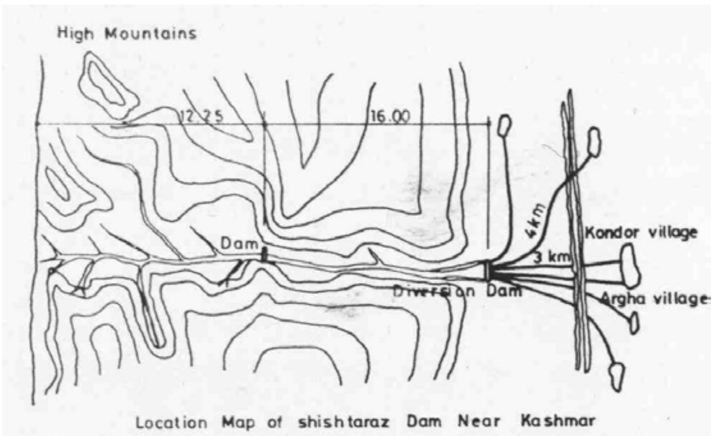

Figure (4) : Location map of Shishtaraz dam near Kashmar

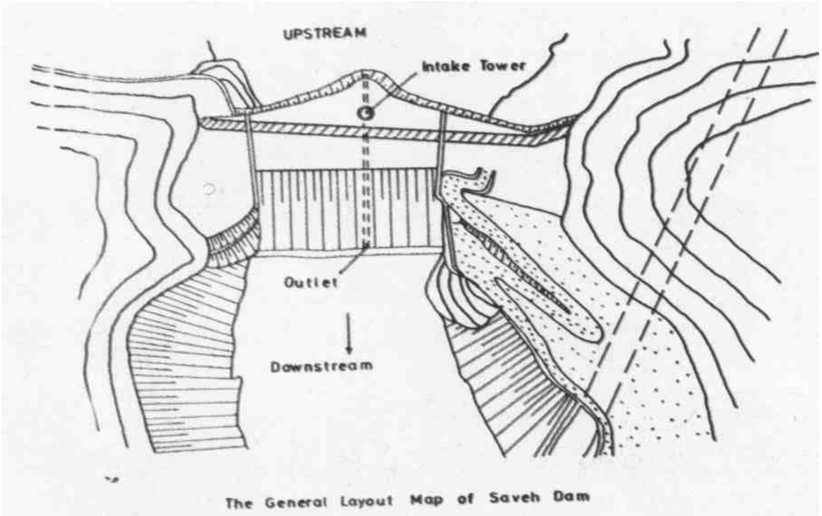

Figure (5) : The general Layout map of Saveh dam

CURVED WEIRS

Early Iranians, even before the Romans, were well acquainted with the load-carrying capacity of arched structures. Typical examples are the Kebar weir, which is more than 700 years old, and the 400 year old Kerrit arch dam.

BUTTRESS WEIRS

The Akhlemad weir, with a crest length of about 230m, a height of 12m and a reservoir volume of 3 MCM, and the 400 year old Fariman weir, which is still in operation, are of this type. The dam construction industry in the Sassanid epoch, particularly during King Shapur I's reign, was at its peak and flourishing. The ages of the dams remaining from this period range from 1300 to 1700 years. Outstanding examples of such structures remain from this era, including : Mizan weir in Shushtar, and the 40 span bridge-weir of Shushtar, with a length of 500m . The Amir historical bridge-weir, located 35km north of Shiraz, which was built on the Kur River in the Buyid epoch, is about 1000 years old. This weir still serves the three purposes of irrigation, bridging over the river and milling. The archaeological excavations carried out around this weir lead to the discovery of numerous relics and remains of intake structures, spillways, conduits and even waste water disposal networks (sewerage systems) which date back to the pre-Achaemenian epoch ie, the Elamite and Assyriass epochs (1500-600 B.C.). In the late middle ages, ie, in the Safavid epoch (1469-1699 A.D.) a new era of hydro engineering began. It was during this time that the numerous weirs and bridges of Mashhad and Isfahan were constructed and diversion weirs and large storage dams were built which remain standing today.

QANATS (SUBTERRANEAN CANAL)

The Qanat, or chain-well, was a Persian hydraulic technique par excellence. It is a method for tapping deep groundwater without the use of lifting devices, by sinking a series of wells and linking them underground. The technique found widespread use in ancient times to serve urban water supply systems.

The Qanat was the result of efforts put forward by the hard working artisans to dig out the desert and to convey every possible drop of water to the fertile farmlands and thus enrich the desert they used to live in.

The Iranian artisan, by adapting himself to his surrounding environment, managed to obtain the water, he needed to have a prosperous life. Many villages were built because of the Qanat. The Qanat is thus a memento in the heart of the desert as a symbol of the eternal battle of Man with his harsh surrounding environment.

The central part of Iran, up to very recently (1960), used to be irrigated by Qanats, and most of the water in this region was supplied from groundwater. Qanats stretched from the foothills of mountains to the plain fields and their lengths varied from one to several kilometers. A good example is the Gonabad region in the northeast of Iran, where the length of the Qanats constructed ranges from 24 km to 32 km. In the same region, there is a 70 km-long Qanat. Dulat-Abad Qanat, close to the Yazd city, about 54 km long. There is also an exceptional Qanant in this region with a length of about 120km. The depth of the main well of this Qanat is 116m. The depth of the main wells which were excavated in the Achaemeniam epoch, are as great as 450m. There are more than 37,588 chain-wells in Iran.

THE DISTANCE BETWEEN THE TWO NEIGHBORING QANAT SHAFTS AND THE MAXIMUM DEPTH OF EACH

The depths of the Qanat shafts vary from zero, at the exit, to a maximum in the main shaft which is situated in the saturated strata. The deepest well excavated in Iran is about 400 m. The distance between the wells usually varies from 15 to 20m, but in some cases, due to the existence of some exceptional natural features it may even reach up to 200m.

DIMENSIONS OF THE HORIZONTAL WELL AND VERTICAL SHAFTS

The dimensions of the horizontal well are about 60×120cm, whereas the vertical shaft (wells) have a diameter of about 80 to 90cm. These dimensions were chosen to reduce the amount of the excavation.

COVER OF THE INNER SURFACE OF THE HORIZONTAL TUNNEL

The geological structure of Iranian Plateau is such that there was no need to take any special measures for protection of the inner surface of the Qanat. During the course of time, as the Qanat’s inner surface was constantly in contact with water, it became covered with a layer of lime, which from the presence in the water formed an impermeable protection. In weak and collapsible ground formations, the Qanats were lined with elliptical clayey segments known as Kool, which was large enough for a person to pass through.

QANAT LENGTH

The length of a Qanat depended on the natural condition of the ground on its path, i.e, the ground slope and the depth of the main wall. The longest Qanat is known to be excavated near the town of Gonabad, in Khorasan province, which has a length of about 120km.

METHOD OF EXCAVATION OF A QANAT

The excavation tools for a Qanat, due to their simplicity, have probably not changed much through the ages.

The first step was to excavate some reconnaissance wells in the selected region, to make sure of the presence of groundwater. The number of these exploratory wells could sometimes be as many as three, and then the water flows would be measured and studied. Having been satisfied with the result, the Qanat artisans would then use surveying equipment to determine the ground slope and the appropriate intervals for the wells, down to the Qanat outlet. Qanat artisans based on a few thousand years of experience, were so skilled that Qanat excavation was like their second nature, and they could start the work simply by carrying out a site appraisal. Generally, excavation of a Qanat starts from the outlet and ends at the water source. Two adjacent wells are excavated first, and then connected to each other by a horizontal well. This method is continues to the end.

EXCAVATION EQUIPMENTS FOR THE QANATS

The equipment used for excavation of Qanats consisted of a wheeled machine, supported horizontally by two vertical poles at some distance above ground level, with a thick rope attached to it. At the other end of the rope, a bucket was tied which carried the equipment down the well and removed excavated material.

CLOTHING

In the earlier period, special care had to be taken as regards the clothing of the people working deep in the wells. Based on observations made by Karaji (6), one thousand years ago, when the well-sinker encountered water seepage, he would put on sheep's leather clothing waxed with ox fat. A large hat with would have protected his head against dripping water.

PROBLEMS WHICH COULD BE ENCOUNTERED

Numerous problems could be encountered during the Qanat excavation and the followings are just a few examples :

ENCOUNTERING A LARGE BOULDER

If a well-sinker encountered a large boulder, he would either break it into pieces with a chisel and hammer, or bypass it. Sometimes, in the case of the existence of numerous boulders, he would lose his orientation, and an open polygon would be made in the horizontal well and transferred to the ground surface, and thus the horizontal well's alignment could be determined.

AERATION OF THE WELL

So that the bottom of the deep wells could be aerated, which was e difficult task, the numbers of the wells were increased, or air would simply be blown into the wells by using apparatus similar to that of a blacksmith (bellows) and a leather trunk. Using lamps in the wells was inevitable, which would produce carbonic gases and therefore selection of the type of lamp fuel was important.

"Existence of heavy air or air polluted with gas inside a well is due to several reasons such as : the large depth of the well, the sulphurous nature of the ground or even the collapse of the horizontal well at the inlet. The sign of a polluted well, which a noon time becomes extremely bad, is that a lamp could not be kept on. The oil-lamp which can be most effective is the one which uses pig, cow or sheep fat as its fuel. After these, olive oil or similar are the best. Kerosene, due to the fumes which it produces, is not suitable at all".

VERTICAL SHAFTS (WELLS) IN LOOSE SAND

The excavation of wells in loose and non-cohesive sandy formation is carried out using wooden formworks the internal dimensions of which are equivalent to the well diameter plus the well-liner thickness. As the well deepens, more formwork is added at the top of the lower one, which is sliding down. Collapse of the well once the wooden boxes rott away, is inevitable.

The next best alternative is using resilient elliptical clayey or concrete loops (Tanbushe) with a minimum diameter of 70cm, i.e, a convenient dimension to allow for manual excavation be carried out. By the removal of the loose sand, the loops would sink down under their own weight. The rate of sinking of the loops depends on their peripheral friction with the adjacent ground material.

STRAIGHT ALIGNMENT UNDERGROUND

People are always faced with the question of how the Qanat artisans could orientate themselves below the ground and proceed in the right direction.

Nowadays, a compass is used for this purpose. It is worthwhile noting that the ancient people of Iran were familiar with the magnet. Kharazmi (9) in his book defines the magnet as : "a store which attracts iron".

The people who used to excavate Qanat were in possession of a campass or similar apparatus in order to be able to proceed in a straight line during their underground excavations. Karaji explains that :

Once two adjacent wells were found to be in alignment with the horizontal conduit, then the well-sinkers, using of a string, would set out this direction on the ground surface. After excavating the two wells to the appropriate depth, string plumb lines were hung down from the centers at the top of the wells. By aiming these two vertical plumb lines, the direction of the rest of the horizontal well could be set out.

The experience of Qanat excavation during the past millennia gave enough confidence to the well-sinkers to carry out their work without resorting to a compass, strings or any other kind of apparatus.

SUBTERRANEAN ORIENTATION

In cases when the route of a horizontal well did not coincide with the straight line in between tow vertical wells, or due to some other reasons because of a zigzag in the work, the well-sinker would lose his orientation.

Then according to what Karaji had proposed, he would set out an open polygon inside the horizontal well, and by measuring the length and angles of this polygon, he would try to duplicate it on the ground surface, and in such a way the well-sinker could pinpoint his route under the ground (Fig.6 & 7).

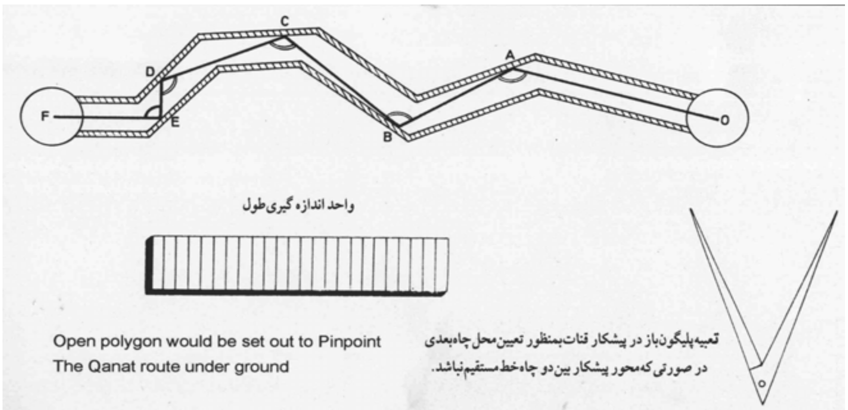

Figure (6) : Open polygon would be set out to pinpoint the Qanat route under ground

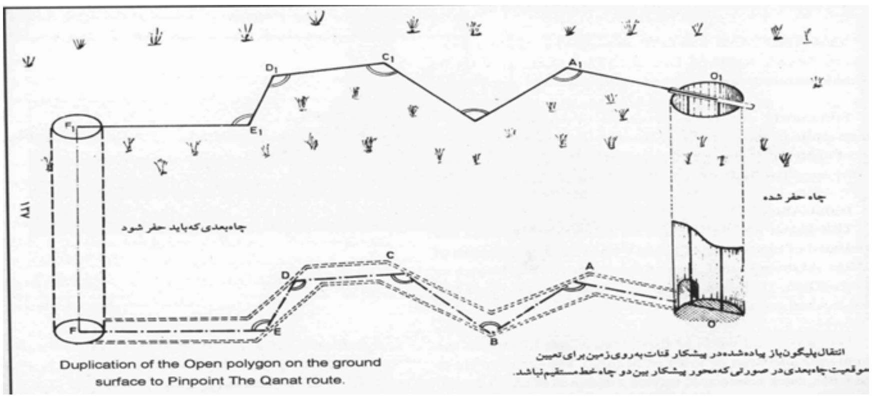

Figure (7) : Duplication of the open polygon on the ground surface to pinpoint the Qanat route

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