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Water Structures in Anatolia from Past to Present

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Abstract: Noteworthy water accumulation and transmission structures built in Anatolia by civilizations from the past to the present are evaluated regarding their technique and form in this study. As a result of evaluation, it can be said that water accumulation structures built by Hittites and Urartians have similarities in terms of technique. From Hittite, Roman, Byzantines and Ottoman times, mostly works of flood control by providing fresh and potable water, and from Urartian and Seljuk times works aimed at irrigation remain standing. Water transmission structures which consist of clay tile pipes, rock carved channels and earth lined channels. Water accumulation structures are generally sluiceway which is built by filling clay material between rock and stone-filled walls. Most of the structures mentioned in the study are still working.

Key words: Anatolia, irrigation, water structures, Hittites, Urartians.

It's not known that humankind, who knows that there will be no life without water, understood that also plants need water. But when it is considered that great civilizations built near river basins, it can be said that human discovered the plant-water relation at the ancient ages before it assumed.

The arise areas of agriculture and, in consequence, irrigated farming are vast river basins supplied by melting of the snow on the high mountains [11,15]. Even the peace between humankind and rivers sometimes become resentful because of the floods, these floods creating an irony in human-water relation by bringing out abundant alluvium materials. The history of water deals with, especially, providing and controlling the water in terms of many important problems, solutions, results and methods.

Providing more products and utilization of these in defence, social life and socialization after transition to irrigated agriculture resulted in city-based civilizations[17,18,25]. These civilizations, which were dependent on agricultural economy, had the authority in politics and cultural grounds against their neighbours when they became richer.

The first activity of humankind to change the environment in favour of him, in other words irrigated agriculture implementations, started in Mesopotamia which lies between Euphrates and Tigris rivers and named as Fertile Crescent. Euphrates and Tigris rivers, with their lateral rivers feeding them, constituted fertile and alluring areas by bringing out large amount of sediments in their streamlines[25,26,27].

The south and east of Anatolia where Sumerian, Babylonia and Assyrian civilizations made irrigated agriculture, it is a natural process that also the lands of Anatolia meets the irrigation. Moreover; Anatolia is the rise point of many rivers like Kızılırmak, Menderes, Aras and Seyhan besides Euphrates and Tigris Rivers. The Civilizations of Hittite, Urartian, Roman, Byzantine, Seljuk and Ottoman which lived on Anatolia manage to use water in agricultural production. In the circumstances where natural conditions are not appropriate, they achieve to utilize water effectively by building water deposits and transmission structures. Some of these issues are raised in more recent studies[3,22,23,24,28,29].

The aim of this study is to give information about the water accumulation and transmission structures which remain standing till now from ancient Anatolian civilizations, still working or being in ruin conditions. The structures of this study in question are examined regarding technique and form to determine their similarities with today's modern structures.

Technically in order to affirm any water retention structure as a dam or a pond, the structure should have a specific height and a geometrical shape and also have facilities like a sluice, filter or etc., or must be built

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upon a water course. Similar to this, in order to affirm a waterline as a channel, it should have cross sectional area as technically and economically, and a bottom slope, etc. [14]. The structures of this study are great engineering works regarding the times they are built. For this reason, when we mention about the structures, actual terms like dam, pond and channel are used.

The oldest water accumulation structure in Anatolia is the newly discovered Hittite dam (Figure 1). It was discovered by Aykut Çınaroğlu and his crew in 2002 within the borders of Çorum province. It is considered that it was one of the ten dams built in Hittite lands as a result of big drought seen in 1240 B.C.

The body of the dam, which is depth is unknown, is 130m in length and 15m in width and consists of 3 components as channel-tank-channel. Also a hieroglyph tablet is found in the tank section. As it is understood from the tablet, it was built in the times of IV. Hittite King, Tudhalia in honour of Goddess Hepat. It is understood that the tank of the body is used for sedimentation of suspended substances and provide irrigation water besides fresh water. It is discovered that the spring water issuing from a conglomerate rock is feeding the reservoir [9]. The location of spring being distant from overflow or flood risk can be an important factor that the structure remain standing till now.

General Directorate of State Hydraulic Works (DSİ), commenced a joint project with archaeologists in order to re-activate the function of Hittite dam, has cleaned 2.5 million m^3 mud from spring section of the body. The water hold in the dam after cleaning and minor rehabilitation works is used in the summer times of 2007 in irrigation. Approximately an area of 20 ha is irrigated with the dam having 30000m^3 water retention capacity. In this way 3250 years old dam has been re-activated.

In the Hittite dam which is similar to the earth fill dams of our days in terms of construction method, andesite rocks as for load bearing elements and the clay is used as an impermeability element.

The dams of Böget (Eşmekaya) in Aksaray and Örükaya dam (Figure 2) in Çorum are the examples of dams remain standing from Hittites till now[16,20]. The dams having similar body specifications consist of two walls and clay and rock fillings between them. There are hypotheses that Hittites have an advanced skill on metallurgy and can melt iron [30]. As a proof of this hypothesis, Örükaya dam built between a rift valley by filling with clay and limestone rocks joint together by lead casting. It is predicted that the depth of the dam is 16m which approximately having 500000m^3 storage capacity. The length of the dam is 40m and its width is 5m. There is one of first sluiceway examples in the dam of which important elements of modern 3m^2 cross sectional dams of our century. Opening and closing of the sluiceway is made by a wooden valve[1,2,21].

There are many water structures of Urartians, which are established a state in Eastern Anatolia, remain standing till now (Figure 3). They built many irrigation channels besides irrigation-oriented dams near their capital of Tuşpa and it's adjacent. In Eastern Anatolia where climate and topography conditions are so arduous and earthquakes are seen frequently and massively, annual construction time is approximately 5-6 months. Their advanced progress in mining must have a major contribution in building many water structures having sufficient quality which is still hard to implement in a short period of time in terms of technique. Yalçın (1999) emphasized that Urartians use working tools like sledgehammer and leverage made of iron.

The channels of Menua (Semiramis/Shamiram) and Ferhat are the still working masterpieces of Urartians in Anatolia. According to hearsay, both of them were built upon a love story. Menula channel (Figure 4), which is 51km long and having a flow of 6-10 m^3/s, is carrying the spring water of Gürpınar plain, which is 50km in distance to Van, to Van province [5,6,12,13]. Besides the irrigation of 5000ha area throughout the channel, 5 megawatt electricity is produced. The channel of Ferhat, which is shorter than Menua channel, is discovered by Oktay Belli and his crew in 1996. The channel of Ferhat transmits fresh water to some parts of Doğubayazıt plain and eastern village settlements with a flow of 3-5 m^3/s from Lake of Balık, 2250m in altitude, which is fed by melting snow of high mountains and spring waters. Although there is not major changes in the flow of Menua channel because it is fed by spring water but the flow of Ferhat channel becomes more in spring times. One of interesting characteristics of Menua channel is that it crosses over Hoşap creek with an aqueduct. The hanging gardens of Kadembastı area, which are built by compacting soil brought other places, are irrigated with the channel which become an epitaph/memorial with 14 epigraphs around it[6,7,13].

The widths of rectangular duct Menua and Ferhat channels are respectively 3.5-4m and 2-2.5m at the points carved inside bedrocks; their depths changes between 1.5-2m and 1-1.5m. Approximately 25 km of Menua channel is carved in limestone crags. Dimensions of Ferhat channel are much smaller because it was curved in andesite which is a more solid rock. There area having a slope of %10 throughout the channel. Very strong retaining walls were built at these points. The material is used in these walls as bearing which are obtained by crushing bedrock throughout the channel and clay monar is used as a binder. The bottom slope of the channels changed into 3/10000 - 50/10000 with these arrangements.

Fig. 1: A view of the Hittite dam

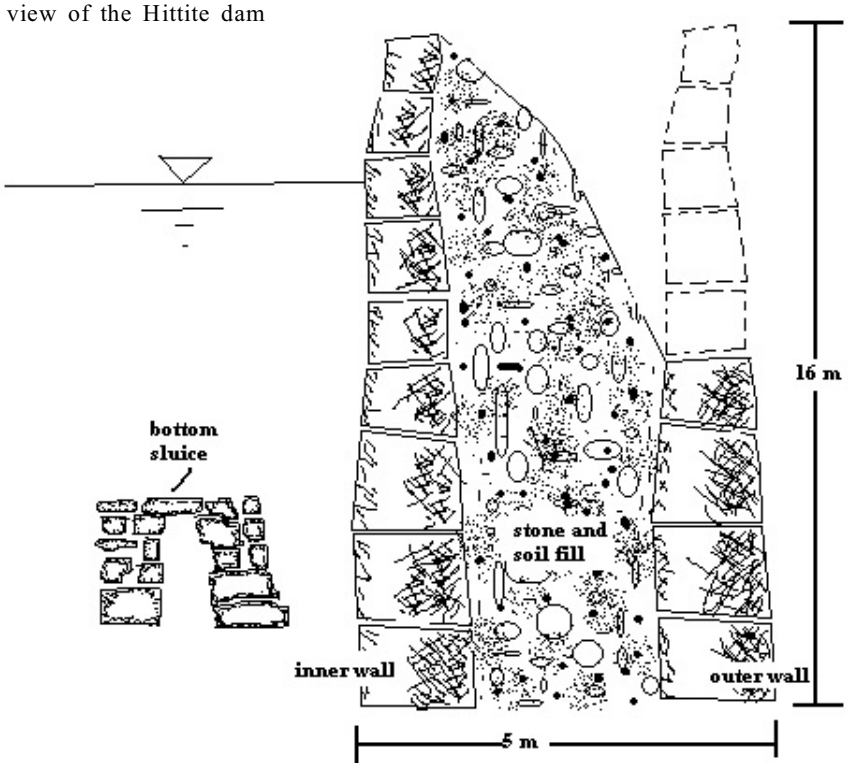

Fig. 2: A cross section of Örükaya dam and its bottom sluice exist from the Hittites in Çorum, Turkey

First studies on channel hydraulics made by Chezy in the second half of 18. Century; it is determined that the flow in open channels are proportional with channel bottom slope and hydraulic radius.

Channel bottom slope must be in a size that enables the critical flow but not be at a value to create erosion. According to hydraulic principles, wetted perimeter of water must be in minimum to provide maximum flow rate in a channel. When Menua and Ferhat channels are evaluated in the light of these scientific facts, it is seen that their cross-sections are in very close values with channel dimensions. When the flow they carry is examined, the channel bottom slope is a level that not causing an erosion. The technicians of that century planned the channel of great flow in parallel to contour lines like today's engineers.

There is an Urartian water collecting facility in order to collect the water of Aygır Lake, which is a volcanic lake [8]. This facility is found in an excavation for building a new facility planned by DSİ. Once again it is understood from the appropriateness point of collecting facility that Urartians are well-advanced in

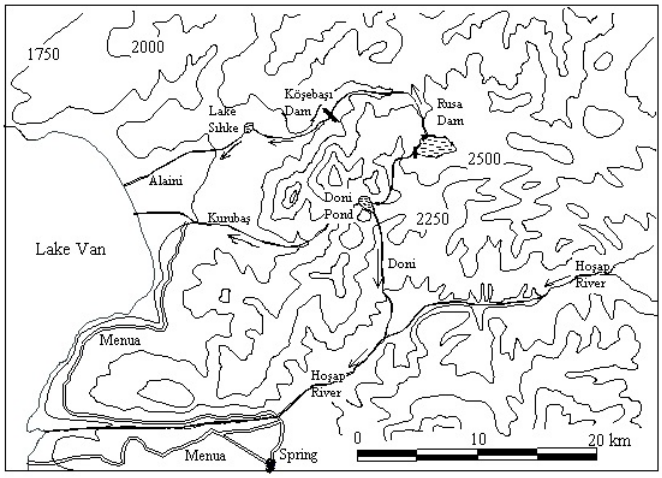

Fig. 3: Topographical map of important Urartian irrigation system in Eastern Anatolia (from Belli 1997a)

Fig. 4: A view of the Menua Channel

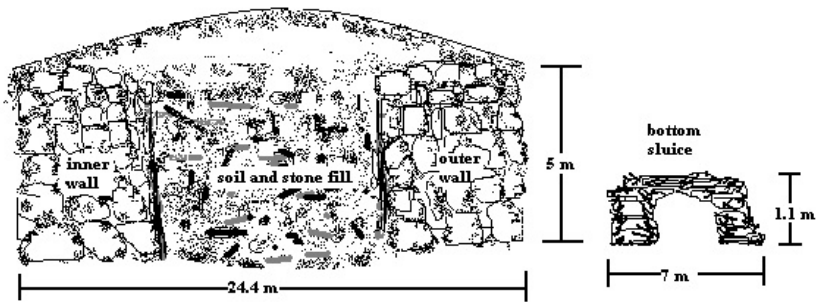

Fig. 5: A cross section of Rusa dam exists from the Urartians in Van, Turkey

hydraulics. The lands between south of Aygır lake and Lake Van are irrigated with the water taken from this facility which consists of both open and piped system of 65-70m in length. The clay tiles in the first examples of ground water galleries of the closed system are made in frusto-conical shape in order to joint each other. The pipes having 28cm of narrow mouth diameter and 30cm wide mouth diameter are 57cm in length and their wall thickness is 2cm. The points where pipes joint each isolated with clay [4].

As the topographic structure where Urartians has lived is so appropriate to collect waters, they have built many numbers of dam and ponds at the narrow basin points by constructing barrages. Most of these structures are in Van province and respectively the important ones are Süphan, Arç, Rusa, Doni, Köşebaşı, Sıhke, Reşan, Meydan Boğazı, Memedik dams and ponds.

Aforementioned Doni, Sıhke and Memedik ponds and Reşan and Arç dams are single wall, Meydan Boğazı dam is triple walls and the others consist of double walls. In order to provide impermeability in the dams having more than single wall, walls are filled with rocks and clay material [7].

Memedik pond is having the longest wall of 1000m and it is followed by Sıhke pond. And Köşebaşı dam has the widest wall of all having 31.5m. The second one is Meydan Boğazı dam with 29.6m.

Süphan dam is the first dam of Urartians and is now irrigating Muradiye plain having an area of 11200ha. 3-tier sluice which enables to take water from different levels of pond water has been damaged in the rehabilitation made by DSİ in 1980. Rusa dam (Figure 5) is the biggest dam of Urartians with 40 million m^3 reservoir capacity. In the dam which water can be taken from two ways, water flowing from sluice (Figure 6) of 70x110cm in west direction is firstly collected in Doni pond. After that, it irrigates the areas in south-eastern part of Van plain at slow flow rate which Menua channel could not. The water which flows in a high rate of 4% in northwest direction is stilled in Köşebaşı dam at first then it flows to Sıhke pond. Excluding Arç dam and Memedik pond, water collecting structures are fed with snow and spring waters and still working. Arç dam is built upon Arç River just like dams of our times and could not resist destructive effects of river waters. Memedik pond which is fed by diverted tributary river of Memedik creek is lost its function by boulder material. Reşan dam is the first crescent dam of Urartians and is in the borders of Ağrı province[19,22].

When the topography of Urartian dams is considered, it is seen that dam places are chosen so appropriately. As a matter of fact, DSİ which is the responsible corporation about water structures and General Directorate of Rural Services (KHGM) put Seyhan dam into service by renovating its wall and expand pond area by constructing a new wall in 300m south direction of Arç dam. A modern Arç dam is constructed in 250m north direction of Arç dam and agricultural lands are irrigated by a channel diverted from Memedik creek as used to be.

There are many water structures in Middle and West Anatolia belonging to Hellenistic, Roman and Byzantine periods. These are engineering works, cisterns and dams related with water transmission.

Water structures built for providing potable and fresh water of settlements like Istanbul, Efes, Bergama, Foça, Side and Aspendos are engineering masterpieces of their times. These water transmissions consist of clay tile pipes and channels carved in rocks. The longest of these is a system of 200kms built in Roman times for providing fresh and potable water to Istanbul from Pınarhisar. The second of these is a system of 100km in length in Foça area which almost has the ideal bottom slope of 0.15 - 0.3‰. Bergama with its eight water transmission line and Efes with four, are the richest settlements in number. Engineering works like tunnel, aqueduct and culvert are seen at the required topographical points in the water transmission structures[10,22].

One of the remaining water accumulation structures of Roman times, Aezani dam (Figure 7) is in borders of Kütahya province. It is predicted that limestone built dam is 20m in height, 80m in length and 6m in width. The dam wall is made arcuated as similar to contemporary concrete arch dams. A precision workmanship is required to obtain symmetrical balance in constructing these types of dams. In this dam type, provides an economic solution in narrow valleys, water load is transmitted to the versants to attenuate force effecting unit length. There is information that Aezani dam is built for protecting from overflows besides water accumulation[10,20].

Another water accumulation structure remain standing from Late Roman period till now is Faruk embankment within borders of Edremit, Van. Embankment having earth fill body is 10m in height, 30m in length and 4m in width. Large and small limestone rocks are used in the body. According to hydraulic characteristic, opening and closure of embankment's sluiceway, which shows a sluiceway feature, is made by a wooden valve.

Löstüğün dam in Amasya, one of the extant dams, belongs to early Byzantine period [22]. The difference of this dam with aforementioned in accordance with construction technique is this one is made of two separate bodies. For this reason it is assumed that its width is 20m. Its height is 12m; lengths of the bodies are 60m and 70m.

Fig. 6: A view the bottom sluice of Rusa Dam

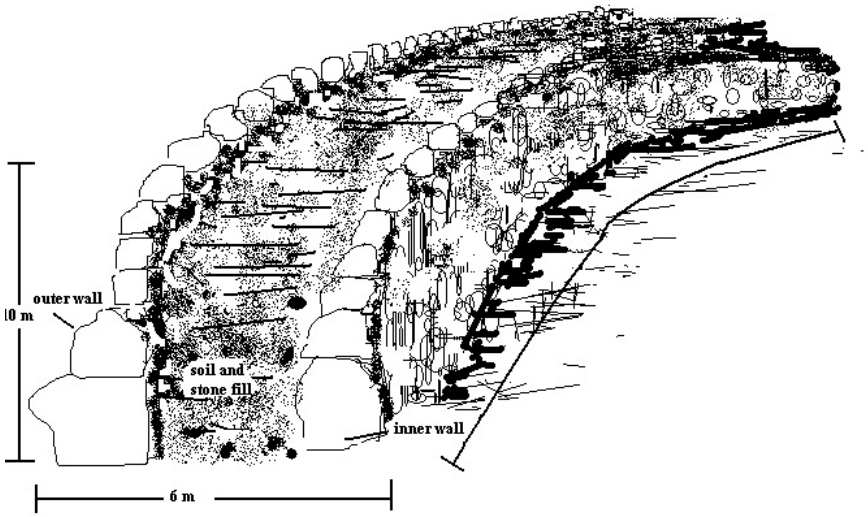

Fig. 7: General view of Aezani dam exists from the Roman period in Kütahya, Turkey

Fig. 8: Topuzlu dam exists from Ottoman Period in Istanbul, Turkey (from Özis 1996)

There is not any water accumulation structure in Anatolia remain from Seljuk period. But irrigation channel which brings out Meram spring waters to Meram vineyards are still working. Seljuks had made rules about utilization of water more prudently and distributed more fairly.

Most of the water structures remain from Ottoman times is fresh and potable water providing-oriented water transmission lines and dams and they are mostly seen in Istanbul and its adjacent areas. Halkalı transmission line is the longest of which is 100km in length with 16 different lines. Kırkçeşme, Taksim and Üsküdar water transmission systems are the other important systems [22]. Water transmission system of Taşlımüsellim line which carries water to Edirne province is approximately 50km long and its 40km part is still working.

One of the nine dams built in Ottoman times are Semalı dam in Amasya; Karanlık (Topuz), Büyükbent, Topuzlu (Figure 8), Ayvat, Valide, Kirazlı, Yenibent and Elmalı dams are within the borders of Istanbul[20,22]. It is known that hides are used to provide impermeability in earth fill dam Semalı. It the only Ottoman dam that lost its function. The biggest Ottoman dam in Istanbul is the Elmalı dam having 19.75m crest height and 1700000m^3 reservoir volumes. Most significant characteristic of these mentioned dams are they are stone-filled.

First modern irrigation project in Anatolia history is "Konya-Çumra Irrigation". With this irrigation system implemented in the late years (1905-1913) of Ottoman times, an area of 2000ha is irrigated. This project is developed in 1965, 1974 and 1985 and irrigation capacity increased into 60000ha [10].

First dam constructed in order to provide fresh and potable water between the years of 1930-1936 after declaration of Republic in 1923 is Çubuk I dam. Main aim of Gölbaşı dam constructed on Aksu River in Bursa is to provide irrigation water. The dam which serves to irrigate an area of 15000ha is in earth fill type and completed in 1943. First irrigation project of Republic history is "Aydın-Nazilli Irrigation".

There has not been a significant work on irrigation system and dam construction till the end of WWII. After that, accomplishment of dam and HEPP construction and major irrigation projects are accelerated. In order to plan, manage and operate water resources, in 1953, and in 1960, General Directorate of Soil-Water are established. Necessary road and irrigation systems for developing and enhancing rural settlements, and construction of small capacity water accumulation structures alienated to KGHM, established in 1984.

An area of 28Mha is in a cultivable land type in Turkey which has a total of 78Mha surface area. Technically and economically an area of 8.5Mha is in an irrigable quality in a total of 26 river basins. By the year 2007, 555 big and 664 small dams having a crete height of 15m or high, or having a reservoir volume of 3 hm^3 are constructed by DSI, KHGM and other corporations. In an area of 5Mha is being irrigated with the completed part of Southeastern Anatolian Project (GAP), the biggest energy production and irrigation project of Republic History.

Conclusion: The lands of Anatolia meet with irrigation water approximately 5000 years ago. Many of the structures constructed in the past for collecting and transmitting the irrigation water are still in service which some of them rehabilitated and even in some without a need of rehabilitation.

It is so much interesting and fascinating that the planners of these structures in the period when the principles of hydraulic are not known, having the same ideas like today's engineers. When it is thought that technicians, workers and administrators of those periods construct these structures in a patient and determined way, even if, with cruel means and methods; there is no doubt that every structure has a story.

In all of the examined dams, it is seen that boulders and rock are used to provide stability and clay is used to provide impermeability which has a compacting characteristic when it contacts with water. It is observed that water sluices constructed in the lower grades of dam body or gradual sluices are planned to provide water from different grades.

It is seen that channels and water galleries mentioned in the study are constructed in a sufficient bottom slope in terms of hydraulic principles and cross section, planned parallel to contour lines and supporting are built where topography is not appropriate.

We can say that Urartians have a contribution in prevalence of meadows and fields and intensity on animal husbandry in East Anatolian Region. Dams and channels constructing on Euphrates and Tigris rivers in South-eastern Anatolia region are just like the modernized reproductions of 5000 years old systems.

In many of Anatolia regions, which are just like open museums, archaeological studies are so less in number. The structures mentioned in this study are not whole works of old ages; they are aforesaid or well known ones. It is possible that; in the following years new discoveries of ancient irrigation structures will continue to surprise mankind.

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