DAMS OF THE ANCIENT CITY OF ISTAKHR

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ABSTRACT

Istakhr, from 500 B.C. to 1000 A.D. was a large metropolitan city of the ancient world. From the Achaemenid era to the early Islamic centuries, Istakhr was either the capital of the Persian Empire or the center of Istakhr province, a part of which is now called Fars Province. A major reason for the growth of Istakhr and its sustaining for 1500 years, besides other considerations, was the presence of Sivand River (Pulvar River in history). To use water for domestic and irrigation purposes, many storage and diversion dams were constructed on the 150-kilometer long Sivand River. Other hydraulic structures such as water mills, tunnels, canals, aqueducts, bridges and water control systems were also built around this river. Most of the diversion dams and the hydraulic structures are of stone masonry work with sarooj mortar. The stonework is coursed on the face and uncoursed inside the structure. Stones are of high quality broken limestone and brought from nearby quarries. In this paper, we introduce some of the remainders of the diversion dams that still are surviving on the Sivand River for more than 2500 years.

KEYWORDS: Ancient Dams, Istakhr, Sivand River, Sarooj.

INTRODUCTION

ISTAKHR CITY

The large mound of the Achaemenian city of Istakhr lies six kilometers northeast of Persepolis and north of the plain of Marvdasht. The actual domain of Istakhr was much wider than its present mound. In fact, Istakhr was the name of several interrelated districts of a long metropolitan city throughout its 1500-year history from Achaemenids era to the early Islamic centuries (Fig. 1). Different parts of the city were located in four different fertile plains. Namely, from south to north, Khafrak-e Paein (a part of Marvdasht plain), Khafrak-e Bala, Kamin and Pasargadae. The Achaemenid royal tombs of Naqsh-i Rustam and Persepolis palaces are located in Marvdasht plain and the fascinating tomb of Cyrus the Great and the ruins of the Toll-i Takht citadel is situated in the plain of Pasargadae. Many other monuments from Sassanid dynasty are identified in these plains. After the invasion of Arabs to Persia in the 7th century and the fall of

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Sassanid dynasty, Istakhr suffered extensive damage and lost its importance. Many people of Istakhr were killed or migrated to other places and the city started to disintegrate until finally only a name was left from it in history and geography books (Tabari, 9th century). Nevertheless, the ruins of many palaces, buildings, tombs, temples, roads and the relics of several hydraulic structures are remained that points to the extension and the glory of one of the greatest city of the ancient world. The hydraulic structures are mostly diversion dams, water mills, canals, tunnels, water control structures and bridges.

SIVAND RIVER

The strategic features of the land of Istakhr was perhaps the first factor for the Achaemenians to consider and select Pasargadae as their first capital. The plain of Pasargadae was far enough from borders of the Empire and more difficult for enemies to reach it. It was also surrounded by mountains that made the defense of the city easier. The fertile plains of Pasargadae, Kamin, Khafrak and Marvdasht and the pleasant climate of the region were of course other factors for the growth of the capital. However, the presence of Sivand River (Pulvar River or Parvab River in history) that flows from north to south through these four plains was a major advantage for the development and sustaining of the city of Istakhr (Figs. 2 and 3). Water from Sivand River was used for irrigation and domestic purposes. Many diversion and storage dams were constructed on the river. Water was flowing throughout the city and gardens in canals and ditches.

DIVERSION DAMS OF ISTAKHR

FIELD INVESTIGATION

During a one-week field survey, several remainders of dams and other related hydraulic structures were detected. The time for survey was chose in such a way that the river has its minimum water flowing, that is, in October. For each structure the geographical coordinates were recorded, at least one picture was taken and the type of material used in construction of the dam was identified. In the following sections we concisely discuss the characteristics of each structure. However, before that, we have to open an introduction to the materials that have been used in almost all of these dams body.

MATERIALS PROPERTIES

Sarooj. Sarooj is a Persian term for a mortar that may be called Iranian Cement. The word sarooj is derived from the middle Persian word “Charook” that means something compounded of four different materials. According to the old Iranian masons, these four compounds are lime, ash, water and cattail flower. The flower of cattail is added to sarooj mortar only if sarooj is supposed to be applied on the surface of walls for plastering. It acts as a reinforcement for distributing the shrinkage of the plaster and prevent it from cracking. There are of course other types of sarooj for special jobs. Like the one with egg white added to lime for sealing cracks. When for the first time Portland cement appeared in Iran as a new construction material, people called it “sarooj-e

farangi" meaning "European sarooj". Sarooj has been widely used as mortar in almost all of the ancient hydraulic structures of Iran to bind bricks or pieces of stones together. Sarooj has been also used to plaster the surface of walls. There are different types of sarooj (Malekzadeh, 2002).

Air-setting sarooj. For ordinary buildings, sarooj is made from a mixture of quick lime, ash and water. This stiff paste is mixed and compacted vigorously for 12 hours and then applied to the work.

Hydraulic-setting sarooj. For hydraulic structures, burnt clay is also added to make a hydraulic sarooj. Burnt clay powder mixed with ash is derived from the so-called *nanak* (bread shape). To make nanak, water is added to manure and clay to make a paste. Using this paste, disks of nanak 4 cm thick and 30 cm in diameter are made. After drying the nanaks under the sun, they are set on each other to make a hollow truncated cone with dry manure in between. Finally, the whole cone is covered and filled with dry manure, leaves and bushes and set fire to it. After 12 hours burning, the furnace is let to cool. At last all the produced materials are pulverized to get nanak powder.

THE REMAINDERS OF THE DAMS AND BRIDGES OF ISTAKHR

Starting from the jointing point of Sivand and Kor River and going upstream, we located the remainders of the dams and bridges as follows.

Structure No. 1. This is Madabad Dam with its spillway at the middle of the dam. The spillway is gated with eight sliding gates. The spillway downstream surface is of the so-called ogee-shape ending in a widening stilling basin. Two separate water mills are incorporated inside the two left and right non-overflow parts of the dam. Madabad Dam was rehabilitated many times during its long life. The last time rehabilitated was 100 years ago.

Up to 30 years ago, the dam was functioning properly. From that time, the irrigation water for the plain of Marvdasht was supplied from the one billion-cubic meter reservoir of Dariush the Great Dam. Consequently, Madabad dam was left idle with no protection or repair. Madabad Dam is a gravity stone masonry dam constructed with broken limestone and sarooj mortar. The ceilings of the water mills are arched with bricks and gypsum mortar and covered with stone and sarooj mortar (Figs. 4 and 5).

Structure No. 2. Nothing is remained of this dam except a part of the stone masonry body inside the right bank of the river, and probably the foundation that is under water and not visible.

Structure No. 3. The lower part of this dam is still surviving. This dam is a good sample to be investigated for detailed information regarding the foundation and stilling basin of such typical dams (Fig. 6).

Structure No. 4. From this oblique dam, only the foundation is remained. The designer of this dam decided to choose the dam axis not at right angle to the direction of water flow in order to have a longer spillway crest and a thinner water layer on the spillway

during flood seasons. The upstream face of the dam is plastered with sarooj mortar to prevent water from seeping through the dam (Fig. 7).

Structure No. 5. Before excavation, we are not sure whether this is the remainder of a dam or a bridge or both (Fig. 8).

Structure No. 6. This structure is a few footings of a relatively large bridge. The stones used to make the piers of the bridge shows that the original bridge was constructed during the Achaemenid period (Fig. 9). The collapsing of the arches of the bridge has caused the river to change its direction locally to the left. This may be the bridge called Khorasan bridge in histort.

Structure No. 7. This is the remainder of a control gate and a bridge on it. Other parts of this structure that have been made of wood, iron and bricks are completely destroyed. Only stone parts of the structure are remained. This structure has been a part of a water supply system for conveying water from Sivand River to Persepolis palaces and probably to some parts of Marvdasht plain. This structure is known as Takht-i Tavoos (Fig. 10).

Structure No. 8. This is a channel dug in the rock to convey water to persepolis. It starts from the aforementioned Takht-i Tavoos gate structure and after six kilometers, reaches Persepolis (Fig. 11).

Structure No. 9. 120 km. far from the confluence of the Kor and Sivand rivers, on a tertiary branch of the Sivand river in the north of Pasargadae plain, we located the remainings of an embankment dam and named it Didegan Dam, because of the Didegan village in its neighbourhood. Didegan Dam is built at the entrance of a small gorge which after one kilometer joins another gorge in which a secondary branch of the Sivand river is flowing towards the Pasargadae plain. Fortunately, some parts of Didegan dam body is remained, enough that we can guess its original dimensions and the materials that have been used to construct it. Figure 12 shows the left abutment of the dam. Figures 13 to 17 show different remainings of the Didegan storage dam system.

CONCLUSION

Our preliminary survey reveals that the Sivand river, throughout a long history of 3000 years, has been considered a major source of water supply for the purposes of irrigation and urban development. The durability of stone masonry diversion dams shows that:

- **a.** the builders of these hydraulic structures were able to select quarries to supply the most suitable crushed stones and had enough experience to produce the best cementicious mortar such as the Iranian cement of Sarooj,
- **b.** the dam engineers knew how to take into consideration various engineering parameters for the site selection of diversion dams, and
- **c.** in the case of limited locations for a reliable dam site, the foundation engineers were able to treat the foundation successfully.

The Didegan storage dam is a good example of large dams in the engineering history of Iran. Various features of this dam and its location show that the Achaemenian engineers:

a. knew how to control the floods of the Sivand river,

b. had enough soil mechanics knowledge to design earth fill dams,

c. could use construction equipments to compact soil.

The Didegan dam case seems to be very astonishing and hence more investigation on different engineering aspects of this and other hydraulic structures of the Sivand river is highly recommended.

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Figure 1. Istakhr, Pasargadae, Persepolis and the Persian Empire.

Figure 2. Map of Pars Province and the city of Istakhr (drawn 1000 years ago).

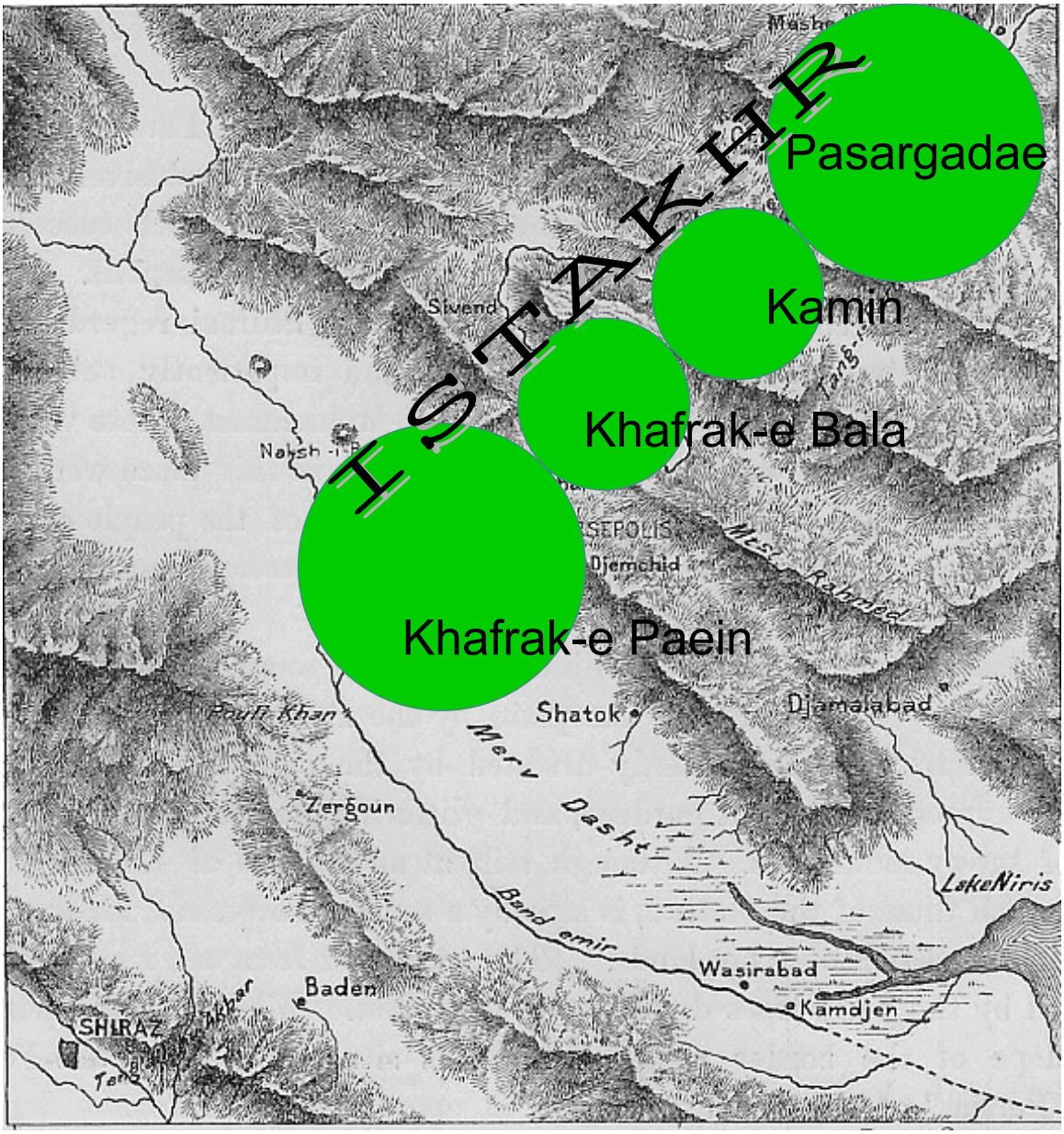

Figure 3. Different parts of the city of Istakhr spreading in four fertile plains of Khafrak-e Paein, Khafrak-e Bala, Kamin and Pasargadae along the sivand river**.**

Figure 4. Madabad Diversion Dam on the Sivand River (downstream face).

Figure 5. Madabad Diversion Dam on the Sivand River (upstream face).

Figure 6. A typical stone masonry diversion dam of the city of Istakhr.

Figure 7. An oblique diversion dam with sarooj plaster on the upstream face.

Figure 8. The remaining of a bridge or a diversion dam or both.

Figure 9. One of the footings of an Achaemenid bridge (probably Khorasan bridge).

Figure 10. The remainder of Takht-i Tavoos control gate.

Figure 11. The remainder of conveyance canal to Persepolis.

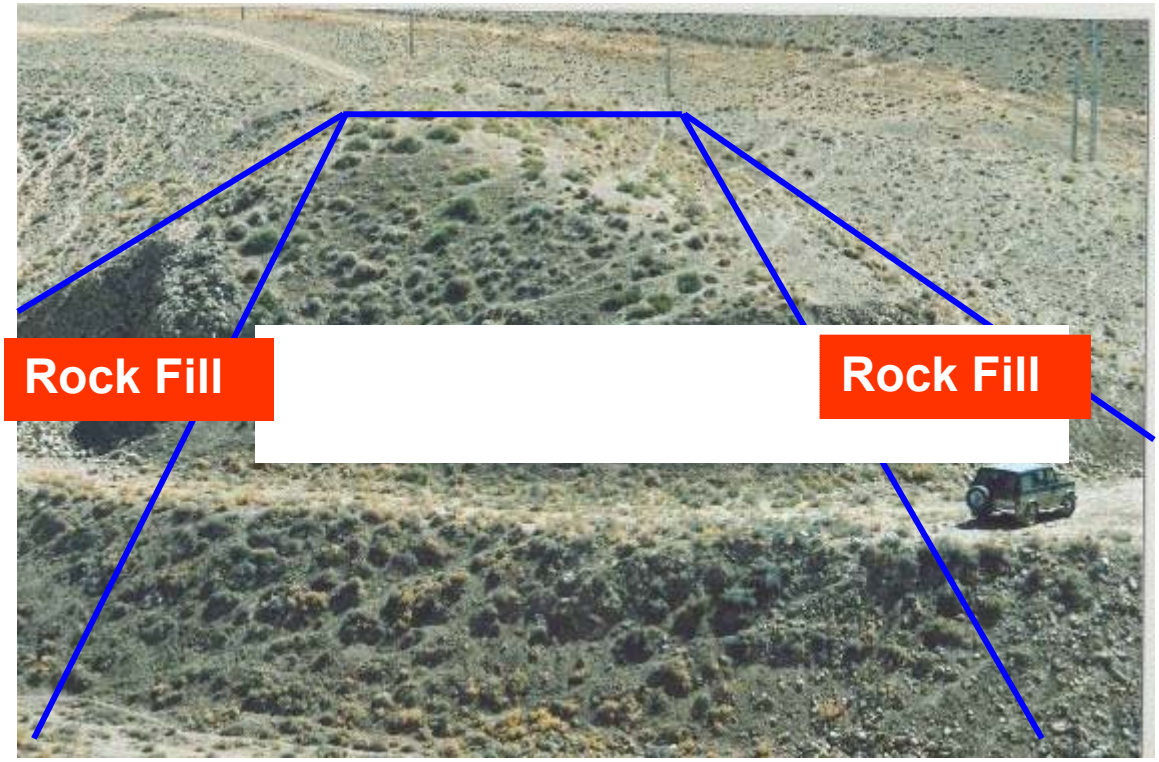

Figure 12. The remainig of Didegan embankment dam on the left abutment.

Figure 13. The texture of rock fill parts of Didegan dam.

Figure 14. The remaining of a stone retaining wall close to Didegan dam.

Figure 15. The remaining of stone pavement downstream of Didegan dam. Probably for scour protection.

Figure 16. Pieces of U-shape stones making a water conveying small canal downstream of Didegan dam.

Figure 17. Bottom of a piece of UU-shape stone with slots for fixing wooden slide gates in them. This has been an element of a water coveying system downstream of Didegan storage dam.