REHABILITATION OF ANCIENT DIVERSION DAMS OF KOR RIVER IN FARS PROVINCE, IRAN

Masomeh Zand[1], Farshid Morshedi[2], Mahmud Javan[3]

ABSTRACT

The ancient hydraulic structures constructed on Kor (Araks) river are examples of the magnificent water engineering works achieved by the old Persian engineers. These structures were built centuries ago, yet some of them are still functioning well in controlling floods and diverting water to the farmlands. In this study some of the stability issues encountered in the rehabilitation process of Tilakan and Feizabad dams are discussed. Scouring depth and materials used for construction are evaluated in this study. The load conditions under which these stability analysis were made are also discussed.

Keywords: ancient dam, Iran, Kor river

INTRODUCTION

Iran is located in a semi-arid region of the world. Water shortage has always been a challenging problem for its people. Therefore, they have always been trying to find the proper solution. Many dams were constructed and underground galleries (Qanats) were excavated by ancient Persians. There are traces of irrigation canals about 6000 years old in the ruins of Sialak, near Kashan, in central Iran. Cyrus the great King of Persia after defeating the Babylonian Army in 539 B.C. built an earth dam for irrigation on Diala, a tributary of Tigris. He ordered excavation of 30 canals for water distribution works. The Persian King Darius the Great (521-485 B.C.) from Achamenian dynasty built dams on River Kor, south of Persepolis while he was in power (Javan, 1996).

Many of the ancient Persian hydraulic structures which were located in the Fars Province of Iran are introduced by Javaheri and Javaheri (1999, 2001).

1- Azad University, Broujerd, Iran, masomeh_zand@yahoo.com
2- Mahab Ghodss Consulting Engineers, Tehran, Iran, morshedi@mahabghodss.com
3- Water Engineering Dept. Shiraz University, Shiraz, Iran, Javan@shirazu.ac.ir

DESCRIPTION OF THE AREA UNDER STUDY

The Marvdasht and Korbal plains are located near the city of Shiraz, in Fars province, southwestern Iran (Fig. 1). The average altitude of the area is about 1590 m. The area is a semi-arid region with an average precipitation of 340mm per year. From agricultural and economical aspects, these two plains are very important in Fars province. The ancient palaces of Persepolis and Estakhr city have promoted tourism industry in these plains. Kor and Sivand rivers are the major rivers of the region. Sivand river flows into Kor river at Pol-e-Khan (Khan bridge) and discharges into Bakhtegan lake. In the last 80 kilometers of Kor river, six diversion dams had been constructed during the past centuries (Fig. 2). The dams were constructed of cut stones with Sarooj mortared joints (lime and ash). These multipurpose dams raise water level in the river and divert irrigation water to the farms. They also create the necessary head for several water mills and act as bridge between the banks of the river.

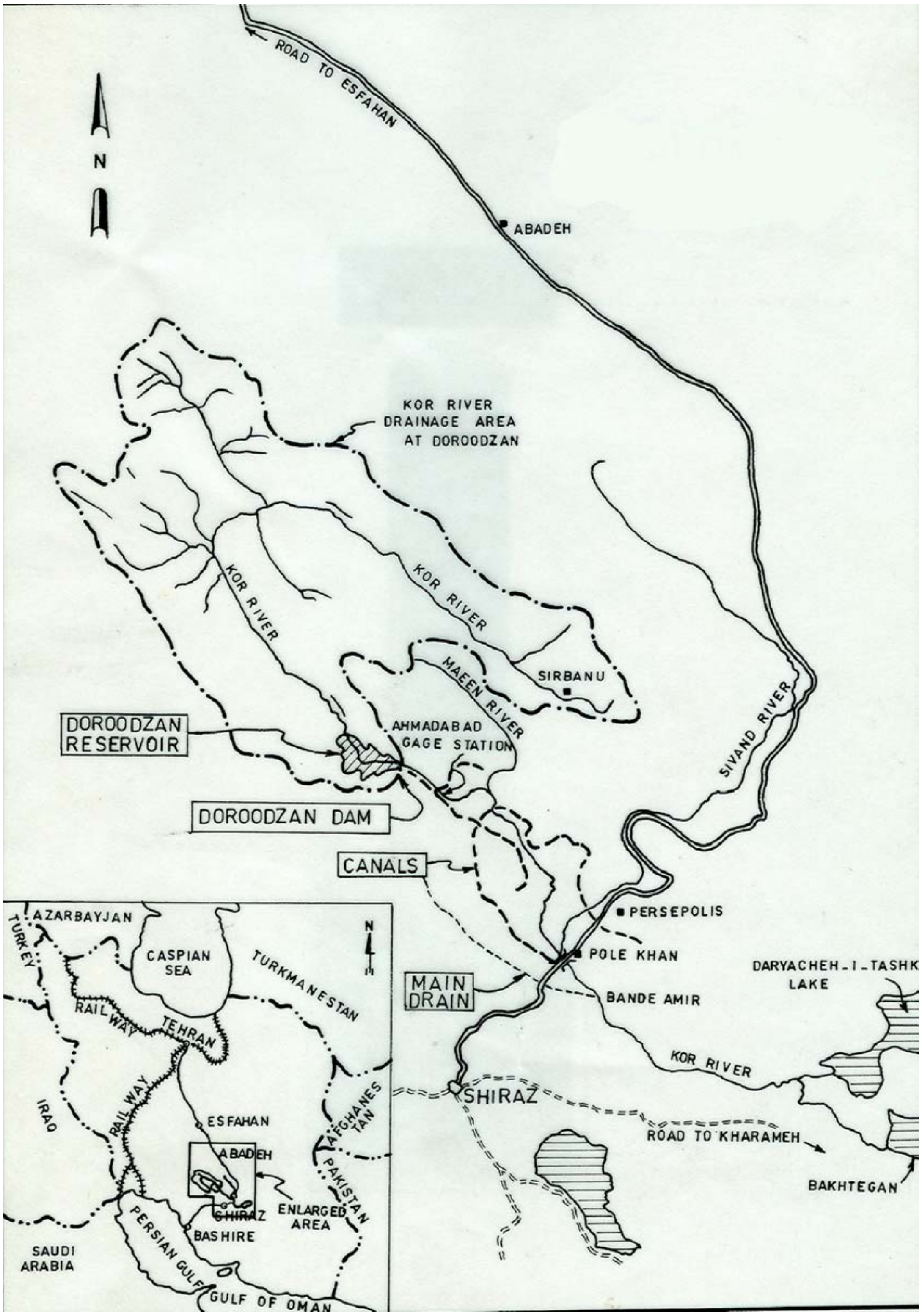

Figure1. Location map of the area under study

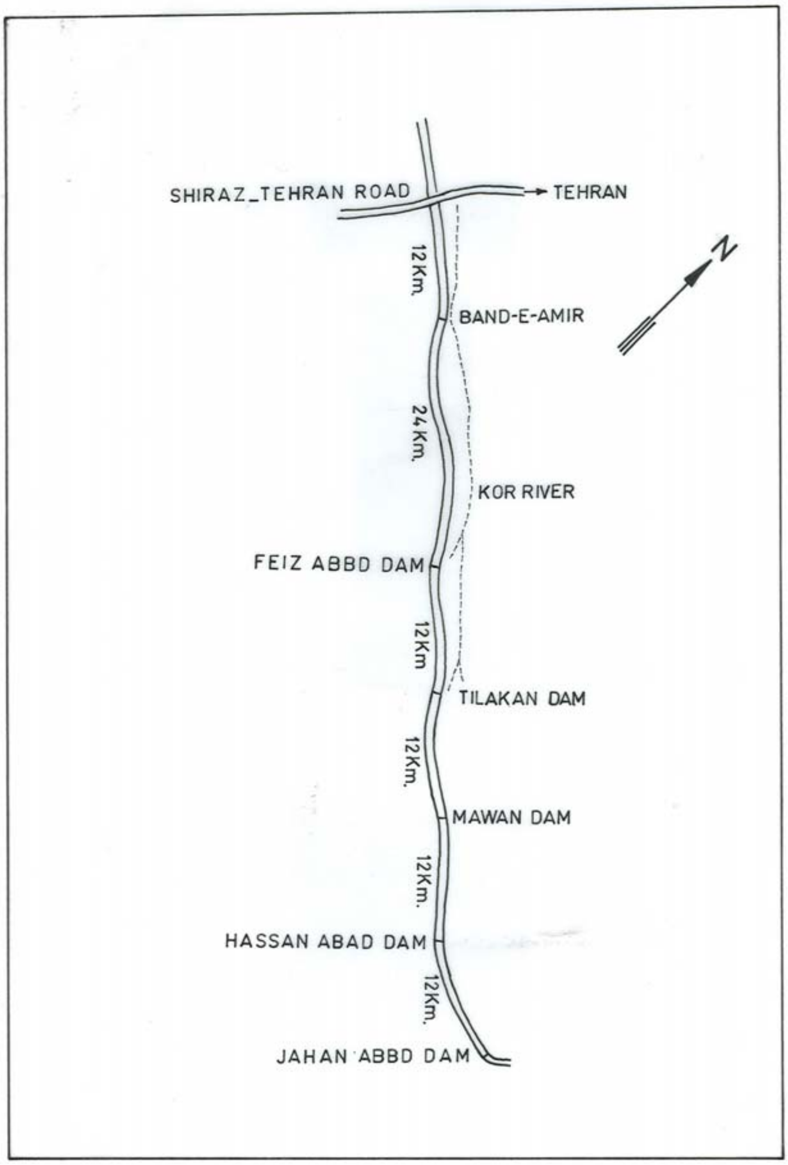

Figure2. Location of Kor river dams

REHABILITATION OF THE OLD DAMS

Rehabilitation of four dams (out of six) has been completed so far. These include Band-e-Amir, Feizabad, Tilakan and Mawan. In this paper rehabilitation of Feizabad and Tilakan are discussed.

FEIZABAD DAM

This dam is located at 23 km downstream of Band-e-Amir. It was reconstructed by Atabak Chaveli about 700 years ago. There were 22 watermills along this dam. The average length of the dam is 250 m while 200 m of the dam is located in the river. Small canals with 0.3 m depth and 0.5 m width divert water to the mills. The dam width varies from 4 to 12 m. At present the spillway crest height is increased about 1.8 m. Only 40 m of the dam length is across the river width and the remaining dam length is constructed along the river (Fig 3). This is due to following reasons:

- The small width of the river and existence of watermills.
- Not enough spillway crest length to pass the flow at high discharges.

At the right bank of the dam there is one meter deep and 1.5 m wide canal. This canal was constructed on the spillway to convey water to downstream at low flows (discharge of less than 10 cubic meters per second). The dam becomes submerged at flows of 90 m^3s^{-1}. Full submergence occurs at discharge of 150 m^3s^{-1}. The average depth of water behind the dam was about 5.5 m. Before rehabilitation, the safety against overturning under earthquake condition was 2.7 and against sliding was 1.6 (Omran Zamin, 1983). Bearing capacity was calculated to be 0.9 Kg/cm^2 under earthquake condition.

After rehabilitation, stability analysis was made for the following loading conditions:

- During construction
- Normal condition
- Flood condition
- Earthquake under normal conditions

Under the above conditions safety factors were more than the allowable values. However, under earthquake condition safety factor against sliding was 1.3. Under this condition the bearing capacity was estimated to be between 1.1 to 1.3 Kg/cm^2. When the dam was considered to be fully submerged, safety factors were more than 1.7. Under normal conditions, safety factors against sliding and overturning were more than 2.0. Due to the existence of a 2m cutoff and 15 cm thick filter, the vertical exit gradient was calculated to be more than 3 that indicates the dam is safe.

Fig. 3 shows the pictures of this dam before and after rehabilitation.

Figure3. Feizabad dam before and after rehabilitation

TILAKAN DAM

Tilakan dam is located at 14.5 km downstream of Feizabad dam. This dam is also a multipurpose one. The dam is submerged at a discharge of 80 cubic meters per second. However, when river flow reaches 230 m^3/sec, the dam becomes fully submerged. The dam length was about 180 m with 34 openings of 1.7 to 3.5 m wide before rehabilitation. The safety factors against sliding and overturning under earthquake are 1.3 and 2.4 (Zand, 2005). The average dam height from river bed was about 5 m. Fig. 5 shows the dam before and after rehabilitation. Fig. 6 shows the earth canals excavated by the farmers for diversion of irrigation water before increasing the crest height of the dam. The command area before rehabilitation was 11000 ha, while it was increased to 12500 ha after rehabilitation.

The stability analysis after rehabilitation was under the same load conditions as Feizabad dam. However, the safety factors against sliding and overturning under earthquake condition (horizontal acceleration of 0.1 g) were 1.25 and 2.4 respectively. Maximum pressure on foundation was calculated to be 1.1 Kg/cm^2. The Lane weighted creep ratio was 4.9 and shows that the dam is safe against piping on its silty clay foundation.

Figure5. Tilakan dam before and after rehabilitation

Figure6. Tilakan dam and the corresponding canals and farms before rehabilitation

RESULTS AND DISCUSSION

- The six diversion dams built on Kor river were not supplying the designed discharges. They also could not provide the necessary head for conveying irrigation water to the farms. Therefore, the Regional Water Authority of Fars decided to rehabilitate them. The remaining two dams (Hassan Abad and Jahan Abad) will be submerged by Bakhtegan lake in the near future. However,the irrigated areas under these dams will be irrigated by Mawan Dam.
- In rehabilitation of Tilakan Dam, Water Authority in collaboration with consulting engineers made intensive efforts in renovating the dam keeping in mind its historical identities.
- Rehabilitation of Feizabad Dam was completed between 2001 to 2003. This dam could also increase the irrigated area to 14900 ha.
- Since these hydraulic structures are our cultural heritages, efforts must be made in such a way that in their rehabilitation the technical and historical characteristics remain as authentic as possible.
- This study suggests that the ancient engineers had the knowledge of proper site selection. The stability analysis also suggests that the Persians understood the principles of stability. They could design dams that were safe against overturning, sliding and piping .

REFERENCES

1- Buske, U. 1995. History of irrigation, drainage and flood control. *ICID Workshop*, Rome, Italy.

2- Javaheri, P., and Javaheri, M. 1999. *Water solution in Fars history*. Iranian National Committee on Irrigation and Drainage, and Water National Museum of Iran, Vol.1. (in Persian)

3- Javaheri, P., and Javaheri, M. 2001. *Water solution in Fars history*. Iranian National Committee on Irrigation and Drainage, and Water National Museum of Iran, Vol.2. (in Persian)

4- Javan, M. 1996. Brief history of ancient Band-E-Amir Dam-Bridge, *Proceedings of the Sixteen Congress of the International Commission On Irrigation and Drainage*, Cairo, Egypt.

5- Zand, M. 2005. *Technical survey of ancient hydraulic structures on Kor and Sivand rivers in Fars*, M.Sc. Thesis, Shiraz University, Shiraz, Iran. (in Persian)