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FEASIBILITY, VALUE ENGINEERING, AND ROCK FILL DAMS CONSTRUCTION: A CASE STUDY

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In this study details of structure of Shahr-e-Bijar concrete-faced rock-fill (CFRD) in Guilan (a province in the north of Iran) and the reasons to select CFRD are presented. To select CFRD first by investigation of 18 different types of dam based on local availability of materials and the ability of constructing by available technology (both Iranian and foreign available technology) six types of them were selected for value engineering. By attention to construction costs, execution time, durability, reliability and performance and ease of construction and operation; and also, the importance coefficient for local government were selected for value engineering. After that 3 types of dam structure (vertical clay core dam, asphalt core dam, and CFRD) had maximum scores. Finally, rock fill dam with concrete surface is selected because despite being more expensive in some cases than other options, it could be considered as a successful dam construction option in Iran because the construction needs no foreign technology and its technology of construction and materials are available. On the other hand, the necessary time for the project is 24 months. The main objective of this project is to avoid time loosing because of materials availability and local technology that needs no finance transferring and no foreign contract that may not be affected by some political condition that delays the project.

Keywords: Shahr-e Bijar, Hydrology, CFRD, Reservoir dam.

1 INTRODUCTION

In Iran, as one of the arid and semi-arid countries of the word, the average annual rainfall is 250 mm, which is 30% less than the average rainfall in the world. Because of this climate and water resources shortage, artificial irrigation is needed and due to this, Iran is known as the leading in Middle East in dam construction. By constructing reservoir dams in the source of rivers not only flood control but also water loss prevention could be done. In terms of materials, dams could be put in various categories, which one of the major categories is concrete, plus embankment dams. In the past, most of the dams are concrete dams in the world because of lack of advanced road building machinery and easy design of them. In 1940, it was a restarting point in the construction of embankment dams.

Based on the recommendation in Bulletin No.92 of International Commission on Large Dams, the application of rock fill dam with clay core is economic if the dam building is zoned correctly because it could be possible to use all available rocks (ICOLD 1993). Rock-fill dam will be built where gravel can be found in large quantity. Also in a place where rainfall is high and where there are problems in embankment dams' construction, rock-fill dam is more acceptable.

Despite the major and considerable advantages of rock-fill dams with concrete surface, there are some disadvantages too. Low-life concrete surface, expensive construction of concrete and lack of enough experience in design and construction of large dams, which increase the risk of cracks in concrete surface are some examples. Also, there are some problems that have been seen since the beginning of the rock-fill dams' construction such as separation of slab from dam and tensile stresses. The separation can cause cracks in the slab which itself leads to reduced safety factor against damages caused by water infiltration. In these types of dam the amount of the leakage from the body may increase because of small deformation specifically in external and also because of cracking of concrete surface by strong earthquake. Consequently, the general stability of the dam will be threatened by the increased leakage. In new modern designed and constructed rock-fill dams the leakage flows in cracks of concrete surface by the body of the dam can be controlled. In dynamic analysis increasing of height in elevation in a dam causes more horizontal and vertical deformation and the maximum is on dam crown.

2 POSITION AND SPESIFICATIONS OF SHAHR-E-BIJAR RESERVOIR DAM

Shahr-e Bijar reservoir dam is in Guilan province (a province in the north of Iran beside Caspian Sea) within 35 km distance from Rasht capital city and is placed near Shahr-e Bijar village to provide drinking water for the capital city and 11 other cities of the province (Figures 1 and 2).

It is estimated that it could supply 6.2 million people water requirements, provides required water for 1,5 million squared meter agricultural lands and generate 24 GW of electricity per year by three hydro power turbine units. The dam is a rock-fill dam with concrete surface (CFRD).

Using CFRD for this dam in Iran is the third experience of this kind of dams. There is no clay core in the dam and water tightness of body of dam is provided by reinforced concrete slab on the upper slope. The height is 91m and the crown length is 438m and it is extended 380m in foundation. The studies of this project started by some counselors' companies and ministry of energy in 1971; and were completed in 2001. Hydrology specifications are presented in Table 1.

Figure 1. Location of dam (Google earth).

Figure 2. Position of Shahr-e Bijar CFRD.

Table 1. Hydrology specifications.

Pre casting the time of finishing the project	May 2013
Primary time of contract	60 months + 28 months
volume of 50 years sediments	25.1 million m^3
Possible maximum flood	1700 m/sec
Volume of dam reservoir	105 million m^3
Area of drainage basin	242 km^2
Volume of annual water supply	165 million m^3

3 DAM COMPONENTS

Diversion system includes coffer downstream dam, coffer upstream dam, diversion tunnel, input structure, and stilling that among these the stilling is not implemented yet (Figure 3). Upstream Cofferdam is a structure with 301 m crown length, 7m-crown width, 20m height, and crown elevation of 160m above sea level in order to guide flooding during construction on dam upstream (Figure 4).

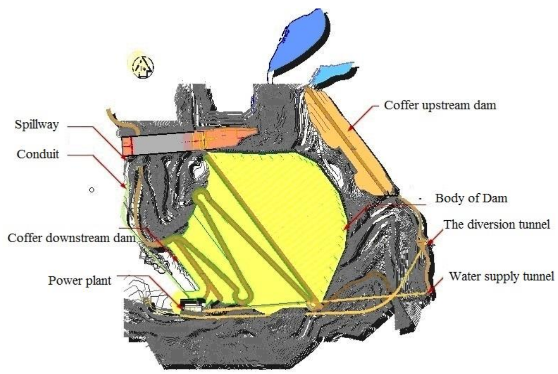

Figure 3. Plan of under construction Shahr-e Bijar CFRD.

Figure 4. Upstream Cofferdam.

Downstream cofferdam is a structure with 176m length, 8m height, and crown elevation of 146m above the sea level in order to reduce project costs on dam downstream, it is connected to the body of the dam. Body specifications data are written in Table 2.

Table 2. Body specifications.

Total volume of embankment	3521709 m^3	Total volume of reservoir	105 million m^3
Total volume of excavation	950000 m^3	Level of river base	140 masl
Total volume of pouring of concrete	25438 m^3	Length of the crown	437 m
Minimum level of operation	160 masl*	Width of the crown	11 m
Maximum level of operation	212.6 masl	Maximum width of basement	380 m
Level of the crown	219.5 masl	Height from footing	90.5 m
* Meter above sea level			

The diversion tunnel is "D shape" and designed for 50-year flood (110 cubic meters per second), and the maximum bottom discharge rate is 48 cubic meters per second (Figure 5).

The dam body cross section (Figure 6) consists of A1 layer of impervious fine material, B1 layer that is consists of random filling, 2AA layer that is the transitional layer, 2A layer that is from transitional material, 3A that is drainage area. Plinth or dam heel reinforced concrete slab that is constructed on rock foundation with low leakage. The plinth exterior width is 4m but the interior width is determined by rock quality parameter (Figure 7).

The free spillway at the right coast is designed based on the maximum flood potential with 844 m^3 per second discharge. The system consists of approach channel, spillway peak, stepped Shute, and stilling (Figure 8). Intake structures include the left intake system, which consists of three intakes in 156.5, 169.5, and 187m, which they end to vertical Shaft (Figures 9 and 10).

Figure 5. The diversion tunnel.

Figure 6. The dam body cross-section.

Figure 7. Plinth.

Figure 8. Spillway.

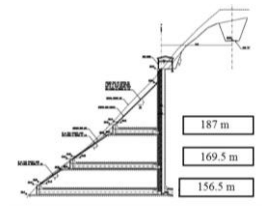

Figure 9. Cross section of intake structure.

Figure 10. Vertical shaft of intake structures.

4 VALUE ENGINEERING

To choose the best option among others, 18 types of dams are presented in Table 3. By investigation of dam types presented in Table 3 and based on local availability of materials and the ability of constructing by available technology (both Iranian and foreign available technology) six types of them were selected for value engineering. The advantages and disadvantages of selected dam types are presented in Table 4.

By attention to the advantages and disadvantages selected of options for structure type of dam 5 evaluation items: 1-construction costs, 2- execution time, 3- durability, 4- Reliability and Performance, 5- ease of construction and operation; were selected for value engineering and also the importance coefficient for local government for each one of the5 items were allotted. Table 5 shows the results of value engineering. The maximum score and minimum limitation of scores were selected based on and the availability of construction technology in the place and availability of consuming materials. On the other word the assigned marks are based on local government importance and local technical issues. The results of Table 5 show that 3 below dam structure types had maximum scores:

Table 3. Various types of dams which are presented for primary assessment.

1	Vertical clay core	**7**	Geo textile	**13**	Concrete surface
2	Inclined clay core	**8**	Injected core	**14**	Geo membrane
3	Concrete core (rigid)	**9**	Bituminous core+ clay core	**15**	Bituminous and asphalt
4	Plastic concrete core	**10**	Wooden core	**16**	Homogeneous soil body
5	Steel plates	**11**	Core with plastic plate	**17**	RCC
6	Asphalt core	**12**	GC core	**18**	Soil-cement body

4.1 Vertical Clay Core Dam

Clay due to lower precipitation in this area has got adequate moisture; even in rainfall months.

Large and usable lump of clay or adequate moisture are available with no conflict because of new high way exit. The sides, specifically the left, are usable in dry months or in pure or mixed zone. So, the most suitable option is clay core by the use of multiple loans resources; and finally, if there are adequate machineries to serve the project, the contractor will be able to complete the operations within the contract duration.

4.2 Asphalt Core Dam

This option is cheaper than CFRD and because of asphalt flexibility has got fewer flaws than CFRD. 3-D and 2-D analysis to evaluate core behavior is functional according to geometry and location.

4.3 CFRD

In the modified design, it was the most expensive option. Although lack of experience in CFRD dam implementation has been important, the qualitative assessment should be considered.

Table 4. Advantages and disadvantages of selected dam types that could be constructed in the place.

Type of Dam structure	Advantages	Disadvantages
Vertical clay core	Common construction Available experience Simple constructing Good behavior in earthquake Safety	Time limitation High volume transportation of materials Possible increase in traffic losses
Inclined clay core	Good behavior in earthquake Safety Simple constructing	High volume transportation of materials Possible increase in traffic losses
Asphalt core	Good behavior in earthquake Safety Adaptation With climatic conditions	-
GC core	Simple constructing Good behavior in earthquake Common construction	High quality control
CFRD (concrete-faced rock-fill)	Simple constructing Good behavior in earthquake Available experience Safety	High quality control Redesign necessity
RCC	Spillway absence Fast constructing	Foundation weakness Redesign necessity

Table 5. Select the type of dam.

Evaluation criteria	Importance Coefficient	Score	Options					
			Vertical Clay core	inclined clay core	Asphalt core	GC core	CFRD	RCC
Construction costs	2	**Max** **Score**	8 4	8 4	6 3	4 2	8 4	4 2
Execution Time	1.5	**Max** **Score**	4.5 3	6 4	6 4	6 4	7.5 5	6 4
Durability and Reliability	1	**Max** **Score**	5 5	5 5	5 5	5 5	4 4	5 5
Reliability and Performance	2	**Max** **Score**	10 5	8 4	10 5	10 5	8 4	8 4
Ease of Construction and Operation	1.5	**Max** **Score**	6 4	4.5 3	6 4	6 4	6 4	6 4
Sum			33.5	31.5	33	31	33.5	29

4.4 Final Evaluations to Select Dam Type

Estimating comparison shows that clay core is hard to implement in an area and takes more time. Asphalt core by the use of Norwegian technology gives more emphasis to schedule and the time because Norwegian contractor tries to make the best use of the time and also make use of his machineries in other projects. Neither asphalt core nor CFRD, does not have universality and diversity of experience of the clay core. Dam with clay core needs three years and a half to be implemented. If we modify this time according to common delays of dam implementation in high rainfall areas, the necessary time to body implementation could be considered five years and the project process duration is six years. CFRD implementation requires two years for embankment and three months for concrete surface. In this case the minimum construction time could be considered three years. The time is a year longer than estimated time in the meeting and it could be said that is so optimistic and more intensive than similar projects.

The necessary time for the project is 24 months. The main objective of this project is to avoid time loosing so selecting the clay core option according to regional rainfall during the year is not the best option. Also for asphalt core option foreign contracts were needed the had lots of limitation but for CFRD option all used technologies and materials are available in Iran and also in Guilan so no finance transferring and foreign contract is needed and because of it no political decision can affect on the project process.

5 CONCLUSION

In this study, details of structure of Shahr-e-Bijar CFRD and the construction methods of them are presented. To select CFRD first by investigation of 18 different types of dam structures based on local availability of materials and the ability of constructing by available technology (both Iranian and foreign available technology) six types of them were selected for value engineering.

By attention to the advantages and disadvantages selected options 5 evaluation items: 1- construction costs, 2- execution time, 3- durability, 4- reliability and performance, 5- ease of construction and operation; and also, the importance coefficient for local government were selected for value engineering. After that 3 types of dam (vertical clay core dam, asphalt core dam, and cfrd) structure had maximum scores.

Finally, rock fill dam with concrete surface is selected because despite being more expensive in some cases than other options, it could be considered as a successful dam construction option in Iran because the construction needs no foreign technology and its technology of construction and materials are available. On the other hand, the necessary time for the project is 24 months. The main objective of this project is to avoid time loosing because of materials availability and local technology that needs no finance transferring and no foreign contract that may not be affected by some of political condition that delays the project.

Acknowledgments

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