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STRENGHTENING AND REMEDIAL SCHEME FOR GOLESTAN HISTORICAL DAM IN IRAN

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ABSTRACT

The remained traces of historical hydraulic structures are valuable capital that maintaining and introducing it to the world is a human duty. More over, many of these structures nowadays have an inevitable role in providing water, although its centuries that they are built. The historical dam, GOLESTAN in Iran is located in Mashhad city, which its historical background refers back to 500 years ago. This dam is a gravity dam with the final height of 21.5 meters from the river bed and the crest length of 130 meters.

Repair of this dam always being taken into consideration for the purpose of paying attention to the valuable historical structure and Its maintenance for future generations, damage assessment and strengthening regarding the stability and seepage control, integrated planning and management for appropriate use of the plan and the periphery area for different purposes such as attracting tourists, providing domestic water supply, artificial recharge of the ground water table.

In this article, the existing conditions related to GOLESTAN historical dam in Iran, it's strengthening and remedial scheme, including dam body and foundation and the appurtenant works is presented in detail.

Key words: Cutoff Wall, GOLESTAN Dam, Repair, Remedy, Strengthening, Seepage, Stability Control, Stress, Waterproofing.

INTRODUCTION

GOLESTAN historical dam is located in north-east of Iran, 8 kilometers west of Mashhad city on GOLESTAN river in coordinates of east longitude 59 27 9 and north latitude of 36 19 35. The area around the dam and it's reservoir regarding the riches of natural environment and the vicinity with high compaction living centers, is worthy of attention as an important resource for echo tourism. Hence many native and foreign people visit it every year (Fig.1 to 3).

It is possible to create a tourist–recreative center while enjoying natural blessings, having healthy recreations and enjoying the appropriate space of the lake. These points should be considered while compiling the plan and the main design, are:

1- Structural orientation and facilities for meeting the needs and improving the environment condition from the aesthetics point of view.
2- Creating harmony between the echo logic of the natural face of the design and improvement suggestions and having the economical justification of the design. For the time being, the specifications and geometrical dimensions of this dam is in Table 1.

Table 1
Specifications of GOLESTAN dam

The length of the dam in stream bed	30.60 meters
The length of the dam in crest	132 meters
The width of the dam in crest	10.5 meters
The width of the dam in stream bed	25 meters
The height of the dam from river bed	21.5 meters

PURPOSES

The most important purposes of the design are mentioned below:

- Paying attention to valuable historic dam and attempting for its maintenance, repair and efficiency.
- Damage assessment, restoration and strengthening of the dam regarding the stability control and infiltration from the dam body and its foundation.
- Anticipating the new spillway for passing the flood water considering the inadequacy of the existing spillway.
- Considering the area around the trace from architectural aspects, area designing and tourism purposes.
- Integrated management and planning for appropriate use of the structure and periphery area.
- Optimum usage from potentials of GOLESTAN River for different consumptions such as agriculture, drinking, artificial recharge of the ground water table and etc.

Fig. 1
Dam and Reservoir view from right abutment.

POTENTIALS AND CAPABILITIES

The major materials used in the structure of the dam are include brick, stone, lime mortar and soil in a way that stone and lime mortar are used in the middle of the structure and brick and lime mortar are used in external surfaces. Being located in the way of healthy climate areas, easy accessibility regarding the appropriate public transportation, cultural–historical tourism attraction, the existence of topography, desirable climate of the region, recreative history and also regional tourism attraction regarding the existence of mater and other natural attraction, being close to the natural recreative main centers are the most important specifications of this historic dam.

The volume of the dam reservoir at present conditions in normal level is 1.1 million cubic meter. If the stored water is going to be regulated for agriculture purposes, the regulated volume of the reservoir will be 2.42 million cubic meter maximum, that in this condition the overflowed volume from reservoir will be 31/7 million cubic meter and if the stored water is going to be regulated for drinking purposes also, regarding the existence of several water reservoir for Mashhad city it is possible to consider a volume about 7.28 million cubic meter in addition to the volume of 2.42 million cubic meter regulated for agriculture. In this way the volume of the regulated water of the reservoir will be 9.7 million cubic meter and the volume of the overflowed water from reservoir will be 25.89 million cubic meter. The general physiographical specifications of river watershed, is shown in table 2 according to (mcm).

Table 2
Physiographic specifications of GOLESTAN drainage basin

Min. Elevation (m)	Max. Elevation (m)	Max. Difference in Elevation (m)	Runoff volume (mcm)	Area (km)	Average slope (%)
1160	3080	1920	37.10	316.67	11.97

DAMAGE ASSESSMENT AND DANGER RECOGNITION

Lack of a single and comprehensive management, excessive construction around dam, legal problems of the estates possession and segregation around the area, Shortage of the infrastructures including access roads, water, electricity, gas, the seasonal nature of the lake and etc., are the most important limitations and dangers that should be considered in this project. Some of the general damages which structures may encounter with are; seepage, deterioration, weathering, local damage, inadequate resistance against earth

quake, improper maintenance, inappropriate organization, designing and improper restoration.

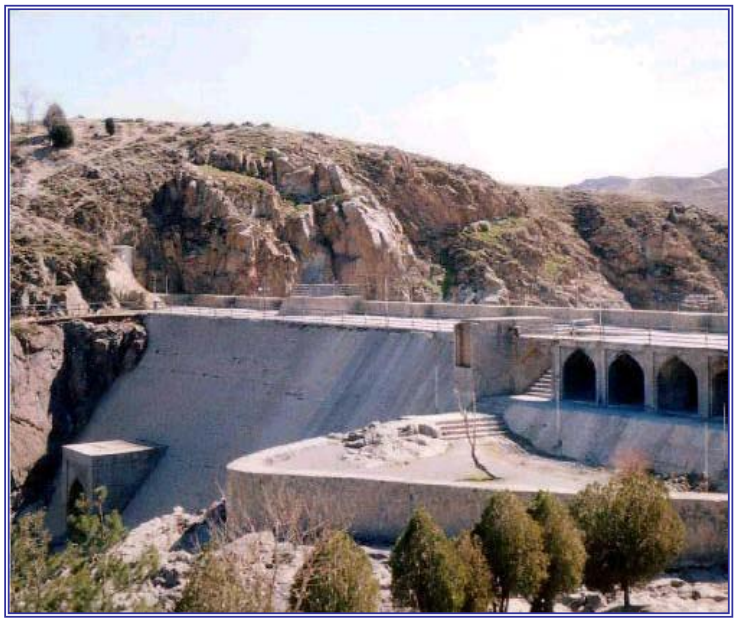

Fig. 2
Downstream view of Dam

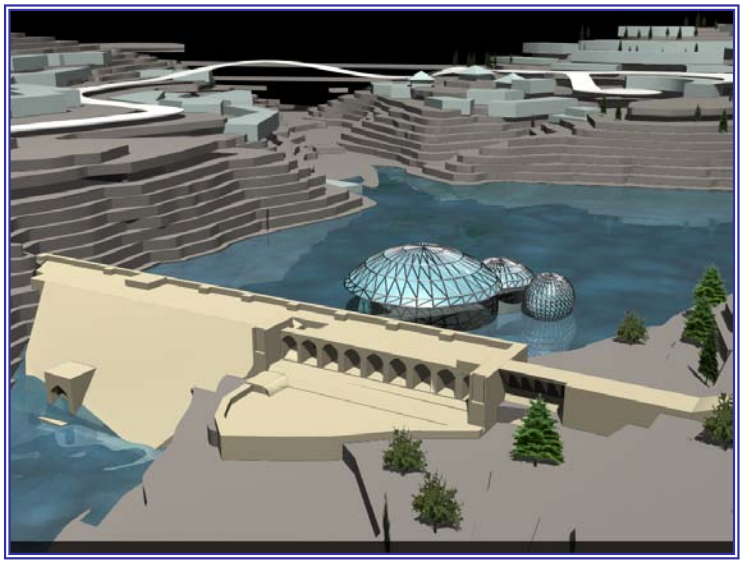

Fig. 3
Schematic view of Dam and water museum at the scope of project

STRATEGIES

In designing and studies processes, management and planning are considered as fundamental stages that show the final orientation of the design in an organized way. Dam strengthening and predicting and establishing tourism infrastructures, space creating and creating attractive spaces to indicate memorable elements through new attached elements are the strategic activities which have been seen in short–term planning in form of organization, medium–term planning in form of equipment and construction of infrastructures and long–term planning in form of development.

ANALYSIS AND DESIGN

The first step in short–term planning is dam strengthening. Assessing dam primary Safety and stability is done through controlling the parameters of overturning, sliding, foundation load bearing capacity and is compared with the criteria related to the stability control of the gravity dams regarding USBR standard (Table 2).

In next stage, structural safety was considered based on the strain and stress control including tensile, compressive and shear stresses and deformations in different part of the dam body. Thus dam model was built and analyzed through plane strain behavior in ANSYS finite elements software (Fig. 4). In order to show the effect of the Dam body materials, first, the materials characteristics in analysis were modified based on the experiments and the present condition of the materials and then the actual resistances of the materials were used for controlling the capacities.

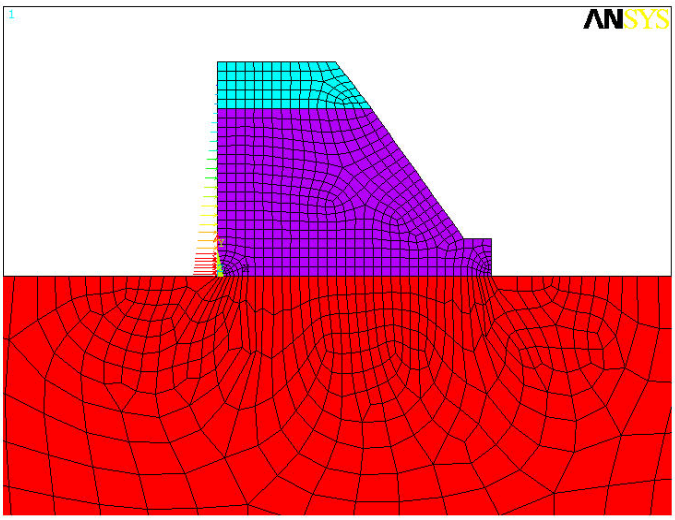

Fig. 4
Discritization of elements for Dam and its foundation

After the first analysis, the model was dynamically analyzed and dam natural vibrational modes in interaction with foundation were calculated for the first 25 vibration modes with mode density contribution coefficient and also mode stiffness. The calculation results showed that the first interaction vibration period is equal to 0.19 seconds and the

equal frequency is 5.2 hertz. One of the advantages of this analysis is the appropriate distribution of the earthquake force in dam body.

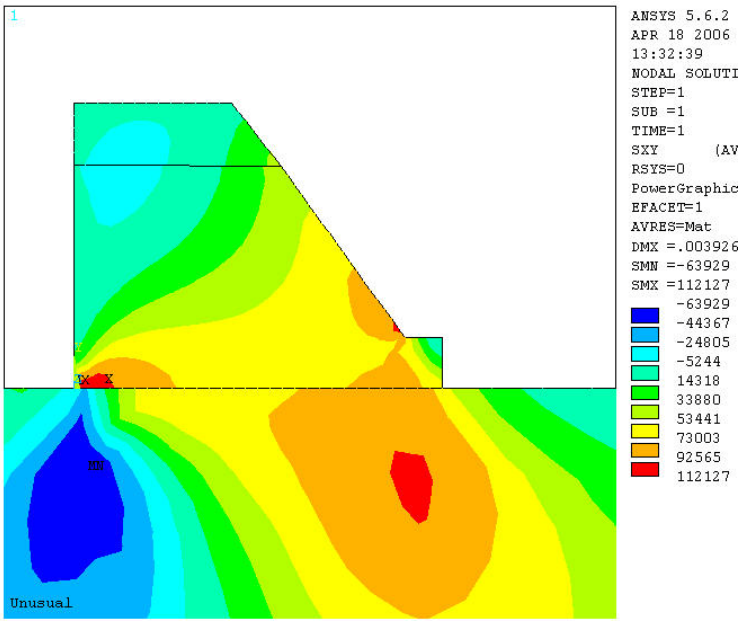

Fig. 5
Stress contours at Dam body and its foundation

The distribution of the different parameters of the dynamic response shows that the stress values in all conditions is in allowable range. The maximum principal tensile stress is 0.6, the maximum Principal compressive stress is 6.4 and the maximum shear stress in the body at low levels is 1.1 kg/cm^2 (Fig. 5). The maximum dynamic displacement is 4.5 millimeter that all are lower than the allowable values.

WATERPROOFING ASSESSMENT OF DAM AND FOUNDATION

The dam and foundation waterproofing assessment was done regarding the achieved results from experimental and field investigations. Based on present studies, it can be said that the most important problem of the dam is seepage through the body and its foundation.

Regarding the dam condition and seepage mechanism, a two dimensional seepage analysis for the critical section of dam was considered. The Analysis has been done through GEOSLOPE/ SEEPW software. 2D steady state seepage analysis was done by this code and the results showed that (Fig. 6):

Table 2
Comparing calculated safety factors with allowable quantities based on USBR code

Load Level or Combination	*Load Type or Control Criteria*	*Safety Factor*	*Allowable Safety Factor*
Normal Load Level	*Dam Overturning*	***10/42***	***2***
	Dam Sliding	***3/09***	***3***
	Compressive Stress	***4/33***	***3***
Maximum Load Level	*Dam Overturning*	***9/12***	***1/5***
	Dam Sliding	***2/67***	***2***
	Compressive Stress	***4/24***	***2***
Extreme Load Level	*Dam Overturning*	***4/02***	***1/25***
	Dam Sliding	***1/71***	***1***
	Compressive Stress	***3/00***	***1***

1. Seepage from inside the dam body is not normal and there is not appropriate waterproofing.
2. The hydraulic gradient inside dam body and foundation in several areas, especially around the interface of body and foundation in downstream (at the toe of the dam) is higher than the allowable limits. This shows that the dam has a considerable leakage of water in normal level condition.
3. Outlet flow from the downstream face shows leakage of water in full reservoir condition, which increases from up to down.
4. Considering the inlet flow pattern, the position of the cutoff wall actually is better to be close to the upstream as far as possible, to reduce the local scour and erosion phenomena to a minimum.

Since the structure of this kind of dams includes two stone walls in upstream and down stream, and infill materials in the middle, so grouting near the upstream face of body is more economical and efficient.

8. DAM REPAIR AND REMEDY

Repairing of GOLESTAN historical dam should be done in two stages. At the first stage which is related to the dam safety recovery, waterproofing, stabilization and strengthening should be done according to their order of importance and regarding the waterproofing and safety assessment studies.

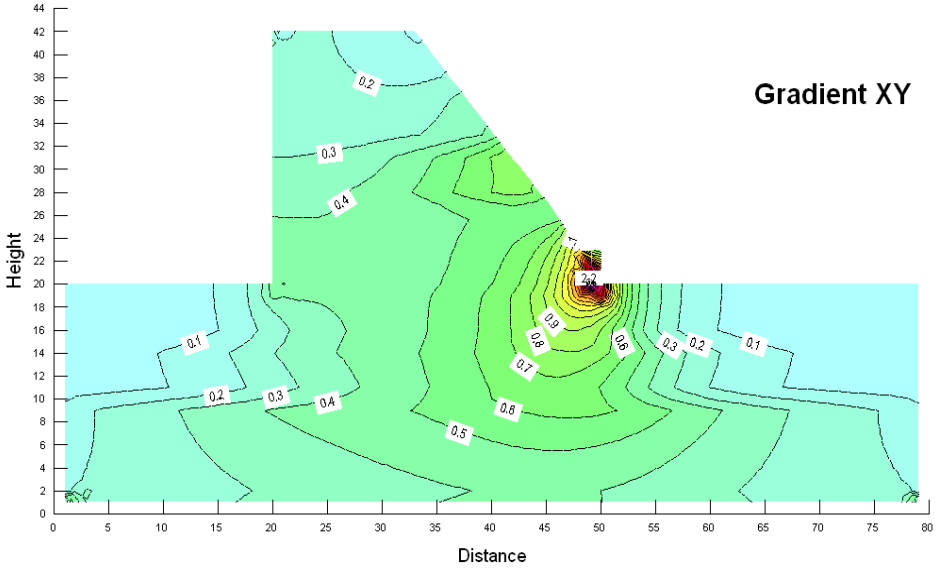

Fig. 6
Hydraulic Gradient contours through Dam body and its foundation

At the second stage, local damages are repaired and reconstructed. In Points where compressive, tensile and shear stresses are higher than the allowable limits, strengthening arrangements should be done. In GOLESTAN dam, shear stress near the foundation and at the interface of new and old sections reaches to about 2 and 1 kg/cm^2, respectively. It seems the existing materials can not support it well. So its better by selecting the appropriate materials for waterproofing, meet the strengthening purposes also synchronously. So the whole dam body should be waterproofed and strengthened completely. Of course waterproofing of the dam-foundation interface is more important regarding the achieved results (Fig.7).

9. CONCLUSION

Providing cutoff wall and strengthening at the interface of the old and new materials, also strengthening at the dam-foundation interface, is considered as an appropriate solution for repair. This approach includes waterproofing of body surface in upstream face, providing a concrete cutoff wall up to the length about 10 meters under the foundation, following the contact grouting at the interface of the new and old materials. Also include grouting the upstream face to depth about 0.5 meters for consolidation and increasing the efficiency of the surface waterproofing. Finally surface strengthening of downstream surface to protect against environmental factors such as probable overtopping is considerable.

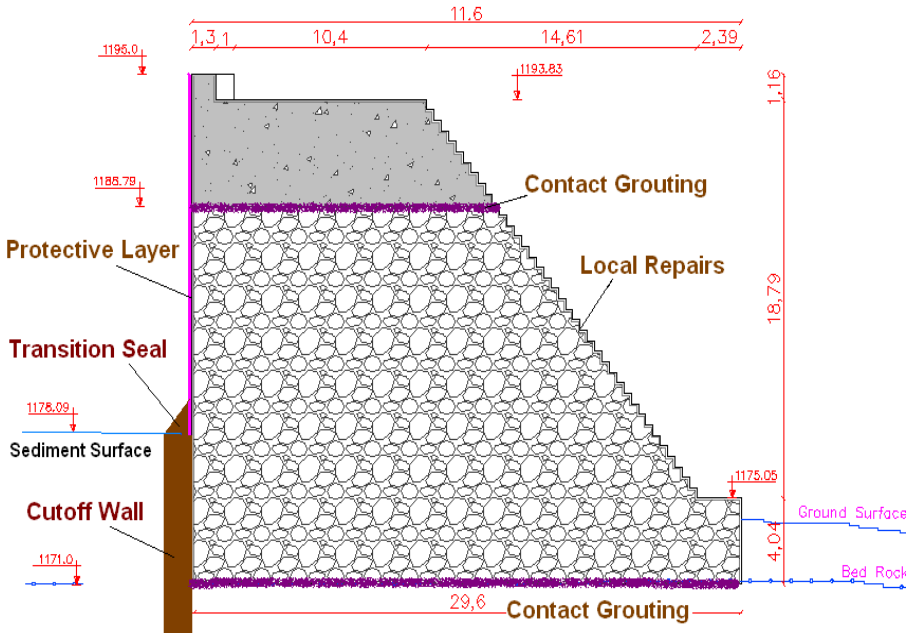

Fig. 7
Strengthening and Repair scheme for Dam and foundation

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