Cure Studies of Bottom Outlet Service Gates of Sediment Discharge Tunnel of Karun 1 Dam

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Abstract

With more than 50 years of exploitation of the first dam projects in Iran, the damage caused by aging, fatigue and corrosion is evident in these projects. The restoration and strengthening of the tunnels and the damaged hydro-mechanical equipment of dam and power plant projects in Iran is a challenge that must be seriously addressed. According to the past more than 50 years since the utilization of the Karun 1 dam, the service and emergency gates of the sediment discharge channel (tunnel T. 3) of this project had severe erosion and had to be changed. due to the lack of intake gates for this tunnel as well as impossible to discharge the lake water due to high performance power plants, redesigning the service and emergency gates of this project and replacing them should be carried out in a condition that the reservoir water height is about 110 meters. In this paper, first the proposed methods for sealing and blocking the tunnel T. 3 are addressed. Then the design procedure of the service and emergency gates and the loads considered in their design will be explained and at the end the proposed method will be examined to replace the gates in situations where the water head is 110 meters on the service and emergency gates.

Keywords: Cure plan; Service gate; Emergency gate; Bottom outlet; Karun 1 dam.

1. INTRODUCTION

The main task of the dam's service and emergency gates is to control the Dam reservoir level and to discharge sediment to downstream of dam. The flow before the service and emergency gates is pressurized and after the gates is free flowing. Therefore, in small openings, water flow will pass through the casing of gates very quickly. The result is a sharp decrease in pressure around the gate groove. This decrease in pressure creates bubbles in the flow, leading to the cavitation phenomenon [1]. Therefore, the possibility of cavitation under the gate and guiding grooves around the gate is very likely. Most damages to service gates include tearing of the bottom seal, or collapse of side bronze of the gates, or corrosion of the bottom or side edges of gates or corrosion of the conduit steel due to cavitation. It is easy to replace the rubber seal and bronze of gates. However, correction of cavitation damage to the steel casing as well as the gate sides may be large enough to replace the damaged parts. In addition, this problem becomes even more acute when there are no intake gate upstream of the service and emergency gate to block the conduit. About 50 years after the operation of Karun 1 Dam, its service and emergency gates are leaking. Due to repeated repairs on the service and emergency gates and water leakage by the gates, the possibility of corrosion of the steel casing due to cavitation in both service gates and emergency gates seems likely. Therefore, first it was necessary to select an appropriate method for repairing or replacing gates and casing. In this project, four proposed methods were selected as the final method and then using modeling results of similar projects with the help of dynamic similarity and geometrically, the forces applied to the gate were determined. Then, by calculating the head loss, the flow rate of the new gates was compared with the required flow rate, and then the new gates with the gate frame (casing) were initially designed analytically, Then, due to the high force applied to the structure, the finite element model of the gate with the steel casing was modeled by COSMOS software and analyzed after loading, and its results were compared with the analytical design.

2. DESCRIPTION OF THE GATE ROOM

Karun 1 Dam is located 55 kilometers northeast of Masjed Soleiman in Khuzestan province and on Karun River. It is a two-arched concrete reservoir dam designed to generate electricity and control floods and to utilize the useful volume of its reservoir, two hydroelectric plants with a capacity of 1000 MW each were built. Karun 1 Dam T3 tunnel consists of a circular tunnel with a diameter of 8 m and a length of 520 m located on the left side of the dam. In the middle of the tunnel, located 250 meters from the entrance and at the intersection with the T4 access tunnel, the gate chamber of the tunnel is responsible for controlling the flow through the tunnel. This control section consists of two rectangular pier openings, each measuring (w) x 3.8 (H) 1/2 m, separated by a bell-mouth shaped entrance and 1.5 m thick concrete wall. Its length is about 28 meters. Each of these two rectangular openings are equipped with two gates at the end. The downstream gate is known as the regulating gate (service) and plays the role of regulating and controlling the flow, and its upstream gate, called the emergency gate (guard), is responsible for disrupting the flow in an emergency condition or damaging the regulating gate. The dimensions of both gates are the same. Figure (1) shows a three-dimensional view of the gate chamber. The flow upstream of the gates is in the form of pressurized flow and downstream of the gates is free flow [2].

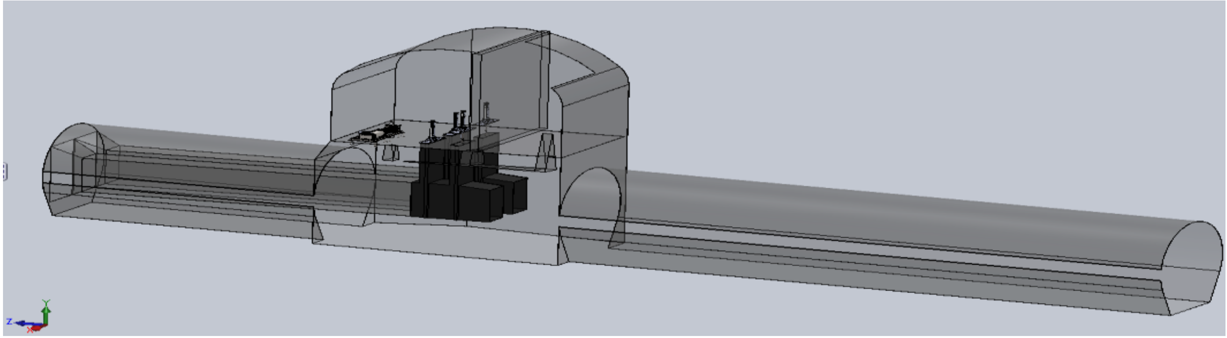

Figure 1. A three-dimensional view of the starting of the steel lining and the gate chamber

3. SUGGESTED METHODS FOR REPAIRING OR REPLACING CONDUIT STEEL LINING

Four methods were studied to correct the steel lining at the gate slot. The first option was to temporarily block the tunnel T. 3 from the tunnel inlet to repair the damaged steel lining after that the tunnel water was discharged. The second option was to block the conduit from the location of the guard gate inside the tunnel. The third option was to dig tunnels into the body of the dam and rail to close the bottom conduit through the crest of dam. The fourth option is to build and install a new gate, downstream of the service gate. After installing the new gate, the existing service gate can be used as an emergency gate and the newly installed gate will act as a service gate. Table 1 summarizes the advantages and disadvantages of the methods. After examining the advantages and disadvantages of all methods and considering the economic and temporal issues, the fourth method is selected. A new gate downstream of the current gate was chosen as the best method [2].

4. HYDRODYNAMIC FORCES APPLIED TO THE NEW GATE

Considering the hydraulic similarity of the flow in the bottom outlet tunnel of Karun 1 dam with the Karkheh and Jareh dams tunnel and based on the models tested for the Karkheh and Jareh dams, the pressure coefficients Kb, K t are equal to the values obtained in the tests performed on It has been assumed on Jereh and Karkheh dams and consequently, the Kt and Kb pressure coefficients of the above dams have been used to find the Ph, Pb and Pt pressures at different gate openings in the Karun 1 Dam project. Table 2 presents the changes of hydrodynamic forces applied to the Karun 1 dam based on the results of testing the Jereh and Karkheh dam models [3].

Table 1 - Advantages and Disadvantages of Repair or Replacement gates [2]

Option	Advantages	Disadvantages
Temporary blockage of the tunnel entrance	-Ability to visit and inspect all T.3 tunnels -Ability to repair or replace existing gates -No need to demolish or replace existing gate chamber space	- need for diving at depths greater than 80 meters to 130 meters -Design and manufacture and installation of immersion blocking gates -High cost of design due to high industrial diving operations -The design time is high due to the high number of industrial diving operations
Temporary blockage of guard garde location	-Ability to visit and inspect all steel coatings -Ability to repair or replace existing gates and frames -No need to demolish or replace existing gate chamber space	-Requires deep diving between 80 meters and 130 meters - Requires diving operations to move the gate inside the tunnel T.3 -High cost of design due to high industrial diving operations -Difficulties in designing, constructing and installing immersion block gates
Temporary blockage with control gate of dam crest	-Ability to visit and inspect all T.3 tunnels -Ensure operation of bottom outlet tunnel equipment -Ability to perform any repair operations on time	- Need to extend the T3 tunnel at the intersection of the vertical shaft -High cost -Requires temporary blockage of tunnel inlet
Install a new gate	- The lowest cost -Easy to build and install equipment -Very little change in hydraulic flow - Perform all reinforcement operations downstream of the gates	- Demolition in the gate chamber

Table 2- Hydrodynamic force on the Karun 1 Dam service gate based on the results of the Jareh and Karkheh model [3]

Opening (%)	based on the results of the Jareh model		based on the results of the Karkheh model	
	Fh (KN)	Fd(KN)	Fh (KN)	Fd(KN)
10	11669.67	128.11	11537.37	49.13
20	11429.06	529.18	11453.12	838.28
30	11308.76	709.32	11224.54	910.85
40	10947.84	783.43	11092.21	947.85
50	10586.92	765.72	10851.59	967.51
60	9985.39	702.30	10514.74	884.5
70	8782.33	467.38	9952.24	796.44
80	7579.27	335.17	8794.36	603.07
90	5774.68	171.17	6652.92	286.59

Considering the factor of 1.5 and the weight of the gate equal to 7 tons and the friction factor of 0.3, the maximum force required to lift the gate is 651 tons and to close the gate is 496 tons [3].

5. ESTIMATES OF FLOW THROUGH THE TUNNEL

In the original design, the flow rate of each conduit under the head is at a maximum of 300 cubic meters per second. In order to check the flow rate of the conduit, first, the head losse coefficients of each conduit are taken into account, then by calculating the sum of the head losses, the conduit flow rate is calculated (Table 3) [3].Observe that under 133 meters of water, the flow rate of the new conduit is 308 cubic meters per second. Therefore, the new conduit geometry satisfies the design requirement of at least 300 cubic meters per second.

Table 3- Hydrodynamic force changes on the Karoon 1 Dam service gate based on the results of the Jareh and Karkheh model [3]

Opening %	HEAD(m)							
	20	40	60	80	100	113	120	133
10	11.2	15	19.4	22	25	26	27	29
20	22.4	31	38.9	44	50	53	55	58
30	33.7	47	58.3	67	75	80	82	86
40	44.8	63	77	89	100	106	109	115
50	56.5	80	97	113	126	134	138	146
60	68.2	96	118	136	152	162	167	176
70	79.8	112	138	159	178	190	195	206
80	89.5	126	155	179	200	213	219	231
90	100	142	174	201	225	2392	246	259
100	119	168	206	238	267	284	292	308

6. INVESTIGATION OF CAVITATION OCCURRENCE IN THE CONDUIT AND GATE GROOVE

In hydraulic structures that are subject to high flow velocities, when the pressure is lower than the amount of water vapor pressure, air bubbles form. These bubbles move along the flow and explode after reaching the high pressure location and Causes destruction. The bumps and roughness of the concrete or metal surface created during the construction or execution of the structure or after the operation can cause current deflection and reduce line stresses and eventually damage the structure. The index used to investigate the probability of cavitation is a dimensionless parameter called the cavitation coefficient, which results from :

$$\delta =(p-pv)/(0.5\rho v^2)$$

In the above relation p is the absolute pressure in the conduit (the sum of relative pressure and atmospheric pressure), v is the velocity of water flow and ρ is the density of water. In addition, pv is the pressure of water saturation vapor. When the cavitation index drops below the critical value, the probability of cavitation phenomenon increases The range of critical values of δ on the surfaces of pressurized ducts and gates is stated in valid references between 0.2 and 0.3 [4]. Calculations of cavitation index based on the maximum head were carried out at three points after the initial bell-mouth of steel casing. (Point 1), in the service gate groove (point 2) and outlet (point 3) as shown in Figure 2 and is shown in Table 4. It is clear from Table 4 that in points 1 and 2 the probability of cavitation is eliminated, but in point 3 where the cavitation index is less than the permissible value just after the service gate, there is a need for proper aeration in this area [3].

Table 4- Cavitation Index

Point	δ
1	119.32
2	0.432
3	0.092

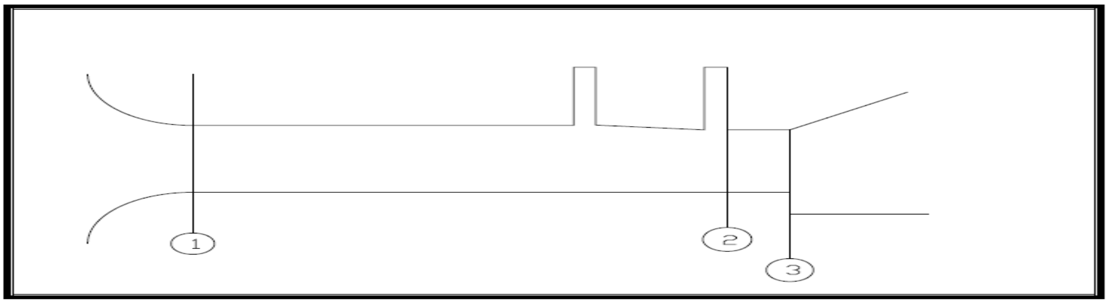

Figure 2. points 1, 2, and 3 to evaluate the cavitation index

7. DESIGN OF SERVICE GATES AND STEEL LINING

The forces applied to the gate and casing are provided in three modes. The first is the force applied to the gate when the water level is at a normal level equal to 113 meters of water. The second is the force applied to the gate when the water level is at a maximum of 133 m of water. The third case is the force applied to the gate when the earthquake-induced overhead is added to the normal head in accordance with the Zinkovich relation equals 176 m of water.

According to the calculations, the lifting force required to raise the gate was 651 tonnes and the lowering force required to close the gate was 496 tonnes. Based on the dimensions obtained from the studies required to obtain the required discharge and to prevent cavitation, the required thicknesses for resisting loads were selected and the design of permissible stresses was performed according to din 19704 code. To ensure the results, 3D modeling was performed by Solid Work software from the gate and steel cacing and static finite element analysis was performed by Cosmos software and the results were compared with the permissible stresses of the din 19704 code, indicating that Equivalent to analytical design and numerical modeling. Fig. 3A is an overview of the 3-dimensional model of the gate and casing. and Fig. 3b is a section view of the 3-D modeled by Solid Work software. Table 5 compares some of the results of the numerical model and the analytical design. The results show that the gate design is suitable against incoming loads [5].

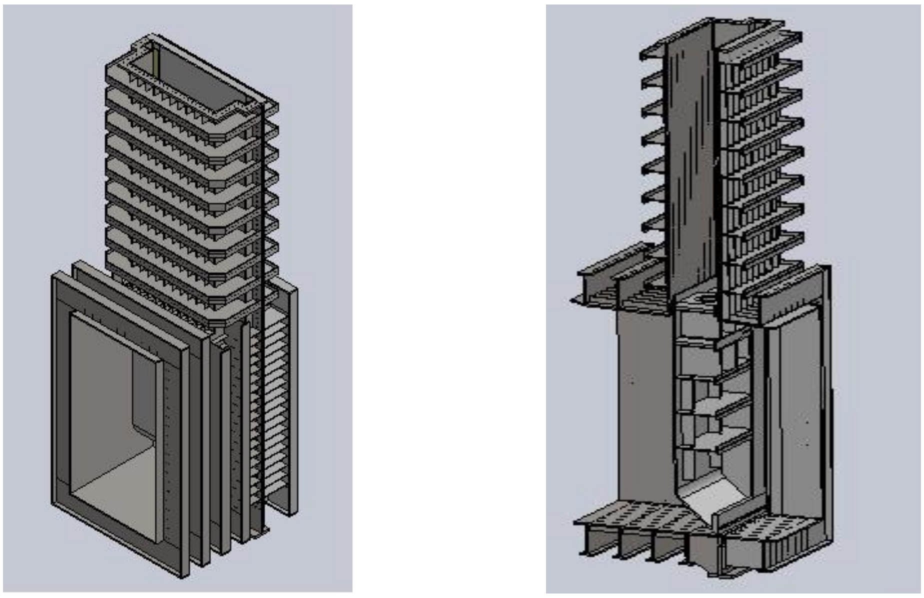

Figure 3. 3-dimensional view of the casing (left) and a sectiom of the steel casing and gate at the work zone (right)

Table 5. Comparison of numerical modeling results with analytical calculations

Stress measurement position	Analytical calculations (MPA)	Numerical Modeling (MPA)	Permissible stress DIN(Mpa)
Compressive Stress in Concrete Under Flanges	5.93	5.5	6
Van Mises stress in the main beams	240	228	275
Van Mises stress on stiffners	141	135	275
Bending Stress in Flanges	10	8.5	210

8. METHOD OF ADDING A NEW GATE TO THE PRIMARY STEEL LINING

Due to the large leakage from the bottom and sides of the gates when both gates are closed, it was necessary to provide a dry surface at the welding site to weld the new steel conduit to the end of the primary conduit. Therefore, the installation procedure was adopted to ensure that the emergency gate was closed first, and then lift the existing service gate to release the leakage from the emergency gate (upstream gate) freely. Then place a temporary gate inside the conduit instead of the current service gate. It is possible to install two 200 mm diameter pipes (proportional to leakage). The dimensions of the temporary gate were also designed to allow water to flow through the temporary gate in emergency situations (the height of the gate should be Lower than the channel height). Finally, the temporary pipes of diameter 200 mm are connected to the temporary gate. The leakage discharge through the emergency gate passes through the pipes downstream of the conduit. Therefore, a dry area is provided to connect the old metal coating to the new one. Upon completion of the welding operation of the new steel roofing duct, and prior to the concrete surrounding the new steel cover, it is necessary to provide shear keys around the tunnel in the rock wall of the tunnel that can transfer the force applied to the new service gate to the tunnel wall. Finally, after reinforcement around the steel casing, the surrounding gate was filled with concrete. The temporary gate will be removed and the old service gate will be replaced after repair. The existing emergency gate will be permanently located in the parking lot and will be removed from operation and the old service gate will handle the emergency gate and installation gate. The newly installed will act as a service gate. In Figure 4 the temporary gate and the new steel casing are marked with temporary pipes 200 mm in diameter [6].

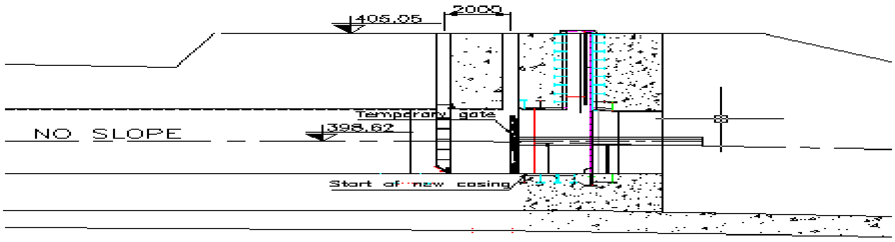

Figure 4. A view of the temporary gate with emergency gate in the closed state and 200 diameter pipes

9. CONCLUSION

According to the studies, installing a new gate downstream of the existing gate requires less cost than the methods of blocking the conduit through the inlet of tunnel or blocking the conduit from the top of the dam or blocking the conduit upstream the emergency gate. Also, by examining the flow rate of the proposed new gates in relation to the required flow of water, it was found that the dimensions intended for the new gates meet the design requirement. Further, by determining the velocity of flow through the new duct and calculating the cavitation index, it was determined that the flow downstream of the new gate would require adequate aeration. Finally, the performance of the designed gates under appropriate loads is evaluated by comparing the results of the numerical model with the results of the analytical calculations. Therefore, the proposed option for sealing the T3 tunnel of Karun Dam is well evaluated.

10. REFERENCE

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