Method of Pull out Sink Gates with Using Buoyancy Force Case study – Rudbar Dam

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Abstract
The dams have one or two bottom outlettunnels according to their usage and dimensions. They are located according to the design requirements and are always at the lowest level of the dam to control the water level of the reservoir. For this reason, the supplying water operations always begin after the service and emergency gates of the bottom outlet tunnel are completed. Due to the drought issues and the water retention in the river, in Iran's Rudbar project, It was necessary to start supplying water before the steel structure in the bottom outlet tunnel was finished. Therefore, the inlet of the bottom outlet tunnel must be blocked by a gate 8 m wide and 11.5 m high and weighing 125 tons. After passing 6 months of supplying water and completion of the erection of service and emergency of the bottom outlet tunnel, temporary gates should be pulled up from a depth of 75 meters and use the bottom outlet tunnel to control the level. This paper describes the design, construction and installation of a 125-ton temporary gate and a solution to pull up these gates from a depth of 75 meters water head using buoyancy and lifting force of less than 2 tons. The operation was the first in the world to be successfully implemented in the Rudbar project.
Keywords: Bottom outlet, Rudbar dam, buoyancy force, temporary gate, pulled up.

1. INTRODUCTION

Rudbar Dam and its power plant is located on Rudbar River (one of the eastern branches of Dez River Basin) about 100 km south of Aligudarz city in Lorestan province. The dam with a crest height of 185 meters and a reservoir volume of 228 million cubic meters with a capacity of 450 MW has two bottom outlet tunnels.

Due to the unpreparedness of the bottom outlet tunnel, the inlet had to be blocked by a gate with 8.4 m width and 11.5 m height (figure 1). According to the calculations, the gate weight was 125 tons, which required 300 tons of lifting force under the 75-meter head and to create balance conditions on both sides of the bottom outlet intake. Under normal circumstances, if there was a fixed tower at the top of the gate, it would not be difficult to pull up this gate. However, due to the large size of the gate and the economical design of the project, the tower was not built for the pulled up of the gate.(The approximate location of the gate after supplying water is shown in figure 2.) Therefore, it was necessary to use another method to remove the gate under the head. so, methods such as the use of helicopters, barges, or the use of diving and balloon attachment, which are described in this paper, were finally selected as the most practical. According to the project conditions, the goal of the project was to reduce the weight of the gate and subsequently reduce the amount of lifting force.

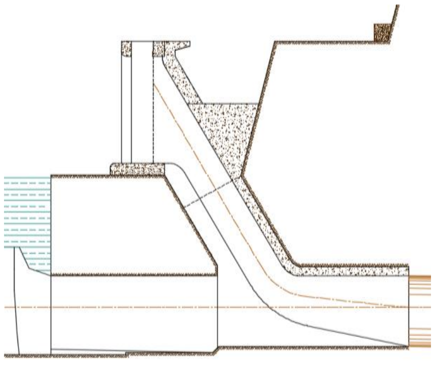

Figure 1. Entrance of bottom outlet tunnel

Figure 2. The location of the gate underwater

The buoyancy force is the resultant force coming from a fluid on a body that is submerged or floating, and this force always acts upward. In the design and construction of dam gates, this force is usually used to calculate lifting forces or to check the gate closure under full flow, which according to the buoyancy force calculation formula and the low volume of gates, this force against Existing forces are very minor. But if the volume increases, for example, the use of a tank, the buoyancy force will also increase. So that small tidal gates can be used automatically with sufficient buoyancy force[3][4][5]. So with increasing water height, the buoyancy force is increased and the gates are closed automatically (figure 3) [6]. This solution can also be used to automatically open larger gates. Radial gates are built on the river in the easternCape equipped with a floating tank. These gates open automatically by increasing the height of the water and after lowering the water height, the floating tank closes the gate.

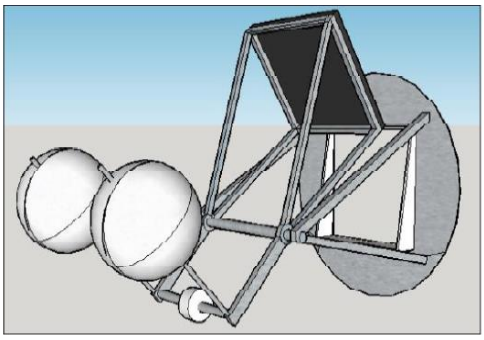

Figure 3. Buoyancy-automated tidal gate[6]

2. GATE DESIGN

The first step in reducing the lifting force is to increase the number of gate segments because in addition to reducing the weight of each segment, reducing the rubber length and contact surface will have a significant effect on reducing the lifting force.After various calculations and researches, the gatewas designed as 5 segments with 2 meters height and one segment (top segment) 1.5 meters height (6 segments total).This resulted in the highest lifting tonnage of 25 tons.On the other hand, by increasing the number of gate segments and reducing them to two meters in height, it was much easier to move it pulling fromthe water and moving to shore.Because of the lack of proper bedding for the crane to be installed on the dam ramp (Figure 4), removal of a 125 ton weight gate will require a very heavy crane.In addition to the high costs and transportation to the workshop, it was not possible to install it on the dam ramp.

Figure 4. Location of crane

Due to the constant density of water and gravitational force, the buoyancy force will increase as the buoyancy volume increases.For this purpose the gate segments in the final design were designed as hollow cubes as shown in Figure 5.

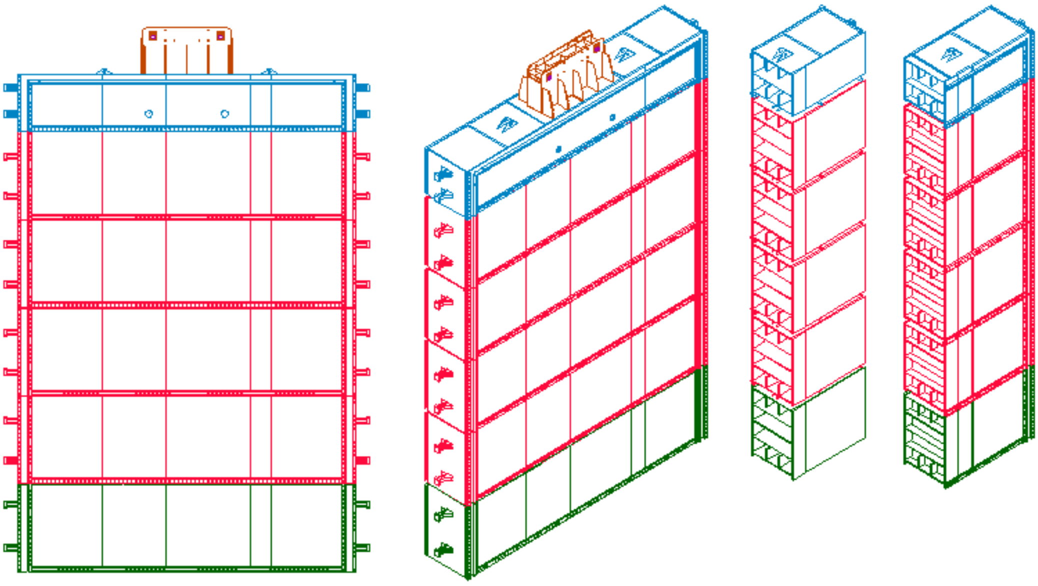

Figure 5. View of gate after design

3. GATE MANUFACTURE

According to the design of gates on buoyancy force, it is of great importance that the gates are hollow and that water does not penetrate into it.Therefore, each segment must be thoroughly tested to ensure that water does not penetrate into it.Initially, all welding lines were fully tested by Penetration test but due to the limitations of this type of test which only tested the welded surface.Therefore it is not possible to test the welding depth in this method and it is very likely that in high pressure welding defects can reach the surface. So, a secondary testing procedure was needed to increase confidence.In this method all gate segments were fully tested by air pressure.The gate were fitted with a one-way valve and pressure gauge, which was then increased to 9 bars,the nominal design pressure, by the compressor.To find welding defects, foam was used on the weld lines which was air exit observed and corrected at high pressures.After correcting the defects, the valves were maintained at 9 pressure for 24 hours and the pressure drop was checked.The constant pressure inside the gate indicated that there were no openings for air outlet or water entry into the gate.

4. ERECTION

Due to the distance of 22 meters of the gate groove (Figure 6) to the location of the crane and the weight of over 25 tones of gate, a crane with a tonnage of 300 tones will be required for erection. The impassability of the access route eliminated the possibility of using a crane of such high dimensions and high tonnage.Therefore, in order to reduce the crane's lifting tonnage, the distance between the crane location and the gate groove should be reduced, which was made possible by the construction of a bridge.So, a bridge with 12 meters wide and 21 meters long that suitable for crane installation, was designed and constructed(Figure 7).

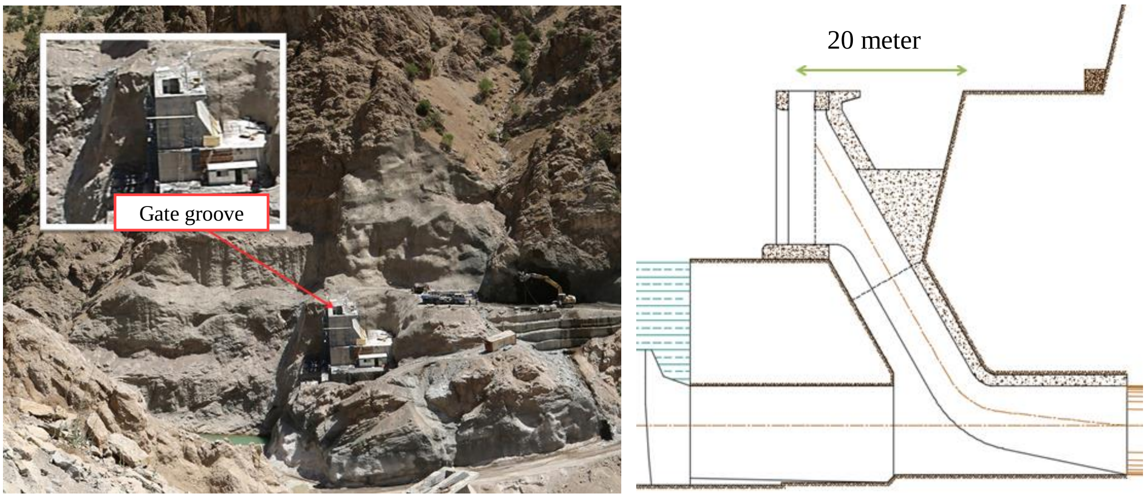

Figure 6. The location of gate and crane installation

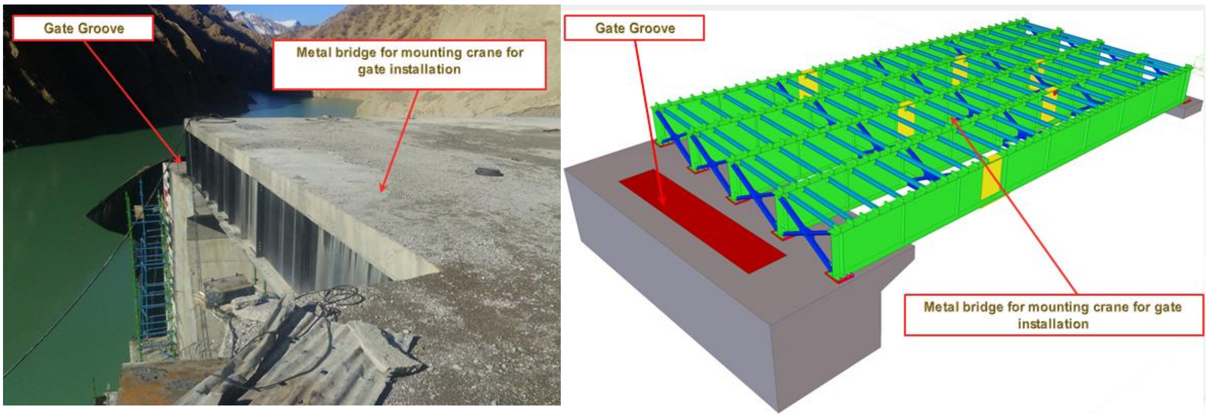

Figure 7. Access Bridge at design stage and after construction and installation

5. PULL OUT THE GATE

Three primary methods were investigated to remove the valves. The first option was to use barge and winch. The second option is the use of helicopters and the third option is diving and balloon.Divers must attach a balloon to the valve beneath the water. The balloon then moves the gate to the surface of the water after blowing and due to the buoyancy force.In Table 1, the advantages and disadvantages of all three methods are summarized.

Table1.Comparison of gate removal methods

Method	Advantages	Disadvantages
Use of barge and winch	High rigidity of the barge Ability to provide high lifting power if needed	Lack of project access to open water and difficult transportation to the project High shipping cost High-depth diving restrictions
Use a helicopter	No need for diving High speed execution Easy transfer of gate to land	High cost of use Low rigidity and locking gate High-depth diving restrictions
Use of air balloons and diving	Difficulty in diving and needing a team with many members Control the gate and prevent the gate from getting lock	High-depth diving restrictions Need special equipment Unable to control the valve during climbing

After investigations to optimize the performance of the method, the first and third methods were combined.The barge or buoy is very important because it provides the platform for the operation and the supply of resistance force to lift the gate. Due to the inability to transport large barges to the site of operation, the barge was built in the workshop.Two cylindrical air tubes with a diameter of 1.2 and 2.5 meters in length were used for the construction of the barge in a steel frame (figure 8) to hold the tubes.

Figure 8. Barge construction

Initially, two 2-ton manual tifor with a distance of 4 meters (spacing of hooks on the gate) were mounted to lift the gates.The required lifting force of the valves was 2.5 tons.A balloon with a power supply of 2 tons was attached to the middle of the gate. With a supply of 0.5 tons, the gate should be removed from the groove and transferred to the surface of the water, which was supplied by tifor (figure 9).

Initially, cables connected to the tifor and balloons were connected directly to the gate by the diver, such as the image.Then, under the supervision of the diver, the gatewas moved to the water surface, using force from the tifor.As the gate rises and the water pressure drops, the volume of balloons and lifting force will increase, which will negate the forces.As a result, the gate would accelerate to the water's surface and would be thrown from the water's surface where subsequent events would not prognosticate.Therefore, the balloon was fitted with an air valve to keep the balloonvolume constant until it came to the surface.

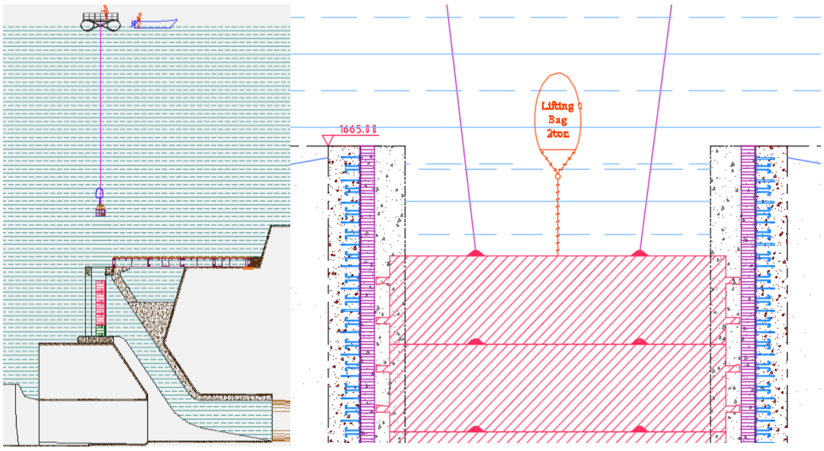

Figure 9. How to lift the gate

6. DIVING OPERATION

Always diving at high depths has many dangers, most notably DCS disease.This disease occurs when nitrogen becomes bubbles in the bloodstream that occur due to too long stoppage under water or too high speed to surface.Usually symptoms of DCS develop late after diving.By Henry's law, the amount of solubility of any gas in the liquid in contact with it depends on the pressure of that gas[7]. Therefore, when the diver is subjected to a pressure several times the atmospheric pressure, a significant amount of air, including nitrogen, which is a neutral gas, enters the solution in the blood.With the rapid decrease in pressure, such as when the diver returns to the water level from a depth of more than ten meters, the dissolved nitrogen in the blood becomes gaseous and forms bubbles inside the bloodstream that cause embolism.These bubbles can occur in the small vessels of different parts of the body and can also block the vessels [8].Therefore, the disease has many types, depending on the location of the obstruction of the vein and its symptoms are very diverse.

These dissolved gases had to be slowly released from body tissues by stopping at various depths as they ascended to the surface, using scientific pressure-harvesting patterns such as the bubble-lowering gradient pattern that traditional diving table methods used. Much safer and more efficient[9].

Due to the immense depth of the diving and the high sea level, the project requires stopping at various stations due to the high depth of the diving and the diver cannot reach a depth of 70 m and return to the water level.As the diver returns to the surface of the water, he must make a forced stop at depths of 6 and 12 meters depending on the depth and timing of the diving [10].

A diving decompression chamber (Figure. 10) was installed on the dam crest and in the dock equipment dock.This diving decompression chambercan simulate different depth conditions.Unforeseeable times when the diver had to make a sudden and emergency exit from the depths of the lake, he had to be immediately transferred to the pressure chamber and his recovery and health conditions immediately monitored and stabilized.

Figure 10. Diving decompression chamber

Due to low diving time at high depth and limitations (each diver will only have one diving license every 24 hours), a 13-person diving team was used.As previously described, the diver was first attached to the gate by the wire diver and then to the balloon, and the diver was monitored to ensure that the valve was not locked in the groove until the gate was completely exited from the fixed part.After the gate reached the water's surface, the gatewas approached by boat to near the dam body. As you can see in Figure 11, it came out of the water.

Figure 11. Exit and carry a segment of the valve

7. CONCLUSIONS

Although the design of hydromechanicalgates has the effect of buoyancy in lifting force calculations, it can be significantly reduced by designing the gates as a tank. Even when using equipment such as cranes and winches are not possible, it is possible to provide the lifting force by diving balloons.

On the other hand, according to the experience gained, it would be possible to start the dam supplying water before the construction of the bottom outlet tunnel by constructing a temporary gate.In the RoudbarLorestan project, using this method, a supplying water time of 6 months was percipitated.That has generated more than 1,000 GWh of electricity, which in addition to generating some $ 200 billion in the country's electricity industry, has also provided 60 million cubic meters of water.Due to the very low budget, this method can be used as a model in the industry and similar.

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