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Research Article

IMPACT OF MAKING THE CREST OF WEIR MULTIFACETED ON DISCHARGE COEFFICIENT OF MORNING GLORY SPILLWAY

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ABSTRACT
When there is a place restriction for the construction of other spillways, morning glory spillway can be used because this spillway is located in dam upstream and reservoir. In this study, by building a physical model of morning glory, the effect of multifaceted crest of weir of discharge coefficient was investigated with 120 different tests on the spillway in two modes: crest control and orifice controls. Laboratory data analysis showed that spillway crest multifaceted increases the flow through and increases the discharge coefficient of morning glory spillway and the most increase is obtained when the spillway crest is made three dimensionally.

***Keywords**: Morning Glory Spillway, Flow Discharge Rate, Crest Control, Orifice Control, Making the Spillway Crest Multifaceted*

INTRODUCTION
Morning glory spillway consists of separate spillway that can be replaced by the side spillway and composed of a concrete circular crest that directs the flow in an inclined or vertical axis. The aforementioned axis is connected to a low-slope tunnel; the axis to the tunnel connection is done by a curve with a large radius. This type of spillway is very economical where the water diversion tunnel is used, morning glory spillway is used to pass reservoir flood when it is not possible or not economical to build a simple free spillway. Morning glory spillway in dam is responsible to drain the excess water at the time of the flood and prevents water spillway of dam crest and prevents dam destruction (especially when the dam is embankment). In morning glory spillway, when the water height on the spillway crest is low the flow is free and control will be on the spillway crest and by increasing the water level, the control part will be transferred to the vertical part and flow discharge will be controlled by orifice flow. From this point onwards, the flow duct may be under the dominating pressure and flow rate is controlled by the filled tunnel. It should be noted that designing the spillways based on filled tunnel is not recommended, but in cases where the height of fall is very low, it will be exception (Novak, 1971). The spillway is used in embankment dams that we prefer to construct the spillway separate from the dam body and in the reservoir because this reduces the risk of scour and dam downstream shell saturation. The cost of construction and maintenance of spillway allocated the bulk of the total cost of dam construction to itself (Kevin *et al.*, 1997).
The equation of discharge for morning glory spillways is expressed as follows:

$$Q = C_d L H^{1.5} \tag{1}$$

$$L = 2\pi R_s \tag{2}$$

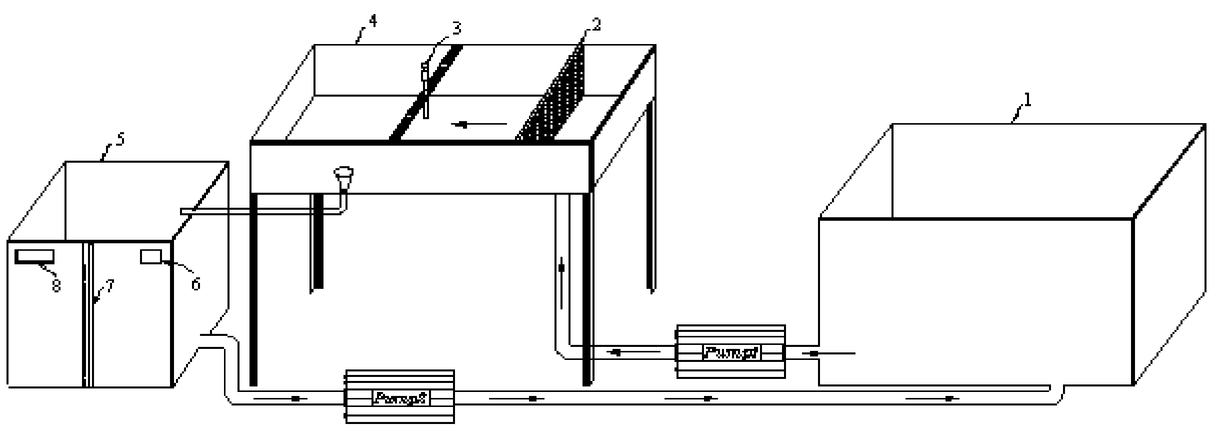
$$Q = \left(\frac{R}{0.2752}\right)^2 H_a^{\frac{1}{2}} \tag{3}$$

Where the Q is discharge through the spillway, C_d is spillway discharge rate, L is the length of the spillway crest, H is the height of water over the spillway, R_s is spillway crest radius, R is the radius of the spillway canyon, H_a is the height difference between the water level in the reservoir and spillway canyon (U.S. Bureau Of Reclamation, 1965). Morning glory spillway in dam is responsible for discharging the excess water at the time of the flood and to prevent water spillway from the dam crest and prevent the destruction of the dam (especially when the dam is embankment). If we can increase the discharge through the spillway for fixed water height on morning glory spillway by making changes in the spillway crest (which is circular in plan), this increases the confidence coefficient of morning glory spillway to drain floodwaters as well as economic savings (Bagheri *et al.*, 2010). Yousefvand (2011) in a research examined the effect of bend on the flow hydraulic in morning glory spillways and concluded that by increasing the bend radius R/d discharge rate increases. Fattor and Bacchiega (2001) by conducting a study concluded that in morning glory spillways if the spillway is drowned, discharge value is 1.34 times than discharge rate in free mode and we will have free eddy in the absence of aeration to the water tunnel in the spillway. Bagheri *et al*., (2010) investigated the effect of polyhedral spillway crests on the discharge intensity of the flow passing through the spillways and on the discharge coefficient of shaft spillways, by constructing physical hydraulic models of shaft spillways and through carrying out 180 different experiments on these spillways. They showed that using polyhedral spillway crests caused an increase in discharge passing through the shaft spillway and also increased the discharge coefficient of the spillway. The greatest increase was obtained when trihedral spillway crests were used. Nohani (2014) investigated the effect of vortex breakers on discharge coefficient for the shaft spillways with sharp edge and wide edge with the physical model. He showed that a 20% increase in spillway discharge coefficient was experienced via using blade-vortex breaker and the increase in spillway discharge coefficient with sharp edge was more than a wide-edged.

In this study, by making the physical hydraulic model of morning glory spillway, the impact of multifaceted crest on the flow rate through the spillway and morning glory spillway discharge rate will be examined by performing different tests on the spillway in two states: crest control and orifice control.

MATERIALS AND METHODS

Hydraulic model will enable designers to predict the main structure behavior and before constructing the structure by eliminating defects or taking into accounts measures for optimal use (Padulano *et al.*, 2013). The physical model built, which was used in the laboratory for performing tests is according to Figure 1, which includes a 2000 liters main reservoir that supplied water needed to perform the tests. The main flume that includes the infondibular part of morning glory spillway has a length of 250 cm, width of 90 cm and height of 40 cm and side walls of the flume was made of 8 mm glass and its floor was Plexiglas. Restraining the side walls and the flume floor against the pressure incurred was performed by angle iron. Transferring water from the main reservoir to the flume was done by 4 pumps. The discharge these pumps could transfer was 100-500 liters /minutes for the main pump, 240 liters per minute for two average pumps, 110 liters per minute for a small pump. The reason why 4 pumps were used was because for low discharges, pumps were used separately and for the high flow rate the pump combination was used. At a distance of 40 cm from the beginning of the flume, baffle screen was used to calm down the flow.



1. Main reservoir 2. Baffle screen 3. Digital depth gage 4. Main flume 5. Time-volume reservoir 6. Pump switch 7. Piezometer 8. Screen

Figure 1: Outline of hydraulic physical model used in the laboratory

To measure the height of water, digital depth gage with accuracy of 0.01 mm was used on morning glory spillway crest. Volume method was used to measure the output discharge of the morning glory spillway (Figure 2) so that the flow out of the morning glory spillway tunnel entered a 400 liters reservoir, which a vertical piezometric tube was connected to the reservoir so that the water level in the piezometer was equal to the water level in the reservoir.
In certain height intervals, some sensors were installed on the piezometer tube (6 points), the sensors were connected to a digital screen and the device recorded the time reached from one sensor to another, with determination of volume of the two sensors, discharge through the spillway was obtained by the division of volume to the time of the flow through the spillway. For increasing the accuracy, measurement was performed for 5 timeframe. To discharge the water of the reservoir to the main reservoir, a pump with a flow rate of 600 liters per minute and a single phase floor cache with a discharge of 11 liters per second was used.

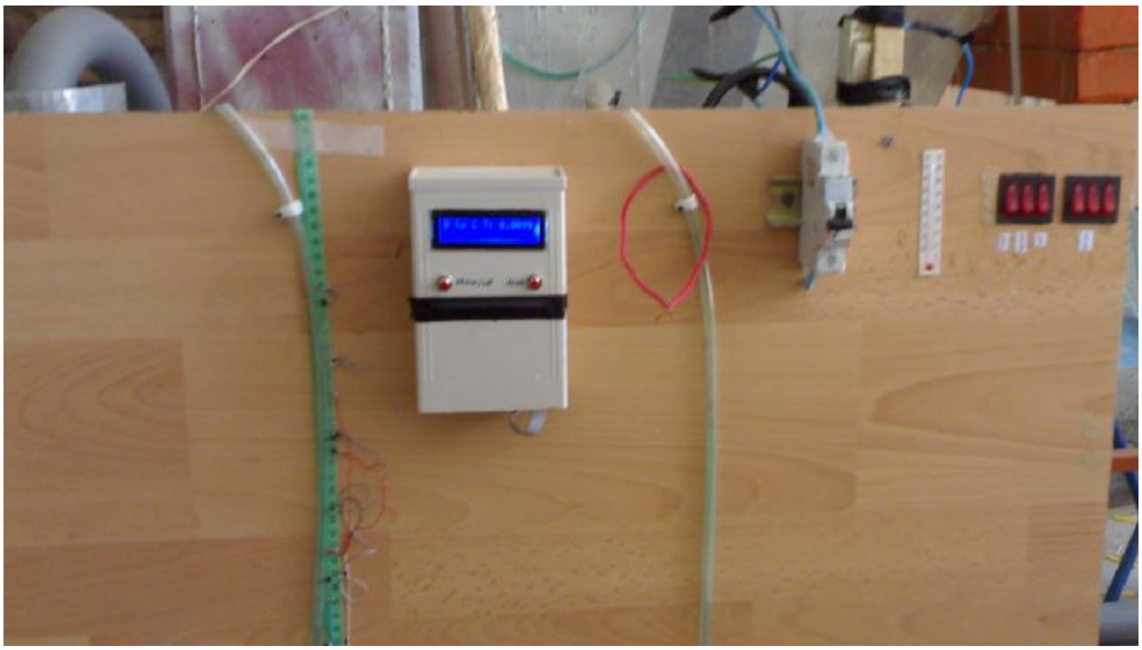


Figure 2: Instruments for measuring flow through the morning glory spillway as volumetric method

To evaluate the effect of multifaceted spillway crest on the rate of flow through the spillway and the spillway discharge coefficient, three morning glory spillways with crest diameters of 14 cm, 17 cm and 20 cm were built that the diameter of shafts, bend and tunnel for three spillways were 5.7 cm, 6 cm and 7.4 cm respectively. Tunnel length in all three spillways is 1 meters and bend is 90 degrees and the shaft was vertical. The three spillways that their crest is circular are considered as the basis and from the infondibular part of each spillway, three other samples were built with the same dimensions and the only difference among the three samples with the base sample was in the shape of the crest that the crest of three samples is trihedral, pentahedral and heptahedral. A total of 12 samples were made from the infondibular part of the spillway which means for each crest diameter according to Figure 3, 4 samples were made.
In these studies, the experiment was started from the morning glory spillway with a crest diameter of 14 cm and shaft inner diameter of 5.7 cm. Methods was in this way that first basic sample (circular crest) was inserted and then by turning the pump on, the water enters the flume from the main reservoir and by fixing the water level on spillway crest, it was measured by digital depth gage and at the same time, the discharge of spillway tunnel was measured by volume method. Thus a point on the discharge - scale curve

was obtained for the spillway, then by turning the pump on individually and in combination, we could establish 10 different heights on spillway crest and the discharge through the spillway was measured by volumetric method, so that discharge- scale curve was obtained for the spillway. Then the infondibular part of the spillway was separated and the funnel shaped part which crest was built as trihedral was installed and the same 10 heights of the previous test was established on the crest of the spillway as a trihedral crest and the corresponding discharge was measured with any height and scale – discharge curve was plotted for the spillway.

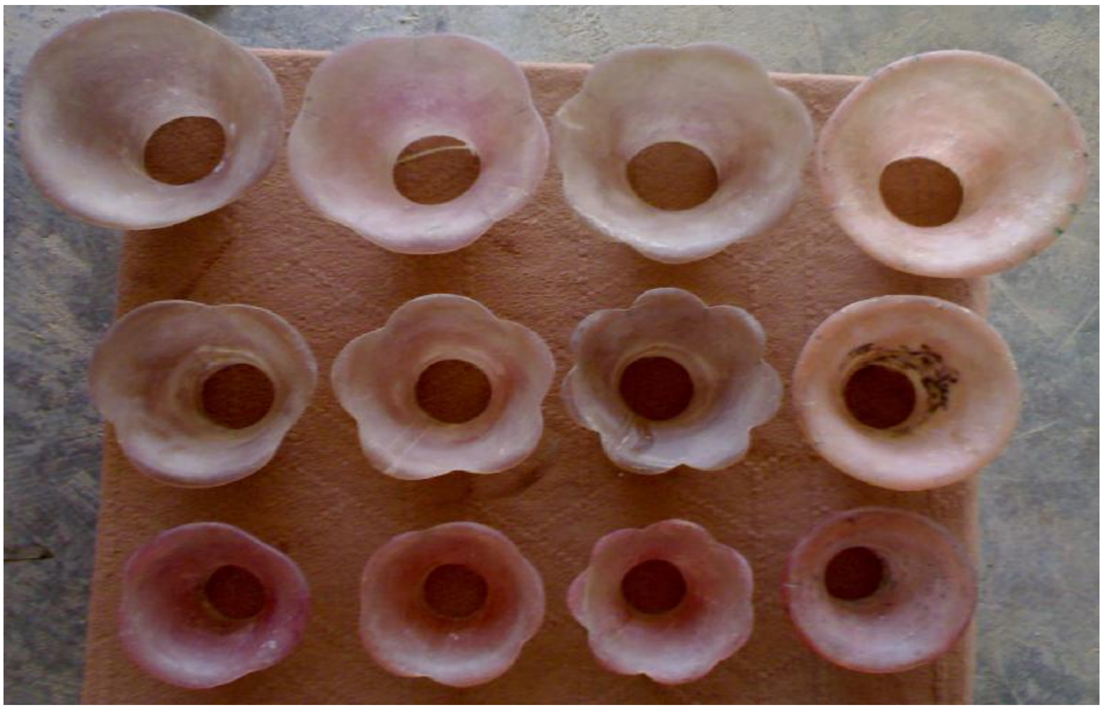


Figure 3: The model made of the infondibular part of morning glory spillway for three diameters of 14, 17 and 20 cm

Then the funnel shape part was removed and the funnel shape part of the spillway that was built as heptahedral was replaced and the above tests was done for it and discharge - scale curve was plotted. Then the spillway was removed and morning glory spillway with a crest diameter of 17 cm and inner shaft diameter of6 cm were installed and above tests were done for them and 4 discharge – scale curves was obtained for it, respectively.

Then the spillway was removed morning glory spillway with a crest diameter of 20 cm and inner shaft diameter of 7.4 cm were installed and above tests were done for them and 4 discharge – scale curves was obtained for it, respectively A total of 120 tests were conducted in two modes of crest control and orifice control.

RESULTS AND DISCUSSION

Using the experimental data obtained from 120 experiments, spillway discharge coefficient was calculated for each test. To determine the morning glory spillway discharge coefficient for the crest control formula (1) and for orifice control formula (3) were used. In Figures (4), (5) and (6) changes in the spillway discharge rate to the depth of submergence for spillway with a crest diameters of 14, 17 and 20 cm in crest control mode is shown and in Figure (7), (8) and (9) changes in the spillway discharge rate to the depth of submergence for spillways with crest diameters of 14, 17 and 20 cm is shown in orifice control mode.

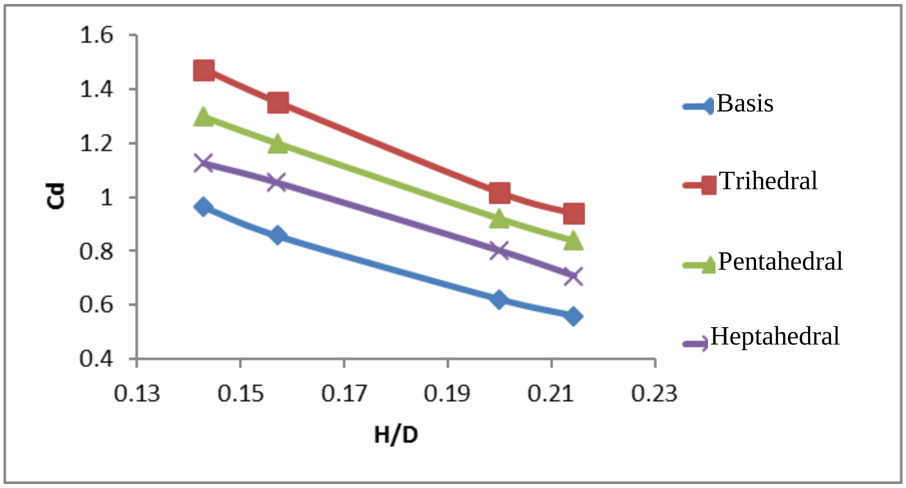


Figure 4: Changes in the discharge coefficient to the depth of submergence in crest control mode for the spillway with a crest diameter of 14 cm

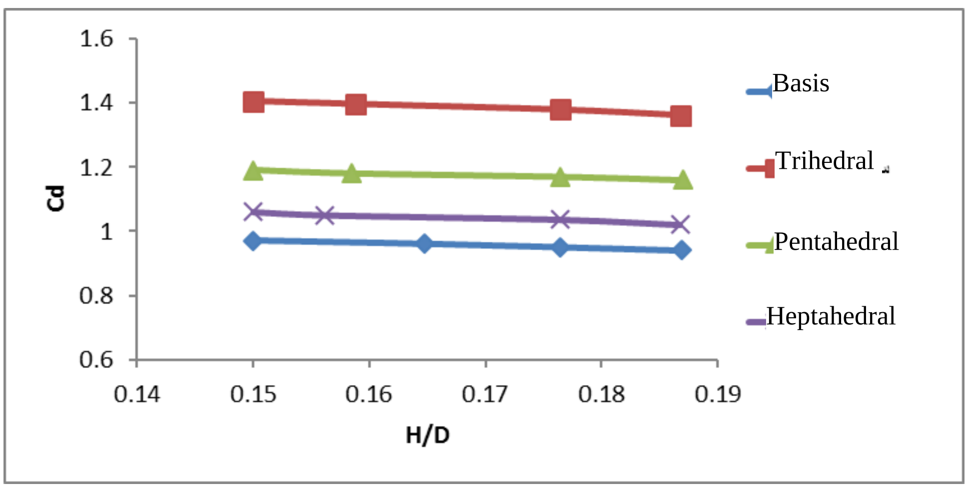


Figure 5: Changes in the discharge coefficient to the depth of submergence in crest control mode for the spillway with a crest diameter of 17 cm

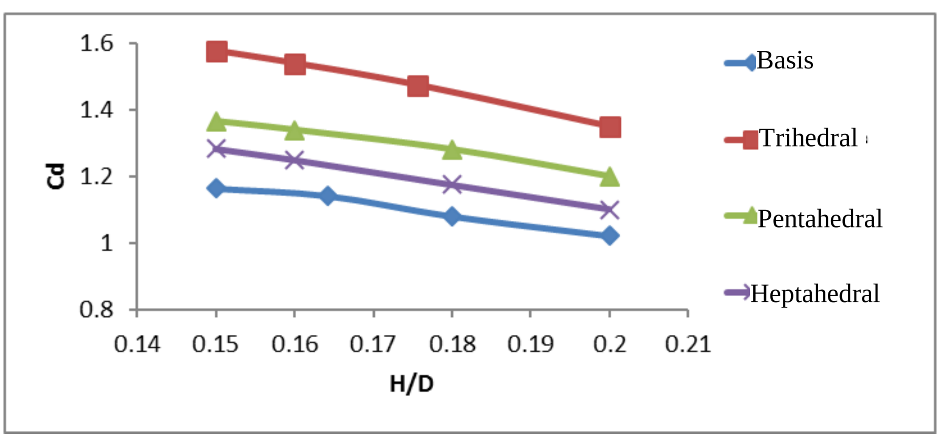


Figure 6: Changes in the discharge coefficient to the depth of submergence in crest control mode for the spillway with a crest diameter of 20 cm

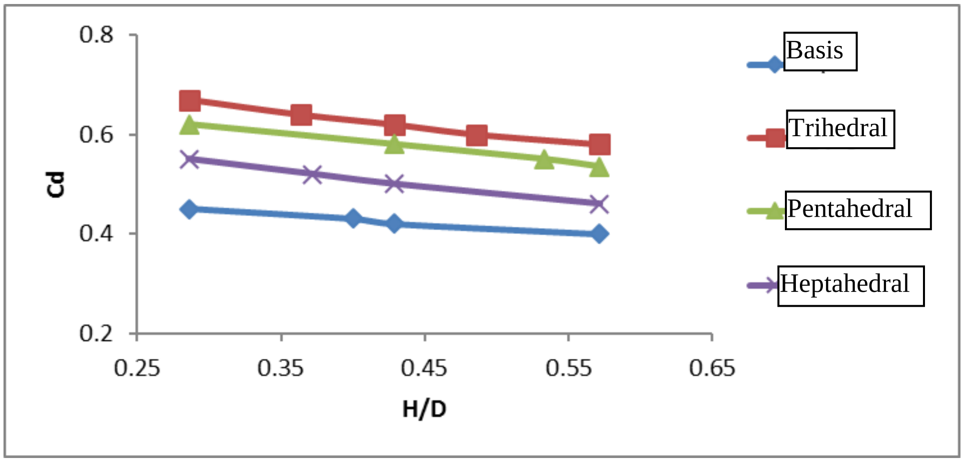


Figure 7: Changes in the discharge coefficient to the depth of submergence in orifice control mode for the spillway with a crest diameter of 14 cm

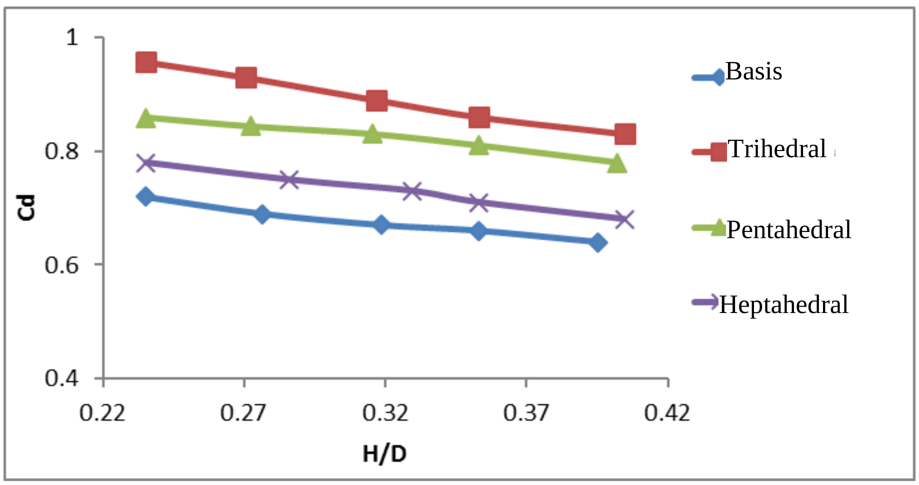


Figure 8: Changes in the discharge coefficient to the depth of submergence in orifice control mode for the spillway with a crest diameter of 17 cm

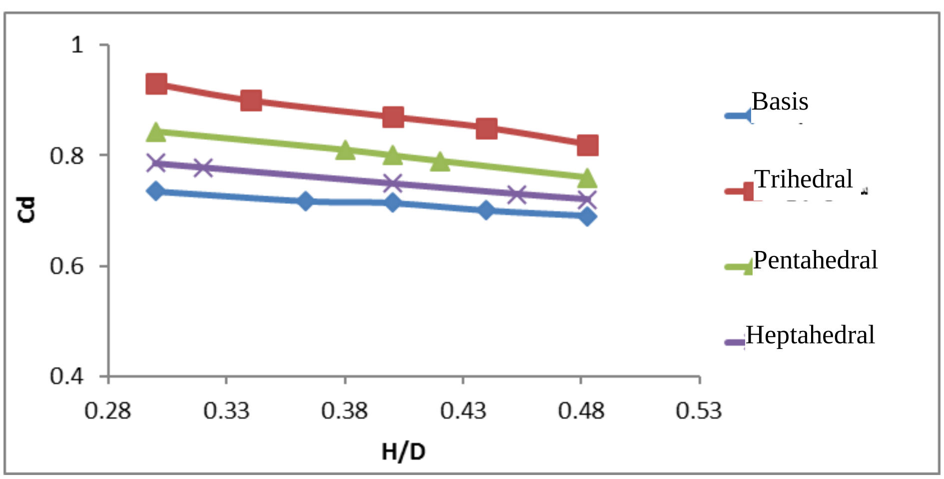


Figure 9: Changes in the discharge coefficient to the depth of submergence in orifice control mode for the spillway with a crest diameter of 20 cm

From the Figures (4), (5), (6), (7), (8) and (9) we can conclude that for a uniform depth of submergence, the spillway discharge coefficient in cases where spillway crest is made as multifaceted is more than the state that the spillway crest is made circular and the most increase in the rate of discharge in morning glory spillway occurs when the spillway crest is made as trihedral and the results obtained for the spillway discharge where the spillway crest is made as heptahedral is close to the base that the spillway crest is made circular, and it can also be concluded that by increasing the depth of submergence, the morning glory spillway discharge coefficient decreases.

The reason that in cases where the crest shape is multifaceted, the morning glory spillway discharge coefficient is greater than the circular shape is that the multifaceted shape of spillway decreases the vortex and water spin and flow lines enter the spillway more regular and the flow through the morning glory spillway increases.

Conclusions

Results that can be obtained by performing the investigation and analysis of the above figures is that making spillway crest multifaceted increases the spillway discharge rate and highest increase in morning glory discharge rate occurs when the spillway crest is made as trihedral. Nohani *et al.*, (2009) in a study by building the hydraulic physical model of morning glory spillway and experimental studies examined the effect of the number and thickness of the vortex breaker blades on the morning glory spillway discharge coefficient and concluded that in featheredge morning glory spillways, the impact of using three vortex breaker blades in increasing the spillway discharge coefficient is more than a case where six vortex breaker blades were used. Alasti *et al.*, (2006) also by constructing hydraulic physical models of morning glory spillway and experimental studies concluded that the length, height, and thickness of the blades and thickness of blades are effective in controlling the vortex and the impact of the increased length of the blade is more effective than increasing the number of them. It can be also concluded that the obtained values for spillway discharge where the crest spillway is made heptahedral is closer to the base so that for spillway with crest diameters of 20, 14, 17 cm in trihedral case, the spillway discharge coefficient is respectively 49, 60 and 34% (in the case of crest control) and 31.61, 47.13 and 24.18 per cent (in orifice control mode) increased compared to the base case, but in the heptahedral case, 8, 21 and 9% (in the case of crest control) respectively and 7.95, 18.86 and 5.91 percent (in the case of orifice control) were increased compared to the base case. Based on the results of this study so that for the water level constant on the morning glory spillway with changes in the shape of the spillway crest (which is circular in plan form), the flow through the spillway increases and also considering that in the case that the crest is made trihedral, the most increase was in morning glory spillway discharge coefficient.

REFERENCES

Bagheri A, Shafai Bajestan M, Moosavi Jahromi H, Kashkooli H and Sedghee H (2010). Hydraulic Evaluation of the Flow over Polyhedral Morning Glory Spillways. *World Applied Sciences Journal* **9**(7) 712-717.

Ebrahim Nohani (2014). An Experimental Study on the Effect of Vortex Breakers on Discharge Coefficient for the Shaft Spillways with Sharp Edge and Wide Edge. *Journal of Civil Engineering and Urbanism* **4**(5) 546-549.

Fattor CA and Bacchiega JD (2001). Analysis of instabilities in the change of regime in morning-glory spillways. *Proc. Congr. Int. Assoc. Hydraul. Res.,* **29** 656–662.

Kevin M, Boyd PE and Michael A (1997). Morning Glory Spillway Repairs at Kingsley Dam. *Proceeding of the International Conference on Hydropower Held in Atlanta, Georgia, August 5-8.*

Novak P (1971). Hydraulic Structure Design. University Of Newcastle, English.

Padulano R, Del Giudice G and Carravetta A (2013). Experimental Analysis of a Vertical Drop Shaft. *Water* **5** 1380-1392.

U.S. Bureau Of Reclamation (1965). *Design of Small Dams* (Water Resources Technical Publications).

Youssefvand F (2011). Analysis of Bend´s (R/d) Effect on the Hydraulic of Morning Glory Spillways. *Eco. & Cons.* **17**(1) 23-28.