Journal of Ferdowsi Civil Engineering, Vol. 30, No. 1. 2017.

Effect of Downstream Wall Slope of Curved Labyrinth Spillways on Discharge Coefficient

M. Goodarzi[1]* M. Ghodsian[2]
M. Mehraein[3]

1- Introduction

Labyrinth spillways have different shapes in plane such as triangular, trapezoidal, rectangular or elliptical. According to previous studies, if maximum flood exceeds the amount of design flood, the discharge cannot flow through the spillways of a dam in a specific head. One of the technical and economical approaches to solve this problem is to use labyrinth spillways. A labyrinth spillway in a given width has a greater crest length than typical linear spillways.

The flow rate for labyrinth spillways can be calculated by using equation 1:

$$Q = \frac{2}{3} c_d L_c H_0^{\frac{3}{2}} \sqrt{2g} \quad (1)$$

In equation 1, Lc is the effective crest length, Cd is the discharge coefficient, Q is the flow rate over the spillway, g is the gravitational acceleration and H0 is the total hydrostatic depth. Given the limitation of channel width or the reservoir in which the spillway is installed, increasing Lc by notching and creating a nonlinear weir is one of the most suitable ways to increase spillway discharge capacity.

Once labyrinth spillway cycles are placed on an arc, arced labyrinth spillways are created. Using this type of spillway in addition to length increase would lead to increased hydraulic conductivity in dam reservoirs.

To the best knowledge of the authors, research in this regard is in its primary stages. On the other hand, no study has been conducted regarding the effect of downstream walls on the hydraulic conductivity of these spillways, and it is necessary that complementary studies be conducted in this respect. In the present study, we consider the effect of downstream wall slope on the hydraulic conductivity of these spillways using laboratory studies.

2- Laboratory Equipment

The constructed labyrinth weir was installed in a flume 2 meters wide, 10 meters long, 90 centimeter deep, and placed on a table. Water flow was injected into the flume by two pumps. Once the water level soars in the channel, the flow first passes over semi-circles installed on the channel. Once water height reaches the height of the table where labyrinth spillway cycles are located, the water flow passes over the table and flows into the cycles. Next, the water flow pours into the underground reservoir after passing over the spillway, and is again transferred into the flume via the pump.

Spillways were made of Plexiglass in 5 cycles (N=5), where N is the number of cycles, with a height of 10 cm, and the labyrinth weir crest was semicircular. In total, 200 tests were performed for 10 different forms of weir, with 4 downstream slopes where α=6◦, θ=27.4◦ and 4 other downstream slopes with α=11.25◦, and θ=27.4◦.

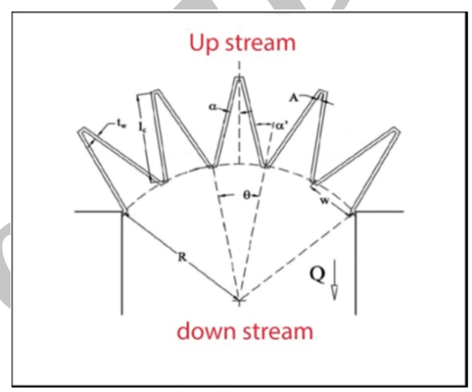

Fig. 1 The profile of Arc labyrinth spillway

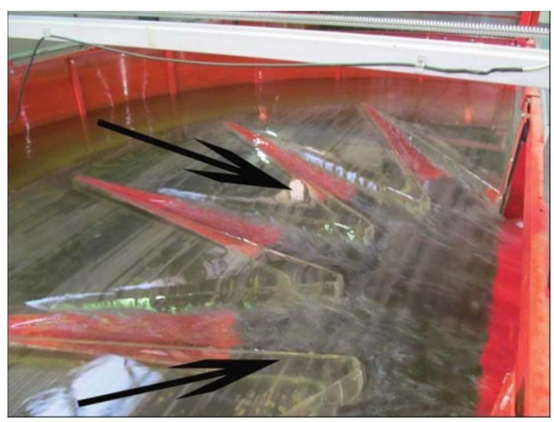

Fig. 2- downstream slope and flow direction

3- Observations and Results

To investigate the effect of downstream slope of arced labyrinth weir, 8 slopes were tested and evaluated.

The flow rate for investigating downstream wall slope ranged from 29 to 179 L/s. Noteworthy observations for the effect of investigations on downstream slope are as follows:

---

[1]*Corresponding Author: graduated student, Civil & Environmental Engineering Tarbiat Modares University.

[2] Professor, Civil & Environmental Engineering Tarbiat Modares University.

[3] Assistant Professor, Faculty of Engineering Kharazmi university.

- For small values of $\frac{H_0}{p}$ for labyrinth weir with downstream wall slope extending from the crest to the end of the cycle, vortices develop at the downstream apex of weir, leading to reduced discharge coefficient of flow, and these vortices disappear after a peak flow discharge.
- For lower values of $\frac{H_0}{p}$ for labyrinth weir with downstream slope extending from the crest to three quarters of the cycle, vortices develop at the downstream apex of the weir. These vortices lead to reduced discharge coefficient of flow and disappear as the flow height increases.
- For α=6°, aeration of flow is not observed.
- Downstream inclination leads to greater length of flow interference area for the flow passing through cycles than that without slope conditions.
- The aeration process stopped for α=11.25° in the area where the slope of the downstream wall is extended. The general equation of discharge coefficient for weirs studied with downstream wall slope for the range of $0.13 \ll \frac{H_0}{P} \ll 0.96$ is as follows:

$$c_d = a(\frac{H_0}{P})^3 + b(\frac{H_0}{P})^2 + c\left(\frac{H_0}{P}\right) + d \qquad (2)$$

The coefficients a, b, c, and d are calculated based on the angle and slope from Table 1.

Table 1- The coefficients a, b, c, and d

	slope	a	b	c	d	R^2
α=6°	84	0.67	-0.65	-0.42	0.62	0.98
	82	1.4	-1.72	0.01	0.58	0.96
	79	1.13	-1.15	-0.37	0.67	0.98
	68	0.47	-0.64	-0.54	0.68	0.98
α=11.25°	80	1.63	-2.61	0.71	0.56	0.99
	76	1.68	-2.49	0.84	0.64	0.97
	70	3.71	-5.8	2	0.47	0.94
	53	2.78	-4.28	1.24	0.54	0.96

4- Conclusions

The downstream slope of arced labyrinth weir reduced the disadvantages of labyrinth spillways, because the slope acts as an obstacle against the flow, thus preventing flow discharge.

- If the downstream slope is extended to the end of the cycle, in addition of increasing confluence, the vortices at the downstream apexes of the weir are affected. Hence, the passing flow rate over the spillway under ideal conditions is reduced. This type of slope at the downstream of weir is not recommended in small length.
- Downstream apex vortex is not observed when the downstream slope is connected the weir crest to mid-length of downstream cycle.
- When the slope extends from the crest to the end of the cycle the flow rate will have a reduction of 4.45 percent in the worst case. The latter is the worst case of this study.
- For a constant flow rate, the downstream slope makes higher flow as compared with the case without this slope condition.
- As the flow height increases, the effect of downstream slope on discharge coefficient decreases.
- A new equation for calculating discharge coefficient of labyrinth weir for different wall slopes which can be used in the range of the non-dimensional parameters of this study is suggested.