Hydraulic comparison of stepped and Chute spillways

Giorgi Noselidze
Technical University of Georgia, Tbilisi, Kostava 77, 0160
LEPL Community College "Spectri", Tbilisi, Georgia, 10, B. Chichinadze St. 0168
gj.noselidze@gmail.com

DOI: https://doi.org/10.52340/building.2025.71.21

Abstract. The thesis presents the comparison of the hydraulic calculation of stepped spillway and chute spillway. The issue becomes even more relevant when, must be resolved, how will be type of spillway, which will conduct discharge water from upstream to downstream. The paper discusses the hydraulic characteristics of two different spillway structures. The results of theoretical calculations clearly show the flow heights at different sections. Calculations were carried out using formulas proposed by various authors.

Key words: Chute spillway, stepped spillway, channel,

1. introduction

A spillway is a structure used to provide the controlled release of water downstream from a dam or levee, typically into the riverbed of the dammed river itself. Spillways ensure that water does not damage parts of the structure not designed to convey water. Water normally flows over a spillway only during flood periods, when the reservoir has reached its capacity and water continues entering faster than it can be released. Today are many type of spillway, but in the article is discussed only two type of spillway, first is stepped spillway and second chute spillway.

A stepped spillway is a spillway with steps on the spillway chute to assist in the dissipation of the kinetic energy of the descending water. This eliminates or reduces the need for an additional energy dissipator, such as a body of water, at the end of the spillway downstream.

Chute spillway is an open channel like structure, which is constructed on steep slope of the gully face with a suitable inlet and outlet. The major part of the drop in water surface takes place in a channel.

2. Main parts.

The first time calculate the stepped spillway and create water level surface. The results of the theoretical calculation are important for determining of water level surface.

There are presented boundary conditions for the hydraulic calculation of spillway structures.

The width of the stepped spillway of rectangular section b=8.5 m.

Water discharge Q=95 m^3/sec

The average width of the leading trapezoidal channel B=9.97 m.

Normal depth of water in the channel $h_0 =$ 1.47 m.

Upstream Z=489.00 m

Downstream Z=466.5 m

Number of steps of spillway n=6

The height of the well d=2 m

Determine the height of the well for the given depth.

$$P = \frac{Z_{upst} - Z_{dst}}{n} + d = 5.75 \qquad (1)$$

Calculate the depth in the narrowed section of the stream

Determine the depth h_c by the selection method. Chart 1

$$y = (p + H_0)h_c^2 - h_c^3 \qquad (2)$$

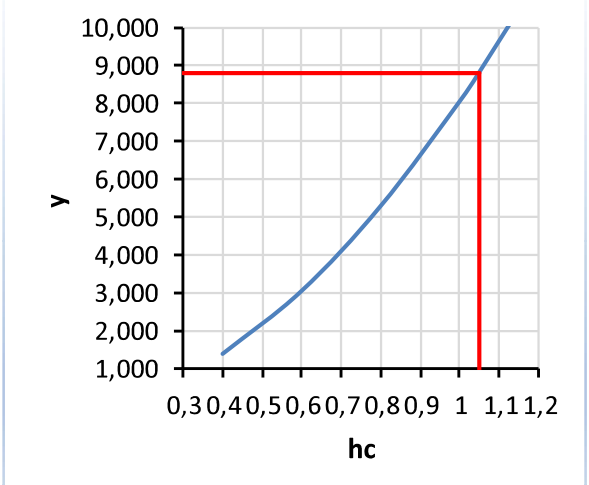

Chart 1

The depth of marriage is equal

$$h_c^c = 0{,}5h_c\left[\sqrt{1+\frac{8}{gh_c}\left(\frac{q}{h_c}\right)^2}-1\right] = 4.93 \quad (3)$$

Pressure on the waterline threshold (at the end of the step)

$$H_0 = \left(\frac{q}{M}\right)^{\frac{2}{3}} \quad (4)$$

Depth of water in the first well

$$H = H_0 - \frac{v^2}{2g} \quad (5)$$

The depth of the well

$$d = h_c^c - H \quad (6)$$

The depth of the water in the well

$$t = d_1 + H \quad (7)$$

Stock factor of Well depth

$$\frac{t}{h_c^c} \quad (8)$$

The second and subsequent steps are calculated as follows $H_0 = 3.31$; $H_0/p = 0.58$; $h_c = 1{,}05$; t = Average speed at the threshold $v = q/H = 3.67$

The length of the drop is calculated by 8 formula

$$l = v\sqrt{\frac{2y}{g}} + 0.8 \cdot 2.5(1.9h_c^c - h_c) = 21.3$$

For hydraulic comparison, it is necessary to carry out a hydraulic calculation of a rectangular cross section of chute spillway and construct a circle of the free surface of the water flow.

The width of the base of the rectangular cross-section of chute b=8.5 m

Water discharge Q=95 m3/sec

Normal depth of water in the cannel $h_0 = 1.47$ m.

Upstream Z=489.00 m

Downstream Z=466.5 m

The length of the chute L=123.19

Slope i=0.203

Basic calculation formula:

$$\frac{il}{h_0} = \eta_2 - \eta_1 - (1-\bar{j})[\varphi(\eta_2) - \varphi(\eta_1)] \quad (10)$$

Let's make the calculation in the form of a table:

Table 1

hi	b	ω	χ	R	i	n	C	Q	η_1	η_2
	$h_0 = 0.48$				$i = 0.203$	$x = 2.5$				
3,53	8,5	30,005	15,56	1,928	0,203	0,011	101,42	1904,02	7,37	4,60
2,2		18,7	12,9	1,450			96,71	981,07	4,60	3,76
1,8		15,3	12,1	1,264			94,53	732,80	3,76	2,09
1		8,5	10,5	0,810			87,76	302,41	2,09	1,46
0,7		5,95	9,9	0,601			83,51	173,56	1,46	1,27
0,61		5,185	9,72	0,533			81,87	139,69	1,27	1,23
0,59		5,015	9,68	0,518			81,47	132,50	1,23	

continue of table 1

$h_{avg.}$	χ avg.	ω avg.	R avg.	C avg.	J avg.	$\varphi(\eta_1)$	$\varphi(\eta_2)$	L	ΣL
2,865	14,23	24,3525	1,69	99,07	102,0456	0,038	0,07	1,07	**1,07**
2	12,5	17	1,36	95,62	108,2315	0,07	0,081	2,78	**3,86**

1,4	11,3	11,9	1,04	91,15	108,7823	0,081	0,253	39,78	**43,64**
0,85	10,2	7,22	0,71	85,64	106,3817	0,253	0,45	47,48	**91,12**
0,305	4,86	2,59	0,27	40,93	51,01277	0,45	0,618	19,82	**110,94**
0,6	9,70	5,1	0,53	81,67	101,74	0,618	0,67	12,26	**123,19**

Based on the calculation results, a free water surface for spillways was created. Fig. 1

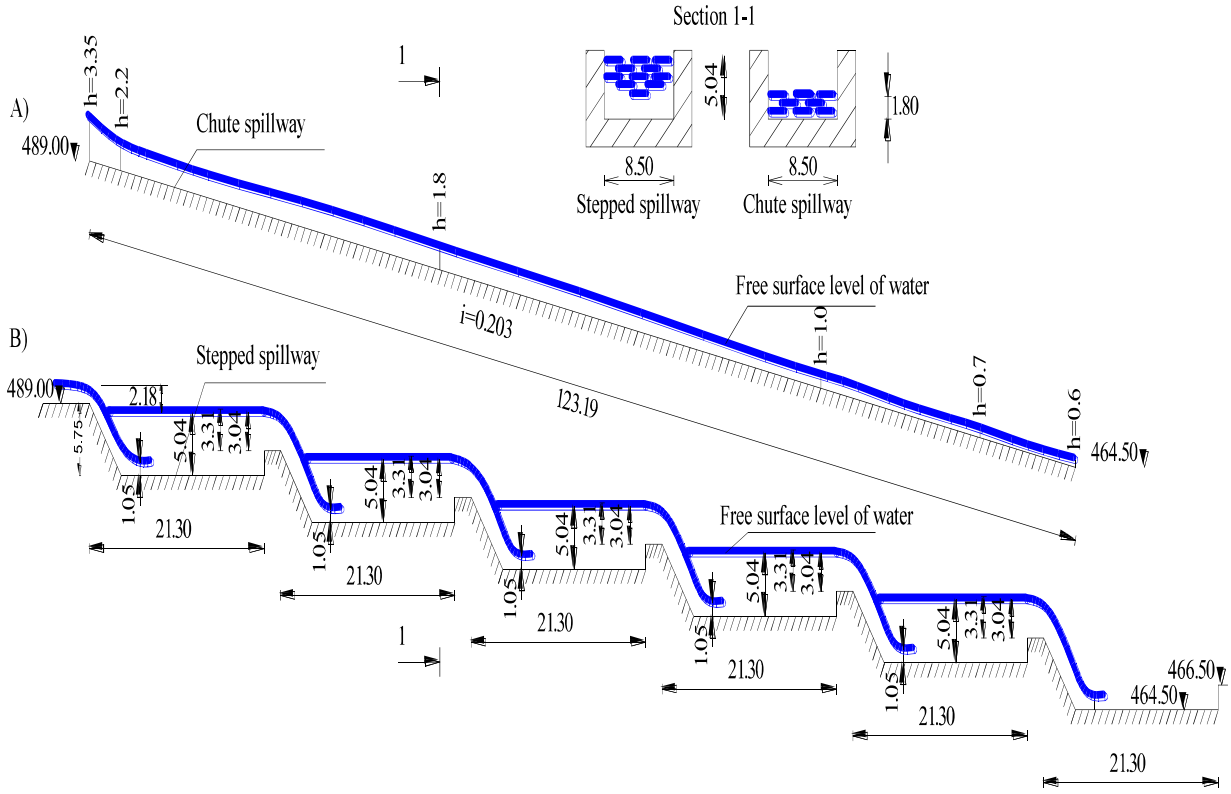

Fig. 1 longitude section of the stepped and chute spillways
A) chute spillway B) stepped spillway

3. conclusion

Analyzing and comparing the results of the theoretical calculations, shows water level of surface in stepped is higher than water level in the chute spillway, for the same boundary conditions. At the same times, it should be noted that in some cases construction of a stepped spillway is justified, because the stepped spillway does not need an additional exit well, extinguishing well of water stream.

$$\frac{2a'}{g}\left(\frac{Q}{b}\right)^2\frac{1}{r_1 h_1^c}+r_1(h_1^c)^2 = \frac{2a'}{g}\left(\frac{Q}{b}\right)^2\frac{1}{r_1 h_1^c}+r_2(h_c^2)^2 - \beta\frac{(h_1^c)^2 h_1^c h_2^c+(h_2^c)^2}{3}l_{II} \quad (11)$$

Under the conditions of the given task, using formula 11, determine the height of the flow in the exit section for chute spillway and construct the dependence curve of h_2^c and Q(h).

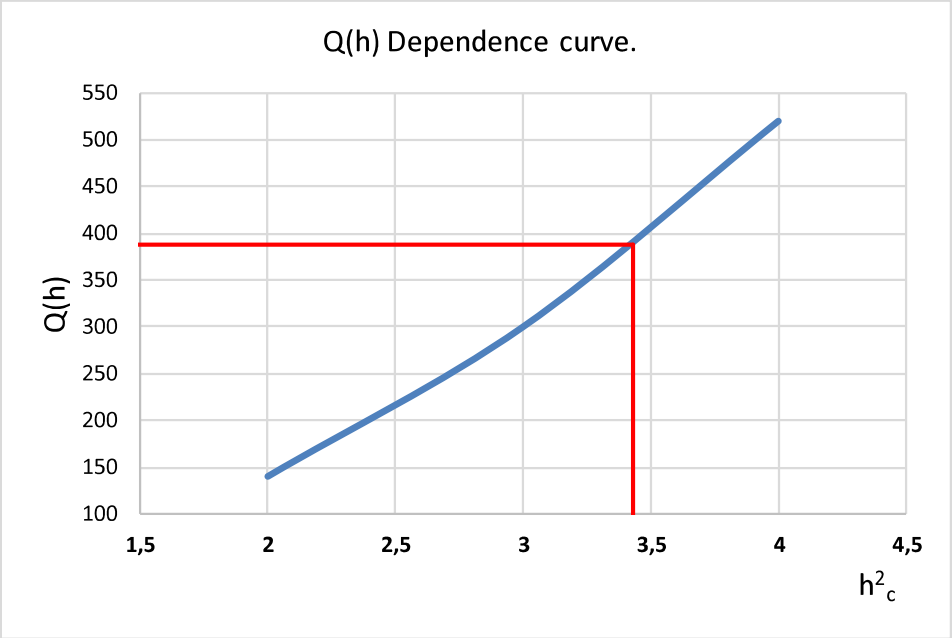

Chart 2

sing formula 11, the height of the flow in the exit section was determined, which is equal to 3.44 meters.

Reference

1. Novak P., Moffat A.I.B., Nalluri C., Narayanan R., Hydraulic structures. Fourth edition. London and New York: Taylor-Francis Group, 2010, 700 p.
2. Parks E. „Hydropower Engineering". London, Larsen and keller Education, 2017, 312 p.
3. P. G. Kisileva. Handbook of hydraulic calculations "Energy" ·Moscow· 1972, 312 p.