Comparison of Linear And Labyrinth Weirs To Increase The Discharge Capacity of Existing Spillways For a Given Head

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Abstract- *The concept of labyrinth sharp crest spillway (LSCS) had used in this study to increase the capacity of spillway without lowering the crest. Existing spillway is considered as the Ogee type. Different kinds of LSCS with different angles from 8°to 30°was used in this work. The experiments were performed in the laboratory on open flume. Ogee prototype was be made of wood and LSCS was made with acrylic.*

During the experiment, water was lower into the flume with delivery valve and maintaining constant head to take discharge values. At any change of water thickness above spillway, the water discharge was measured. Observation was done on the Ogee, linear weir and LSCS[Triangular and Trapezoidal Labyrinth Weir].

As a result, Triangular labyrinth weir with 8°side wall angle is best suitable weir to spill the water with less head of water more discharge was noted.

Keywords- Spillway capacity, Ogee Spillway, Labyrinth spillway, coefficient of Discharge.

I. INTRODUCTION

1.1 General

In the last few years, the behaviour of the water in the nature has changed because of the change in the climate. Climate change triggers extreme water; an example of this situation is that excessive rainfall rate has increased. The flow of water entering a reservoir is undetermined because of the fact that it is related to the intensity of the rainfall. It is known that intensity increase in the rainfall causes significant changes in reservoir water levels. This situation can end up with the failure of a dam.

However, being a safe dam not only means a structurally stable dam but also means a hydrologically safe dam. In other words, a dam may have inadequate spillway capacity making the dam unsafe hydrologically. To increase the spillway capacity is often by additional construction of spillway. However, these efforts are often obstructed due to field conditions that do not support such option. Increased spillway capacity without reducing the reservoir volume is an alternative that is selected in this study. For this reason, experimental methods used for increasing the spillway capacity of the dams will be investigated and compared in the present study, and they are labyrinth weirs and linear weirs and Ogee spillway.

Labyrinth weirs supply an increase of crest length for a given channel width, Figure 1.1. Therefore, they increase the flow capacity for a given water head. The crest length can be increased around five times by using a labyrinth spillway instead of a standard spillway. Furthermore, the discharge capacity of a labyrinth spillway can be twice as much as that of a standard spillway.

In the present study, design methods of the different angles labyrinth weirs and ogee spillway will be explained and these methods are compared both in hydraulic aspect with one another as well as with linear weirs.

1.2 Objectives of the Present Study

In order to be protected from probable maximum flood and to ensure dam safety hydrologically, rehabilitation works have been done on the spillways to increase their discharge capacity. Consequently, it is the main objective of this study to investigate some practical methods used in increasing the spillway capacity of dams. In this respect, labyrinth weirs and Ogee spillway were selected as the two effective methods to achieve it.

In this study focus will be on the different types and different angles of labyrinth weirs as important alternative way of increasing spillway capacity compared to linear weir and ogee spillway.

II. METHOD TO DESIGN

2.1 Introduction

Generally, for dams Ogee spillway is used to spill water from upstream side to downstream side because of its best performance. So, in this present study Ogee spillway and linear weir is considered to compare its results with Labyrinth weirs experimentally.

Physical modeling of Ogee was done by wood, linear weir and labyrinth weirs are made by acrylic. In this study two types of labyrinth weirs are considered one was Triangular shape another one was Trapezoidal shapes made with an angle range from 8°to 30°.

2.2 Design of Ogee Spillway

Require dimensions were taken to analyze the ogee spillway is as follows:

Height of the ogee spillway = 45cms, Free board = 15cms, Width of the ogee spillway= 30cms. Assuming downstream facing profile should be in 0.7H : 1V.

Now, $Q = C_d * L_e * He^{\frac{3}{2}}$

where, L_e= L - 2[N * K_p+ K_a]H_a

Let us first work out the approximate value of H_e

L_e = L = clear water away = 1 x 30 = 30cms.

0.02$m^3/s = 2.2 * 0.45 * H_e^{\frac{3}{2}}$

H_e=0.07175 it is for 0.02m^3/s

The height of the spillway above river bed (h)= 45cms.

Since $\frac{h}{H_d}$ i.e. $\frac{0.45}{0.074175} = 6.0667 \geq 1.3$

It is high spillway.

Down Stream Profile:

The W.E.S. d/s profile for a vertical u/s force is given by equation.

$X^{1.85} = 2 * H_d^{0.85} * y$

Y = $\frac{x^{1.85}}{2*Hd^{0.85}}$

$$Y = \frac{x^{1.85}}{2*(0.07417)^{0.85}}$$

$$Y = \frac{x^{1.85}}{0.219153}$$

The downstream slope of the dam is given to be 0.7H:1V

Hence $\frac{dy}{dx} = \frac{1}{0.7}$

Differentiate the equation of the downstream profile with respect to x, we get

$\frac{dy}{dx} = \frac{1.85*x^{0.85}}{0.21915} = \frac{1}{0.7}$ X $= 0.123$

For the value of x = 0.123m, y = 0.0955m

Up Stream Profile may be designed as per the equation as, y =

$\frac{724(x+0.27H_d)^{1.85}}{H_d^{0.85}}) + 0.126H_d - 0.4315H_d^{0.38}(x+0.27H_d)^{0.625}$

where H_d= 0.0745 m. This curve goes up to x =-0.27H_d=-0.020 by substituting the $H_d$values, y values are determined .

bucket: Spillway has been designed. A reverse curve of a bucket at the toe with a radius to (h/4)=0.45/4=0.1125m. It has to be designed at angle of 60°.

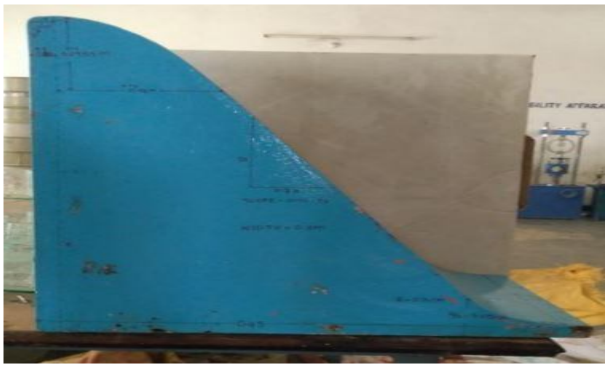

Figure 2.1: Ogee spillway physical model by wood

2.3 Labyrinth Weir

The concept behind labyrinth spillway is to provide added crest for a given spillway width, so that less head is required to pass a given discharge. The additional crest length is obtained by a series of trapezoidal or rectangular walls. Ratio of Length of spillway width to the spillway height is an important parameter responsible for flow pattern

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The flow capacity of a weir is largely governed by the weir length and crest shape. A labyrinth weir is a linear weir that is ’folded’ in plan-view to increase the crest length for a given channel or spillway width.

Due to the increase in crest length, a labyrinth weir provides an increase in discharge capacity for a given upstream driving head, relative to traditional linear weir structures.

2.3.1 Design Procedure done for 8°Triangular Labyrinth Weirs

- Ensure that H_T/ P is smaller than 0.9.

H_T/ P = 1.5/8 = 0.19 ≤ 0.9

- Consider the criteria 3≤ *w/P* ≤4.

15/8 = 2 within range

- By inserting the value of the weir height (P), the range of w (width of one cycle) can be obtained. After then, the number of cycles can be calculated.

Number of cycles considered is N = 2

- The wall thickness (t) is equal to P/6. (Tullis, et al. 1995) t= P/6 = 8/6 = 1.33cm but physical model was made by .5cm thick glass plate.
- The value of inside apex width (A) is between t and 2t. (t≤A≤2t) a= 1.0cm taken for triangular 2.0cm taken for trapezoidal weir
- Labyrinth angle is usually chosen from the range of alpha values of 8°- 30°.
- Outside apex width (D) is calculated from:

D = A + 2t tan(45-α/2) = 1+ 2*t tan(45-(8/2)) = 2.73cm

- Obtain L1 (actual length of side length) by using α and w. Then calculate the effective length as follows:

L= (D/2 +L1+ A+L1+ D/2) N

L = (2.73/2 + 440 + 1 + 440 + 2.73/2)2 = 1.76mts

- Calculate the discharge over the labyrinth weir using Equation - 1.1

Labyrinth Weir Models The labyrinth triangular and trapezoidal weir models were made with 5 mm thick glass plate. The models were made for 8°, 10°, 15°, 20°, 25°, & 30°degrees. These models are tested in a rectangular flume Linear weir also design based on labyrinth concept taking effective length as 0.3m and height of the weir P is 0.08m and made with acrylic 5mm glass plate.

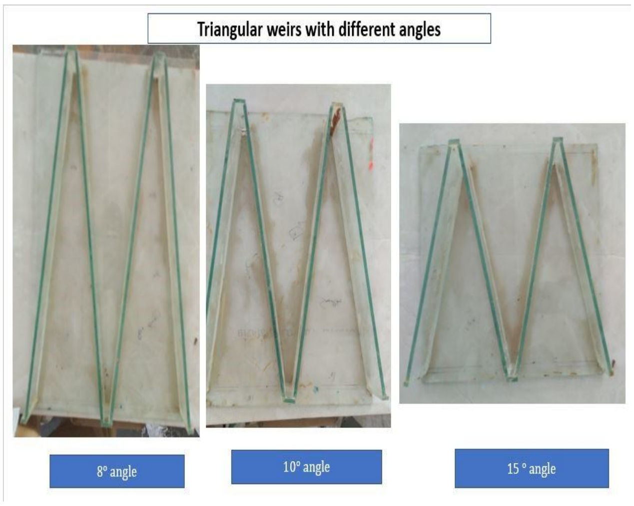

Figure 2.2: 8°, 10°&15°Angles Triangular Labyrinth Weirs

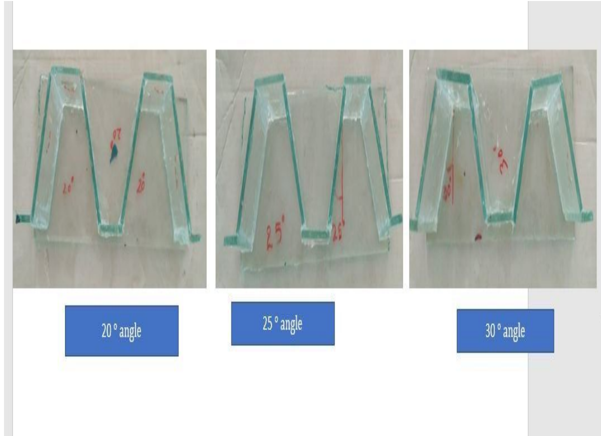

Figure 2.3: 15°& 20°Angles Trapezoidal Labyrinth Weirs

Table 2.1: Main parameters obtained from Design Procedure

Side wall angle (α)	Weir height (P) in m	Effective crest length L_c in m for Triangular	Effective crest length L_c in m for Trapezoidal	w/P	N
8°	0.08	1.76	1.146	2	2
10°	0.08	1.42	0.966	2	2
15°	0.08	1.02	0.702	2	2
20°	0.08	1.00	0.570	2	2
25°	0.08	0.64	0.487	2	2
30°	0.08	0.54	0.444	2	2

III. EXPERIMENTAL PROCEDURE

3.1 Introduction

To determine the most effective labyrinth weir i.e., which gives more discharge with less head of water, also co-efficient of discharge variation for different angles of (triangular & trapezoidal) labyrinth weir including linear weir and ogee spillway are determined.

3.2 Experimental Procedure

The experimentation was started by priming the pump to create vacuum pressure, then calibrating the delivery Value to maintain constant head. Each labyrinth weir was then tested with a starting head was 0.5cm, which was gradually increased at each increment of 0.25cm head of water, so as to obtain increment of H_T/P ratio of 0.05. The testing was done for each weir for about 6 different flow rates. The flow rates were measured using calibrated volumetric tank. The total head over the weir was taken as the difference in the water surface and the crest and was measured at 4 to 5 times the maximum total head over the weir upstream from the face of the weir.

1. Maintained the slope of flume as zero (s_0).
2. Fitted the model in the flume on which experiment is conducted one after another model.
3. Press the start button, Note down the level of water over weir with the help of point gauge, here head of water (H) is maintaining constant then reading starts from 0.5cm to full discharge. Note down the time for 10 cm rise of water in collecting volumetric tank with stop watch.
4. Change the discharge by operating flow control valve and Repeat the steps for about 6 different discharges. Same procedure for all different types of Labyrinth weir including Linear weir and Ogee spillway.

IV. RESULTS AND DISCUSSIONS

4.1 Introduction

The Theoretical Discharge $Q_{th}$was calculated for Ogee Spillway, linear weirs, also for Labyrinth weir, then Actual Discharge Q_{act} was calculated. Then graphs were plotted, Head on x-axis against Q on y-axis for Ogee, Linear & Labyrinth weirs, to select best.

- **4.2 Comparison of all Weirs Discharge(Q) with head(H)**

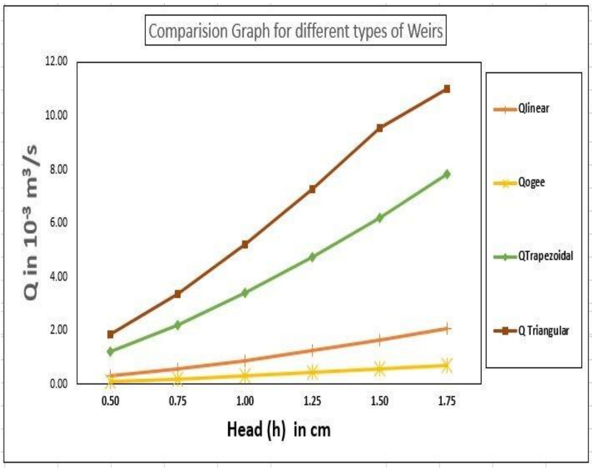

Figure 4.1: Comparison between Head of water with discharge Q of Linear weir, Ogee Spillway and (Triangular and Trapezoidal) Labyrinth Weir.

To find out the best model, i.e., model which gives high discharge at low heads a comparison graph is plotted for various models, Head against discharge. Then the best model is selected and it is selected as Triangle shape with sidewall angle 8°will give high Q for low heads. From Comparison graph between head with different discharge Q of linear weir, ogee spillway, triangular and trapezoidal labyrinth weir, it is concluded that triangular labyrinth weir is best weir to spill more water with low head.

V. CONCLUSIONS

The main goal of this study is to investigate the methods in increasing the spillway capacity of the dams, so that area of submergence can be reduced during high flood times If spillway crest length increases, the discharge capacity also increases. So which will increases the crest length for the given width of channel.

Therefore, they increase the flow capacity for a given water head. The capacity of a labyrinth spillway is a function of the total head (H_T), the crest length L, and discharge coefficient (C_d)

In light of these studies, the following conclusions are obtained:

1 The Ogee Spillway was design to fit in the tilted flume then discharge(Q) values were taken for different 'H' values.
2 Labyrinth weirs were designed for Triangle & Trapezoidal shapes with different angles.
3 When the ratio of H_T /P increases in labyrinth spillways, discharge coefficient C_d starts to increases and the benefits

gained by using a labyrinth spillway. Therefore, there is a limitation for H_T/P ratio of 0.9 for a successful design of a labyrinth spillway.

4 For different 'H' values discharge 'Q' is observed for Labyrinth weir again among those the angle which gives high Q is selected as best. Then C_d values also calculated.

5 Then 8°Triangle & Trapezoidal Labyrinth weirs are compared with Ogee and Linear, to find the Best model.

6 After comparison of all weirs such as Linear, Ogee spillway, Triangular weir and trapezoidal weir, from graph concluded that Triangular weir is best suitable to spill water more with less head.

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