MODIFICATION OF STEPPED SPILLWAY FOR HYDRAULIC INVESTIGATION

Submitted in partial fulfillment of the requirements

For the degree of

Bachelors of Engineering

by

Khot Saad -16DCE72

Moin Kazi -16DCE65

A. Basit Sayyed -16DCE82

Mohd. Arwaz -16DCE75

Under the Supervision of

Prof. Junaid Maste

Department of Civil Engineering

Anjuman-I-Islam's Kalsekar Technical Campus

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Certificate

This is to certify that the project report entitled as "**Modification Of Stepped Spillway For Hydraulic Investigation"** submitted by the team of the above mentioned students studying in 'Anjuman-I-Islam's Kalsekar Technical Campus', New Panvel is an authentic work carried out by them under my guidance.

The report was submitted in partial fulfillment of the requirement for the award of the degree of Bachelor of Engineering in Civil Engineering.

Prof. Junaid Maste

(Project Guide)

Dr. Rajendra Magar
(H.O.D-Civil Engineering)

Dr. Abdul Razak Honutagi
(Director)

Project Report Approval for B.E.

This project report entitled "***MODIFICATION OF STEPPED SPILLWAY FOR HYDRAULIC INVESTIGATION***" by "***Khot Saad (16DCE72), Kazi Moin (16DCE65), A. Basit Sayyed (16DCE82) and Mohd. Arwaz (16DCE75)***" is approved for the degree of "***Bachelor of Engineering***" in ***"Department Of Civil Engineering***".

Examiners

1.-----------------------

2.-----------------------

Date:

Place:

Declaration

We declare that this written submission represents our ideas in our own words and where others' ideas or words have been included, we have adequately cited and referenced the original sources. We also declare that we have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. We understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Khot Saad (16DCE72):

Moin Kazi (16DCE65):

A. Basit Sayyed (16DCE82):

Mohd. Arwaz (16DCE75):

Acknowledgement

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Abstract

The terminal structure of a spillway plays a major role in dissipating specific energy of excess flood to safeguard the river channel and downstream structure. The ogee profile spillway is hydraulically efficient, structurally stable and more adequate to dispose excess flood effectively on downstream end of river channel. This spillway will be helpful to control the erosion, scouring and pondage if suitable energy dissipater provided at terminal structure. Due to high discharge of excess flood there are chances of causing erosion on Spillway bed, which is a major problem to affect the spillway capacity. Excess air entrainment causes positive pressure on spillway bed and helpful to achieve maximum energy dissipation by replacing ogee profile by steps. But there are chances of erosion on the nosing of steps which ultimately leads to the failure of structure so to reduce the erosion on nosing and maintain the minimum energy dissipation the sharp edges are converted into curves at specified radius. Therefore, after testing we can conclude that this spillway is best suitable for energy dissipating to overcome the spillway problems by enhancing minimum energy dissipation or not.

Keywords: - Ogee spillway, curves, pondage, steps, specific energy and energy dissipation, etc.

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Chapter 1

Introduction

1.1 Spillway:

A spillway is a structure used to provide the controlled release of flows from a dam into a downstream area, typically the riverbed of the dammed river itself.

Ogee and Stepped Spillways:

Usually there are various types of spillways but we are focusing mainly on Ogee and Stepped Spillway. **Ogee spillway** is the overflow-type spillway which has a controlled weir and is Ogee shaped (S- shaped) profile. A **Stepped spillway** is a spillway with steps on the spillway chute to assist in the dissipation of the Specific energy of the descending water.

1.1.1 Ogee Spillway:

An ogee-shaped spillway was an improvement upon the free overfall spillway which solved many problems such as objectionable scour and deep plunge pool. But, the drawback we faced in ogee spillways was cavitation due to negative pressure and also it creates in whole structure which eventually caused crack in structure.

1.1.2 Stepped Spillway:

The maximum possible number of steps, are an efficient and desirable alternative to traditional smooth-back spillways. But, One should not forget the drawbacks of stepped spillways such as erosion of the steps.

1.2 Proposed Spillway:

In this we would be combining Ogee and Stepped Spillway so that we can find out at maximum head how much is the Specific energy. Less the Specific energy less the scouring, Higher the head more the generation of electricity.

Figure1.1 Types of spillway

1.3 Objective:

1) To Compare the Discharge Coefficient of Ogee Spillway, Stepped Spillway and Proposed Spillway.

2) To Compute and Compare the Loss of Specific Energy in Stepped Spillway and Ogee Spillway.

Chapter 2

Literature Review

I) Development of Working Model for Ogee Profile Spillway Using Steps and Roller Bucket for Enhancement of Energy Dissipation:

2.1 General:

In ogee spillways the hydraulic jump type of stilling basin is generally preferred as an energy dissipater but it requires the longer span and creates the problems like scouring, erosion due to high amount of specific energy generated at toe portion of spillway. Roller bucket is another option of energy dissipation but it has the limitations. The movement of roller that mixes with incoming flow results in dissipation of energy and prevents the scouring. It requires also sufficient tail water depth for functioning effectively and need to maintain the tail water depth in a range of 1.1 to 1.4 time's sequent depth and preferred if Froude number is greater than 4.5. The stepped spillway is also more prominent and its steps act as roughness elements to reduce flow acceleration and terminal velocity. The reduced velocity and the cushioning effect of the entrained air thus reduce the cavitation's potential. There is now increasing interest and broad scope in finding ways to bridge gap by providing suitable energy dissipating devices at terminal structure to overcome the erosion and scouring problems in ogee spillway. In this present research the attempt has been made to identify effect of step sand roller bucket utilized to overcome the scouring and erosion in ogee spillway. Energy dissipation devices dissipate the Specific energy of excess flood with the help of effective devices at the toe portion of spillway. It helps to obtain uniform flow at the downstream side of river also minimizes the erosion damage at the downstream end. To normalize the velocity distribution on spillway there is a need of suitable energy dissipation devices. Many failures of dams have been reported due to inadequate capacity or improper design of spillway. It improves the project with the ability to release excess or flood water in a controlled or uncontrolled manner to ensure the safety of the dam. To avoid the overturning of the dam, It is of paramount importance for the spillway facilities to be designed with sufficient capacity to avoid overtopping of the dam, especially when an earth fill or rock fill type of dam is selected for the project. Spillway is a hydraulic structure used to release water on a regular basis for water supply, hydroelectricity generation etc. Spillways are provided with energy dissipation devices (e.g. Stepped spillway, Stilling Basin, Chute blocks, Buckets, Friction Blocks, End Sill) for dissipation of energy arising out of change in energy level upstream and downstream of the structure. The present research is highly emphasis on utilization of combined effects of steps and roller bucket combinable at terminal structure of ogee spillway. Henceforth the model has been designed and developed with a scale of 1:33.33 for ogee spillway.

2.2 Review of Literature:

The experiments were conducted for different models in Fluid Mechanics laboratory of AISSMS's COE, Pune. The experiments were performed for four alternatives namely; i) ogee spillway with plain roller bucket (OPRB) model, ii) ogee spillway with slotted roller bucket (OSRB) model, iii) stepped spillway with plain roller bucket (SPRB) model and iv) stepped spillway with slotted roller bucket (SSRB) model. The experiments were performed in a 6 m long, 300 mm wide and 300 mm deep hydraulic flume for discharge range 0.0052 to 0.0063

m^3/s. The experiments were performed with 4m and 6m head resp. The discharge of water in flume was measured by using orifice meter and a kept horizontal for all observations. The head over the profile surface of model were measured by using pressure taps provided along the chute surface at an interval of 4.5 cm, as shown in Fig.2. The gross head of pumped water at 3 HP over the crest of model was measured by using pressure gauge attached to the flume. The plain bucket, slotted bucket and steps were interchangeable for 4 m and 6 m head.

Figure 2.1: Experimental setup of ogee profile stepped spillway in laboratory

2.3 Gaps and Findings:

- Findings of TEL and ED % for Ogee and Stepped Spillway for 6.5m head.

  1. T.E.L for spillway with ogee profile is 0.247 which is more over stepped profile spillway as 0.179 at tap distance 65 cm.
  2. % ED for spillway with steps is 77.23 which are more over ogee profile spillway as 68.61 at tap distance 65 cm.
  3. Spillway with steps shows better result over ogee profile spillway up to tap distance 65 cm

- Findings of TEL and ED% for Ogee and Stepped Spillway for 4m head.

  1. T.E.L for spillway with ogee profile is 0.195 which is more over stepped profile spillway as 0.177 at tap distance 65 cm.

2. % ED for spillway with steps is 78.01 which is more over ogee profile spillway as 75.5 at tap distance 65 cm.

3. Spillway with steps shows better result over ogee profile spillway up to tap distance 65 cm.

2.4 Summary:

In this paper, the specific energy and energy dissipation are compared for Ogee spillway with plain roller bucket (OPRB), Ogee spillway with slotted roller bucket (OSRB), Stepped spillway with plain roller bucket (SPRB) and Stepped Spillway with slotted roller bucket SSRB models at 4m & 6m head etc. And concluded that at lower head of 4m ogee spillway with plain roller bucket (OPRB) dissipates 80 % of specific energy for discharge 0.0052 m^3/s and for higher head of 6m stepped spillway with slotted roller bucket (SSRB) dissipates 83.36 % of specific energy for discharge 0.0062 m^3/s. Therefore it is concluded that stepped spillway with slotted roller bucket model (SSRB) can be considered a suitable energy dissipating model for Khadakwasla dam.

The experiments are performed with a discharge in range of 0.0052 to 0.0064m^3/s. The results of all devices are compared with specific energy and their energy dissipation values. The obtained results with minimum Energy Dissipation (ED) at tapping distance for ogee spillway were 12 %.

(ll) Design and evaluation of stepped spillway for High dam:

2.1 General:

The purpose of this research was to investigate the hydraulic performance of stepped spillways. The experimental study was conducted at Utah University ulah water Research

Laboratory In Logan. As stepped spillway is good way to reduce energy on high dam. This reduction of energy can lead to lower velocity on the face of the structure and a smaller stilling basin required to contain the hydraulic jump. As reduce in basin size economy has achieved.

2.2 Review of literature:

Model	Slope	Step Size	Number of Steps
A	0.7H:1.0V	.75"H x 1.07"V	36
B	0.7H:1.0V	.375"H x .536"V	65
C	0.5H:1.0V	.375"H x .75"V	49
D	0.5H:1.0V	.188"H x .375"V	90

Table 2.3: Model Configuration

Four stepped spillway model was made prototype Height is over 67 feet and steps in the range of 1-2 feet. Energy losses of 4 models about 95% at low to 65% as high flowrates tested. While testing they has bifurcated based on flow type (transitional & turbulent). On a crest portion there is a transitional flow on these on that small size of steps has been installed and in transitional flow size different.

These small steps begin just beyond the crest and increase in size until the desired step size for the constant slope region is attained. Based on observation during testing If these steps are too large, they can cause the flow to hit the tread of the step and leap away from the spillway in a leap frog pattern. If the steps in this transition region are too small, they can cause the leap frog pattern to move further down the face of the spillway in the region of the constant size steps. In the model testing, there was very little difference in energy dissipation between the different size steps.

The slope of the spillway is totally dependent on the downstream slope of the dam. On the slopes tested in the study, the 0.7: 1.0 V slope dissipated slightly more than the 0.5H:l . OV slope. Basins are used where high velocity and high discharge flows are encountered and the Froude number is greater than 5. The Type II stilling basin is a hydraulic jump energy dissipater that causes a hydraulic jump to form at the base of the spillway. This hydraulic jump dissipates much of the Specific energy in the flow and makes the flow safe to enter the downstream channel For smooth spillways, the Type II stilling basin can be very large and costly to construct. With reduced velocities on the stepped spillway, the Type ll stilling basin for a stepped spillway will be considerably smaller at a considerable cost savings.

To evaluate the performance of a stepped spillway compared to that of a smooth spillway, a design procedure adapted from the USBR was used. Based on velocities at the toe of both a smooth spillway and a stepped spillway, Type II stilling basin dimensions were calculated in a spreadsheet application. The dimensions of both stilling basins are then compared in tables to determine the reduction in size of the stilling basin using the stepped concept. This procedure showed a reduction of 42% to 28% in the stilling basin length and 62% to 43% in the total stilling basin volume over a range of unit flowrates from 15cfs/ft < q < 140 cfs/ft. This reduction in size will greatly reduce the material and construction costs in the prototype. Larger models should be built to limit the viscous effects sometimes encountered on smaller models.

(III) Stepped spillway hydraulic model investigation:

2.1 General:

Normally we have a standard ogee profile but in this with ogee profile a continuous steps induced in it, from just below the crest, to the toe. The steps significantly increase the rate of energy dissipation on the spillway face, thus eliminating. To evaluate the effectiveness of the flow transition from the smooth crest profile to the steps, to quantify the energy dissipation on the spillway face, and to define the flow characteristics on the steps.

2.2 Review of Literature:

The model analysis has been done on Monksville, Utah, Bethlehem. Proposed three stepped spillway model was made prototype Height is over 121 m. and the crest width is 61 m.

1. Model A 1:10 of the upper(6.9 m) of the spillway. The model extended down to seven steps below the point of tangency. Model A was used to evaluate the flow transition from the spillway crest to the first several steps and the nature of flow over the steps, for the range of spillway discharges of interest.

2. Model B—A 1:25 scale model of the standard WES ogee spillway profile used as the basis for the stepped spillway. It was a model of the entire 120 ft (36.6 m) spillway profile. This

model was briefly tested to provide comparison data for the full stepped spillway profile model.

3. Model C—A 1:25 scale model of the entire stepped spillway profile. Tests with model C were primarily to evaluate energy dissipation in the flow over the stepped spillway and anticipated flow depths along the spillway, to establish training wall dimensions.

Specific energy in the flow at the stepped spillway toe varies from about 12 to 6% of the energy at the standard spillway toe for this range of model discharges. This represents a Specific energy dissipation of 84%, which is as good as or superior to the energy dissipation achieved in a typical well-developed hydraulic jump. An ogee spillway with a stepped face can be designed to perform satisfactorily for the full range of discharges encountered by the spillway.

A stepped spillway energy dissipation characteristics are comparable to those of an unstepped spillway with a hydraulic jump stilling basin at the toe.

Research should be conducted to provide additional information necessary to optimize the step geometry for a given spillway discharge, face slope, and crest elevation.

Chapter 3

Methodology

3.1. General design of Ogee, Stepped and Proposed:

3.1.1. Ogee spillway:

Design Steps for Ogee Spillway:

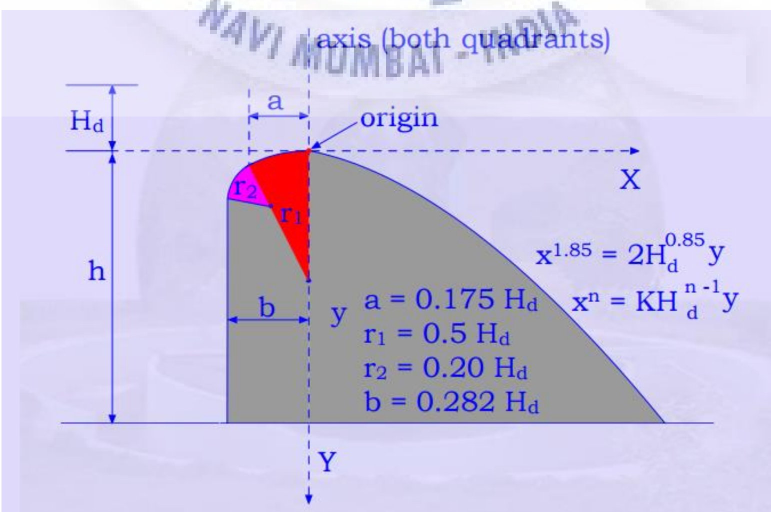


Figure 3.1: Ogee Spillway

For **H**,

Acceptable range: 1.5-3.0 Hd

If, **H<Hd** - positive gauge pressure on Crest

H>Hd – negative pressure develops on the surface

$x^n = K.Hd^{n-1}.y$

Where,

x and y = are the co-ordinates of the point on the crest profile with the origin at the highest point C of the crest, called the apex.

Hd = Design Head including the Velocity Head

K and n = are the constant depending on the upstream face

Slope of the U/S of the Spillway	K	n
Vertical	2.0	1.85
1:3 (1H:3V)	1.936	1.836
1:1.5 (1H:1.5V)	1.939	1.810

Table 3.1: Value of K and n

$X^{1.85} = 2.\ Hd^{0.85}$ y - for vertical face of u/s

<u>Spillway Discharge Equation:</u>

$Q = C_w.\ L_e.h_e^{3/2}$

Where,

h_e = Effective head

C_w = Coefficient of Discharge

L_e = Effective length of spillway crest

$$L_e = L - 2(K_p.N + K_a).H_d$$

Where,

L= the net clear length of crest

K_p = pier contraction coefficient (depends on various shape of piers)

K_a = Abutment contraction coefficient (depends on shape of abutment)

N = No. of Piers

For experimental investigation by Rouse and Reid, actual head may exceed by 50% in design head and a 10% increase in the coefficient of discharge, subject to local pressure.

So after doing proper research over design of an ogee spillway we found out a case study on Monksville Dam which is part of the Wanaque south project developed by the North Jersey district water supply commission and the Hackensack water company. In their design they have a crest radius of 4. 37mm and 10.92mm and a crest riser of 3. 84mm The slope of y= x^1.85/12.46 is used with 1V:0.7H. Point of tangency is at y=2.75' and x=6.76'. An overall length is of 43.15cm, width =30.5cm and height 32.2 cm.

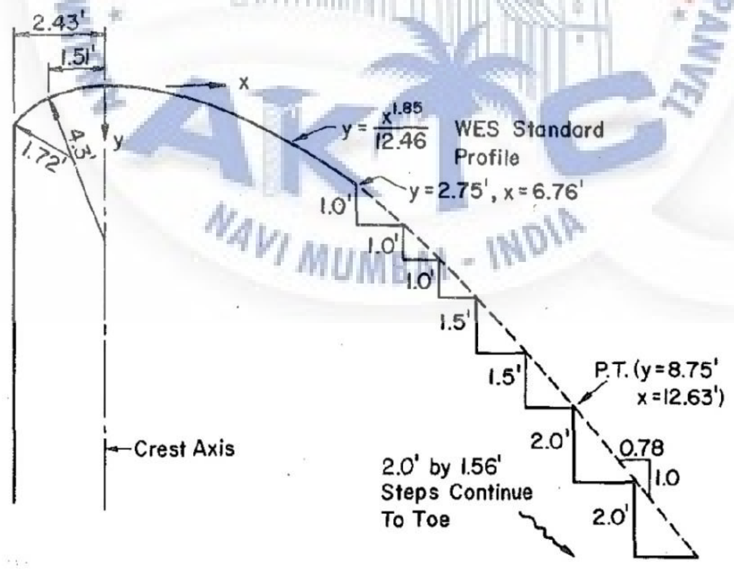


Figure 3.2: Design of Monksville Dam

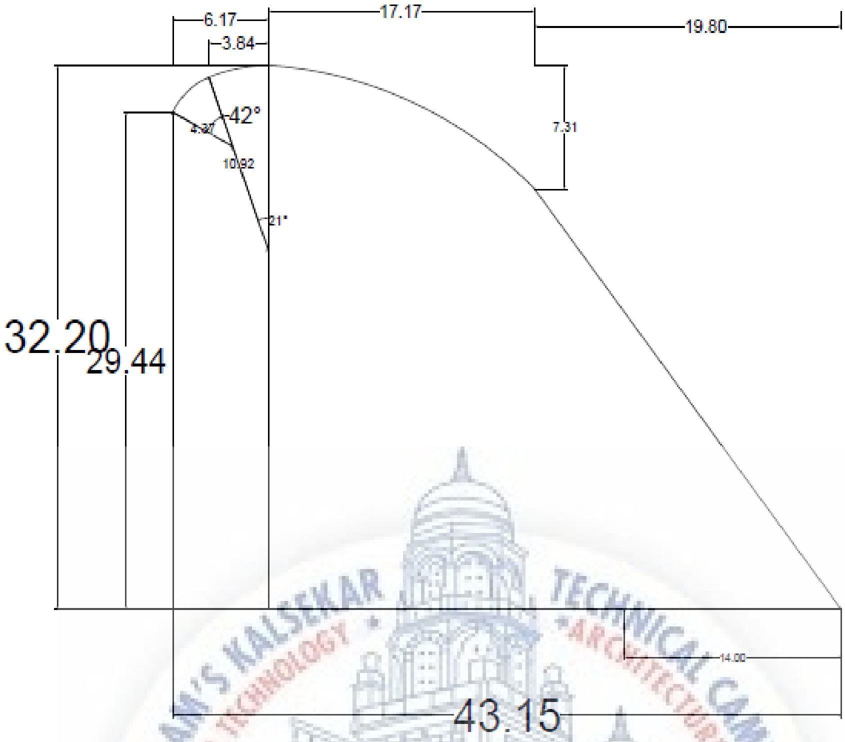


Figure 3.3: AutoCAD drawing of Ogee Spillway

3.1.2. Stepped spillway:

Stepped spillway design was also taken from the same case study in which it was designed for probable maximum flood of that area. But in this standard profile was there from upstream face to the point of tangent on spillway face which was depended on both the design head and upstream face slope. We instead of giving standard profile till point of tangency we provided steps with varying risers. As stepped spillway can't be designed hydraulically we designed it by geometrically. (Although design of stepped is a trial and error method for fixation of risers and tread). We kept them varying rather than keeping same to obtain a proper profile similar to that of ogee spillway. Crest profile, length and width were similar to ogee spillway.

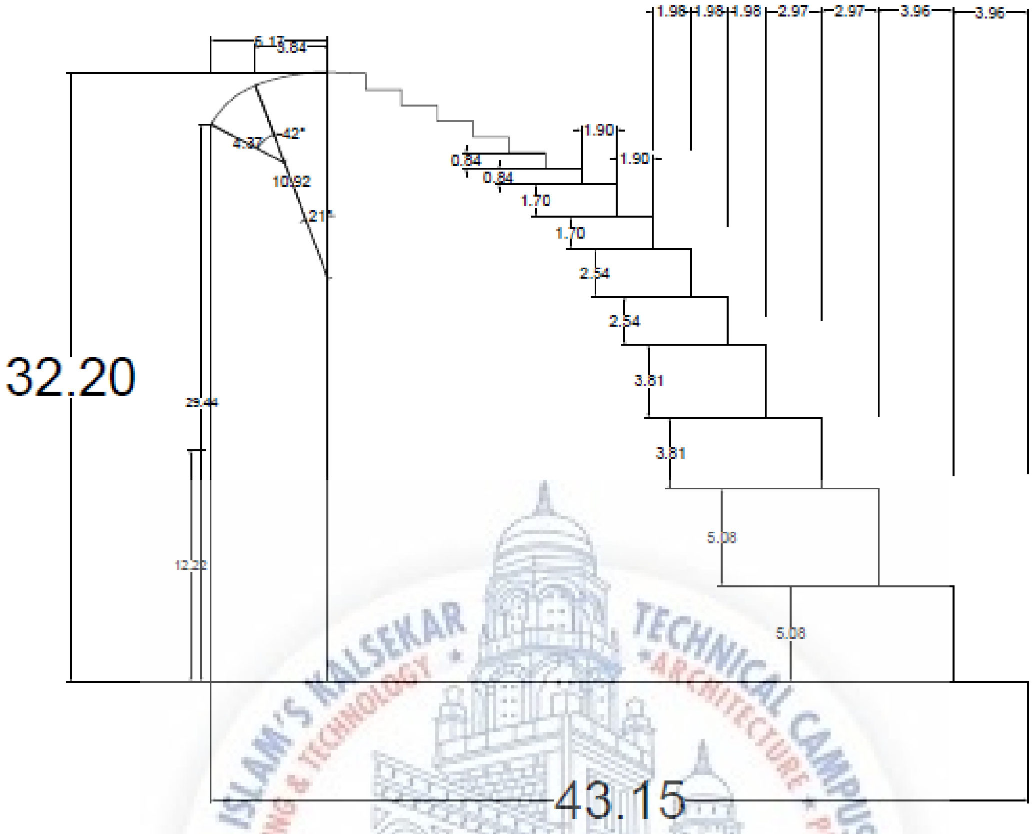


Figure 3.4: AutoCAD drawing of stepped Spillway

3.1.3 Proposed Spillway:

All the dimensions are same as that of stepped spillway which have been taken from the paper studied in the literature review. Fig 3.2 shows the dimension of the stepped spillway and ogee spillway in single drawing. So for changing it into our concept we provided a 3mm radius at each step nosing. And above curve of ogee spillway before steps was also converted into steps of required geometric dimensions.

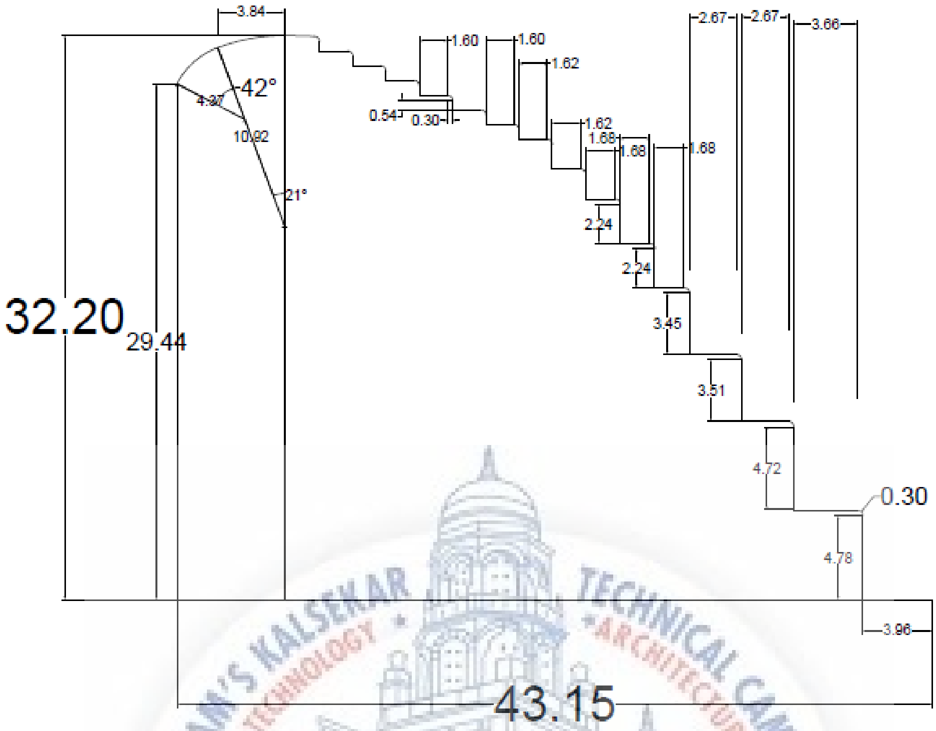


Figure 3.5: AutoCAD drawing of Proposed Spillway

3.2 Materials:

Whole model was made by plywood with same scale kept on AutoCAD drawing. Corners were joined by nails. As plywood is not water proof material. We provided with a water proof coating.

Figure 3.6: Models made of wood

Application of coating:

- Before applying coating all the joints (gaps) were filled up by the lime putty to give a uniform and smooth surface for coating.

-Firstly we applied the coating of red oxide primer. (Basically red oxide is an iron oxide (Fe_2O_3) and is used to adhere surfaces and to form a binding layer that is better prepared to receive the paint. Even it seals the corners and is preventing mold i.e. it makes somewhat waterproof.)

Primer requires 6hrs to get cured but after cured it is not ready for an overcoat. So after keeping it for 24hrs another coat of primer is applied.

Figure 3.7: Models Coated with Red oxide

Now, after 24hrs white oil paint is applied. We had added white spirit to modify its viscosity and in some proportion varnish is also added to increase it glossiness. (Oil paint is used as it last forever on wood and is waterproofing coat.)

Another coating of oil paint is also applied after 24hrs.

-Model is ready for experimentation.

Figure 3.8: Ogee Spillway Model

Figure 3.9: Stepped Spillway Model

Figure 3.10: Proposed Spillway Model

3.3 Experimentation:

The experimental phase of this study consists of the test on the dimensional models of Ogee Spillway, Stepped Spillway and Proposed Spillway.

Our All Profile having same dimensions as Width 30.5cm, length 43.15cm and Height 31cm which was tested on Hydraulic Tilting Flume.

Pointer gauge scale was used to measure depth of water.
To study the variation in specific energy as a function of depth of flow for a given discharge in a Hydraulic Flume and also study the variation in coefficient of discharge.

Figure 3.11: Performing Experiments on Spillway

Procedure:

1) For testing of spillway we arrange the spillway profile in the flume by fixing it properly and by applying wax so that there is no leakage and to avoid any error during experimentation.

2) Then, we start the motor from which the water is supplied to the main tank and through pipes the water was carried from the main tank to the channels, than the water was flowed over the profile.

3) Constant discharge is maintained in the open channel by applying maximum pressure and was set with the help of manometer tube attached to the flume. Manometer readings were noted.

4.1) we find out the water depth at crest and bottom level of **ogee spillway** profile.

I) For Manometric Reading:

X_1 = 285 mm X_2 = 310 mm

Difference (x) = $X_2 - X_1$ = 25 mm

Readings:

At Crest Level = 0.199 m

At Water Level = 0.182 m

Difference (h) = 0.017 m

H = h × 12.6

= 0.017 × 12.6 = 0.315

II) For Manometric Reading:

X_1 = 275 mm X_2 = 325 mm

Difference (x) = $X_2 - X_1$ = 50 mm

Readings:

At Crest Level = 0.199 m

At Water Level = 0.177 m

Difference (h) = 0.022 m

H = h × 12.6

= 0.022 × 12.6 = 0.63

4.2) The readings for **Stepped Spillway** at every steps at bed level as well as at the surface of water level, for two different manometric readings.

Manometric reading X_1=275mm X_2=325mm, Difference=50mm				Manometric reading X_1=285mm X_2=310mm, Difference=25mm			
Step No.	At Bed Level	At Water Surface Level	Difference	Step No.	At Bed Level	At Water Surface Level	Difference
S16	0.197	0.174	0.023	S16	0.197	0.1776	0.0194
S15	0.207	0.1852	0.0218	S15	0.207	0.1928	0.0142
S14	0.215	0.1963	0.0187	S14	0.215	0.2044	0.0106
S13	0.223	0.208	0.015	S13	0.223	0.21	0.013
S12	0.2325	0.216	0.0165	S12	0.2325	0.221	0.0115
S11	0.2395	0.227	0.0125	S11	0.2395	0.229	0.0105
S10	0.2484	0.2335	0.0149	S10	0.2484	0.238	0.0104
S9	0.2577	0.244	0.0137	S9	0.2577	0.247	0.0107
S8	0.2737	0.2544	0.0193	S8	0.2737	0.2565	0.0172
S7	0.2914	0.267	0.0244	S7	0.2914	0.277	0.0144
S6	0.3157	0.2727	0.043	S6	0.3157	0.297	0.0187
S5	0.3415	0.3092	0.0323	S5	0.3415	0.313	0.0285
S4	0.379	0.339	0.04	S4	0.379	0.352	0.027
S3	0.4187	0.384	0.0347	S3	0.4187	0.399	0.0197
S2	0.47	0.436	0.034	S2	0.47	0.448	0.022
S1	0.5307	0.473	0.0577	S1	0.5307	0.459	0.0717

Table 3.2: Stepped Spillway Readings

4.2) The readings for **Proposed Spillway** at every steps at bed level as well as at the surface of water level, for two different manometric readings.

Manometric reading X_1=275mm X_2=325mm, Difference=50mm			
Step No.	At Bed Level	At Water Surface Level	Difference
S16	0.1955	0.1686	0.0269
S15	0.205	0.1887	0.0163
S14	0.2126	0.2	0.0126
S13	0.221	0.2097	0.0113
S12	0.23	0.2166	0.0134
S11	0.239	0.2243	0.0147
S10	0.247	0.237	0.01
S9	0.256	0.2437	0.0123
S8	0.2725	0.2543	0.0182
S7	0.29	0.2687	0.0213
S6	0.315	0.289	0.026
S5	0.3415	0.312	0.0295
S4	0.384	0.3463	0.0377
S3	0.418	0.4034	0.0146
S2	0.468	0.407	0.061
S1	0.53	0.4087	0.1213

Manometric reading X_1=285mm X_2=310mm, Difference=25mm			
Step No.	At Bed Level	At Water Surface Level	Difference
S16	0.197	0.1757	0.0213
S15	0.207	0.1888	0.0182
S14	0.215	0.202	0.013
S13	0.223	0.2104	0.0126
S12	0.2325	0.2186	0.0139
S11	0.2395	0.2285	0.011
S10	0.2484	0.2364	0.012
S9	0.2577	0.2467	0.011
S8	0.2737	0.256	0.0177
S7	0.2914	0.2772	0.0142
S6	0.3157	0.2978	0.0179
S5	0.3415	0.3217	0.0198
S4	0.379	0.3548	0.0242
S3	0.4187	0.4003	0.0184
S2	0.47	0.407	0.063
S1	0.5307	0.417	0.1137

Table 3.3: Proposed Spillway Readings

7) Calculate the specific energy using relationship, E = $\frac{V2}{2g} + h$

3.4.1) Calculation of Discharge Coefficient:

Ogee Spillway:

I) For Manometric Reading :

X_1 = 285 mm X_2 = 310 mm

$Q_{act} = K\sqrt{H} = 3.356\times10^{-3} \times\sqrt{0.315} = 1.8835\times10^{-3}$ m^3/s

$Q_{th} = \sqrt{2 \times g}\times L\times H^{3/2} = 4.2364\times10^{-3}$ m^3/s

$\mathbf{C_d = \frac{Qact}{Qth}}$

C_d = 0.4445

II) For Manometric Reading :

X_1 = 275 mm X_2 = 325 mm

$Q_{act} = K\sqrt{H} = 3.356\times10^{-3} \times\sqrt{0.63} = 2.66\times10^{-3}$ m^3/s

$Q_{th} = \sqrt{2 \times g}\times L\times H^{3/2} = 6.2364\times10^{-3}$ m^3/s

$\mathbf{C_d = \frac{Qact}{Qth}}$

C_d = 0.426

Stepped Spillway:

$$C_d = \frac{Qact}{Qth}$$

$$Q_{th} = \sqrt{Qact \times (1.7 \times B \times h^{\frac{3}{2}})}$$

$$Q_{act} = K\sqrt{H}$$

Step No.	Manometric Difference (m)	Diff. In Pressure head	At Bed Level	At Water Surface Level	Difference	Width	Theoretical Discharge	Actual Discharge	Coefficient of Discharge
S16	0.05	0.63	0.197	0.174	0.023	0.305	0.002194908	0.002663742	1.213600806
S15	0.05	0.63	0.207	0.1852	0.0218	0.305	0.002108448	0.002663742	1.263366518
S14	0.05	0.63	0.215	0.1963	0.0187	0.305	0.001879324	0.002663742	1.417393798
S13	0.05	0.63	0.223	0.208	0.015	0.305	0.001592902	0.002663742	1.672258025
S12	0.05	0.63	0.2325	0.216	0.0165	0.305	0.001710935	0.002663742	1.556893032
S11	0.05	0.63	0.2395	0.227	0.0125	0.305	0.001389322	0.002663742	1.917296252
S10	0.05	0.63	0.2484	0.2335	0.0149	0.305	0.00158493	0.002663742	1.680668389
S9	0.05	0.63	0.2577	0.244	0.0137	0.305	0.001488199	0.002663742	1.789910467
S8	0.05	0.63	0.2737	0.2544	0.0193	0.305	0.00192437	0.002663742	1.384215638
S7	0.05	0.63	0.2914	0.267	0.0244	0.305	0.002294367	0.002663742	1.160992364
S6	0.05	0.63	0.3157	0.2727	0.043	0.305	0.003509311	0.002663742	0.759050012
S5	0.05	0.63	0.3415	0.3092	0.0323	0.305	0.002831538	0.002663742	0.9407405
S4	0.05	0.63	0.379	0.339	0.04	0.305	0.003324034	0.002663742	0.8013583
S3	0.05	0.63	0.4187	0.384	0.0347	0.305	0.002987911	0.002663742	0.891506732
S2	0.05	0.63	0.47	0.436	0.034	0.305	0.00294259	0.002663742	0.905237518
S1	0.05	0.63	0.5307	0.473	0.0577	0.305	0.004375245	0.002663742	0.608821349
								Total =	1.247706856

Table 3.4: Stepped Spillway Cd Calculation

Step No.	Manometric Difference	Diff. in Pressure Head	At Bed Level	At Water Surface Level	Difference	Width	Theoretical Discharge	Actual Discharge	Coefficient of Discharge
S16	0.025	0.315	0.197	0.1776	0.0194	0.305	0.00162448	0.0018835	1.15947913
S15	0.025	0.315	0.207	0.1928	0.0142	0.305	0.00128552	0.0018835	1.46520359
S14	0.025	0.315	0.215	0.2044	0.0106	0.305	0.00103238	0.0018835	1.82446205
S13	0.025	0.315	0.223	0.21	0.013	0.305	0.00120315	0.0018835	1.56551315
S12	0.025	0.315	0.2325	0.221	0.0115	0.305	0.00109745	0.0018835	1.71629719
S11	0.025	0.315	0.2395	0.229	0.0105	0.305	0.00102573	0.0018355	1.83747473
S10	0.025	0.315	0.2484	0.238	0.0104	0.305	0.00107743	0.0018355	1.80713657
S9	0.025	0.315	0.2577	0.247	0.0107	0.305	0.00103683	0.0018355	1.81165771
S8	0.025	0.315	0.2737	0.2565	0.0172	0.305	0.00184258	0.0088355	1.26018341
S7	0.025	0.315	0.2914	0.277	0.0144	0.305	0.00129907	0.0018355	1.49914407
S6	0.025	0.315	0.3157	0.297	0.0187	0.305	0.00150317	0.0018835	1.19188136
S5	0.025	0.315	0.3415	0.313	0.0285	0.305	0.00216768	0.0018835	0.86892159
S4	0.025	0.315	0.379	0.352	0.027	0.305	0.00208154	0.0018835	0.90488087
S3	0.025	0.315	0.4187	0.399	0.0197	0.305	0.00164328	0.0018835	1.14621098
S2	0.025	0.315	0.47	0.448	0.022	0.305	0.00178517	0.0018835	1.05510874
S1	0.025	0.315	0.5307	0.459	0.0717	0.305	0.00433014	0.0018835	0.43498558
								Total =	1.34698259

Table 3.5: Stepped Spillway Cd Calculation

Proposed Spillway:

$$C_d = \frac{Qact}{Qth}$$

$$Q_{th} = \sqrt{Qact \times (1.7 \times B \times h^{\frac{3}{2}})}$$

$$Q_{act} = K\sqrt{H}$$

Step No.	Manometric Difference	Diff. in Pressure head	At Bed Level	At Water Surface Level	Difference	Width	Theoretical Discharge	Actual Discharge	Coefficient of Discharge
S16	0.05	0.63	0.1955	0.1686	0.0269	0.305	0.002468509	0.002663742	1.07908964
S15	0.05	0.63	0.205	0.1887	0.0163	0.305	0.001695357	0.002663742	1.571198406
S14	0.05	0.63	0.2126	0.2	0.0126	0.305	0.00139765	0.002663742	1.905872415
S13	0.05	0.63	0.221	0.2097	0.0113	0.305	0.00128804	0.002663742	2.068058885
S12	0.05	0.63	0.23	0.2166	0.0134	0.305	0.00146369	0.002663742	1.819881601
S11	0.05	0.63	0.239	0.2243	0.0147	0.305	0.001568948	0.002663742	1.697789065
S10	0.05	0.63	0.247	0.237	0.01	0.305	0.001175224	0.002663742	2.266583553
S9	0.05	0.63	0.256	0.2437	0.0123	0.305	0.001372617	0.002663742	1.940630709
S8	0.05	0.63	0.2725	0.2543	0.0182	0.305	0.00184151	0.002663742	1.446499181
S7	0.05	0.63	0.29	0.2687	0.0213	0.305	0.002072074	0.002663742	1.285544251
S6	0.05	0.63	0.315	0.289	0.026	0.305	0.002406304	0.002663742	1.106984964
S5	0.05	0.63	0.3415	0.312	0.0295	0.305	0.002645374	0.002663742	1.006943774
S4	0.05	0.63	0.384	0.3463	0.0377	0.305	0.003179629	0.002663742	0.837752477
S3	0.05	0.63	0.418	0.4034	0.0146	0.305	0.001560936	0.002663742	1.706503138
S2	0.05	0.63	0.468	0.407	0.061	0.305	0.004561607	0.002663742	0.583948244
S1	0.05	0.63	0.53	0.4087	0.1213	0.305	0.007638641	0.002663742	0.348719419
									1.416999983

Table 3.6: Proposed Spillway Cd Calculation

Step No.	Manometric Difference	Diff. in Pressure Head	At Bed Level	At Water Surface Level	Difference	Width	Theoretical Discharge	Actual Discharge	Coefficient of Discharge
S16	0.025	0.315	0.197	0.1757	0.0213	0.305	0.001742399	0.00188355	1.081009552
S15	0.025	0.315	0.207	0.1888	0.0182	0.305	0.001548519	0.00188355	1.216355976
S14	0.025	0.315	0.215	0.202	0.013	0.305	0.001203152	0.00188355	1.56551315
S13	0.025	0.315	0.223	0.2104	0.0126	0.305	0.001175279	0.00188355	1.602641282
S12	0.025	0.315	0.2325	0.2186	0.0139	0.305	0.001265098	0.00188355	1.488857503
S11	0.025	0.315	0.2395	0.2285	0.011	0.305	0.001061469	0.00188355	1.774474327
S10	0.025	0.315	0.2484	0.2364	0.012	0.305	0.00113305	0.00188355	1.662372323
S9	0.025	0.315	0.2577	0.2467	0.011	0.305	0.001061469	0.00188355	1.774474327
S8	0.025	0.315	0.2737	0.256	0.0177	0.305	0.001516502	0.00188355	1.242036287
S7	0.025	0.315	0.2914	0.2772	0.0142	0.305	0.001285521	0.00188355	1.465203596
S6	0.025	0.315	0.3157	0.2978	0.0179	0.305	0.001529335	0.00188355	1.231613557
S5	0.025	0.315	0.3415	0.3217	0.0198	0.305	0.001649536	0.00188355	1.141866525
S4	0.025	0.315	0.379	0.3548	0.0242	0.305	0.001917452	0.00188355	0.982319374
S3	0.025	0.315	0.4187	0.4003	0.0184	0.305	0.001561264	0.00188355	1.206426496
S2	0.025	0.315	0.47	0.407	0.063	0.305	0.003929782	0.00188355	0.479301537
S1	0.025	0.315	0.5307	0.417	0.1137	0.305	0.006119041	0.00188355	0.30781791
									1.263892733

Table 3.7: Proposed Spillway Cd Calculations

3.4.2) Calculation of Specific Energy:

Calculate the specific energy using relationship, E = $\frac{V2}{2g} + h$

For Stepped Spillway:

Step No.	Manometric Difference (m)	Diff. In Pressure head	Area	Velocity	Specific Energy	Loss of Energy
S16	0.05	0.63	0.007015	0.312887847	0.027989745	
S15	0.05	0.63	0.006649	0.317107513	0.026925238	0.001064507
S14	0.05	0.63	0.0057035	0.329503668	0.024233775	0.002691463
S13	0.05	0.63	0.004575	0.348175205	0.021178694	0.003055081
S12	0.05	0.63	0.0050325	0.339977103	0.022391153	-0.00121246
S11	0.05	0.63	0.0038125	0.364412404	0.01926842	0.003122733
S10	0.05	0.63	0.0045445	0.348757927	0.021099393	-0.001830973
S9	0.05	0.63	0.0041785	0.356156203	0.020165201	0.000934192
S8	0.05	0.63	0.0058865	0.32691235	0.024747079	-0.004581878
S7	0.05	0.63	0.007442	0.308299768	0.029244483	-0.004497404
S6	0.05	0.63	0.013115	0.267579933	0.046649287	-0.017404805
S5	0.05	0.63	0.0098515	0.287422011	0.036510571	0.010138716
S4	0.05	0.63	0.0122	0.272461822	0.043783662	-0.00727309
S3	0.05	0.63	0.0105835	0.282317816	0.038762352	0.00502131
S2	0.05	0.63	0.01037	0.283759836	0.038103957	0.000658395
S1	0.05	0.63	0.0175985	0.248614641	0.060850318	-0.022746361
						-0.032860573

Table 3.8: Stepped Spillway Calculation of energy Loss

Step No.	Manometric Difference	Diff. in Pressure Head	Area	Velocity	Specific Energy	Loss of Energy
S16	0.025	0.315	0.005917	0.274544484	0.023241726	
S15	0.025	0.315	0.004331	0.296818571	0.01869038	0.004551346
S14	0.025	0.315	0.003233	0.319327771	0.015797259	0.002893121
S13	0.025	0.315	0.003965	0.303443136	0.017693055	-0.001895796
S12	0.025	0.315	0.0035075	0.312887847	0.016489745	0.001203309
S11	0.025	0.315	0.0032025	0.320085375	0.015721949	0.000767796
S10	0.025	0.315	0.003172	0.320852052	0.015646995	7.49545E-05
S9	0.025	0.315	0.0032635	0.318579049	0.015872916	-0.000225921
S8	0.025	0.315	0.005246	0.282931332	0.021280027	-0.005407112
S7	0.025	0.315	0.004392	0.295782539	0.018859088	0.002420939
S6	0.025	0.315	0.0057035	0.277078453	0.02261297	-0.003753882
S5	0.025	0.315	0.0086925	0.249374442	0.031669603	-0.009056633
S4	0.025	0.315	0.008235	0.252768071	0.030256458	0.001413145
S3	0.025	0.315	0.0060085	0.273493242	0.023512363	0.006744095
S2	0.025	0.315	0.00671	0.26604646	0.02560758	-0.002095217
S1	0.025	0.315	0.0218685	0.198008287	0.073698332	-0.048090752
						-0.050456606

Table 3.9: Stepped Spillway Calculation of energy Loss

For Proposed Spillway:

Step No.	Manometric Difference	Diff. in Pressure head	Area	Velocity	Specific Energy	Loss of Energy
S16	0.05	0.63	0.0082045	0.300872562	0.031513879	
S15	0.05	0.63	0.0049715	0.341015213	0.022227185	0.009286693
S14	0.05	0.63	0.003843	0.363687202	0.019341508	0.002885678
S13	0.05	0.63	0.0034465	0.373724047	0.018418739	0.000922768
S12	0.05	0.63	0.004087	0.358133094	0.019937172	-0.001518433
S11	0.05	0.63	0.0044835	0.349938174	0.020941423	-0.001004251
S10	0.05	0.63	0.00305	0.385319204	0.017567324	0.0033741
S9	0.05	0.63	0.0037515	0.365884807	0.019123226	-0.001555902
S8	0.05	0.63	0.005551	0.331743794	0.023809273	-0.004686048
S7	0.05	0.63	0.0064965	0.318952311	0.026485045	-0.002675771
S6	0.05	0.63	0.00793	0.303443136	0.030693055	-0.00420801
S5	0.05	0.63	0.0089975	0.294012064	0.033905866	-0.003212811
S4	0.05	0.63	0.0114985	0.276525583	0.04159737	-0.007691504
S3	0.05	0.63	0.004453	0.35053585	0.020862762	0.020734608
S2	0.05	0.63	0.018605	0.245181781	0.06406392	-0.043201158
S1	0.05	0.63	0.0369965	0.206469285	0.123472761	-0.059408841
						-0.091958882

Table 3.10: Proposed Spillway Calculation of energy Loss

Step No.	Manometric Difference	Diff. in Pressure Head	Area	Velocity	Specific Energy	Loss of Energy
S16	0.025	0.315	0.0064965	0.268205855	0.02496638	
S15	0.025	0.315	0.005551	0.278962167	0.022166355	0.002800025
S14	0.025	0.315	0.003965	0.303443136	0.017693055	0.0044733
S13	0.025	0.315	0.003843	0.305823264	0.017366966	0.000326089
S12	0.025	0.315	0.0042395	0.298407308	0.018438579	-0.001071613
S11	0.025	0.315	0.003355	0.316384344	0.016101889	0.002336691
S10	0.025	0.315	0.00366	0.309576399	0.016884686	-0.000782798
S9	0.025	0.315	0.003355	0.316384344	0.016101889	0.000782798
S8	0.025	0.315	0.0053985	0.280911707	0.021721987	-0.005620099
S7	0.025	0.315	0.004331	0.296818571	0.01869038	0.003031607
S6	0.025	0.315	0.0054595	0.280123728	0.021899455	-0.003209074
S5	0.025	0.315	0.006039	0.273147266	0.023602723	-0.001703268
S4	0.025	0.315	0.007381	0.259782154	0.027639693	-0.004036969
S3	0.025	0.315	0.005612	0.278201008	0.02234474	0.005294952
S2	0.025	0.315	0.019215	0.204516343	0.065131852	-0.042787112
S1	0.025	0.315	0.0346785	0.176450559	0.115286891	-0.050155039
						-0.090320511

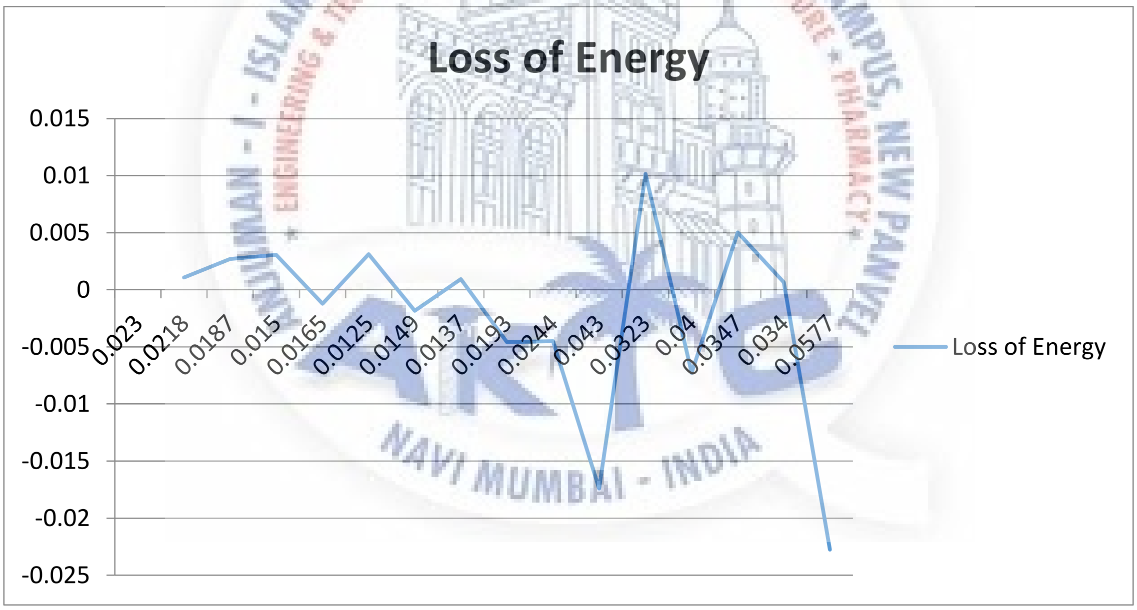
Table 3.11: Proposed Spillway Calculation of energy Loss

Chapter 4

Result and Discussions

4.1. Stepped Spillway with Manometric Difference =0.05 m:

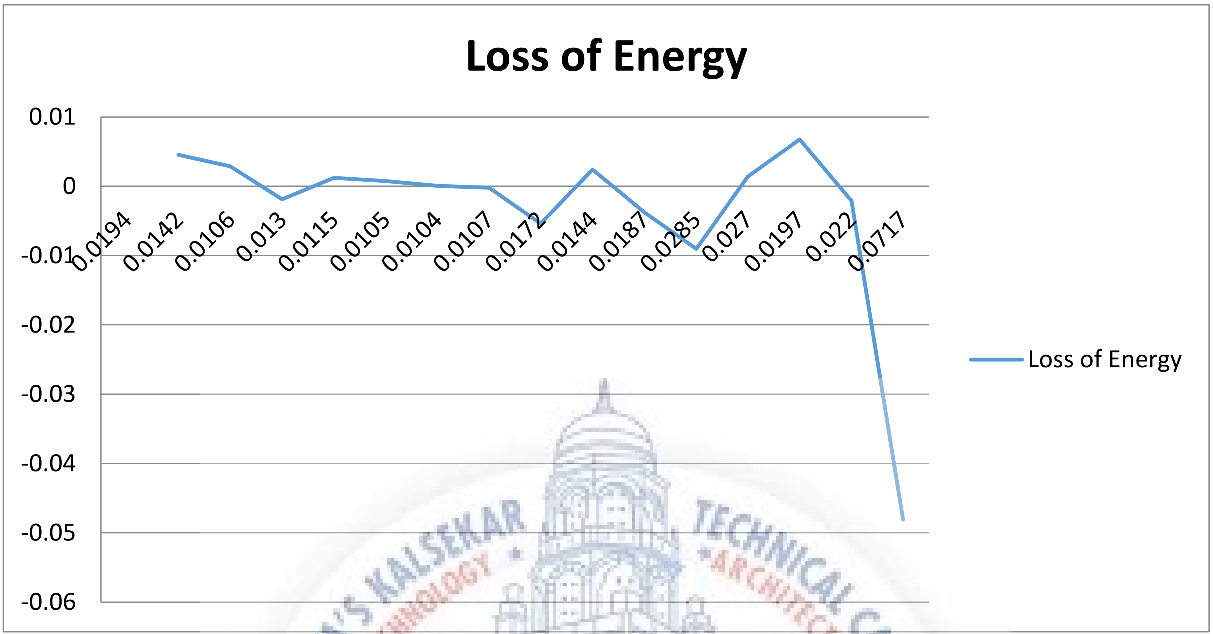
Loss of energy we were getting at the toe of the Stepped Spillway were -0.02274



Graph 4.1: Loss of energy for Stepped Spillway with Manometric Difference =0.05 m

4.2. Stepped Spillway with Manometric Difference =0.025 m:

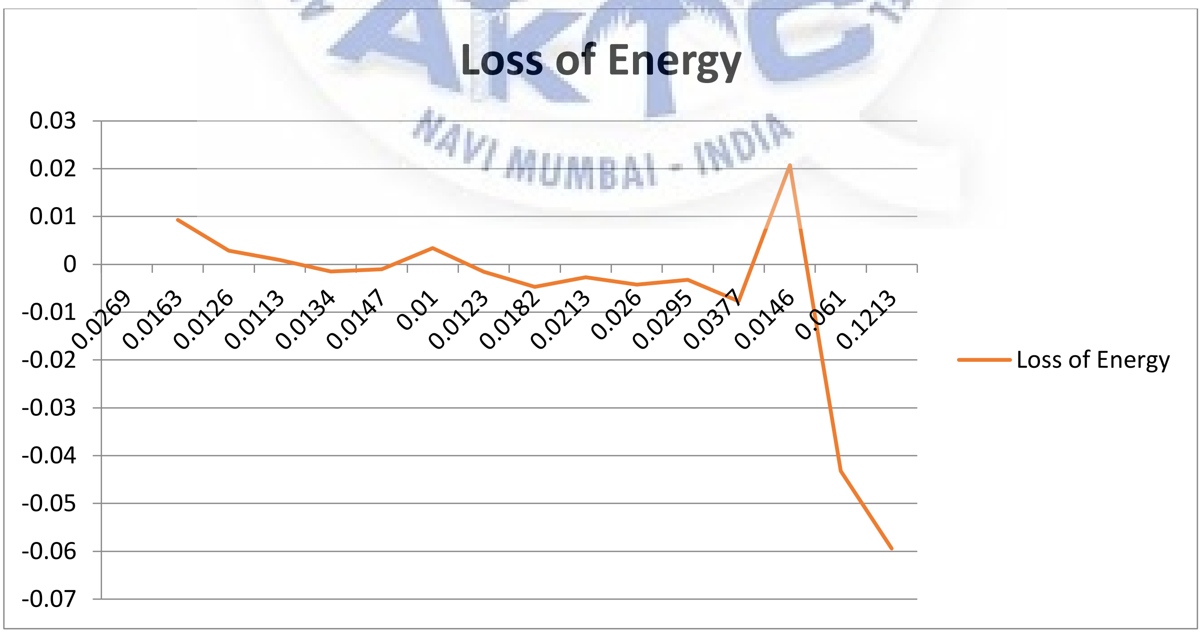
Loss of energy we were getting at the toe of the Stepped Spillway were -0.04809



Graph 4.2: Loss of energy for Stepped Spillway with Manometric Difference =0.025 m

4.3. Proposed Spillway with Manometric Difference =0.05 m:

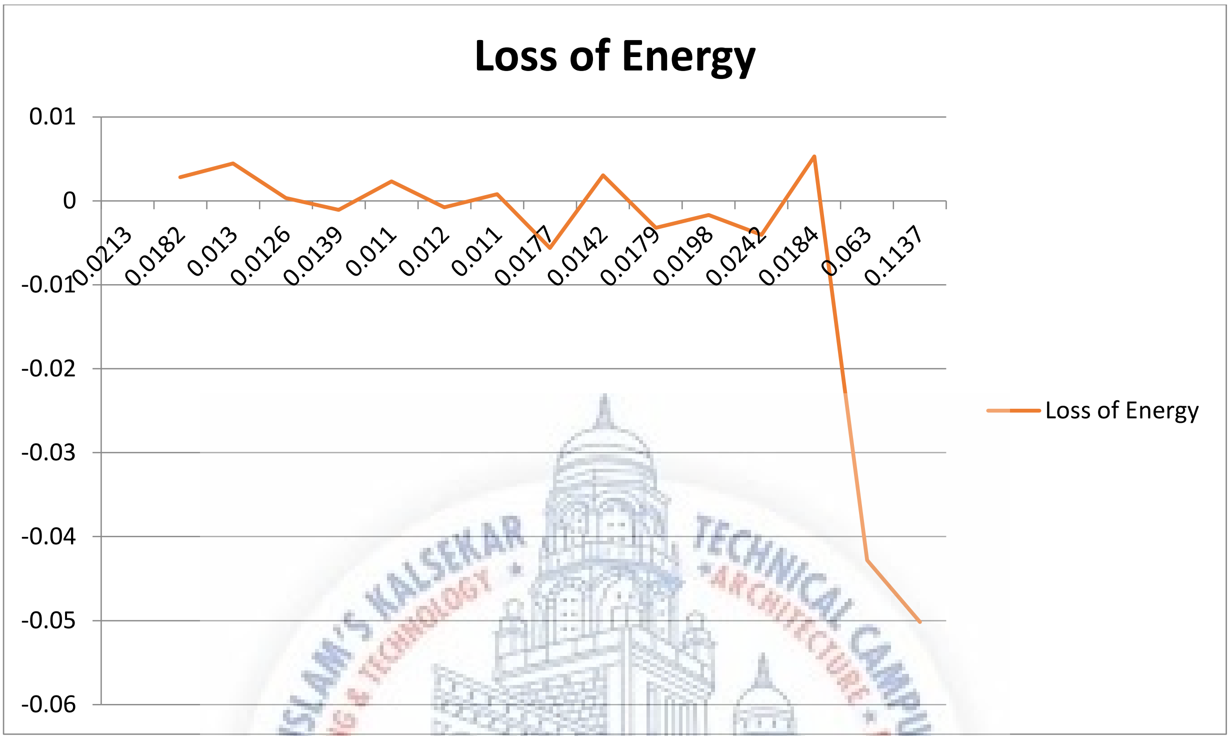
Loss of energy we were getting at the toe of the Proposed Spillway were -0.05940



Graph 4.3: Loss of energy for Proposed Spillway with Manometric Difference =0.05 m

4.4. Proposed Spillway with Manometric Difference =0.025 m:

Loss of energy we were getting at the toe of the Proposed Spillway were -0.050155



Graph 4.4: Loss of energy for Proposed Spillway with Manometric Difference =0.025 m

4.5. Coefficient of Discharge:

Ogee Spillways Cd values:

I) For Manometric Reading:

X_1 = 285 mm X_2 = 310 mm

C_d = 0.4445

II) For Manometric Reading:

X_1 = 275 mm X_2 = 325 mm

C_d = 0.426

Stepped Spillway (SS) and Proposed Spillway (PS) Cd values:

Step No.	SS Diff= 0.05	PS Diff=0.05	SS Diff=0.025	PS Diff=0.025
S16	1.213601	1.07909	1.159479	1.08101
S15	1.263367	1.571198	1.465204	1.216356
S14	1.417394	1.905872	1.824462	1.565513
S13	1.672258	2.068059	1.565513	1.602641
S12	1.556893	1.819882	1.716291	1.488858
S11	1.917296	1.697789	1.837478	1.774474
S10	1.680668	2.266584	1.850714	1.662372
S9	1.78991	1.940631	1.811659	1.774474
S8	1.384216	1.446499	1.269018	1.242036
S7	1.160992	1.285544	1.449914	1.465204
S6	0.75905	1.106985	1.191881	1.231614
S5	0.940741	1.006944	0.868922	1.141867
S4	0.801358	0.837752	0.904881	0.982319
S3	0.891507	1.706503	1.146211	1.206426
S2	0.905238	0.583948	1.055109	0.479302
S1	0.608821	0.348719	0.434986	0.307818
Average	1.247707	1.417	1.346983	1.263893

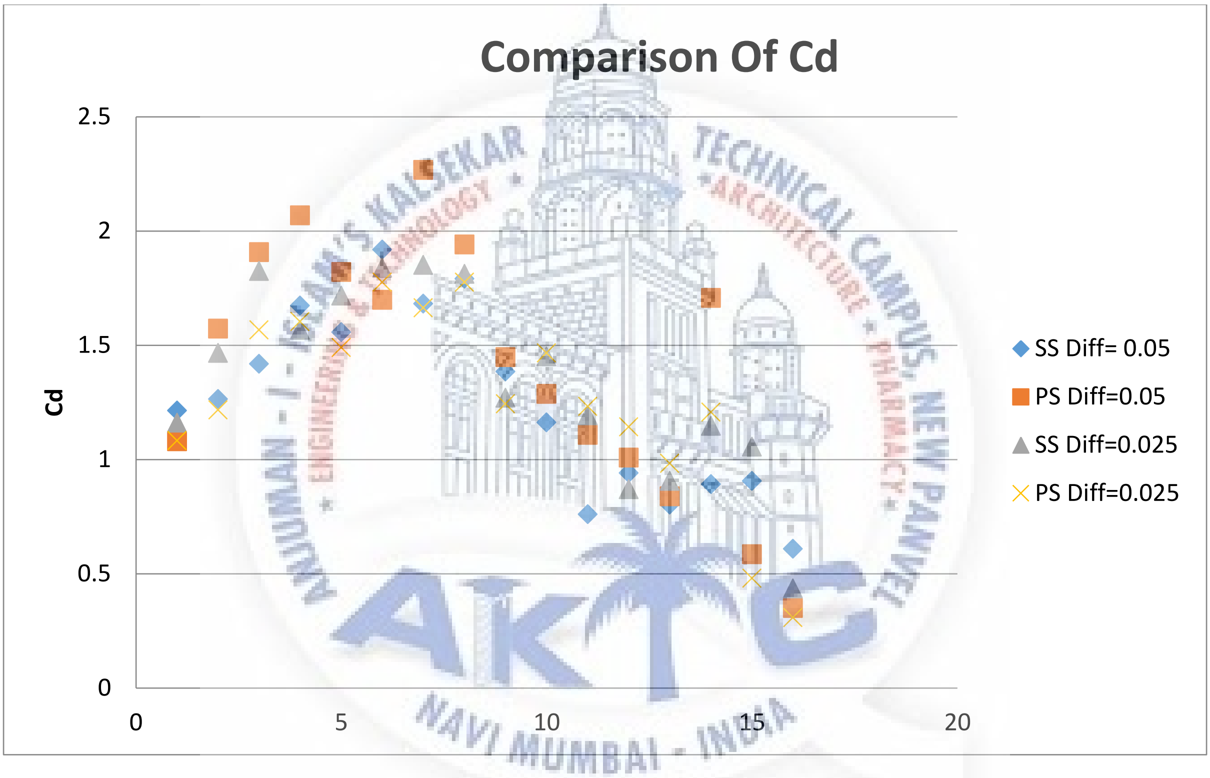
Table 4.1: Comparison between Four different Cd values

Average Coefficient of Discharge Calculated for Stepped Spillway with Manometric difference of 0.05m is 1.2477.

Average Coefficient of Discharge Calculated for Stepped Spillway with Manometric difference of 0.025m is 1.3469.

Average Coefficient of Discharge Calculated for Proposed Spillway with Manometric difference of 0.05m is 1.4169.

Average Coefficient of Discharge Calculated for Proposed Spillway with Manometric difference of 0.025m is 1.2638.



Graph 4.5: Comparison of Cd at different Steps

Chapter 5

Conclusion

5.1 Conclusion:

1. Loss of energy was calculated for all the four Spillway Readings at the toe as the minimum from above readings must be considered.
2. We require lesser energy at the bottom most part of our dam and we are achieving that by our proposed spillway so that our motto is achieved by giving curve to the nosing of the stepped spillway.
3. Minimum value of loss of energy was found in Proposed Spillway i.e. **-0.05015** and maximum value of loss of energy was found in Stepped Spillway i.e. **-0.02274**. As the value was minimum in the Proposed Spillway, it is better than Stepped Spillway.
4. Minimum average Cd obtained from the result was **0.42** of Ogee Spillway and maximum average Cd obtained from the result was **1.4169.**

5.2 Future Scope:

1. As in this current model we had designed the stepped and proposed spillway geometrically which is a trial and error method. So one can change the step sizes i.e. increasing or reducing riser and tread size. Even by increasing the diameter of curve portion at nosing in proposed spillway.

2. We can also apply the principle of draft tube i.e. to reduce the velocity of the discharged water to minimize the loss of specific energy at the outlet.

3. This we can achieve by reducing the area at the crest level and increasing the area simultaneously at each step till bed level. If the energy losses in this is so what similar to the losses we had achieved upper expectations we can conclude that this new design can be used for economization.

4. We can also perform the test of air entertainment to conclude that the proposed spillway creates less or more eddies compared to that of stepped spillway. If it comes less than stepped, we can say there is less chances of erosion in proposed spillway.

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