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Research Article

A Case Study: Innovating Energy Dissipation In Ogee Spillways With Modified Ski Jump Designs

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ARTICLE INFO

ABSTRACT

The consumer's decision to make online purchases is intricate and refined, with trust playing a significant role and exerting a powerful influence on their buying choices. The future of electronic commerce (e-commerce) hinges primarily on trust. There are a number of factors that, according to literature, help buyers and sellers build trust while doing business online. However, only a handful of characteristics, such perceived security and privacy, are really the focus of any given study. Incorporating all the features mentioned in the literature into a unified model is the goal of this research. Following a comprehensive literature review, this study used qualitative methods to inquire into the elements that help build trust in online environments. The popularity of e-commerce is increasing globally due to the convenience it offers to both online retailers and customers. However, with the increasing prevalence of e- commerce, several major issues arise, including privacy concerns, customer dissatisfaction, inefficient deliveries, and most importantly, trust issues. The researcher conducted a qualitative study focused on the perceived trustworthiness of e-commerce. The aim was to determine if the findings align with previous studies and to offer online users with information that can assist them in making informed decisions when buying or selling things online. According to empirical statistics, clients have a positive attitude towards online purchases, albeit they are less confident when compared to offline transactions. Based on the data that is available, it is clear that trust is important to customers.

Keywords: *Energy Dissipation, Ogee spillway, Ski type energy dissipator, Maithon dam*

1. Introduction

Large floods with enormous inflows into reservoirs have been occurring more frequently in recent years. Dam spillways must be built to release floodwaters that exceed the capacity of the reservoir. The proper design of spillways is still critical to prevent dam overflow and potential failure. The spillway must be able to handle strong flows without risking the dam's safety. When a big design flow is required, a particular spillway must be developed to accommodate the larger flow. Because of the tremendous flow over the spillway, the design must be quite complex and must contend with cavitation and high flow kinetic energy issues.
The ski-jump bucket energy dissipator can send the jet far enough away from the bucket lip to keep it safe. Compared to other energy dissipators, it has some cost advantages. When geology and topographic conditions allow, a trajectory bucket kind of energy dissipator is the most cost-effective option at sites with geologically hard strata.
A spillway is a structure that allows water to flow from a dam into the downstream side of the dam in a controlled manner. Surplus floodwater is channeled into spillways. Spillways are required for all types of dams and can be found within the body of the dam, at one end of the dam, or altogether separate from the dam.
A dam's spillways serve as a safety feature. Many dam collapses have been documented due to insufficient spillway capacity or inappropriate spillway design, particularly for earthen and rockfill dams, which are likely to be destroyed if overtopped, as opposed to concrete dams, which may not fail with slight overtopping for a short length of time.

Energy dissipation devices dissipate the kinetic energy of surplus flood with the highest velocity of flow on the downstream side of the dam. The E.D. flow in a Ski-jump bucket is discharged in the form of a Trajectory away from the hydraulic system and into a plunge pool. A ski jump bucket is used as an E.D. for spillways when the tailwater depth is insufficient for the formation of the hydraulic jump and the river channel bed downstream consists of sound rock and can bear the impact of the high-velocity jet without severe scour. The floodwaters that travel over the spillway are raised away from the dam's toe and into the channel as a free release upturned jet, avoiding substantial scour downstream of the spillway. Within the bucket, there is very little E.D. save for shear along the bucket surface. The device is used to extend the distance between the structure and the point where a high-velocity jet collides with the channel bed, lowering the risk of excessive scour downstream of the spillway.

2. Literature Review

Dissipative devices dissipate excess flood kinetic energy providing equipment downstream of the dam for maximum energy dissipation of the water flow. It helps to achieve uniform water flow in the downstream stream. It minimizes damage downstream from erosion. The following study describes the method of releasing the amount of energy in the spillway. Many experiments have been carried out with hydraulic power radiators and the results show that an energy dissipation ratio of 0% to 70% has been achieved.
The downstream end of an ogee spillway's terminal structure is critical for dissipating specific energy efficiency and properly releasing floodwater. The tremendous kinetic energy of the water released causes scouring of the channel bed at the toe portion of the spillway. To lessen the scouring action, it is necessary to reduce the intensity of kinetic energy. Jian-Hua et al. [4] proposed a theoretical method for predicting the trajectory of ski jumps, which was taken into consideration and adjusted. The current method is based on parameter analysis of the effects of take-off speed and angle. The results revealed that take-off velocity has a considerably bigger impact on the site of an impact than take-off angle. Sinpiger and Bhalerao [3] have computed throw distances by using a new equation compared with the result obtained from model studies. He observed that lip angle 350 and a chute slope of 1:7.734 give a good performance of ski jump type bucket. On a stepped chute, Qian et al. [9] tried to improve energy dissipation and unit discharge. They introduced a ski-jump-step energy dissipator, which consists of two stages, each of which contains a ski-jump, a prestep, an aeration basin, and a stepped chute. The results reveal that the stepped chute's unit discharge limit increases to 118 m2 / s, while the energy dissipation increases to 75.8%. Pfister et al. [8] used physical models to conduct their research. The conclusions reached here are helpful in the construction of ski jumps. Apart from its air properties, the jet impact location onto the plunge pool surface may be determined at this point. The latter helps determine the stability of the plunge pool in terms of scouring. Additional parameters for ski jump design include maximal dynamic bottom pressures and bucket choking. Mujumdar et al. [10] used a 1:100-scale ski jump energy dissipator model to investigate the application of BIS 7365(1985) [2], design principles, finding that energy dissipation ranged from 26% to 54.44% due to air intake and impact. Jill Lucas et al. [6] used a deflector with a simple shape that deflects the jet underwater and displays flight path parameters with characteristic movements in drift situations. The standard beam deflection in the design situation is the proposed angle of $20°\ to\ 25°$. Large deflections are best created to control side erosion but the order of the liquid that penetrates is much less than 3 and is independent of the layout, establishing a situation close to the impact of the drift. The relative top of the baffle increases the deflection of the beam. Roman Juon et al. [7] focuses on the use of ski jumping excavators. Tests were conducted to discover deflectors with simple shapes, floor load distribution, and reduced and tip ballistic features. The effect shows that the shape of the deflector affects the shape of the beam and the power consumption.

3. Experimental Setup and Methodology

A trajectory bucket-type E.D. was designed and constructed into a hydraulic model of an ogee spillway. In the fluid mechanics lab, the hydraulic model research was conducted. The hydraulic model will be set in a hydraulic flume. The laboratory created a controlled environment in which no outside variables, such as the weather, could have an impact on the tests or data obtained. The hydraulic pump was fed water from the hydraulic flume's input, allowing it to maintain a continuous level of water behind the spillway model while allowing water to overflow past the radial gate's crest. As part of a hydraulic model of an ogee spillway, a trajectory bucket type E.D. was built and manufactured.

The pumping water storage tank is 1.5m x 0.8m x 1.2m in size. A centrifugal pump was used to pump water from the storage tank to the hydraulic flume through conduit tubing. A 1.572 HP pump with a 2900 rpm speed and a 45 percent overall efficiency and maximum discharge was used. A valve was fitted before the water comes the hydraulic flume to control the flow of water or discharge. The water flow is controlled by the valve.

Initially, try out different discharges with a traditional ski bucket. After setting the full discharge, rulers were used to measuring the depth of the water flow at the bucket's lip and in the plunge pool. The trajectory's maximum and lowest distances from the bucket's lip, as well as its maximum height, were computed. For more precise measurements, it was verified that the water flow over the spillway model remained consistent and did not vary greatly. Pre- and post-jump depths were measured with a pointer gauge for each experiment, and jump lengths were measured with a scale calibrated on the channel's sidewall.

Table 5 summarizes the findings. The ratio of a non-dimensionless functional group of jump characteristics to the Froude number is graphically displayed, and their behavior at different velocities is investigated.

4. Case Study: Maithon Dam

The Maithon Dam Project is located in the district of Dhanbad, Jharkhand, on the river Barakar, a tributary of the river Damodar. The Damodar River is a tributary of the Ganga River. On the River Barakar, the Maithon Dam is located at latitude 23°4713.06 north and longitude 86°4901.44 east. The town of Maithon is located directly downstream of the dam. A catchment area of 6391.74 km² has been estimated. It stretches from latitude 23°46.34.12 N to longitude 85°0916.26 E, and from longitude 86°5319.20 E to latitude 24°3209.80 N. The dam stands 56.08 meters above the lowest river bed level and spans 4426.76 meters, with a 4064.35-meter earthen embankment and a 362.41-meter concrete overflow section. The reservoir holds 1,093.54 mm³ of gross storage and 441.64 mm³ of live storage. Between 1951 and 1957, the project was put together. The spillway was initially built to pass a maximum discharge of 13,592 m³/sec via 12 bays with gates 12.19 m wide and 12.50 m high gates over an Ogee profile.

4.1. Technical Details of the Dam

Table 4.1 Technical Details of the Maithon Dam
(Source: Flood Estimation report by Central water Commission, 2017) [4]

Description	**Value**
Gross storage capacity	1093.54 mm³
Full reservoir level	152.40 m
Maximum Water Level	150.88 m
Minimum Draw Down Level	132.59 m
Dead Storage Level	132.59 m
Dam Top Level	156.06
Lowest foundation level	99.96 m
Lowest river bed level	103.63 m
Crest level	140.21 m
Height above deepest foundation level	56.08 m
Length of the dam at the top	4426.76 m
Width of Dam at Top	6.71m
Maximum area of water spread	99.55 Km²
Spillway Type	Ogee
Type of Gates	Radial
Size	12.5 m (Ht) × 12.19 m (W)
No. of Bays	12 nos.
Total Spillway Capacity	13592 m³/s

4.2. Design of Ogee Spillway and Ski-jump Bucket Energy dissipator

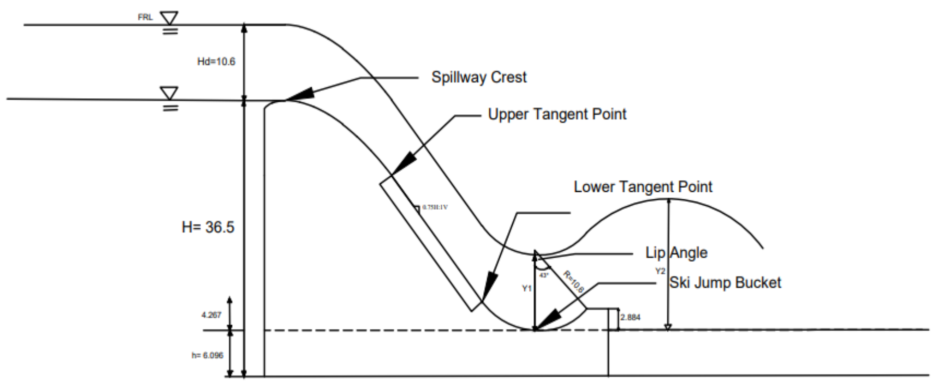

Figure 4.1. Profile of Ogee Spillway and Ski type energy dissipator

4.3. Design of Ogee Spillway: The Ogee spillway is designed as per BIS 6934-1948 [1] with salient features of Maithon Dam, Dhanbad (Jharkhand, India).
He = 10.43 m

H/He = 4.55 > 1.33 .... High flow Spillway

$He + H/He$ = 14.96 > 1.7 ....Cd is not affected by Tailwater conditions and the spillway remains a high Spillway.

Effective Length Of spillway: Assume the U/S face of the dam and spillway is proposed to be kept vertical. Assuming 90 degree cut water nose piers and rounded abutments.

Le = 178.8 m
H_d = 10.6 m

Downstream Profile

$Y_i = (X_i^{1.85})/14.874$

Upstream profile: The U/S profile as per the US Army corps

X_i = -2.859m

Y_i = [0.724 (X+ 0.27H_d) ^1.85]/ [H_d] ^0.85 + 0.126 H_d -0.4315 [H_d] ^0.375 [X+0.27H_d] ^0.675
Reserve curve at toe with radius(R) = 12.195 m

A= 0.175 H_d = 1.8543 m

B= 0.282 H_d = 2.9881 m

r_1 = 0.5 H_d = 5.298 m

r_2 = 0.2 H_d = 2.119 m

4.4. Design of Ski-Jump Bucket type Energy dissipator:
The Ski-Jump Bucket is designed as per BIS 7365-2010 [2] with salient features of Maithon Dam, Dhanbad (Jharkhand, India).

Bucket Radius R= 0.6- 0.8 √ (H.H5)

V_1 = 30.8 m/s

V = 27.26 m/s

Y_1 = 2.775 m

R = 10.62 m

Throw length

X/ Hv =sin² Ø + 2cos Ø √ (sin2 Ø + y/Hv)

X = 75.689 m

The vertical distance of throw above the lip

a= Va² sin² Ø/2g= 17.613 m

Scour at the point of impact ds = m (q H4) $^{0.5}$

ds = 33.45 m

Critical Depth (Y_c) = 8.356 m

Sequent Depth (Y_2) = 19.21 m

Froude No. (Fr_1) = 5.9 >1
Hence, Steady jump flow is shooting on the upstream side

E_1 = 51.09 J

E_2 = 20.00 J

Therefore,
Energy Loss (E.D.) = 60.18%

5. Results and Discussions

Experimental investigation involves a laboratory investigation controlled, and measured to gather different energy dissipation and specific energy relationship. Experiments were carried out for a variety of approach flow conditions. The approach flow condition was adjusted, and it was discovered that as the discharge was reduced, the depth of flow decreased.

Table 5.1. Alternative Design I at ∅ = 30^0

q (m^2/s/m)	H_d (m)	∅	Y_1 (m)	Y_2 (m)	Yt (m)	Yc (m)	X (m)	a (m)	ds (m)	R (m)	Fr_1	E_1	E.D. (%)
20	4.3		0.77	10.89	10.1	3.44	65.68	9.47	17.2	8.07	10.7	42.9	75.79
33	6.05		1.22	13.02	11.8	4.83	65.68	9.47	22.2	9.57	8.48	45.2	70.45
47	7.56	30°	1.71	15.29	13.6	6.05	65.68	9.47	26.3	10.70	7.28	47.2	66.47
60	8.94		2.2	17.22	15.1	7.15	65.68	9.47	29.8	11.64	6.52	49.1	63.59
76	10.44		2.77	19.21	16.4	8.36	65.68	9.47	33.4	12.57	5.9	51.1	60.18

Table 5.2 Alternative Design II at ∅ = 35^0

q (m^2/s/m)	H_d (m)	∅	Y_1 (m)	Y_2 (m)	Yt (m)	Yc (m)	X (m)	a (m)	ds (m)	R (m)	Fr_1	E_1	E.D. (%)
20	4.3		0.77	10.89	10.1	3.44	71.33	12.46	17.2	8.07	10.7	42.9	75.79
33	6.05		1.22	13.02	11.8	4.83	71.33	12.46	22.2	9.57	8.48	45.2	70.45
47	7.56	35°	1.71	15.29	13.6	6.05	71.33	12.46	26.3	10.70	7.28	47.2	66.47
60	8.94		2.2	17.22	15.1	7.15	71.33	12.46	29.8	11.64	6.52	49.1	63.59
76	10.44		2.77	19.21	16.4	8.36	71.33	12.46	33.4	12.57	5.9	51.1	60.18

Table 5.3. Alternative Design III at ∅ = 40^0

q (m^2/s/m)	H_d (m)	∅	Y_1 (m)	Y_2 (m)	Yt (m)	Yc (m)	X (m)	a (m)	ds (m)	R (m)	Fr_1	E_1	E.D. (%)
20	4.3		0.77	10.89	10.1	3.44	74.73	15.65	17.2	7.13	10.7	42.9	75.79
33	6.05		1.22	13.02	11.8	4.83	74.73	15.65	22.2	8.46	8.48	45.2	70.45
47	7.56	40°	1.71	15.29	13.6	6.05	74.73	15.65	26.3	9.46	7.28	47.2	66.47
60	8.94		2.2	17.22	15.1	7.15	74.73	15.65	29.8	10.29	6.52	49.1	63.59
76	10.44		2.77	19.21	16.4	8.36	74.73	15.65	33.4	11.12	5.9	51.1	60.18

Table 5.4. Existing Design at ∅ = 43^0

q (m2/s/m)	Hd (m)	∅	Y1 (m)	Y2 (m)	Yt (m)	Yc (m)	X (m)	a (m)	ds (m)	R (m)	Fr1	E1	E.D. (%)
20	4.3		0.77	10.89	10.1	3.44	75.68	17.62	17.2	6.055	10.7	42.9	75.79
33	6.05		1.22	13.02	11.8	4.83	75.68	17.62	22.2	8.079	8.48	45.2	70.45
47	7.56	43^0	1.71	15.29	13.6	6.05	75.68	17.62	26.3	9.038	7.28	47.2	66.47
60	8.94		2.2	17.22	15.1	7.15	75.68	17.62	29.8	9.828	6.52	49.1	63.59
76	10.44		2.77	19.21	16.4	8.36	75.68	17.62	33.4	10.62	5.9	51.1	60.18

Table 5.5. Alternative Design IV at ∅ = 45^0

q (m^2/s/m)	H_d (m)	∅	Y_1 (m)	Y2 (m)	Yt (m)	Yc (m)	X (m)	a (m)	ds (m)	R (m)	Fr1	E1	E.D. (%)
20	4.3		0.77	10.89	10.1	3.44	75.86	18.94	17.2	6.58	10.7	42.9	75.79
33	6.05		1.22	13.02	11.8	4.83	75.86	18.94	22.2	7.81	8.48	45.2	70.45
47	7.56	45^0	1.71	15.29	13.6	6.05	75.86	18.94	26.3	9.46	7.28	47.2	66.47

60	8.94		2.2	17.22	15.1	7.15	75.86	18.94	29.8	9.50	6.52	49.1	63.59
76	10.44		2.77	19.21	16.4	8.36	75.86	18.94	33.4	10.26	5.9	51.1	60.18

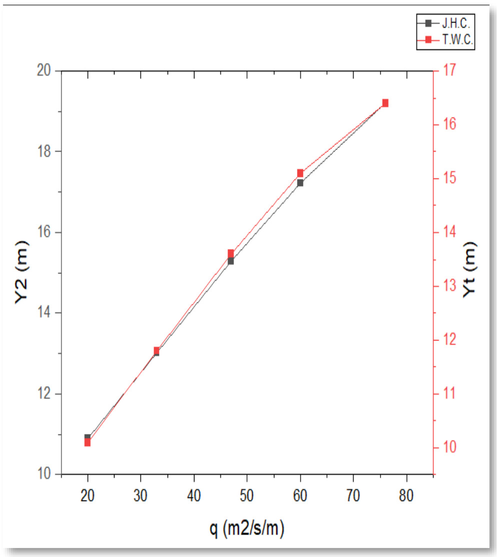

Figure 5.1. J.H.C. /T.W.C. Vs. Unit discharge

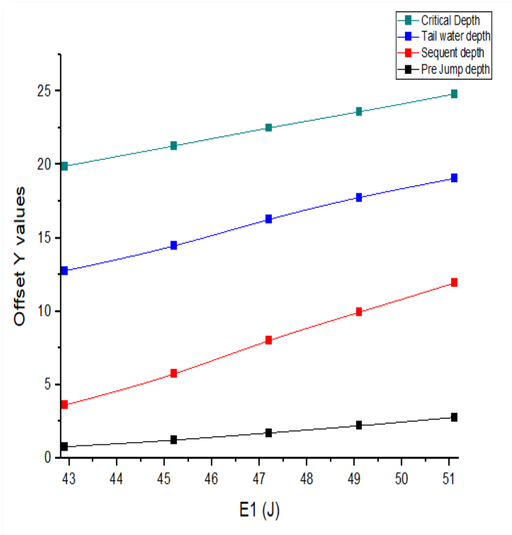

Figure 5.2. Depth. Vs. Specific Energy

A graph is plotted for the jump height curve and tailwater curve for varying unit discharges. Figure 5.1 shows that the jump water curve is above the Tailwater curve for a unit discharge indicating that the jump is away from the toe of the spillway.
The concepts of specific energy and critical depth are useful in the analysis of problems related to transitions. Figure 5.2 shows the specific energy diagram of the supercritical flow in a channel. Since the flow is supercritical, a drop in specific energy causes a rise in the water surface.

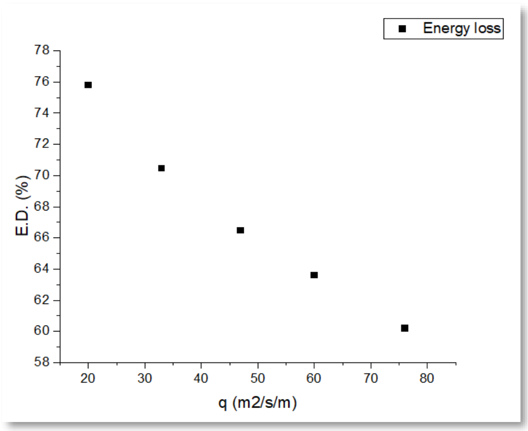

Figure 5.3. Energy Dissipation. Vs. Unit discharge

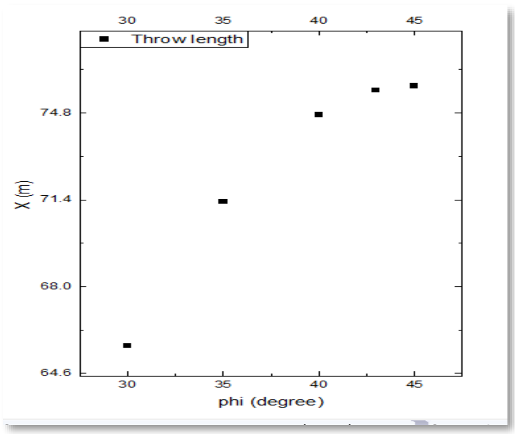

Figure 5.4. Throw Length Vs. Lip angle

Figure 5.3 shows how the E.D. varies with the unit discharge, In particular, in unit discharge, the dissipation is about 60 % -76%.
Throw distances are computed using the BIS equation. Throw distances using the velocity of the jet of water in the ski jump bucket are designed for different lip angles. Figure 5.4 shows a higher lip angle throw length is high. The variation was observed in the range of 60% to 80%.

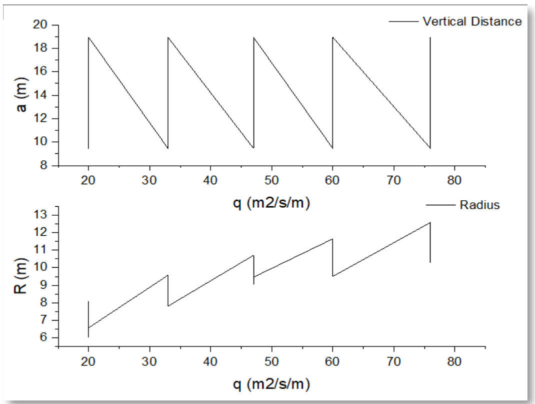

Figure 5.5. Vertical distance, Radius Vs. Unit discharge

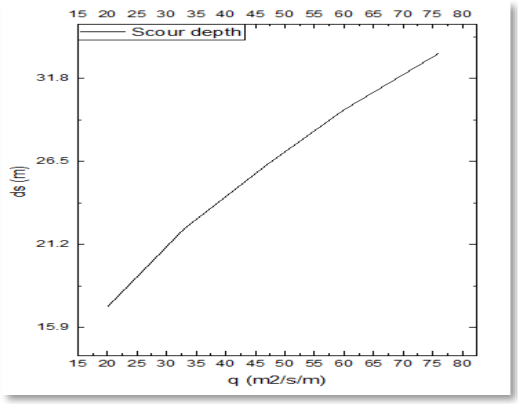

Figure 5.6. Scour Vs. Unit discharge

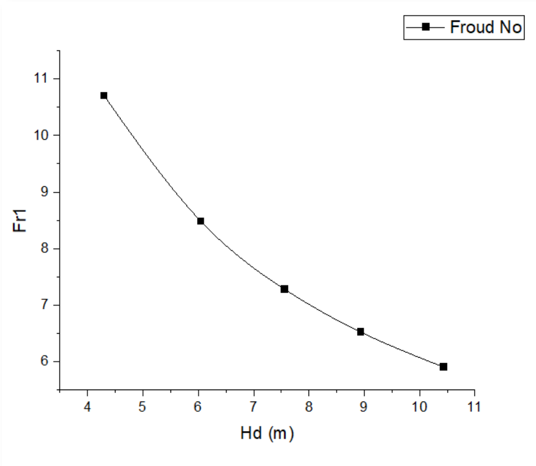

Figure 5.7. Froude No. Vs. Design head

A graph is plotted for varying discharge versus vertical distances and the radius of the bucket. Figure 5.5 shows that for varying unit discharge, Although the vertical distance remained constant, there was change in the bucket's radius.

The water surface and scour profiles for the ski jump bucket were calculated and compared with varying unit discharge.

It was observed in Figure 5.7 that for varying design heads, Froude No varies from 5 to 11. It indicates that the downstream extremity of the surface roller and the point at which the high-velocity jet tends to leave the floor occur in practically the same vertical plane. The energy absorption in this type of jump ranges from 45 to 70 %.

5. Conclusions

Ski-jump bucket designs with varied flow conditions were investigated at the tailwater pool level to figure out a solution that maximized energy dissipation while limiting trajectory throw length and width of impact. To measure the energy dissipation of the various trajectory bucket models, a combined study of trajectory profiles, impact width, plunge pool depth, and depth at bucket lip was established. We can draw a conclusion based on the outcome.

- Jump water curve is above the Tailwater curve for a unit discharge that indicates that the jump is away from the toe of the spillway.
- The throw distance and vertical distance from the lip level to the highest point of the centre of the jet are greater in terms of lip angle, allowing us to minimize the lip angle and regulate eroding.
- Energy dissipation range is 60 % - 76% for different parameters like discharge, head, and lip angle.

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7.Abbreviations

Q	Discharge, (m^3 / s)
q	Unit Discharge, (m^2/s / m)
L	Effective length of overflow crest, (m)
H	Head of the overflow, (m)
V	Velocity of flow , (m/s)
N	Number of piers
g	Acceleration due to gravity, (m/s^2)
A	Horizontal dimension defining U/S quadrant of the crest
B	Vertical dimension defining U/S quadrant of the crest
E.D.	Energy Dissipation/ Dissipator
R	Radius of Bucket
X	horizontal throw distance from bucket lip to the centre point of impact with tailwater, (m)
$\emptyset$	bucket lip angle (exit angle) with horizontal, (in degree)
a	vertical distance from the lip level to the highest point of the centre of the jet, (m)
r_1	Radius from Origin of coordinates, (m)
r_2	Radius from breast wall, (m)
H_d	Design head, (m)
H_e	Effective head, (m)
H_5	Reservoir pool elevation minus jet surface elevation on the bucket, (m)
K_a	Abutment contraction co-efficient
K_p	Pier contraction co-efficient
C_d	Discharge coefficient for design head
V_a	Approach velocity, (m/s)
X_i, Y_i	Co-ordinates of the Ogee profile
V_1	Initial Velocity, (m/s)
F_{r1}	Froud No.
Y_1	Initial depth before jump, (m)
Y_2	Depth after jump, (m)
Y_t	Tail Water depth, (m)
Y_c	Critical depth, (m)
E_1	Initial Specific Energy, (J)
E_2	Final Specific Energy, (J)
d_s	Depth of scour below tailwater level, (m)

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