EXPERIMENTAL INVESTIGATION OF OGEE SPILLWAY WITH AN ALTERED SKI JUMP ENERGY DISSIPATOR: MAITHON DAM, INDIA

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Abstract: It is used to track reservoir discharges through ogee spillways. Recent years have seen an increase in the use of ski-jump buckets to release flood water downstream of dams. A curved solid surface near the toe of the spillway is called a ski-jump bucket. A ski-jump bucket type energy dissipator is thought to be more suitable when the tail water depth is significantly less than the following depth of a hydraulic jump. In the ski-jump bucket, the spillway flow is launched into the air from the toe to a great distance as a free-dispensing upturned jet (trajectory), which then lands on the channel bed downstream. Experimental investigations were carried out with the aim of producing an efficient design for the spillway of the Maithon dam in Dhanbad, Jharkhand, India. According to experimental studies, a conventional ski-jump bucket has less energy dissipation. Model tests were carried out for various discharges in a hydraulic flume with a cross section of 30x30 cm and a length of 6 m. Based on the Froude similarity criterion, a 1:150 scale model of the object was produced. In each test, the energy dissipation and trajectory characteristics were assessed. This study's main objective was to improve the trajectory and energy dissipation in a modified ski-jump bucket compared to a standard ski-jump bucket. The outcomes demonstrated that the modified ski-jump bucket provided a decent trajectory and enhanced energy dissipation. The range of energy loss is 48.39% to 72.46%.

Keywords: Energy dissipation, Trajectory length, Trajectory height, Ski jump energy type Dissipator, Ogee Spillway, Radial gate.

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Introduction: Dissipation of kinetic energy produced at a spillway's base is required. This is essential to prevent erosion of the riverbed and banks, as well as to safeguard the dam and other buildings like the spillway, powerhouse, canal, etc. By bringing the energy of the flow down to reasonable levels, energy dissipators prevent erosion in downstream regions. According to Khatsuriya, energy is lost at the base of the spillway through internal friction, turbulence, and high-velocity diffusing into the fluid mass (2005). Turbulence is created when kinetic energy is applied, and the energy is then lost. The three categories of energy dissipators for spillways are as follows. Ski jumps have been around since the middle of the 1930s. The three main components of ski-jump bucket energy dissipator constructions are as follows: 3. Plunge pool, 2. Ski-jump bucket, and 1. Ski-jump/Trajectory.

Mazumdar and Patel (2001) examined a model made up of a 1:100 scale ski jump energy dissipator to determine whether the IS:7365-1985 design guidelines were applicable. According to the findings, energy dissipation from air entrainment and impact wears from 26% to 54.4%. **Utkarsh Nigam et al. (2015)** By measuring the hydrodynamic forces operating on the stilling basin using transducers, it is possible to estimate the hydrodynamic uplift force on the apron of the stilling basin using a hydraulic model. Triangular-shaped buckets are a brand-new style of bucket that by **Steiner et al. (2008) and Jian-hua et al. (2016).,** The hydraulic performance of a triangular-shaped bucket compared to a circular bucket was studied. **Pfister et. al. (2014), Amirmasoud Hamedi et. al. (2014) G.P.B. Neluwala et. al. (2012) investigated** the properties of hydraulic leaps that arise on uneven, horizontal channel beds under various flow conditions were studied. On the stepped chute, an effort was made to maximise energy dissipation and unit discharge by **Qian et. al. (2016).** A new kind of energy dissipator known as a ski-jump-step energy dissipator was created. It has two stages, each of which has a ski-jump, a prestep, an aeration basin, and a stepped chute. Results showed that the stepped chute's unit discharge restriction increased to 118 m2/s and that the energy dissipation increased by up to 75.8%. **Jian hua et. al. (2016)** Studied the effect of take-off velocity e on characteristics of trajectory for a triangular shaped flip bucket. Ramarao et. al. (2016) and Sundarlal et. al. (2016) to determine the length and depth of the deepest scour downstream of the ski jump bucket and to complete the design of the prefabricated plunge pool, scour tests for the ski jump bucket energy dissipator were conducted.

Ski jump bucket energy dissipators have not received much scientific attention in attempts to lessen scour and enhance energy dissipation. Using six-legged concrete and riprap in the Tail channel decreases cover, but shifts the scour hole to the extreme, which necessitates a longer length of protection and raises the cost, according to the Mohammad et al. (2020) research. There has not been any research on how to change the ski jump bucket to increase energy dissipation. Therefore, a unique method of modified buckets is employed in the current study to enhance energy dissipation.

Methodology: At a scale of 1:150, the model was made using the Froude similarity criterion. The ogee spillway was created to provide a radial gate for experimental study in accordance with

Indian Standards IS: 6934:1998 and IS: 4623:2000. The scale selected is determined by the size and discharge capacity of the hydraulic flume, prototype spillway data, and other factors. The Maithon dam spillway is designed using prototype data. The goal of this research is to minimise scour extent by using an original strategy. In this innovative design, a deflector is added to both sides of the bucket to transform a standard ski-jump. To get the best dissipation under the gated situation, many alterations were tested in the current study. The findings are mostly presented in terms of the typical dimensions and nondimensional factors, offering practical advice for dam engineering. The tests were conducted at flows of 0.005 m^3/s (highest discharge) and 0.001 m^3/s (minimum discharge).

Study Area: The hydrologic characteristics of the Maithon dam are examined in the current study. In the state of Jharkhand, near Maithon, 48 kilometres from Dhanbad, is where you may find the Maithon Dam. The Maithon Dam is a hybrid of concrete and earth. Estimated to be 6391.7 km^2, the Barakar River's catchment area extends to the dam site. The barrage can hold a maximum of 1093 MCM in storage and 56.08 m in height. Spillway was built to withstand a 13,592 m^3/s flood. Radial gates that are 12.19 metres wide and 12.50 metres high are installed in each of the spillway's 12 bays.

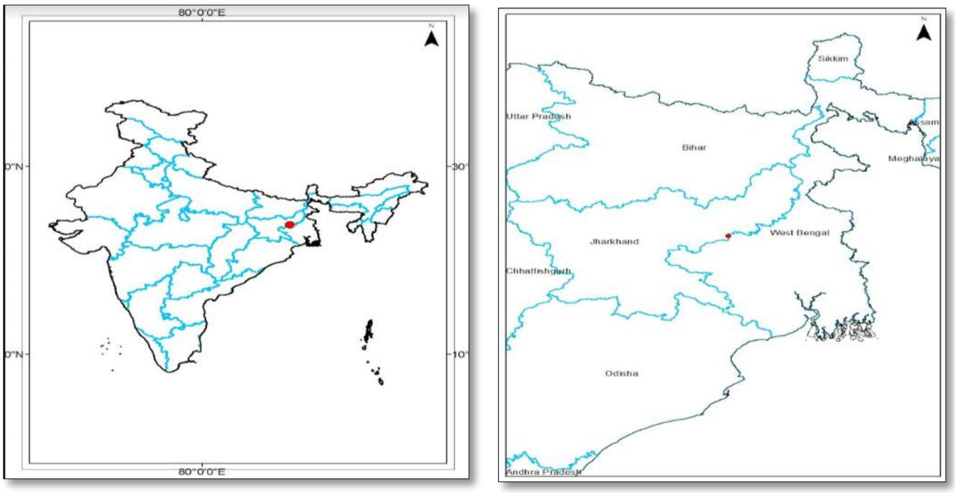

Image 1: Location of Maithon Dam

For design and modelling, data and information acquired from several relevant sources are included. The original numerical model has been examined to determine the site's current energy dissipation. To achieve maximal energy dissipation, original numerical models were modified with various parameters and evaluated with earlier research.

Experimental Program: The fluid mechanics lab at AISSMS, COE, Pune, was used for the hydraulic model study. The hydraulic replica will be kept inside a hydraulic flume. The laboratory created a controlled environment where no external factors, including the weather, could affect the experiments or data collected. The hydraulic pump received its water supply from the hydraulic flume's input, enabling it to keep the water level behind the spillway model constant while allowing water to overflow over the crest of the radial gate. A hydraulic model of an ogee spillway was built, and it included a trajectory bucket type energy dissipation. The pumping water storage tank is 1.5 x 0.8 x 1.2 metres in size. Water was pushed using a centrifugal pump and conduit tubing from the storage tank to the hydraulic flume. A 1.572 HP pump with a 2900 rpm speed, a 45 percent overall efficiency, and maximum discharge was employed. Before the water entered the hydraulic flume, a valve was fitted to control the flow of water or discharge. The valve controls the water's flow. Start by experimenting with different discharges using a typical ski bucket. After the full discharge was activated, the depth of the water flow at the rim of the bucket and in the plunge, pool was measured using rulers. Calculations were made to determine the trajectory's maximum height, its maximum and minimum separations from the bucket's lip. For more precise measurements, it was demonstrated that the water flow over the spillway model remained constant and did not vary substantially. Pre- and post-jump depths were measured for each experiment using a pointer gauge, and jump lengths were determined using a scale that was calibrated to the channel's walls.

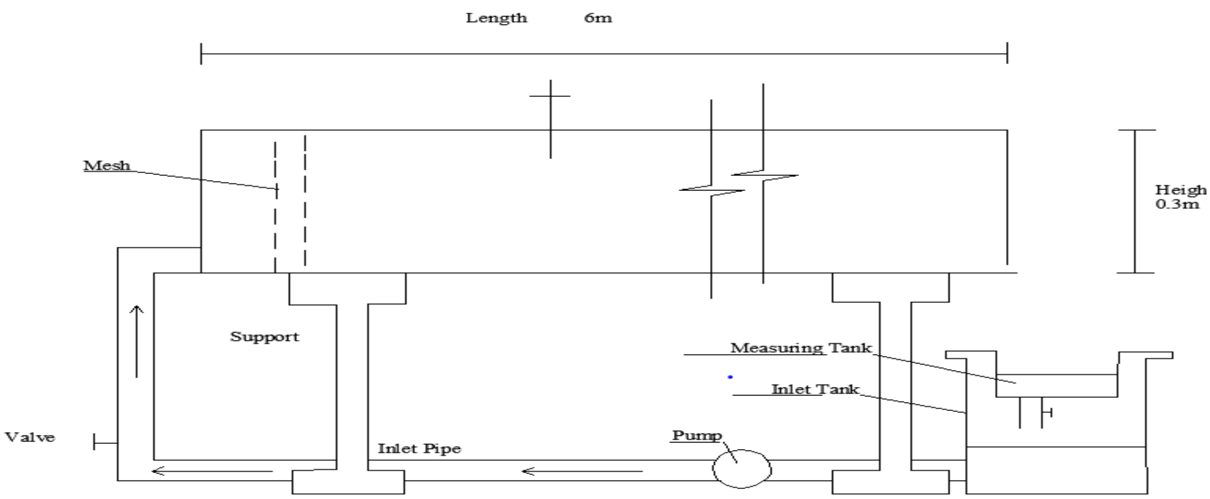

Figure 2: Schematic of experimental setup

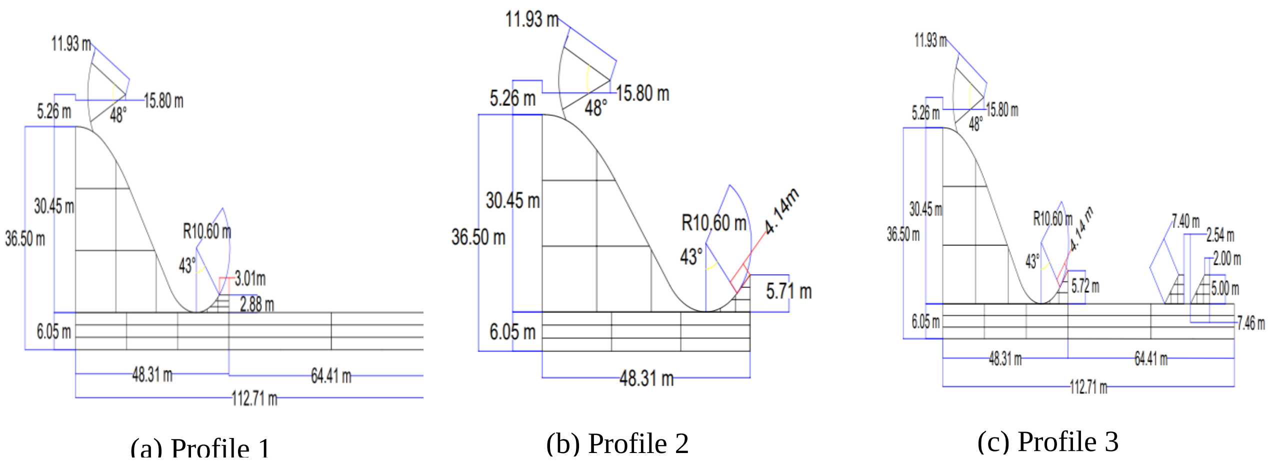

Figure 3: Profile of Ogee Spillway and Ski type energy dissipator with different alteration.

The first bucket design, shown in Figure 3(a), has been the subject of research for the maximum design of 0.005 m^3/s with the gate fully open. It was discovered that an energy dissipation of roughly 50% occurred in a ski jump bucket type energy dissipator with a radius of 10.60 m. To maximise dissipation and reduce erosion, three distinct bucket designs were examined.

For investigations with a maximum discharge of 0.005 m3/s, modified designs were applied. In order to increase the energy dissipation at the downstream at the dam site, the length after the bucket radius is extended in revised profiles 2 and 3 illustrated in Figure 3(b, c). In order to achieve maximum energy dissipation and manage the erosion effect, profile 3 (Figure 3(c)), a variation of profile 3 (b), is provided with wedges of size 5 metres in height, 2 metres in width horizontally, and 7.40 metres inclined at a 45-degree angle.

Results and Discussions: The experiment has been completed, and the numerical results have been shown. The stream performs a hydraulic leap in the stilling basin before entering the ski jump bucket, where it loses a lot of energy, for a flow range of 0.001 to 0.005 m^3/s, as shown in Tables 1, Table 2, and Table 3 for different profiles

Table 1: Profile 1 with varying discharge

Flow Condition	Q	V_1	Y_1	Y_2	X	a	E_1	V_2	% E.D.	Fr_1	Y_c
	m^3/s	m/s	m	m	m	m	J	m/s	%	-	m
1	0.005	2.31	0.021	0.01	0.235	0.085	0.294	1.667	48.39	5.07	0.0625
2	0.004	1.96	0.02	0.0098	0.3	0.075	0.216	1.360	51.77	4.42	0.0539
3	0.003	1.50	0.019	0.0085	0.29	0.073	0.135	1.176	41.64	3.44	0.0445
4	0.002	1.07	0.018	0.0083	0.23	0.06	0.077	0.803	46.39	2.52	0.0339
5	0.001	0.88	0.011	0.008	0.21	0.053	0.050	0.417	66.47	2.62	0.0213

Table 2: Profile 2 with varying discharge

Flow Condition	Q	V_1	Y_1	Y_2	X	a	E_1	V_2	% E.D.	Fr_1	Y_c
	m^3/s	m/s	m	m	m	m	J	m/s	%	-	m
1	0.005	2.45	0.02	0.012	0.3	0.105	0.326	1.389	66.17	5.53	0.0625
2	0.004	2.12	0.018	0.011	0.32	0.103	0.248	1.212	65.30	4.97	0.0539
3	0.003	1.86	0.016	0.01	0.315	0.095	0.192	1	68.31	4.72	0.0445
4	0.002	1.28	0.015	0.01	0.22	0.087	0.099	0.67	67.02	3.32	0.0339
5	0.001	0.71	0.014	0.0098	0.22	0.08	0.039	0.340	60.28	1.93	0.0213

Table 3: Profile 3 with varying discharge

Flow Condition	Q	V_1	Y_1	Y_2	X	a	E_1	V_2	% E.D.	Fr_1	Y_c
	m^3/s	m/s	m	m	m	m	J	m/s	%	-	m

1	0.005	1.63	0.03	0.0299	0.24	0.15	0.166	0.557	72.46	3.01	0.0625
2	0.004	1.35	0.029	0.021	0.23	0.13	0.122	0.634	65.85	2.52	0.0539
3	0.003	1.50	0.019	0.015	0.21	0.11	0.134	0.667	71.97	3.42	0.0445
4	0.002	1.23	0.016	0.01	0.17	0.07	0.093	0.667	64.71	3.09	0.0339
5	0.001	0.98	0.01	0.00765	0.15	0.055	0.059	0.435	70.62	3.13	0.0214

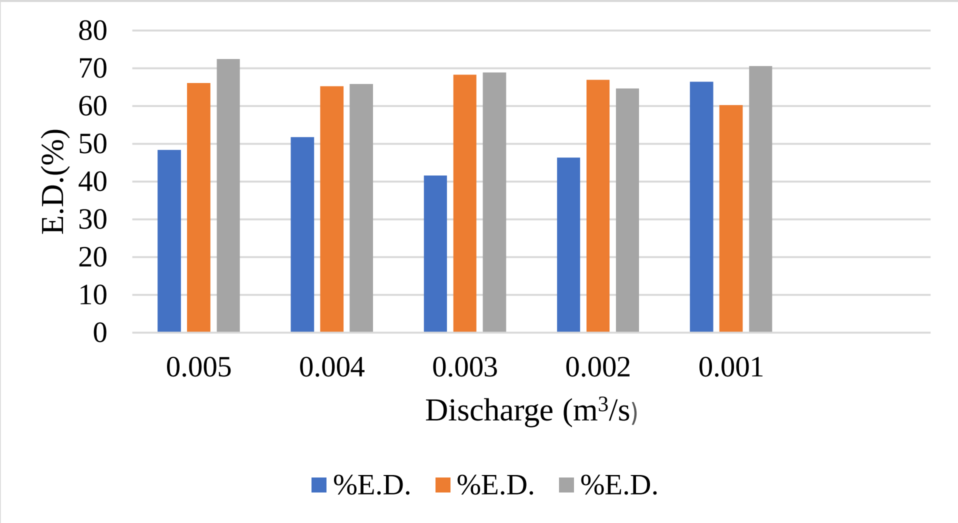

Figure 4: Energy dissipation with varying discharge for different profiles

Results for energy dissipation with variable discharge for various profiles are shown in Figure 4. Ski-jump bucket energy dissipation for maximal discharge is reported to range from 48.39% to 72.46%. Ski-jump buckets with modified profile 3 dissipate more energy than ski-jump buckets with hydraulic lifts for all flow conditions.

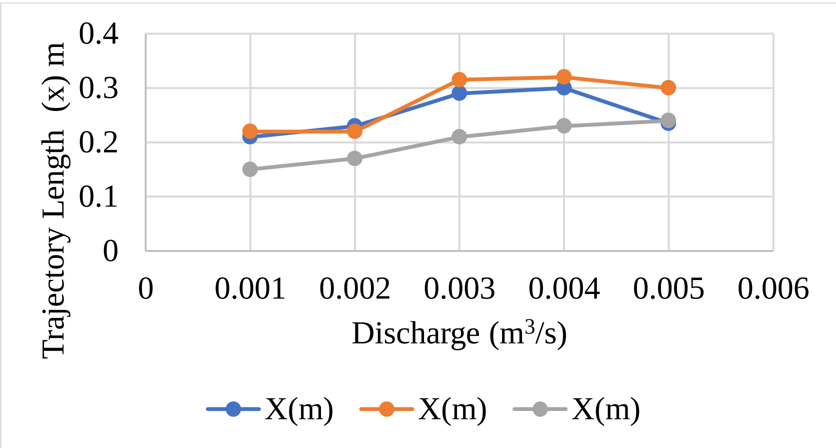

Figure 5: Trajectory length with varying discharge for different profile

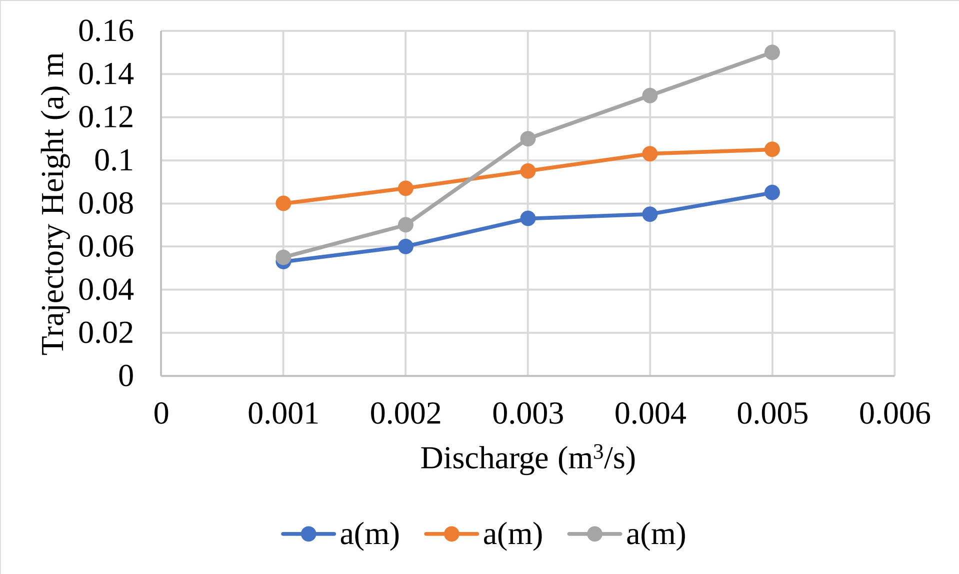

Figure 6: Trajectory height with varying discharge for different profile

The horizontal distance of the trajectory measured from the bucket lip to the point of contact of the nappe of the trajectory in tail water is known as the trajectory length. The height of a trajectory is defined as the vertical distance between the highest point of the trajectory's nappe and the bucket lip. Figures 5 and 6 depict the trajectory characteristics of various profiles for various flow conditions. It said that a drop in discharge is discovered to cause the trajectory length and trajectory height to decrease. The findings are displayed in Figure 5: Profile 3's trajectory is shorter than that of Profiles 1 and 2. It was because, based on the results, profile 3 has a lower velocity on lip while exiting the jet, but, based on the results for trajectory height displayed in Figure 6, it was found that profile 3 has a higher trajectory height than profiles 1 and 2. It occurred as a result of the obstacles that were offered in profile 6 to regulate the jump's. placement and reduce energy loss.

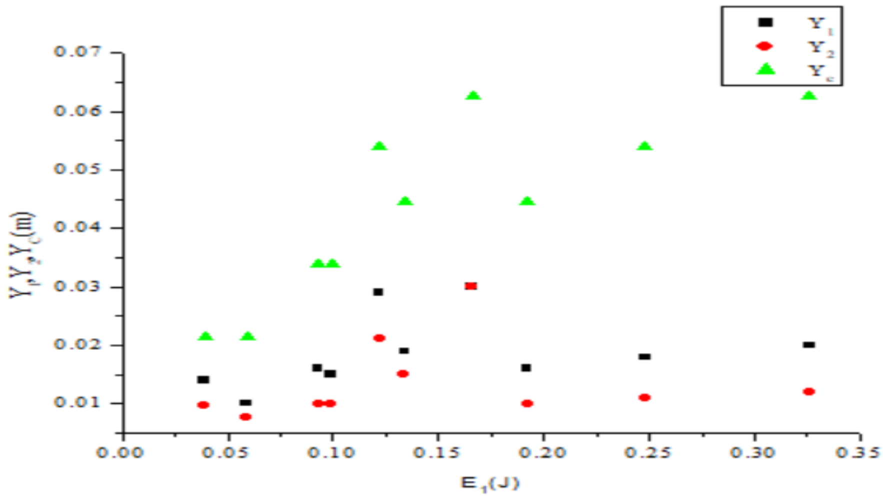

Figure 7: Depth. Vs. Specific Energy

Figure 7 depicts the jump height curve for different specific energies, showing that the leap is away from the spillway's toe.

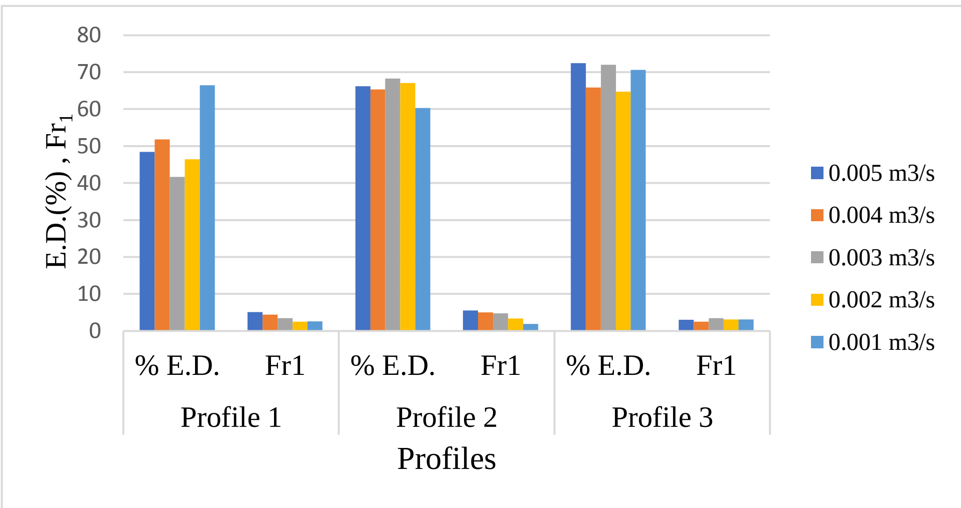

Figure 8: Energy dissipation vs Froude No. for different profile

For various profiles, Figure 8 shows the relationship between Energy dissipation and Froud No. It was shown that when Froude no is higher, dissipation is lower, and vice versa. This is because differing profiles cause the velocity to vary. According to Figure 8, Profile 3 has achieved more energy dissipation with a lower Froude number.

Conclusions:

Ski-jump buckets were experimentally explored in the current study with various modifications. To understand the trajectory aspects and energy dissipation, five flow conditions were examined. Experimental investigation leads to the following conclusions:

1. It was discovered that the energy dissipation for various Profiles ranged from 48.39% to 72.46%. It was discovered that Profile 3 dissipated more energy than Profile 1 and Profile 2 under all flow conditions.
2. The top trajectory length for profile 3 was found to be larger than that of profiles 1 and 2. The trajectory length was found to fluctuate between 0.15 m and 0.35 m for all flow conditions.
3. It was discovered that the trajectory height for various profiles varied between 0.055m and 0.15m. Profile 3 was shown to have a greater upper trajectory height than profiles 1 and 2 for all flow conditions.

For all profiles, it was discovered that the trajectory length and trajectory height decreased as the discharge did. Profile 3 includes the height, length, and energy dissipation of the trigger trajectory. Energy dissipation is greater in profile 3 due to the downstream blockage provided after the redesigned bucket form.

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