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COMPARISON OF CHARACTERISTICS OF HYDRAULIC JUMPS OVER SMOOTH AND ROUGH BED

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Abstract: Hydraulic jumps are mostly used as energy dissipators to release extra water flow energy downstream of hydraulic structures like spillways and sluice gates. The properties of hydraulic jumps produced on smooth and bumpy beds are examined in this study utilising laboratory experiments. In both smooth and rough bed conditions, the study of leap will be conducted on a horizontal bed. A 6 m long, 0.30 m wide, and 0.75 m deep rectangular flume was used for the experimental programme.

This experiment will be conducted in a rectangular flume, which is made up of a rough bed that is created by inserting a rectangular wooden strip at regular intervals. Sequent water depth and beginning water depth are measured for various bed surfaces. The distance jump from the gate and the subsequent depth ratio were shorter on the rough bed than on a smooth one. When the discharge condition altered, the hydraulic parameters starting water depth, subsequent water depth, and flow rate were measured.

***Index Terms* – Bed characteristic, Stilling basin, Froude's number, Sequent depth, Energy dissipation, Hydraulic jump.**

I. INTRODUCTION

Hydraulic jump in a prismatic channel is a transitional phenomenon that occurs when the flow varies from supercritical to subcritical flow. The jump can occur in the prismatic as well as non-prismatic channels such as triangular, parabolic, trapezoidal, gradually expanding and abruptly expanding channels.

The surplus kinetic energy of the flow through the turbulence is released and transformed into energy via a hydraulic jump. To prevent extreme scouring and potential damage of downstream, a hydraulic jump is frequently employed in hydraulic engineering applications as an energy dissipator below chutes, weirs, gates, and spillways.

A hydraulic jump occurs when a discharge of water with higher supercritical flow velocity on the upstream side is met with a subcritical flow with lower velocity and variable depth of flow on the downstream side. The occurrence of hydraulic jump is subject to the initially fluid velocity. If the initial velocity of the fluid is below the critical speed, and then their no jump is possible.

II. SMOOTH AND ROUGH

- The features of hydraulic jumps across both smooth horizontal and smooth sloping channel beds have been thoroughly defined and documented.
- There have been very few investigations on the characteristics of hydraulic jumps over uneven horizontal surfaces, and these studies are now only available in publications.
- Only a small amount of study has been done on the properties of hydraulic jumps across uneven horizontal surfaces, and the findings from those studies have just recently been published in scholarly journals.
- With a clearly defined crest and a comparatively smooth surface downstream, the hydraulic jump has a tendency to be more regular and symmetrical on a smooth bed. This is so that the hydraulic jump will be more stable as a result of the flow remaining more uniform, with less turbulence and energy loss.
- On a rough bed, the hydraulic jump has a tendency to be unsteady and unstable, with a broken and turbulent surface downstream. This is because the uneven bed disturbs the flow, increasing turbulence and energy dissipation, which can result in the creation of eddies and vortices that can damage the jump's surface.

- In general, the properties of hydraulic jumps on smooth and rough beds can differ greatly depending on the particular conditions and parameters of the flow, and understanding these differences is crucial for a range of technical and environmental applications.

1.1.1 Condition for formation of Hydraulic jump

• Whenever the flow transitions from a supercritical to a subcritical depth. There won't be a surge in the flow when the Froude value is 1 or higher.

• When the Froude number range falls inside or exceeds 1.

• A jump can only form when the flow transitions from a subcritical to a supercritical flow condition.

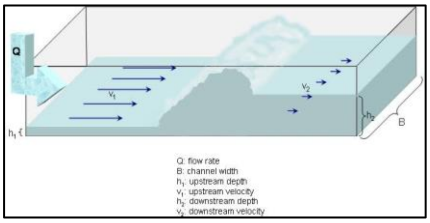

Figure 1: - Hydraulic jump formation

1.1.2 Practical applications of hydraulic jump

- Due to the jump taking place in more turbulent air, there is a significant energy loss. Since the energy is produced and released by a hydraulic jump, the level of energy downstream of a dam is rather high. If the additional energy is not released, it will scour the bed and erode the banks.

- It is used as a mixing tool to blend chemicals for water purification.

- It is utilised for municipal water supplies and to remove air pockets from water supply pipes.

- When the hydraulic leap forms, the depth rises quickly, producing a considerable downward load. The thickness of the apron also decreases as a result of the down lift force being lessened. It is used to perform irrigation training exercises, lower pumping heads to reduce cost of the apron and boost water levels in canals to widen the command area.

1.2 Objectives of the work

- To evaluate how channel roughness affects the hydraulic jump properties.

- To determine the position and size of the hydraulic jump in relation to the smoothness and roughness of the bed.

- To examine the hydraulic jump's flow characteristics.

2.1 EXPERIMENTAL DATA COLLECTION AND ANALYSIS

Numerous bed conditions, including a horizontal channel bed and various discharge conditions, have been tested for hydraulic jumps. The details of them are as follows.

There were four runs taken for beds with rough flow rates and five runs total for beds with smooth flow rates. The data that were gathered are detailed in the table below.

FOR SMOOTH BED

Table 1.

depth of flow (y) cm	velocity at u/s (v) m/s	discharge (q) m3/s	y1 cm	y2 cm	y2/y1	velocity at pre jump (v1) m/s	velocity at post jump (v2) m/s	Froude no. (fr1)	head over spillway cm	length of jump cm	d/s gate opening cm
44	0.315	0.0374	2.3	12.1	5.26	5.0399	0.958	10.61	9	82	6.6
44	0.315	0.0374	2.6	15.2	5.84	3.74	0.641	7.40	8.9	21	6.5
44	0.315	0.0374	2.4	9.3	3.87	6.26	1.618	12.90	9.7	87	6.9
44	0.315	0.0374	2.2	14.2	6.45	5.49	0.851	11.81	9.6	21	6.3
44	0.315	0.0374	1.9	14.2	7.47	5.30	0.710	12.27	8.5	41	6.9

Table 2.

Depth of flow (Y) cm	Velocity At U/S (V) m/s	Discharge (Q) m3/s	Y1 Cm	Y2 Cm	Y2/Y1	Velocity at pre jump (V1) m/s	Velocity at post jump (V2) m/s	Froude no. (Fr1)	Head over spillway cm	Length of jump cm	D/S gate opening cm
43.6	0.220	0.0258	2.5	13.4	5.36	3.90	0.728	10.17	9.3	53	9
43.6	0.220	0.0258	2.3	14.1	6.13	2.54	0.415	5.34	9.2	23	6.3
43.6	0.220	0.0258	2.2	12.7	5.77	2.19	0.380	4.71	9.2	66	6.4
43.6	0.220	0.0258	1.9	9.4	4.94	5.78	1.17	13.38	9.2	89	9.2
43.6	0.220	0.0258	2.1	12.9	6.14	3.87	0.631	8.52	9.2	71	6.1

Table 3.

Depth of flow (Y) cm	Velocity At U/S (V) m/s	Discharge (Q) m3/s	Y1 Cm	Y2 Cm	Y2/Y1	Velocity at pre jump (V1) m/s	Velocity at post jump (V2) m/s	Froude no. (Fr1)	Head over spillway cm	Length of jump cm	D/S gate opening cm
42.7	0.163	0.0187	1.7	11.7	6.88	4.39	0.639	10.74	8.6	46	5.2
42.7	0.163	0.0187	1.9	12.8	6.73	7.20	1.07	16.67	8.6	19	5.1
42.7	0.163	0.0187	1.7	11.4	6.70	2.91	0.435	7.12	8.6	68	5.4
42.7	0.163	0.0187	2.1	6.8	3.23	3.85	1.19	8.48	8.6	91	6
42.7	0.163	0.0187	1.8	11.8	6.55	2.20	0.336	5.23	8.6	71	5.3

Table 4.

Depth of flow (Y) Cm	Velocity At U/S (V) m/s	Discharge (Q) m3/s	Y1 Cm	Y2 Cm	Y2/Y1	Velocity at pre jump (V1) m/s	Velocity at post jump (V2) m/s	Froude no. (Fr1)	Head over spillway cm	Length of jump cm	D/S gate opening cm
40	0.111	0.0119	1	9.8	9.8	2.53	0.259	8.07	6.5	9	3.4
40	0.111	0.0119	1.2	8.4	7	1.73	0.248	5.04	6.5	23	3.6
40	0.111	0.0119	1.1	3.6	3.27	5.69	1.74	17.32	6.5	114	3.9
40	0.111	0.0119	1.3	7.6	5.84	5.40	0.925	15.32	6.5	85	3.7
40	0.111	0.0119	1.1	7	6.36	5.10	0.802	15.52	6.5	79	3.6

Table 5.

Depth of flow (Y) Cm	Velocity At U/S (V) M/s	Discharge (Q) M3/s	Y1 Cm	Y2 Cm	Y2/Y1	Velocity at pre jump (V1) M/s	Velocity at post jump (V2) M/s	Froude no. (Fr1)	Head over spillway Cm	Length of jump Cm	D/S gate opening Cm
38	0.066	0.0067	0.8	4	5	2.58	0.516	9.20	4.5	21	2.6
38	0.066	0.0067	0.7	4.6	6.57	1.99	0.303	7.59	4.5	16.5	2.1
38	0.066	0.0067	0.6	3.7	6.16	2.65	0.430	10.92	4.5	26	2.4
38	0.066	0.0067	0.6	4.4	7.33	3.59	0.490	14.79	4.5	17	2.3
38	0.066	0.0067	0.8	4	5	2.17	0.435	7.74	4.5	62	3.1

FOR ROUGH BED

Table 1.

Depth of flow (Y) Cm	Velocity At U/S (V) m/s	Discharge (Q) m3/s	Y1 Cm	Y2 Cm	Y2/Y1	Velocity at pre jump (V1) m/s	Velocity at post jump (V2) m/s	Froude no. (Fr1)	Head over spillway cm	Length of jump cm	D/S gate opening cm
44	0.322	0.0382	2.3	11	4.78	2.54	0.533	5.34	9.5	62	7.5
44	0.322	0.0382	2.6	10.6	4.07	2.69	0.661	5.32	9.5	73	7.7
44	0.322	0.0382	2.4	9.4	3.91	2.68	0.686	5.52	9.5	79	8.2
44	0.322	0.0382	2.6	12.6	4.84	2.14	0.443	4.23	9.5	42	7
44	0.322	0.0382	2.3	11.7	5.08	2.57	0.507	5.41	9.5	66	7.2

Table 2.

Depth of flow (Y) Cm	Velocity At U/S (V) m/s	Discharge (Q) m3/s	Y1 Cm	Y2 Cm	Y2/Y1	Velocity at pre jump (V1) m/s	Velocity at post jump (V2) m/s	Froude no. (Fr1)	Head over spillway cm	Length of jump cm	D/S gate opening cm
43.6	0.276	0.0325	2.3	11.6	5.04	1.74	0.345	3.66	9	42	7.2
43.6	0.276	0.0325	2.2	10.7	4.86	1.94	0.398	4.08	9	61	7.4
43.6	0.276	0.0325	2.1	10.5	5	2.61	0.522	5.75	9	69	7.6
43.6	0.276	0.0325	2.2	9.7	4.40	2.81	0.639	6.05	9	78	7.7
43.6	0.276	0.0325	2.1	9.6	4.57	3.33	0.728	7.34	9	82	7.9

Table 3.

Depth of flow (Y) Cm	Velocity At U/S (V) m/s	Discharge (Q) m3/s	Y1 Cm	Y2 Cm	Y2/Y1	Velocity at pre jump (V1) m/s	Velocity at post jump (V2) m/s	Froude no. (Fr1)	Head over spillway cm	Length of jump cm	D/S gate opening cm
42.6	0.230	0.0264	2.1	10.6	5.04	2.73	0.541	6.01	8.5	38	6
42.6	0.230	0.0264	1.9	9.4	4.94	2.06	0.417	4.77	8.5	58	6.3
42.6	0.230	0.0264	1.8	8.8	4.88	2.16	0.443	5.14	8.5	69	6.5
42.6	0.230	0.0264	1.7	8.5	5	2.47	0.495	56.05	8.5	76	7
42.6	0.230	0.0264	1.7	8.2	4.82	2.49	0.516	6.09	8.5	83	7.5

Table 4.

Depth of flow (Y) Cm	Velocity At U/S (V) m/s	Discharge (Q) m3/s	Y1 Cm	Y2 Cm	Y2/Y1	Velocity at pre jump (V1) m/s	Velocity at post jump (V2) m/s	Froude no. (Fr1)	Head over spillway cm	Length of jump cm	D/S gate opening cm
40.4	0.166	0.018	1.9	6.6	3.47	1.02	0.294	2.36	7	32	4.1
40.4	0.166	0.018	1.7	6.7	3.94	1.43	0.362	3.50	7	41	4.4
40.4	0.166	0.018	1.5	6.2	4.13	1.67	0.404	4.35	7	52	5.2
40.4	0.166	0.018	1.9	7.2	3.78	1.58	0.417	3.65	7	36	4.6
40.4	0.166	0.018	1.4	6.4	4.57	1.74	0.380	4.69	7	48	5.4

3.1 GRAPHICAL ANALYSIS

- Graph shown the variation between Froude number and Y2/y1

SMOOTH BED

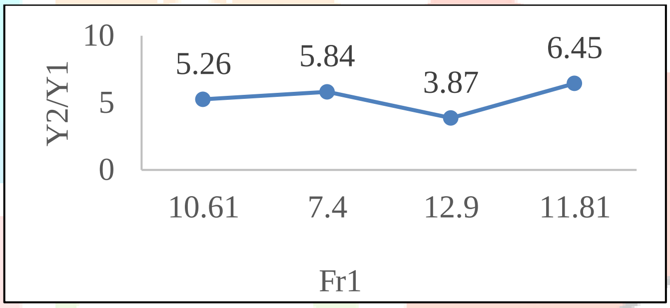

Figure 2: - variation between f_{r1} and y2/y1 properties

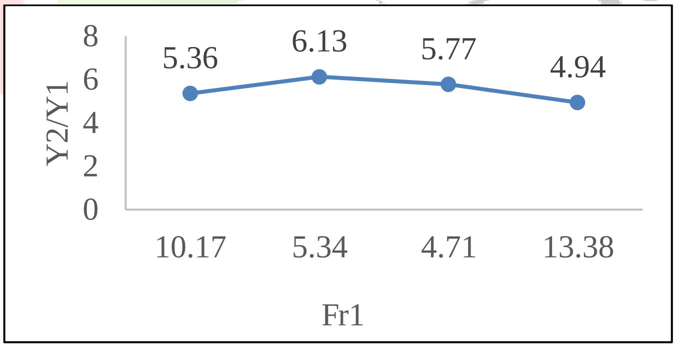

Figure 3: - variation between f_{r1} and y2/y1 properties

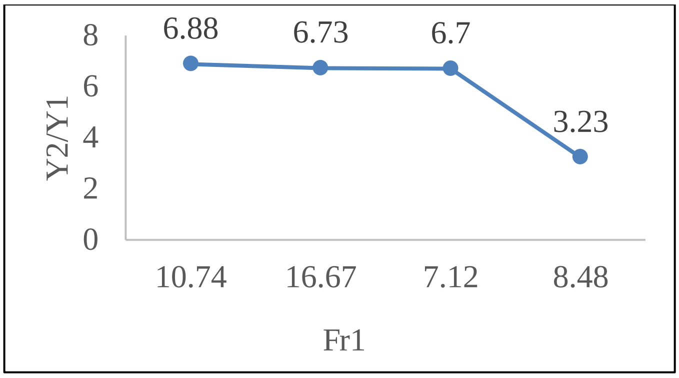

Figure 4: -variation between f_{r1} and y2/y1 properties

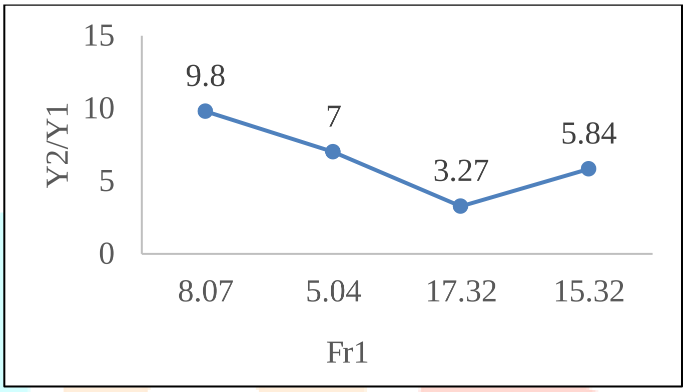

Figure 5: - variation between f_{r1} and y2/y1 properties

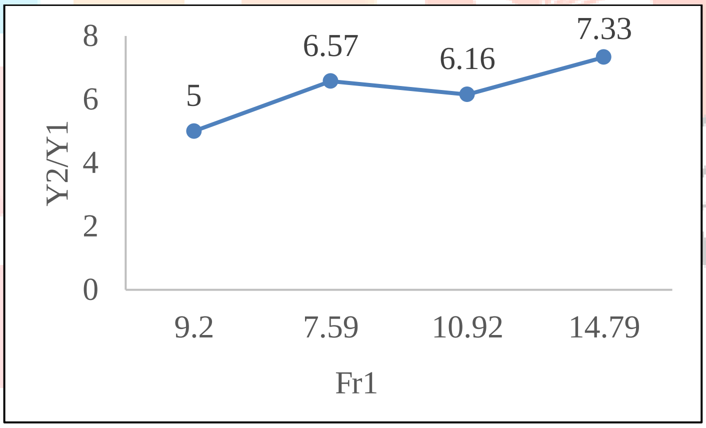

Figure 6: -variation between f_{r1} and y2/y1 properties

ROUGH BED

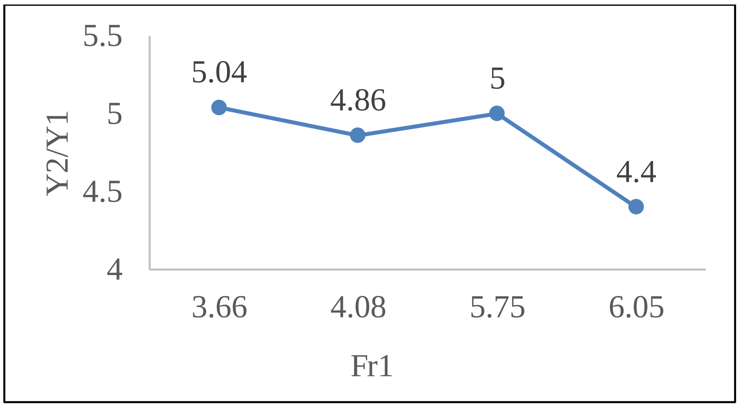

Figure 7: - variation between f_{r1} and y2/y1 properties

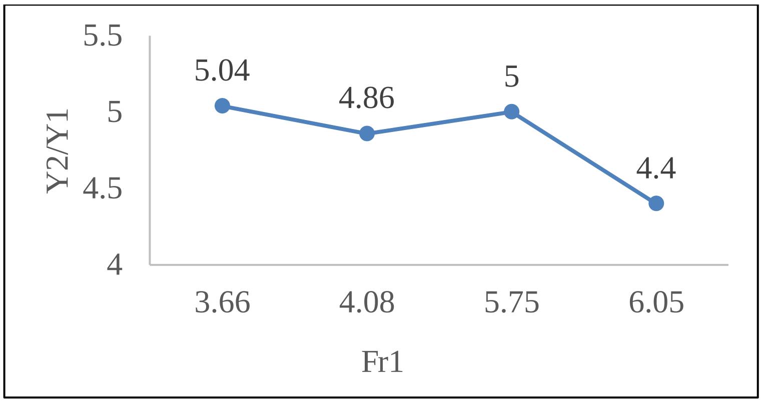

Figure 8: - variation between f_{r1} and y2/y1 properties

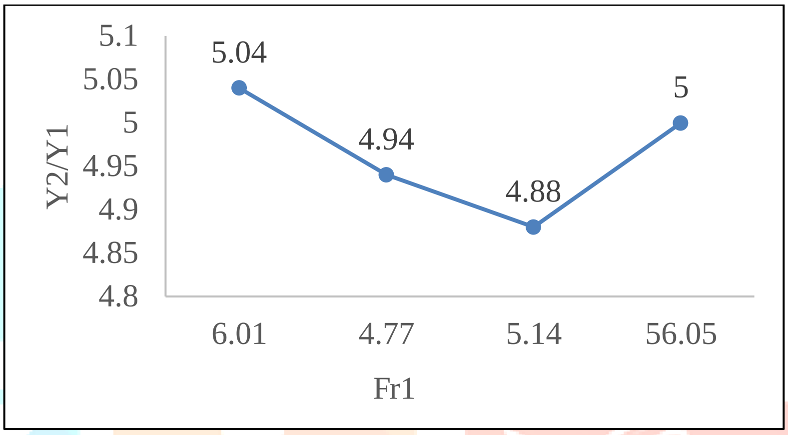

Figure 9: - variation between f_{r1} and y2/y1 properties

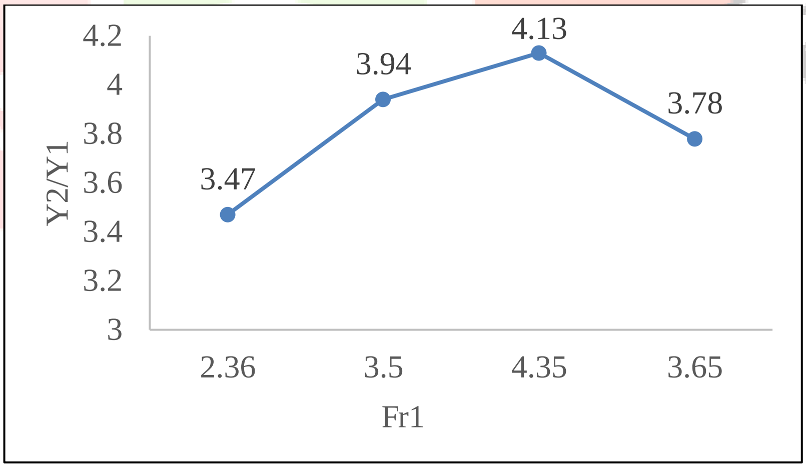

Figure 10: - variation between f_{r1} and y2/y1 properties

4.1 Conclusion

The Froude's number, the sequent depth ratio, jump height, and relative energy loss. A rectangular flume that was both horizontal and inclined was used to measure the hydraulic jump characteristics. The results lead to the following conclusions:

- The Froude's number has a significant impact on the hydraulic jump length, Sequent depth ratio, and relative energy loss.
- The Froude's number has a significant impact on the reduction in jump length and subsequent depth.
- Low reduction was seen for small Froude's number whereas bigger reduction was seen for large value Froude's number.

- The relative energy loss increases nonlinearly with increasing Froude's number.
- The jump outlet feature is more sensitive to the modification of the inlet Froude's number.
- The theoretical and observed value of the subsequent depth ratio for approached Froude's number exhibits higher fluctuation. In horizontal channel bed, the water surface is undulating with a very slight ripple and rollers, resulting in Undular and Weak jump.
- Despite the shape of the channel bed, the subsequent depth ratio declines with relative roughness. The subsequent depth ratio for the smooth aluminium bed decreases by 10%, which may be a result of the aluminium bed's little roughness and experimental mistakes.
- One of the best influences on hydraulic jump length is roughness. The flow resistance and energy loss rise as the stilling basin becomes rougher.
- The jump characteristics for beds that had been intentionally roughened were discovered to depend on the Froude number, roughness height, and roughness density.

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