STUDY OF THE POSITION OF HYDRAULIC

JUMP ON SMOOTH SLOPING FLOORS USED

IN THE DESIGN OF IRRIGATION STRUCTURES

by

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بسم الله الرحمن الرحيم

NOTATIONS

General Symbols: subscripts 1 and 2 denote section before and after the hydraulic jump, respectively.

SYMBOL	DESCRIPTION
A	cross - sectional area
B	width of the channel
C_v	coefficient of velocity
E	energy
F	froude number
f	function of
g	acceleration due to gravity
H	total head
h	drop height
h_f	friction loss
H_L	head loss
h_v	velocity head
K	constant
L	length
L_j	length of hydraulic jump
L_r	length of roller
M	momentum
m	mass

SYMBOL	DESCRIPTION
P	total pressure
Q	total discharge
Q_c	total discharge (critical flow)
q	discharge per unit width
S	slope of floor
T	time
V	volume
v	mean velocity
v_c	critical velocity
W	weight
X	horizontal distance from beginning of slope floor to the beginning of the front of the hydraulic jump
y	depth
y_j	height of hydraulic jump
y_m	mean depth
y_n	normal depth
Z	elevation above datum
β	momentum corrective factor
γ	specific weight
δ	dimensioless parameter
θ	angle between slope and horizontal
η	dimensionless parameter
λ	kinetic - flow factor

SYMBOL	DESCRIPTION
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
[illegible]	[illegible]
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CHAPTER I

INTRODUCTION

Many investigators have studied the hydraulic jump on continuous sloping floors. Few studies have been made on the problem of limited sloping floors in the form of glacis or standing wave weirs. The writer studied the problem of the limited sloping floors in a shape of sloping portion interrupting a horizontal bed as a result of a drop in bed level.

Limited sloping floors used in irrigation structures may be employed to form a hydraulic jump for the purpose of energy dissipation , to accomodate a certain bed drop due to degradation downstream of an existing barrage. Effect of the jump position is important in the design of irrigation structures from the point of view of the length of protective apron under the hydraulic jump.

It is preferable to form the jump as near as possible to the beginning of the slope to have the total jump formed on the sloping part.

This serves in shortening the solid part of the floor.

The main objective of this research may be summarized as follows:

1. Investigate theoretically and experimentally the Phenomenon of flow over limited sloping floors of smooth surface.

2. Combine the important flow , fluid, and channel variables in a functional relationship to be used as a model for laboratory experiments.
3. Find the relations that govern the position of the hydraulic jump for different ranges of flow conditions.
4. Study the main characteristics of the jump.
5. Study the velocity distributions and their relations with the length of jump.
6. Determination of the best slope to be used in the design according to the field flow conditions.

In the laboratory experiments nine values of apron slope have been tried (1 to 1, 2 to 1, 3 to 1, 4 to 1, 5 to 1, 6 to 1, 8 to 1, 10 to 1 and 12 to 1).

The momentum Principle was employed to develop an expression for the flow on limited sloping floors. Dimensional analysis was used to assist in finding an expression for the position of the hydraulic jump as a function of flow , fluid and geometry of the bed Change of position of jump was studied with flow and fluid. Characteristics for differnt floor slopes by laboratory investigations that covers the flow ranges which are usually used in the field

For floor slopes 3 to 1, 4 to 1, 6 to 1, 10 to 1 and 12 to 1 velocity distribution measurements were established. Contour lines of equal velocities were drawn out for the longitudinal sections in the direction of flow. The velocity distributions and contours were employed to estimate the length of jump.

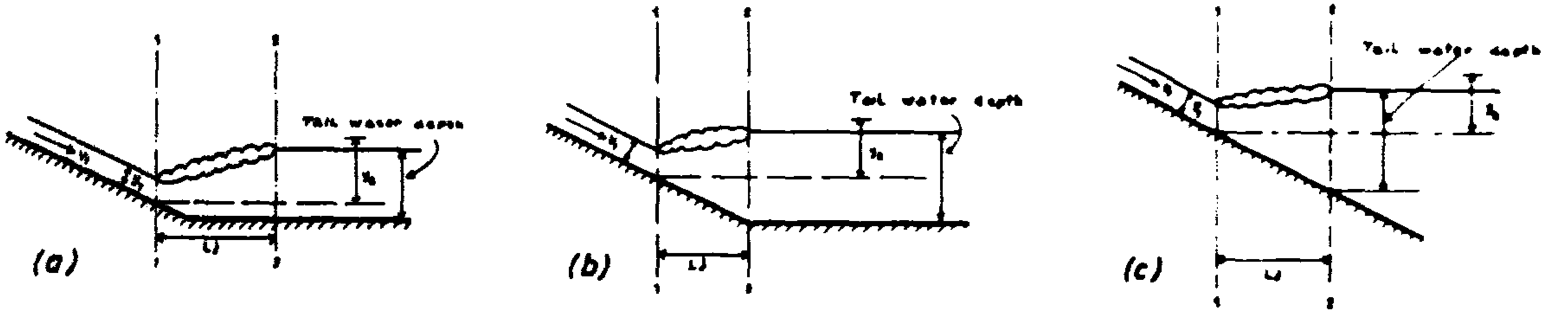

FIG. (1) OCCURRENCE OF THE HYDRAULIC JUMP ON A SLOPING APRON: (a) CASE I ,(b) CASE II ,(c) CASE III .

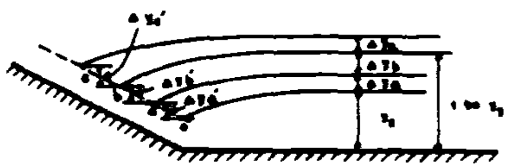

FIG. (2) PROFILE OF THE HYDRAULIC JUMP ON A SLOPING APRON.

The different formations of the hydraulic jump depend primarily upon where the terminus of the jump falls. As shown in Fig.(1a), case I prevails when the toe of the hydraulic jump forms on the slope, while the terminus, or end, of the jump occurs on the horizontal apron.

In case II, illustrated by Fig.(1b), the toe of the hydraulic jump occurs on the slope as in case I, but the end of the jump occurs at the junction of the slope and the horizontal apron.

As shown in Fig.(1c), case III prevails when the hydraulic jump forms entirely on the sloping apron. Cases II and III are practically the same, and further analysis will be made only of cases I and III.

It will be noted that case I is virtually that of the hydraulic jump formed on a horizontal apron, operating with excessive tailwater. As the tailwater is further increased, the formation of the hydraulic jump can be changed progressively from case I to case II and finally to case III.

If the tailwater depth is increased by a vertical element Δy, the front of the hydraulic jump does not rise an equal amount vertically. Instead, the jump profile undergoes an immediate change as the slope becomes part of the stilling basin, as illustrated by Fig. (2).

For an increase in tailwater depth Δy_a, the front of the assuming a straight-line profile from the beginning to the end of the jump. Over 600 tests were made in a glass-walled flume 2.5 ft wide, 3 ft deep, and 30 ft long. Investigations were made on slopes of 1 on 6, 1 on 3 n 1 on 2, and 1 on 1. Unfortunately, Yarnell's work was interrupted by his death.

In 1935, Rindlaub Conducted a series of experiments at the University California hydraulic laboratory. Experiments were made in a glass walled flume 3 ft deep and 0.5 ft wide. Investigations were made on four slopes of 8.2, 12.5, 24,2, and 30°, with most of the experiments being made on the slope of 12.5°. In his analysis, Rindlaub compensated for the pressure component on the sloping floor by including a dimensionless term, which can be determined experimentally, to account for any external forces.

Experiments in a rectangular channel having a maximum Slope of 1 on 14 were performed in 1936 at columbia University by Bakhmeteff and Matzke. In order to compensate for the weight of the jump on a sloping floor, a dimensionless cubic equation was developed which was found to be dependent upon the shape of the jump. Unfortunately, the slopes investigated were very small, and consequantly no generalization can be made from the results.

During 1941, Puls presented a method of routing stream flow through a hydraulic jump in open channels. Puls's analysis included several factors which previously were considered negligible. These forces included the friction of the channel boundaries, the shear applied to the top boundary of the stream, and the differential boundary reaction introduced by the weight of the jump body. Solution of the jump by the puls step method is both long and laborious, and several trials must be made for each solution. It is doubtful that the added accuracy of this method is warranted.

Carl kindesvater 1944, classified the common forms of the hydraulic jump in sloping channels into four general cases Fig. (3):

Case 1: With the entire roller on the horizontal floor which is the hydraulic jump in horizontal channels.

Case 2: The toe of the roller is on the slope and the end of the roller is on the horizontal floor.

Case 3: The toe of the roller is on the slope and the end of the roller is at the junction of the sloping and horizontal floors.

Case 4: The entire roller is on the slope .

In each case, the water surface and channel bottom down stream of the jump, as well as the referance axis , are assumed to be horizontal.

Case 1, that is the case of the hydraulic jump on horizontal bed, the momentum principle can be applied to Fig.(4).

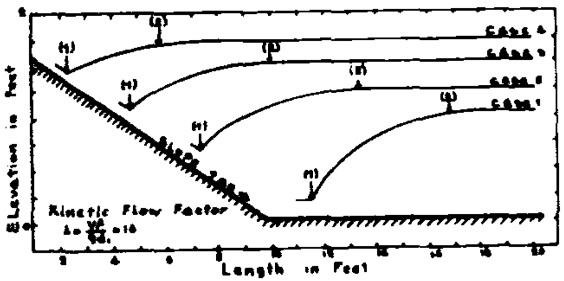

FIG (3)

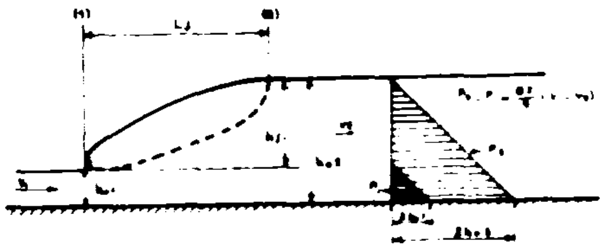

FIG (4)

THE HYDRAULIC JUMP IN A HORIZONTAL RECTANGULAR CHANNEL

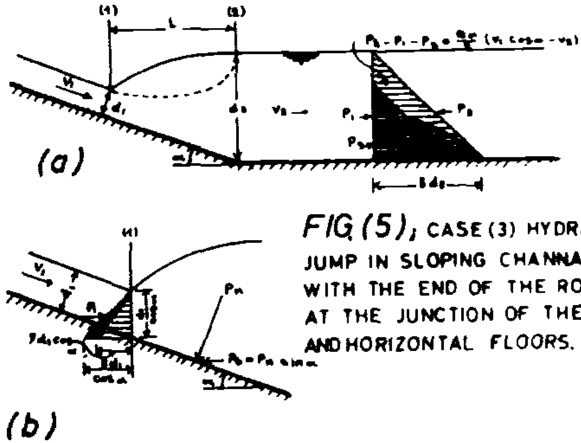

FIG (5), CASE (3) HYDRAULIC JUMP IN SLOPING CHANNALS, WITH THE END OF THE ROLLER AT THE JUNCTION OF THE SLOPING AND HORIZONTAL FLOORS.

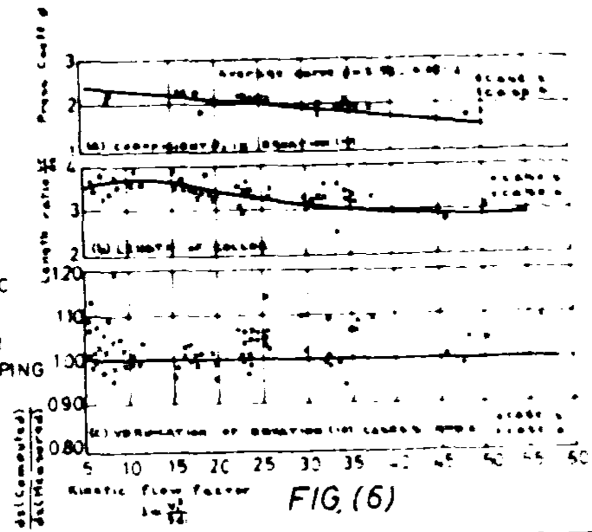

FIG (6)