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A STUDY OF THE SUBMERGED HYDRAULIC
JUMP IN STILLING BASINS OF LOW
HEAD IRRIGATION STRUCTURES

BY

IMAN MAHMOUD ELAZIZY
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SUPERVISED BY

Prof Dr. Mohamed W. Abdelsalam

Professor of Irrigation Design and Hydraulics,
Faculty of Engineering,
Ain Shams University

Dr. Abdel Mohsen El Mongy

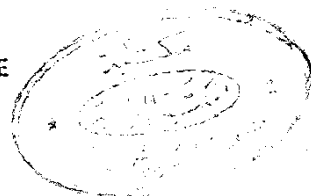
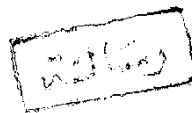
Lecturer of Irrigation Design and Hydraulics,
Faculty of Engineering,
Ain Shams University

Dr. Abdel Kawi Khalifa

Lecturer of Irrigation Design and Hydraulics,
Faculty of Engineering,
Assiut University

1985

629.8042
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EXAMINERS

Prof. Dr. MAHMOUD ABDEL HALEM ABOU-ZEID
Chairman Water Research Center.

Mahmoud Abu-Zeid

Prof. ALY ABDEL HAFIZ HELMY
Professor of Irrigation,
Ain Shams University.

A. d. H. Helmy
30.7.1985

Prof. Dr. MOHAMED W. ABDEL SALAM
Professor of Irrigation Design
and Hydraulics,
Ain Shams University

Mohamed W. Abdel Salam



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LIST OF SYMBOLS

The following symbols have been adopted in this thesis and are defined wherever they first appear:

A	= Area;
A_r	= Function of Froude number;
a_r	= A surface characteristic;
b	= The reciprocal of the universal mixing constant;
C	= Factor of flow resistance;
C_c	= Coefficient of contraction;
C_d	= Coefficient of discharge;
c, c'	= Coefficients;
C_f	= Coefficient of friction;
C_s	= Shape correction factor;
E_1	= Specific energy at the beginning of the jump;
E_2	= Specific energy at the end of the jump;
EL_s	= Energy loss in submerged jump;
e	= A measure of roughness size;
F_1	= Froude number at the beginning of the jump;
F_G	= Froude number through the gate opening;
G	= Gate opening of the sluice gate;
g	= Gravity acceleration;
H	= Water depth up stream the sluice gate;
h	= height of sill;
I	= Intensity of roughness;
L_{ej}	= Length of submerged jump end;
L_r	= Length of roller of submerged jump;
L_B	= Length of stilling basin;
L_e	= Length from entrance section to the sill;
L_t	= Total length of nonuniform flow;
m, m'	= Coefficients;
M	= Momentum force;
P	= Pressure force;

q	= Discharge/unit width;
q_1	= Initial discharge/unit width;
Q	= Discharge;
R	= The hydraulic radius;
$\bar{R}$	= Correlation coefficient.
S	= The energy slope;
V	= Mean velocity;
x	= Longitudinal distance from the gate;
x_1, x_2	= are exponents;
y	= Depth of water;
y_1	= Water depth at the beginning of the jump; initial depth;
y_2	= Water depth at the end of the jump; sequent depth;
y_0	= y_4/G
y_3	= Back up depth, just down stream the gate;
y_4	= Tail water depth in the submerged jump;
y_c	= Critical water depth;
U_1	= Average velocity at supercritical flow;
U_1	= Average velocity at the contracted section;
U_2	= Average velocity at the end of the jump;
U_m	= Maximum velocity in direction of flow;
u	= Forward velocity;
W	= width of block;
δ	= Boundary layer thickness;
δ_1	= Reference length;
δ_2	= Depth of forward flow;
δ_3	= Depth of back word flow;
α, π	= Slopes;
γ	= Specific weight of water;
τ_0	= Boundary shear stress;
ρ	= Mass density of water;
ν	= Kinematic viscosity;
β	= Momentum coefficient;

λ = Longitudinal spacing between roughness elements
 ψ = Initial depth; and
 ϕ = y_2/y_1

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CHAPTER (I)

INTRODUCTION

CHAPTER (1)

INTRODUCTION

Irrigation structures may be classified according to the working head, into two distinctive types; the first is the high head structures and the second is the low head structures. Spillways are one of the examples of the high head structures; while barrages, canal head structures, and weirs are examples of low head structures.

The phenomenon of the hydraulic jump occurs when the flow changes its regime from supercritical to subcritical flow. The hydraulic jump is a useful means of dissipating the excess energy existing in the supercritical flow downstream hydraulic structures.

The length of the stilling basin on which a hydraulic jump occurs, should be long enough for the velocity distribution to regain its normal form. Accordingly, from the economical point of view, the length of the jump must be minimized in order to have a minimum length of the stilling basin. Accessories for controlling the jump are usually installed in the basin. The main purpose of such control is to shorten the range within which the jump will take place and thus to reduce the size and cost of the stilling basin.

The aim of this work is to study how to minimize the length of the submerged hydraulic jump using rough beds with different intensities downstream hydraulic structures. A rough bed with brass cubes, 1.6 cm length, is arranged in a staggered way downstream the sluice gate.

In this study the submerged hydraulic jump is investigated experimentally under different flow conditions,

with Froude number ranging from 1.1 to 3. In the experimental work, four gate openings and five discharges for each opening are used. Also, five submergence ratios are studied for each discharge and each gate opening. The four bed roughness intensities used are $I = 0\%$, $I = 1.5625\%$, $I = 6.25\%$ and $I = 25\%$. The average water surface profile, the average hydraulic grade profile, the jump length " L_{ej} ", the roller length " L_r ", the backed up depth " y_3 ", the tail water depth " y_4 ", and the velocity distribution were measured during the experimental work.

Statistical analysis are adopted to analyse the experimental data and regenerate the necessary characteristic design charts of the submerged hydraulic jump for different roughness intensities.

The theoretical analysis is developed, using continuity and momentum principles in the study of the jump control volume. Besides, the dimensional analysis is used to find dimensionless expressions describing jump characteristics.

In this research we came to the conclusion that, the use of a roughness intensity 10% gives a minimum jump length and a maximum energy dissipation for the submerged hydraulic jump in the range of Froude number lying between 1.1 and 3.0. This same value of intensity (10%) was also found by Dr. Abdellateef M. in a study of the free hydraulic jump, a study carried out in the same laboratory during the last five years.

Hence, in the design of irrigation structures, rough floors of intensity 10% can be used downstream these structures, for both free and submerged hydraulic jumps.

The experimental investigations were carried out in the hydraulic laboratory of the University of Ain Shams,

Cairo, Egypt, during the period 1983-1985. For the statistical and mathematical computations, a "Commodore" personal computer was used.

CHAPTER (II)

LITERATURE REVIEW

- 2.1 Introduction.
- 2.2 Submerged hydraulic Jump.
- 2.3 Effect of Roughness on Flow.
- 2.4 Forced Hydraulic Jump.

CHAPTER (2)

LITERATURE REVIEW

2.1 Introduction

The hydraulic jump is one of the most interesting phenomena in the field of hydraulic engineering. It constitutes the rapid transition from supercritical to subcritical flow. The hydraulic jump has been used as energy dissipation device on hydraulic structures such as dams and regulators, before it was analysed mathematically. The jump formed in a smooth and horizontal rectangular channel is known as the classical jump.

The supercritical depth at the beginning is called y_1 , and the subcritical depth at the end is called y_2 ; the two depths are called the sequent depths. A theoretical analysis of the hydraulic jump was first found by Belanger [47]. He applied momentum principle, neglecting the boundary shear stress on the bed, and the turbulent velocity fluctuation, he found that the ratio of the sequent depths in classical jump is,

$$\frac{y_2}{y_1} = \frac{1}{2} (\sqrt{1 + 8 F_1^2} - 1) \quad (2.1)$$

in which,

y_1 = water depth at the contracted stream;

y_2 = water depth at the end of the jump;
sequent depth;

$F_1 = U_1 / \sqrt{g y_1}$ = the initial Froude number; and
 U_1 = velocity at the contracted stream.

The first recorded investigation of the hydraulic jump was by Leonardo da Vinci [47] in 1490, and Bidone [12] 1818. Since then a very large number of research papers