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Design of Stilling Basins Using Artificial Roughness

A Thesis Submitted in Partial Fulfilment of the Master Degree
Civil Engineering – Irrigation and Hydraulics department

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List of Symbols

Symbols	Refers to	Dimensions	Units
a,b	Coefficients of relative jump length depend on intensity	$M^0L^0T^0$	unitless
a`,b`	Coefficients of relative sequent depth depend on intensity	$M^0L^0T^0$	unitless
a``,b``	Coefficients of relative energy loss depend on intensity	$M^0L^0T^0$	unitless
c, d	Coefficients of relative jump length depend on relative roughness length	$M^0L^0T^0$	unitless
c_d	Coefficient of discharge	$M^0L^0T^0$	unitless
c`, d`	Coefficients of relative sequent depth depend on relative roughness length	$M^0L^0T^0$	unitless
c``, d``	Coefficients of relative energy loss depend on relative roughness length	$M^0L^0T^0$	unitless
E_1	The specific energy at the initial depth	$M^0L^1T^0$	cm
E_2	The specific energy at the sequent depth	$M^0L^1T^0$	cm
E_L	The energy loss due to the jump	$M^0L^1T^0$	cm

E_L/E_1	The relative energy loss.	$M^0L^0T^0$	unitless
F_1	The initial Froude number	$M^0L^0T^0$	unitless
F_r	The resistance force due to roughness	MLT^{-2}	dyne
F_{rr}	The relative roughness force resistance	$M^0L^0T^0$	unitless
G	Gate opening	$M^0L^1T^0$	cm
g	The gravitational acceleration	M^0LT^{-2}	cm/sec^2
I	The roughness intensity	$M^0L^0T^0$	unitless
L_b	The location of roughness with respect to the gate	M^0LT^0	cm
L_b/Y_1	The relative jump position	$M^0L^0T^0$	unitless
L_j	The length of the hydraulic jump	M^0LT^0	cm
L_j/Y_1	The relative jump length.	$M^0L^0T^0$	unitless
L_r	The roughness length	M^0LT^0	cm
L_r/Y_1	The relative roughness length	$M^0L^0T^0$	unitless
M_1	The momentum force at the beginning of the jump	$M.L.T^{-2}$	dyne
M_2	The momentum force at the end of	$M.L.T^{-2}$	dyne

	the jump		
P_1	The hydrostatic pressure force at the beginning of the jump	$M.L.T^{-2}$	dyne
P_2	The hydrostatic pressure force at the end of the jump	$M.L.T^{-2}$	dyne
q	The discharge per unit width	$M^0.L^2.T^{-1}$	cm^2/sec
r	The height of the bed roughness	M^0LT^0	cm
R	Correlation factor	$M^0L^0T^0$	unitless
R_N	Reynolds's number	$M^0L^0T^0$	unitless
V_1	The average velocity at the beginning of the jump	$M^0L.T^{-1}$	cm/sec
V_2	The average velocity at the end of the jump	$M^0L.T^{-1}$	cm/sec
Y_1	The initial depth of the hydraulic jump	M^0LT^0	cm
Y_2	The sequent depth of the hydraulic jump	M^0LT^0	cm
Y_2/Y_1	The relative sequent depth of the jump	$M^0L^0T^0$	unitless
γ	The specific weight of water	$ML^{-2}T^{-2}$	$dyne/cm^3$

μ	The dynamic viscosity	$ML^{-1}T^{-1}$	poise
ρ	The mass density	$ML^{-3}T^{0}$	gm/cm^3

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KEY WORDS:

Stilling basin, roughened stilling basin, hydraulic jump on roughened beds, stilling basin with roughness, stilling basins with blocks, baffled blocks, and USBR stilling basin.

Abstract

The stilling basins are commonly used to dissipate the energy and protect the down stream floor from erosion. Several researchers studied the efficiency of the stilling basins and how to improve their efficiency. The aim of the present work is to improve the roughened stilling basin using T-shape roughness instead of rectangular shape roughness and then design this new shape of roughness. In order to design the new stilling basin an experimental work was carried out. Five different intensities and eight different lengths were tested under four gate openings and six different flows for each gate opening. The experiments were carried out in the hydraulics laboratory of the Faculty of Engineering Ain Shams University. As a result of the present work the best intensity ranged between 7.2 to 8.8 % and the best roughness length as $L_r/Y_1=16$ where L_r = roughness length and Y_1= initial depth. The T-shape roughness save materials and reduce the jump length compared to the rectangular shape of roughness.

Chapter 1

INTRODUCTION

Irrigation structures have a great importance in our life allover the world. The irrigation heading up structures can be classified mainly into two categories: high head structures (such as dams and spillways) and low head structures (such as regulators and weirs). The problem is the excess energy that results from constructing these structures and the erosive action which happens downstream these structures due to this energy. So, heading up structures must be followed by energy dissipators to prevent the scour and erosion downstream such structures.

Hydraulic jump is considered as a powerful energy dissipator. Mainly it's formed downstream the hydraulic structure to convert the flow from supercritical flow to subcritical flow. But the hydraulic jump causes turbulence and apron erosion, so stilling basins are used to protect the downstream apron from erosion by dissipating the excess energy by the generated friction in terms of stilling basin blocks. The stilling basin blocks are arranged in a staggered way to make the path of high energy water longer to dissipate more energy.

As a matter of fact, the length of the stilling basin of a hydraulic jump should be long enough to permit the flow to regain its normal depth and velocity before the earthen section. Thus minimizing the length of the floor of the stilling basin is one of the important considerations from the economical point of view.

1.1 Scope of Work

The present experimental research aims at improving the efficiency of the stilling basins using a new shape of roughness elements (T-shape) from both the economical and hydraulic point of views and finding out the best intensity and length for the used shape. Such research would be carried out using physical model for the testing stilling basin.

1.2 Objectives

The main objectives of the present study may be summarized as follows:

1. Investigating theoretically and experimentally the flow over stilling basin using a new roughness shape.
2. Studying the flow characteristics and water surface profile along the stilling basin.
3. Determining the change in flow characteristics due to change in intensity and length of roughness.
4. Finding out the best length and the best intensity for the new shape of roughness.
5. Comparing between the new shape of roughness and the ordinary shape of roughness (rectangular shape).
6. Finding out which shape is more efficient and economic.
7. Calculating the efficiency of the designed stilling basin.

1.3 Plan of Study:

The study comprises six chapters that can be demonstrated as follows: