


AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
IRRIGATION & HYDRAULIC DEPARTMENT

SCOUR DOWNSTREAM IRRIGATION STRUCTURES

BY

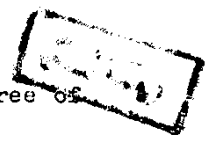
SOHEIR MOHAMED KAMEL

B.Sc. Civil Eng. - Ain Shams University



A THESIS

Presented in Application For the Degree of
MASTER OF SCIENCE
IN CIVIL ENGINEERING



SUPERVISED BY

Prof. Dr. MOHAMED WAFAYE ABDELSALAM

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

Prof. Dr. MOHAMED EL NIAZY HAMMAD

Head of Irrigation and Hydraulic Department,
Faculty of Engineering - Ain Shams University

Dr. ABDEL KAWY KHALIFA

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

1987

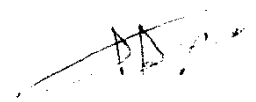

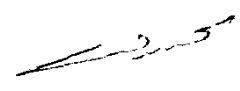

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

وَقُلْ أَعْمَلُوا فِى سَبِيلِ اللَّهِ
عَمَلَكُمْ وَرَسُولِهِ وَالْمُؤْمِنِينَ

صَدَقَ اللَّهُ الْعَظِيمُ



THE EXAMINERS

1. Prof. Dr. MOHAMED HAMDY EL-KATEB
Head of Irrigation and Hydraulic Depart.
Faculty of Engineering, Cairo University. 
2. Prof. Dr. ALY ABDEL-HAFEIZ HELMY
Prof. of Irrigation Design and Hydraulics
Faculty of Engineering, Ain Shams University. 
3. Prof. Dr. MOHAMED WAFAYE ABDEL-SALAM
Prof. of Irrigation Design and Hydraulics
Faculty of Engineering, Ain Shams University. 
4. Prof. Dr. MOHAMED EL-NIAZY HAMMAD
Head of Irrigation and Hydraulic Depart.
Faculty of Engineering, Ain Shams University. 

ACKNOWLEDGEMENTS

I would like to express my deep gratitude to Prof. Dr. Mohamed Wafaie Abdel-Salam , Professor of Irrigation Design, Faculty of Engineering , Ain Shams University, for his valuable contribution in the supervision and effective notes during the completion of this work .

I am also greatly indebted to Prof. Dr. Mohamed El-Niazy Hammad , Head of Irrigation and Hydraulic Department, Faculty of Engineering , Ain Shams University , for his generous help , moral support and kind cooperation .

I feel deeply grateful to Dr. Abdel-Kawy Khalifa , Lecturer of Irrigation Design, Faculty of Engineering , Ain Shams University , for his untiring efforts and constant encouragement throughout all steps of this work .

I am also deeply thankful to all the staff of Irrigation and Hydraulic Department , Faculty of Engineering , Ain Shams University , for their kind advice and great help in conducting this work .

LIST OF SYMBOLS

- D_{10} = Diameter of grain at passage of 10% of sieved material.
 D_{50} = Mean sediment diameter.
 D_{60} = Diameter of grain at passage of 60% of sieved material.
 d_s = Maximum depth of scour.
 d_0 = Characteristic depth of scour .
 F_1 = Froude number at vena contract.
 G = Gate opening.
 H = Water depth upstream the gate.
 h_o = The crest level of notch.
 h_n = The water surface reading.
 h = Difference between h_n & h_o .
 L = Length of solid apron , downstream the gate.
 R_n = Reynold's number .
 L_h = Whole length of scour.
 q = Discharge passing / unit width of the channel.
 Q = Discharge.
 T = Time.
 T_o = The time taken for maximum scour depth to attain a value of d_o .
 V = Velocity of flow.
 X_i, Y_i = Co-ordinates of point on scour hole.
 Y_1, Y_2, Y_3 = Water depths at three sections on solid apron.

ρ_s = Sediment density.

σ_g = Geometric distribution of sediment diameter about the mean.

ρ = Fluid density.

ν = Fluid kinematic viscosity.

γ_s^1 = Submerged weight of soil .

R = Coefficient of correlation .

L_s = The distance between the end of solid apron and the location of the maximum depth of scour .

INDEX

I- <u>INTRODUCTION</u>	1
II- <u>LITERATURE REVIEW</u>	5
2.1- Irrigation structures	7
2.2- Soil material	13
2.3- Scour holes	21
2.4- Time scale	33
2.5- Froude number	40
2.6- Depth of flow or water head	46
III- <u>THEORETICAL APPROACH</u>	47
IV- <u>EXPERIMENTAL WORK</u>	54
4.1- Apparatus	54
4.1.1-The flume	54
4.1.2-The gate	58
4.1.3-The bed soil materials	60
4.2- Methods of measuring	63
4.2.1-Measuring of discharge	63
4.2.2-Measurements of water depths	65
4.2.3-Measurements of scour depths	68
4.2.4-Measurements of the carriage positions	68
4.2.5-Steel mould	69
4.3- Test procedure	69

4.4- The experimental results	72
4.4.1-Contour lines of the scour readings in model A	72
4.4.2-Scouring and silting	122
4.4.3-Scour parameters	134
<u>V- ANALYSIS AND DISCUSSION</u>	135
5.1-Relation between the time factor and the contour lines of the scour area in model A	135
5.2-Relation between the time factor and maximum depth of scour	150
5.3-Relation between maximum length of the scour and maximum depth of scour	159
5.4-Relation between length of the deepest point of the scour hole and the maxi- mum depth of scour	170
5.5-Relation between dimensionless d_s and Froude No	179
5.6-Similarity of scour profiles and its general equations	188
5.7-Relation between variables of the scour	188
5.8-Relation between the time factor and the shape of the scour area in model B	244
5.9-Comparison between scour in models A and B	246

5.10- Comparison between the effect of the	246
supercritical and subcritical flow .	
in the scour hole .	
 VI- <u>CONCLUSION AND RECOMMENDATIONS</u>	250
6.1- Conclusion	250
6.2- Recommendations	251
* <u>APPENDIX</u>	252
* <u>REFERENCES</u>	275
* <u>ARABIC SUMMARY</u>	

I- INTRODUCTION

I- INTRODUCTION

Heading up works , such as weirs and regulators are the most water structures exposed to many of hydraulic actions resulting from water pressure forces . The most important action is scour action . The effect of scour action is very serious as it affects the stability of water structures directly causing failure with time .

Many types of energy dissipators are used to dissipate the amount of energy such as the hydraulic jump which can be formed only when a stream flowing with supercritical velocity is transformed to a subcritical flow. This operation followed by reduction of the velocity from $V > V_c$ down to $V < V_c$ where V_c is the critical velocity . During the velocity reduction , the stream loses a considerable amount of energy.

This energy which is dissipated helps to decrease the amount of scour .

The formation of the hydraulic jump depends on the relationship between the existing tail water depth and the depth required to form it. . Therefore, specially in a wide irrigation channel the depth of water required to form a hydraulic jump on the solid apron (down-

stream irrigation works) takes a considerable time to reach the required depth from the adverse flow . During this time a sheet flow of supercritical velocity is formed , and no energy dissipates on the apron . The velocities are very high in this case causing scour and erosion of the bed soil . The scour and erosion on soil leads to failure of some irrigation structures.

The case of sheet flow is the case where the flow is supercritical , velocities are very high and local scour and soil erosion are very dangerous . The study of the local scour and erosion on soil downstream irrigation structure and their effects on the stability of these structures are the aim of this work .

The scour process depends on many variables, mainly the velocity of approach flow . This process depends on the value of the velocity or in other expression on Froude number, whereas the velocity itself depends on the depth of flow.

From this view , the goal is studying of the scour process and its changes with time . As a plan for this study a one-vent regulator model representing an Egyptian irrigation

practice was chosen to clarify the scour effect on bed of two model channels. The aim of this research is to study the following main points :

- 1- Study of scour hole parameters .
- 2- Study of the changes of the scour hole parameters with respect to the time .
- 3-Develop the relationship between the dimensionless terms of scour hole relative to head of water upstream the gate .
- 4- Comparison between this case of sheet flow on the scour (super critical flow) and the scour occurring after the existence of hydraulic jump on the apron .
- 5- Comparative study of the scour on two different channel sections in ,downstream(models A and B).

This research work is divided into two parts, namely a theoretical study and an experimental study. In the theoretical study a dimensional analysis approach is used to develop the relation between all variables affected the scour . Also, it helps in understanding the behavior of the scour phenomenon .

In the experimental study two models are used , model A and model B . The two models are identically similar. Except the downstream channels, for model A it is trapezoidal in cross-section . While, for model B it is a rectangular in cross-section .

For model A the following experimental investigations were conducted under different flow conditions. The gate opening ranges from 1 to 2.5 cm. (4 different openings) three different heads of water upstream the gate ranges from 12 to 24 cm., twelve discharges ranges from 2.4636 to 8.7123 liter/sec., constant length of floor downstream the gate . One type of soil conformed the bed of model channel, Froude number ranging from 4.3 to 9.4 and five different times (5 - 90 min.) .

The same experimental investigations were conducted for model B but for three different gate openings (1 , 1.5 , 2 cm.) and for one head upstream the gate.

The water depth at different sections on the solid apron and the depths of scour were measured, and velocities of flow were calculated . Also , a contour map was prepared for the scour hole for each test.

The statistical analysis is used to analyse the experimental data and to prepare the necessary charts for the characteristics of scour .