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Prediction Of Maximum Scour Around Brige Piers Due To Aquatic Weed Racks

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1. ABSTRACT

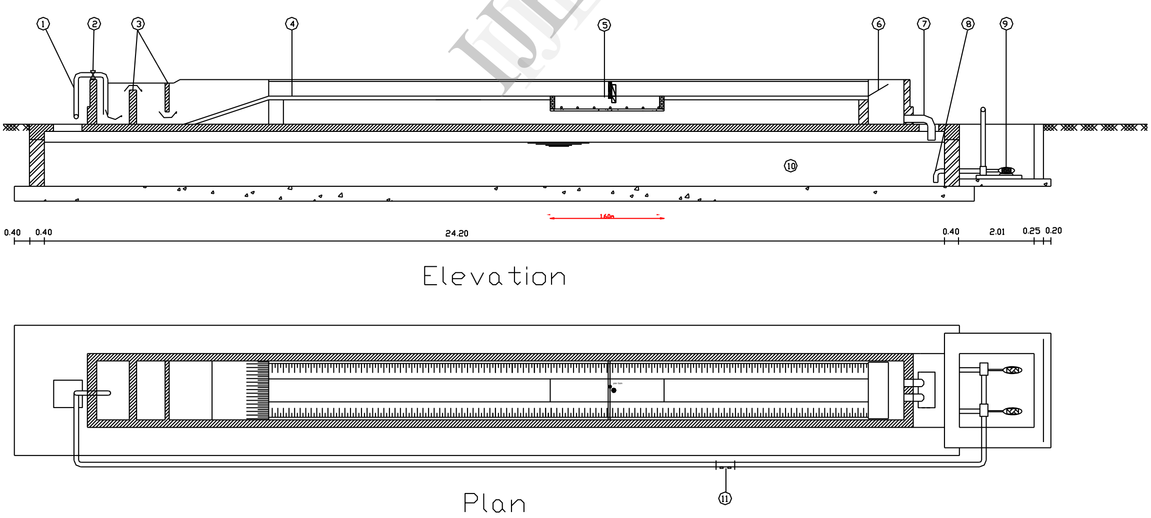
The formation of local scour holes around bridge piers is almost an unavoidable problem in alluvial channel beds subjected to the erosive action of oncoming flow. The design and construction of bridges spanning across alluvial channels requires the knowledge, or at least as accurate estimate as possible of maximum scour depth which might occur during the anticipated life of the bridge near the piers. Debris, consist of floating aquatic weeds and other resources, can have a substantial impact on bridge scour in several ways. A build-up of materials can reduce the size of the waterway under a bridge causing contractions scour and increase local scour in the channel. Installation of aquatic weeds racks may use the body of bridges for hanging up the rack structural elements; that cause buildup of floating weeds and trashes before piers, which cause significant impacts on scour around piers. The main interest of this research is to experimentally study the magnitude of the equilibrium local scour at bridge pier placed in sandy soil due to existence of weed racks and various configurations of weed accumulations. The study went through physical models for 145 scour test runs; the research produced results for developing improved methods for quantifying the depth of scour at bridge piers considering both the accumulation variables and the range of hydraulic factors involved.

2. INTRODUCTION

Most of the open water irrigation channels in Egypt suffer from heavy infestation of aquatic weeds especially the submerged and floating ones that cause lots of hydraulic problems for the open channels such as increasing water losses, obstructing water flow, and reducing channels water distribution efficiencies as well as threat the hydropower plants. Installations of aquatic weed racks are commonly used solution for keeping water distribution efficiency and saving the hydropower plants turbines through trapping floating weeds and other trashes. Such installation either through using the body of bridge structure for hanging up racks structural elements or insert isolated piers to support aquatic weeds racks' own weight and resist forces exerted by trapped floating weeds and trashes. These construction methodologies may cause excessive local and contraction scour around piers, either bridge piers or the inserted ones. The effects of floating weeds accumulation can vary from minor flow constrictions to severe flow contraction resulting in significant pier scour. This research accomplished its basic objectives of developing guidelines for predicting the depth of scour hole at bridge piers due to weeds and trashes accumulations as well as methods for quantifying such scour due to these accumulations. Laboratory studying plan was proposed to develop a series of tests for a wide range of floating weeds configurations under clear water sediment transport conditions.

3. EXPERIMENTAL WORK

The experimental work performed by T.Gamal for his PhD Thesis. The experimental was carried out in the hydraulics laboratory of the Channel Maintenance Research Institute within the National Water Research Center, El_Kanater El_Khairiah, Egypt. The flume used in the experimental work is a reinforced concrete flume and has a total length of 22.10 m. The operating system of this flume is re-circulated through an underground reservoir, with dimensions (24.10 m long, 1.75 m wide, and 1.5 m height) to supply the flume with water. The layout of the flume and all the hydraulic structures within the experiment can be shown in Figs (1).



1 5 inch diameter pipe
2 Control valve
3 Turbulence elimination
4 Horizontal bed trapezoidal flume
5 Sand Basin
6 Tilted tail gate
7 8 inch diameter drain pipe
8 5 inch diameter suction pipe
9 Group of motors and pumps
10 Under ground reservoir
11 Current flow meter

Figure (1) experimental flume and its underground reservoir

Graded sandy soils were tested to study its characteristics on local scour. The sample was sieve analyzed to be used in all experiment runs. The mean diameter of the experiment bed material is D_{50} = 0.50 mm. To study the impact of floating aquatic weed´s accumulation at weed rack in open channel on local scour depth around piers, a single weed rack with various depths and blocked portion was installed in flume Fig (2), (3). Five different discharges were examined for simulation cases in this study as 20, 25, 30, 35 and 40 liter/second; and three various trash rack depths Y_b as (2/3, 1/2 and 1/3 of water depth (Y) from water surface), as water depth kept constant at 30 cm, are used with each discharge. For every trash rack's depth, opening areas of trash racks were varied from 10% to 90% as Mentioned opening area percentages are referred to total opening area of total water cross section. The simulation cases are divided into three main groups based on racks' depth.

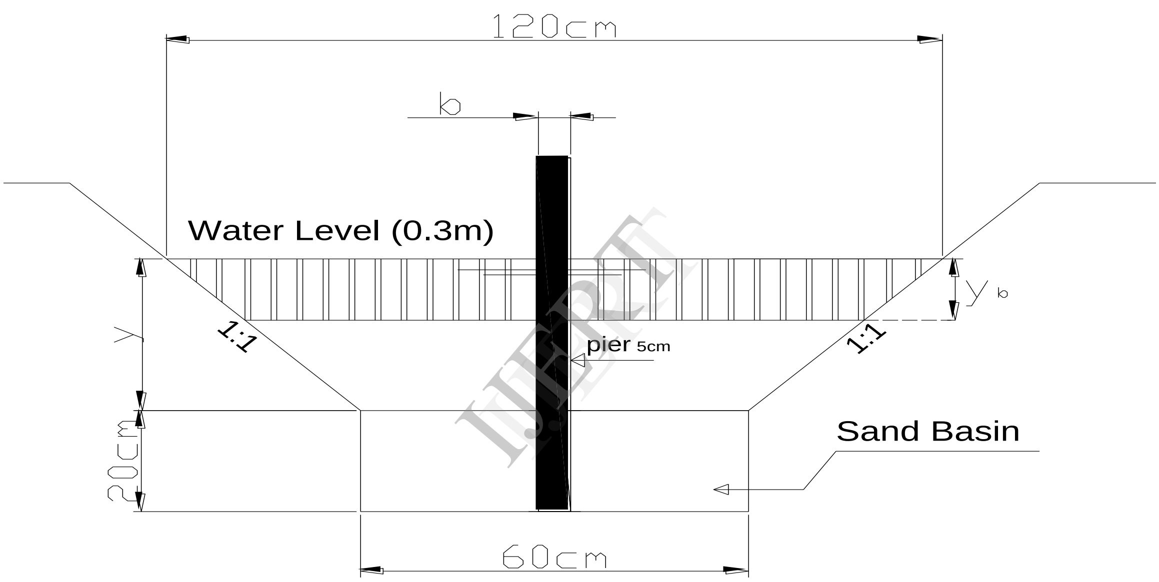


Figure (2). Definition sketch for flume structure, scoured soil basin, pier and weed rack.

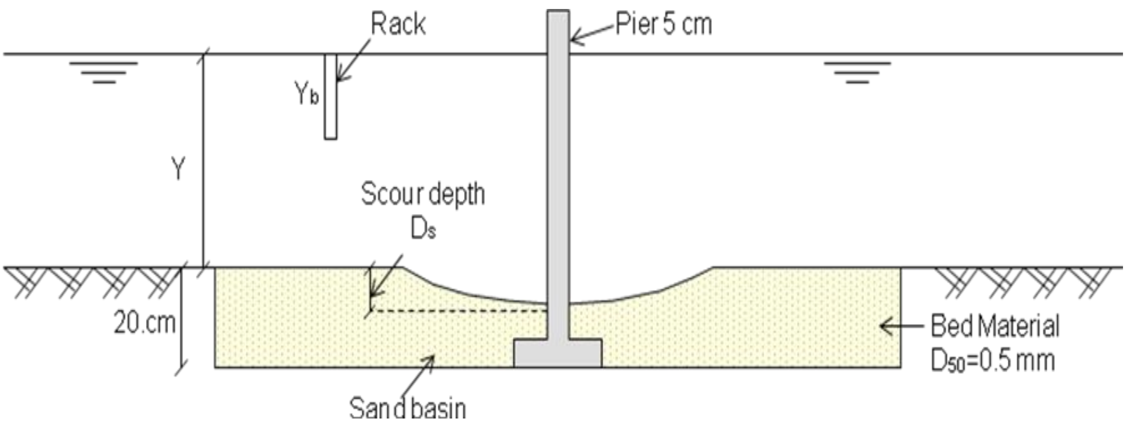


Fig (3) Definition sketch for weed rack, scour depth and bed materials.

4. RESULT AND DISCUSSION.

Froude number were found in proportional relationship with scour depth; which make sense as scouring forces and shear stress at the bottom of the pier increase due to the reduction of cross section opening area and flow is pressured to detour underneath the rack. Rack´s depth was found to have significant impact on scour depth; so shallow rack allow flow pass more smoothly beneath the rack as water opening is considered to be close to water surface, while in case of deep rack; flow passes roughly under pressure with higher velocities underneath the rack through water opening which is considered to be away from water surface; that cause increase in downward forces which increase scour of bed materials. The result points were regressed using statistical software and three power equations were obtained for relations between Froude number and scour depth (d_s) for various rack depths Y_b as following :-

For rack depth (Y_b) = 2/3 (Y)

$$d_s / b = 27.47 (F_r)^{3.21} (A_0/A_T)^{-1.7}$$

Coefficient of multiple determination (R^2) =.92

Adjusted Coefficient of multiple determination (R_a^2) =0.912

For rack depth (Y_b) = 1/2 (Y)

$$d_s / b = 471.13 (F_r)^{5.7} (A_0/A_T)^{-1.57}$$

Coefficient of multiple determination (R^2) =0.89

Adjusted Coefficient of multiple determination (R_a^2) =0.89

For rack depth (Y_b) = 1/3 (Y)

$$d_s / b = 2239.1 (F_r)^{7.78} (A_0/A_T)^{-4.84}$$

Coefficient of multiple determination (R^2) =0.897

Adjusted Coefficient of multiple determination (R_a^2) =0.89

Where

d_s scour depth mm

b pier diameter (mm)

F_r Froude number

A_o Area opening (cm^2)

A_t Total water cross section area (cm^2)

Relation between discharges and average scour depth

Fig (4) shows the relation between discharges and average scour depth for various blocking percentages for three racks' depths. The scour depth was found proportionally increasing as Froude number increases and preference of achieving minimum scour depths are associated with lower rack depths and lower discharges.

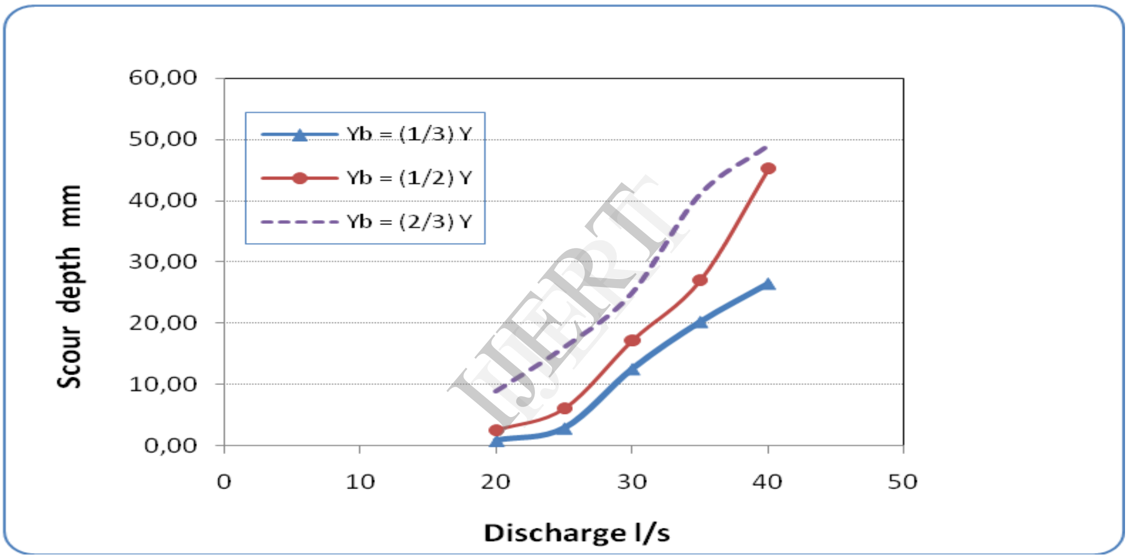


Fig (4) Relation between discharges and average scour depth for rack's depth Y_b = 1/3, ½ and 2/3 water depth (Y).

Effect of rack depth on discharge reduction percentage

To investigate the effect of rack's depth and blocking percentages on discharge reduction (Q_{red}%); the discharge reduction percentage (Q_{red}%) corresponding to five discharges (20, 25, 30, 35, 40 liter/sec) under condition of three rack depths were plotted against blocking percentage of weed rack as shown in Fig (5, 6, 7, 8, 9). For three cases of mentioned rack depths, shallower rack's depth recorded minimum discharge reduction for the majority of rack blocking percentages. The reduction in discharge is obviously due to the increase in blocked area that increase heading up and create larger back water curve and increase the associated storage volume before rack.

Q_{red} = water surface heading at rack (Δh) multiplied by velocity at depth (Δh/2) multiplied by Top water width (120 + Δh), Figure (2).

Q_{red} % = Q_{red} / Q (passing)

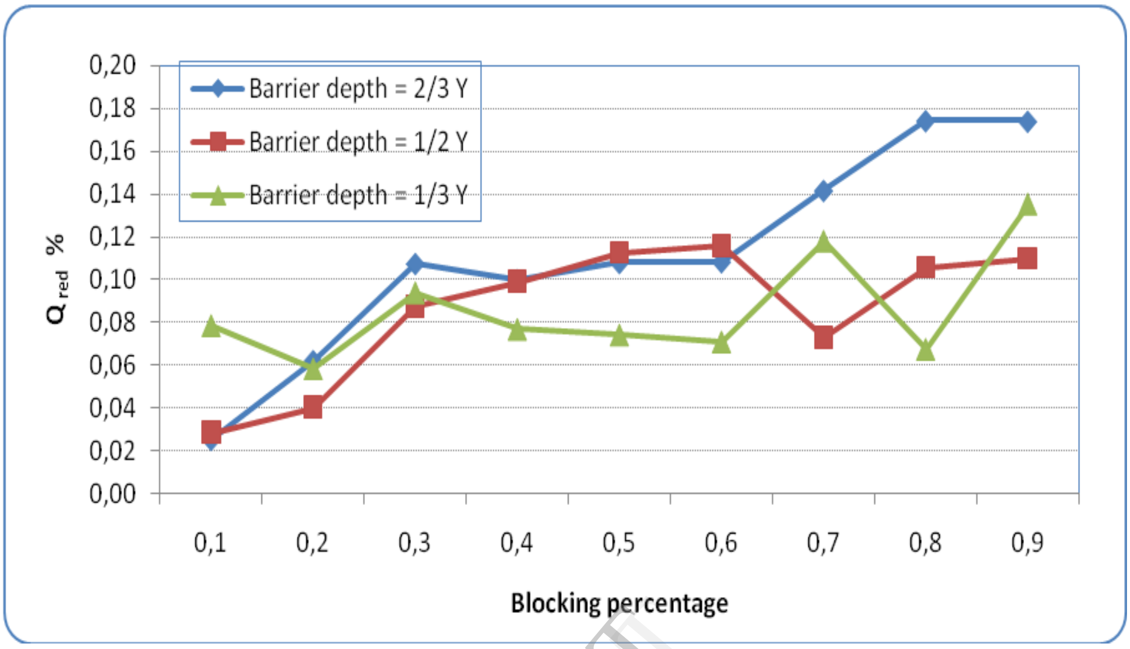


Fig (5) Effect of rack depth on Q_{red}% (Discharge = 20 l/s) for different blocking percentages.

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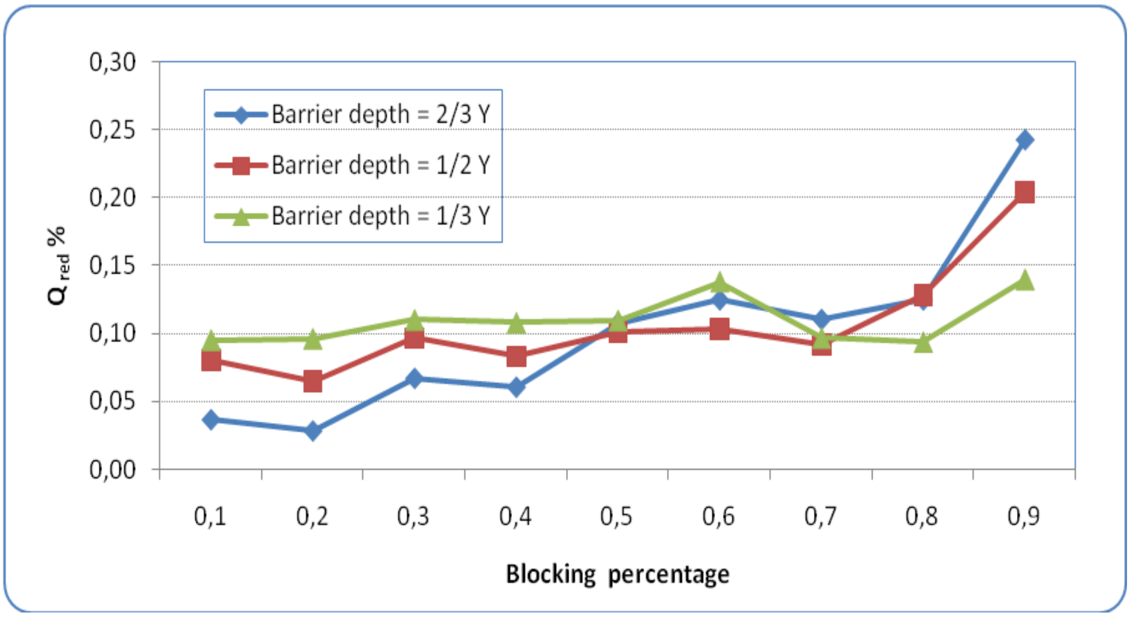

Fig (6) Effect of rack depth on Q_{red}% (Discharge = 25 l/s) for different blocking percentages.

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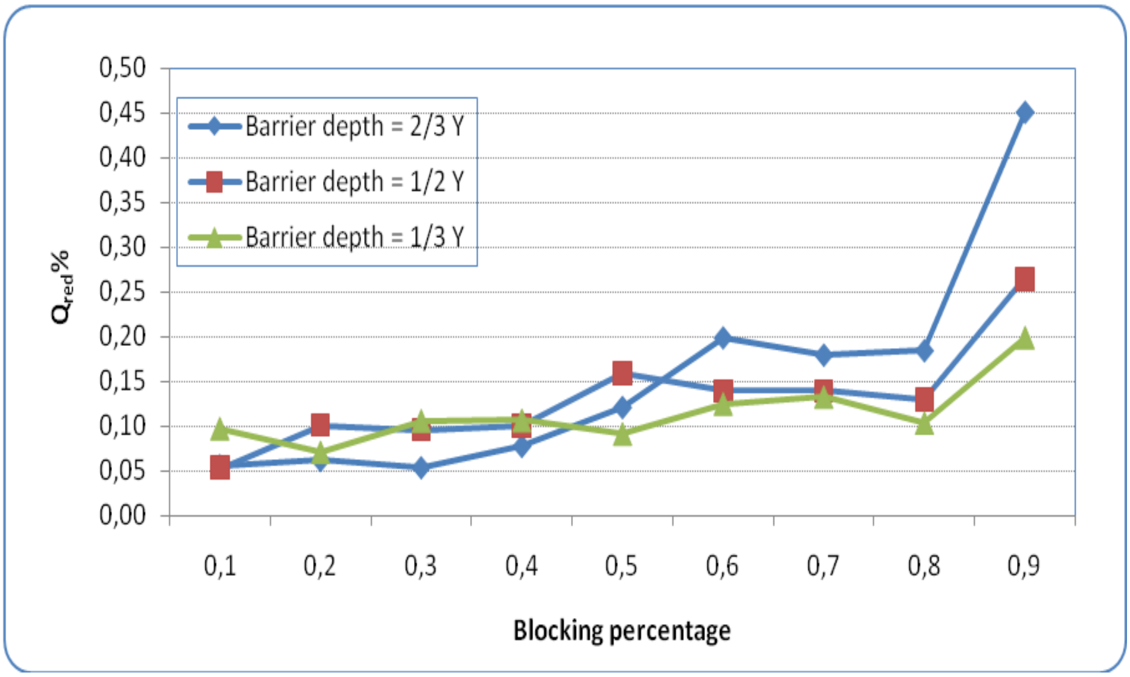

Fig (7) Effect of rack depth on Q_{red}% (Discharge = 30 l/s) for different blocking percentages.

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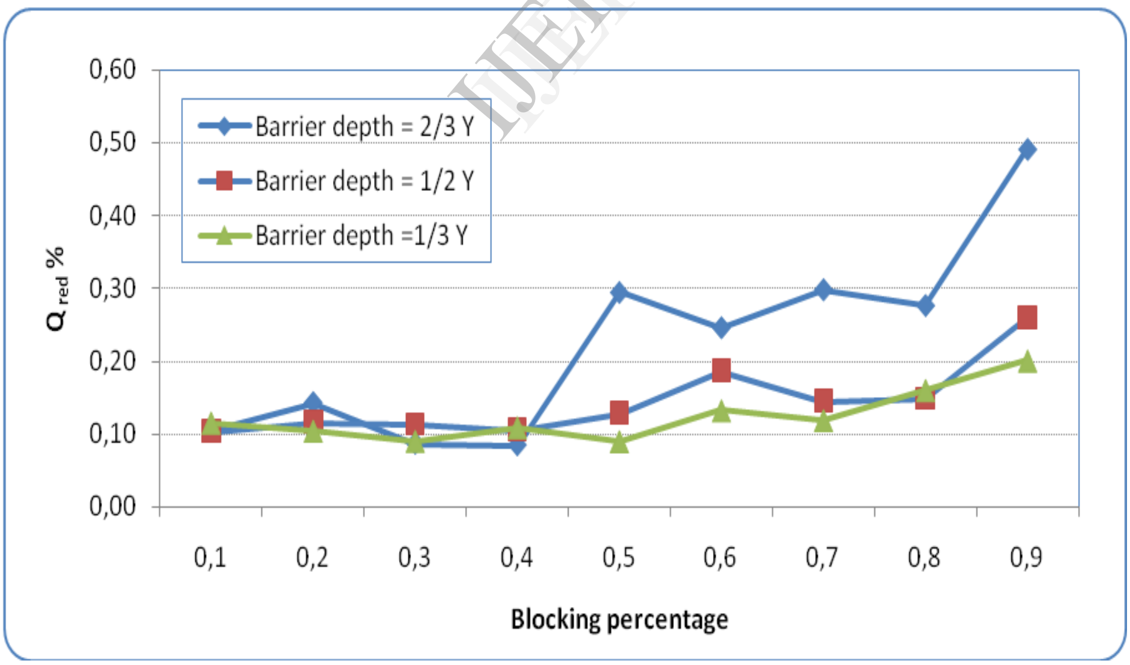

Fig (8) Effect of rack depth on Q_{red}% (Discharge = 35 l/s) for different blocking percentages.

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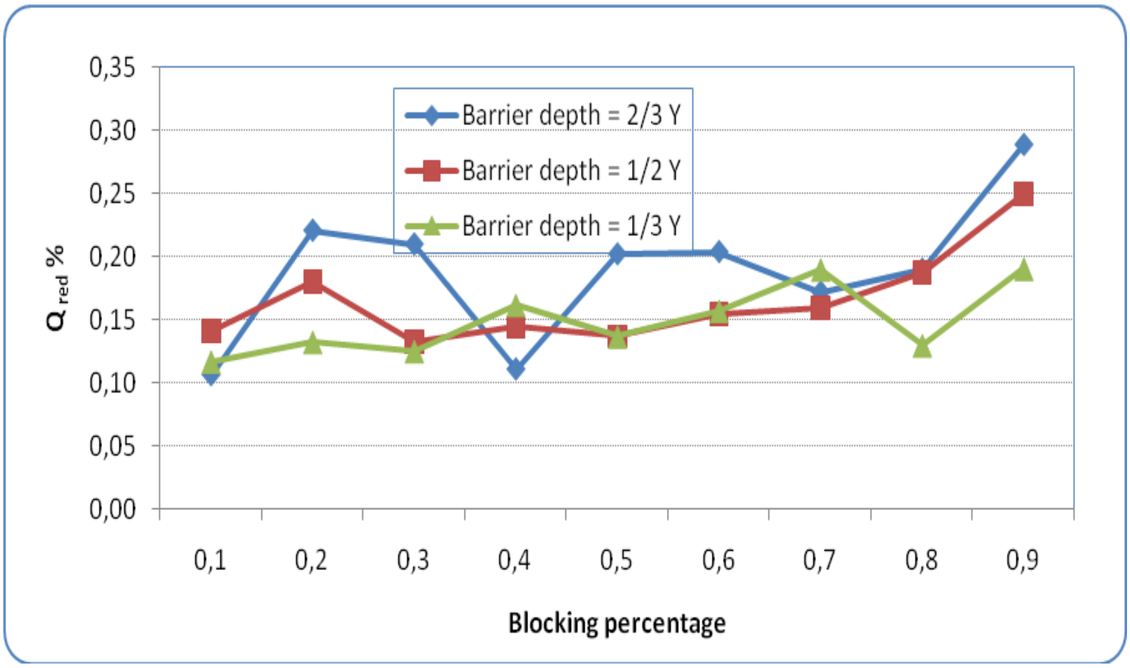

Fig (9) Effect of rack depth on Q_{red}% (Discharge = 40 l/s) for different blocking percentages.

5. CONCLUSIONS

1- Proportional relationship was found between Froude number and scour depth at pier due to increasing velocity and shear stresses at the bottom of the pier.

2- Blocking ratio found increases discharge reduction significantly. Up to stage of 40% blocking ratio of the total rack surface area, the reduction to some extent increases. Higher than 40-50% blocking ratio, the increase in discharge reduction record abrupt increase to sever values.

3- Blocking ratio increases scour depth in general case. The scour depth slightly increases according to blocking ratio. The scour depth start to Jump to extreme values as blocking ratio goes higher than 40-50%.

4- Rack depth proved to have influence on scour depth as it increases Froude number and also increase discharge reduction.

5- Rack depth of one third of water depth proved to be acceptable depth as it resulted in least values for scour depth and discharge reduction.

6. REFERENCES

- ✍ Abdou, M.I., (1993). ”Effect of Sediment Gradation and Coarse Material Fraction on Clear-water Scour around Bridge Piers” Ph .D. Dissertation, Colorado State University.
- ✍ Abed, L. (1991). “Local scour around bridge piers in pressure Flow,” PhD Dissertation, Civil Eng. Dept., Colorado State Univ., Colorado, USA.
- ✍ Ahmed Ferdous and Rajaratnam N., (1998). “Flow around bridge piers”, Jour. Hydr. Eng. ASCE, Vol. 124, No. 3, PP 288-300.
- ✍ Breusers, H.N.C. Nicollet, G. and Shen .H.W. (1977); "Local scour around cylindrical piers" J.Hydr. Res. Delft. The Nether lands 15 (3) 221-252.
- ✍ Chital,S., (1962). “Scour at Bridge Crossing”. ASCE .Vol.1, PP191-196.
- ✍ Daragahi, B., 1987, Flow field and local scouring around a cylinder, Bulletin TITRAVBU-137, Department of hydraulics Engineering , Royal Institute of Technology Stockholm, Sweden.
- ✍ Ettema R., (1980). “Scour at Bridge piers” University of Auckland, School of Engineering, Rep. No.216, Auckland, New Zealand.
- ✍ Hopkins, G.R., Vance, Vance R.W., and Kasraie B. (1983); Scour around bridge piers, Federal Highway Administration, Washington D.C. final Report FHWA- RD-78-163., (1980).