INVESTIGATING THE FLOW CHARACTRISTICS USING DIFFERENT GROIN LENGTHS AND ANGLES

دراسة خصائص الأنسياب بأستخدام رؤس حجريه مختلفة الأطوال والزوايا

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الخلاصة:

يهدف البحث لدراسة تأثير الرؤوس الحجريه على خصائص سريان المياه فى القنوات المكشوفه حيث تم تنفيذ ٢٨ إختبار بمعامل معهد بحوث الهيدروليكا التابع للمركز القومى لبحوث المياه وتم إختبار ثلاث متغيرات (معامل إختناق المجرى، زاوية ميل الرأس الحجريه، والتصرف المار خلال المجرى). كان معامل إختناق المجرى المستخدم هو ١، ١٥، و ٢، وكانت زاوية ميل الرأس الحجريه المستخدمه هى ٦٠°، ٩٠°، ١٢٠°. تم إختيار عدة تصرفات مختلفه هى ١٠، ٢٠، و ٣٠ لتر/ث وعند إمرار كل تصرف يتم إختبار تأثير زاوية ميل الرأس الحجريه وأيضاً إختبار تأثيرمعامل إختناق المجرى. كان الهدف من هذه الأختبارات تحديد أقصى وأقل طول فعلى مؤثر للرأس الحجريه على التغيرات المورفولوجيه لقاع المجرى حيث تم تسجيل التغيرات الرسوبيه للقاع وأيضاً عمق وعرض النحر المتكون. بعد ذلك تم تحليل وتمثيل البيانات و بناء على الملاحظات المعمليه تم دراسة تأثير الرؤوس الحجريه المختلفة الزوايا والأطوال عند التصرفات المختلفه على الأنسياب وتوزيع السرعات. أيضاً تم عمل علاقات هندسيه مختلفه بين خصائص الرؤوس الحجريه وأيضاً خصائص إنسياب المياه مع خصائص النحر والترسيب. من أهم النتائج التى تم إستنتاجها أن الرؤوس الحجريه الرأسيه (بزاويه ٩٠°) بمعامل إختناق ٢، يعطى أقصى طول فعلى وأن الرؤوس الحجريه أيضاً بزاويه ٩٠° ولكن بمعامل تقلص ١، تعطى أقل طول فعلى أيضاً تم ملاحظة أن التغيرات المورفولوجيه تتناسب طردياً مع طول الرأس الحجريه ومع التصرف المار بالمجرى.

ABSTRACT:

This research aims to investigate the impact of river training structures (i.e. groins or spur dikes) on the flow characteristics of a stream. Twenty eight run experiments were carried out in the Hydraulics Research Institute (HRI), the National Water Research Center (NWRC). Three main effective variables were tested (i.e. contraction ratio (L/B), groin orientation angle, and the discharge). It is to be noted that the tested contraction ratios were 0.1, 0.15 and 0.2. On the other hand, the tested orientation angles were 60°, 90° and 120° (i.e. attracting, straight, and repelling groins, respectively). The tested discharges were 10, 20, and 30 litre/s.

Measurements were undertaken to determine the working length, scour, so as silting geometry and observations were documented. The measurements were analyzed and represented. Based on the experimental observations, the effect of the groins on the flow was described. Also, prediction attempts, to describe the interaction between the groin-fields and the main channel, are presented.

Based on the analyzed experimental results, it was clear that the straight groin of 0.2 contraction ratio provides the maximum working length while, the attracting groin of 0.1 contraction ratio provides the minimum working length. It was also determined that the morphological changes are directly proportional to groin length and discharge.

Keywords: Groins, Flume Model, Contraction Ratio, Orientation Angle, Working length.

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1. INTRODUCTION

Groins (spur dikes) are structures constructed at an angle to the flow in order to deflect the flowing water away from critical zones. Unfortunately, they induce negative impacts on the stream bed and banks.

The various mechanisms of stream bank erosion generally fall into two main groups, bank scour and mass failure. In many cases of bank instability both will be evident. Bank scour is the direct removal of bank materials by the physical action of flowing water and are often dominant in smaller streams and the upper reaches of larger streams and rivers. Mass failure (i.e. bank collapse and slumping) occurs when large chunks of bank material become unstable and topples into the stream or river in single events. Mass failure is often dominant in the lower reaches of large stream and often occurs in association with scouring of the lower banks. By looking carefully at the processes operating at a site it might be possible to reduce the probable causes of instability.

As flow speed increases, the erosive power of flowing water also increases and scour might occur. Undercutting of the bank toe is an obvious sign of scour processes. Effective strategies for combating scour are generally aimed at reducing flow speed through renegotiation and in some cases through strategic bank or channel works.

Due to the importance of combating the scour, this study was initiated. It was conducted at the HRI (NWRC). The investigation steps so as the obtained results are given in this paper.

2. LITERATURE REVIEW

Primarily, the literature, in the field of scour and scour protection, was reviewed. Many researchers were interested in that field. For example:

- In 1992, the **World Wildlife Found** published a report named 'Living Rivers'. This plan has the objective to recover the natural river landscape that will lead to a return of river characteristic plants and animals. Next to this plan, many initiatives and plans from different points of view, like navigation, nature and landscape have been published.
- **Ibrahim M (2010)** developed a 2-D hydrodynamic model to investigate the effect of spur dikes on local scour but it was a mathematical investigation. On the other hand, this research applied the physical model to be more confidence and accurate.

Based on the above literature, a shortage in the experimental investigations was evident. For that reason, the present research was initiated with set objectives.

3. STUDY OBJECTIVES

The main objectives of this research are:

- Study the water level along the flume with and without groins.
- Investigate the effect of groins on the water velocity and the scour
- Study the working length of groins in order to determine the number of utilized groins; the best length and angle of groins to produce a low scour depth and a low silting height.

4. THE EXPERIMENTAL WORK

The experimental work was carried out in the laboratory of the HRI of the NWRC, Delta Barrage.

4.1. THE IMPLEMENTED FLUME

The used flume has a rectangular cross section with overall length 40.0 m, 0.4 m width and 0.6 m deep, Figure (1). The side walls along the entire length of the flume are made of glass with wood-frames, to allow visual investigation of the flow patterns and stability of bed protection. The horizontal bottom of the flume is made of ceramics and wood. The water enters the flume from a pump which feeds the flume with a maximum discharge of 30 l/s. The flume is equipped with a steel wooden gate with an orifice with a rectangular shape. There is, also, a movable downstream gate. It is located at the end of the flume. The bed material size is around 0.6 mm at 50% passing and the density of the sand is around 2.6 Kg/m^3, Figure (2). It was checked by sieve analysis before it was used.

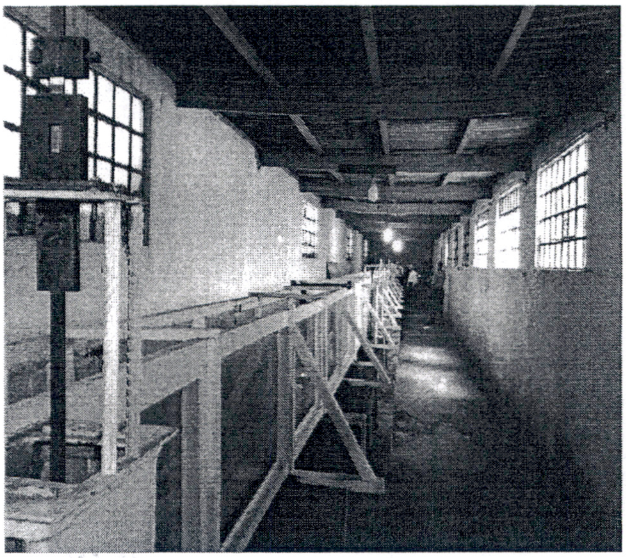

Fig. 1: General View of the Used Flume

4.2. THE IMPLEMENTED BED MATERIAL

The flume has a moveable bed (i.e. moving particles). These particles were chosen to be sand. A sieve analysis was thus executed to the chosen bed material.

A sieve analysis is a practice or procedure used to determine the particle size distribution of the granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal, manufactured powders, grain and seeds, down to a minimum size depending on the exact method. The Standard grain size analysis test determines the relative proportions of different grain sizes as they are distributed among certain size ranges. The grain size analysis is widely used in classification of soils. Information obtained from grain size analysis can be used to predict soil water movement although permeability tests are more generally used. The balance to be used should be sensitive to the extent of 0.1% of total weight of sample taken.

The results of the executed sieve analysis, to the used bed material (i.e. sand), are given in Figure (2).

Sample (1)

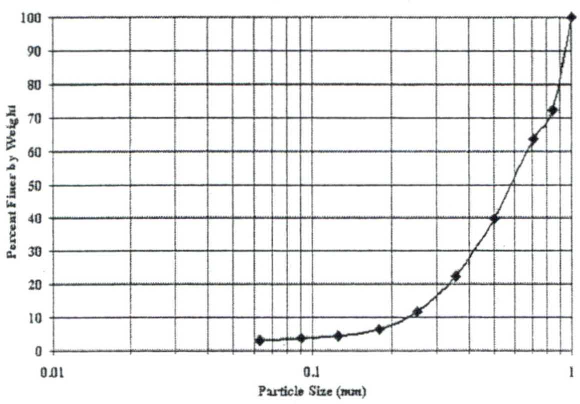

Fig. 2: Results of the Bed Material Sieve Analysis

4.3. IMPLEMENTED MEASURING DEVISES

The implemented measuring devices comprised a flow meter, current meter and gauges. A camera and a video were also available.

One ultrasonic flow-meter with an accuracy of $\pm$ 1% were used to determine the discharge. It was installed on a 16" diameter feeding pipe, Figure (3).

Fig. 3: Ultrasonic Flow-Meter

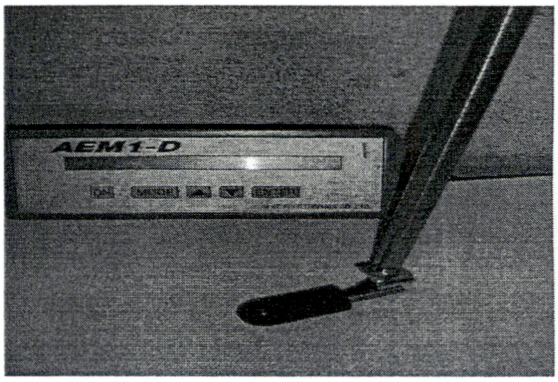

Fig. 4: Electro-Magnetic current-meter

The flow velocities were measured using an Electro-Magnetic current-meter type E.M.S. (manufactured by Delft Hydraulics), Figure (4). The device was connected to a mean value meter to show the average velocity within a selected time period.

To monitor the water levels, two point gauges with side stilling wells were installed. Also, a mobile point gauge with an accuracy of ± 0.1 mm was used to measure the water and bed level.

Video and photo cameras were also essential to record the flow patterns and to monitor the stability of the rip-rap. In order to measure the flow discharges, flow meter sensors were installed on the flow feeding pipe.

4.4. EXECUTED MODEL RUNS

A comprehensive test program was thus designed, Table (1), to cover the different flow and operation conditions of the flume. Different contraction ratios (ratio between groin Length and flume width (40 cm) were investigated. The tested ratios were 0.1, 0.15 and 0.2. Different orientation angle degree was tested. The orientation angle is the inclined angle between the groin and the flow. The tested angles were 60, 90, and 120 degree. Also, different discharges were tested. These were 10, 20, and 30 l/s.

Runs were executed and measurements were undertaken.

5. OBTAINED RESULTS OF THE WORKING LENGTH

The measurements results were analyzed and tabulated. Table (1) gives the values of the working length to the different executed runs.

Table 1: The working length

RUN NAME	Working length (m)	R.P (m) Depth	S.P (m) Width
$10S_{20}$	1.290	0.410	0.880
$20S_{20}$	1.860	1.460	0.400
$30S_{20}$	3.690	3.160	0.530
$10A_{20}$	0.814	0.259	0.555
$20A_{20}$	1.175	0.925	0.250
$30A_{20}$	2.330	2.000	0.330
$10R_{20}$	1.100	0.350	0.750
$20R_{20}$	1.590	1.250	0.340
$30R_{20}$	3.150	2.700	0.450
$10S_{15}$	0.920	0.850	0.070
$20S_{15}$	1.100	0.950	0.150
$30S_{15}$	1.730	1.500	0.230
$10A_{15}$	0.870	0.810	0.060
$20A_{15}$	0.970	0.870	0.100
$30A_{15}$	1.370	1.200	0.170
$10R_{15}$	0.500	0.440	0.060
$20R_{15}$	1.140	0.950	0.190
$30R_{15}$	1.715	1.500	0.215
$10S_{10}$	0.600	0.540	0.060
$20S_{10}$	0.890	0.755	0.135
$30S_{10}$	1.490	1.300	0.190
$10A_{10}$	0.375	0.330	0.045
$20A_{10}$	0.705	0.625	0.080

$30A_{10}$	1.010	0.900	0.110
$10R_{10}$	0.335	0.300	0.035
$20R_{10}$	0.730	0.650	0.080
$30R_{10}$	0.980	0.850	0.130

Notes :

S : straight groin (i.e. angle 90^0)

A : attracting groin (i.e. angle 60^0)

R : repelling groin (i.e. angle 120^0)

xS_y : one of the tested straight groin cases

xA_y : one of the tested attracting groins cases

xR_y : one of the tested repelling groins cases

x : discharge in l/s (i.e. 10, 20 and 30 l/s were tested)

y : contraction ratio (i.e. 0.1, 0.15 and 0.2 were tested)

From the table it can be deduced that:

- For a fixed orientation angle and discharge, the working length is directly proportional to the groin length.

- The effectiveness differs according to the groin type. The most effective type was found to be the perpendicular one as it indicates the longest working length. There was a very clear similarity between the repelling and attracting type groins. The similarity was found between angle 60^o (repelling) and 120^o (attracting) with slight increase in the working length for the repelling type that started from a contraction ratio of 0.20.

6. EFFECTS ON BED CONFIGURATION

The bed configuration (i.e. scour hole and silting), was investigated. The results of these investigations were plotted.

6.1. SCOUR HOLE

The scour hole was investigated. The results of these investigations were plotted on figure (5). It could be noticed that:

- The straight groin presents the maximum scour values in terms of length and depth and width.

- The attracting groin presents the minimum values under fixed groin length and discharge.

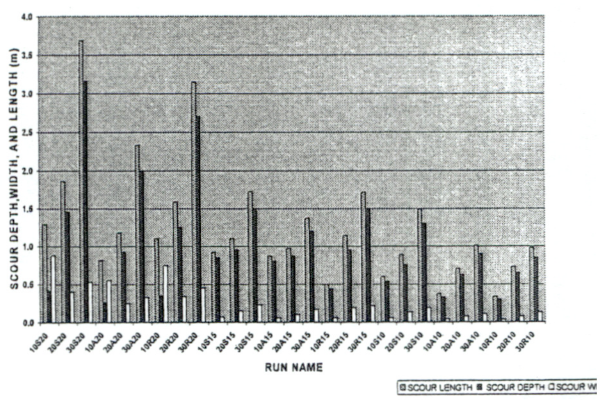

Fig. 5 : Length, Depth, and Width of Scour Holes

Also, figures (6), (7), and (8) illustrate the sensitivity of scour hole against groin length, orientation angle, and discharge respectively. It could be noticed that:

- The scour depth has less sensitivity to the tested variables than the scour width.
- Both groin length and discharge presents the same attitude with the geometry of scour hole.
- The orientation angle affected the geometry of scour holes (i.e. the straight groin of 90° showed the minimum scour length, the attracting groin presented the peak value.
- The impact of the orientation angle was exclusive on the scour length; however it was inconsiderable on the scour depth.

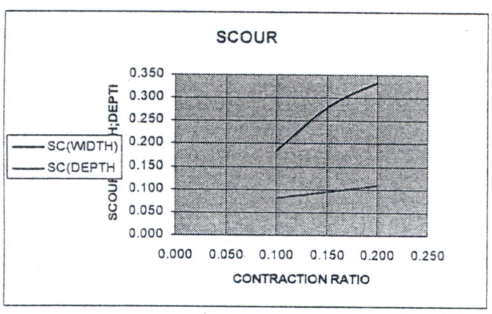

Fig. 6: Effect of Contraction Ratio on the Scour Holes

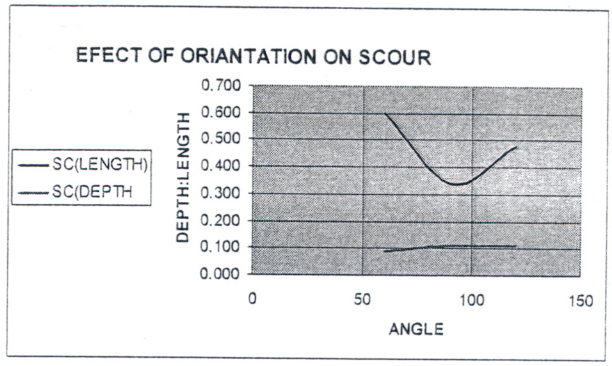

Fig. 7: Effect of Orientation Angle on the Scour Holes

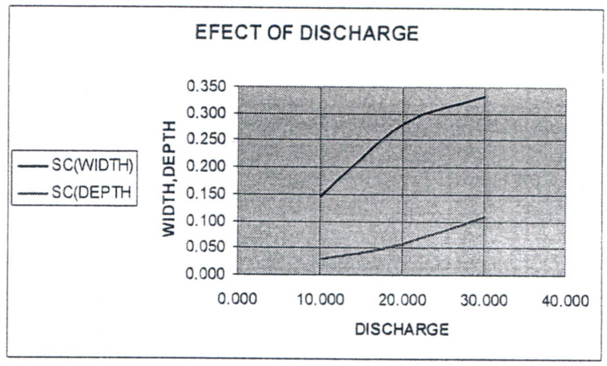

Fig. 8: Effect of Discharge on the Scour Holes

6.2. SILTING

Tests assured to the presence of both scour holes and silting accumulations. The geometry of the silting form depends on groin length, orientation angle, and discharge. The measurements results were plotted on figure (9). From the figure it can be seen that:

- The straight groin produced the maximum silting height.
- The attracting groins (i.e. repelling groin) produced the minimum silting height.

- The impact of the tested variables on silting width was higher than their impact on silting height. This was also noticed with respect to the scour holes.
- Both groin length and discharge are directly proportional to the silting parameters (width and height).
- The impact of orientation angles on silting height was trivial.
- The straight groin of 90° produces the maximum silting width value.
- The repelling groin produces the minimum silting width value.

7. EFFECT OF CONTRACTION, ORIENTATION AND DISCHARGE

The impact of contraction ratio, orientation angle, and discharge on the geometry of silting region was investigated. Figures (10), (11), and (12) represent the results of this investigation.

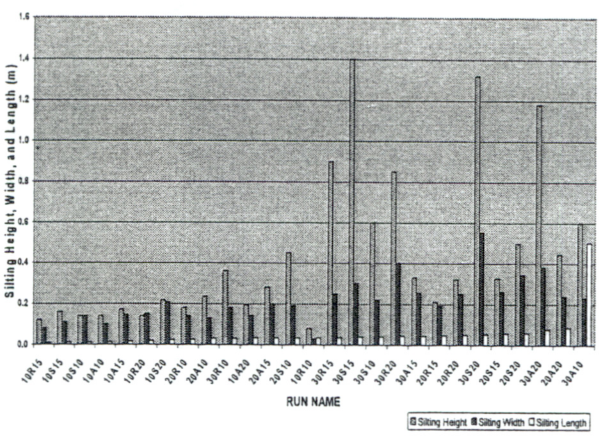

Fig. 9: Height, Width and Length of Silting

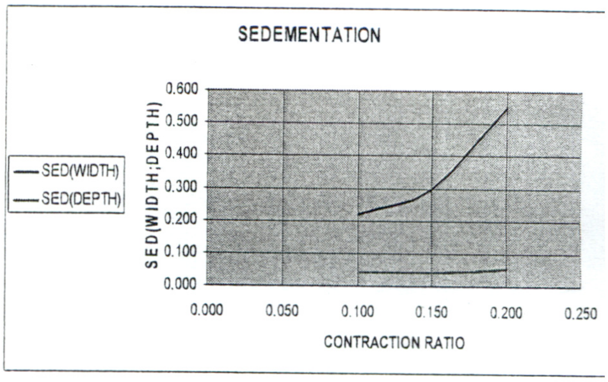

Fig. 10: Effect of Contraction Ratio on Silting

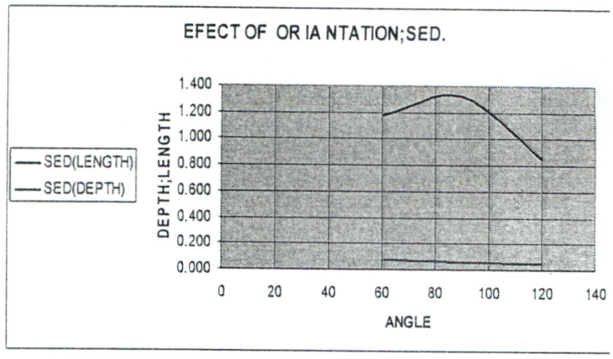

Fig. 11: Effect of Orientation Angle on Silting

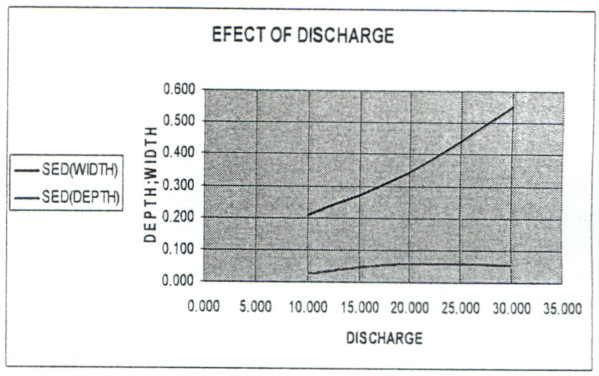

Fig. 12: Effect of Discharge on Silting

8. CONCLUSIONS

This study investigated the effect of angled single groin located in open channel on working length, and bed configuration including scour and deposition. Based on the results, it was concluded that:

- The working length is directly proportional to discharge and groin length.
- The straight groin of 90° presented the maximum working length under fixed discharge and groin length.
- The straight groin gave the maximum scour depth and silting height.
- For fixed orientation angle, both groin length and discharge are directly proportional to scour hole and deposition.
- The impact of testing parameters on scour depth and silting height is negligible when compared to their impact on scour and silting lengths.

It was further recommended to:

- Examine a greater range of orientation angles.
- Investigate a wider domain of groin lengths.
- Study more contraction ratios and a wider range of discharges.

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