International Journal of Water Resources and Environmental Engineering Vol. 3(8), pp. 167-175, September 2011
Available online at http://www.academicjournals.org/ijwree
ISSN 1991-637X ©2011 Academic Journals

Full Length Research Paper

The effect of inclined groins on the flow

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Accepted 26 July, 2011

Hydraulic structures, such as pile dikes, groins, splitting dikes, have been constructed in natural rivers to improve the channel stability to bank or bed erosions by reducing flow velocity or changing flow direction. In order to produce better river environments, river flow mechanisms with the hydraulic structures need to be intensively studied. In this paper, an experimental flow field with non-overflow groins in a straight rigid-boundary channel was produced, and the characteristics of the flow with groins positioned in stagger were also investigated by measuring two dimensional flow velocity fields. Eight different types of groins were positioned on the left side of the model channel. The velocity distributions around the groin and the geometry of bed flume before and after are measured. The effects of various groin parameters (width of groin per channel width, and its inclination) on the change in water velocity are studied. The model studies are performed using regular waves in a basin. The results show that the maximum water velocity was when the groin width was equal to one fifth of the flume width. The groin preferred to place inclined with 60° with the flume side.

Key words: Nature-oriented river works, open channel flow, meandering river, experimental works, open channel flow, coastal evolution.

INTRODUCTION

A groin is one of the structures that is constructed in natural rivers or streams to either protect the bank from erosion or maintain navigation safety (Uijttewaal, 2005). The groin has variable lengths and heights and is usually constructed in perpendicular to shoreline. Groins can be constructed as a single structure or in series. As the long shore drift current approaches the groin, it is forced to slow down and change direction. This change in velocity causes sand suspended in the current to be deposited on the up- drift side of the groin. As the current then continues around the groin, it becomes turbulent and actually contributes to erosion on the down drift side of the groin. Several investigations have been conducted in the past to study the effects of groin parameters on the amount of accretion. Some of the most important studies and their conclusions are summarized as follows.

Price and Tomlinson (1968) conducted a study on the effects of groins on stable beaches and studied the coastal changes for various groin parameters, using a three-dimensional physical model. The effect of the groins on the beach was similar for the different wave angles (α=20°, α=5°) and for the fixed groin spacing.

Shoreline geometry down-drift of the last groin in a groin field is critical. Larson et al. (1987) proposed an analytical model for shoreline down-drift of a terminal groin and they gave an equation for model.

Brampton and Goldberg (1991) studied the effects of groins on shingle beaches on the beach evolution, using a three-dimensional physical model. They studied a shore with three groins, and after ten yearly observations they found that the accretion at the up-drift side of groins was equal to the erosion at the down-drift side.

Hanson and Kraus, (1991) experimentally studied the effects of a series of three groins on shore evolution and proposed a numerical model (GENESIS) and concluded that this model was in agreement with the findings of the physical model.

Webb (1994) carried out a field study about groins at three sites, using aerial photographs of groin fields. Dimensionless parameters that determine whether the groins are “long” or “short”, and “high” or “low” are given. Long term and seasonal changes were investigated by plotting the dimensionless groin variables as a function of time and season. He proposed the variable of dimensionless groins spacing for all investigated region. Kraus et al. (1994) carried out physical model studies on groin parameters and proposed that groin length be equal to groin opening.

Table 1. The experimental runs.

Case	Runs	Width ratio (%)	Angle (°)
I	1	5	90
	2	10	
	3	15	
	4	20	
II	1	20	30
	2	20	60
	3	20	90
	4	20	120

Badici et al. (1994) studied the effects of groins on shore, using a 3D physical model. The tests were carried out at two different wave basins with the beach length of 8 and 28 m. A straight beach in the absence of groins was tested for each set of variables, and then one or two impermeable surface piercing groins with different lengths were installed and tested.

Leont'yev (1997) proposed a numerical model to simulate the short-term temporal changes in shoreline position due to a structure interrupting the long shore sediment transport. The impacts of the groin-type construction and under water trench of arbitrary orientation relative to the shore are investigated and tested the model using the laboratory data.

Todd and Robert (2010) studied the littoral drift rose (LDR) concept for improvement in understanding of long-shore sediment transport and consequent shoreline processes in areas with smooth (gradually varying) offshore bathymetry extending over a coastal region where the deep water wave climate is reasonably uniform.

I˙smail et al. (2005) studied the effects of various groin parameters (length, head length and opening) and wave parameters (wave height, wave period and wave angle) on the accretion of the area protected by T-shape groins in a physical model and compared it by a numerical model. The results of a numerical model are compared with field data obtained by deep sounding measurements at coasts, Trabzon Province, Turkey. The finding from this study may be employed in designing T-shape groins.
Zupeng and Syunsuke, (2009) studied experimentally the flow field with non-overflow groins in a straight rigid-boundary channel and the characteristics of the flow with groins positioned in stagger. The experiment showed that the maximum velocity appeared at the downstream from a groin for the two-fifths of the distance between groins, and reattachment points appeared at the downstream for the four-fifths of the distance between groins.

In this study the effect of groin width and its inclination on the velocity at different depths are presented. The results show that the maximum water velocity was when the groin width was equal to one fifth of the flume width. The groin preferred to place inclined with 60° with the flume side.

EXPERIMENTAL

Experimental procedure

To investigate flow fields of open channel flows in which perpendicular and inclined groins were located, a series of experiments were carried out in laboratory-scale. These series of experiments with four different cases of groin arrangements were conducted: perpendicular groin with different width ratios (groin width divided by flume width) varied from 5, 10, 15 and 20%. And four other different cases of inclined groin with different inclinations of 30, 60, 90 and 120° with the width ratio is 20%, the flow rate direction of 30 L/sec, Table 1 shows the runs of experimental study.

Flume model

Physical model studies were conducted in a three-dimensional flume in the Hydraulic Laboratory of Hydraulics Research Institute, National Water Research Center, Cairo, Egypt. Eight runs of experiments were conducted by using a flexible glass laboratory flume. The flume is 40 m long, 0.40 m wide and 0.6 m deep. The bed material was fine sand d_{50}=0.16 mm. Figure 1 shows the appearance of the experiment channel. Each groin was made of acrylic plate with following dimensions, 4 cm in width, 60 cm in height and 0.5 cm in thickness, and they were arranged on one side of an open channel. The ultrasonic flow meter is used to measure the flow discharge and the velocity is measured by electromagnetic meters. The measurements for two components of the flow velocity in a horizontal plane were carried out using an electro-magnetic current meters. The velocity measured at depth of (z=0.12, 0.36, and 0.48 m) measured from the bed and it measured at (y= 0, 0.2, 0.3 and 0.4 m) the coordinate of point observation are shown in Figure 2. Nodes of the coordinate system of Figure 2 show locations of measurement points, and black obstacles in Figure 2 represent groins.

Analysis of experimental results

Experimental data are analyzed using four parameters, depth for measurement (d_{meas}), groin width (W_{groin}), groin inclination (α_{groin}), and. A dimensionless accretion parameter is defined as follows:

Figure 1. Experimental open channel.

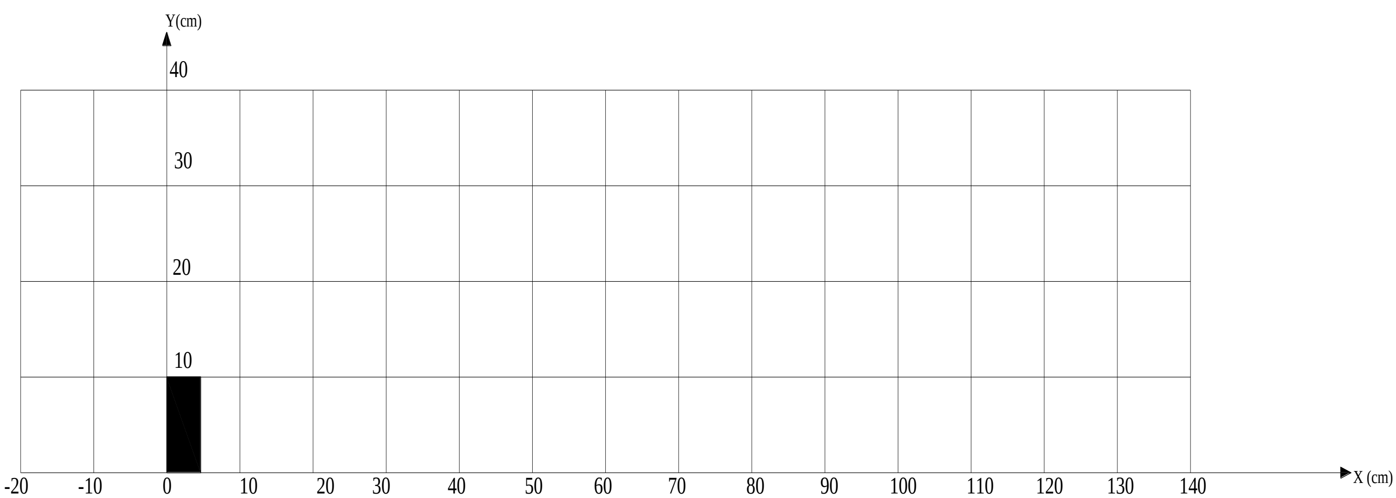

Figure 2. Coordinate system.

$$R_1 = w_{groin}/w_{flume}$$

$$R_2 = d_{meas}/d_{total}$$

Where: W_{groin} is the groin width, and w_{flume} is the width of flume.

RESULTS AND ANALYSIS

Effect of depth

To find the depth of maximum velocity the velocity is

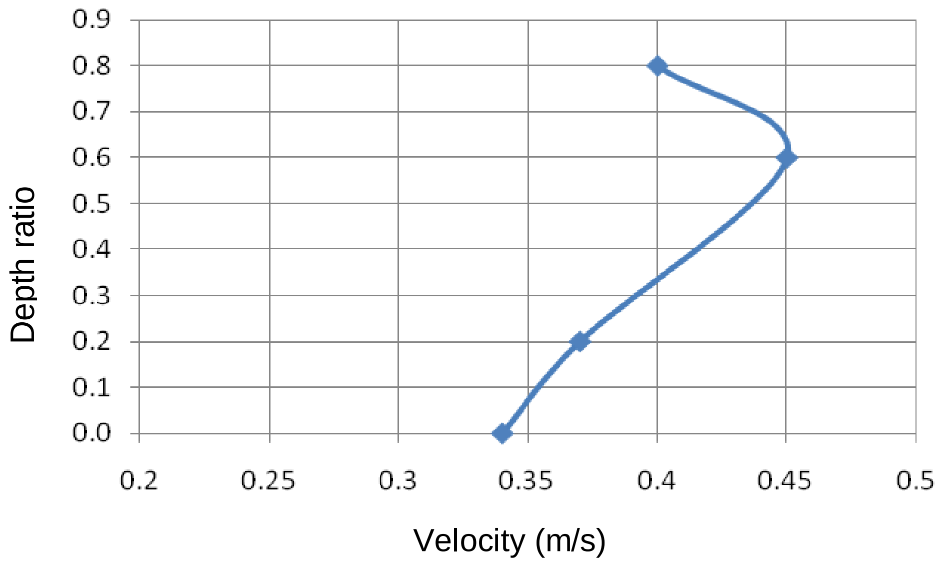

Figure 3. The relation between the depth ratio and the velocity.

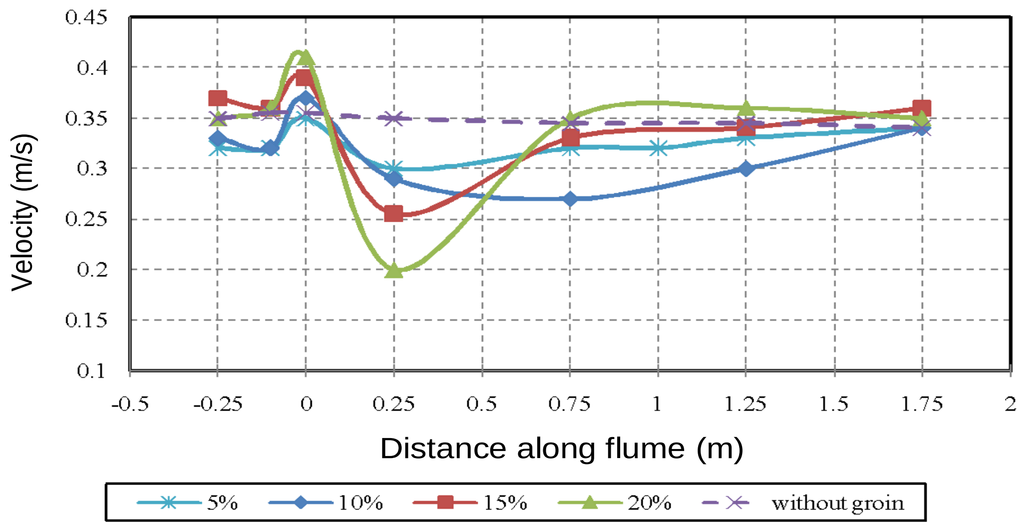

Figure 4. The velocity measured for different width ratios at 0.2 of total depth (z=0.12 m).

measured from the bed of flume at different depth 0, 0.2, 0.6, and 0.8 of total depth. Figure 3 illustrates the relation between the water velocity and the depth ratios (measured depth/ total depth). It shows that the maximum velocity occurred at depth of 0.6 total depth measured from the bed. The minimum velocity measured at the bed.

Effect of groin width

Figure 4 shows the water velocity measured at the depth of 0.2 of total depth (z=0.12 m) for different width ratios. Figure 5 shows the velocity distribution at 0.6 of total depth for different width ratios. The two figures show that the maximum velocity occurred at the groin for groin with 20% width ratio. The minimum velocity is occurred after groin at 14% of effective length from groin (the effective length is the length which affected by occurrence of groin over the total length).

Figure 6 shows the velocity ratio with and without groin at bed. The figure illustrates the maximum velocity ratio increases by 15% with the increase of width ratio by 5% and the minimum velocity ratio decreases by 20% with the increase of width ratio by 5%. Equation 1 gives the relation between the maximum velocity with and without

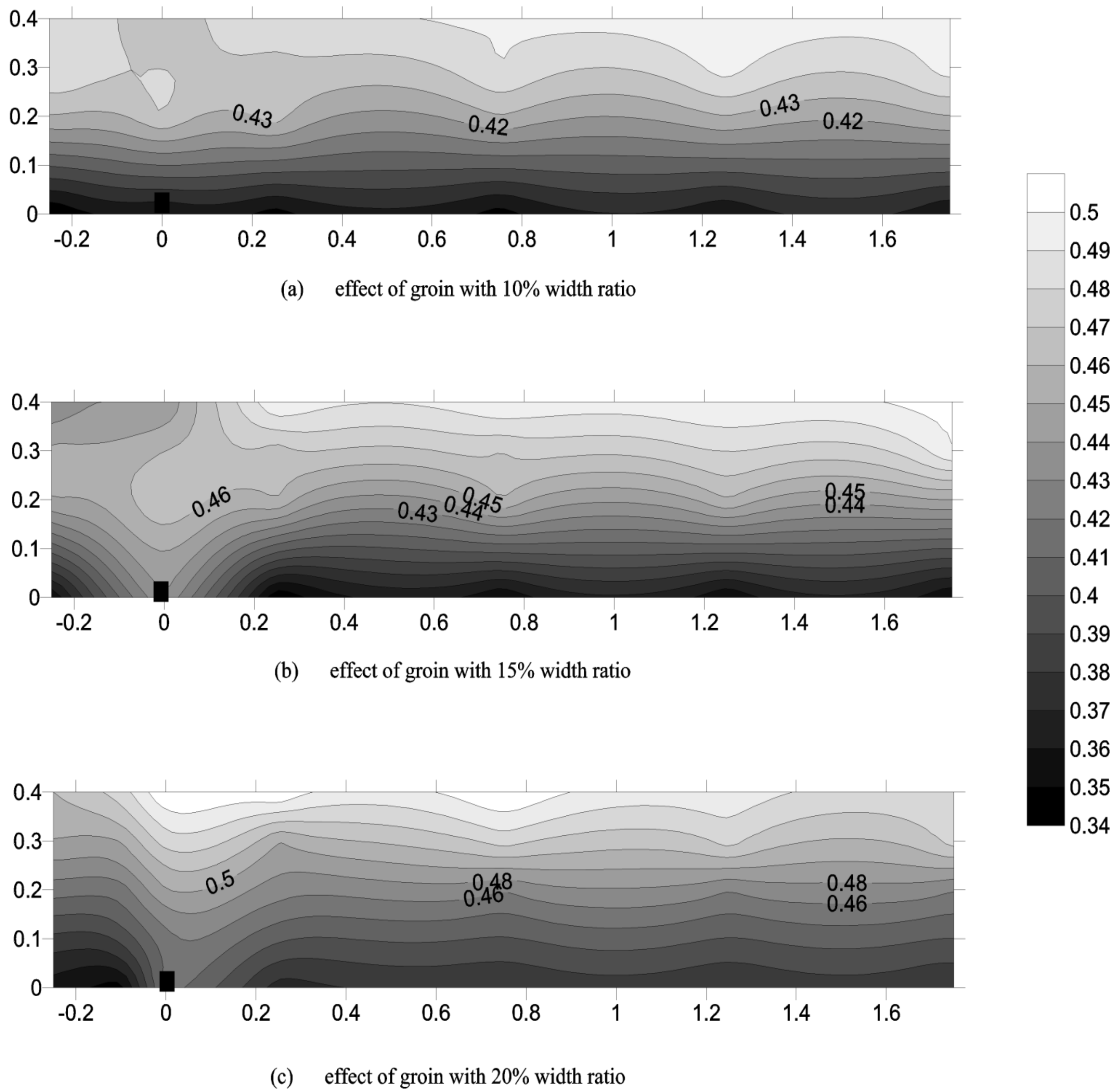

Figure 5. The velocity distribution at bed 0.6 of total depth (z=0.36).

groin, the width of groin, and the width of the flume.

$$\frac{V_{max\text{-}with}}{V_{max\text{-}without}} = 1.38\frac{W_{groin}}{W_{flume}} + 0.89 \qquad (1)$$

Where: $V_{max\text{-}with}$: The maximum velocity with the groins, $V_{max\text{-}without}$: The maximum velocity without groins, W_{groin}: The width of groin, W_{flume}: The width of flume.

Equation 2 gives the relation between the minimum velocity, the minimum velocity without groin, and the width ratio.

$$V_{min-with}/V_{min-without} = -2.457\, W_{groin}/W_{flume} + 1.1 \qquad (2)$$

Where:

$V_{min\text{-}with}$: The water velocity with the groins after groin, $V_{min\text{-}without}$: The water velocity without groins, W_{groin}: The width of the groin, W_{flume}: The width of flume. Figure 7

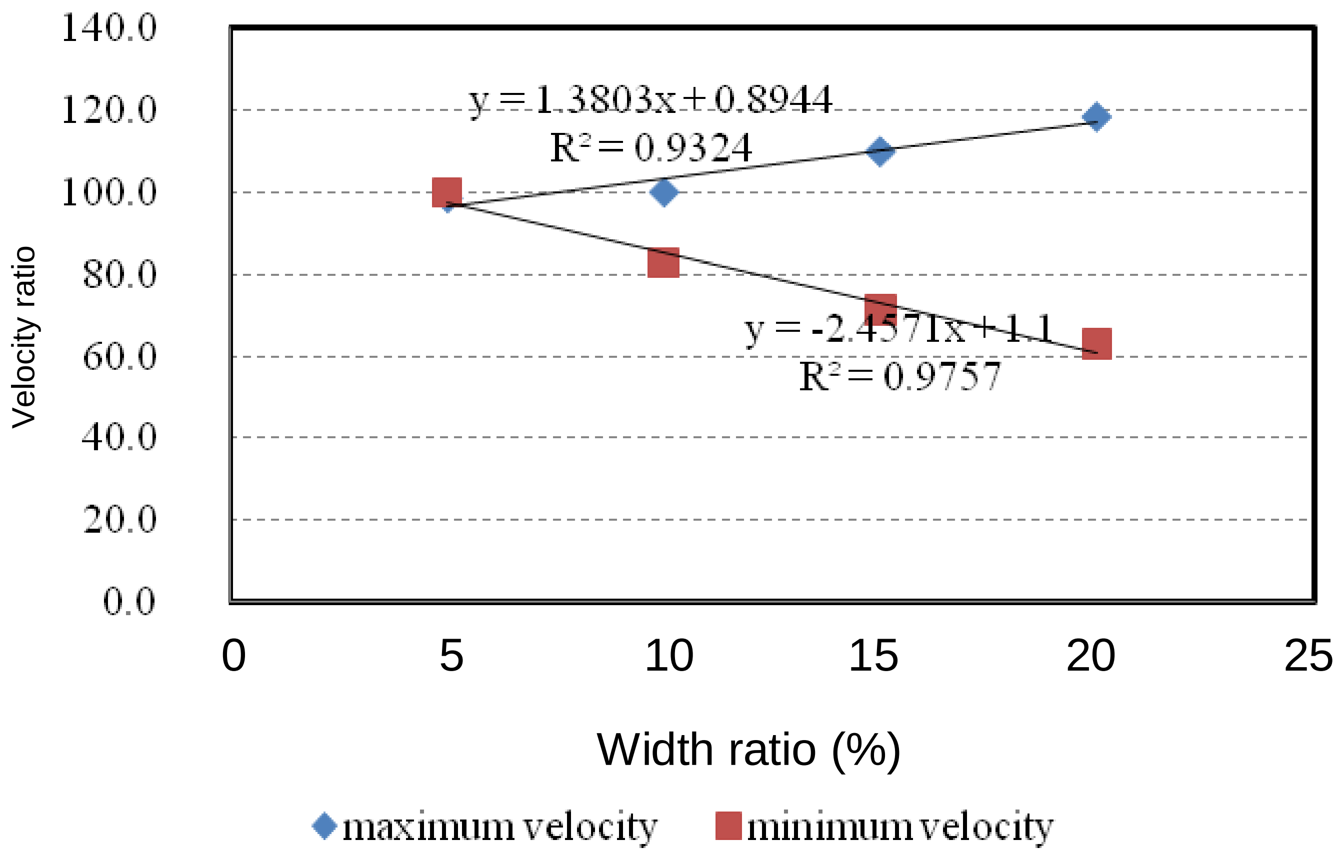

Figure 6. Effect of width ratio on velocity ratio.

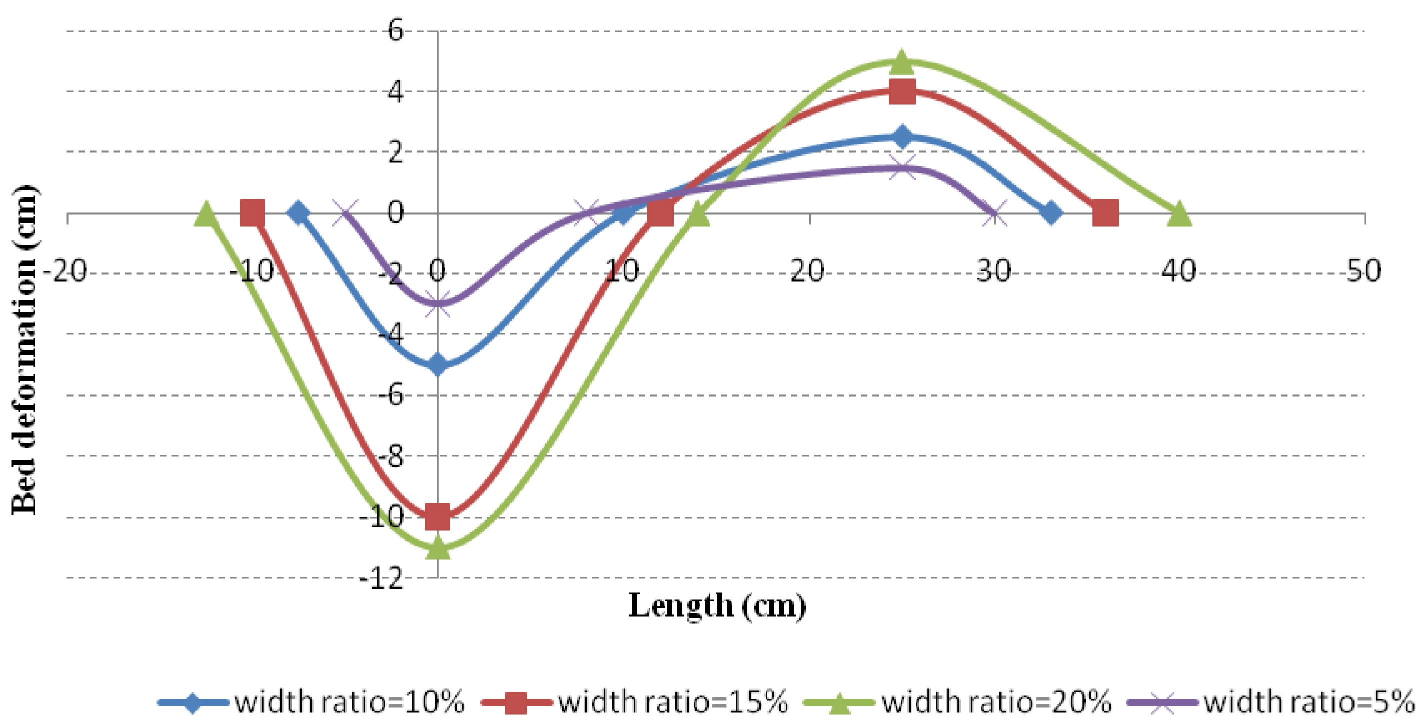

Figure 7. The bed deformation for different width ratios.

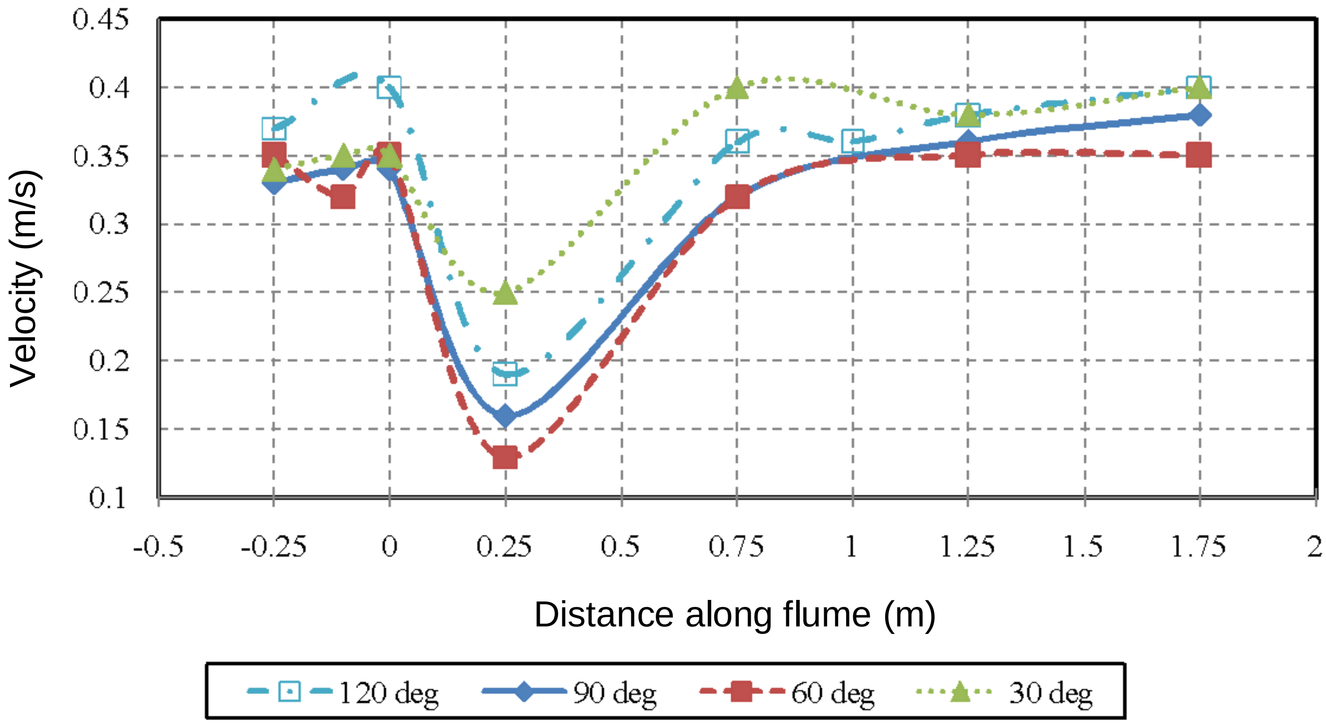

Figure 8. Velocity along the flume distance for different inclinations at 0.2 of total depth (z=0.12 m).

shows the bed deformation for different width ratios. The maximum scour and the maximum length occurred at the groin for width ratio of 20%. The maximum silting and the maximum length occurred at the groin for width ratio of 20%.

Effect of inclination

Figure 8 shows the velocity at the bed of the flume for different inclinations. It illustrates that the minimum velocity occurs at inclination with 60° after 12.5% of effective length. The maximum velocity occurs at groin with inclination of 120°.
Figure 9 shows the contour line of velocity with varied inclination with width ratio is 20% at depth 0.6 of total depth. Figure 10 shows the relation between the velocity ratio with groin, the velocity ratio without groin and the inclination of the groin. The figure illustrates that the velocity ratio decrease by 15% with the increase in width ratio by 60%. The groin with inclination of 60° gives minimum velocity. Equation 3 gives the relation between the maximum velocity with and without groin, and the groin angle.

$$\frac{V_{with}}{V_{without}} = 2\times10^{-5} \propto_{groin}^{2} - 0.001 \propto_{groin} + 1.02 \quad (3)$$

Where: V_{with}: The water velocity with the groins at groin, $V_{without}$: The water velocity without groins, α_{groin}: The angle of the groin.

Equation 4 gives the relation between the minimum velocity with groin and without groin, and the groin angle.

$$\frac{V_{with}}{V_{without}} = 4 \times 10^{-5} \propto_{groin}^{2} - 0.003 \propto_{groin} + 0.46 \quad (4)$$

Where: V_{with}: The water velocity with the groins after groin, $V_{without}$: The water velocity without groins, α_{groin}: The angle of the groin.

Conclusion

In this study, open channel flows with groins were investigated. Experiments were performed with a groin with different width ratio and various inclination of groin. The conclusions of this study are given as following:

(1) The maximum velocity occurred at depth of 0.6 total depth measured from the bed. The minimum velocity measured at the bed.
(2) The maximum velocity occurred at the groin with 20% of width ratio.
(3) The maximum scour occurred after groin at 14% of effective length.

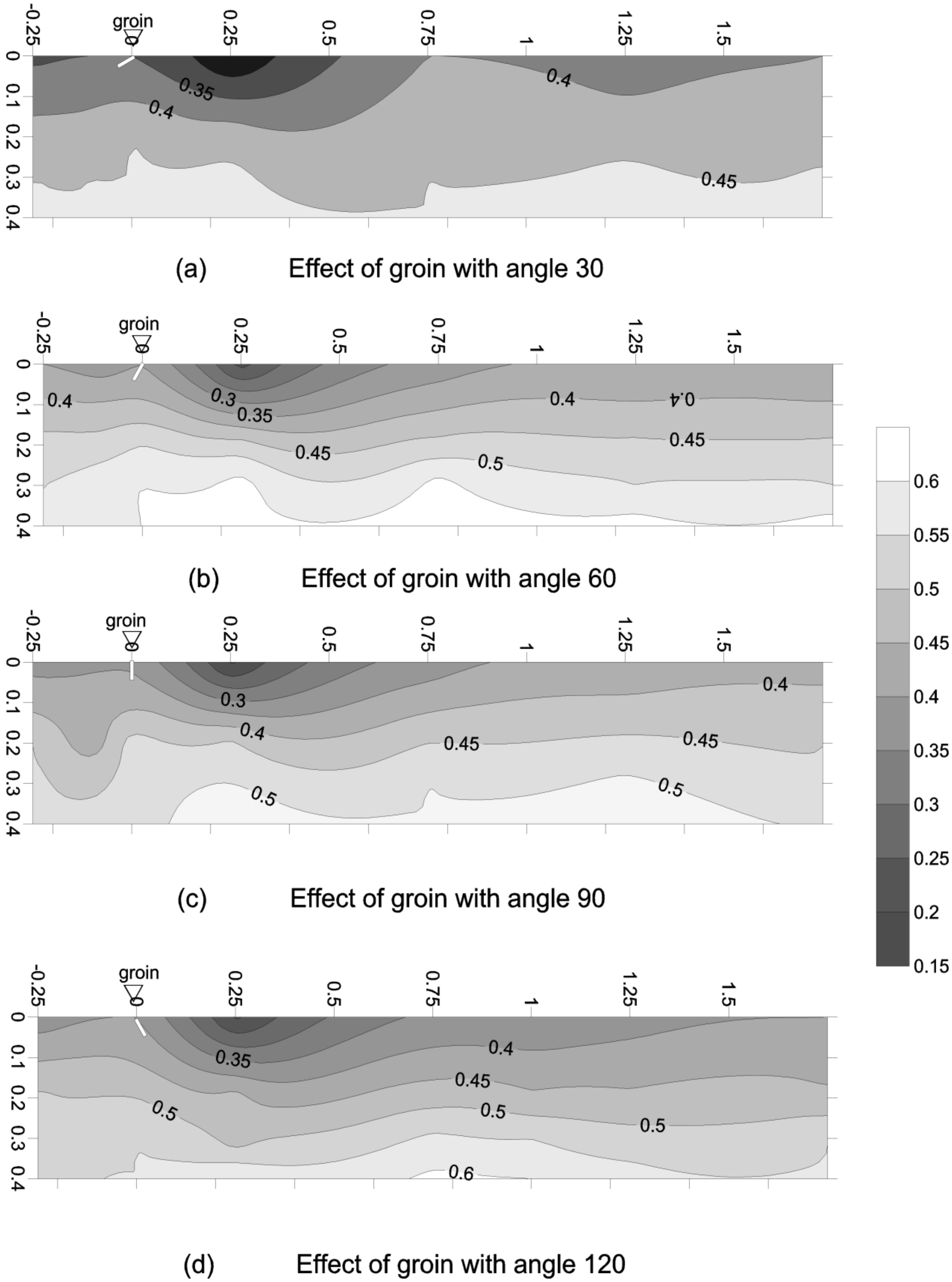

Figure 9. The velocity contour line with different inclinations (z=0.36m)

(4) The maximum scour length and depth occurred for groin with 20% of width ratio.

(5) The minimum velocity is occurred after groin at 14% of effective length from groin (the effective length is the length which affected by occurrence of groin over the total length).

(6) The groin with inclination of 60° gives minimum velocity.

(7) The groin with angle 90° makes also a small velocity but its effect continues to another side which increases

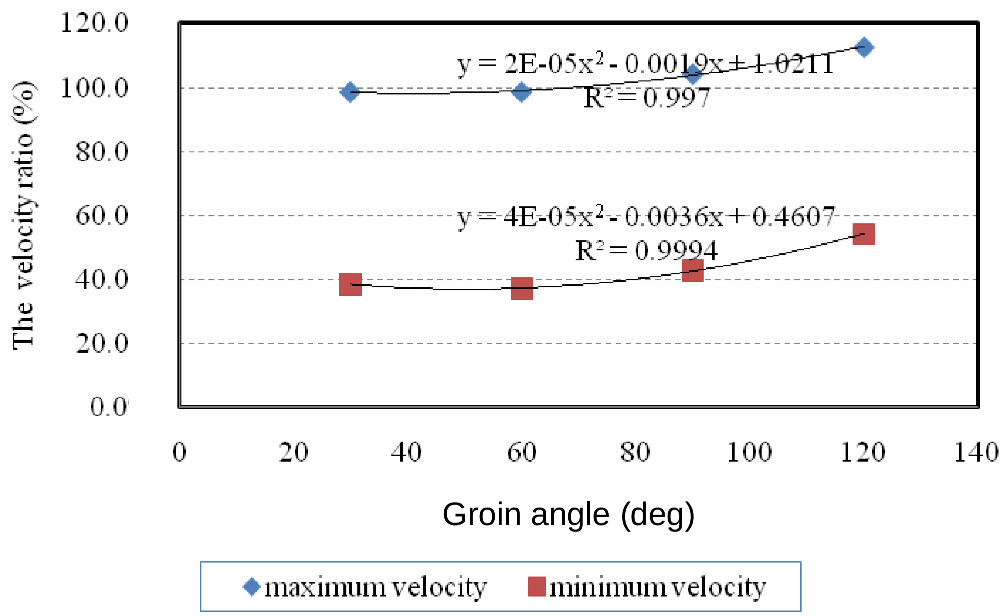

Figure 10. Effect of groin angle on velocity ratio at groin.

the sediment in other side.

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