FLOW ANALYSIS AROUND GROYNE WITH DIFFERENT PERMEABILITY IN COMPOUND CHANNEL FLOODPLAINS

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ABSTRACT

Presented herein are the results of an experimental study on the flow characteristics around compound channel floodplain groynes with various permeability and length. Both the permeable and impermeable groynes are considered to clarify the influences of floodplain groynes on flow structure, velocity, and water surface. A channel consisting of a main channel and one floodplain with flat and fixed bed was used. The width of floodplain is the same as the main channel width. Pile groyne models with three different relative lengths relative to floodplain width (L_r), 0.5, 0.75, and 1.0, with three different permeability values (P= area of water crossing the groyne/total projected area of groyne) 40%, 60%, 80% plus an impermeable groyne were used and installed in the floodplain with single arrangement. The 3D flow velocities at both of the horizontal plane above floodplain bed by 0.25 of floodplain water depth (h) and at the main channel centerline in the vertical plane were measured using an Acoustic Doppler Veloci-meter (16 MHz Micro-ADV). The flow pattern around groynes was analyzed in both the horizontal and vertical planes. The results show that, for permeable groynes as the permeability increased the groyne length has limited influence on the flow structure. For the horizontal plane maximum and tip velocities were decreased while the minimum and bank velocities were increased as the permeability increased. Empirical formulas to describe these relations depending on the groyne relative length and permeability were suggested. The influence of permeable groynes installation in the compound channel has insignificant effect on the main channel flow while the impermeable groynes affect greatly the main channel flow structure. Both the groyne permeability and length ratio have obvious effects on the floodplain water depth.

Keywords: Flow Pattern, Water Surface, Groyne Permeability, Compound Channels.

1. Introduction

Groynes are the hydraulic structures that have functions of protecting bank erosion and maintaining water level by deflecting flow direction. The groynes are continuously installed to control the flow for navigation safety, improve the channel alignment and to trap littoral drift or retard erosion of the shore. Recently groynes attract attention again because the natural bank form made by groynes is very beneficial to river ecosystem (Uijttewaal, 2005, Yeo, 2005, Yeo and Kang, 2008, Kadota et al., 2008, Gu and Ikeda,

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2008, Teraguchi et al., 2008, Muraoka, (2008) and Ahmed 2010)). They reduce flow velocities along the riverbanks and create recirculation zones downstream of a structure providing a favorable bio-habitat. If a groyne is mainly applied for navigation purposes, the relevant design issue is to secure the depth of the main channel. However, if a groyne is aimed at improving the stream environment or protecting a bank, flow separation or the recirculation zones affected by it becomes important (Kang 2011).

Groynes can be classified according to their functions, objects, forms, and materials. There are many types according to their shape as T-groyne, L-groyne, permeable groyne and impermeable one. The impermeable groynes are generally constructed using local rocks, gravel, or gabions where the permeable ones consist of rows of piles, bamboo, or timbers (Teraguchi et al. 2008, Ettema and Muste, 2004).

In addition, groynes are divided into overflow and non-overflow groynes according to the flow condition. A groyne without overflow should not be submerged under flooding, because it is mainly used in large rivers with a high bank level. The flow characteristics and patterns in the groynes vicinity and main channel vary according to groyne type. Therefore, their analysis is necessary to select the appropriate groyne type in the field. The flow through a permeable groyne partly penetrates the structure so that the downstream velocity is reduced. The permeable groyne resistance to the flow is less than that of the impermeable one. Nonetheless, the permeable groyne has the advantages of excellent stability and relatively easy maintenance (Yeo 2005 and Kang 2011). By varying the clearance between the piles, the flow gradient along the bank can be adjusted (Schiereck 2004). However, to maintain a navigation channel, this type of groyne is less suitable. Uijttewaal (2005) conducted experiments on four different groyne types including the standard reference groyne. The standard reference groyne is a straight groyne perpendicular to the riverbank with slopes of 1:3 on all sides, the second type of slope 1:6 and extends into the main channel, the permeable groyne consisting of pile rows, and the hybrid groyne consisting of a lowered impermeable portion with a pile row on the top. The flow patterns in the shear layer and the turbulent properties around a groyne head were analyzed. It was observed that the groyne types induce diverse flow patterns. It was expected that the groyne permeability would produce an additional effect. Yeo (2005) and Kang (2011) conducted an experimental study on the tip velocity and down stream recirculation zone of single pile groyne of different permeabilities, it was found that for the impermeable rectangular groyne an increased velocity at the groyne tip and a broad range of the recirculation zones were observed. For the permeable pile groyne, the velocity at the groyne tip, the vortex strength, and the scale of the recirculation zone tended to decrease as the openings between the piles increased. These quantitative findings on the flow patterns for groynes of various geometries and permeabilities are practically important to design and evaluate their performance in the field of applications.

River floodplain groynes are used and play an important roles in high floods attenuation and protection work; especially, in rivers with large floodplains. Impermeable Groynes, transverse levees, and bridge embankments are considered as contractions on the stream-wise flow direction. Ahmed (2010) investigated the flow in symmetrical compound channel with impermeable floodplain groynes in one side experimentally. It was found that the flow structure, velocity and water depth are mainly depend on groyne relative length and on the relative distance between series groynes. The flow velocity at the main channel centerline and in the other floodplain mid-water was increased. Using impermeable groyne with large relative length in river floodplains increases the generation of eddy and roller zones downstream the groyne which lead to scouring and deposition activities. Therefore, quantitative analyses on the flow patterns for groynes of various permeability rates in compound channel are considered practically useful to evaluate their performance in field applications. Herein, the flow characteristics of the groynes of various permeabilities in compound channel were analyzed using the hydraulic experimentations. The main purposes were to analyze the velocity fields in Horizontal, and Vertical planes, the velocity at the tip of the groynes and the water surface changes in the groyne field.

2. Flow patterns around groynes

The installation of groyne leads to a common flow pattern, this flow due to groyne presence was divided into the main flow zone and the recirculation zone formed at its downstream portion (Fig. 1). At the tip of groyne structure the flow is separated and deflected. The deflected flow flows in the main stream area (center of channel) with a certain angle. The separated flow forms pulsating flow in the downstream of groyne. The boundary of the recirculation zone was defined along the separation streamline and the zero velocity line formed within this zone. Turbulence is produced, then is dispersed, and decays in this zone, Yeo (2005). The velocity U_{tip} at the groyne tip and the flow separation angle θ are key factors used to analyze the velocity increase and the vortex at the groyne tip. A variety of flows are formed downstream depending on the groyne type. The flow pattern in the main channel affects the riverbed and the thalweg line, Kang (2011). Weitbrecht *et al*. (2002) analyzed the flow dynamics in a mixing layer between the dead-water zones formed by successive groynes. In successive groyne fields, one large gyre at the centre of the dead-water zone dominates the flow, while a small counter-rotating gyre lies at the upstream corner of the dead water zone. Ettema and Muste (2004) adapted the flow features produced by the low wall in a uniform 2D approach flow from Arie and Rouse (1956) and described significant flow features around a spur dike.

In the current experimental investigation, a single permeable groyne was installed perpendicularly in semi-symmetrical compound channel floodplain for the purpose of analysis of the flow field and tip velocity around it. According to the change of the length and permeability of groyne, the approaching and tip velocity at groyne filed were measured. Furthermore, in each case the flow pattern and velocity profiles were analyzed.

The experiments were conducted in a water re-circulating flume in Assiut University, Egypt. The flume is 0.30 m in both depth and width and 13.5 m in length, which incorporates transparent test section of 10.00 m long as shown in Fig. 2a. At the downstream of the flume, a tailgate is located which consists of a brass plate hinged to the bottom and adjustable in crest height by means of screw. The tailgate provides the means to control the tail-water elevation. The flume was adjusted to a longitudinal slope of 0.0025.

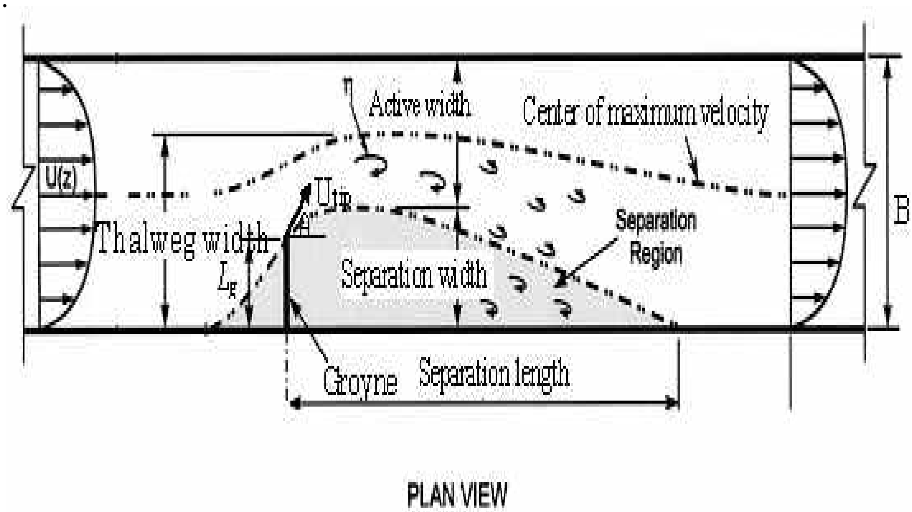

Fig. 1. Flow maximum velocity centerline and separation zone around a single impermeable groyne (dike) in uniform and rectangular channel with flat bed (modified, source (Ettema and Muste 2004)

3. Experimental setup

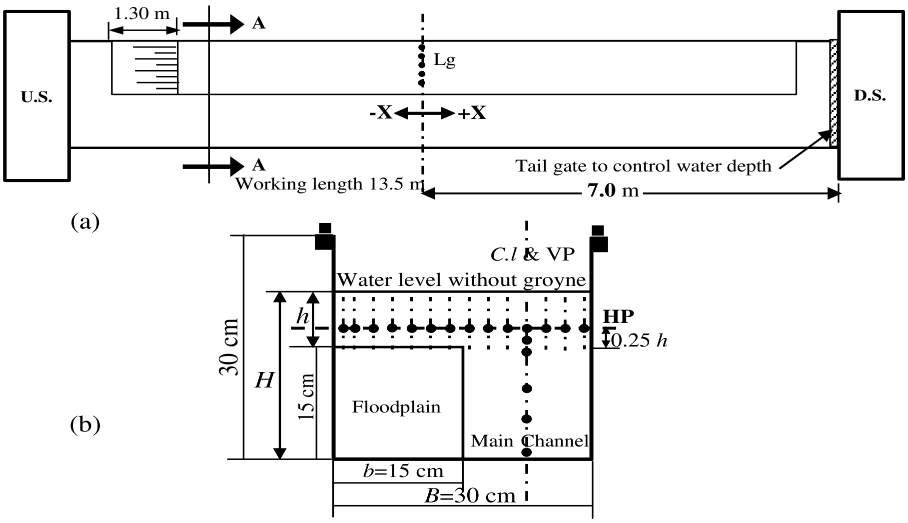

Fig. 2. (a) channel layout, (b) cross-sectional view (A-A) showing velocity measuring points for the horizontal and vertical profiles with groynes

The rectangular flume section was converted into Perspex-acrylic unsymmetrical compound channel section having a main channel with width of 0.15 m and one side floodplain with the same width "b= 0.15 m" where the floodplain relative width b/B = 0.5. The roughness coefficients were kept constant and equal in both the main channel and the floodplains. A steady discharge Q was regulated to be 0.0175 m^3/s and measured by a stander nozzle-meter. The experiments were conducted with flow water depth in the channel floodplains h=0.08 m (floodplain relative water depth = h/H=0.34) where Froude number equal to 0.3. The Reynolds number was always sufficiently high to guarantee a fully turbulent flow. The longitudinal, lateral and vertical flow velocities components U, V and W respectively, were measured at fourteen points at the horizontal plane "HP" located at depth of 0.25h from the floodplain bed with interval of 0.02 m. Also, at six points in the main channel centerline vertical plane "VP" at "0.3, 5.5, 10.5, 15.5, 16.7 and 18 cm" from the bed of the main channel. Those points marked with black circles as shown in Fig. 2b. The flow velocities components in both the horizontal and vertical planes, HP and VP respectively, were measured at several locations upstream and downstream the groynes. The velocities were measured by an Acoustic Doppler Velocimeter (16-MHz MicroADV, Sontek) and sampling frequency is 20 Hz. At each point, the mean velocity in stream-wise and transverse directions, U, V respectively, were obtained by averaging the velocities and then the mean resultant velocity value $=\sqrt{(U^2+V^2)}$ and direction were estimated. The water surface elevation was measured at several locations upstream and downstream the groyne with a point gauge of accuracy of 0.1 mm mounted on a movable sliding carriage. The experiments were conducted using models with different groyne permeability values (0%, 40%, 60% and 80%). The permeable groynes were made of glass piles with cross sectional diameter of 0.5 cm. For each case of groyne permeability, three groyne models with relative lengths L_r (L_r = groyne length "L_g"/ floodplain width "b"), 0.5, 0.75, and 1.0 were used. All groynes were kept perpendicular to both the main channel centerline and the longitudinal flow direction.

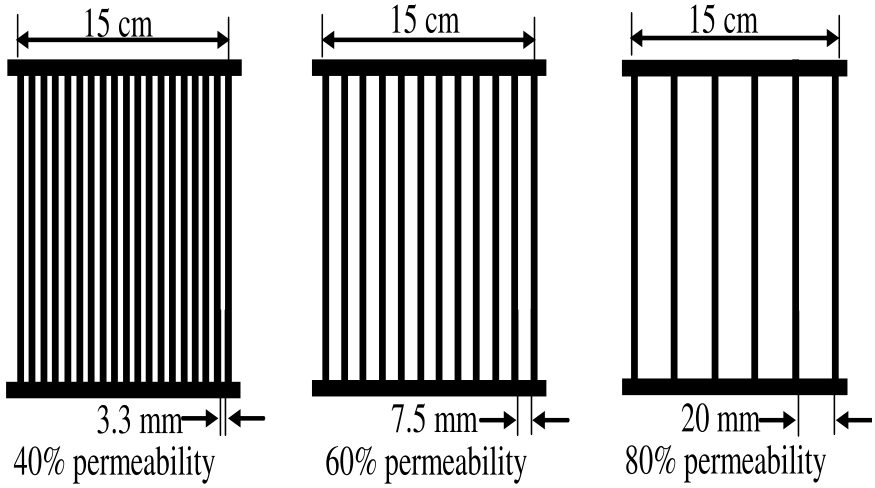

Fig. 3. Groyne model with three different permeability values and L_r=1.0

4. Results and discussions

In this section, the results and analysis of the experimental program conducted to elucidate the effects of floodplain permeable groynes on both of the compound channel water flow structure, velocity, and water depth are presented. Symbols mentioned in figures of velocity profiles at horizontal HP and vertical VP planes are as follows; $\mathbf{G_{00}}$ means the measured points located at the **G**royne model centerline, D_{21} means that the profile is located **D**ownstream the groyne by 0.21 m, U_{08} means **U**pstream the groyne by 0.08 m. The groyne (G_{00}) is considered at the zero distance (*X*=0.0), and the distance downstream G_{00} is considered positive while upstream it is negative.

4.1. Velocity profiles and flow pattern changes in the horizontal plane (hp)

As shown in Fig. 4 (a and b), the horizontal profiles and isolines of velocity around the impermeable groyne with relative length of 1.0, 0.75 and 0.5 were plotted from a distance of 1.0 m to 3.0 m upstream and downstream the groyne respectively. At each horizontal profile, the maximum $(U_{max})_h$, the minimum $(U_{min})_h$ and the velocity near the left bank (2.0 cm from the wall side) in the groyne side $(U_b)_h$ were determined. In Fig 4 (c, d and e) the values of the longitudinal relative maximum, minimum and bank velocities were plotted for groyne with relative length 1.0, 0.75 and 0.5. For all figures, the great effect of the groynes on the flow structure is at relative length from -5 to 15 while the flow is slightly affected by the groynes installation beyond these values. As the groyne relative length increased, the value of the maximum relative velocity increased but for the relative minimum and bank velocities values, the groyne relative length has little effect. The maximum relative velocity $(U_{max}/U_o)_h$ takes 1.85, 1.7 and 1.5 with changing L_r to be 1.0, 0.75 and 0.5 respectively. Ahmed (2010) found that $(U_{max}/U_o)_h$ takes 2.75, 2.4 and 1.8 for L_r equal 1.0, 0.75 and 0.5 respectively and for the same hydraulic conditions. These changes in the values of the maximum velocities may due to the difference in the floodplain arrangement, where in Ahmed (2010) the floodplain was symmetrical in both sides with width twice the main channel width.

In addition, the relative minimum velocity $(U_{min}/U_o)_h$ and the relative velocity near the left bank $(U_b/U_o)_h$ were changed with the same rate and the minimum value for both of them was −0.5. For the impermeable groynes, reverse flow occurred on the left floodplain near the bank area, but it disappeared as the relative distance increased.

From Figures 4 and 5, it is clearly notice that, for all groynes permeability and relative length values, the floodplain velocity downstream of the groyne decreases. An effective reduction of the velocity downstream of the groyne of more than 20% extended to a distance more than 40 times the groyne length downstream groyne.

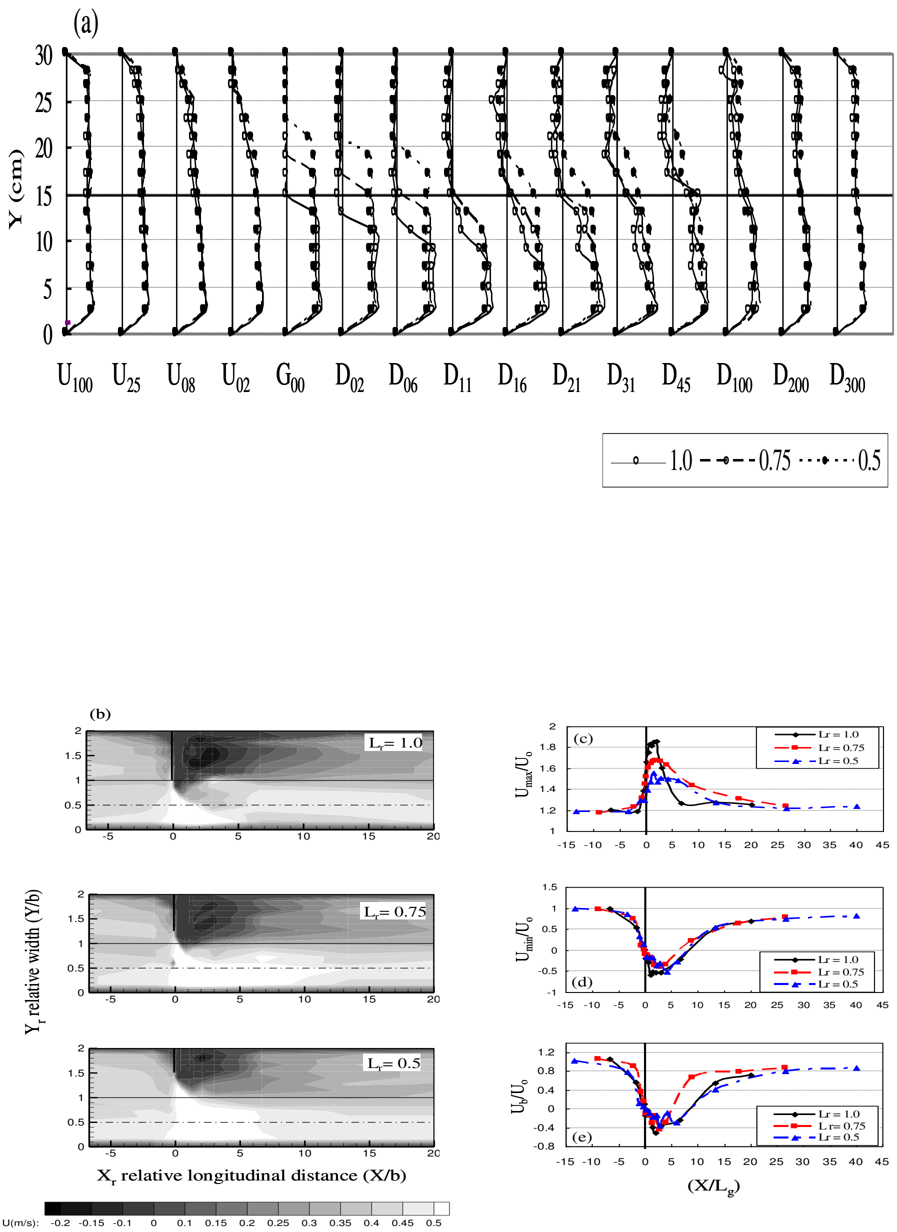

Fig. 4. Single impermeable floodplain groyne with relative length "L_r = 1.0, 0.75 and 0.5" (a) longitudinal velocity U profiles in the horizontal plane "HP", (b) contour maps of the flow longitudinal velocity U at HP, and (c, d and e) Values of $(U_{max}/U_o)_h$, $(U_{min}/U_o)_h$ and $(U_b/U_o)_h$ on HP, where U_o is the approach velocity

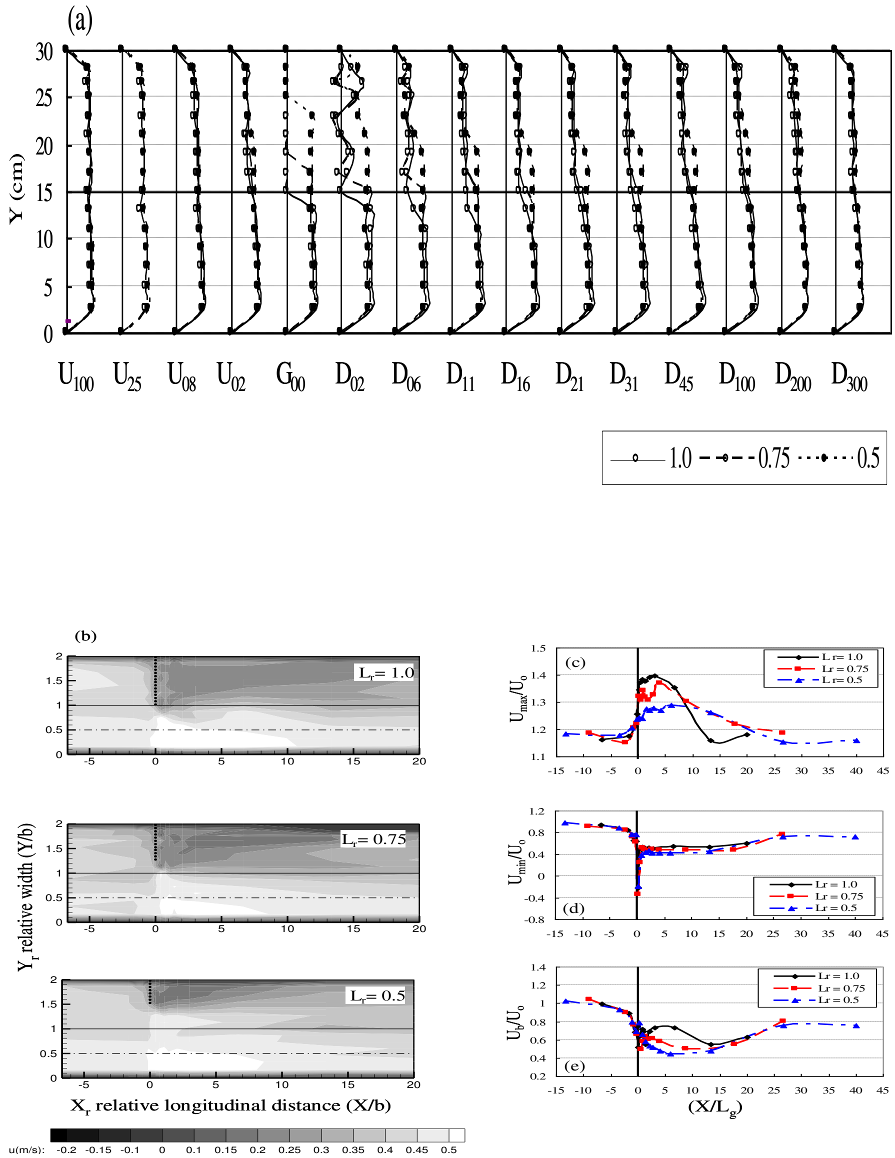

Fig. 5. Single floodplain groyne with permeability P = 0.40 and L_r = 1.0, 0.75 and 0.5 (a) Longitudinal velocity "U" profiles in the horizontal plane HP, (b) U's contour maps at horizontal plane HP. (c, d and e) values of (U_{max}/U_o), (U_{min}/U_o) and (U_b/U_o) in the horizontal plane along the channel main direction

Fig. 6 (a) shows the relationship between the maximum relative velocity values and the groyne permeability with three relative length values. Empirical formula describing the relationship between maximum relative velocity and both of groyne permeability and relative length could be obtained as shown in Table (1).Fig. 6 (b) shows the variations of the HP's minimum relative velocity values with groyne permeability, it is clear that, the groyne relative length has no obvious effect on the minimum relative velocity. The average values of the relative minimum velocities are -0.53, -0.27, 0.59 and 0.72 for permeability's 0, 40, 60 and 80% respectively. For the permeability effect on the flow over the floodplain, it could be divided in two zones, P>50% and P< 50%. If the permeability is less than 50%, the vortex formed and negative velocity appeared over the floodplain, so the velocity gradient is large. While, if the permeability more than 50% the vortex is vanished and there is no negative velocity appear, also the reduction still more than 25% of the approach velocity. For the bank velocity, the effective reduction occurs when the permeability lies on the range from 0.4 to 0.6. as shown in Fig 7.

Hence, the bank protection is one of groyne main functions; one aim of the current research is getting empirical formulas to better describe the relationship between the bank flow velocity and various groyne's parameters such as permeability and length. As shown in Figures 6 and 7, the groyne permeability has the most effect on bank velocity where the groyne relative length has a small effect on it. The reduction on the floodplain velocity occurs obviously as the groyne permeability ranged form 0.5 to 0.75.

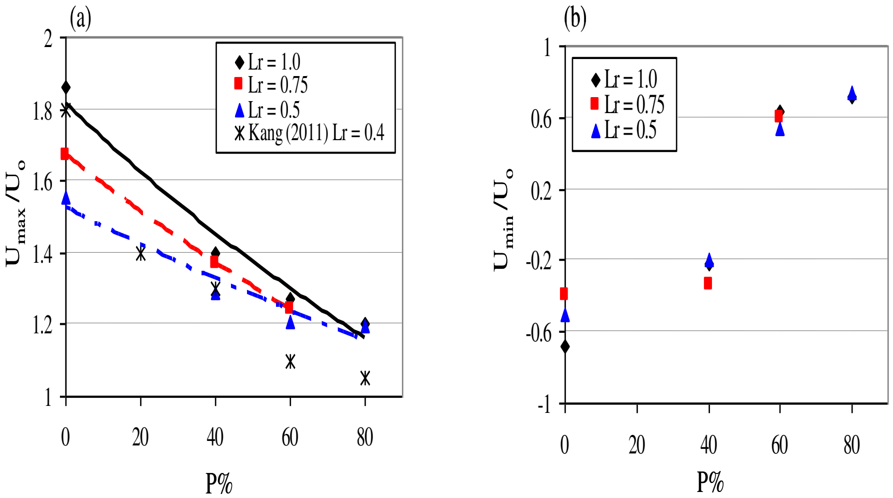

Fig. 6. The permeability versus (a) the ultimate values of relative maximum velocities (b) the minimum values of relative minimum velocities for L_r = 1.0, 0.75 and 0.5

Table 1
Empirical equation of maximum

0 %< P < 80%	$U_{max} / U_o = a e^{-b P}$	
	a	b
$L_r = 1.0$	1.8159	0.0056
$L_r = 0.75$	1.6718	-0.005
$L_r = 0.5$	1.5249	0.0035
$0.2 \leq L_r \leq 1.0$	$U_b / U_o = -0.0002 P^2 + 0.029 P^{-0.43}$	

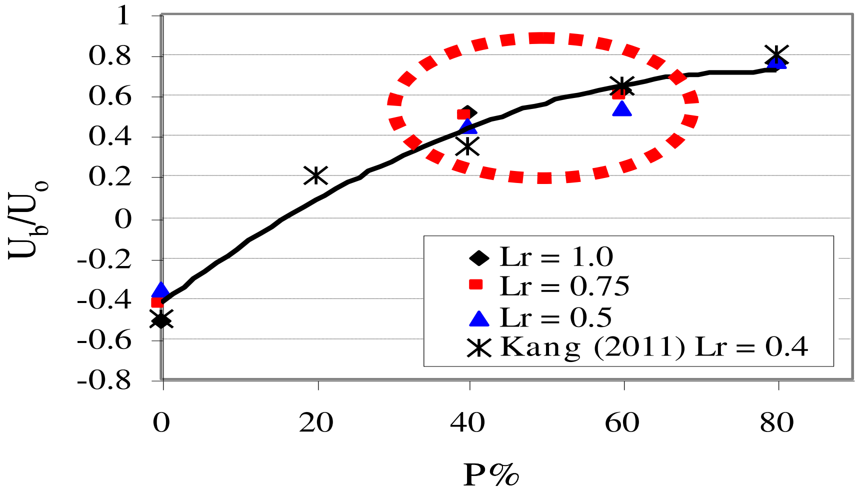

Fig. 7. The variation of relative bank velocities relative velocity with the permeability

4.2. Velocity profiles and flow pattern changes in the vertical plane.

In order to estimate the effect of the floodplain groyne relative length and permeability on the main channel velocity distribution, the longitudinal velocity values in the vertical plane "VP" at the main channel centerline were measured upstream and downstream of the groyne in the same manner as in the horizontal plane. According to the arrangement of the device used to measure the velocity in this investigation (16 MHz MicroADV), the allowable measuring range of the velocity in the vertical plane was limited up to 0.78 of the total water depth "H" from the bottom of the main channel (at 0.25h above the floodplain bed) as shown in Fig. 2(b). Ahmed (2010) found that, in case of impermeable groyne, the main channel maximum longitudinal velocity "U" in the vertical plane is at the lower zone of the vertical plane VP while the minimum velocity is shifted upward to the surface, so that the maximum velocity can be considered within the measured range of the flow velocity in the vertical plane.

Fig. 8 (a, b and c) shows the plotting of the relative velocity distribution in the vertical plane VP in different cross sections upstream and downstream of the impermeable groynes with L_r= 1.0, 0.75 and 0.5. From Fig. 8 (a) it is clear that the impermeable groyne with great length ratio (L_r=1.0) causes a strong velocity gradient which is largest next to the floodplain bed. The eddy zone and the vortex constructed downstream of the groyne field do not allow a fully developed vertical profile. This result is compatible with the result of Uijttewaal (2005) in case of stranded groynes and Ahmed (2010). As the length ratios decreased the velocity gradient become smaller as shown in Fig. 8 (b and c). The values of the maximum relative velocity $(Umax/Uo)_v$ take 145, 165, and 185% with changing the Lr to be 0.5, 0.75, and 1.0, respectively as shown in Fig. 8 (c).

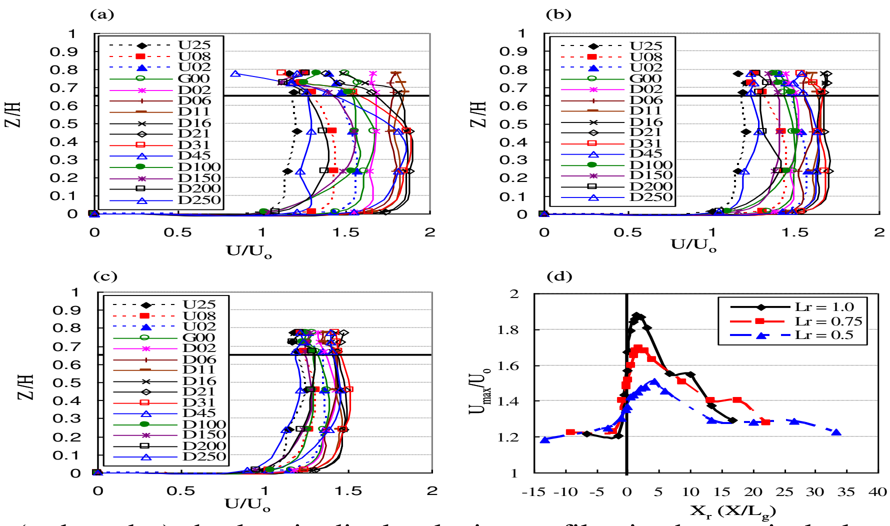

Fig. 8. (a, b and c) the longitudinal velocity profiles in the vertical plane VP of impermeable groyne with relative length L_r= 1.0, 0.75 and 0.5 respectively, and (d) the maximum relative longitudinal velocity in the vertical plane along the channel direction

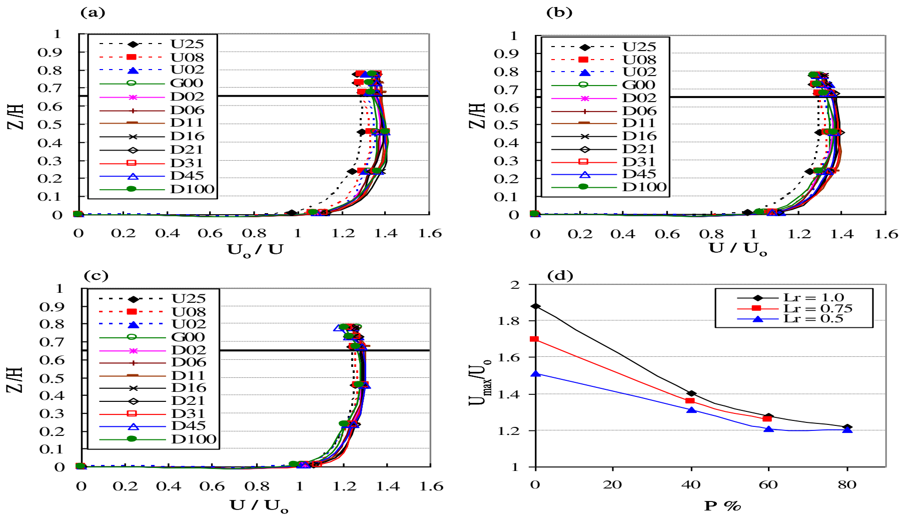

Fig. 9 (a, b and c) the longitudinal velocity profiles in the vertical plane VP of permeable groyne with P=0.60 and relative length Lr= 1.0, 0.75 and 0.5 respectively, and (d) the relationship between the maximum relative longitudinal velocity (Umax/Uo) with the groyne permeability P

For permeable groynes (pile groyne), the extension of its effect on the main channel is limited compared with the impermeable ones. Most of the changes in the flow structure were found around the groynes on the floodplain. In all cases of permeable groynes, the velocity distribution is rather uniform in the measured range of the total depth as shown in Fig. 9 (a, b and c). Uijttewaal (2005) found that for the permeable groynes extended into the main channel where the effect of the piles was present over the full water depth and gave a uniform vertical profile. The maximum relative velocity in the vertical plane can be considered constant for all groyne relative lengths with the same permeability which can be estimated as 1.35, 1.25 and 1.2 for groyne with permeability P= 0.40, 0.60 and 0.80 respectively, as shown in Fig. 9 (d).

4.3. The tip velocity

The flow at the groyne tip is been steeply directed to the main channel. The largest velocity part moved and the velocity is increased. The intensive vortex occurred at the tip can lead to a local scour. The results analysis focuses on the variation effect of the relative tip velocity and deflection angle according to the variation of the floodplain groyne relative length and permeability. Comparing the result of this study with those of Yeo (2005) and Kang (2011) as shown in Fig. 10a, it is found that, for groynes with relative length related to total channel width equal to 0.375, 0.25 and 0.2 the measured relative tip velocity increased from 1.1 to 1.6 as the groyne permeability increases from 0 to 0.80. However, for the groyne relative length to channel width equal 0.5 the relative tip velocity increased reaching a maximum value of 1.78 in case of the impermeable groyne. The large relative length of the groyne (groyne length equal the floodplain width) causes the floodplain flow deviate and combine with the main channel flow which leads to maximizing the tip velocity. According to the variation of permeability, the tendency of variation of the relative tip velocity is different, as the permeability increases the relative tip velocity decreases where the flow through the permeable groyne partly penetrates the structure so that the flow velocity is reduced. Empirical equations were determined to describe the relation between the permeability and the relative tip velocity for various values of groyne relative length as mentioned in Table 2.

Fig. 10-b shows the comparison between the measured data with the results of Yeo (2005), Kang (2011) and the results suggested in Guidelines on the geometry of groynes for river training (Wallingford, 1997). Where the area ratio, A^* was defined as $A^* = A_g/(A_c - A_g)$. Here A_g is the lateral projecting area of groyne on the channel cross section and A_c is the flow total cross sectional area. As shown in Fig. 10b, the present experimental results coincide with both the suggested range and the suggested experimental equation by Yeo (2005) within the range of $0.02 < A^* < 0.35$ as in Table 2.

The measured values of the tip velocity deflection angle (θ) (the angle of the tip velocity with the longitudinal direction of flow) for this study, Yeo (2005) and Kang (2011) were plotted versus permeability as shown in Fig. (5). It is clear that as the groyne permeability increases the deflection angle decreases. Using those data with acceptable agreement, the relationship between the angle (θ) and the permeability could be described as shown in Table 2 as an empirical formula.

From the good agreement between the experimental results and the results of Yeo (2005) and Kang (2011), the tip velocity is not affected by the floodplain and has the same values and deviation for floodplain channel and only main channel streams.

4.4. Water surface profiles around the groyne field

As a result of floodplain groyne installations, the flow area which plugged (restricted) by the groyne projection area causes water surface oscillation in the groyne field and heading up occurs upstream the groyne. Fig. 12 (a and b) shows the changes of water depth (change% = (depth with groyne – depth without groyne)/ depth without groyne)*100) in the two longitudinal sections, the first one locates at the floodplain centreline (FP) while the other locates at the main channel (MC) centreline. Groynes with permeability P=0.0, 0.60and relative length of 1.0, 0.75 and 0.5 were used.

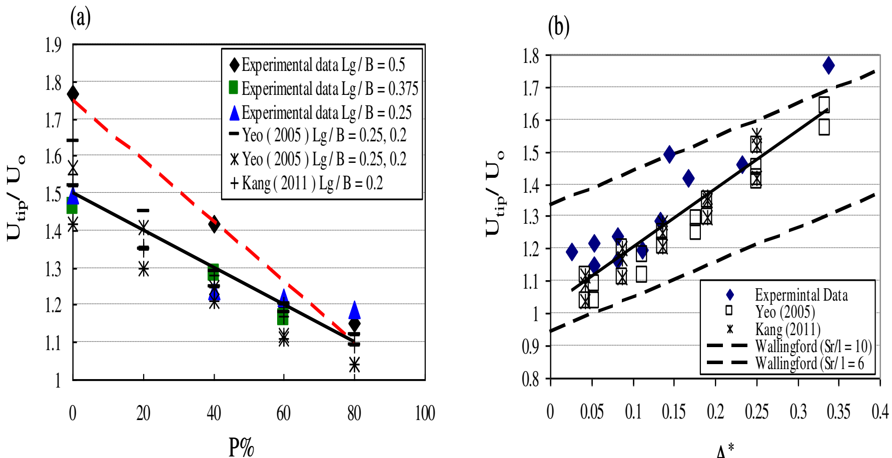

Fig. 10. Tip velocity variation with (a) permeability and (b) area ratio

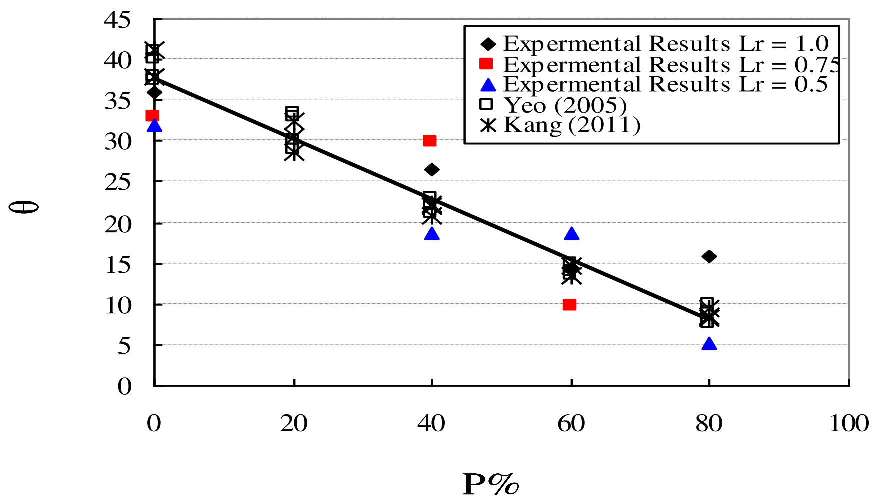

Fig. 11. Flow separation angle (θ) versus permeability P

Table 2
The empirical equations of relative tip velocity and the separation angle.

	Empirical Equations
Present study	$U_{tip} / U_o.=-0.008\ P +1.75$ $L_g / B = 0.5$
Present study	$U_{tip} / U_o\ = -0.005\ P + 1.5$ $0.2 \leq\ L_g / B \leq 0.375$
Yeo (2005) and present study	$U_{tip} / U_o=1.76\ A^*+1.015$ $0.02 \leq A^* \leq 0.35$
Present study	$\Theta\ =\ -0.3685\ P\% + 37.59$ $0 \leq P \leq 80$

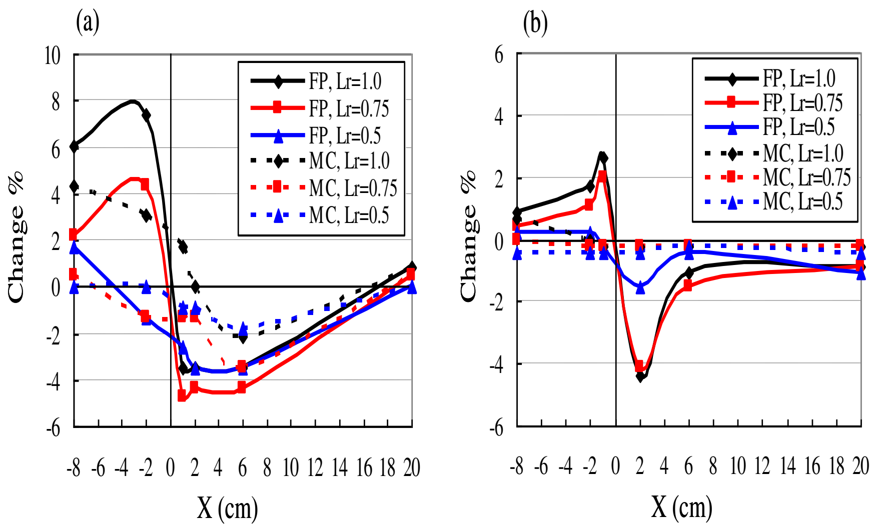

Fig. 12. Changes of water depth at the floodplain and the main channel centerlines for groyne with relative length L_r=1.0, 0.75 and 0.5. (a) Impermeable groyne, and (b) Permeable groyne (P =0.60)

As shown in Fig. 12 (a and b) the influence of the floodplain groyne on the flow water depth is greater at the floodplain centreline upstream and downstream of the groyne than at the main channel centreline in case of permeable groyne while the floodplain impermeable groyne affects both the floodplain and main channel flow surface. In case of the impermeable groyne with L_r=1.0, there are significant effects on the flow water surface due to groyne bulk area obstruct the floodplain flow. It is found that as the groyne relative length increase the changes of water depth in the floodplain increases and the greatest value of the heading up occurs just upstream and downstream the groyne.

Fig. 13 (a and b) shows the changes of water depth in tow lateral sections, the first section is upstream the groyne by 2 cm (U_{02}) and the second one is downstream it by 2 cm (D_{02}) for both the impermeable groyne and the permeable one (P=0.60), both of them with three relative length value (L_r=1.0, 0.75 and 0.5). the floodplain locates at the distance from 15 to 30 (the flume left side). In the floodplain, the changes of the water depth upstream the groyne increases as the groyne relative length increases for both the permeable groyne and the impermeable one and moves towards the groyne inside edge. While downstream of the groyne, the flow water surface lowers and slightly decreases as the groyne relative length increases. In case of impermeable groyne, the maximum raising on the upstream water depth could be estimated to 8, 4.5 and 3.5 % for groyne relative length L_r equal to 1.0, 0.75 and 0.5 respectively. As the permeability increases, the water depth slightly affected, thus for permeable groyne with P=0.60 the changes of floodplain water depth is only 2.5%, 2% and 1.5% for L_r 1.0, 0.75 and 0.5 respectively. For all values of permeability and length ratios, the change of water depth downstream of the groyne has averaged value as -4.5%.

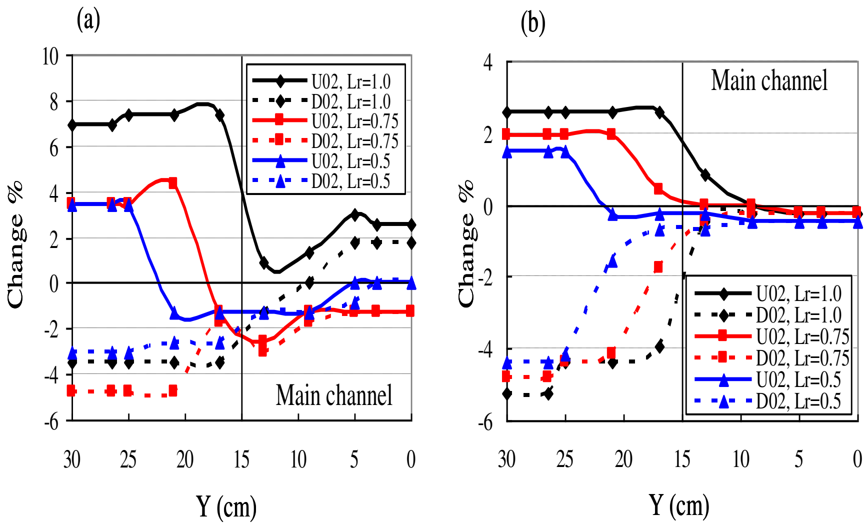

Fig. 13. Changes of water depth across the lateral section of the flume for L_r=1.0, 0.75 and 0.5. (a) impermeable floodplain groyne, (b) permeable groyne (P=0.60)

5. Conclusions

The present study is conducted using single groyne installed in a compound channel's floodplain to determine how much the groyne factors and parameters such as groyne type, length and permeability influence the flow field. The experiments showed the detailed information regarding the flow pattern. The findings will be of use considering optimization in river system with respect to ecology, floodplain protection and bed scour prevention.

Some main conclusions could be drawn as follows:

1. For single floodplain groyne regardless its permeability and length; its great influences on the flow pattern occur in region located from 5 times the groyne length upstream the groyne to 15 times downstream it. Beyond this range, the flow is slightly affected.
2. For the impermeable floodplain groyne, the groyne relative length has significant effects on both the flow structure and velocity at the groyne tip. As the groyne length increases, both the main channel flow velocity and the tip velocity increase while the velocity near the banks decreases.
3. For the floodplain permeable groynes (where; P=0.40, 0.60 and 0.80), the groyne relative length slightly affects the flow compared with the impermeable ones while the great effect is only due to the permeability. The maximum and tip velocities are inversely proportional to the permeability, while the minimum and bank velocities increase as the permeability increases.
4. For permeable floodplain groyne, the water depth greatly varies just upstream and downstream of the groyne. The water depth at the main channel centreline has no changes with permeable groyne, while it has small changes in case of impermeable groyne.
5. Finally, it is highly recommended to use the permeable floodplain groynes for the purposes of flood protection and scour prevention, where this type of groynes does not completely resist the flow and effectively reduces the flow velocity downstream of the groyne and furthermore avoid the scour problems around it.

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Nomenclature

A_c	Flow total cross sectional area
A_g	The lateral projecting area of groyne on the channel cross section
b	Width of the floodplain
B	Total channel width
h	Floodplain water depth
H	Main channel water depth
X_r	Relative longitudinal distance measured from the groyne (X/b)
Y_r	Relative lateral distance measured from main channel wall (Y/b)
L_g	Groyne length
L_r	Relative groyne length (L_g/b)
P %	Permeability of the groyne (area of water crossing the groyne/total projected area of groyne) * 100
U_b	Velocity near the floodplain bank
U_{max}	Maximum measured velocity in horizontal or vertical planes
U_{min}	Minimum measured velocity in horizontal or vertical planes
U_o	Flow approach velocity upstream the by 100 cm
U_{tip}	Velocity at the tip of the groyne
θ	Inclination angle of tip velocity to the horizontal

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تحليل السريان حول الرأس الحجري المسامي (المنفذ) داخل مسطحات الفيضان للقنوات المركبة

مخلص:

يحتوي هذا البحث على نتائج الدراسة المعملية وتحليل السريان المعملي حول الرؤوس الحجرية المسامية المستخدمة في مسطحات الفيضان للمجاري المائية ذات القطاعات المركبة. شملت الدراسة تأثير نفاذية الرأس الحجري وطوله النسبي (منسوباً إلى عرض مسطح الفيضان) على خصائص السريان المختلفة (السرعات، شكل سطح المياه، شكل توزيع السرعات في مجال وحول الرأس الحجري)

شملت الدراسة استخدام رؤوس حجرية غير منفذة و ثلاث نماذج للرؤوس الحجرية المنفذة بمقدار نفاذية 40%، 60% و 80% وأطوال نسبية 0.5، 0.75، 1.0 والتي تم تثبيتها في مسطح الفيضان للمجري المائي (ذو مسطح فيضان من جانب واحد) وكان عرض المجرى الرئيسي مساوياً لعرض مسطح الفيضان.

باستخدام جهاز قياس السرعات ثلاثي الأبعاد (Acoustic Doppler Veloci-meter 16MHz Micro-ADV) وبتحليل النتائج وجد أن تأثير طول الرأس الحجري على خصائص السريان يقل مع زيادة النفاذية. وبتتبع تحليل السرعات عرضيا عند مستوى قياس أفقي (0.25 من عمق المياه في مسطح الفيضان مقاساً من القاع) وجد أن السرعة القصوى والسرعة المقابلة للرأس الحجري تقل قيمتهما بزيادة النفاذية بينما تزداد قيمة السرعة الدنيا والسرعة المجاورة للجدار الخارجي لمسطح الفيضان. تأثير الرأس الحجري الغير منفذ كبير على خصائص السريان في المجرى الرئيسي مقارنة بالرأس المنفذ. تم صياغة عدد من المعادلات التجريبية التي تصف العلاقة بين كلاً من النفاذية والطول النسبي للرأس الحجري ومعدل التغير في سرعات السريان.