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Experimental Investigation on Flow Velocity Variation in Compound Channel with Non-Submerged Rigid Vegetation in Floodplain

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Abstract: Lateral momentum transfer (LMT) from floodplain into main channel is one of most important hydraulic phenomenon in the compound channels, which produces some vortexes on the banks of main channel. These vortexes make energy losses and also increasing the flow resistance due to bed roughness. The turbulence and velocity variation along the flow and its section increases with the density of non-submerged vegetation in floodplain, especially in the case of rigid covers. This variation of velocity due to the turbulence increases the severity of LMT in the width of the channel.In this research, some laboratory experimental investigation has been conducted, In a compound channel established in a flume with non-submerged vegetation cover in order to determine the impact of vegetation cover on the velocity and roughness variation, quantitively. The experiments plan defines in different scenarios including two types of vegetation density and covering all the width of the floodplain and 50 percent of its area. Also, hydraulic condition sets for three level of flow discharge. The results shown that the velocity reduced by increasing in the vegetation density. But in the same condition, the main channnel velocity increases extensively. Finnaly, the camparision of the different senarios results shown that the roughness variation has a fine corellation with LMT and energy losses in the longititude of the flume.

Key words: Flow resistance · Compound Channel · Vegetation · Floodplain

INTRODUCTION

River is a main part of hydrology cycle which has specific characteristics. The vegetation is an important element if each river which impacts on river bed and banks conservation, but it increases water level and reduces flow velocity in the channel and makes some problems like innundattion of flood plain. Becouse of this, it is important to assess the flow resistance.

Floodplain vegetation is classified to three groups. grass, shrub and trees that trees have most resistance against flow [1]. Mannig's coefficient is a basic factor of mathematical models in natural river simulation. This factor varies with the hydraulic and vegetation condition. The result of river modelling depends on a suitable choice of maning's coeficient directively. In this study, the variation of velocity and manning's coefficient in different vegetation and flow depth condition has been investigated in details.

Helmio *et al.* studied flow condition in compound channels. Their results emphasised on the complication of the flow pattern due to the LMT from flood plain into main channel (Fig. 1). As a result of this study, apparent shear stress τ_a was introduced. Also, several equations were presented for calculation of the new parameter [2].

Thornton *et al.* studied apparent shear stress in experimental flume, unsymmetrical rectangular compound channel with floodplain vegetation in two levels of density and submerged condition that resulted in several equations to calculate τ_a [3]. Tsujimoto *et al.* investigated flow resistance due to the artificial bamboo vegetation planted in one third of width rectangular flume with non-submerged condition [4]. Wu Fu-Sheng investigated effect of rods as non-submerged rigid vegetation on flow resistance parameters in rectangular flume with 12.5 m long and 40 cm width[5]. Habersak *et al.* studied flow resistance caused by wooden sticks representing vegetation in floodplain with flood flows condition.

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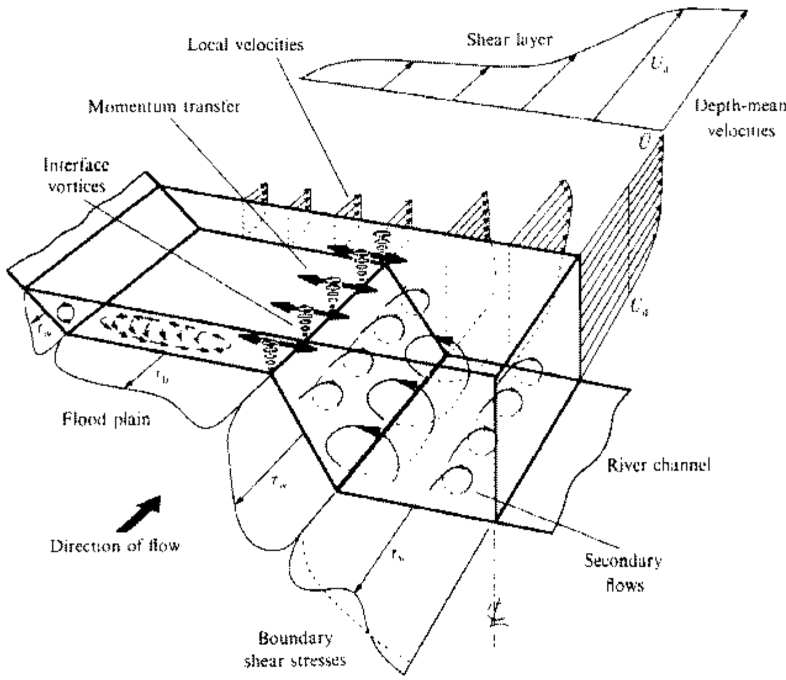

Fig. 1: Lateral momentum transfer and vortexes in compound channel [2].

A forudian model with the scale of 1:25 constructed based on field data for analysis to derive a representative geometry of the Kamp River [6]. Leu *et al.* investigated on the effect of riparian vegetation on velocity and flow depth variation using two-dimensional numerical model [7]. This research was done to find optimum presence of vegetation in floodplain. As mentioned above, a lot of studies have been done to determine the effect of vegetation on flow resistance. In this study, is focused on floodplain vegetation of symmetrical trapezoidal compound channels which is similar to the natural flow in rivers. Plastic trees are used as the vegetation in non-submerged condition.

MATERIALS AND METHODS

Some experiments were carried out in the Hydraulics Laboratory at Soil Conversation and Watershed Management Research Institute of Iran, In order to investigate the impact of woody vegetation in rivers floodplain on cross-sectional velocity and roughness coefficient. Tests were conducted in a glass-walled flume with length of 14m and width of 1.5m. The section is design as a symmetric trapezoidal compound channel with fixed longitudinal slope of 0.001. The bed of floodplain was covered by a layer of gravel (d50=10mm). The vegetation cover is modeled by some synthetic trees with the height of 22 cm and planted in checkered pattern with the distance of 10cm between each other. these strees covered a length of 4m in the flume and all measurements conducted in this part (Fig. 2).

In this study, two main scenarios defined according to the density of vegetation cover of floodplain; in first one, the whole area of the floodplain covered by the trees. in the second scenario, the coverage reduced to 50 percent of flood plain area. The experim1ents are done in four level of flow depth including 7.5, 10, 13 and 16cm, for each coverage in non-submerged condition.

Flow depth and velocity of the simulated vegetation were measured in three sections along the vegetation. A Nixon probe micro-propeller was used for the measuring of flow velocity. A sharp rectangular weir located in the downstream of the flume was used to control the flow discharge. All flow depth measurements were done by a point gauge with 0.1 mm accuracy.

A common approach to the determination of flow resistance is based on manning formula, which relates a mean cross-sectional velocity V to hydraulic redius R and energy grade line slope S_f as

$$n = \frac{1}{V} \cdot R^{2/3} \cdot S_f^{1/2} \quad (1)$$

Fig. 2: The Experimental Flume

Table 1: Hydraulic parameters and variables in the Experiments.

Flow Depth in Floodplain(cm)	Submergence Ratio	Mean Velocity in Cross Section(m/s)	Discharge(l/s)	Reynold Number	Froude NumberEnergy	Line Slope
7.5-16	0.35-0.7	0.25-0.29	32-71	4846-10130	0.22-0.29	0.002-0.0075

In all experiments flow condition was sub-critical and turbulent and hydraulic parameters and variables used are indicated in Table 1.

RESULTS AND DISCUSSION

In this study, results of cross-sectional velocity and flow resistance (Manning's coefficient) variations in different vegetation and flow depth conditions are shown as diagram to do some camparisions.

For example, as shown in Figure 3, in the flow depth of 7.5cm, the mean velocity is considerably increased in the main channel. This increment is about 63 and 37 percent for scenarios 1 and 2 versus non vegetation condition, respectively. Also, mean velocity in floodplain zone decreased 15 and 40 percent in the two scenarios respectively.

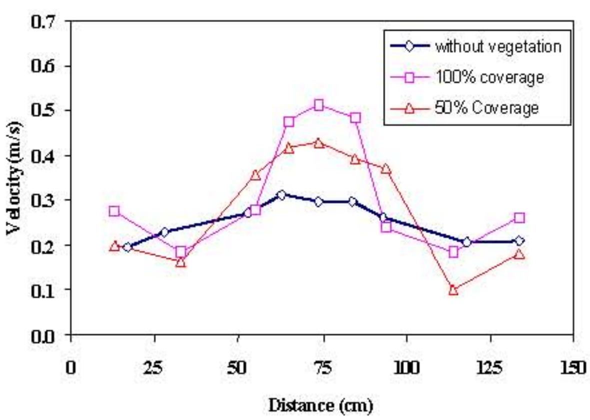

Fig. 3: Variation of cross-sectional velocity (flow depth in Floodplain=7.5 cm)

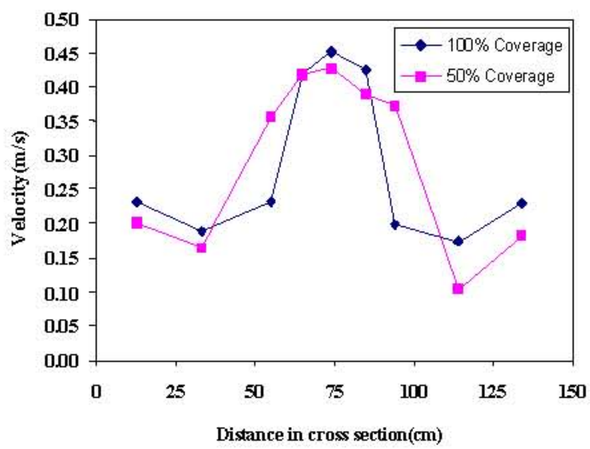

Fig. 4: Variation of cross-sectional velocity (flow depth in Floodplain= 7.5 cm and Q=32 l/s)

Due to high importance of vegetation management in floodplains, variation diagram of cross-sectional velocity for different floodplain coverage conditions and flow depths are shown in Figures 3 to 7.

The figures above indicate significant difference between floodplain and main channel flow velocities due to the presence of vegetation. In addition, to manage optimum floodplain considering river restoration, erosion control and flood control, full percent vegetation planting in floodplain is not recommended. Also, lateral momentum transfer, shear stress, energy losses and finally flow

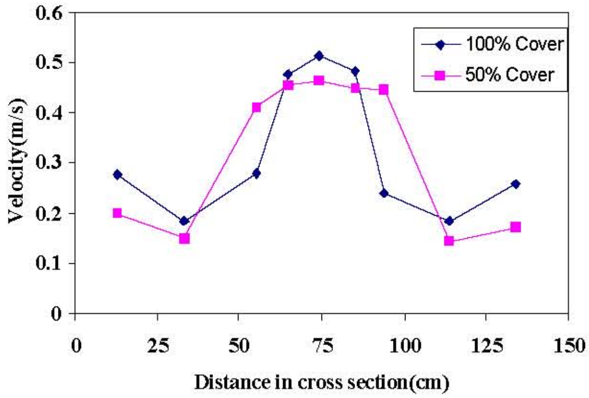

Fig. 5: Variation of cross-sectional velocity (flow depth in Floodplain= 10 cm and Q=49 l/s)

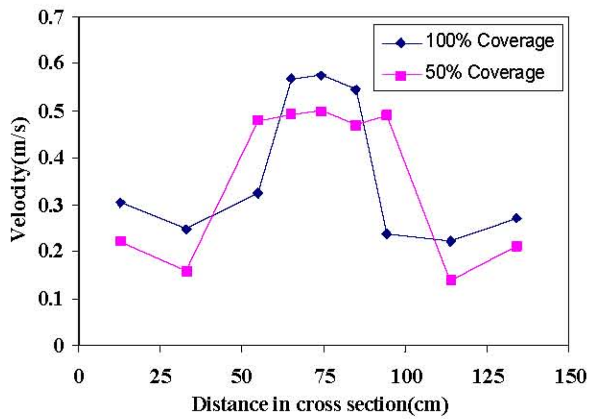

Fig. 6: Variation of cross-sectional velocity (flow depth in Floodplain= 13 cm and Q=62 l/s)

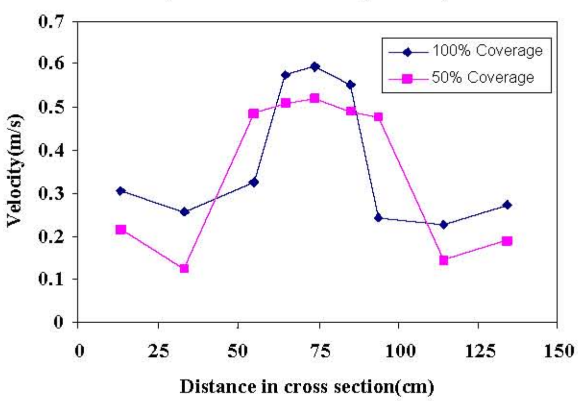

Fig. 7: Variation of cross-sectional velocity (flow depth in Floodplain= 16 cm and Q=71 l/s)

resistance are increased by floodplain vegetation. In order to show flow resistance value, Manning's coefficient is calculated in different conditions of vegetation and flow depth as shown in Figure 8. As indicated below, in 50 and 100 percent coverage

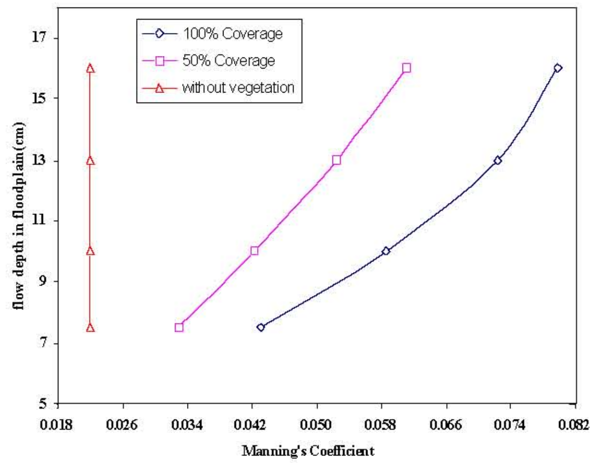

Fig. 8: Variation of manning's coefficient in different vegetation condition and flow depth.

conditions manning's coefficient is increased two and three times comparing non vegetation condition respectively.

CONCLUSION

This study presents that floodplain vegetation result in velocity decrease in floodplain and also increase of velocity in main channel. The variation caused some rise in lateral momentum transfer and energy loss. Manning's coefficient calculated confirms the results above. Therefore, floodplain vegetation would be effectively managed through coverage percentage effects on flow resistance from this study results.

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