International Journal of Integrated Engineering, Vol. 5 No. 1 (2013) p. 58-63

Influence of Two-line Emergent Floodplain Vegetation on A Straight Compound Channel Flow

Mazlin Jumain[1,*], Zulkiflee Ibrahim[1], Zulhilmi Ismail[1], Nur Hartini Ibrahim[1], Md Ridzuan Makhtar[2] and Mohd Rafique Nordin[3]

[1]Faculty of Civil Engineering, Universiti Teknologi Malaysia, 81310 Skudai, Johor, MALAYSIA.
[2]Hydraulic and Hydrology Laboratory, Universiti Teknologi Malaysia, 81310 Skudai, Johor, MALAYSIA.

Abstract: Floods are frequent events occur in Malaysia and cause loss of life, human suffering and widespread damages to buildings, crops and infrastructure. Effort to understanding on this phenomenon is an interesting research. The objectives of this study are to determine the stage-discharge relationship, roughness coefficient and streamwise velocity distribution in a vegetated straight compound channel. The effects of two-line emergent vegetation along the edge of floodplain are studied by using a flume in the Hydraulics Laboratory, Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM). The results on stage-discharge relationship, Manning's n and velocity distribution for overbank flows are presented in this paper. From the analysis, it is found that the vegetation influences stage-discharge where retardation of flow takes place. The maximum velocity zone is observed to be in the main channel and less fluid momentum transfer takes place in the presence of vegetation. Vegetated floodplain also influence the increases of channel roughness.

Keywords: Straight compound channels, vegetation, overbank flow, stage-discharge, velocity, roughness

1. Introduction

Many natural rivers have significant vegetation, which plays important roles for erosion prevention and habitat creation. Vegetation that exists within the floodplain commonly will increase the flow resistance and changes of velocity distribution. According to Chow [1] vegetation may be regarded as kind of surface roughness; it reduces the capacity of the channel and retards the flow. Hence, the presence of vegetation is related to control flooding event.

When the water flows exceed the capacity of a channel it is called as overbank flow which is also known as flooding condition. In this condition, most erosion occurs and therefore, it has been used in several mobile bed experiments [2]. It is important to understand the hydraulic processes in order to maintain the rivers as safe and environmental-friendly. Therefore, the influence of vegetated floodplain on overbank flows is an interesting research. Cao et al. [3], Rameshwaran and Shiono [4] and Sun and Shiono [5] are examples who have investigated the flow pattern in compound channel with vegetated floodplain.

Experimental investigations on the flood flow characteristics in vegetated straight compound channels has been undertaken. The effects of two-line emergent vegetation along the edge of floodplain are studied by using a rectangular flume in the Hydraulics Laboratory, Faculty of Civil Engineering, Universiti Teknologi Malaysia (UTM).

The aim of this research is to enhance knowledge on the river hydraulics due to the presence of emergent vegetation on its floodplain. The objectives are to determine the stage-discharge relationship, velocity distribution and flow resistance by Manning's n coefficient in a straight compound channel with two-line emergent vegetation on floodplain edge. This study is focussed on the influence of vegetation arrangement on overbank flow characteristics. The vegetation is arranged by tandem and staggered on the floodplain. The experimental research is covered the study on overbank flows for non-vegetated and vegetated floodplain cases at DR = 0.28 and DR = 0.47. DR is the relative depth of the flume channel.

2. Research Methodology

This study involved data collection through experimental investigation by using a rectangular flume, as shown in Fig. 1. The dimension of a physical model is 4.0 m length and 0.6 m width, which is consists of rectangular main channel with 0.2 m width and 0.05m depth located at side of a single floodplain. Fig. 2 shows a cross-section of a straight compound channel. This experiment observed by difference arrangement of two-line emergent vegetation on floodplain condition with fixed bed straight rectangular compound channel, as shown in Fig. 3 and Fig. 4. Wooden rods of 10 mm diameter (d) are used to simulate the emergent floodplain vegetation. A spacing of 4d is adopted in the study.

*Corresponding author: mazlinjumain@gmail.com

penerbit.uthm.edu.my/ojs/index.php/ijie

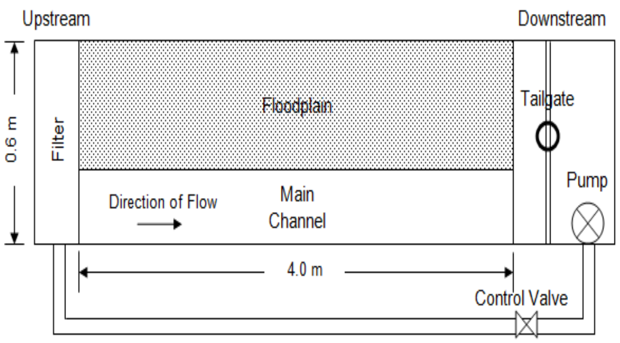


Fig. 1 Plan view of channel

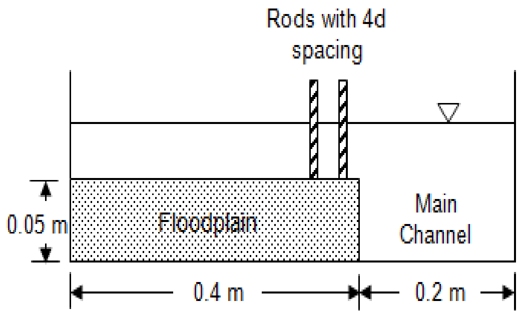


Fig. 2 Cross-section view of channel

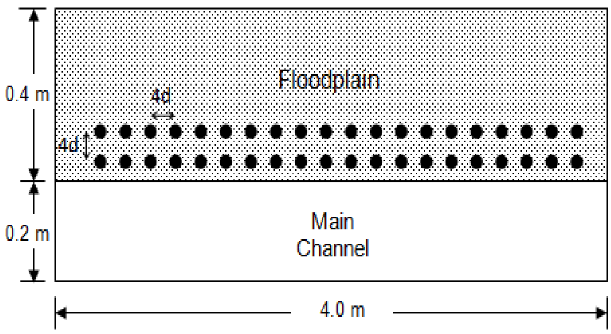


Fig. 3 Tandem arrangement of wooden rods on floodplain

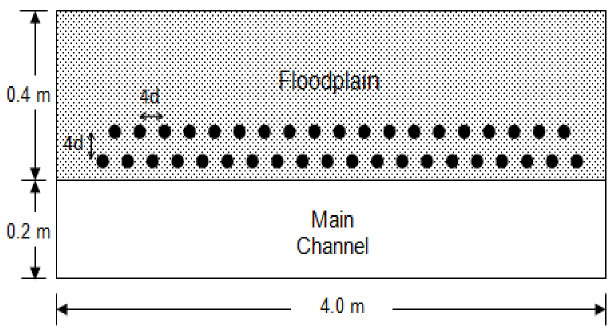


Fig. 4 Staggered arrangement of wooden rods on floodplain

The experimental investigation involved different equipment which is used to measure the different types of data. The water depth has been measured by using point gauge, while velocity values are measured by using a pitot tube. Using the velocity values, the discharges in the flume are calculated by using the mid-section method. The following equations are used in data analysis:

$$DR = \frac{(H-h)}{H} \qquad (1)$$

where DR is the relative depth; H is the mean water depth in main channel (m); and h is the height of main channel from mean bed level (m).

$$U = \sqrt{2gh} \;; \quad h = h_{in} - h_{out} \qquad (2)$$

where U is stream-wise velocity (m/s); g is acceleration of gravity (m/s^2); h is difference of fluid heights inside and outside of pitot tube (m).

$$n = \frac{A\, R^{2/3}\sqrt{So}}{Q} \qquad (3)$$

where n is Manning's roughness coefficient; A is area of water flow (m^2); R is hydraulic radius (m); S_o is bed slope of channel; Q is discharge (m^3/s); and P is wetted perimeter of flow (m).

$$F_r = \frac{U_m}{\sqrt{gD}} \qquad (4)$$

$$R_e = \frac{4U_m R}{v} \qquad (5)$$

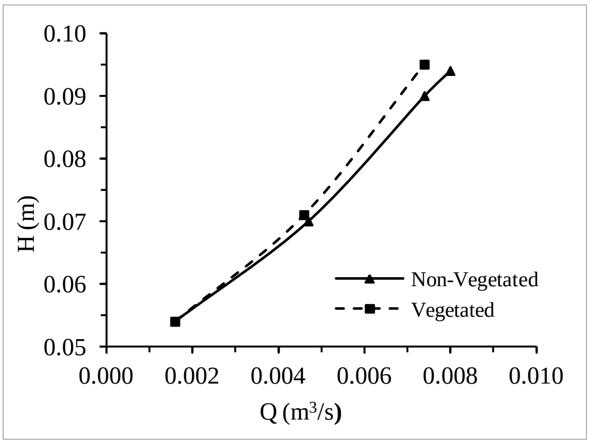
where F_r is Froude Number; U_m is mean velocity (m/s); g is acceleration of gravity (m/s^2); D is hydraulic depth (m), R_e is Reynolds Number; R is hydraulic radius (m); and v is kinematic viscosity (m^2/s).

3. Results and Discussion

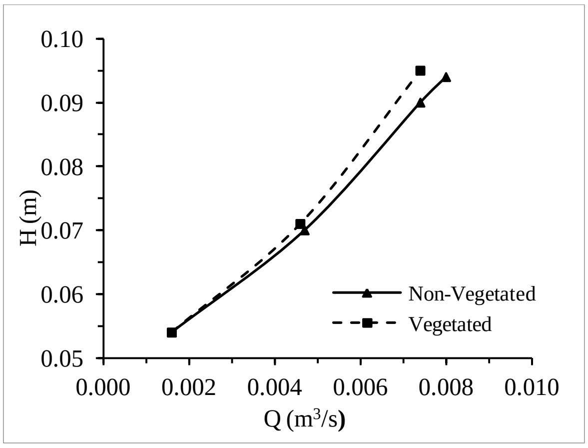
The experiment has been conducted under uniform flow condition in order to apply uniform flow theory in the analysis. The uniform flow is achieved when slope of water surface (S_w) is equal to slope of channel bed (S_o) at all time. The classification of flow in a channel is turbulence for Reynolds number exceeds 4,000 and subcritical flow (low velocity) condition occurs when Fr is less than 1. Both of approach explained that the regime of flow classified as subcritical-turbulence for straight compound channel.

3.1 Stage-Discharge Relationship

The changes of water depth with variation of discharges are presented as this stage-discharge rating curve. This study is conducted in overbank flow because the vegetation is placed on along the edge of floodplain. From the Fig. 5, the graphs show that the discharge increases with water depth. According to Hin Joo et al. [7], for water flows after bankfull in vegetated case, the slope of the graph was steeper compared to non-vegetated case. It has been found that the increase of water depth from smooth floodplain to vegetated floodplain on both of graphs is almost 5%.



(a) tandem



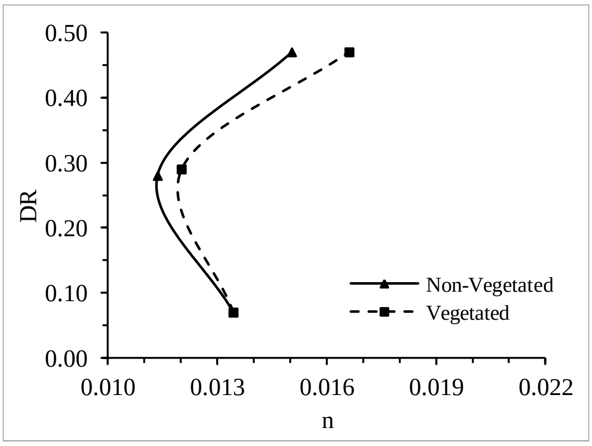
(b) staggered

Fig. 5 Stage-discharge relationship for (a) tandem and (b) staggered emergent vegetation on floodplain

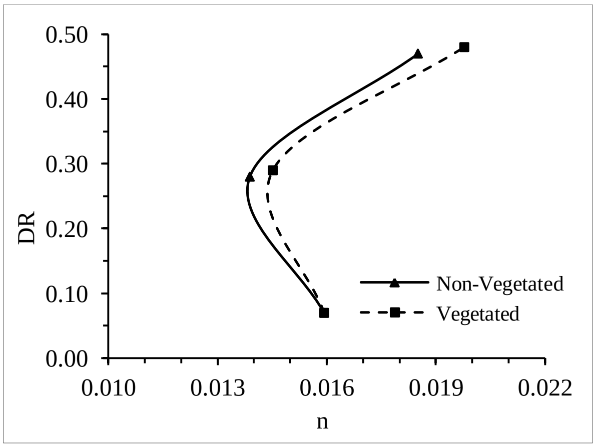
3.2 Manning Coefficient, n

The flow resistance in a channel is represented by the Manning's coefficient, n value as shown in Fig. 6. The Manning's n should be remain constant in inbank flow and starting increase when reach overbank flow where the relative depth is increase too. This is happen because of changes in roughness surface between main channel and floodplain. The minimum discharge is taken as relative depth (DR = 0.07 ≈ 0) and considered as bankfull condition where (DR = 0). The other discharge and relative depth are taken based on overbank condition.

However, it has been found that the Manning's n value for bankfull condition is higher than overbank condition. Based on Fig. 6 (a), the average Manning's n value for non-vegetated case is 0.013, meanwhile for vegetated case is 0.014. From Fig. 6 (b), the average Manning's n value for non-vegetated case is 0.016, meanwhile for vegetated case is 0.017. The values indicate that roughness coefficient for staggered vegetation is higher than tandem vegetation. It is due to effects of vegetation arrangement on floodplain which creates additional resistance to flow hence contributing to higher Manning's n. The roughness of floodplain surface also can increase resistance of flow along the channel. The roughness surface between main channel wall and floodplain occurs due to imperfect condition during the construction of the model. In reality, the value of *n* is highly variable and depends on a number of factors [1].



(a) tandem



(b) staggered

Fig. 6 Manning's n for (a) tandem and (b) staggered emergent vegetation arrangements

3.3 Stream-wise Velocity Distribution

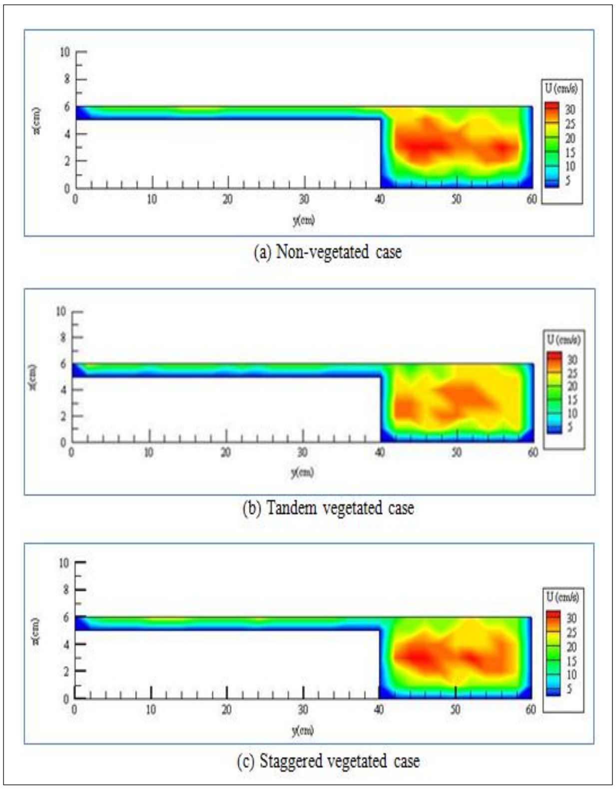
In order to obtain velocity distribution profiles, stream-wise velocity components have been plotted using the Tecplot 360 software. Plots are made based on velocity values to describe the flow patterns in the main channel. The plots show the stream-wise velocities in cm/s. Fig. 7 illustrates the cross-sectional distribution of stream-wise velocity in the compound straight channels at two relative flow depths (DR = 0.28 and DR = 0.47). The maximum velocity takes place in the middle of main channel, and decreases towards the channel walls and bed. The flow pattern is quite similar with observations by Sun and Shiono [5] and Sanjou et al. [8]. The velocity on the floodplain is smaller than the velocity in the main channel. This is due to different depths of floodplain and main channel. Table 1 indicate the summary of mean velocities in the main channel and the floodplain for non-vegetated and vegetated (tandem and staggered arrangements) cases.

Table 1 Mean velocity for non-vegetated and vegetated cases

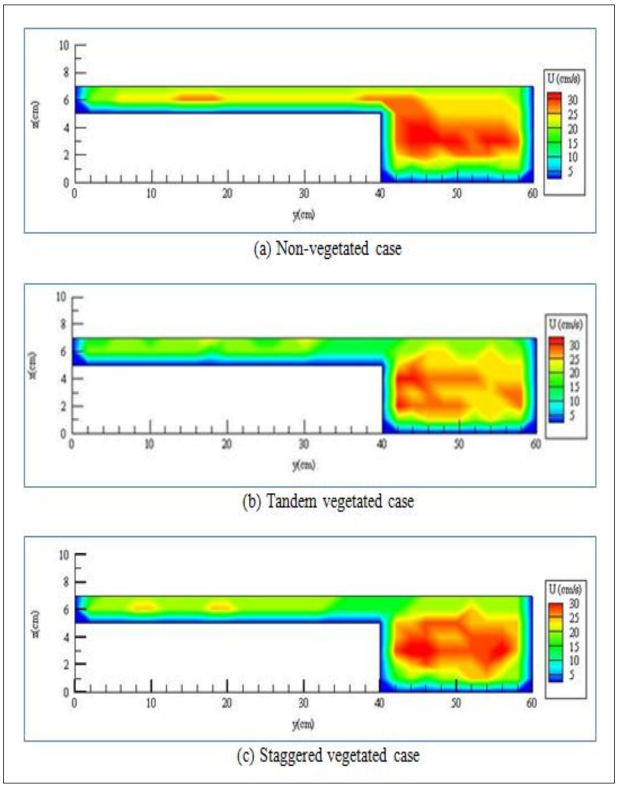
Case		***Mean velocity, U_m in the main channel (cm/s)***	***Mean velocity, U_m in the floodplain (cm/s)***
DR=0.28	Non-vegetated	24.13	21.20
	Vegetated		
	Tandem	23.76	20.48
	Staggered	24.04	19.66
DR=0.47	Non-vegetated	24.31	21.92
	Vegetated		
	Tandem	24.48	19.71
	Staggered	25.81	18.36

For the non-vegetated cases, the flow is well-dispersed in main channel and floodplain at higher relative depth. While, in the vegetated cases (tandem and staggered arrangements), when water from main channel starts to move into the floodplain, the rods limited the momentum transfer process from main channel into the floodplain. The maximum velocity still occurs at the centre region of the main channel. The low velocity zone developed at the main channel-floodplain interface. It happens due to the vegetation at the edge of main channel.

The flow distribution for tandem case is slightly better than staggered case. Larger maximum velocity cell remained in the main channel for the staggered rods case. This mean that staggered rods produced larger drag force to the flow. Thus, the rods arrangement influenced the momentum transfer between main channel and floodplain.



(a) DR = 0.28



(b) DR = 0.47

Fig. 7 Stream-wise velocity distribution for (a) DR = 0.28 and (b) DR = 0.47

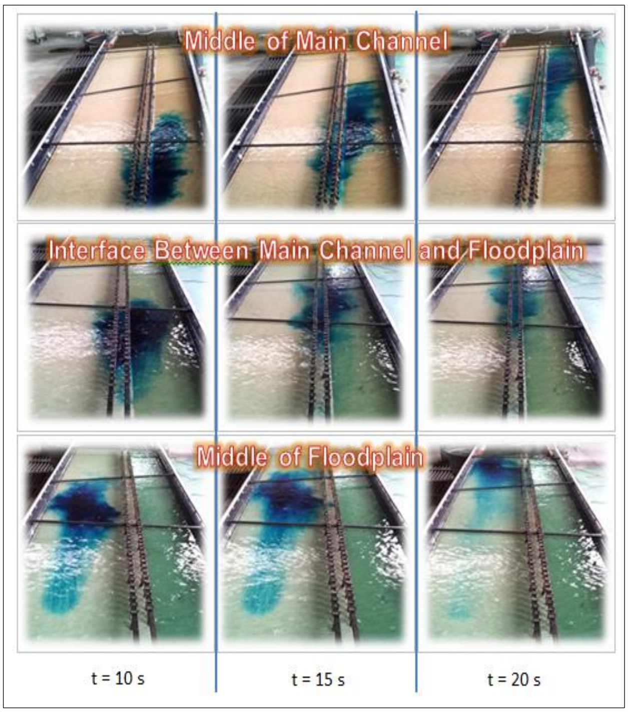
3.4 Video Observation

A recording video is made to observe pattern of the velocity of water in the floodplain and main channel through the experiment using dye for non-vegetated cases and vegetated cases. The tracer is released in the middle of main channel, floodplain and interface between floodplain and main channel. The flow velocities become decrease from upstream to downstream when the tracer scattered.

From the Fig. 8, it have been shown that the tracer flow through the velocity in main channel and floodplain areas. The mean velocity for the non-vegetated, U_m is 22.66 cm/s, while for the vegetated case, U_m is 20.14 cm/s. Based on the tracer in the figures, it has been found that the maximum velocity still occurs at the centre region of the main channel. Fig. 8 (a) shows that the tracer move quickly when no vegetation exists compared to the flow velocity in vegetated cases show in Fig. 8 (b) which is tracer move slowly when there are existence of vegetation. Thus, it has been found that the tracer movement influenced by the mean velocity value. The presence of rods limited the momentum transfer between main channel and floodplain flows due to drag forced generated by the rods. The rods also tend to retard the flow and disturbed the momentum transfer from the main channel into the floodplain.

(a) non-vegetated

Fig. 8 Recorded tracer movement for case of (a) non-vegetated and (b) vegetated at DR = 0.28 (Indicated at difference point of tracer release)



(b) vegetated

Fig. 8 Recorded tracer movement for case of (a) non-vegetated and (b) vegetated at DR = 0.28 (Indicated at difference point of tracer release)

4. Conclusion

This paper presents the influence of two-line emergent vegetations along the edge of its floodplain on straight compound channel flow. The hydraulics of straight compound channel with two-line emergent vegetation floodplain was studied in the laboratory using a rectangular flume. The effects of vegetation arrangement are focussed on stage-discharge relationship, flow resistance and stream-wise velocity distribution. The findings of the study are (i) vegetated floodplain retard the water flow and cause the water depth increase in the main channel compared to channel with non-vegetated floodplain, (ii) the existence of tandem vegetation gives higher water depth compared to staggered vegetation arrangement, (iii) velocity is decreases near the vegetation but increases when far or further from the vegetation, (iv)vegetations increased the flow resistance (Manning's n) and affects the behaviour of overall flow velocity, (v) the presence of rods limited the momentum transfer between main channel and floodplain flows due to drag forced generated by the rods, and (vi) the staggered vegetations produced higher flow resistance in the compound channel compared to tandem vegetations.

5. Acknowledgement

The authors would like to thank and express a sincere appreciation to all parties who have involved in the implementing of this research.

References

[1] Chow, V.T. Open Channel Hydraulics. *McGraw-Hill Book Co*., New York, (1959).

[2] Thornton, C.I., Abt, S.R., Morris, C.E., and Fischenich, J.C. Calculating Shear Stress at Channel–Overbank Interfaces in Straight Channels with Vegetated Floodplains. *Journal of Hydraulic Engineering*, Volume 126 (12), (2000), pp. 929–936.

[3] Cao, S., Liu, X., and Yang, K. Flow and Sediment Behaviors in Compound Channels with Vegetated Floodplains. *Proceeding of the 5th Int. Symposium on Environment Hydraulics.* Arizona, USA, (2007).

[4] Rameshwaran, P., and Shiono, K. Quasi Two-Dimensional Model for Straight Overbank Flows Through Emergent. *Journal of Hydraulic Research*. Volume 45(3), (2007), pp. 302-315.

[5] Sun, X., and Shiono, K. Flow Resistance of One-Line Emergent Vegetation Along the Floodplain Edge of a Compound Open Channel. *Journal of Advances in Water Resources*, Volume 32(3), (2009), pp. 430-438.

[6] Zulhilmi, I., and Shiono, K. The Effect of Vegetation Along Cross-Over Floodplain Edges on Stage Discharge and Sediment Transport Rates in Compound Meandering Channels. *Proceedings of the 5th WSEAS International Conference on Environment, Ecosystems and Development*, Venice, Italy, (2006).

[7] Joo, H., and Seng, D. M. Y. Study of Flow in Non-Symmetrical Compound Channel with Rough Floodplain. *Journal of the Institution of Engineers Malaysia*, Volume 69 (2), (2007), pp. 18-26.

[8] Sanjou, M., Nezu. I., Suzuki, S., and Itai, K. Turbulence Structure of Copound Open-Channel Flows with One-Line Emergent Vegetation. *Proceeding of the 9th. Int. Conference on Hydrodynamics*, Shanghai, China, (2010).