MASS AND MOMENTUM EXCHANGE IN SEMI CLOSED EMBAYMENT

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1. Introduction

An embayment along the riverside is contributing to provide and maintain the ecological process from the environmental point of view. The exchange processes between a dead zone in the embayment and the main channel gives the most important role for maintaining wide variety of fauna and flora in the river. It means that the riverside embayment is expected to provide preferable environment for natural lives.

In natural river, owing to a dead zone formed in the space and rather slow velocity, sediment tends to be deposited in the space and it becomes shallower. It results in a narrow entrance on the connection between main channel and dead-water zone. From the practical engineering, that connection also often found as a partially closed partition made by artificial works.

A few researchers treated the partially blocked side cavity and analyzed the exchange processes on their experiment. Tominaga et al.[5),6)] investigated the mass exchange in closed embayment, by using dye injection method. They found out that the water exchange rate is generally proportional to the velocity scale in the embayment area but it was affected by intermittent and three dimensional flow structures. Another information of mass and momentum exchange in an embayment are gained from the open embayment result's which the interface between main channel and the embayment is found to be open interface. Muto et al.[2)] found that the exchange coefficient of mass and momentum are more effective in the ratio L/D=3 than the square embayment case due to instability of the dominant circulating flow formed in the embayment. Nezu and Onitsuka[3)] also reported the same result. Brevis et al. [4)] reported the location of the main source for turbulent mass exchange is located at the channel-embayment interface, were Kelvin-Helmholtz instabilities are generated.

In this study, we investigated the effect of the length of the entrance, together with the variations of the width and location of the entrance, on the mass and momentum exchange in the interface between embayment and main stream experimentally by using PIV method.

2. Experimental Setup

Experiments were conducted in a tilting straight rectangular channel with 8m length, 0.3m width with an adjustable slope. The slope of the flume *S* was set as 1/1000. The test section was located 4 m downstream from the entrance. Several cases on the combination among the entrance placement, the width and length of entrance were carried out. The variations of experiments are shown in Fig.1. These cases can be generalized into three general categories according to the entrance location of the embayment. The entrance channel was located at upstream-end, downstream-end, and middlestream along

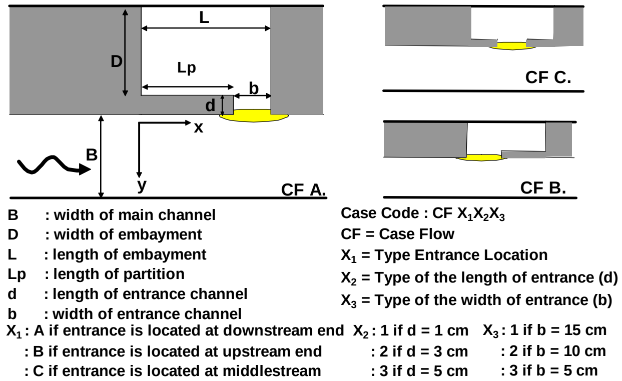

Fig.1 Variations of experiment and the encoding.

the interface between main channel and embayment. In all cases, the discharge *Q* was 0.00156m^3/s and the water depth *h* was set to 0.04m by adjusting the downstream weir. The mean velocity was 0.260m/s, Froude number was 0.42 and Reynolds number was 10400.

In order to quantify the exchange processes, velocity distributions in the main channel-embayment interface were measured using a particle image velocimetry (PIV) technique. In the present analysis, the flow velocities were calculated by PIV using about 3200 successive images in 16s with an interval of 1/200s.

3. Result and discussion

In the case considered, such as the embayment attached to a straight channel, the lateral exchange between the embayment and the main flow region through the interface layer is most predominant. Thus the lateral components of velocity and shear stress play important roles. This lateral component contributes to mass exchange whereas the shear stress contributes to momentum transfer.

The effectiveness of exchange is estimated quantitatively by introducing mass exchange coefficients, *k'* and momentum exchange coefficient, θ, as follows [1)]:

$$k' = \frac{1}{\rho U_m b}\int_0^h\int_0^b \rho\left|\overline{v}\right| dxdz \qquad (1)$$

$$\theta = \theta_{mv} + \theta_{rs} = \frac{1}{\rho {U_m}^2 b}\left\{\int_0^h\int_0^b \rho\, \overline{u}\, \overline{v} dxdz + \int_0^h\int_0^b \rho\overline{uv} dxdz\right\} \qquad (2)$$

The estimated exchange coefficient by Eqs. 1 & 2 are shown in Figs 2, 3, 4 and 5. Fig.2 shows that the mass exchange coefficients decrease in all cases by narrowing the entrance width. The results also show the effect of entrance location. The mass exchange in the semi closed embayment is effective when the entrance is located in the middlestream. The effects of entrance length seem similar in the cases upstream and downstream entrance which the mass exchange decreases as the entrance length become longer.

Fig3. shows that momentum exchange coefficients from Reynolds stress decrease in all cases by narrowing the

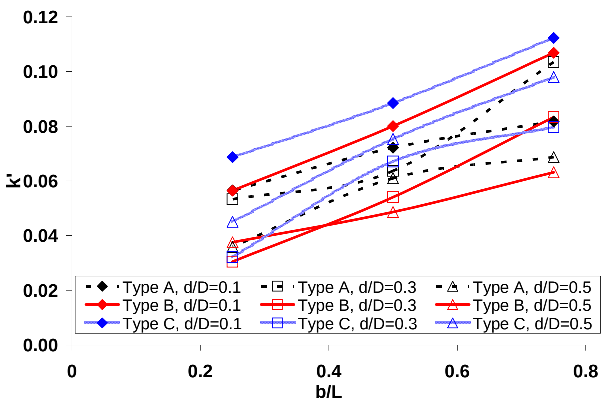

Fig.2 Mass exchange coefficient for all cases.

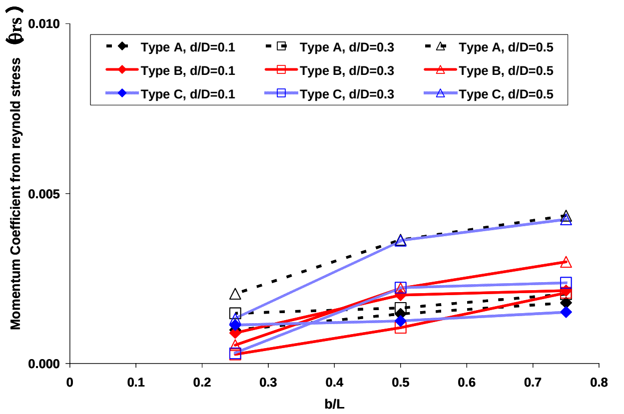

Fig.3 Momentum exchange coefficient from Reynolds Stress (θrs) for all cases.

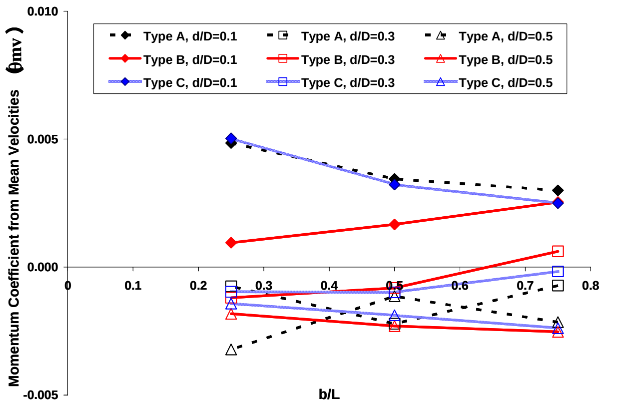

Fig.4 Momentum exchange coefficient from mean velocities (θmv) for all cases.

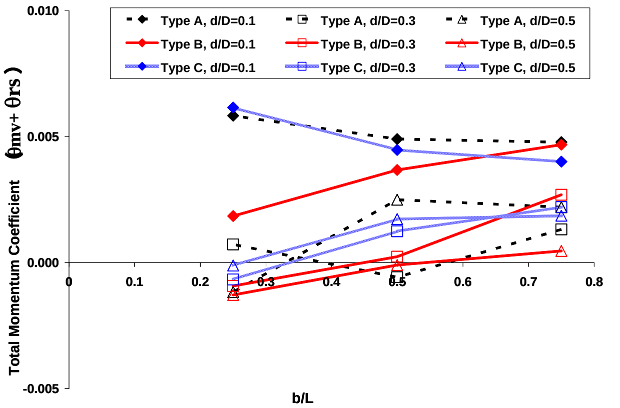

Fig.5 Total Momentum exchange coefficient for all cases.

entrance width. The values of momentum coefficients from Reynolds stress are always positive. It means that the momentum transferred from main channel to embayment. The momentum exchange from Reynolds stress is found to be higher when the length and the width entrance become longer. On the other hand, the momentum exchange coefficients by means of average velocities (Fig.4) give contribution only when the length of the entrance is small. Otherwise, the value is nearly zero or negative. These mean that the long-time averaged velocity contribute to the momentum exchange caused by mean velocities and transported from embayment to main channel.

From Fig.5, the total momentum exchange coefficients patterns are found similar with the one from the mean velocities. It indicates that mean velocity components have significant effect on the momentum exchange in the interface between main channel and embayment. The total momentum transfer is higher when the entrance length becomes small. The effect of entrance width can not be seen clearly in the result of total momentum exchange coefficient and momentum exchange coefficient from mean velocities.

4. Conclusion

Mass and momentum exchange in an embayment zone connected to a main channel through an entrance channel were investigated experimentally. Effects of the length, width and location of the entrance channel were tested. The entrance length has an effect on the reduction of mass and momentum exchange between the main channel and the embayment when the entrance length becomes longer. Mean velocities component need to be considered in the momentum exchange calculation since the momentum transfer transported from embayment to main channel in the case of d/D>0.3 and give similar pattern to total momentum exchange in the channel-embayment interface.

REFERENCES

1) Ikeda, S., Yoshike, T., and Sugimoto T.: Experimental study on the structure of open channel flow with impermeable spur dikes, *Annual Journal of Hydraulic Engineering, JSCE*, Vol.43, pp.281-286, 1999.
2) Muto, Y., Imamoto, H., and Ishigaki T.: Velocity measurements in a straight open channel with arectangular embayment, *Proceeding of 12th Congress of APD-IAHR*, Bangkok, Thailand, pp.353-362, 2000.
3) Nezu, I., and Onitsuka, K.: LDA Measurements of side cavity open channel flows; Wando models in rivers, *Advances in fluid modeling & Turbulence Measurements, Proceedings of the 8th International Symposium on flow modeling and turbulence measurements*, Tokyo, Japan, pp.169-176, 2000.
4) Brevis, W., Niño, Y., Vargas, J.: Experimental characterization and visualization of mass exchange process in dead zones in rivers, *Proceedings of the International conference on fluvial hydraulics*, Lisbon, Portugal, pp.235-242, 2006.
5) Tominaga, A. and Jong, J.: Effects of conjunction channel on water exchange in riverside embayment, *2nd International Symposium on Shallow flows*, Hongkong, 2008.
6) Tominaga, A. and Nugroho, E. O.: Effects of inlet configuration on water exchange in closed embayment, *Annual Journal of Hydraulic Engineering, JSCE*, Vol.53, 2009