TURBULENCE CHARACTERISTICS AND BOUNDARY LAYER DEVELOPMENT IN ARMORED GRAVEL BED

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1. INTRODUCTION

Varieties of open channel flows belong to the class of hydraulically rough-bed flow. Although channel hydraulics has been studied extensively for the last two decades but there are still many unsolved problems awaiting clarification, and past studies were mainly focused on the velocity distribution at the upper part of the armored layer. The purpose of this experimental study is to investigate the turbulence characteristics inside the armored layer and boundary layer development in dense armored gravel bed.

2. EXPERIMENTAL PROCEDURE

Series of experiments were carried out using open channel flume with 14 [m] length and 0.5[m] in width with 2 armored bed condition. Fig.1 (a) and Fig.1 (b) shows the gravel (Group-II) and stones (Group-I) arrangement in the bed. The arrangements were chosen considering the bed material in Futase Dam in Arakawa River. Group-II type gravel of 3 [cm] layer was laid on the wooden board bed from 1 to 14 [m] and Group-I type stones were placed on the gravel layer ranging from 1.3 to 8.5 [m], in case1 they were placed directly on the gravel layer (Interval between 2 layers of Stones was 2cm) but in case2 (Interval between 2 layers of Stones was 8cm) and were buried 1 [cm] into the gravel layer. All measurements were taken at the centre section around 6.3 [m] where the water depth was not affected due to the resistance. Using Particle Image Velocimetry (PIV) technique, the vertical velocity distribution and Reynolds shear stress around 5 locations in armored bed for 12 experimental runs of both cases were obtained.

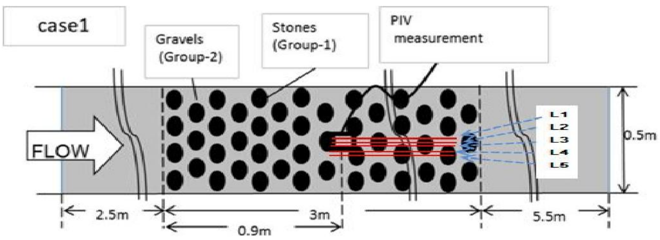

Fig. 1(a): Schematic of experimental setup –case1

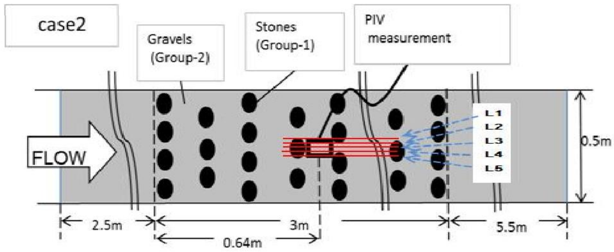

Fig. 1(b): Schematic of experimental setup-case2

3. RESULTS AND DISCUSSIONS

3.1 Vertical Distribution of Longitudinal Velocity

Fig. 2(a) and Fig. 2(b) shows the averaged longitudinal velocity distribution from L1 to L5 at 1.3[m] and 6.3[m] in case1 and case2.

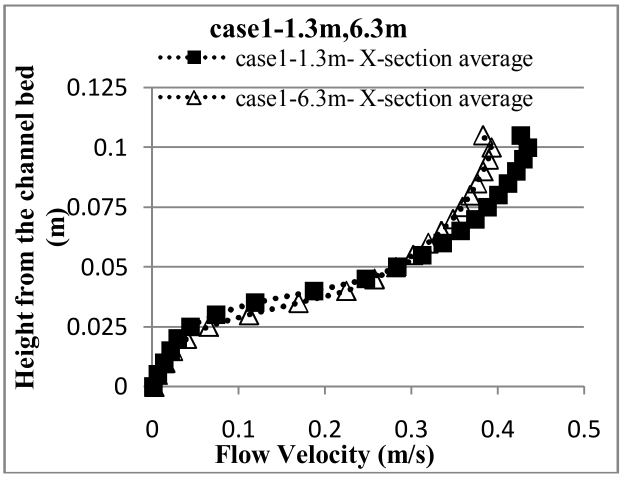

Fig. 2(a): Averaged Longitudinal Velocity Distribution -case1

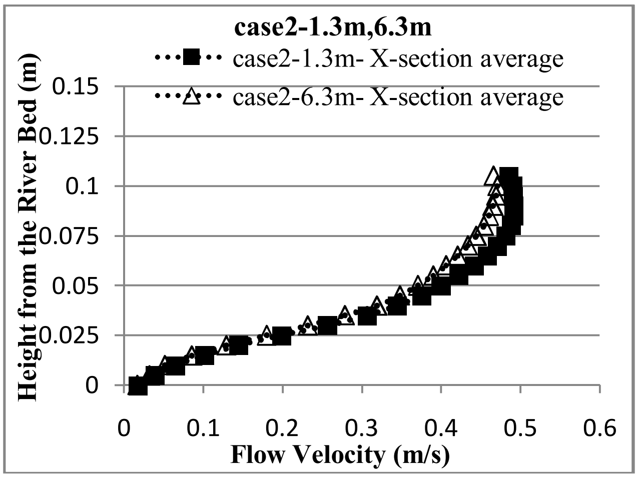

Fig. 2(b): Averaged Longitudinal Velocity Distribution–case2

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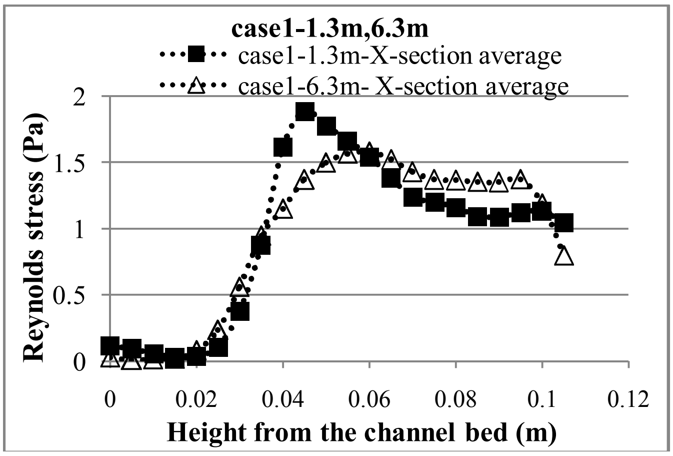
The velocity above the stones height has larger velocity as compared to region behind stones, it is because of the sheltering effects by large roughness elements which is large in case of case1 than in case2. By comparing two cases, it can be noted that in case1 the velocity near the bottom is smaller than in case2 it is because of the low momentum exchange by the narrower spacing. When the relative depth is small, the flow velocity distribution of the above stone is substantially linear distribution rather than a logarithmic distribution. The reason can be justified by the log law distribution in which when the relative water depth is small the vortices are mixed near the water surface. When the mixing length is constant, the velocity distribution has been proved to be a linear function (Tanaka et al., 2014)

3.2 Reynolds Shear Stress Distribution

Fig. 3(a) and 3(b) shows the time averaged Reynolds shear stress in both cases at location 1.3[m] and 6.3[m]. In both case, near the height of the stone, Reynolds stress is decreasing towards the bottom. In case1, the water near the stone doesn't flow in the neighborhood vicinity because of dense arrangements of stones and it is believed that there is little exchange of the momentum for the fluid at the neighborhood of base. On the other hand, in case2 since the spacing between is larger in comparison with case1, the momentum exchange is greater, so the Reynolds shear stress is high.



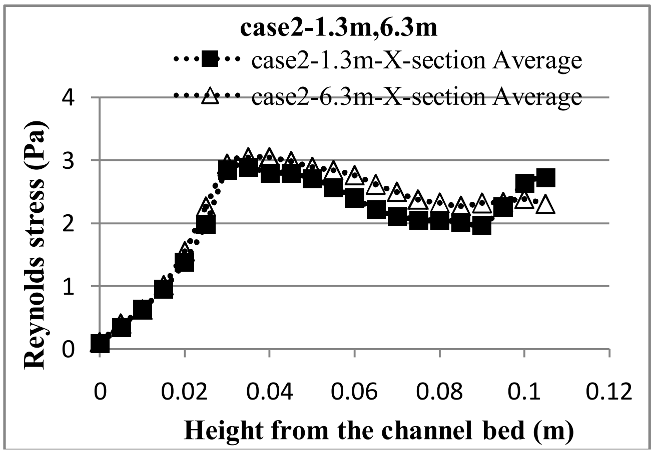


Fig. 3(a): Time-averaged Reynolds shear stress: case1 Fig. 3(b): Time-averaged Reynolds shear stress: case2

3.3 Boundary Layer Development

Fig. 2(a) and Fig. 2(b) shows that from the top of the stones a high-velocity gradient is developed in the vicinity of channel bed, which is associated with the frictional stresses generated between the fluid particles and the stones. The layer of fluid adjacent to a solid boundary where viscous effects are evident is called the “boundary layer" which is very close to the external velocity already at a small distance from the wall and it is possible to define the boundary layer thickness as that distance from the wall where the velocity differs by 1 percent. Fig-2 (a) shows increase in boundary layer thickness because of the dense armored resulting in small viscosities and large Reynolds numbers i.e. a dimensionless number derived through dimensional analysis of the flow and defined by the ratio of inertial to frictional forces which is average flow rate time diameter of stone divided by kinematic viscosity the fluid. In case2, because of large spacing between layers it causes decelerated flow and fluid particles are forced outwards which means that boundary layer is separated from the wall and full velocity is achieved. This phenomenon is associated with formation of vortices and large energy losses in the wake of the body. It has long been suspected that flow resistance is related to the velocity distribution.

4. CONCLUSIONS

a) Velocity distribution shows exponential trend near the roughness height and above the roughness height, it shows almost linear distribution but close to the logarithmic law distributions.
b) Reynolds shear stress increases by increasing space between stones it is because when the spacing is larger there is large exchange of the momentum of the fluid and hence the larger shear stress.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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