Flow Resistance and Turbulent Structures in Cases Two and Three Dimensional Over a Completely Rough-bed Surface in an Open Channel

Kumamoto University Student member ○ Sukarno TOHIRIN
Kumamoto University member Terunori OHMOTO

1. Introduction

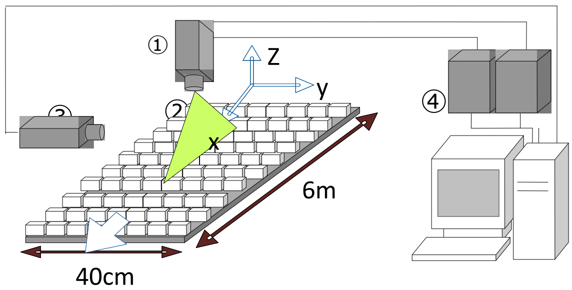
The magnitude of resistance flow, turbulent structures and momentum transport over a completely rough-bed surface in an open channel were determined by the longitudinal cross section profile of channel; shape, size and arrangements of roughness, pitch ratio and water flow condition. Numerous works has accumulated that it is importance knowledge.

There are many experimental results were reported, however no systematic explanation about resistance and turbulent characteristic in cases three-dimensional roughness, such as which was expressed by G.M. Smart et al (2002) that the effect of the separation vortices from roughness elements on the resistance characteristic of flow until in that year still unknown. Nakayama (2005) base on his investigated for compared two, and three dimensional turbulent flow over a completely rough-bed surface by using DNS, and then expressed, no variance was found outside at the roughness layer, despite there are variance near the roughness elements. Ohmoto et al (2009), the measurement revealed that stable and highly regular upflows and downflows exist near the roughness elements. T. Kameda et al,(2004.), reported that the magnitude of Reynold shear stress and mean flow velocity over square roughness elements were occurred through the length of the inflection point line over in the groove region. This studies had revealed that the magnitude of flow resistance and turbulent structures, particularly the magnitude of Reynold shear stress, $-u'w'$, and secondary current flow, W, were occurred at the inflection point line over in the groove region, as suggested T. Kameda et al (2004).

2. Experimental Apparatus and Method

The flume was used in the experiment is a circulation-type variable-slope with dimension, 10 m long, 40 cm wide and 20 cm high, the flume bed and sidewalls were made of acrylic resin so that pictures can be taken and laser beam can be emitted from sidewalls. Flow measurement condition, among others an air-cooled, infrared pulse laser was used as the light source. The laser sheet beam thickness was set at 1 mm, and the pulse interval at 2000µs. Visualization images read by synchronizing the laser beam and the CCD camera were recorded as 125 fps(frame per second), 1024X1024 pixel monochrome video image on the hard of the computer processed by PIV method. For each measurement plane, 2000 images were taken, and these experimental was used Nylon particles 80 µm.

Several parameters and variables also was used in those experimental, each of them: discharge, Q= 4 l/s, flume gradient, Io = 1/500, λ = 10 cm, and δ = 1.0 cm.



(1) Double-pulsed Laser Illumination system
(2) Laser sheet
(3) CCD-Camera kodak mega plus ES 1.0
(4) Pulse –Laser main unit

Fig. 1. Flow measurement System

3. Experimental Result

Fig. 2. Expressed that the value of λ = 10 cm was produced from the relationship between the distance on the groove region, λ, normalized by roughness height, k, with the water flow depth, ho, normalized by, ho smooth. Fig. 3, shown that the relationship between discharges, Q(l/s) with water flow depth, ho(cm), in cases 3D the value of flow resistance around 7% are bigger than in case 2-D, as effect of spacing, δ = 1.0 cm, those value was examined by using equation(1). Fig. 4, shown that the longitudinal distribution of Reynold shear stress, $-u'w'$, in cases 3D are stronger than for cases 2D, examined by using equation (2) and (3), indicate that the magnitude of shear stress at the top of the roughness elements, Z = 0 cm, as effect of δ = 1.0 cm. Fig. 5. Shown that secondary current, W, in cases 3D are greater than in cases 2D, and also described that upflow and downflow was occurred near the roughness elements as effect of vortex flux in the groove region. Fig, 6 and 7, the local vertical distribution of Reynold shear stress, respectively, shown the magnitude of shear stress were occurred at the top of the roughness elements, Z= 0.0 cm, however in cases 3D near at the down stream of roughness elements the magnitude of shear stress are increased as effect of the spacing, δ = 1.0 cm. In generally the magnitude of shear stress in cases 3D are bigger than in cases 2-D. Specially in cases 2D its .has corresponding which was expressed by T. Kameda et al(2004).

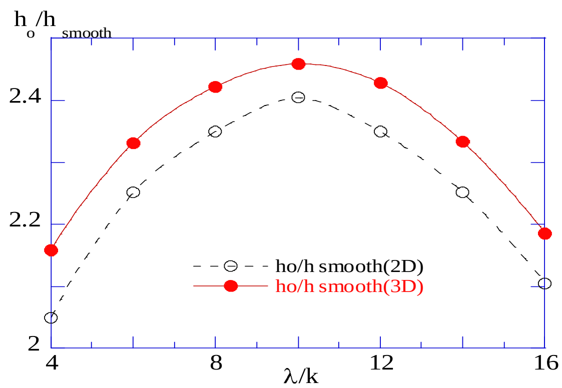


Fig. 2. Relationship between flow depth and λ/k

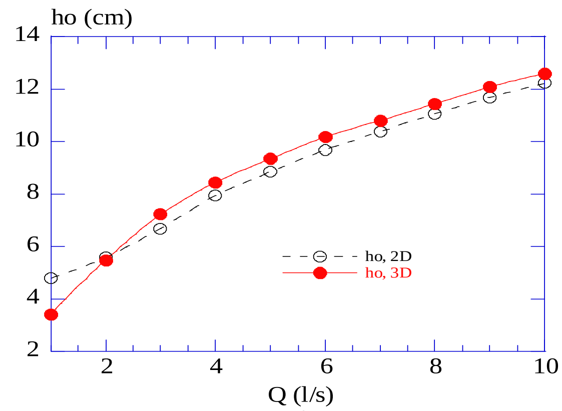


Fig. 3. Relationship between flow depth and discharges

The equation which was used for this studies, as following,

Ratio of flow resistance,

$$\varphi = \frac{\rho g h_{o(3D)} I_o \left(1-\frac{k}{h_{o(3D)}}\right)}{\rho g h_{o(2D)} I_o \left(1-\frac{k}{h_{o(2D)}}\right)} \;\ldots\ldots\ldots(1)$$

Where, ρ is the mass density of fluid, g is gravitational acceleration, ho is the water flow depth, Io is the flume gradient, and k is the roughness height.

Turbulent structure,

$$\left(-\overline{u'w'}\right)_{\substack{2D\\ Z=0;0.1;0.3}} = \frac{1}{\lambda}\int_0^{\lambda} -u'w' \, dx \ldots\ldots\ldots\ldots (2)$$

Where, z is the flow depth

$$\left(-\overline{u'w'}\right)_{\substack{2D\\ Z=0;0.1;0.3}} = 2\int_0^{6}\frac{1}{\lambda}\int_0^{\lambda} -u'w' \, dxdy \ldots\ldots (3)$$

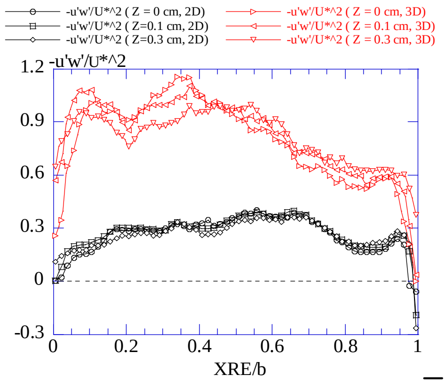


Fig. 4. Longitudinal distribution of Reynold shear stress, $-\overline{u'w'}$,

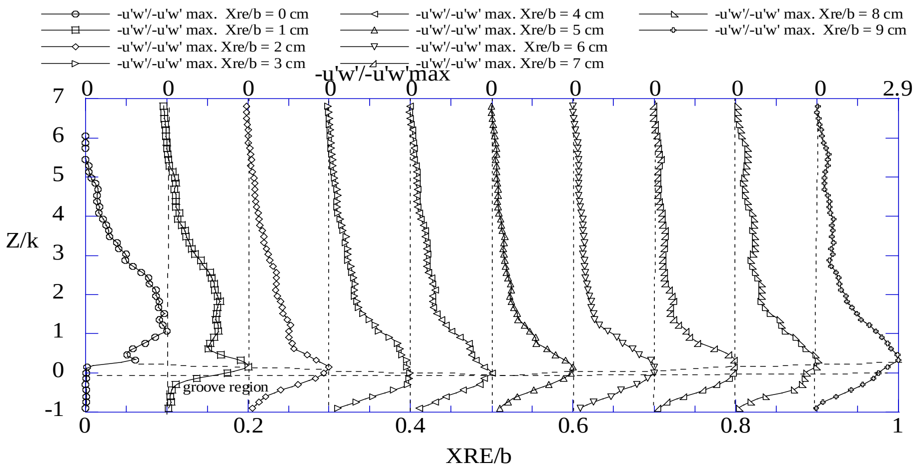


Fig. 6. Transversely special averages Reynolds shear stress profiles over roughness elements in the groove at two-dimensional roughness .

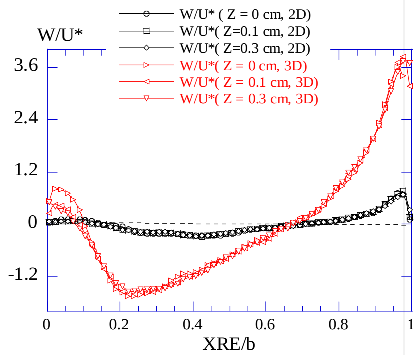


Fig. 5. Longitudinal distribution of secondary current, W,

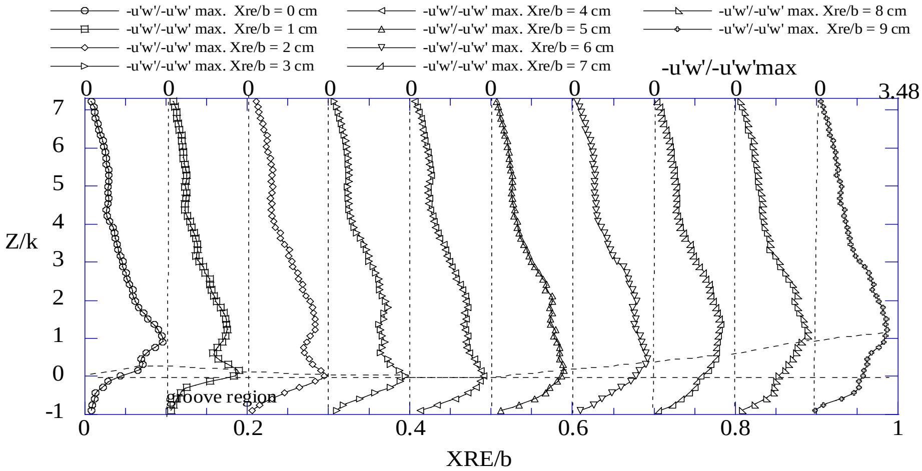


Fig. 7. Transversely special averages Reynolds shear stress profiles over roughness elements in the groove, at three-dimensional roughness.

4. Conclusion

Base on this studies, has been revealed that the value of flow resistance, and turbulent structures like on this below,

1 .Water flowing in the open channel with discharge, Q = 4 l/s, λ=10 cm, δ= 1.0 cm and Io =1/500 are produce water flow depth are 0.46 cm higher for case 3-Dimensional than in case 2-D.

2 .The value of ratio flow resistance in the cases 3-D has 7% higher than that in cases 2-D.

3 .The magnitude of turbulent structures in cases: mean flow velocity, U, Reynold shear stress, -u′w′, secondary current, W, of the longitudinal and vertical distribution shown that in cases 3D are stronger than in cases 2-D.

4 .The differences of values of flow resistance, and turbulent structures over square roughness elements in an open channel, between cases 2D with 3-D, particularly for cases 3D it was caused friction velocity at the top of the roughness elements which was separated by spacing, δ = 1.0 cm on the transverse direction.

5. References

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