Attached Form 8

Abstract of Thesis

Title of Thesis: Fundamental Study on Flow Resistance and Turbulent Structure in an Open Channel with artificial roughness
(人工粗度を有する開水路粗面流れにおける抵抗則および乱流構造に関する基礎的研究)

Graduate School of Science and Technology
Field: Environmental Conservation Engineering; Course: Turbulent flow in an open channel
(Main Supervisor Prof. Terunori OHMOTO)

Name: スカルノ SUKARNO

Summary of Thesis

Abstract

Four series of measurements were undertaken over a bed-wall surface in an open channel, 3 while varying shape types of artificial roughness elements; the roughness elements were cylindrical, spherical, square ribs roughness, and a smooth bed (i.e., no elements). A Particles Image Velocimetry (PIV) was used to measure the spatial distribution of vertical velocity on the vertical cross section (VCS), and horizontal cross section (HCS) measurement. Overall, the experiments were undertaken with water flow maintained at a steady and uniform in the flume.

The arrangements of cylindrical and spherical roughness elements were set over a completely rough-wall surface, thus enabling two-dimensional roughness measurements; however the square ribs roughness elements were arranged in two-models; for the first, a square ribs roughness was arranged in term at longitudinal spacing roughness, ?, equal to 100mm, and with no transverse spacing, d equal to 0mm as two-dimensional roughness arrangement, for the second the consecutive longitudinal

spacing roughness, ?, equal to 100mm and transverse spacing roughness, d, equal to 10mm, respectively, thus enabling three-dimensional roughness model.

A new method of measurement and data processing was developed by using PIV, and its measurements enabled elucidation of flow velocity in an open channel. The results of the experiment show characteristics of flow resistance and fluctuation of turbulent flow in the longitudinal and vertical distribution including the main flow velocity, U, secondary currents velocity, W, Reynolds shear stress,$(-\overline{u'w'})$, convective momentum transport-UW, and turbulent intensity, u_{rms} and w_{rms} they are examined respectively for, each case, below.

In the case of shallow turbulent flow over regularly arrayed spherical roughness in an open channel results indicated significant degrees of spatially regular variation in the time-averaged velocities, where the upflow velocity was much stronger than the downflow. Homogeneous turbulent characteristics were also generated along the rough bed in the case of a large ratio of sphere diameter to flow depth. In addition, Reynolds shear stress and turbulent intensity showed minimum values at the ridge of roughness elements and maximum ones at the trough. These organized flow structures were caused by vortex shedding generated by the roughness elements.

In the case of turbulent characteristics of shallow flow over rough surface with regularly arrayed spherical roughness experimental results indicated significant degrees of spatially regular variation in time-averaged velocities, in which the upflow generated over the upper region of the roughness surface was about 8% of the cross sectional average velocity, much stronger than the downflow. In addition, Reynolds shear stress and turbulent intensity showed minimum values at the ridge of roughness elements and maximum ones at the trough. These organized flow structure may be due to vortex shedding caused by the roughness elements.

In the case of effect of regularly arrayed roughness on flow resistance and turbulent flow structure in an open channel, experimental results indicated that flow resistance with spherical roughness is higher than that with cylindrical roughness; also, significant degrees of spatially regular variation in time-averaged velocities were generated along the rough elements in the case of a large ratio of roughness height to flow depth. In addition, Reynolds shear stress and turbulent intensity abruptly decreased near the ridge of roughness elements. This may be due to the difference in

flow resistance between cylindrical roughness and spherical one. These organized flow structures were explained by form induced stress.

In the case effects of regularly arrayed square ribs roughness on flow resistance and turbulent flow in an open channel, results indicated that flow resistance with three-dimensional square ribs roughness was higher than that with two-dimensional square strip roughness. The maximum value of flow resistance appeared in transverse spacing, δ/k (transverse spacing/roughness height ratio) =1, and significant degrees of spatially regular variation in time-averaged velocities were generated along the rough elements.

This research shows that PIV has great potential for obtaining accurate data to detect flow velocity in an open channel, and also the software such as Matlab, Kaleidagraph and Tecplot may be used to produce illustration images pertaining to turbulent flow structures and stream line velocities in an open channel. This research demonstrates the important effects of regularly arrayed cylindrical, sphere and a square strip roughness.