論 文 の 内 容 の 要 旨

論文題目

A field and laboratory study on heterogeneous sediment transport model with grain shape effect in alluvial rivers

（沖積河川における河床材料形状を考慮した混合粒径土砂移動モデルに関する現地調査および実験研究）

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In gravel bed rivers, the shapes of bed sediments are important both from the sediment transport as well as river’s ecological point of view. Resistance from large roughness elements and the flow variability are the main characteristics of gravel bed rivers. Morphological changes especially in gravel bed rivers are necessarily associated with the bed load sediment transport. For the gravel bed rivers, the prediction for sediment transport quantities can be improved if the transport parameters of models are determined with respect to the physical shape and movement characteristics of sediments. Both deterministic and stochastic methods are available to estimate the bed load transport rates. Unlike probabilistic methods, however, the deterministic methods mainly depends on the critical shear stress criterion which is easy to be applied but is relatively less efficient as it does not accounts for the entrainment probability and mobility of sediments. The latest stochastic model is capable of estimating the partial fractional transport rates, however, some parameters are ambiguously defined. A further improvement is suggested by defining these parameters for the four Zingg’s shapes of sediments. Also the shape factors are used in various models but just as a multiplying factor to reduce the effective shear stress value. This practice is not sufficient for uncovering the geological and transport information that is hidden in the shapes of sediments. With the help of field study, laboratory experimentations and quantitative assessment, the targets of this research work are achieved.

In this research work, I planned to observe the sediment transport in the real rivers to check why software are deficient in estimating the transport quantities and finally to suggest and apply the improvements. To accomplish the tasks of research, field visits were conducted on Japanese gravel bed rivers where channel characteristics, flow characteristics, sediment transport phenomenon and dependency of large size sediments on stream habitat were observed. The Oppegawa River (おっぺ川) was selected as the study reach where geometric data (profiling, cross sectioning etc.), hydraulic data (velocity, depth, and discharge) and the sediment data (photo and sediment samples from surface and subsurface) were collected and analyzed by software to evaluate the efficiency of software.

Qualitative study of the gravel bed rivers and their analysis by various software revealed that shape of sediments is a key factor for entrainment from sub surface, partial mobility. As a result of comparison of software analysis, the stochastic approach was found to be relatively better than all other approaches, and it was felt that by including the shape effect the efficiency of the existing model can be improved.

Three parameters of the stochastic model are affected if particle shape are included i.e. the $V_{p,i}$ (mean velocities of sediments), Y_i (particles mobility factor) and the Δ_i (Subsurface entrainment factor). Here "i" is a diameter.

The $V_{p,i}$ was extended for each gravel shape classified based on the Zingg's shapes category and renamed as $V_{p,im}$ ("m" for Zingg's shapes category) as uni-size particles do not move with the same velocity. More than 300 mixed sized sediments from the Oppegawa River (4 mm to 32 mm) were colored in four Zingg's shapes and the mean velocities were computed in an acrylic glass flume (0.9 m x 0.038 m x 0.15 m) and plotted against the effective shear stress (θ'_i). The final design curves of (θ'_i vs $V_{p,im}$) were obtained by extrapolating the experimental relation.

The Y_i was merged in the $V_{p,im}$, as it itself accounts for the partial fractional transport. The Y_i as obtained in the original stochastic model can be eliminated when mobilization of sub fractions (shape groups) was defined by their mean velocities, however the impact assessment of this parameter comparison of sediment quantities was made with the original and modified stochastic model. Using it in conjunction with $V_{p,im}$ the total transport quantities were found exaggerated.

The third and the last parameter of stochastic model that was studied for the modified stochastic model is the subsurface entrainment factor Δ_i. It shows the entrainment of sediments from the sub layers to the active layer. Validity of this parameter was studied in the (7 m x0.3 m x0.15 m) glass flume. The entrainment of subsurface sediments was accessed in terms of change in on bed sediment size distribution. The resulted curves revealed that effect of this parameter is not significant. No more entrainment from bottom layers were observed even for the laboratory sand whose fixity was much less than that of natural sediments, hence a uniform factor of 1 (no entrainment effect) can be used in the modified approach.

In addition to the improvement of the movement characteristics of sediment shapes, the physical characteristics of each grain like shape roughness were also included in the modified model by the Fourier shape analysis. First by modifying the open source code (Contour Analysis) (written in C #) to get the peripheral coordinates of sediments of size 4 mm to 32 mm then the Fourier shape coefficients were obtained for the required number of shape harmonics and finally the relative roughness of sediment shapes were worked out. By using this relative roughness, new parameter "shape deviation factor ς_m"

was suggested.
In gravel bed rivers, the mean velocity profile and shear velocity are significantly affected by gravel when water flow over large roughness elements. To count for this effect, the effect of deep and shallow flow layers was added by using both log law and tanh law. Gravel bed rivers also provides the natural habitat to the aquatic life. River habitat can be preserved by using the large size sediments, but they may affect the flow and can disturb the spatial distribution of sediments. Relations exist between the size distribution and blockage ratio. This relation was explored by laboratory experimentations, a relationship between blockage ratio and change in sediments size distribution between the wake and direct flow areas were obtained. For understanding the effect of boulders on bed changes, boulders were placed in different formations, then the effects could be explained qualitatively.
The modified model was calibrated with the Manning's "n" for the water discharge and with optimum harmonic number for shape deviation factors"ς_m" for the sediment discharge.
Excel VBA code was written for all sections of computations i.e. image processing, Fourier shape analysis and finally for the comparative computations of two models i.e. original and the modified stochastic model.

For the evaluation of the modified approach, the online sediment transport data for the two gravel bed rivers i.e. Big Wood River near Ketchum and Salmon river below Yankee fork of Idaho State, USA was used. This data was collected by the USDA Forest Service - RMRS - Boise Aquatic Sciences Lab. The results of analysis were improved when compared with original method and in reasonably good agreement with the field measurements.