学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Studies on morphodynamics in shallow rivers with effects of vegetation and large wood using computational models

(浅水流河川の河床変動に及ぼす植生および流木の影響の解明とその数値解析モデリング)

Many studies have been conducted to understand the effect of vegetation. However, the effect of vegetation (static vegetation type) in meandering channel and effect of large wood (L/D > 10, L: stemwise length, D: stem diameter; kinematic vegetation type) in braiding channel are insufficient. Those vegetation types are important factor to significantly alter bar formation, channel braiding and generation of thalweg in river. To expand our understanding of interaction between bed morphology and both of vegetation types, we investigated the responses of bed morphology through numerical model and laboratory experiment.

In first part, for the study on effect of vegetation (static vegetation type), simulations conducted using a two-dimensional, depth-averaged river flow and river morphology model to investigate the effect of vegetation growth and degree of flow discharge on a shallow meandering channel. To consider the effects of these factors, it was assumed that vegetation growth stage is changed by water flow and bed erosion. The non-uniformity of the vegetation growth was induced by the non-uniform and unsteady profile of the water depth due to the irregular shape of the bed elevation and the unsteady flow model reliant on hydrographs to evaluate three types of peak discharges: moderate flow, annual average maximum flow, and extreme flow. To compare the effects of non-uniform growing vegetation, the change in channel patterns was quantified using the Active Braiding Index (ABI), which indicates the average number of channels with flowing water at a cross section and the Bed Relief Index (BRI), which quantifies the degree of irregularity of the cross-sectional shape. Two types of erosion were identified: local erosion (due to increased flow velocity near a vegetation area) and global erosion (due to the discharge approaching peak and the large depth of the channel). This paper demonstrated that the growth of vegetation increases both the ABI and BRI when the peak discharge is lower than the annual average discharge, whereas the growth of vegetation reduces the BRI when the peak discharge is extreme. However, under extreme discharge, the ABI decreases because global erosion is dominant. The conclusions from this study help to deepen the understanding of the interactions between curved river channels and vegetation.

In second part, for the study on effect of large wood deposition (kinematic vegetation type), the large wood deposition patterns is analyzed in shallow flows, considering the effect of large wood roots, by means of laboratory experiments and computer simulations. In this part, we first conducted laboratory experiment to develop the large wood dynamic model. For the computations, we used the depth-averaged two-dimensional model, Nays2DH, on iRIC to simulate shallow flows. A newly developed large wood simulation model was combined with the shallow flow model. The laboratory tests were performed by changing several hydraulic parameters: discharge, channel slope, and anisotropic bed friction. In shallow water with a depth similar to the large wood diameter, the root effect increases the critical draft for wood motion (the depth at which the large wood contacts the river bed) by increasing the draft at the root. The experimental results showed two different patterns of motions: the large wood tends to move toward the side walls and deposit on the bed after passing an obstacle. In addition, with less flow discharge, large wood deposition becomes more laterally dispersed, and with more flow discharge and a greater channel slope, large wood forcibly flows downstream because of the larger drag force and water depth. In such processes, the large wood root significantly affects the large wood motion. The computational results showed that the proposed coupling model reproduced the fundamental aspects of the phenomena.

Through the laboratory experiment, we got the reasonable reproducibility of large wood dynamic model. And then we applied this model to practical experiments: Welber et al. (2013) and Bertoldi et al. (2014), which are based on observation data of Tagliamento River, Italy. In this study, we modified Exner equation to consider the bed morphology with large wood deposition, and we improved detail motion of large wood due to transition of projection area and anisotropic bed friction, which are able to consider three angles among stemwise direction, streamwise direction and wood particle pass direction. From the simulation results, we quantitatively calculate the ABI, BRI, and mean values of the deposition position, and deposition angle. We then analyze the relationship between the bed morphology responses and the wood deposition patterns in terms of the root wad effect and input supply. The proposed model reproduces the prominent features of the flume experiment, indicating that the present numerical approach can clarify and predict the behavior of large pieces of wood in accordance with the bed morphology.