STUDY ON SANDBAR FORMATION AND MIGRATION IN THE SUSPENDED SEDIMENT DOMINATED BRAHMAPUTRA RIVER

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1. INTRODUCTION

Sandbars are formed in terms of interactive process among river flow, sediment transportation and bed forms. Formation and deformation of sandbars considerably affect the river bank erosion which is one of the key issues for the river engineers and decision makers. The non-equilibrium characteristics of sediment transportation in suspended sediment dominated rivers creates difficulties to set up boundary conditions. Therefore there are very few numerical simulation results which predict sandbars formation and deformation process in suspended sediment dominated mega-river. In addition it is difficult to define the initial conditions satisfactorily from the sparsely available bathymetric data of river bed topography for the rivers with very active planforms. Satellite information is a viable option to overcome the problems associated with the initial conditions. Brahmaputra is one of the suspended sediment dominated mega-size river where the river planform changes very rapidly both in space and time. This study aims to predict the formation and migration of sandbars in Brahmaputra River by numerical simulations and remotely sensed data in order to obtain useful information for river management.

2. METHODOLOGY

2D depth integrated models developed by Takebayashi et al. (2003) is used for conducting the numerical simulation which includes computation of flow field and bed variation simultaneously. The governing equations of the two-dimensional water flow, mass conservation of sediment in flow body and mass conservation of bed sediment are described using Cartesian coordinate system, respectively as follows.

$$\Lambda\frac{\partial z}{\partial t}+\frac{\partial uh}{\partial x}+\frac{\partial vh}{\partial y}+\frac{\partial u_g h_g}{\partial x}+\frac{\partial v_g h_g}{\partial y}=0 \tag{1}$$

$$\frac{\partial hu}{\partial t}+\frac{\partial huu}{\partial x}+\frac{\partial huv}{\partial y}=-gh\frac{\partial(h+z_b)}{\partial x}-\frac{\tau_x}{\rho}+\frac{\partial h\sigma_{xx}}{\partial x}+\frac{\partial h\tau_{yx}}{\partial y}-\frac{F_{vx}}{\rho} \tag{2}$$

$$\frac{\partial hv}{\partial t}+\frac{\partial huv}{\partial x}+\frac{\partial hvv}{\partial y}=-gh\frac{\partial(h+z_b)}{\partial y}-\frac{\tau_y}{\rho}+\frac{\partial h\tau_{xy}}{\partial x}+\frac{\partial h\sigma_{yy}}{\partial y}-\frac{F_{vy}}{\rho} \tag{3}$$

$$\frac{\partial z_b}{\partial t}+\frac{1}{1-\lambda}\left(\frac{\partial q_{bx}}{\partial x}+\frac{\partial q_{by}}{\partial y}+E-D\right)=0 \tag{4}$$

$$\frac{\partial ch}{\partial t}+\frac{\partial uch}{\partial x}+\frac{\partial vch}{\partial y}=\epsilon_x\frac{\partial^2 ch}{\partial x^2}+\epsilon_y\frac{\partial^2 ch}{\partial y^2}+E-D \tag{5}$$

$$\tau_x=\tau_b\frac{u_b}{\sqrt{u_b^2+v_b^2}},\tau_y=\tau_b\frac{v_b}{\sqrt{u_b^2+v_b^2}},\frac{\tau_b}{\rho}=u_*^2\quad\sigma_{xx}=2\varepsilon\frac{\partial u}{\partial x},\sigma_{yy}=2\varepsilon\frac{\partial v}{\partial y},\tau_{xy}=\tau_{yx}=\varepsilon\left(\frac{\partial u}{\partial y}+\frac{\partial v}{\partial x}\right)$$

where, t is the time, x and y are the coordinates in flow and transverse direction, u_g and v_g are the x and y components of depth averaged seepage velocity, h_g is the seepage flow depth, λ is porosity and Λ is the parameters related to the porosity of the soil. Other symbols are defined commonly.

Yorozuya et al. (2013) proposed a relation between flow depth and flow width to interpolate channel geometry for numerical simulation.

$$\frac{h_1}{h_0}=\left(\frac{B_1}{B_0}\right)^{\frac{3-6m}{7m}} \tag{6}$$

$$\frac{h_1}{h_0}=\left(\frac{B_1}{B_0}\right)^{-\frac{24}{35}}\quad (m=5/2) \tag{7}$$

where h and B are flow depth and flow width respectively, 0 and 1 represent reference section and new section, m is the exponent of non-dimensional bed shear stress associated with bedload movement.

Eq. (6) was derived using equations of continuity for water flow and sediment transportation assuming equilibrium bedload transportation which is evaluated by $q_{b*}\approx\tau_*^m$. m is specified as m= 5/2 according to Egashira et al. (1991).

Keywords: Brahmaputra River, 2D depth integrated model, sandbars formation, sandbars migration.
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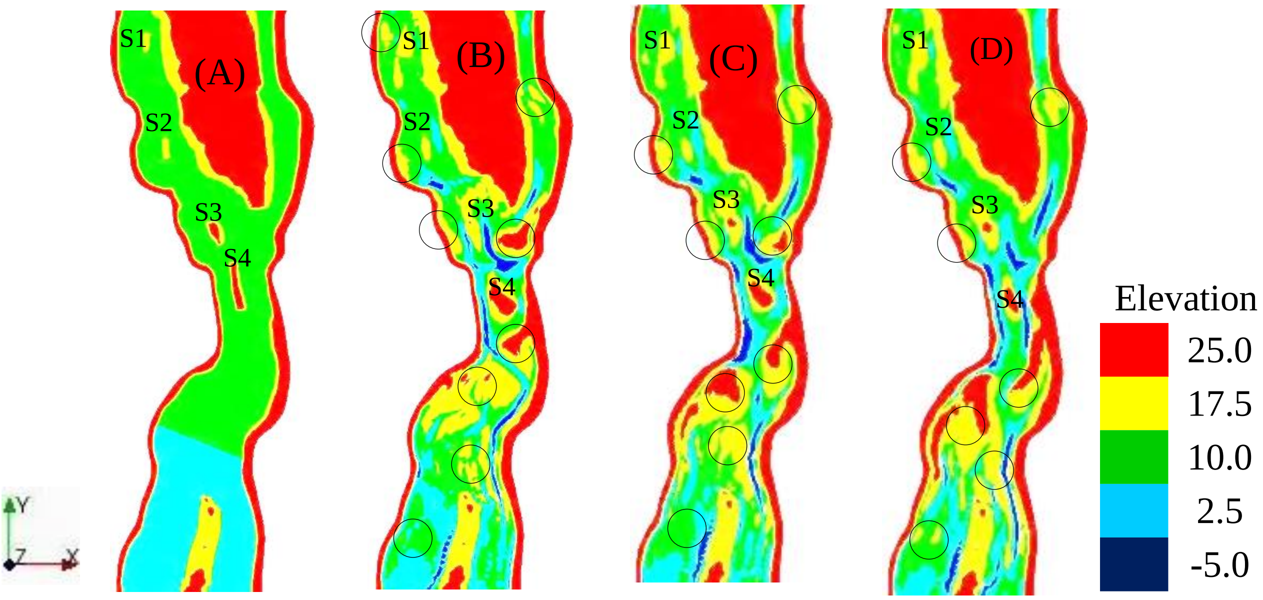
3. RESULTS AND DISCUSSIONS

The study reach of the Brahmaputra River is about 90 km long and 12.50 km wide, is divided into 11,800 computational grid having spatial resolution of about 300 m. Fig. 1(A) shows the initial topography of the study reach which is specified by Eq. (7) from Panchromatic Remote-sensing Instrument for Stereo Mapping Digital Surface Model (PRISM-DSM) of Japan Aerospace Exploration Agency (JAXA) for the numerical simulation. Constant discharge is supplied from the upstream boundary and uniform flow condition is employed to specify the downstream flow depth. The sandbars formation and deformation are studied for three cases (65000, 90000 and 100000 $m^3 s^{-1}$ which equivalent to the flooding events with return 2.33, 20 and 50 years respectively). The results are shown in Figs. 1 (B), (C) and (D) where S1, S2, S3 and S4 represent the existed (old) sandbars and their corresponding deformed shape whereas the black circle shows newly appeared (new) sandbars. The ratios of particle fall velocity to average friction velocity at the beginning of each computation are 0.34, 0.28 and 0.20 indicate the dominance of suspended sediment.



(A) original state, (B) case 1:65000 $m^3 s^{-1}$, (C) case 2: 90000 $m^3 s^{-1}$, (D) case 3: 100000 $m^3 s^{-1}$
S1, S2, S3 and S4: Existed (old) sandbars and their deformed shape, circle: newly appeared (new) sandbars

Fig. 1 Sandbars development and deformation under different flooding condition

In each computational cases existed (old) sandbars S1, S2 and S3 are protruding both in flow and transverse direction and sandbar S4 is migrating to the downstream direction with deformed shape. Bed evolutions due to erosion and deposition are dominant at the head and tail of the sandbars respectively. The numerical results suggests that relative size of the cross-sections and curvature of the bankline determine the initial locations erosion and deposition areas which is changing at the beginning of sandbars formation. The eroding areas are shifting towards the bank region during the migration of sandbars. The speed of migration corresponding to new and old sandbars are about 2.0 to 10.0 m hr^{-1} and 1.6 to 3.0 m hr^{-1}, and depends on the size of the sandbars and magnitude of flood discharge. The actual migration rate of bedform observed from field measurement data in the Brahmaputra River is 1.11 to 16.8 m hr^{-1}. The geometric shape and locations of the newly formed sandbars also agree with the observed sandbars. The ratios of suspended load to bed one range from 25 to 40.

4. CONCLUSIONS

Present numerical results predict successfully migration and deformation of existed (old) sandbars as well as of newly appeared (new) sandbars in suspended sediment laden braided Brahmaputra River. The migration speeds of actual bedforms are covered by the present numerical results.

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