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BED PROFILE VARIATIONS WITH SAND-GRAVEL MIXTURE IN A STEEP CHANNEL RESERVOIR BY MODIFYING TRACTIVE FORCE

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1. Introduction

The modes of sediment transport in a river system are mainly bed load and suspended load. The sizes of the sediment particles of the same density mixture of sand-gravel are considered in calculation of sediment deposition, i. e., very fine particles are more in suspension and coarse materials are transported as bed load. Authors studied the process of sediment deposition for the mixture of sediment (of sizes 0.1, 1.0, and 2.5 mm), experimentally, where the characteristics of the delta formation towards both the downstream and the upstream were found. In this paper, bed profile variations due to the deposition of the sediment mixture in a steep channel reservoir has been estimated on basis of the facts as mentioned above.

2. Experimental Study

The experimental study of deposition of sediment mixture was studied in a laboratory flume (10m long, 0.15m wide and 0.30m deep in a fixed slope of 0.02) as shown in Table 1, where the dam height, sizes of particle, and the flow discharge are varied. The equal mix proportions of sediment particles are made by dry volume and a rate of sediment supply of mixture was 1.11x $10^{-5}m^3$/sec/m width of the channel with a model dam built at the downstream end. The water level and bed variations along the channel were measured appropriately.

Table 1

Sets (Runs)	Sediment Sizes (d_i) in mm	Dam Heights (W) in m	Water Discharge (q) in m^3/s/m
K	0.1, 2.5	0.10	$2.00x10^{-2}$
L	0.1, 2.5	0.10	$2.66x10^{-2}$
M	0.1, 2.5	0.10	$3.33x10^{-2}$
N	0.1, 2.5	0.07	$2.0x10^{-2}$
O	0.1, 2.5	0.07	$2.66x10^{-2}$
P	0.1, 2.5	0.07	$3.33x10^{-2}$
Q	0.1, 1.0, 2.5	0.07	$2.66x10^{-2}$
R	0.1, 1.0, 2.5	0.10	$2.66x10^{-2}$

The fine sand can only be transported just downstream of the delta because the fine particle is on the larger mobility and low settling velocity in the mixtures than the coarse grains. As shown in Fig. 1, the layer of fine particles z2 (F-layer) on the initial bed consists of only fine particles. However, the deposition layer of the mixed particle z1 (M-layer) was observed inconsistent in composition.

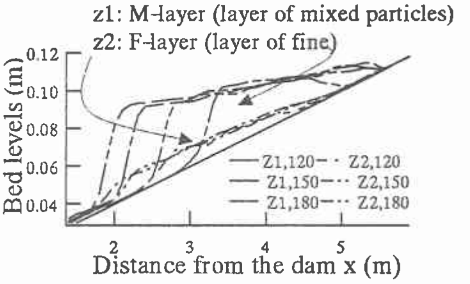

Fig.1 Observed two deposition layers (M and F-layers) in Run K (times in minutes)

3. Calculation of Bed Variations

For the calculation of flow, the one-dimensional energy equation and continuity equations for the steady flow are used. The hydraulic jump occurs at the section, where the following condition of conservation of momentum equation is satisfied between two sections:

$$h_2 / h_1 = \left(\sqrt{1 + 8F_1^2} - 1\right) / 2, F_1 = v_1 / \sqrt{gh_1} \qquad (1)$$

Where, h_1 is the flow depth before the jump, h_2 is the flow depth after the jump, v_1 is the flow velocity in upstream before the formation of jump.

Average bed profile: The tractive force on the top of the deposited sediment layer is almost critical shear stress of the bed material, where the clear mobility difference between fine and coarse grains exists. The sediment discharge for each grain size, q_{Bi}, should be used in the Equation of continuity of sediment at any section as:

$$\partial z_s / \partial t + 1/(1-\lambda).(\partial q_B / \partial x) = 0, \quad q_{Bi} = i_{bi} \left(sgd_i^3\right)^{0.5} K\left(\varepsilon_1 \tau_{*i} - \varepsilon_2 \tau_{*ci}\right)^m \qquad (2)$$

where t is time, λ is the porosity of the sediment, q_B is the sediment discharge per unit width of the river bed, q_B is the total bed load calculated by the summation of bed loads (q_{Bi}) of each grain size d_i for the equilibrium sediment discharge by Suzuki et. al (1995), i_b is an average frequency of each sediment particles on the surface (=0.5), s is the submerged relative density of the sediment, τ_{*i} $(=u_*^2/sgd_i)$ is the dimensionless shear stress, u_* is the shear velocity, τ_{*c} ($\approx$0.047) is the dimensionless critical shear stress, ε_1 and ε_2 are the modification factors for the shear stresses τ_{*i} and τ_{*c}, respectively, K(=8) and m(=2/3) are the constant coefficients.

Sediment in suspension: Considering the equilibrium condition, the suspended load transport rate for the fine particles (d_i=0.1mm) can be stated as followings:

$$q_s = \int_a^h \bar{u}\bar{c}dy, \quad \omega c + \varepsilon_s \frac{dc}{dy} = 0 \tag{3}$$

where, $\bar{u}$ $\bar{c}$ are averaged velocity and sediment concentration by volume at a distance y above the bed, respectively, a is thickness of the bed level transport, h is flow depth, ω ($\approx 3.32d^{1/2}$) is fall velocity of sediment particle (Morris and Fan, 1998), c is sediment concentration, and ε is momentum diffusion coefficient. The concentration of suspended particles at a depth y is given by the Rouse equation:

$$\frac{c}{c_a} = \left(\frac{h-y}{y}\frac{a}{h-a}\right)^Z, Z = \frac{\omega}{\beta k u_*} \tag{4}$$

Lane and Kalinske (1941) assumed β=1; however some of the researcher suggested the value of β=1.2. The value of a is generally considered equal to 0.05h and the concentration of sediment at a is given below:

$$c_a = 5.55 * \Delta F(w)\left[\frac{1}{2}(u_*/\omega)\exp(-\omega/u_*)^2\right]^{1.61} \tag{5}$$

where, $\Delta F(w)$ is the average percentage of the sediment particle in ppm unit. The part of deposition of suspended particles in Δt second is calculated by the continuity equation of sediment as below:

$$\Delta z_{ss} = \frac{c\omega}{(1-\lambda)}\Delta t \tag{6}$$

Observed and calculated profiles: Typical comparison (for 2 hours for run P and Q) of calculated and observed bed profiles of total deposition and suspended particles are shown in Fig. 2. In the figure, h represents the water surface profiles and z1and z2 represent the total deposition and profile of suspended particles, respectively. The observed averaged bed profiles and water surface profiles as well as the position of the hydraulic jump seem to be coincided with the simulated ones.

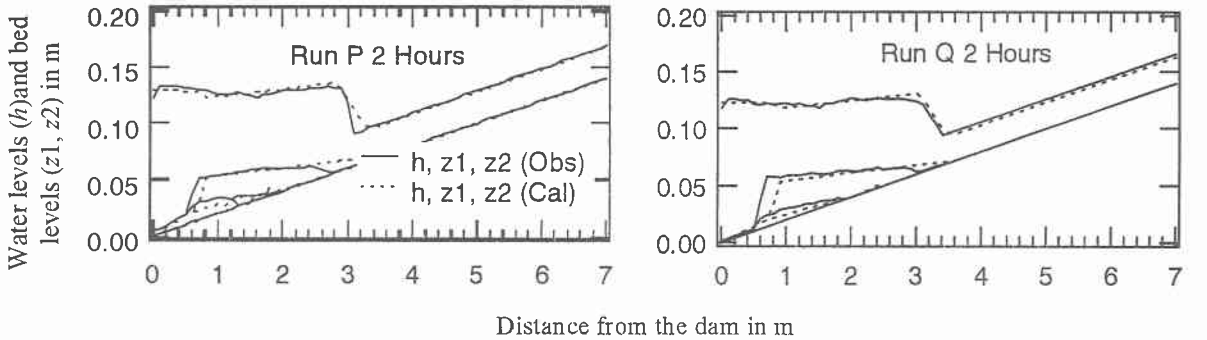

Fig. 2 Typical observed and calculated total bed profiles with deposition of suspended particles and water depths in Run P and Q

4. Conclusions

The deposition profile of the sand-gravel mixture consists of two distinct layers of deposition of mixed and fine particles in steep channel reservoir, where the upward shift of the hydraulic jump was observed with the progress of deposition. The averaged bed profile of the sand-gravel mixture is simulated considering the average frequency of each grain size and the fine sediment particle in suspension. The observed and calculated bed profiles (z1 and z2) are found in a considerable agreements as water depths are on comparison.

References

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