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MUD TRANSPORT ON SLOPING BED

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1. INTRODUCTION

Although there have been a few studies such as mud bed deformation (Shen et al, 1994), the dynamics of mud shore profiles (Lee and Mehta, 1997), and downward flow of mud layers (Kessel and Kranenburg, 1998), there is no published attempt to quantitatively examine time-dependant profile change on mud beaches. In fact, the previous beach process studies mainly deal with non-cohesive bed which their behavior markedly differs from that of cohesive materials.

Following the general structure of numerical models of sandy topography evolution (Winyu and Shibayama, 1996), the present study offers a two-dimensional beach transformation model for cohesive materials.

2. BEACH DEFORMATION MODEL

(1) Wave-Mud Interaction Model

In order to consider both shoaling and wave attenuation effects on the distribution of wave height, the wave energy dissipation term due to mud is considered in the equation of wave energy conservation. Applying the exponential wave height decay over a horizontal mud bed, the relation between energy dissipation rate of mud, ε_{Dm}, and the wave attenuation rate can simply be derived as

$$\varepsilon_{Dm} = -\frac{d}{dx}(C_g E) = 2C_g k_i E \tag{1}$$

where $E = \rho g H^2/8$ is the wave energy per unit surface area, ρ is the water density and C_g is the group velocity.

The energy dissipation rate, due to both effects of mud and wave breaking, in the transient zone will be approximated as

$$\varepsilon_D = \varepsilon_{Dm} + \varepsilon_{Db} \tag{2}$$

where ε_{Db} is the energy dissipation rate of wave breaking. Winyu's model, a modification of Dally model, is used for the energy dissipation rate of wave breaking (Winyu and Shibayama, 1996):

$$\varepsilon_{Db} = \frac{0.15 C_g \rho g}{8h}[H^2 - (\Gamma h)^2] \tag{3}$$

where

$$\Gamma = \exp[-0.36 - 1.25\frac{h}{\sqrt{LH}}] \tag{4}$$

The local values of wave attenuation rate, k_i, and mud mass transport are calculated by a multi-layered viscous model in which the fluid system, including the water layer, is divided into N layers (Tsuruya et al., 1987).

(2) Gravity-Driven Flow of Fluid Mud

Fig. 1 shows the sketch of the proposed multi-layered model where x coordinate is parallel to the bed and θ represents the inclination of the bed.

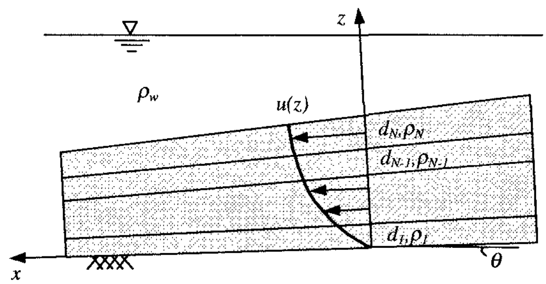

Fig. 1 Definition sketch of multi-layered viscous model

Neglecting the inertia forces and assuming the hydrostatic pressure, the momentum balance in the x-direction for the j_{th} layer of the fluid mud will lead to

$$\mu_j \frac{\partial^2 u}{\partial z^2} = (\rho_j - \rho_w) g \sin\theta - g\cos\theta$$
$$\{\sum_{n=j+1}^{N}[(\rho_n - \rho_w)(\frac{\partial z_n}{\partial x} - \frac{\partial z_{n-1}}{\partial x})] + (\rho_j - \rho_w)\frac{\partial z_j}{\partial x}\} \tag{5}$$

where μ_j is the viscosity of j_{th} layer.

The governing equation can be easily integrated for each sub-layer. $2N$ unknown constants, existing in N equations of velocity, are determined from the boundary conditions.

(3) Beach Profile Change

The conservation equation of sediment mass is employed to calculate beach profile change:

$$\frac{\partial h}{\partial t} = -\frac{\partial q_s}{\partial x} \tag{6}$$

where h is the water depth and q_s is the rate of cross-shore (seaward) volumetric sediment transport per unit length of shoreline. Eq. (6) can be solved numerically using the finite difference method. The mass transport rate is calculated by a time averaged formula.

(4) Procedure of Calculation

The flow chart of the present beach deformation model is shown in Fig. 2. The loop of dynamic beach deformation allows the determination of beach profile at any desired time.

3. LABORATORY EXPERIMENTS

An experimental setup is built to study the transport of an inclined fluid mud. The experiments are carried out in a 17.00 m long, 0.60 m wide wave flume. The regular wave is generated by a piston-typed wave generator at the

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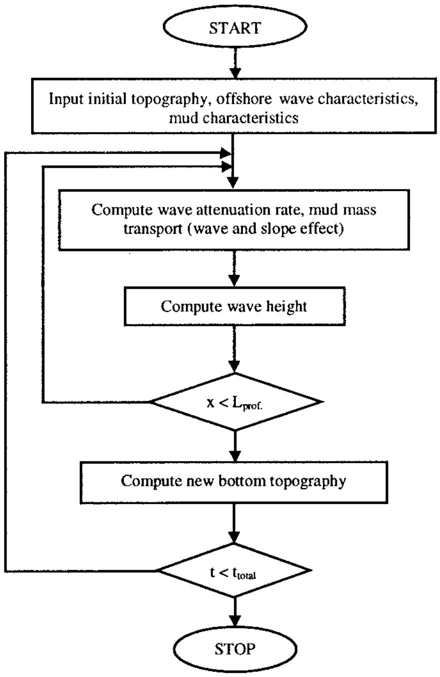

Fig. 2 Flow chart of numerical model

end of the flume. Mud sample is prepared by careful mixing of commercial kaolinite with tap water and it is put in a 20 cm high box. Prior to the experiment, the box is tilted to its desired angle (0.05 rad) and the slope of mud surface is measured. Fig 3 shows the sketch of experimental setup.

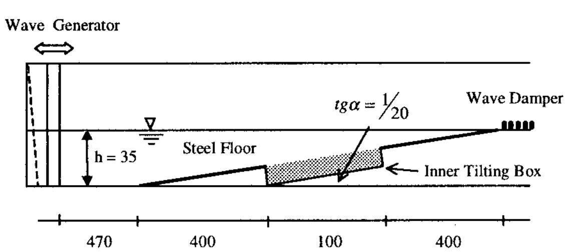

Fig. 3 Experimental setup (not to scale), units in cm

The experiment is started by generating waves for a short time of around 60 s (the proper duration time depends on the experimental conditions). The mud motion is investigated by using colored mud, with the same water content as the experimental mud, as a tracer (Sakakiyama and Bijker, 1988). The experiment is repeated for three different cases.

4. COMPARISON AND DISCUSSION

Fig. 4 shows the numerical and experimental results for the first case. Although there seems a delay of dissipation effect of mud on wave height distribution, Fig. 4(1), a good agreement is seen for all the measured parameters.

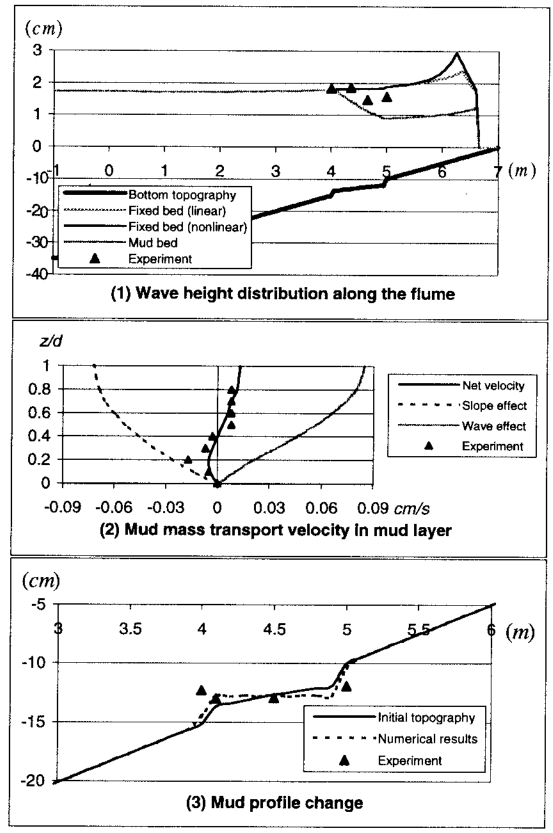

Fig. 4 Comparison between numerical model and experimental results (H_0 = 1.73, W = 148.7%)

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