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RESPONSE OF SAND BAR FORMATION AT A JETTIED RIVER ENTRANCE TO WAVES

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1. INTRODUCTION

Strong actions of waves cause the movement of sediment and changes of topography at the river mouth frequently. The formation and evolution of sand bar at river mouth relates closely to typical seasonal river discharge. A small discharge in the river creates condition for sediment transported and deposited at the river mouth. Under the action of perpendicular waves, sediment is transported and deposited at the jettied river entrance, forming sand bars at this area. There are a lot of hydrodynamic factors influencing to the formation of sand bars such as wave parameter, grain size, and current that relate to sand bar particularities as well as their position. Tanaka et al. (2005) presented an estimation method for the height of sand bars at a river mouth and area development of them. Nguyen and Tanaka (2005) introduced sand bar formation in the study on laboratory experiment. This study shows the simulation of sand bar formation at a jettied river entrance under the action of perpendicular waves by numerical method.

2. NUMERICAL SIMULATION OF SAND BAR FORMATION

2.1. Wave model

In a jettied river mouth, influence of perpendicular waves to sediment movement is dominantly. Waves approach the mouth on a sloping bottom, they increase in height and decrease in length due to shoaling. The increase in wave height continues until some critical ratio is reached between wave height and water depth, at that point waves break. The wave height distribution is calculated by the nonlinear shoaling laws in the shoaling regions. Wave deformation at the mouth could be described as in **Fig.1**. Waves motion to the mouth and break when they reach a critical state as shown in **Eq.** (1). Wave deformation in the surf zone was described by several numerical models. The breaker decay model allows waves reformation occur, that relate closely to modeling profiles with multiple bars (Dally, 1985). Wave height in the surf zone can be determined from **Eq.** (2).

$$\frac{H_b}{h_b}=1.14\left(\frac{\tan\beta}{\sqrt{H_0/L_0}}\right)^{0.21} \quad (1)$$

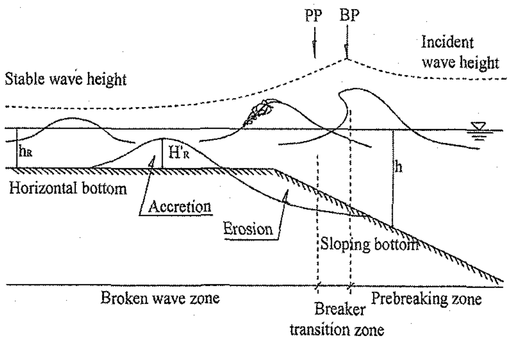
$$\frac{d(H^2\sqrt{h})}{dx}=\frac{-K_1}{h}\left(H^2\sqrt{h}-K^2h^2\sqrt{h}\right) \quad (2)$$

in which H, H_b are the height of wave and breaking wave, h, h_b the water depth and breaker depth respectively, $\tan\beta$ the local seaward slope of breaking point, H_0, L_0 the deep water wave height and length, $K = 0.4$, $K_1 = 0.15$.

Wave energy dissipation strongly increases due to the generation of turbulence after breaking. In the surf zone, energy dissipation produced by breaking is considerably larger than the ones due to bottom friction. Thus, energy dissipation by bottom friction is calculated in the model using linear wave theory to determine the horizontal component of the wave orbital velocity at the bottom and assuming shear stress proportional to the horizontal velocity component squared. The changes of wave energy flux along the profile relate to energy dissipation. The energy flux (F) could be written using shallow water wave theory, as in **Eq.** (3).

$$F=\frac{1}{8}\rho gH^2\sqrt{gh} \quad (3)$$

Here ρ is the water density, g the gravity acceleration.



PP: Plunging point, BP: Breaking point

Fig. 1 Wave deformation at river mouth

2.2. Transport rate calculation and sand bar formation

Variation of sediment transport rate at the river mouth reflects properties of the forcing. Transformation of wave at the jettied river mouth causes the different in the sediment transport rate in the regions of breaking and broken waves. In the surf zone, the distribution of transport rate is the function in which the energy dissipation per unit volume is a main factor. Depending on the wave conditions, existing profile shape, and sand properties, the cross-shore sand transport at the mouth will be predominantly directed either offshore or onshore. **Fig.**2 b,d show onshore direction sediment transport rate at the mouth that was calculated by numerical model for large scale data. Sand bar formation at the mouth due to waves is the effect of the onshore transport that leads to accretion of sand in the river mouth (**Fig.** 2 a,c). In case of offshore transport, the upper of cross section in the mouth will be erosion and accretion at the break point notably. In the surf zone, transport rate is proportional to the excess energy dissipation per unit volume over equilibrium energy dissipation. Transport rate can be calculated as in **Eq.** (4), (Larson and Kraus, 1989).

$$q=\begin{cases} K\left(D-D_{eq}+\dfrac{\varepsilon}{K}\dfrac{dh}{dx}\right) & D>D_{eq}-\dfrac{\varepsilon}{K}\dfrac{dh}{dx} \\ 0 & D<D_{eq}-\dfrac{\varepsilon}{K}\dfrac{dh}{dx} \end{cases} \qquad (4)$$

in which q is the sand transport rate, K the empirical transport rate coefficient K=1.9x10^{-6}, D the wave energy dissipation per unit volume, $D=\dfrac{1}{h}\dfrac{dF}{dx}$, D_{eq} the equilibrium energy dissipation per unit volume, ε the transport rate coefficient for the slope-dependent term, ε=0.0006.

Changes of bottom layer under wave actions for sand bar formation are calculated from the distribution of the cross-shore transport rate and mass conservation of sand. In order of calculation, the elevation of sand bar profile is determined from previous and transport rate of two times after a time step. **Fig.** 2 shows the results of numerical simulation of sand bar formation at river mouth under the action of right waves. After breaking, wave height decrease steeply, energy flux creates sand movement toward river mouth and formation sand bar there, as shown in **Fig.** 2a, c. Outside of breaking region, energy dissipation is reduced less than equilibrium ones thus, there is no sand movement in this areas (**Fig.** 2b,d).

3. CONCLUSION

The numerical model was applied to simulate sand bar formation at a jettied river mouth. Results of the model described sediment movement process and the evolution of sand bar at the mouth by the time of wave action. However, this model was applied to only the large scale data. Thus, the model will be applied for small scale research to clarify the formation of sand bar and further verification in the near future.

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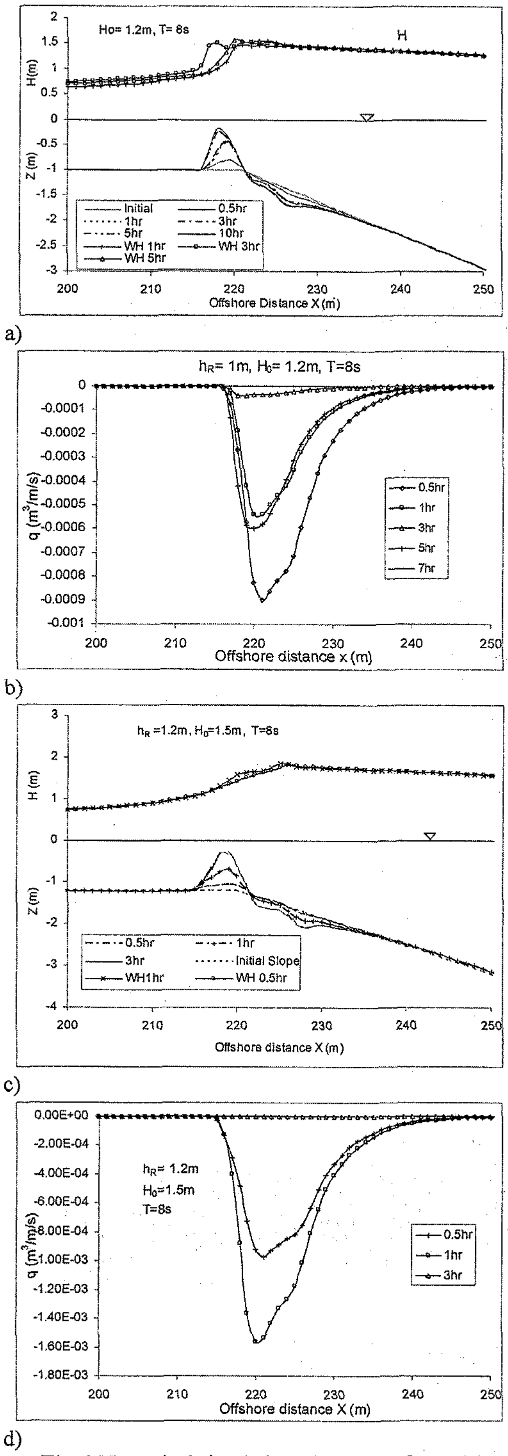

Fig. 2 Numerical simulation of sand bar formation