

CHAPTER 237

A NUMERICAL MODEL FOR BEACH DEFORMATION AROUND RIVER MOUTH DUE TO WAVES AND CURRENTS

by

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Abstract

A numerical model is proposed for beach deformation under wave and current in river mouth area. The model includes three major driving forces for sediment transport which are wave, wave-induced current and river discharge. Interaction of wave and current is also included. Laboratory experiments are performed to be compared with numerical results. Wave field, current field and beach deformation are compared between laboratory and numerical results and good agreements are obtained.

1. Introduction

In asian coastal region, we have many problems for the maintenance of waterway which connects big river port with open ocean. The examples are Chao Phraya river in Thailand or Mekong river in Vietnam. In the present paper, sedimentation and beach processes will be considered in river mouth area in order to minimize maintenance costs for these large rivers. A new numerical model is proposed for the simulation of beach processes in this area under waves, wave induced current and river discharges. Laboratory experiments are also performed to understand the physical mechanism of sediment transport and the results are used to examine the numerical model.

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2. Numerical Model

A numerical model is developed to predict bottom topography changes around river mouth. The model is composed of three sub-models which are wave model, current model and beach deformation model. The wave field is calculated by using mild slope equation with including wave-current interaction effect (Ohnaka and Watanabe, 1990). The breaking point is determined by the comparison of wave phase velocity and water particle velocity. Near-bottom velocity variations and the distribution of radiation stress are evaluated by using the calculated wave field. The current field associated with sand movement is calculated including wave induced current calculated from distribution of radiation stress, and river discharge. The river current is introduced into the model as boundary conditions which are given as water level and depth-averaged current velocity at river area. Since we included wave-current interaction, it is necessary to calculate by iteration process in order to get converged solutions for wave calculation and current calculation.

Bed load transport rate is calculated from bottom shear stress caused by wave orbital motion, wave induced nearshore current and river current. The bottom friction factor is calculated from wave-current friction factor of Tanaka and Shuto (1980). Sand transport formula of Watanabe et al., (1986) is used to calculate bed load. Suspended sand discharge from the river and suspended sand due to wave breaking are also included in the model. The suspended sand flux from river is calculated from the following formula which is derived from Brown type formula.

$$q = A \frac{q_b}{1 - \lambda} \dots \dots \dots (1)$$

where

$$\frac{q_b}{u_* d} = 10 \left(\frac{u_*^2}{sgd} \right)^2 \dots \dots \dots (2)$$

and u_* : bottom shear velocity, λ : porosity, s : sand specific gravity in water and d : sand diameter. The value A is a empirical constant and set to be 5×10^{-4} for the present calculations.

The suspended sand is produced in river mouth and wave breaking area. The suspended sand concentration in wave breaking are given according to the result of Nielsen (1986). The suspended sand is transported by river current and wave-induced current and deposit to the bottom with sediment fall velocity (Numano et al., 1989).

Table 1: Laboratory Conditions

Case	Wave Period (s)	Deep Water Wave Height (cm)	Flow Velocity in River Mouth (cm/s)	River Discharge (cm ³ /s)
1	1.34	3.41	20.0	222
2	1.39	6.09	20.0	222
3	1.38	2.75	18.5	421

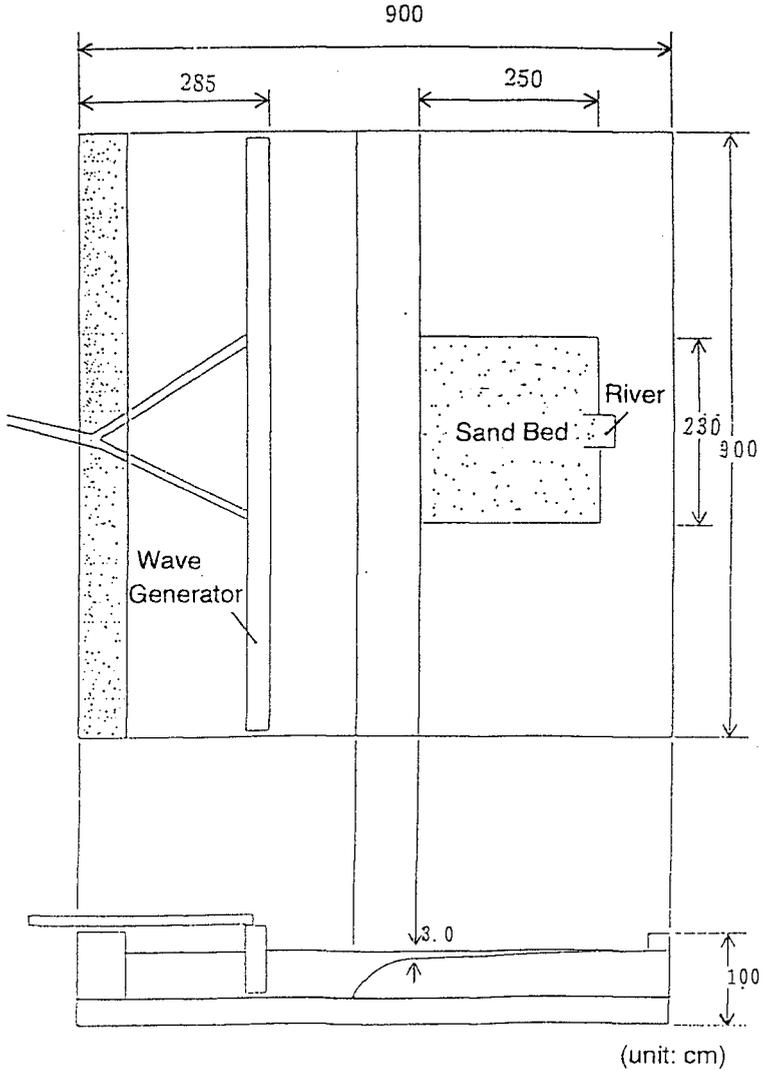


Figure 1: Laboratory Set-up

The calculated results of wave field, current field and bottom topography changes will be compared with laboratory results in order to examine the accuracy of numerical model.

3. Laboratory Experiment

Laboratory experiments are performed in a wave basin designed to facilitate the understanding of the mechanism of sand movement as well as the behavior of wave and current field around river mouth. Well-sorted sand (median diameter 0.15 mm) are laid in the wave basin to make an 2.5 times 2.3 meter test bed with the initial slope of 1/20. A river mouth with water discharge was installed at upper end of the test bed. Figure 1 shows the laboratory set up. The distribution of wave height and the variation of near-bottom velocities in the test section are measured in details by using capacitant wave gages or an ultra-sonic velocity meter respectively for three conditions of monochromatic waves and river discharges.

The laboratory conditions are listed in Table 1. These conditions corresponds to the following situations: (1)effect of river discharge and effect of wave to sand transport are almost equivalent (case 1), (2)wave effect is greater than river discharge effect (case 2) and (3)river discharge effect is greater than wave effect (case 3). The changes of bottom topography during each experimental run are measured. In these three cases, bar or terrace are formed in front of river mouth and this may cause interruption of waterway.

4. Comparison of numerical results and laboratory results

Figure 2 shows distributions of nearshore current for case 3. In the figure, calculated and measured velocities are shown. Here, the calculated values are depth-averaged values and the measured values are in the vicinity of bottom. The measured values may include the effect of undertow. As a result of interaction process, the calculated current field becomes asymmetric in terms of river mouth and this agrees with laboratory phenomena.

Figure 3 shows the comparison of wave field. The top figures show the two dimensional distributions of calculated wave fields by the numerical model. The bottom figures show the corresponding two-dimensional distributions of measured wave fields in the laboratory experiment. The middle figures show comparison of calculated and measured values in on-offshore distribution in front of river mouth. There are under-estimations of wave height in wave breaking area and over-estimations in the surf zone. This means the physical process

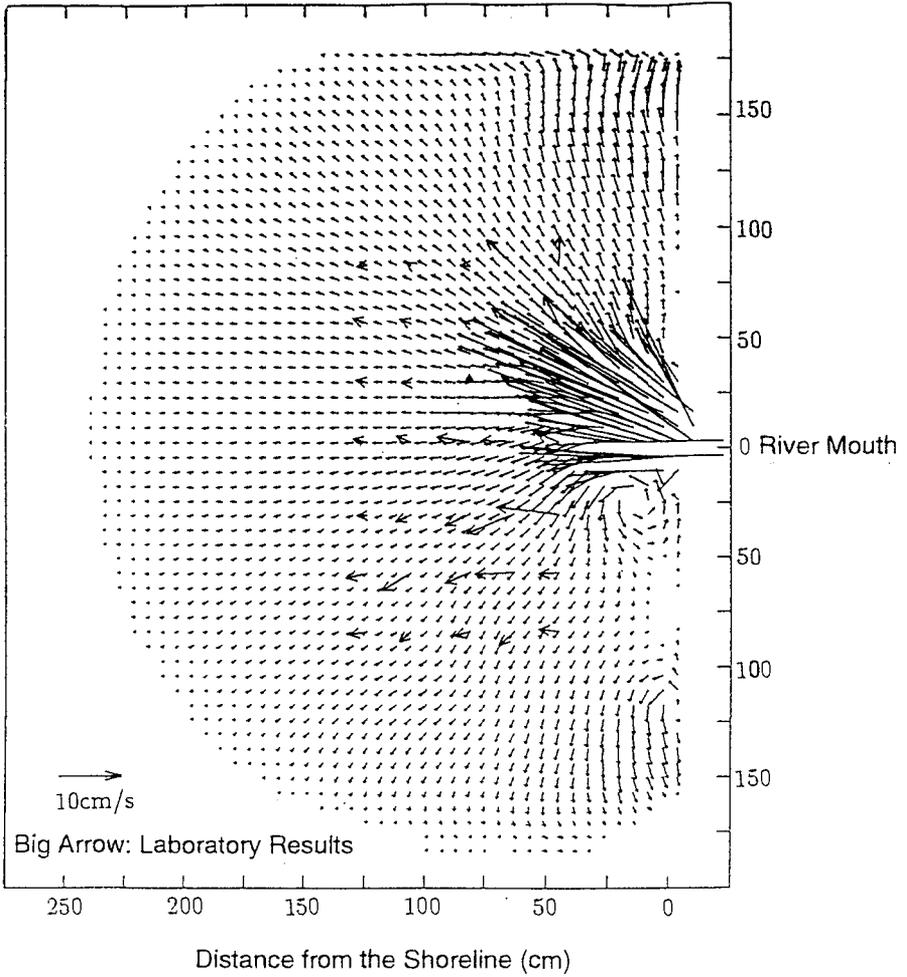


Figure 2: Measured and calculated current field (Case 3)

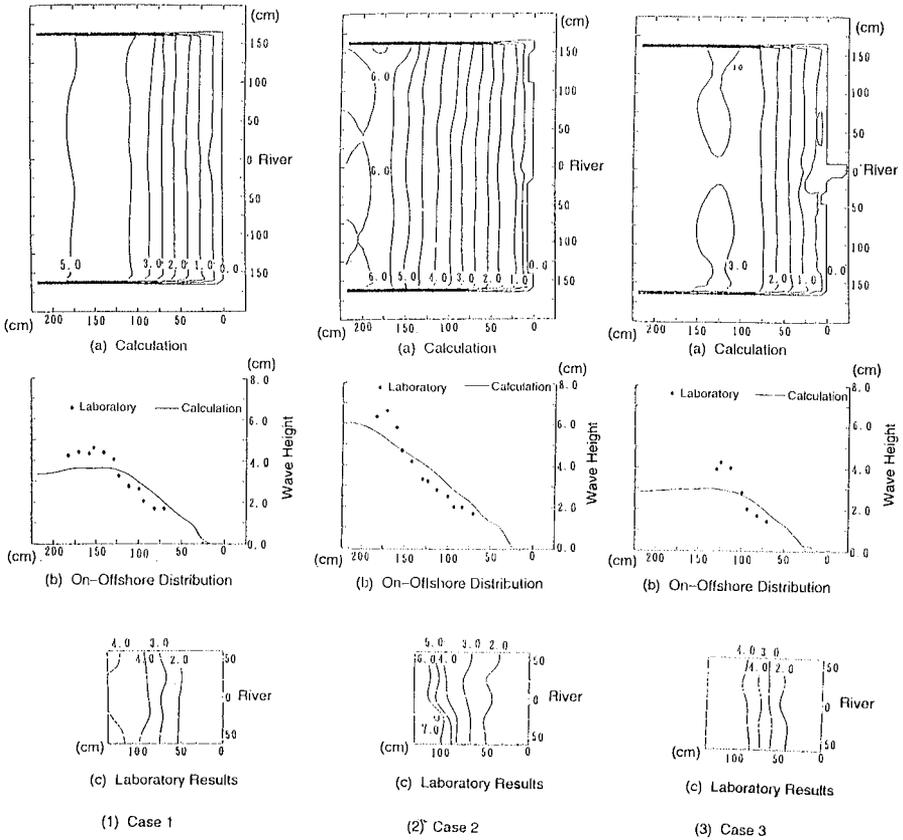


Figure 3: Comparisons of wave field
(a)calculated wave field,
(b)comparison of on-offshore distribution and
(c)measured wave field in laboratory

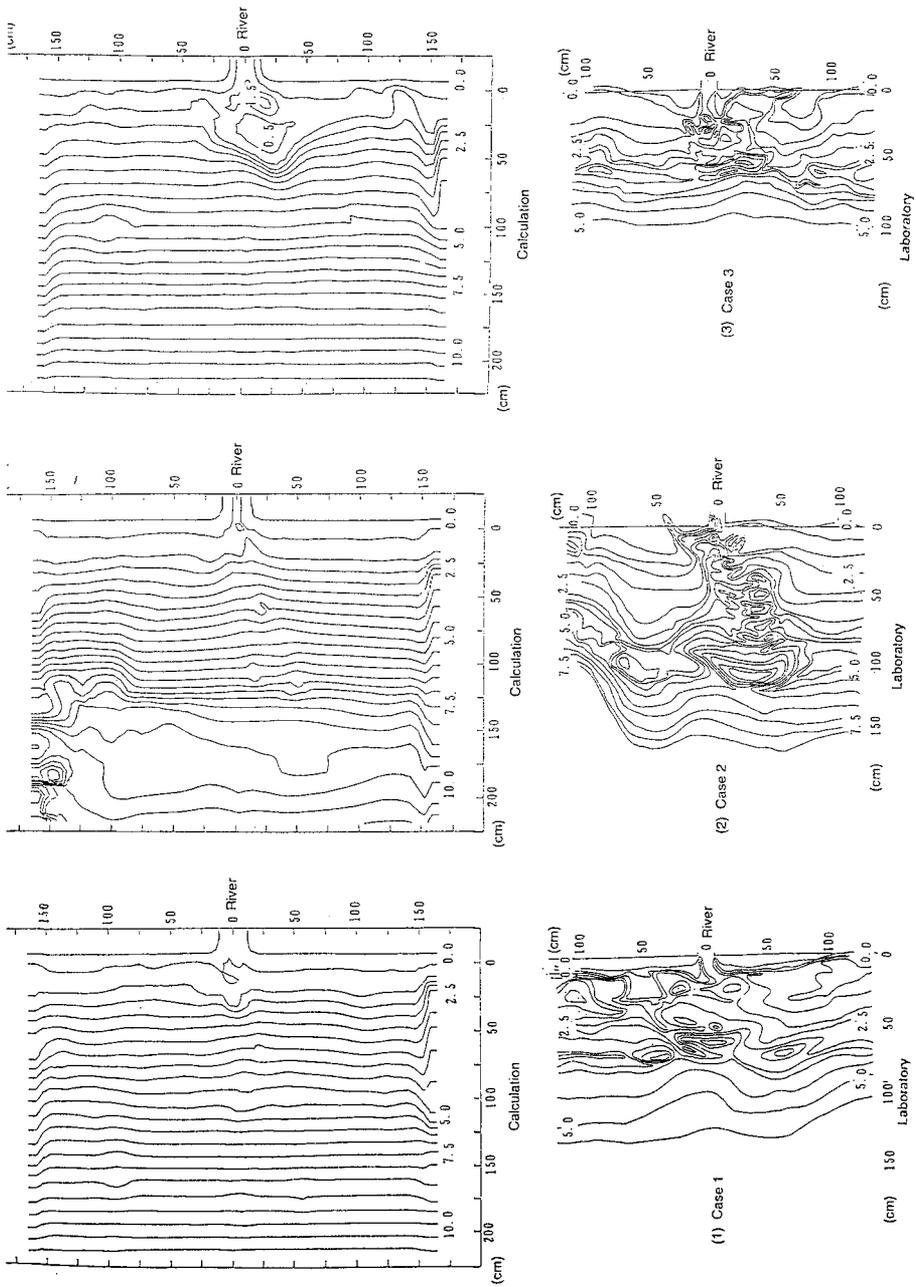


Figure 4: Comparison of beach topography change

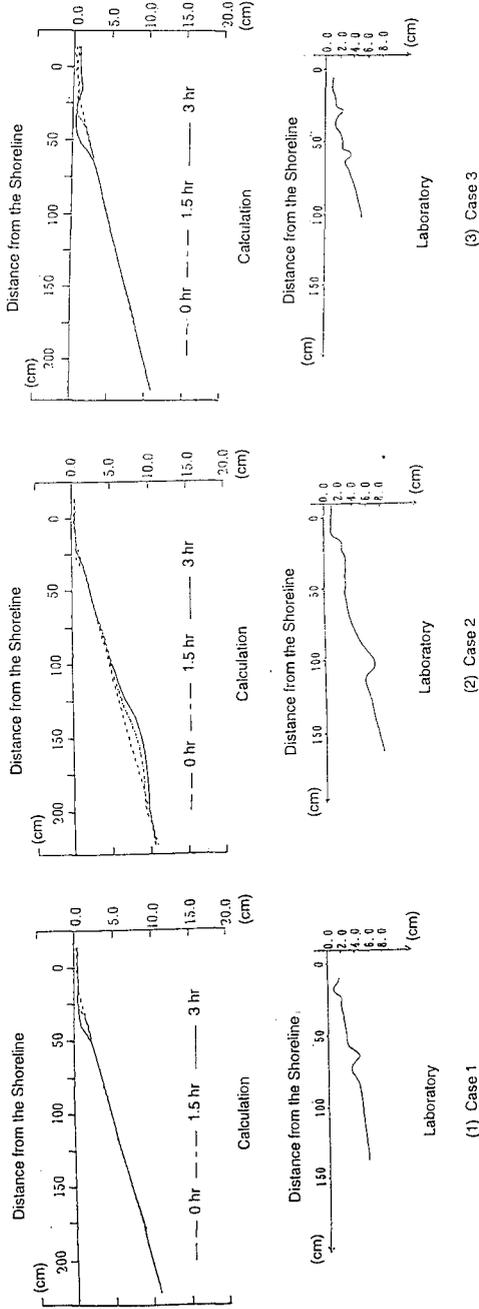


Figure 5: Cross-sectional change of beach topography in front of river mouth

of interaction between wave and current in wave breaking area is not fully included in the numerical model.

Figure 4 is the comparison between calculated beach topography in the numerical model and measured topography in the laboratory experiment. The measured area in the wave basin is limited because of limited area of movable sand bed area. In case 3, terrace formation in front of river mouth is well estimated by the numerical model. In cases 1 and 2, bar formation in offshore area is clearly observed in laboratory but is not so clear in numerical model.

Figure 5 shows cross-sectional change of beach topography in front of river mouth. In case 3, we can observe the formation and offshore directed movement of terrace. In the calculation, the terrace gradually developed in front of river mouth.

From these figures, we can judge that the present numerical model, which includes wave-current interaction, bed load and suspended load due to wave breaking and river discharge, is useful to predict laboratory results of beach changes in the vicinity of river mouth areas.

5. Conclusion

A numerical model is developed for prediction of beach profile change in river mouth area. The model is compared with laboratory results. From the comparison, we can conclude that the model is not satisfactory but promising for the future development. The possible modifications are (1)more precise evaluation of wave field, (2)including the effect of vertical distribution of current field and (3)more precise evaluation of diffusion and dispersion process of suspended sand.

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