土木学会第51回年次学術講演会（平成８年９月）

II-64 Numerical simulation of beach deformation under irregular waves

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1. Introduction

Most of the beach deformation models are dealing with regular wave action. Still, one main characteristic of waves is obviously their randomness. Several methods have been employed accounting for different approaches towards irregular waves inclusion within a beach deformation model. However, the random character of waves is still difficult to deal with. Laboratory experiments concerning beach deformation under irregular waves have started to be increasingly performed, creating therefore a base for theoretical studies to be pursued.

The present paper is a study conducted on beach deformation under the action of irregular waves. The calculation is based on the method of Shibayama and Winyu (1995). Significant wave was used for the wave input. The input data for the numerical analysis were provided by the Beach Deformation Research Project (Chairman, Prof. Y. Kawata). Supplied data included initial conditions for the experiment, experiment procedures, and significant wave height, wave period and duration of the experiments for each case.

2. Numerical model

The two-dimensional beach deformation model of Shibayama and Winyu was developed for the regular wave case. However, significant wave method was used to take into account the effect of irregular waves. Within the model, the suspended load was calculated as a product of sediment concentration and fluid velocity.

A two layer sediment transport model was considered. In the upper layer, transport rate is computed as a product of time-averaged suspended concentration and time-averaged velocity at respective elevations and then integrating the product over this layer one can obtain the suspended load. Time averaged concentration profiles are computed from the simplified steady diffusion equation given as follows

$$c w_s + \varepsilon_s \frac{\partial c}{\partial z} = 0 \tag{1}$$

where C is the time averaged sediment concentration, w_s is the falling velocity of the sediment particle, ε_s is the diffusion coefficient and z is the upward vertical coordinate. The transport rate in the bottom boundary layer was calculated in the form of an empirical formula using a procedure similar to Watanabe (1982), restricted yet to the region close to the bed (bed load).

The time-averaged velocity profile was computed based on the assumption of the eddy viscosity model as

$$\tau = \rho \nu_t \frac{\partial U}{\partial z} \tag{2}$$

where ρ is the fluid density, τ is the time averaged shear stress, ν_t is the eddy viscosity coefficient, U is the time-averaged velocity and z is the upward vertical coordinate from the bed. Also, quasi-steady assumption for the wave field computation was used. Wave height transformation was calculated using the improved Dally model.

Having thus the total transport rate, the cross-shore changes in local water depth are obtained by solving the sediment mass conservation equation

$$-\frac{\partial h}{\partial t} = -\frac{1}{1-\lambda}\frac{\partial q_t}{\partial x} \tag{3}$$

where t is the time, x is the horizontal coordinate in cross-shore direction, λ is the porosity and q_t is the total transport rate per unit width.

The total load at the local section of crosshore sediment transport rate, q_t, is expressed as a product of vertical distribution of sediment concentration, $c(z,t)$, and sediment velocity, $u_s(z,t)$ integrated over depth and wave period as

$$q_t = \frac{1}{T}\int_0^T \int_\delta^h c(z,t) u_s(z,t) dz dt \tag{4}$$

where T is the wave period, δ is the level above which there is no effective movement of sand particles and z is the vertical coordinate measured upward from the bed. Sediment velocity, u_s, is assumed equal to the fluid velocity, u.

3. Comparison with laboratory experiments

Results of the numerical simulation have been compared with laboratory data performed for irregular waves case. The results of the laboratory experiment on irregular waves were provided by the Beach Deformation Research Project. The experiments which were carried out in October 1995 comprised two cases, 1 and 2. Case 1 was divided in two stages since wave characteristics were changed during performing experiments.The input data initially provided included the initial bottom profiles, grain size distribution curve and wave characteristics for the two cases. After submitting the computed results, output data of the experiment were provided by the Project, enabling thus computational and measured data to be compared. The output for the numerical simulation was analyzed for the initial, middle and final part of each case. Bottom profile, wave height distribution and wave set up have been calculated and plotted in figures 1,2 and 3. At the same time, mean concentration and mean velocity as well as suspended sand flux were calculated for different locations up to the shoreline. Since data provided by the Project was time history of bottom profile and did not include the results of measurements for the concentration, velocity and sediment flux, up to this moment, comparison between simulation and measured data is limited to the bottom profile.The qualitative analysis of the beach profile indicates the accretional trend for all three cases. The general pattern for an accretional type of beach is also obtained by the computational results. In spite of this, one can notice for all cases a slight "shift" between the location of the computed and measured submersed bar. Figures 4, 5 and 6 are presenting the results of the laboratory experiment and the ones computed using numerical simulation. For case 1b the location of the bar is almost the same for both measured and computed data. Case 1a reveals an comparatively increased "shift" while for case 2 this appears obviously in a more evident way.

The present model might also give some deformed estimation regarding the total volume of sediment transport, especially due to the fact that the sediment transport rate formula used upper and lower layer was treated in the manner of an empirical formula. The average diameter used during the experiments was 1 mm which leads to the underestimation of quite a large volume of bed load type transport which could not be estimated correctly by the present model.

4. Conclusions

A comparison between numerical and laboratory data was performed using the significant wave method for evaluation of wave input for the numerical model. The analysis revealed a general similar beach deformation pattern of the beach transformation but some discrepancies have occurred. It becomes clear that the approach by using significant wave dimensions when analyzing the beach deformation under irregular wave can only be applied for predicting the general feature for the beach evolution. A different approach has to be employed for simulating the irregular wave action in order to obtain a quantitative and more reasonable estimation of the phenomena.

5. References

1. Shibayama, T., (1984): Sediment transport mechanism and two-dimensional beach transformation due to waves, Doctoral dissertation, University of Tokyo, 159 pp.

2. Winyu, R., (1995): Cross-shore sediment transport and beach deformation model, Doctoral dissertation, Yokohama National University, 196 pp.

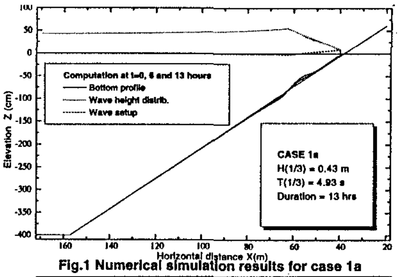

Fig.1 Numerical simulation results for case 1a

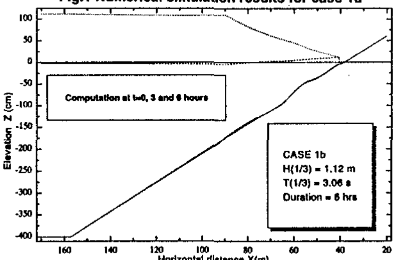

Fig.2 Numerical simulation results for case 1b

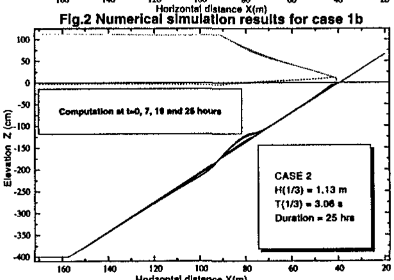

Fig.3 Numerical simulation results for case 2

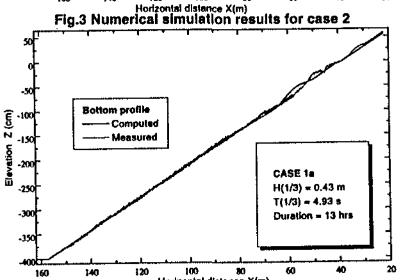

Fig.4 Comparison of computed and laboratory data for case 1a

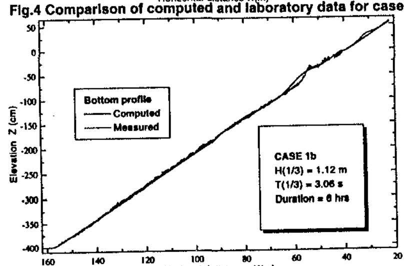

Fig.5 Comparison of computed and laboratory data for case 1b

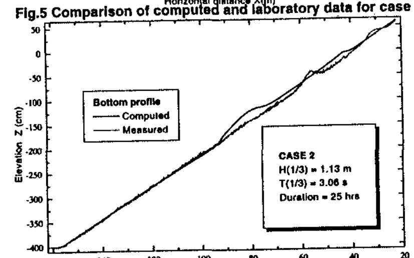

Fig.6 Comparison of computed and laboratory data for case 2