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A STUDY ON FLOW FIELD NEAR THE SAND BARRIER AT A RIVER MOUTH

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1. Introduction.

A sand barrier is often formed at a river mouth. This causes clogging of the mouth and affects flow field in the neighborhood of the river mouth. Many of the hydrodynamics processes responsible for the flow field near the sand barrier at a river mouth are river discharge and wave induced currents. In this study, flow field near the sand barrier at the river mouth is studied by means of numerical simulation.

2. The model system.

The model system consists of wave and current model. Parabolic mild slope equation with including wave-current interaction given by Kirby (1986) was used for the wave model. The critical state of the wave steep-ness for breaking wave is determined by using Sakai's breaking criterion (1989) which is based on Goda's expression (1974) and modified to include the current effect. The wave height inside the breaker zones is computed using bore model. The depth averaged continuity and momentum equations were used for the current model to compute flow field near the sand barrier at the river mouth. The momentum source is the gradient of the radiation stress. The momentum sink is represented by the bottom shear stress in terms of the Manning roughness coefficient. The flow impedance is the momentum diffusion where the diffusion coefficient is computed according to Longuet-Higgins (1970) which is based on the surf-zone turbulence due to breaking waves.

Since wave-current interaction is included, it is necessary to compute through iterative process in order to get converged solutions for wave computation and current computation. The iteration procedure runs as follows. For the first step, first of all, near-shore wave field is computed without considering wave-current interaction (assuming no flow in the whole domain). Then, computed near-shore waves, through radiation stress, provide driving force for the currents. For the second step, the computed current yielded from the above computation, modifies the wave field and provides radiation stress again which acts as driving force for the currents (1st iteration). From hereon, the iteration process continues until a certain degree of accuracy is achieved e.g. the ratio $|E_{kin}^{n+1} - E_{kin}^{n}| / E_{kin}^{n+1}$ becomes less than a test convergence value. E_{kin}^{n} is the total kinetic energy in the flow domain in n th iteration and expressed as

$$E_{kin}^{n} = \Sigma_i \Sigma_j ((u_{i,j}^{n} + u_{i+1,j}^{n})^2 + (v_{i,j}^{n} + v_{i,j+1}^{n})^2) h_{i,j} \Delta x \Delta y / 8 .$$

Where u, v are velocity component in on-shore and along-shore direction respectively, h is water depth, Δx, Δy are grid interval in on-shore and along-shore direction respectively.

The effect of the river discharge in the current model is introduced into the model as boundary conditions far enough upstream where no waves affect the river discharge.

3. Numerical analysis.

Numerical simulation have been conducted to reproduce the flow field near the sand barrier obtained by hydraulic experiment. Wave propagates over a current near the sand barrier. The overall numerical domain is 20 m in along-shore direction by 11 m in cross-shore direction which consists of a sea and the river with trapezoidal section of the bottom width of 0.6 m and the river bank slope of 1/4. The river length is 5 m. Discharge of the river is 12 l/s and water depth at the river is 0.04 m. Sand barrier of 0.4 m by 0.4 m was set at the mouth of the right hand side of the river. The beach slope is 1/10, and the water depth at the deep sea is 0.39 m. The deep water wave height is 0.09 m and wave period is 0.9 s. The incident waves have an angle of 30.5 degree from the river axis. For the computations, grid size was 4 cm and time step was Δt=0.001 s. In the wave model, finite difference approximation of the governing equation in the implicit Crank-Nicolson scheme leads to the simultaneous equations with unknown quantities of the wave amplitude in along-shore direction at certain on-shore distance. The solutions are obtained by the quick solver for the tridiagonal matrix of the equation. Initiated at the offshore boundary, this procedure is marched toward the shoreline. In the current model, the leap-frog scheme and upwind scheme for the convective term are used. The converged computation required 2 iterations.

4. Results and discussion.

Computed wave height distribution near the river mouth is shown in the Fig.1. The contour line is depicted in every 0.005 m. This shows the effects of the current on the wave field. In the front of the mouth, the opposing current significantly affects and refracts the wave propagation to decrease the wave height.

Fig.2. shows the velocity distribution near the sand barrier at the river mouth. The discharge jet is deflected by the long-shore current, at the same time the river flow to bend towards the far bank. The jet entrainment on the near bank side is restricted by the presence of the solid boundary, causing a re-circulation region with decreased surface elevation (low pressure) is formed (see also Fig.4.). The computed re-circulation region have a good agreement with the observed one (Fig.3.). The grid interval shown in the photograph is 10 cm. The distribution of the wave set-up is shown in the Fig.4. Clearly from this figure, due to the breaking wave, the water level at the river mouth rises due to wave set-up.

5. Conclusions

Flow field near the sand barrier at a river mouth was studied based on two-dimensional depth averaged continuity and momentum equations with including wave-current interaction. The flow pattern was predicted well by numerical simulation where the computed re-circulation region is compared with experiments.

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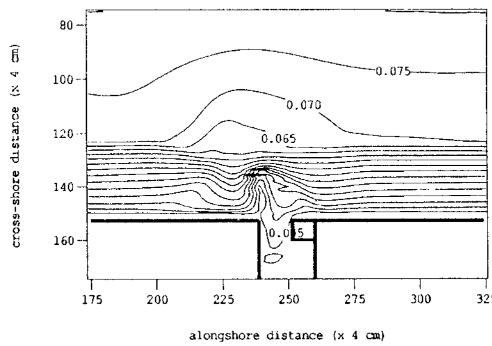

Fig.1. Wave distribution near the mouth

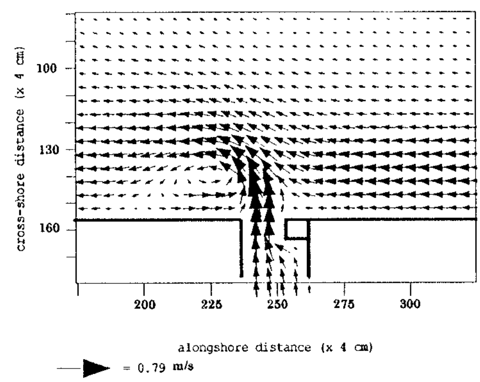

Fig.2. Flow field near the sand barrier

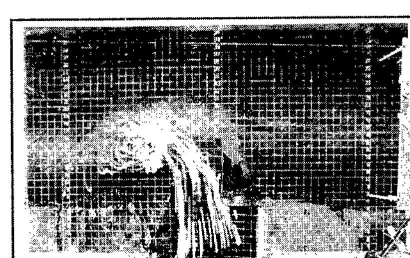

Fig.3. Observed re-circulation region

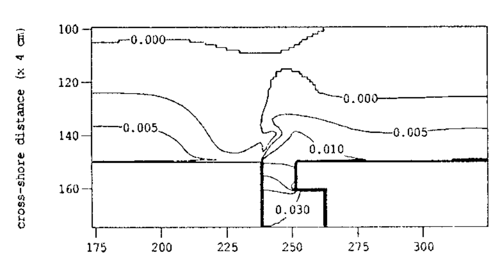

Fig.4. Wave set-up distribution