APPLICABILITY OF 3D MORPHODYNAMIC MODEL TO MEDIUM-TERM BEACH EVOLUTION

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The applicability of a three dimensional coastal area model based on a Hybrid model for medium-term beach evolution was investigated. The three dimensional model was first tested against groins for three cases in order to investigate the influence of the time history of the incident waves, and the time stepping techniques to feedback on the predicted final bathymetry. Then, the model was applied to Kunnui fishing port for 1, 3, and 4 years, to calibrate and verify the model. For the model tests, the performane of the model was investagated; and for Kunnui fishing port, the model results show good agreement with the field observations.

1 Introduction

Beach evolution models are classified into three categories, which are coastline model (long-term), coastal area model (medium-term) and beach profile model (short-term), e.g. De Vriend *et al*. [1].

For predictions in the long- or medium-term, the sediment transport rates due to nearshore currents were only taken into account, because the contribution of cross-shore sediment transport due to waves can be neglected, Shimizu *et al*. [2]. In these cases, the nearshore current fields were determined by depth-averaged (2DH) model. However, for the predictions of short-term and under stormy wave condition, the sediment transport rates due to waves and undertow in the surf zone play a very important role in the beach evolution, especially the formation and migration of sand bar, Kuroiwa *et al*. [3]. For the filling-up problem in the medium-term around Akasaki port in Tottori, Japan, Kuroiwa *et al*. [4] indicated that the undertow under the stormy waves influence on deposition of sediment around the port mouth. In case where undertow remarkably contributes the beach evolution, the three dimensional (3D) nearshore current model (i.e. quasi 3D = Q3D) with undertow is required. Therefore, Kuroiwa *et al*. [5] proposed a prediction system of 3D beach evolution with 2DH and Q3D hydrodynamic modes according to the wave condition and prediction period in the medium-term.

The final goal of this study is to investigate the applicability of 3D beach evolution with 2DH and Q3D hydrodynamic modes. In this study, according to the wave condition and prediction period in the medium-term, the 3D beach evolution with 2DH and Q3D hydrodynamic modes was selected. Also, the influence of time history of incident wave and time stepping techniques to feedback into the hydrodynamic computation were investigated.

2 Numerical Model

The morphodynamic model presented in this study is based on the coastal area model with a shoreline change presented by Kuroiwa *et al.* [5]. The model consists of hydrodynamic module, sediment transport module, and beach evolution module, as shown in Figure.1.

The wave module is based on the multi-directional random wave model, which is based on the energy balance equation with an energy dissipation terms due wave breaking and wave diffraction. The nearshore current module has two modes, which are Q3D mode and 2DH mode. According to the wave conditions and prediction periods, the hydrodynamic mode was selected.

The total sediment transport rate was defined as the sum of the bed load due to the wave orbital velocity, the steady current velocity at sea bottom, and the suspended load due to nearshore currents with undertow in the surf zone, Kuroiwa *et al.* [4].

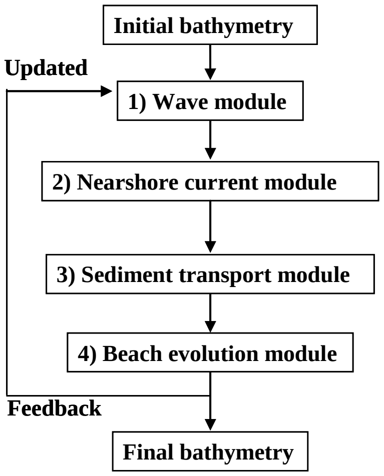


Figure 1. Flowchart of the numerical model.

Furthermore, in order to predict the shoreline changes, the local sediment transport rates in the run-up region were considered. The transport rates were determined using a simple method of linear decay from a reference point at the shoreline to limit run-up heights. The changes in bottom elevation and shoreline were calculated using the continuity equation of sediment transport rate that were proposed by Watanabe *et al.* [6]. The shoreline was treated as a moving boundary. The new bottom topography was fed back into the hydrodynamic and sediment transport computations.

3 Model Tests

First, three model tests associated with groins were carried out to investigate the influences of the time history of wave data and time stepping techniques to feedback into the predicted final bathymetry. The computation was performed in an area of 1.6km in the alongshore direction and 1.0km in the cross-shore direction. The initial bathymetry with the gradient of 1:90 was set. The grid size was $\Delta x = \Delta y = 20$m. The predictions with three different time histories of wave were carried out. The total wave energy of cases C1, C2, and C3 was equal. Figure 2(a) shows the time variation of wave data input at offshore boundary for C1, C2, and C3, respectively. The principal wave direction was 20 degree. The detailed input data for the computations are listed in Table 1. According to the wave conditions and prediction periods, the hydrodynamic mode was selected and the magnitude of the undertow velocity (A_s) was set.

Table 1. Wave data and dimensionless coefficients for model tests

Step			Period, day			H_s	T_s	*mode*	A_s	C_w	C_s	E_s
C1	C2	C3	C1	C2	C3							
1,5,6,10	1,2,3,4	1	30	30	120	1.0	6.0	2DH	0.0	0.2	0.005	20
2,4,7,9	5,7,8,10	2	5	5	20	2.0	7.0	2DH	0.0	0.2	0.005	20
3,8	6,9	3	2	2	4	3.0	8.0	Q3D	2.0	0.2	0.005	20

Figures 2(b), (c), and (d) show the predicted bathymetries around the groins for C1, C2, and C3, respectively. To investigate the influence of the time history wave data on the final beach evolution in medium-term, a comparison between the final bathymetries of Case 1 and Case 2 was done, and it was found that the shoreline and 1 m contour depth between the groins for Case 1 were different from those of Case 2, although the input data of the computations for the two cases was same. These differences appeared due to the time variation of wave data input at the offshore boundary. This result shows that the time history of wave data was significantly playing an important role in the prediction of the 3D morphodynamics in the medium-term, especially over the shallow water areas.

The influence of the repetition frequency of hydrodynamic computations on the final beach evolution in medium-term was further investigated by comparing the final bathymetries for Case 1 and Case 2 with the final bathymetry of Case 3. From these comparisons it was found that the computed final bathymetry of Case 3 was quietly different from those of Case 1 and Case 2, especially the shoreline, 1m, and 2m contour depth between the groins, as shown in Figures 2(b), (c), and (d), although the wave energy for the three cases was same. These differences were due to the influence of the repetition frequency of hydrodynamic computations, and also the number of the stormy waves affecting on the final beach profile.

From these tests, it was concluded that the influences of the time history of wave data, especially the stormy waves, and the time stepping techniques to feedback into the predicted final bathymetry were highly effecting on the medium-term beach evolution, especially over the shallow water areas.

The time variation of wave data input, especially the stormy waves, at the offshore boundary, and the influence of the repetition frequency of hydrodynamic computations on the final beach profile should be taken in to account for good prediction of the 3D morphodynamics in medium-term beach evolution.

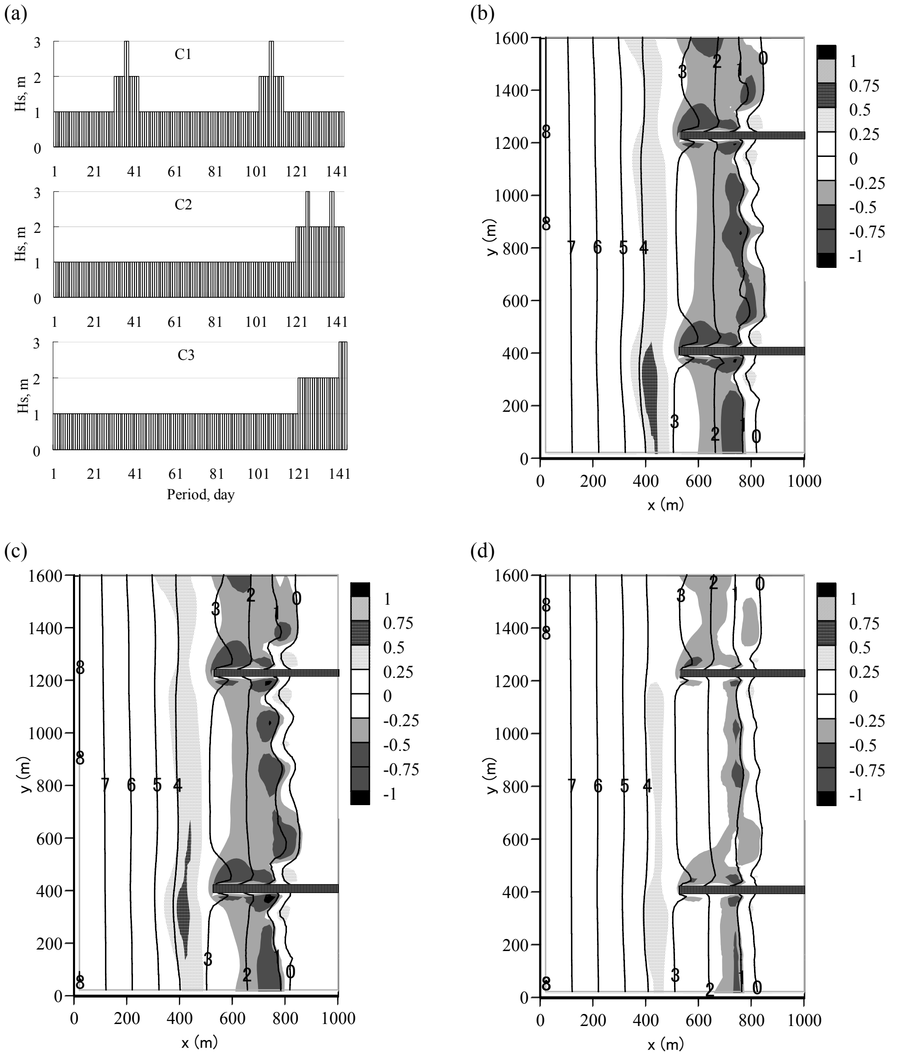


Figure 2.(a) time variation of wave data input at offshore boundary for C1, C2, and C3, respectively; (b) predicted bathymetry around the groins for C1; (c) predicted bathymetry around the groins for C2; (d) predicted bathymetry around the groins for C3.

4 Model Application

In order to verify the field applicability of the 3D beach evolution model, we tried to reproduce the medium-term topography changes during four years of the construction of Kunnui fishing port in Hokkaido, Japan [7].

Kunnui fishing port was planned in 1985 and completed in 1994. Before completion of the port, the bottom contours were almost parallel, and after one year, a tombolo was rapidly formed behind the port from 1989 to 1990, as shown in Figures 3(a), and (b), respectively. In this study, the beach evolutions from 1989 to 1993 were simulated to verify the present model. Figure 3(d) shows the measured bathymetry in 1993.

4.1 Model Setup

The computation was performed in the area of 1.0km in the alongshore direction and 0.8km in the cross-shore direction. The initial bathymetry with the gradient of 1:90 was set. The grid size was Δx = Δy =10m. As the port was under construction during the simulation period, the boundary of the port assumed varying with the time. According to Shimizu *et al.* [8], [9], the significant wave height of less than 0.5m is omitted, because the waves can not contribute against the beach evolution around the Kunnui fishing port. Therefore, the duration of which the beach evolution was generated in 1 year was 120 days. The time variation of wave data input at the offshore boundary was taken into account. The computations of the wave and current modules were repeated 10 times to reach to 1 year beach evolution and 40 times for four years beach evolution. The principal wave direction was perpendicular to the shoreline. The spreading parameter S_{max} was set as 75. In case of the significant wave height of less than 1m (H_s<1.0m) for the medium-term beach evolution, the nearshore current field was determined by 2DH mode. However, if the significant wave height is greater than 1m (H_s>1.0m) for stormy wave conditions, the Q3D was used to calculate the nearshore current field. The median diameter of sand particle was 0.20mm. The dimensionless parameters in the sediment transport formulae were defined by using the trial and error method. The detailed input data for the computations are listed in Table 2.

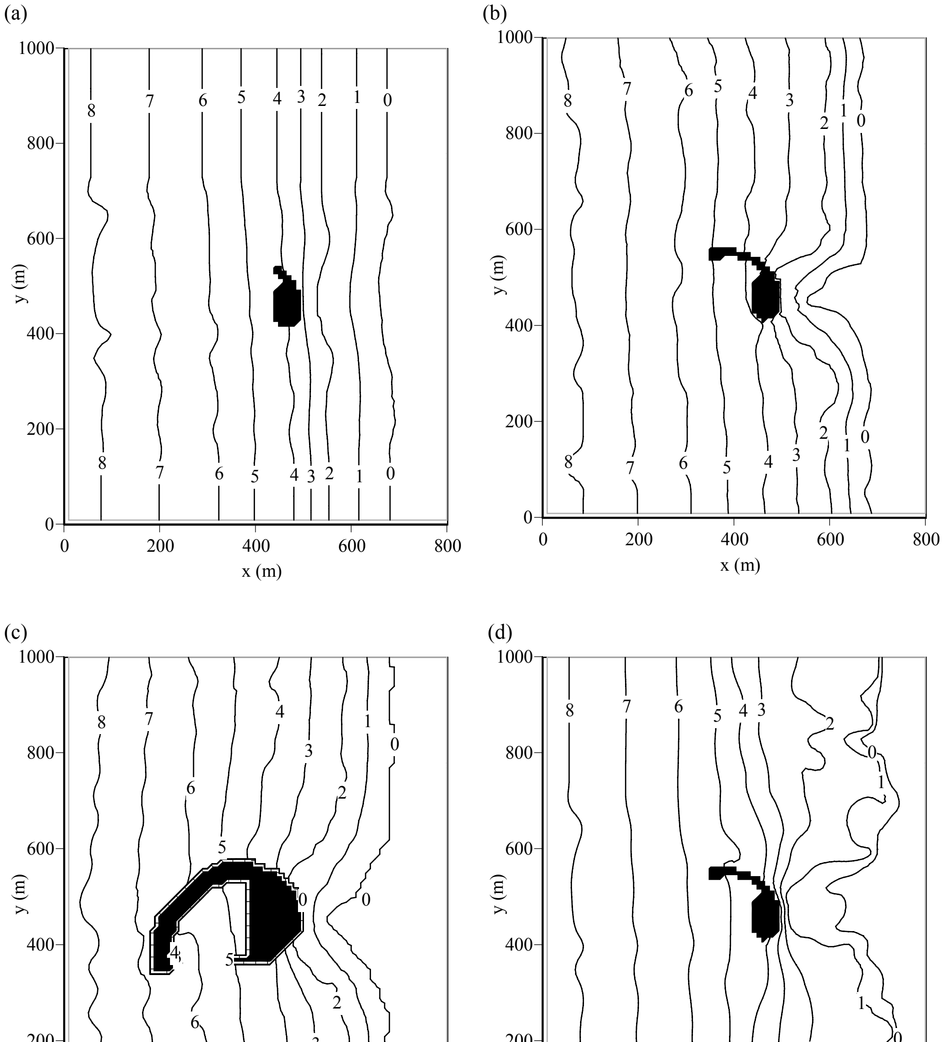
Table 2. Computational conditions of the hydrodynamic model

Step	Period, day	H_s	T_s	*mode*	A_s	C_w	C_s	E_s
1,5,6,10	28	0.75	7.0	2DH	0.0	0.5	0.05	30
2,4,7,9	1.9	1.25	8.0	Q3D	2.0	0.5	0.05	30
3,8	0.2	2.0	10.0	Q3D	2.0	0.5	0.05	30

4.2 Results and Discussion

Figure 3(d) shows the computed bathymetry after 1 year beach evolution (1989-1990). Comparing with the measured bathymetry in 1990, it was found that the tombolo was formed behind the Kunnui fishing port, as shown in Figure 3(b). Although the predicted tombolo was different from the measured topography in 1990, the shoreline and the depth of contour lines of 1m, 2m, and 3m advanced to offshore direction due to the circulation behind the fishing port.

Figure 4 shows the computed bathymetry after 4 years (1989-1993). Comparing between the computed and measured bathymetry, it was found that the tombolo was appeared behind the Kunnui fishing port, but it was different from the measured. The computed bathymetry was slightly different than the observation in the sharp shape formed behind the port including the shoreline, 1m and 2m contour depths.



Figures 3.(a), (b), and (c) the measured bathymetries in 1989, 1990, and 1993, respectively; (d) the computed bathymetry after 1 year beach evolution .

From these results, it was found that the shoreline and bottom topography change such as the formation of tombolo behind the port could be qualitatively computed. However, we tried to investigate the applicability of the present model in the equilibrium state by simulate the measured bathymetry in 1990 (after tombolo formation behind the port) to predict 3 years beach evolution. The computed bathymetry after 3 years (1990-1993), shows good agreement with the measured bathymetry in 1993, as shown in Figure 5. It was found from this application that our model was able to predict the morphodynamics in medium-term beach evolution.

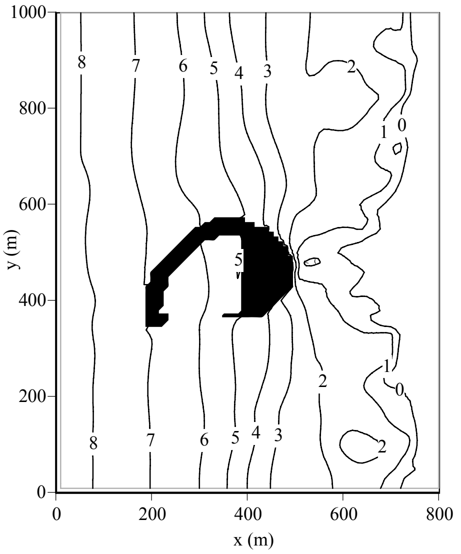


Figure 4. The computed bathymetry after 4 years beach evolution (1993).

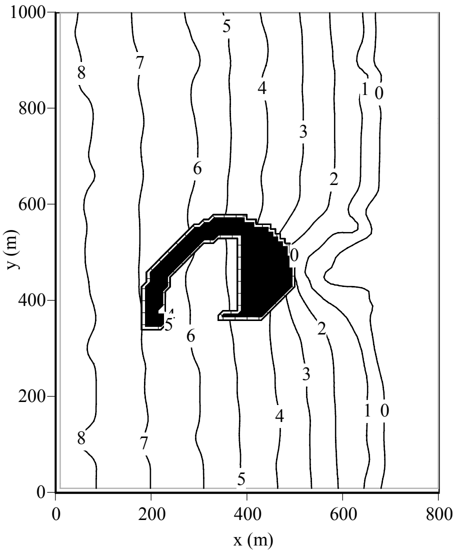


Figure 5. The computed bathymetry after 3 years beach evolution (1993).

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