Predictive model of 3D beach evolution around groins

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1. Introduction

To apply many practical problems associated with a beach evolution, many coastal area models have been proposed. (eg. Kuroiwa *et al*. 2000, 2004). However, these conventional models have still been incomplete, because the field verifications and prediction techniques have not been sufficiently investigated and discussed. The purpose of this study is to investigate the applicability of 3D coastal area model based on Hybrid model presented by Kuroiwa *et al*. (2004). The prediction techniques involving the method of setting incident wave condition at offshore boundary, and the influence of time history of incident wave and time stepping to feedback into the hydrodynamic computation, were also 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*. (2004). The model consists of a hydrodynamic module, a sediment transport module, and a beach evolution module, as shown in Fig.1. 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. Nearshore current module has two modes, which are (Q-3D) mode based on Kuchiishi *et al*. (2004) and 2DH mode based on Nishimura (1981). According to 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, as given by Kuroiwa *et al*. (2000). 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 reference point at the shoreline to limit run-up heights, as presented by Kuroiwa *et al*. (2004). The changes in bottom elevation and shoreline are calculated using the continuity equation of sediment transport rate proposed by Watanabe *et al*. (1986). The profile changes in the run-up region were also determined from the continuity equation. The shoreline was treated as a moving boundary. The new bottom topography was fed back into the hydrodynamic and sediment transport computations.

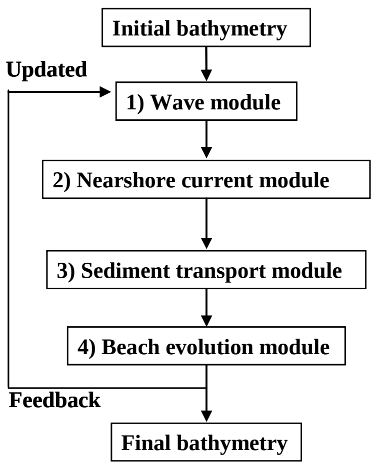
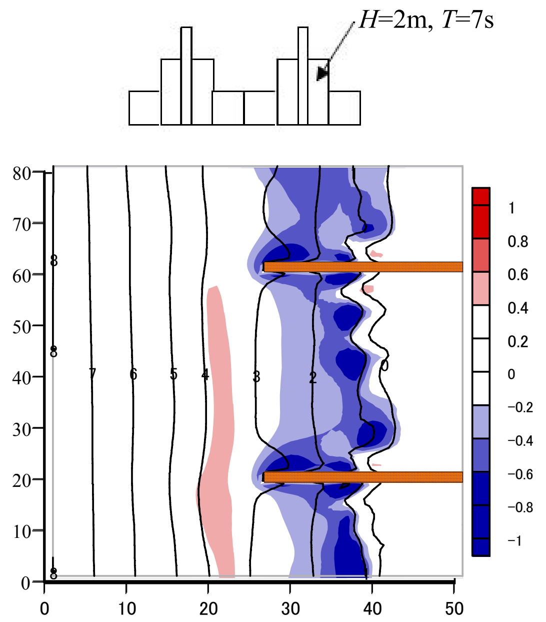


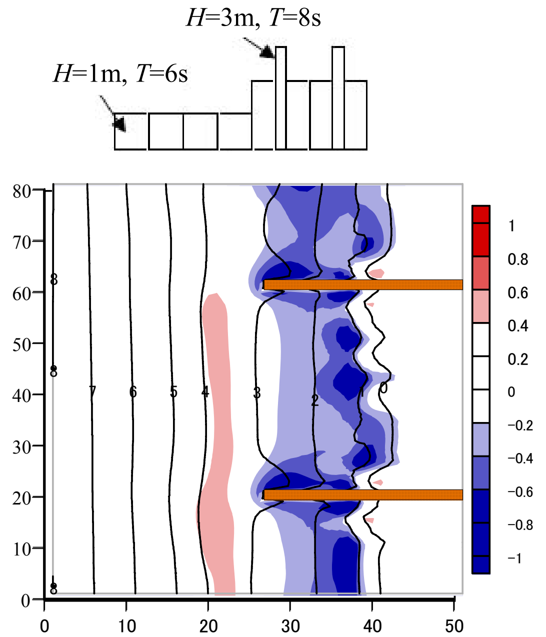
Fig.1 Flowchart of the numerical model

3. Model Tests

First, two model tests associated with groins were carried out to investigate the influences of the time history of wave data to the predicted final bathymetry. Fig.2 shows the simulated bathymetries around the groins. The predictions with two different time histories of wave were carried out. The total wave energy of Case 1 was equal to Case 2. 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 sizes were Δx = Δy =20m. The detailed data for the computation are listed in Table 1. The principal wave direction was 20 deg. A_s H≤2.0m, the nearshore current field was determined from 2DH mode. In this case, the undertow velocities was not contribute to beach profile changes (A_s=0.0). While in case of H>2.0m, the nearshore current field was determined from Q3D mode (A_s >0.0). The setting of dimensionless parameters in the sediment transport formulae were investigated using the trial and error method as shown in Table 1. By comparing the final bathymetries of Case 1 and Case 2, it was found that the computed final bathymetry of Case 1, especially the shoreline and 1 m contour depth in the vicinity of the groins are different from those of Case 2. from these tests, it was concluded that the stormy waves were significantly effecting the beach evolution, and also the time history of wave data were highly playing an important role in the prediction of the 3D morphodynamics, especially over the shallow water areas.



(a) Case 1



(b) Case 2

Fig.2 Predicted bathymetry after 144 days of wave action

Table 1.Wave data and dimensionless coefficients for model tests

Step Case 1	Step Case 2	days	*Hs*	*Ts*	*mode*	A_s	C_w	C_s	E_s
1,5,6,10	1,2,3,4	30	1.0	6.0	2DH	0.0	0.195	0.005	20
2,4,7,9	5,7,8,10	5	2.0	7.0	2DH	0.0	0.195	0.005	20
3,8	6,9	2	3.0	8.0	Q3D	2.0	0.195	0.005	20

4. Model Application around Groins

The applicability of the model to the 3D medium-term beach evolution was investigated for a field site. The study area is located in the eastern part of Rosetta Promontory shoreline in Egypt, as shown in Fig. 3, which is witnessing an erosion problem. Whereas, the main source of sediments was supplied by Nile River. Fanos *et al*. (1995) studied the development of Rosetta Promontory and showed that between 1500 and 1900 *AD*, the eastern and western parts protruded respectively by about 11 and 8.5 kilometers into the sea, as shown in Fig. 4. This accretion phase reversed at the beginning of the 20th century as a result of the construction of the High Aswan Dam, water control works along the Nile River, and the action of waves and currents. The length of the promontory was eroded by about 5 kilometers between 1900 and the present time. In order to treat the high rate of erosion that area taking place, several studies have been conducted in the past. Firstly, to control the erosion at the tip of promontory, two revetments of 1.5 and 3.5km long were constructed between 1986 and 1991 on the western and eastern parts, respectively. Following that 9 and 5 groins have constructed on the western and eastern parts of the promontory, respectively. In this study, the bottom topography and shoreline changes during the period from May 2006 to November 2008 around two groins were selected for applying the presented model. Fig. 5 shows part of the simulated bathymetry. The computation was covered an area of 0.8km in the alongshore direction and 2.8km in the cross-shore direction. The gradient of initial bathymetry of slope 1:300 was set. The grid sizes were Δx = Δy =20m. The time variation of observed wave data, located at the offshore boundary close to the study area, for year 2004, was considered as an input for the present model. The time series of the wave data is shown in Figure 6. The detailed data for the

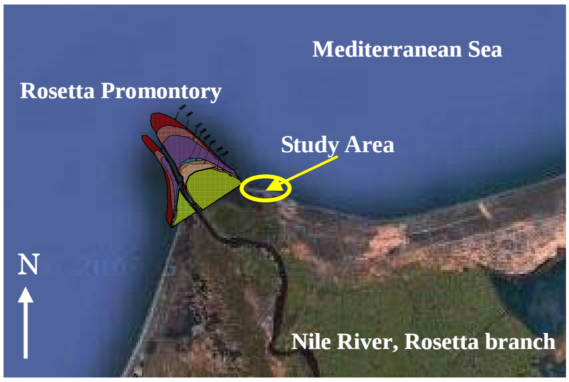


Fig.3 Location of the study area

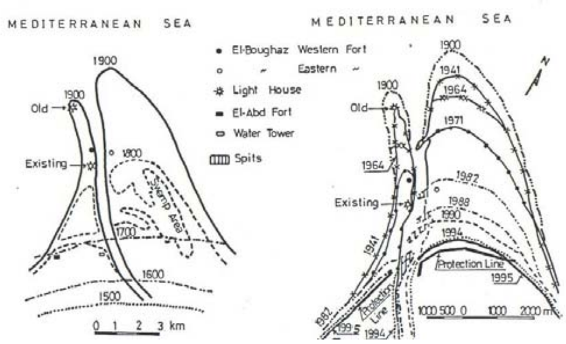


Fig.4 Shoreline advance and retreat, Rosetta Promontory

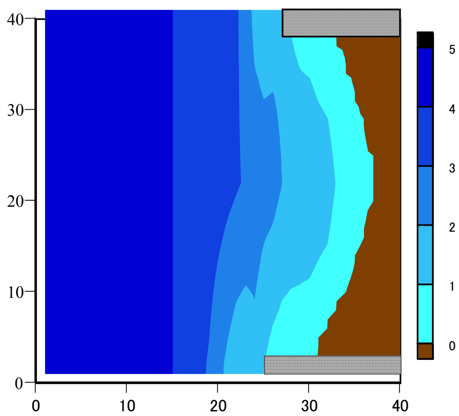


Fig.5 Measured bathymetry in May 2006

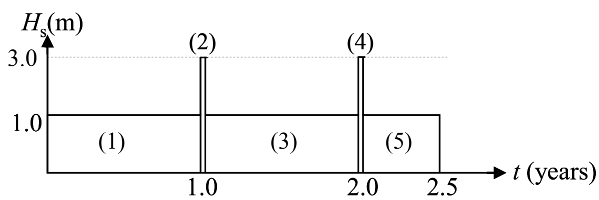


Fig.6 Time variation of wave data input at offshore boundary

computation are listed in Table 2. The principal wave direction was almost parallel to the shoreline with θ equal to 83.0 deg. The spreading parameter S_{max} was set as 25. The computed significant wave height (H_s) distribution for step 2 is shown in Fig. 7. The median sand particle size was 0.20mm. Fig. 8 shows the predicted bathymetry after step 5 which corresponding to 2.5 years later. Comparing with the measured bathymetry in Nov. 2008, as shown in Fig. 9, it was found that although the shoreline at the mid- center between the groins was advanced, the topography and shoreline changes in the vicinity of the groins was retreated.

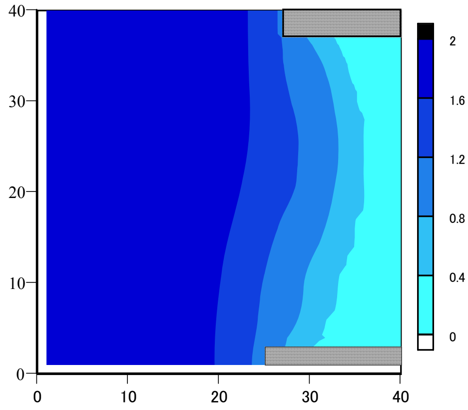


Fig.7 The computed significant wave height distribution for step 2

Table 2.Wave data and dimensionless coefficients in medium-term prediction

Step	days	*Hs*	*Ts*	*mode*	A_s	C_w	C_s	E_s
1,3	364	1.0	7.0	2DH	0.0	0.195	0.0001	20
2,4	2	3.0	8.0	Q3D	2.0	0.195	0.001	20
5	182	1.0	7.0	2DH	0.0	0.195	0.0001	20

From these results, it was found that, the beach evolution surrounded two groins could be qualitatively predicted.

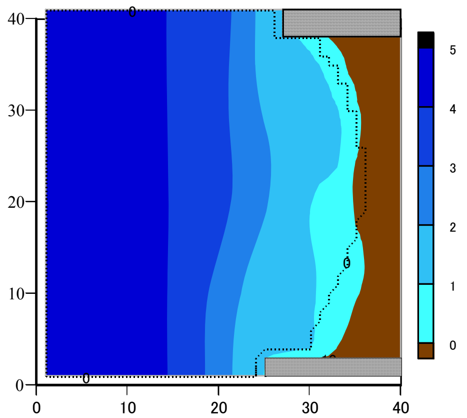


Fig.8 The computed bathymetry after step 5

5. Summary

In this study, the applicability of 3D coastal area model based on Hybrid model presented around the groins was investigated. The prediction techniques involving the method of setting incident wave condition at the offshore boundary, and the influence of time history of incident wave into the hydrodynamic computation, were also investigated. The beach evolution surrounded two groins at Rosetta Promontory shoreline in Egypt could be qualitatively predicted.

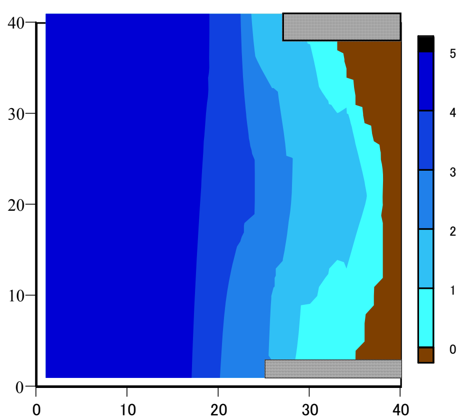


Fig.9 Measured bathymetry in Nov. 2008

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Kuroiwa *et al.* (2000): Numerical prediction of bottom topographical change using Q-3D nearshore current model, **Kuroiwa *et al.* (2004):** Medium-term Q-3D coastal area model with shoreline change, **Kuchiishi *et al.* (2004):** Field verification of a numerical Q-3D nearshore current model, **Ahmed Khaled Seif. (2009):** Applicability of 3D Morphodynamic Model to Medium-term Beach Evolution, **Fanos *et al.* (1995):** Erosion of Rosetta Promontory, the Nile Delta, Egypt.