STUDY ON ANNUAL SHORELINE CHANGE AROUND A HEADLAND

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Headland is a coastal structure to control longshore sediment. This study focuses on the annual variation of shoreline position around a headland at Kashima coast, Ibaraki. With results of radar measurement, shoreline position, intertidal slope, and cross-section area are estimated by time-stack data processing. And their features are discussed in terms of wave condition and compared with computation results of current field. To understand connection among variation of shoreline position, intertidal slope, cross-section area, and current field, wave deformation and current variation around the headland are computed by REF/DIF-1 and SHORECIRC model.

Key Words **:** *headland, shoreline position, intertidal slope, current field, REF/DIF-1, SHORECIRC*

1. INTRODUCTION

Headland is a coastal structure to control lonshore sediment transport, and a considerable number of headlands are constructed in Japan. This study focuses on the annual variation of shoreline position around a headland at Kashima coast, Ibaraki.

Wave climate at Kashima coast differs in seasons. In winter season, wave heights are high and high waves are incident from the northern. On the other hand, in summer season, wave heights are low and primary incident wave direction is southern. Shoreline positions around a headland respond to the wave climate: Northern sides of the headland are generally deposited in winter season and are eroded in summer season, and at southern side of the headland, the opposite is observed.

X-band radar has been installed to trace annual variation of shoreline positions around a headland. Variation of shoreline position, intertidal beach slope and beach volume are estimated and their features are discussed. Then, numerical computations on wave and current filed are done to understand the observed morphological behavior. To compute the wave and current field, REF/DIF-1 (Kirby et al., 1994) is used as wave deformation model and SHORECIRC (Svendsen et al., 2000) is used as circulation model.

2. STUDY AREA AND RADAR OBSERVATION

(1) Study area and radar observation

Fig. 1 is an aerial photograph of the study area. The area is approximately 3.8 km south form the research pier HORS, PARI (http://www.pari.go.jp). The headland located at X=0 m. The X-band radar is installed at (X, Y) = (120 m, -40 m) to trace the hourly shoreline distribution around the headland.

Radar data are collected and processed every hour to time averaged images (Takewaka, 2005). Data collected for year 2010 are analyzed in this study. **Fig. 2** shows time averaged images for high and low tide. It shows that shoreline positions shift seawards by ebb tide.

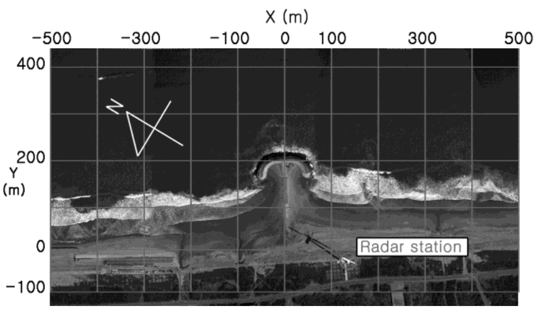

Fig.1 Study area
X-band radar is installed at (X, Y) = (120 m,-40 m)

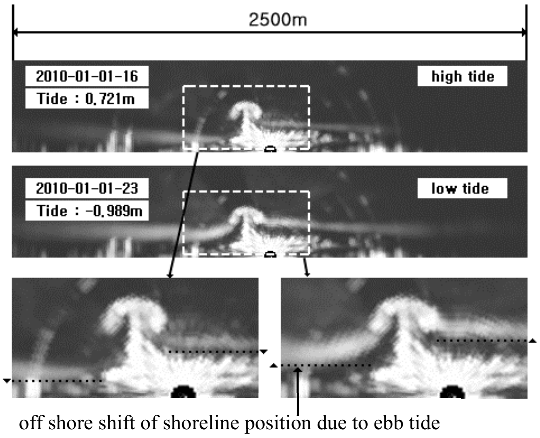

Fig.2 Time averaged images around headland

(2) Data processing

Six locations, X=-200 m, -150m, -100 m, 100 m, 150m, and 200 m, are selected to process time-stack images to estimate shoreline position, intertidal slope, and cross sectional area. **Fig. 3** is a part of time-stack image for 15 days, which shows hourly instantaneous shoreline positions of X=-100 m and X=100 m with tidal variation.

Time-stack image shows variation of shoreline position in time. White lines in the top and mid panel are shoreline positions marked by manual inspection and bottom panel shows the tidal variation. **Fig. 3** shows that shoreline moves seaward when the tide is ebbing and vice versa.

Variation of shoreline positions, intertidal beach slopes, cross sectional areas, and beach volumes are estimated in the following manner: Intertidal beach slopes are calculated by using linear regression method with the measured shoreline position and tide. Data length used for the regression is 7 days. Mean shoreline position is estimated with the result of regression. Cross sectional area is also estimated from the result of regression for the height from -0.7 m to +0.7 m around mean sea level. Beach volumes are then calculated with the averaged cross sectional areas of both sides of the headland and distance between measurement locations.

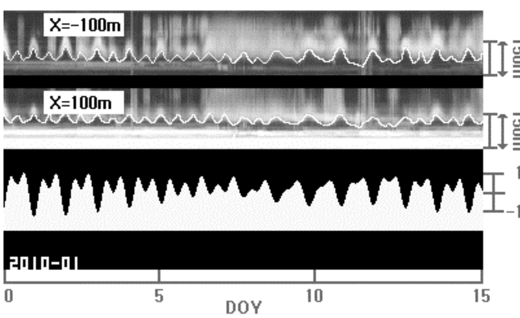

Fig.3 Time stack for X=-100 m and X=100 m, and tide level (bottom panel) for period of day 0 to 15 (Doy, 2010)

(3) Result of radar observation

Fig. 4 shows annual variation of shoreline position, intertidal beach slope, beach volume, and significant wave height and wave direction measured at Kashima Port. Positive wave direction indicates northern incident wave, and 0° indicates normal incidence to shore.

Wave characteristics are different with seasons: In winter season, wave heights are high and higher incident waves arrive from the northern. On the other hand, in summer season, wave heights are low and primary incident wave direction is southern.

Shoreline positions are fluctuating all the year. Northern sides (X=-200 m, and X=-100 m) of the headland are generally accumulating in winter season and are eroding in summer season. Southern sides (X=100 m and X=200 m) of the headland have the opposite trend.

The variations of the intertidal beach slopes of northern sides (X=-200 m, and X=-100 m) and southern sides (X=200 m and X=100 m) show significantly different features for the periods of doy (day of year) 200 to 250. For most of the periods, variations of the intertidal beach slopes of X=-100 m and X=-200 m, and that of X=100 m and X=200 m show similar behavior, respectively. On the other hand, for the period of doy 200 to 250, the slopes at X=-100 m and 100 m are becoming milder whereas the slopes at X=-200 m and 200 m show almost no change.

Beach volumes can be used as an index determining occurrence of erosion or accumulation. It can be seen from the variation of beach volumes that southern side of headland is eroding in winter season and accumulating in summer season, and the opposite is observed at the northern side.

3. NUMERICAL COMPUTATION

As discussed in the previous chapter, trends of intertidal beach slope variations differ from doy 200 to 250. The slopes at X=-100 m and X=100 m are becoming milder whereas there are no considerable changes of the slopes at X=-200 m and X=200 m. To infer the reason of this difference, numerical computations of the wave and current are carried out.

In order to compute the current field, wave filed data is necessary. To estimate the incident wave field, a backward propagation computation is performed with wave data measure at Kashima port wave station. Backward propagation computation is done by a refraction computation. Once the offshore wave data from the backward propagation is determined, forward computations are carried by REF/DIF-1 (Kirby et al.,1994). Results of wave computation by REF/DIF-1 are verified with the wave data measured at Kashima wave station, and then wave data at -10 m water depth in front of the headland are employed as incident wave data for the detailed computation around the headland.

As mentioned previously, variations of the intertidal beach slopes of northern and southern of the headland show significant different show for the period of doy 200 to 250. To understand causes for different features of variations of the intertidal beach slopes for the period of doy 200 to 250, two types of numerical computation for the period of doy 200 to 250, and the period of doy 261 to 311 are carried out, respectively. Wave heights for the period of doy 261 to 311 are higher than the period of doy 200 to 250.

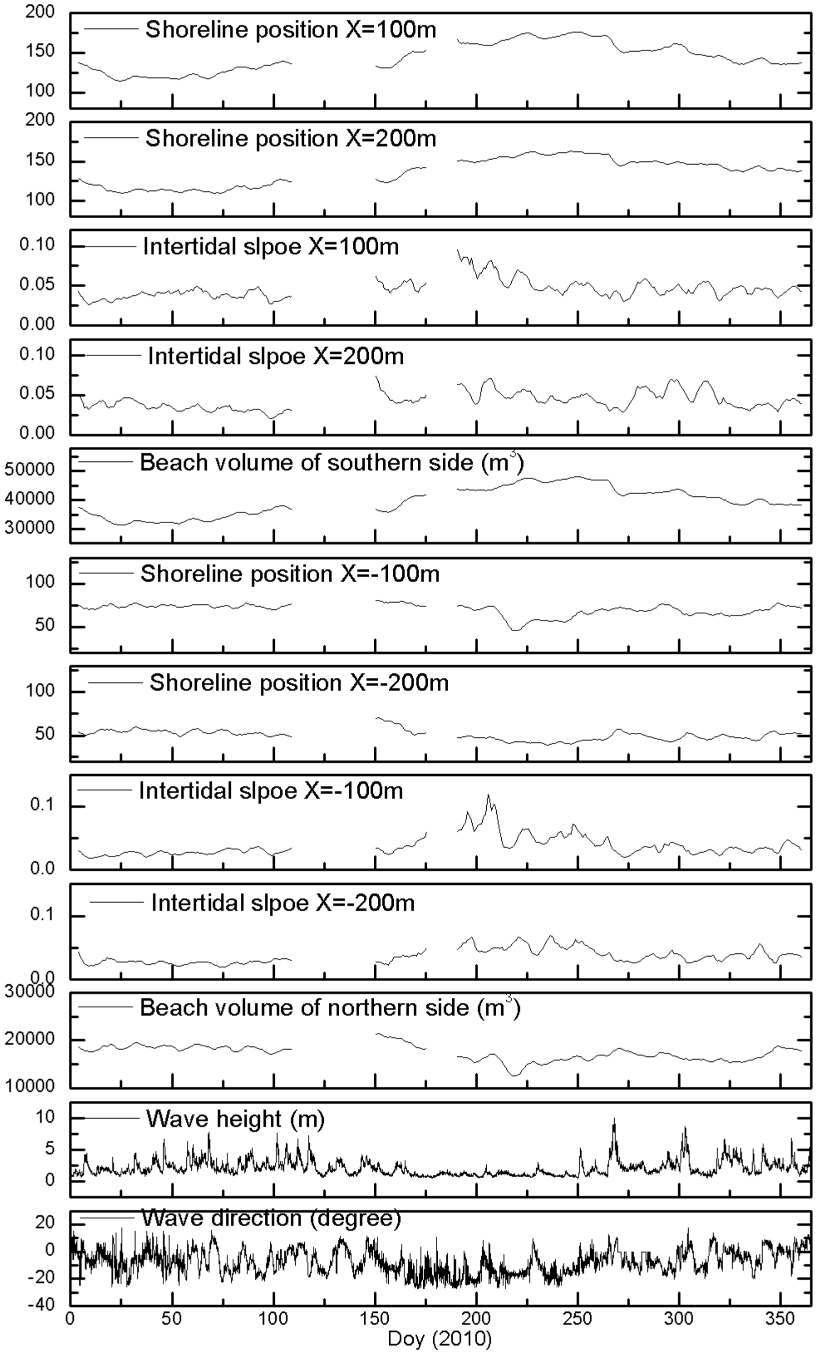

Fig.4 Annual variation of shoreline position, intertidal slope, beach volume, wave height and direction of year 2010.

Wave conditions for the computation are incident wave height H=0.84 m, wave period T=8.7 sec, and incident wave angle θ=-36.7° (average of the period of doy 200 to 250) and H=2.1 m, T=8.0 sec, and θ=-14.5° (average of the period of doy 261 to 311), respectively.

Through the numerical computations, the reason of variations of the intertidal beach slopes for the period doy of 200 to 250 may be understood and differences of current field both periods (doy 200 to 250 and doy 261 to 311) are discussed.

To compute the wave and current field, REF/DIF-1 is used for the wave deformation model and SHORECIRC is used for the circulation model. REF/DIF-1 is developed by Kirby et al. (1994) and uses a nonlinear parabolic mild slope equation as governing equation. SHORECIRC is developed by Svendsen et al. (2000) and uses a Quasi-3D equation as governing equation.

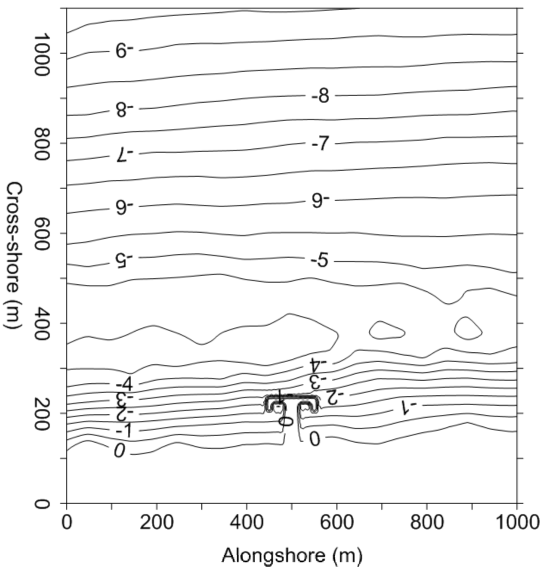

Fig.5 Bathymetry of study area

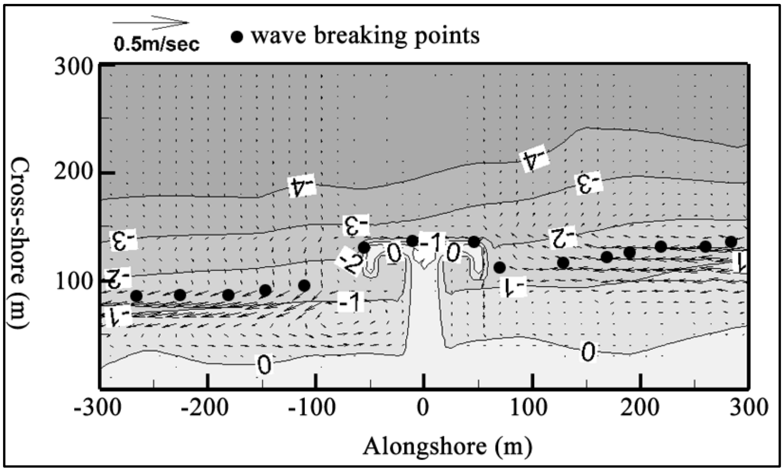

Fig.6 Current distribution (H=0.84 m, T=8.7 sec, and θ=-36.7°)

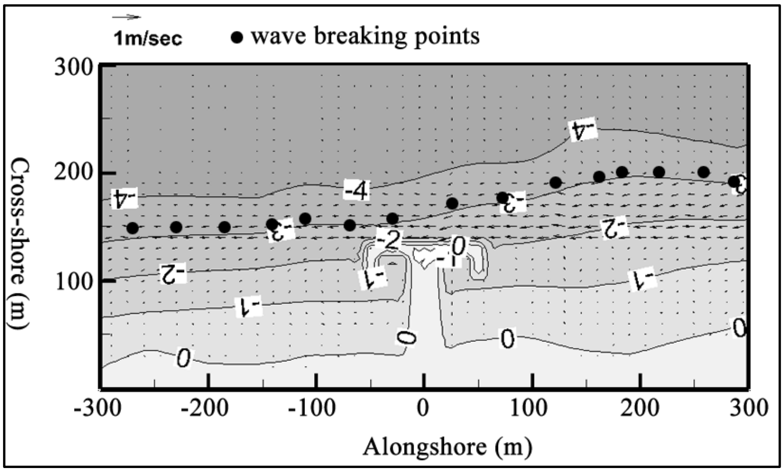

Fig.7 Current distribution (H=2.1 m, T=8.0 sec, and θ=-14.5°)

Bathymetry of the study area is shown in **Fig. 5**., and results of the computations are shown in **Fig. 6** and **Fig. 7. Fig. 6** and **Fig. 7** show current distribution and wave breaking distributions. Note that current vectors are skipped to improve readability.

Fig. 6 is the result of computation for the period of doy 200 to 250. It shows that waves are breaking between depth of -2 m and -1 m. Longshore currents are by passing the headland from south to north and isolated circulations are formed around the headland with flow separation and attachment.

As mentioned previously, intertidal beach slopes at X=-100 m and X=100 m are becoming milder for the period of doy 200 to 250, **Fig. 6** shows that current separates at the vicinity of the headland at X=100 m. Then, the flows attaches the shore at X=-100m. This flow pattern could make intertidal slopes milder at X=-100 m and X=100 m.

Fig. 7 is the result of computation for the period of doy 261 to 311. It shows that waves are breaking along the depth line of -3 m. Longshore currents are flowing beyond the headland from south to north and there are no the isolated circulations around the headland, and no flow separation and attachment. The headland is totally immersed in the surf zone.

For the period of doy 260 to 310, variation of intertidal slopes of northern sides (X=-200 m, and X=-100 m) and southern sides (X=100 m and X=200 m) were synchronizing. **Fig. 7** shows no formation of detached vortices at the headland and this kind of flow pattern may not significantly affect the configuration of the shoreline, so there were no un-synchronizing changes for intertidal beach slopes for this period.

4. CONCLUSION

In this study, study on annual shoreline change around the headland at Kashima coast is performed. Through time averaged image (**Fig. 2**) and time stack image (**Fig. 3**), annual variation of shoreline position, intertidal slope, and beach volume are estimated. They show a seasonal change according to seasonal wave characteristics.

From the numerical results of the current field, it is suggested that morphological changes around the headland are closely related with the longshore current pattern.

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