COUNTERMEASURE AGAINST EROSION BEHIND SUBMERGED BREAKWATER DUE TO SEA LEVEL RISE

Yoshiaki Kuriyama, Port and Airport Research Institute, kuriyama@pari.go.jp
Masayuki Banno, Port and Airport Research Institute, banno-m@pari.go.jp

INTRODUCTION

Submerged breakwaters are considered to be preferable countermeasures against beach erosion where the availability of sediments for nourishment is limited and tourism is prevalent because submerged breakwaters do not interfere with the view of the horizon from the shore. However, sandy beaches protected by submerged breakwaters are assumed to be vulnerable to relative sea level rise (SLR) and land subsidence because the crests of submerged breakwaters are below sea level.

Kuriyama and Banno (2016) numerically predicted the future shoreline change under SLR and land subsidence on the Niigata West coast in Japan, which is protected by submerged breakwaters. The prediction showed that the shoreline will retreat 60 m over the next 100 years. In this study, we investigated the effects of countermeasures against the erosion due to SLR and land subsidence.

STUDY SITE

The Niigata West coast suffered beach erosion since the 1910s. As a countermeasure, a number of detached breakwaters were constructed near the shore since the 1950s, but erosion still took place seaward of the breakwaters. Hence, since 1988, submerged breakwaters and groins have been constructed and beach nourishment has been implemented behind the submerged breakwaters. The crown height of the submerged breakwaters was assumed to be 2.5 m below the low water level in 2001. The investigation area lies between the first and second groins as shown in Figure 1.

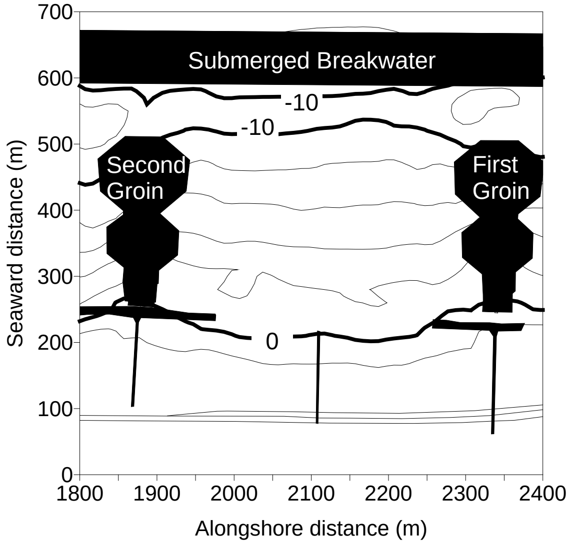

Figure 1 - Morphology in July 2011 in the investigation area.

Based on the wave data obtained at a water depth of 35 m, the offshore waves have large seasonal variations (Figure 2). The wave height and period are larger than 1.5 m and 6 s, respectively, from November to March, but smaller than 0.5 m and 5 s from June to August.

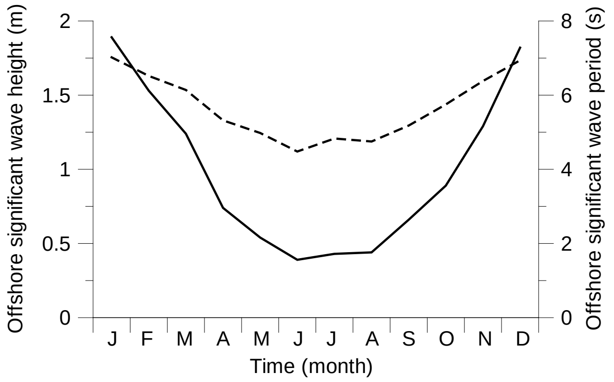

Figure 2 - Monthly-averaged offshore significant wave height (solid line) and period (broken line).

METHODS

As countermeasures against the beach erosion due to SLR and land subsidence, we think of heightening the crown of submerged breakwater in 2031 by 1.0, 1.5 and 2.0 m. To examine the effects of the countermeasures, we predicted the shoreline change from 2011 to 2061 using the shoreline prediction model employed by Kuriyama and Banno (2016), which was confirmed to reproduce the shoreline change on the investigation area during the period from 2001 to 2011.

The model, which is expressed by Equations (1) and (2), assumes that the shoreline change is caused by cross-shore sediment transport, and that the shoreline change rate is a function of the offshore wave energy flux taking into account the wave energy dissipation due to the submerged breakwater. The shoreline change rate was also assumed to be negatively proportional to the shoreline position.

$$y_{s,i} = y_{s,0} + \sum_{j=1}^{i} \left(\frac{dy_s}{dt} \right)_j \Delta t \tag{1}$$

$$\left(\frac{dy_s}{dt} \right)_j = a_0 + a_1 + a_2 E_j^2 + a_3 E_j + a_4 y_{s,j-1} + a_5 \left(\frac{d\overline{\eta}_j}{dt} - \frac{dz_{r,j}}{dt} \right) \tag{2}$$

where t is the time, a_0 is the geometrically obtained shoreline change rate due to land subsidence, i.e., a_0 = (amount of land subsidence)/(foreshore slope), a_1 to a_5 are coefficients, $\overline{\eta}$ is the time-averaged sea level, and z_r is the elevation of a reference point for land subsidence measurement. The subscript j indicates the number of time steps. The time interval was set at 3 months.

As the input offshore wave heights and periods, the values measured from 2001 to 2011 were repeatedly used. The offshore wave heights considering the wave energy dissipation over the submerged breakwater were estimated using the model developed by Kuriyama (2010), which estimates the cross-shore variation of root-mean-square wave height assuming that the wave height probability density function has a Rayleigh distribution. The estimated significant wave heights 150 m shoreward of the submerged breakwater ($z = -8.8$ m) were transformed to the offshore values using the shoaling coefficients.

The amounts of sea level rise and land subsidence were the same as those in Kuriyama and Banno (2016). The amount of sea level rise was set to equal the amount of projected sea level rise under the RCP8.5 scenario. The amount of subsidence was set at 13.0 mm/year, which is the mean value at the study site for 2001-2011.

RESULTS AND CONCLUSION

The model prediction showed that the increase in the crown height of submerged breakwater is effective against the beach erosion due to SLR and land subsidence (Figure 3). Even a 1.0 m increase induces shoreline advance of 4.5 m from 2021-2031 to 2041-2051 owing to the enhanced energy dissipation over the heightened submerged breakwater. Although the shoreline retreats from 2041-2051 to 2051-2061, the shoreline in 2051-2061 is still located seaward of that in 2021-2031, before the crown height increase.

A 1.0 increase in the crown height is effective and economical from the view point of coastal protection. However, at least 1.5 m may be required for the crown height increase because of the size of blocks used for the submerged breakwater.

A crown height increase of 2.0 m reduces the wave energy flux by about 70% and induces a large shoreline advance. However, a 2.0 increase makes the crown of the submerged breakwater about 1 m below the low water level, and may interfere with the scenic landscape at wave troughs. Careful coordination between coastal protection and tourism is required.

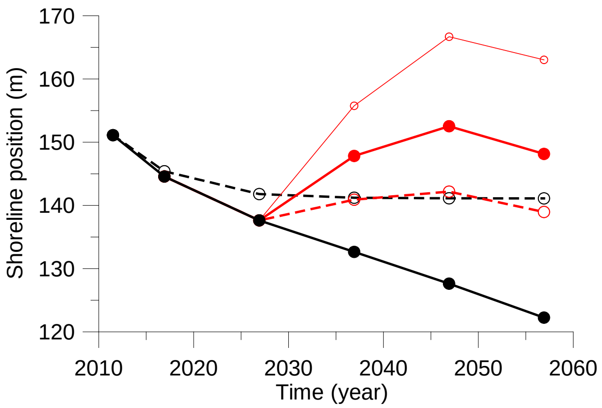

Figure 3 - Predicted shoreline position averaged for 10-year periods. Black solid and broken lines represent the values predicted with SLR and land subsidence and without both, respectively. The red thick broken, thick solid and thin solid lines represent the values with increases in the crown height by 1.0, 1.5 and 2.0 m, respectively.

REFERENCES

Kuriyama, Banno (2016): Shoreline change caused by the increase in wave transmission over a submerged breakwater due to sea level rise and land subsidence, Coastal Engineering, ELSEVIER, vol. 112, pp. 9-16.

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