Preparing for Future Erosion of Sandy Beaches Caused by Climate Change by Focusing on Beaches that Experienced Sea Level Rise

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1. Sea level rise caused by climate change

The Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) reported that the global mean sea level is already rising and predicts that sea level rise will also continue in the future. The "Special Report on the Ocean and Cryosphere in a Changing Climate (SROCC)," published in 2019, predicts that the global mean sea level will rise 0.71 meters (0.51 to 0.92 meters) by the end of the 21st century (2081-2100) under the most severe RCP8.5 emission scenario.

Since one effect of sea level rise on coastal areas is retreat of the shoreline to the inland side, disappearance of many sandy beaches is feared. Therefore, the Coast Division is conducting research on a simple technique for estimating the shoreline response to rising sea levels as a technique that can be used by coast administrators when studying the necessity of countermeasures for coastal areas under their jurisdiction.

2. Beach erosion caused by sea level rise

The amount of shoreline retreat in response to sea level rise cannot be predicted simply by multiplying the slope of the beach by the amount of water level rise. This is because a beach has an equilibrium cross-sectional profile, and its topography changes so as to maintain that profile, resulting in larger shoreline retreat (**Fig.-1**).

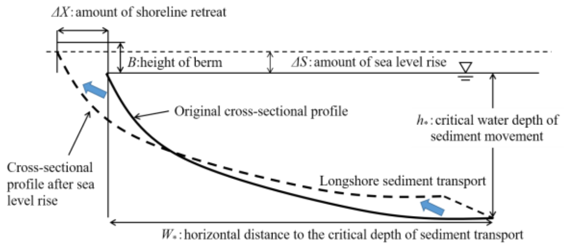

Fig.-1 Schematic diagram of topographical change due to sea level rise

This rule is called the Bruun rule. Although the Bruun rule is widely used worldwide as a technique for predicting the shoreline response of beaches to climate change, the premise that the amount of sediment in the cross section in the shore-to-offing direction does not change is considered to be unsuitable for the actual condition of beaches in Japan and has rarely been used in work at the practical level.

Recently, however, a model (hereinafter, called the modified Bruun rule) that can consider changes in the amount of sediment due to longshore sediment transport (littoral drift), beach nourishment, etc. has been proposed. Therefore, we verified the applicability of the modified Bruun rule to coastal areas in Japan by comparing the results of predictions by the proposed model and the topographical changes actually measured at local sites.

3. Focusing on coasts that have experienced relative sea level rise

In Japan, some coastal areas have experienced relative rises in sea level as a result of decreases in the ground level caused by crustal movement or ground subsidence (**Fig.-2**). Five of those coastal areas (Iburi, Niigata, Kujukuri, Fuji and Suruga coasts) were selected, also considering whether sounding measurements were carried out in the past. Among these, the fastest rate of ground level decrease was 15.0 mm/y at the Kujukuri coast, which is far larger than the 3.6 mm/y global average rate of mean sea level rise observed to date.

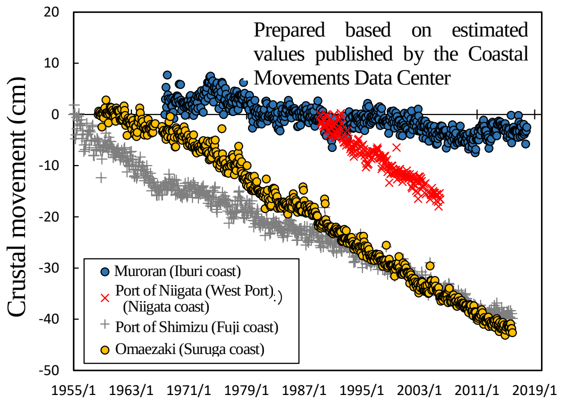

Fig.-2 Crustal movement near coastline

The change in the amount of sediment in the cross section at these five coasts was obtained from the sounding results at two different times, and the amount of ground subsidence observed in the vicinity during the same period was regarded as the amount of relative rise in the sea level. This relative sea level rise was then substituted in the above-mentioned revised Bruun rule, and the amount of shoreline retreat between the two times (periods of 6 to 42 years) was calculated. At some survey lines, the calculations showed shoreline retreat even though virtually no changes were observes in the shorelines in the actual measurements. However, the calculation results were close to the measured values at lines where there were no detached breakwaters, jetties or similar structures in the water (**Fig.-3**). Although care is necessary when applying the revised Bruun rule under some coastal conditions, it was considered to possess sufficient accuracy for use in the stage of identifying coastal areas where countermeasures are required from among this country's very long coastline.

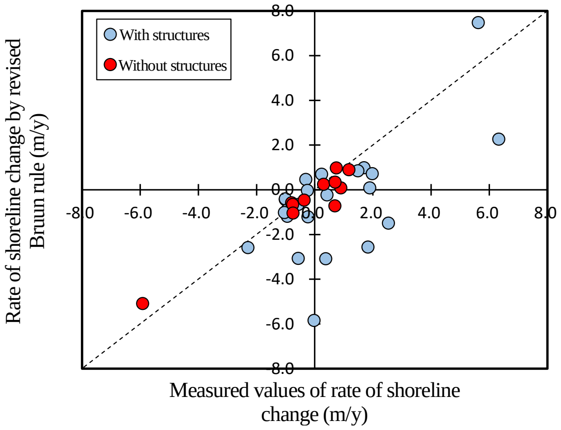

Fig.-3 Calculated and measured results of shoreline change

4. Degree of influence of sea level rise on eroded coastlines

On the basis of the results of calculations by the modified Bruun rule, we analyzed the shoreline response observed in the past at the five coasts due to changes in the amount of sediment in the cross section in the shore-to-offing direction, and due to relative sea level rise, and found that the influence of changes in the amount of sediment had been predominant in shoreline change at virtually all of the survey lines at four of the coasts, with the exception of the Kujukuri coast (**Fig.-4**).

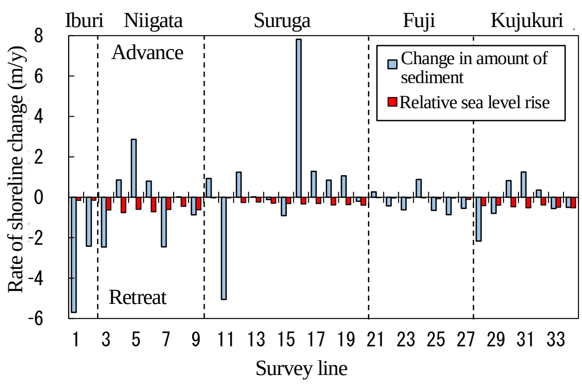

Fig-4 Shoreline change due to change in amount of sediment and due to sea level rise

This result means that the locations where countermeasures should be implemented on a priority basis are places where there is a disequilibrium in the balance of sediment inflow and outflow, and this is also applicable when considering the predicted sea level rise in the future. At eroded coasts, it is important to proceed steadily with the current erosion countermeasures, but in addition to those measures, a general wide-area survey by a simple technique such as the modified Bruun rule method is also required so as not to overlook sandy beaches where it will no longer be possible to secure the necessary beach width due to sea level rise.

5. Prediction of shoreline response at long coastlines

In order to confirm the applicability of the modified Bruun rule to long coastlines containing a mixture of accumulation sections and erosion sections, we attempted to reproduce the shoreline response observed over a period of 38 years from 1977 to 2015 at the Minami Kujukuri coast (from Katakai fishing port to Taito fishing port). In 8 of the 10 calculation target sections (excluding the two end sections), the average measured value of shoreline retreat was 31.0 m, but the predicted value was limited to an average of 10.0 m. This is not a negligible difference for this coastline, which includes many locations where the beach width is already less than 50 m. In this study, a decrease in the amount of littoral drift was not anticipated in sections where headland groups have been installed, but this is considered to be a cause of the above-mentioned difference. This result suggests that it is important to improve the accuracy of predictions of the distribution of littoral drift for future predictions of shoreline response.

6. Future development

In spite of issues such as development of a prediction method with high accuracy for future changes in the amount of sediments, it was possible to confirm that the prediction technology verified in this research is also applicable to synoptic studies by persons in charge of coast administration. However, the effect of climate change considered in this study was limited to mean sea level rise, and study of future changes in waves, which affect drift sand, are currently in progress. Moreover, research on a detailed technique which can be used in future predictions of individual coasts, as in the example of the Kujukuri coast presented here, is also underway. Together with the simple method introduced in this paper, we would also like to provide information to coast administrators.

☞For more information:

1) Kunihiro Watanabe et al.: Journal of the Japan Society of Civil Engineers, Ser. B2 (Coastal Engineering), Vol. 76, No. 2, pp. I_529-I_534, 2020.
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