NUMERICAL SIMULATION OF GRAVEL NOURISHMENT TO THE SEISHO COASTLINE IN JAPAN

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INTRODUCTION

It is feared that as a consequence of the potential future intensification of tropical cyclones due to ongoing climate change the patterns of coastal erosion around the world could change. In this study, the mesoscale meteorological model WRF (Weather Research and Forecasting), the third-generation stand-alone wave model SWAN (Simulating WAves Nearshore), and the coastal deformation model XBeach (eXtreme Beach behavior) are combined to calculate the short-term coastal deformation caused by high waves during the approach of Typhoon No.21 (Paolo) in 2017 to the Seisho Coast and Niigata Coast in Japan (Nishida and Shibayama, 2020). The model is then applied to predict future patterns of coastal erosion. Potential countermeasures to prevent future coastal erosion are then examined. The construction of detached breakwaters, which are currently used as a countermeasure against coastal erosion in many parts of the world, is often opposed by local residents due to the changes they can produce on the fishing environment and landscape. Therefore, it is often desirable to stabilize the beach without constructing structures offshore. Thus, gravel nourishment is proposed as a countermeasure against the short-term erosion that can be caused high waves, and its benefits and impacts were verified through numerical simulations.

METHODOLOGY

Fig. 1 shows the flowchart of the coupled model used. The pseudo-warming method was used to construct the future climate (Mäll et al., 2020, Nakamura et al., 2020). The output results of WPS (WRF Preprocessing System), which is a pre-processing system of WRF, are added to the differences between the present and future climate of 14 GCMs output parameters (including sea surface temperature, air temperature and relative humidity).

The effectiveness of gravel nourishment was examined using the gravel beach model of Nishida and Shibayama (2020). The calculation of sediment transport by XBeach uses the advection-diffusion equation. Therefore, it cannot properly reproduce the movement of gravels. Thus, the Shields parameters was calculated from the wave height at each mesh, and the resulting gravel transport was calculated using the bedload formula (see Fig. 2). In addition to a purely gravel beach, the coastal deformation of a mixed beach composed of both sand and gravel was calculated by linearly superimposing the sand transport rate calculated by XBeach and the bedload transport rate calculated by gravel beach model. A number of different ratios of sand and gravel were simulated, in order to obtain the optimum ratio to prevent coastal erosion.

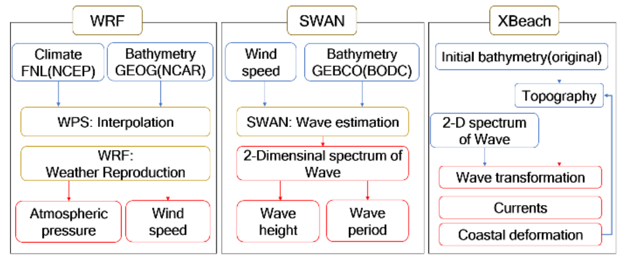

Figure 1 - Overall coupled model

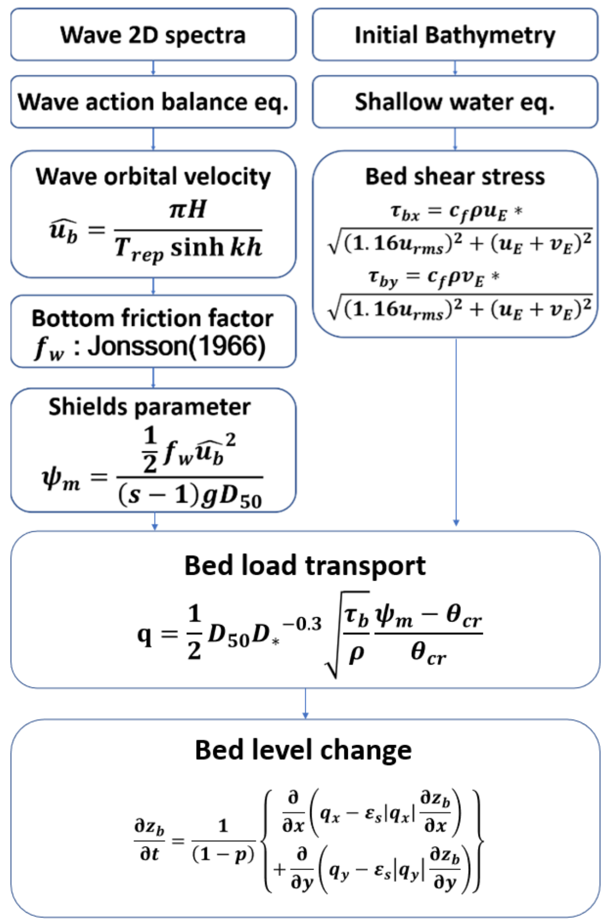

Figure 2 - Gravel transport model

RESULTS

Fig. 3 shows the simulated beach profile of the Seisho Coast for both the present and future climate, considering only sand or gravel nourishment. In the case of sandy beaches, the landward side of the shoreline is eroded and a sandbar is formed slightly offshore from the wave breaking zone, which causes the shoreline to recede. Coastal erosion is likely to be exacerbated by future climate, given the likely intensification of tropical cyclones. When gravel nourishment is employed the bedload transport rate is reduced, and shows little difference between the current and future climates. These results indicate that gravel nourishment effectively prevents coastal erosion as it stabilizes the beach both for present and future climates. Similar results were also obtained for Niigata Coast.

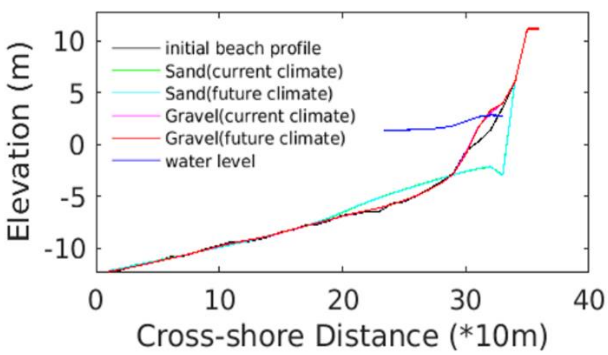

Figure 3 – Simulation of potential cross-sections of the Seisho Coast considering gravel and sand nourishment, for present and future climates.

Fig. 4 shows a cross-sectional view of the Seisho Coast when a mixture of sand and gravel are employed. Generally speaking, as the ratio of gravel increases, the amount of coastal erosion decreases due to the reduction in sand transport, with. Fig. 5 showing the changes in the Seisho coastline when the ratio of sand to gravel is 1:7. Although some coastal deformation is observed, this is rather small, and the coast is overall stable.

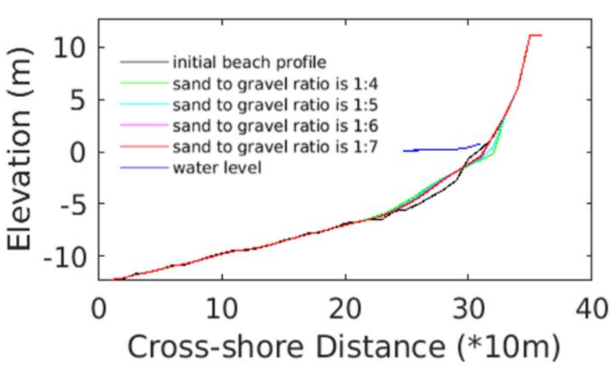

Figure 4 – Simulation of potential cross-sections of the Seisho Coast considering a variety of mixtures of sand and gravel nourishment.

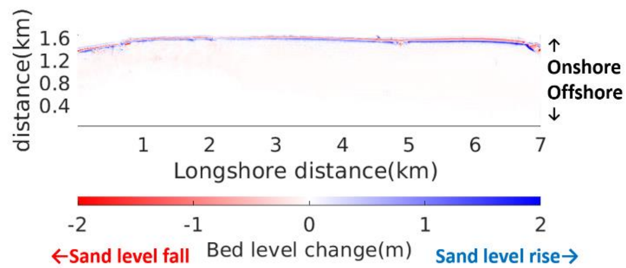

Figure 5 – Simulation of potential future plan view of the Seisho Coast considering gravel nourishment (Sand to gravel ratio of 1:7)

CONCLUSIONS

Nourishment with gravel results in a more stable coastline against the short-term erosion caused by high waves. For the case of the Seisho Coast, the use of a ratio of sand to gravel of 1:7 seems particularly effective. In this study, sand and gravel movements are superimposed linearly, and the effect of armouring, in which the movement of sand is prevented by gravel, is not considered. However, since the sand transport rate is likely to be larger in a future climate, it is possible to consider this overestimation to be a conservative assumption.

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