COMPARING BEACH MORPHOLOGICAL CHANGES BETWEEN GRAVEL AND SANDY COASTS

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INTRODUCTION
In recent years, the risk of coastal erosion during typhoons in Japan has been gradually increasing, and this could become even more pronounced in the future as projections show that 10-yr return wave heights could increase due to future tropical cyclone intensification (Shimura *et al.*, 2014) and sea level rise (Udo *et al.*, 2013). In the present work, the authors focus on short-term sediment transport caused by present-day typhoons and, given the narrow widths of many sandy coasts in Japan, even one typhoon may cause significant coastal erosion.
In the past, gravel nourishment has been conducted as a countermeasure against the coastal erosion caused by typhoons. For example, gravel nourishment was started from 2006 at the coast of Akiya (a part of the Sagami Bay coast, see Figure 1), based on techniques previously used in the south of England (Shibayama *et al.*, 2015). There is a submarine canyon (depth > 1000 m) in Sagami Bay, and this can result in a concentration of wave energy at specific parts of this coastline, as shown by the concentrated damage and erosions caused by Typhoon Fitow in 2007 along the Seisho coast (Tajima *et al.*, 2008).

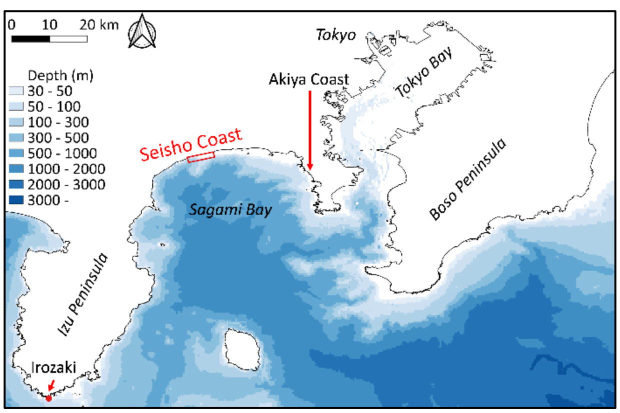

Figure 1 - The location of Sagami Bay

However, the effectiveness of gravel nourishment has not been sufficiently examined by past numerical simulation and experiments. To examine the effectiveness of this type of countermeasures, numerical simulations of beach morphological changes due to high waves during the passage of typhoons were performed. In order to do so, the authors developed a gravel transport model by modifying XBeach (Nishida and Shibayama, 2020), which was applied in this study to compare the beach morphological changes along the Seisho coast during typhoons by comparing nourished gravel and sandy profiles.

METHODOLOGY
The authors focused on 4 typhoons (Typhoons Phanfone in 2014, Lan in 2017, Jongdari in 2018, and Hagibis in 2019).
The authors then applied the SWAN (Booji *et al.*, 1999) and XBeach (Roelvink *et al.*, 2009) models to simulate the wave field and coastal hydrodynamic and morphodynamic processes during each typhoon. Figure 2 shows the flow of the numerical simulation.

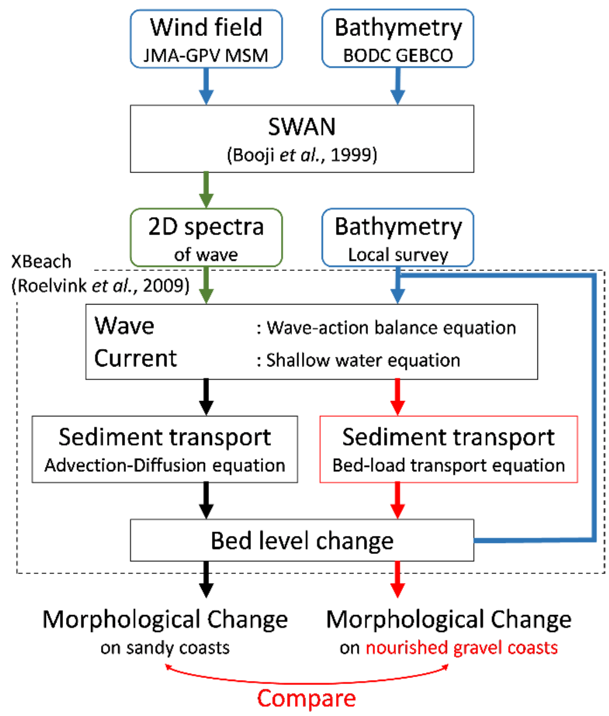

Figure 2 - The flow of numerical simulation

First, the authors collected JMA-GPV MSM (wind field dataset) and GEBCO (bathymetry) data as inputs for SWAN. The authors applied the SWAN model to simulate the wave field and verified the results (significant wave height, significant wave period, and wave direction) by comparing them with wave observation records. 2D wave spectra were used as wave inputs for XBeach, which was used to simulate the hydrodynamic and morphodynamic processes on sandy coast profiles. In the XBeach model, the sediment transport was calculated by employing the advection-diffusion equation. However, gravel cannot be suspended, and is instead transported as bed-load. McCall *et al.* (2015) developed a gravel transport model

(1D) known as XBeach-G. The authors followed this methodology of gravel morphodynamics based on a bed-load transport equation and extended it to a 2DH simulation (Nishida and Shibayama, 2020). For this, the bed-load transport equation proposed by van Rijn (2007) was employed. Finally, the authors compared the beach morphological changes during typhoons between nourished gravel coasts and sandy coasts.

RESULTS

Figure 3 shows the erosion cross-shore profile change for a sandy coast. The shoreline area (elevation between -3 m and 1 m) was eroded, with sand moving to the offshore area (depth between 3 m and 6 m). Figure 4 shows the deposition cross-shore profile change for a nourished gravel coast, indicating that in this case gravel was deposited at the shoreline (elevation between -3 m and 2 m). Gravel in this area moved as bed-load from the offshore area (depth > 3 m) towards the beach.

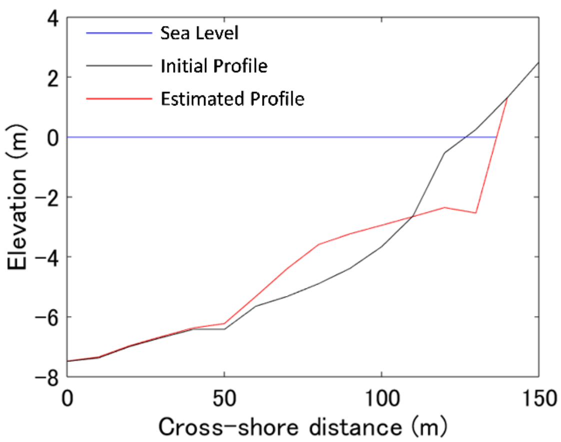

Figure 3 - Cross-shore profile change of a sandy coast

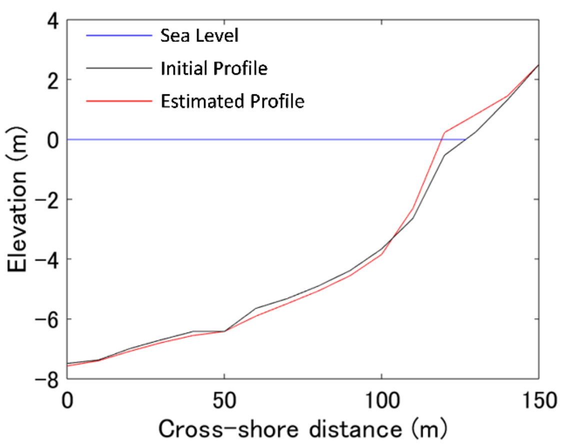

Figure 4 - Cross-shore profile change of a nourished gravel coast

DISCUSSION

The authors found that gravel moved from offshore to land to form a depositional beach due to the high waves caused by typhoons, and it appears more cost-effective to nourish such coastlines using gravel than sand. However, the number of local bathymetry surveys (Emery method or using echo sounders) is rather limited, so it is actually difficult to fully validate the simulation. This shows the necessity to document and measure beach morphological changes during typhoons to verify the gravel transport model proposed and be able to improve on the guidelines to formulate countermeasures against erosion for other coastlines in Japan.

CONCLUSIONS

This study discussed the effectiveness of coastal erosion countermeasures that employ gravel nourishment. The authors applied a gravel transport model (Nishida and Shibayama, 2020) and compared beach morphological changes during typhoons between nourished gravel coasts and sandy coasts. The results of the numerical simulation suggested that gravel nourishment can be effective to prevent the coastal erosion due to the high waves that are generated by typhoons.

ACKNOWLEDGEMENTS

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REFERENCES

Booji, N., Ris, R. C. and Holthujisen, L. H. (1999): A third-generation wave model for coastal regions: 1. Model description and validation, Journal of Geophysical Research: Oceans, 104(C4), pp. 1133-1152.

McCall, R. T. (2015): Process-based modelling of storm impacts on gravel coasts, PhD thesis, Plymouth University.

Nishida, Y. and Shibayama, T. (2020): Coastal erosion prevention by gravel nourishment, presented at the 28th Ocean Engineering Symposium (in Japanese).

Roelvink, D., Reniers, A., van Dongeren, AP., Vries, J. T., McCall, R. and Lescinski, J. (2009): Modelling storm impacts on beaches, dunes and barrier islands, Coastal Engineering, 56(11), pp. 1133-1152.

Shibayama, T., Izumi, M., Sato, A., Sawano, Y. and Hirao, A. (2015): Evaluation of Gravel nourishment at Akiya coast, Kanagawa Prefecture, Journal of Japan Society of Civil Engineering, Ser. B2 (Coastal Engineering), 71(2), pp. I_769-I_774.

Shimura, T., Mori, N., Yasuda, T. and Mase, H. (2014): Projection of Future Ocean Wave Extremes Based on MRI-AGCM3.2H Ensemble Experiments, Journal of Japan Society of Civil Engineering, Ser. B2 (Coastal Engineering), 70(2), pp. I_1266-1270.

Tajima, Y., Sato, S., Yoshii, T., Hosokawa, J., Yamada, K., Ishikawa, T. and San-nami, T. (2008): Locally Concentrated Damages and Erosions on Seisho Coast Caused by Typhoon T0709, Proceedings of Coastal Engineering, Japan Society of Civil Engineering, 55, pp. 1386-1390.

Udo, K., Takeda, Y., Yoshida, J. and Mano, J. (2013): Future Projections of Beach Erosion in Japan using Sea Level Change Data of the MIROC5 model, Journal of Japan Society of Civil Engineering, Ser. G (Environmental Research), 69(5), pp. I_239-I_247.

van Rijn, L. C. (2007): Unified View of Sediment Transport by Currents and Waves: part I and II, Journal of Hydraulic Engineering, pp. 649-667.