NUMERICAL STUDY ON ACCUMULATION MECHANISM OF CORAL GRAVELS AROUND BALLAST ISLAND, THE CORAL CAY OFF THE COAST OF IRIOMOTE ISLAND

Yoshimitsu Tajima, The University of Tokyo, yoshitaji@coastal.t.u-tokyo.ac.jp

INTRODUCTION

Understanding the formation mechanisms of a coral cay or a coral beach is essentially important to consider better conservation and protection strategies and measures of coral coast. Ballast island is a coral cay formed on the isolated reef located off the coast of Iriomote island, Okinawa, Japan. While this small coral cay frequently alters its shape under the attacks of severe waves, coral gravels gather around the island and keep the island around the same location. This study carries out the field survey and the numerical study to investigate the physical mechanisms of above mentioned characteristic behavior of coral gravels.

FIELD AND NUMERICAL STUDIES

As shown in Fig.1, Ballast island is located on the isolated reef partially shaded by two islands, Iriomote and Hatoma. Two sets of wave gauges and velocity meters were installed respectively at E200 and W200 as shown in Fig.1. Fig.2 shows the example of the observed time-series of the significant wave heights, tidal water depth and phase-averaged current velocity components when the typhoon passed near the site. It is seen in Fig.2 that the observed wave heights at E200 and W200 show periodic change with tide level because the wave height on the reef is limited by wave breaking at the reef edge. It is also seen in the Figure that the observed current velocity components in the northward and the eastward directions also changes with tide when the significant wave heights at E200 and W200 are relatively small whereas relatively large southward velocity components, i.e., negative v, is dominant on September 28th when significant wave heights at E200 and W200 were relatively high. This feature indicates that the tidal current is dominant under the relatively calm daily wave conditions whereas the wave-induced current becomes dominant under the stormy wave conditions.

Energy balance equations with breaking dissipation terms were applied for computation of the spectral random wave field around these islands (Fig.3). The computation domain contains both Iriomote and the Hatoma islands and the incident wave conditions were determined based on the GPV data obtained at around 2km north of Hatoma island.

Based on the computed wave fields, spatial distributions of the wave radiation stress was computed and the computed wave radiation stress was introduced to the non-linear shallow water equations for computation of the wave-induced current field around Ballast island on the isolated reef. These models were validated through comparisons with measured data at E200 and W200.

The validated models were then applied for investigation of how the coral gravels on the reef are transported and concentrate around Ballast island. Through observations of moving coral gravels captured by the under-water interval camera at E200, this study assumed that bedload transport is dominant on the reef and applied Madsen's (1991) bedload sediment transport model under the wave-current interacting fields. The model also accounted for the wave-associated transport due to bed slopes and asymmetric and skewed wave orbital velocity profiles. As shown in the left-end panel of Fig.4, the shallow bathymetry around the Ballast island was flattened since refraction effect around such shallow

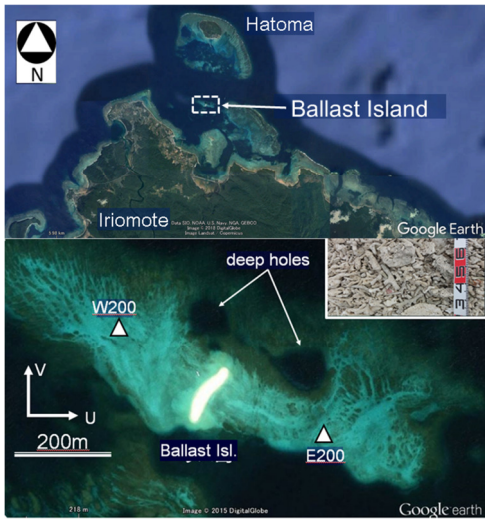

Figure 1 Satellite view of Hatoma, Iriomote and Ballast islands

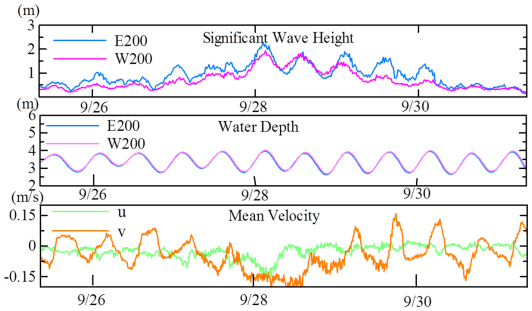

Figure 2 Observed wave, tide and current.

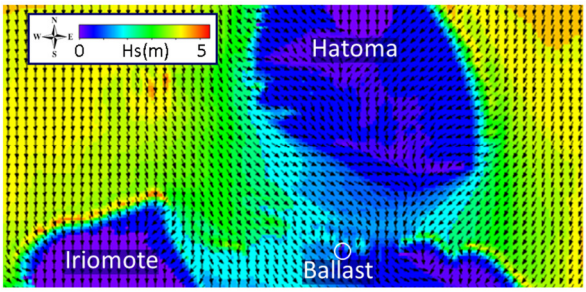

Figure 3 Example of the computed wave field around Ballast

topography may alter the wave direction toward the island and thus enhance the concentration of gravels around the island while there should be no such shallow topography before the formation of the island.
Offshore wave conditions were randomly selected from those obtained by the GPV data based on their occurrence probabilities and local bathymetry change due to accumulation of coral gravels were determined by time-integrating the horizontal balance of computed bedload transport rates (Fig.4). To investigate the relative importance of various related factors, the same computation was repeated by activating or deactivating each of factors listed in Table 1. In Table-1, the first column, "wave," indicates that the model accounted for the sediment transport associated with asymmetric and skewed wave-orbital velocity profile. The color in Fig.4 indicates the local water depth.

DISCUSSIONS

Case 1 neglected the influence of tidal and wave-induced current and accounted only for the "wave-associated sediment transport," while cases 2 and 3 respectively added the influence of tidal current and wave-induced current. The difference among cases 1, 2 and 3 are relatively small and this relatively little difference indicates that the influence of tidal and wave-induced current is relatively small compared to the dominant influence of wave-associated sediment transport on the movement of the coral gravels on the reef. Cases 4 and 5 also accounted only for the wave-associated sediment transport but influence of the two deep holes located just north side of the island or Hatoma island were respectively neglected. In the cases 4 and 5, as seen in the figure, the area of darker (colder) color, which indicates the accumulation of coral gravels, are shifted southward compared to case 1 and this feature indicates that the shading effect of Hatoma island and refraction effect of two deep holes on the reef have significant influence on local concentration of coral gravels around Ballast island. It was also found that wave-associated bedload transport played a dominant role in accumulation of coral gravels around Ballast island relative to the transports by either tidal or wave-induced currents.

Table 1 Cases of the numerical study

case	wave	tidal current	wave-induced current	deep holes	Hatoma Island
1	○	×	×	○	○
2	○	○	×	○	○
3	○	×	○	○	○
4	○	×	×	×	○
5	○	×	×	○	×

REFERENCES

Madsen, O.S.(1991): Mechanics of cohesionless sediment transport in coastal waters, Proc. Coast. Sed.'91 .

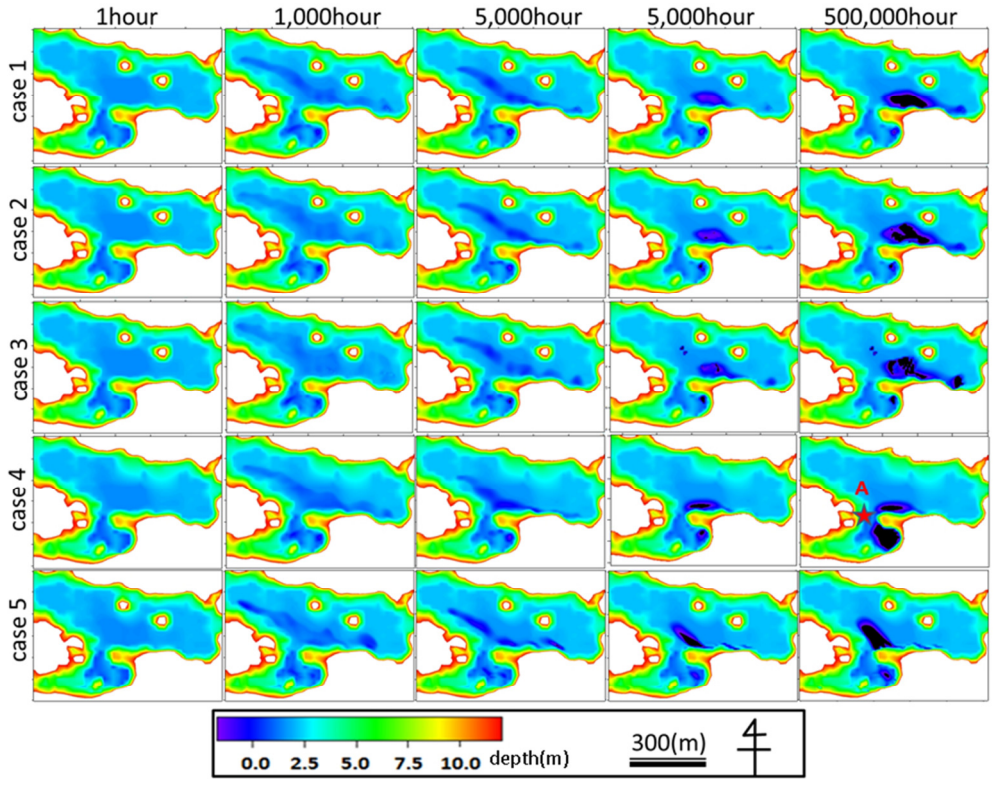

Figure 4 Time-varying computed accumulation of coral gravels in different cases 1, 4, and 5.