Impact of Dredging at Sand Bar on Shoreline Change

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Dredged hole in the nearshore zone may change direction of wave propagation due to wave refraction and diffraction. These physical phenomenon change the longshore sediment transport and hence the shoreline. In order to evaluate the pattern change of shoreline under short wave condition, some experiments were conducted in 3D wave basin. Wave height and topography of the beach were measured before and after sand dredging. The shoreline change due to sand dredging at the nearshore bar is discussed in terms of the change of wave breaking position at the lee of dredged hole and its both sides before and after sand dredging. The result showed the shoreline accretion and erosion at the lee and both sides of dredged hole after sand bar dredging. It is shown the significant physical characteristics are responsible for change the pattern of the shoreline. The source of infilled sediment and infill rate of dredged hole is also discussed.

Key Words: 3D wave basin, wave refraction, wave diffraction, breaking wave height, infill rate

1. INTRODUCTION

In some developing countries, sand dredging in the nearshore zone is very popular. However, the sediment management in coastal area is in infancy. But in Japan, in order to make effective sediment management in coastal area, sand is sometimes dredged at the nearshore zone in the deposited areas and then nourished to the eroded areas. Sediment management in terms of nearshore sand dredging is important for beach nourishment and recycling. The impacts of dredged hole to the shoreline change have been investigated in many studies, however, varied results of shoreline change were showed, i.e. along the shoreline, both accretion and erosion were found behind the dredge hole in different conditions.

Horikawa et al. (1977) conducted experiments in wave basin and assessed the impact of offshore dredged hole to the shoreline change using the refraction model, in which accretion was observed at the lee of the dredged hole. Motyka and Willis (1974) used a wave refraction model for the offshore dredged hole and the results give the reverse of that observed by Horikawa et al. (1977). Bender (2001) modeled the shoreline change by combined wave refraction and diffraction, and found that the changes of shoreline could alter with specifications of wave conditions and unchanged dredged hole. Work et al. (2004) studied the impacts to shoreline due to the sand dredging outside the surf zone. The results showed that the sediment was accumulated at the lee of dredged hole; however, wave diffraction was neglected in wave model. McDougal et al. (1996) studied the wave diffraction caused by dredged hole under long wave condition and showed that the appropriate selection of dredged hole dimension and placement may lead to significant reduction in wave height in the lee of dredged hole. The shadow region, with wave heights reduced to 30% of the incident wave height, is approximately the width of the dredged hole and five wavelengths long. The accretion in the lee of the dredged hole can occur if
the width of dredged hole is large enough. However, only long waves were considered.

In the present study, the dredged hole is located at the breaker zone and short incident wave is considered. In order to identify the location of accretion and erosion areas caused by nearshore bar dredging, experiments were conducted in 3D wave basin considering the wave refraction and diffraction. In addition, to evaluate the effect of the width of dredged hole to the magnitude of shoreline retreat, the geometry of dredged hole was altered by changing the width with the same length of dredged hole.

### 2. RESEARCH METHODOLOGY

Three cases of experiment were carried out in 3D wave basin that is 10 m long, 5 m wide, and 0.6 m deep (Fig.1). The table 1 showed the summarization of the experiment conditions. The median grain size of the sediment is 0.2 mm and the initial slope of the beach is 1:10 for all the cases. To create semi-equilibrium profiles that have a bar type profile, regular wave is generated with incident wave height $H = 14$ cm and wave period $T = 1$ s. Wave is generated for 240 minutes to obtain a barred profile from the initial beach slope, then sand was dredged once. The geometry of dredged hole is $b$ (m) long, $a$ (m) wide and $d$ (m) deep. After the sand dredging, the wave is generated for two more hours in all the cases.

The beach topography and wave height measurements were repeated every 30 minutes in case E1. Because the dredged hole in the nearshore zone is filled up very quickly after sand dredging, the beach topography and wave height were measured at 10, 20, 30, 45, 60, 120 minutes after sand dredging in dredged cases E2D1, E2D2.

![Fig.1 Experiment setup (W: wave gauge).](image)

![Fig.2 Shoreline at 240mins from initial beach slope (E1-E2D1-E2D2).](image)

![Fig.3 Shoreline change at 120mins after sand dredging (E2D1).](image)
placed on a trolley car to measure the wave height distribution in the middle of the beach at 50 cm interval (A-B line in Fig.2). At each position, the wave height was measured for 10 s before moving to the next position.

3. RESULTS AND DISCUSSIONS

(1) Shoreline change

The figure 2 showed the shoreline of all cases after 240 minutes of wave generation from initial beach slope. In 3D wave basin, even in the same experimental conditions, it is very difficult to reproduce the same shoreline for all cases after 240 minutes of wave generation from initial beach slope. Therefore, the difference of shoreline change between experiments with and without sand dredging is not discussed in this study. The shoreline at 240 minutes of wave generation is considered as the zero line in each case and the shoreline change is measured from this zero line. The figure 3&4 showed the shoreline changes due to sand dredging in two experiments E2D1 and E2D2, respectively. The magnitude of shoreline retreat of the experiments in 2D wave flume is also shown in these figures.

After 240 minutes of wave generation from initial beach slope, the beach profile has not yet reached an equilibrium. Even in the case without sand dredging, some amount of sediment is continuously transported offshore (Fig.5). However, the volume of transported sediment is not significant. Thus, it can be assumed that the shoreline change after 120 minutes in cases E2D1, E2D2 may be mainly caused by the sand dredging.

When waves approach to the coast, the wave propagation direction may be changed by wave refraction and diffraction. If wave refraction and wave diffraction are considered independently, the wave refraction process causes the erosion at the lee of dredged hole flanked by two accretion areas while wave diffraction process behaves the opposite way. McDougal et al. (1996) studied the variation of diffraction coefficient in the lee of dredged hole by changing the geometry of the dredged hole. The diffraction can be taken into account when \( a/L \geq 1, b/L \geq 0.5, d/h = 3 \). The dredged hole in all of experimental cases is located in the nearshore zone, however, its...
depth and width are \( d/h < 1, a/L < 0.5 \). Therefore, the wave diffraction process is expected to be less significant than refraction in this area.

After sand dredging, wave breaking positions in the line A-B move further onshore, while in the case without sand dredging E1, it is stable or move offshore (Fig.6). I.e. in dredging cases, the wave breaking positions in the dredged hole area move further onshore, while in both the sides of dredged hole it is stable or move offshore. Wave propagation at the lee of dredged hole diverges away to both the sides and causes the wave refraction in this area (Fig.7). The result is that the sediment at the lee of dredged hole transported to both the sides causes the erosion and flanked by two accretion areas (Fig.3&4).

The sand dredging volume in case E2D2 is double that of case E2D1 by increasing the width of dredged hole. The magnitude of shoreline retreat in either case looks similar (Fig.3&4), this result is appropriate to the result of numerical modelling studied by Demir et al. (2002). Varying dredged hole width, had little or no effect on magnitude of shoreline retreat, but on the pattern of shoreline.

(2) Infill rate

The figure 8 showed the infill rate of dredged hole after sand dredging. The infill rate is calculated by dividing the filled volume of dredged hole by the dredged volume at a certain time after sand dredging. Van Dolah et al. (1998) studied infill rate in sand borrow sites used for beach nourishment projects in South Carolina, the result showed that the infill rate is proportional to the distance of dredged hole from the shore. Sand bar is located at breaker zone, i.e. at the most activation of seabed zone. Any change of the bathymetry in this area can cause the significant change of hydrodynamic conditions within the nearshore zone, thereby causing highly transport.

![Fig.7 Sketch of wave refraction induced by nearshore bar sand dredging results in shoreline change.](image)

![Fig.8 Infill rate of dredged hole (E2D2).](image)

![Fig.9 Change in depth at 10-30mins after sand dredging (E2D2).](image)
gradient and profile change). In 3D wave basin experiments, the dredged hole may be filled up by sediment transported from the foreshore and the vicinity as well (Fig. 9 & 10). Chu et al. (2014) studied the offshore bar sand dredging by conducting some experiments in 2D wave flume, the result showed that the sediment transport rate is quickly decreased in the first two hours after sand dredging. However, dredged hole has not filled up yet (Fig. 8). In 3D wave basin experiments, just one hour after sand dredging 80% volume of dredged hole is filled and completely filled up after two hours. However, the amount of sand from the lee of dredged hole is not sufficient to fill up the dredged hole (Fig. 11). Figure 12 showed that just after sand dredging a large amount of sand transported to both the sides of dredged hole and then transported into the dredged hole. In addition, by making a comparison of the magnitude of shoreline retreat at the lee of dredged hole between the 2D wave flume and 3D wave basin experiments, the result showed that the shoreline retreat in the 2D wave flume experiments is larger (Fig. 3 & 4). Therefore, the source of infilled sediment of the dredged hole is not only transported from the area behind the hole but also from its both sides.

5. CONCLUSIONS

In the nearshore bar sand dredging, with the short wave period condition and the width of dredged hole is small compared to wave length, the wave refraction is a significant process to produce the shoreline pattern and the wave diffraction can be neglected. In this case, the shoreline is eroded at the lee of the dredged hole, flanked by two accretion areas.
The dredged hole in the nearshore zone is filled up very quickly after sand dredging. A part of infilled sediment volume is transported from both the sides of the area behind the dredged hole.

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REFERENCES

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