Characteristics of Bottom Turbidity Around the Inlet of Hamana Lake

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Around Imagire-guchi coastal topographic changes are influenced by the rate of sediment transport due to currents and wave. The main source of sediment supply is from Tenryu River. The dominant direction of alongshore sediment transport in the west side of Tenryu River mouth is westward. At Imagire-guchi, two jetties have impeded alongshore sediment transport. As a result, a large amount of sediment has accumulated on the east side of the east jetty. On the contrary, a shoreline retreats on the west side of the west jetty due to decrease of sediment supply from the east. A tidal range is about 1.5m at the maximum along the Enshu Nada Coast. This tide level change induces large quantities of water exchange between Hamana Lake and the coastal sea. However, the details on the relationship between current characteristics and sediment transport are still not clear. In this study, field observation on waves, currents and turbidity was carried out off the channel of Imagire-guchi under the ebb tide condition. Then the mechanism of sediment transport was discussed through the analysis on turbidity generation near the bottom.

Key Words: *Grain size, turbidity generation, rms velocity, inlet*

1. INTRODUCTION

Nearshore sediment transport processes are difficult to predict accurately because the driving forces such as nearshore circulation is composed of some complicated phenomena with the time scales from seconds (e.g., wave) to years (e.g., littoral cell circulation) (Emily *et al.*, 2002). Wave and tide are two predominant factors that influence coastal processes around an inlet (Syamsidik *et al.*, 2008).

Coastal topographic changes are influenced by the rate of sediment transport due to currents and waves. Beach erosion or sedimentation is very important on the supply of sediment entering or leaving the beach system. Flow has a carrying capacity to move the sand from one place to another as bedload near the bottom and suspended load in the water column. The discontinuity of sand movement in the coastal area causes erosion in one place and accumulation in other places. Thus the pattern of topographic changes is much affected by the condition of coastal waves and current.

A large amount of water exchange between inland water and a coastal area is generated through an inlet. This water exchange often generates a strong current. In consequence, the continuity of an alongshore sediment near the inlet is greatly disturbed and hence significant beach erosion and/or accumulation are caused around the inlet.

For Imagire-guchi, the inlet of Hamana Lake connecting with the Enshu Nada Coast, previous field observation revealed that a strong offshore-going current through an inlet has a great influence on sediment transport around the inlet (Syamsidik *et al*, 2008; Syamsidik, 2009). However, the details on the relationship between current characteristics and sediment transport are still not clear. In this study, field observation on waves, currents and turbidity was carried out off the channel of Imagire-guchi under the ebb tide condition. Then the mechanism of sediment transport was discussed through the analysis on turbidity generation near the bottom.

2. STUDY AREA

Imagire-guchi is located in the middle part of the Enshu Nada Coast facing to the Pacific Ocean (Fig. 1). The main source of sediment supply is from Tenryu River. The dominant direction of alongshore sediment transport in the west side of Tenryu River mouth is westward. At Imagire-guchi, two jetties

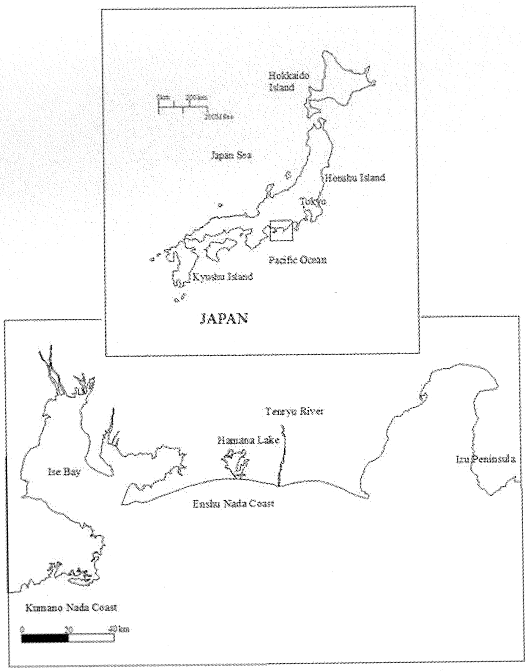


Fig. 1 Location of Imagire-guchi and Enshu Nada.

were constructed to stabilize the navigation channel from 1954, and the construction was completed in early 1970's (Kuriyama *et al.*, 2003). The jetties have impeded alongshore sediment transport. As a result, a large amount of sediment has accumulated on the east side of the east jetty. On the contrary, a shoreline retreats on the west side of the west jetty due to decrease of sediment supply from the east (Fig. 2). A tidal range is about 1.5m at the maximum along the Enshu Nada Coast. This tide level change induces large quantities of water exchange between Hamana Lake and the coastal sea. Under the ebb tide condition, a maximum instantaneous current velocity is over 1.0m/s in the channel. The strong current has an influence on sediment transport around the inlet, too.

3. SUMMARY OF FIELD SURVEY

(1) Grain size distribution around Imagire-guchi

The sediment samples were collected around Imagire-guchi. The samples were obtained from a bottom in the sea and at the shoreline on a beach. The middle lateral line passing the top of the east jetty (Fig. 2) is in or at the offshore edge of the surf zone when wave condition is moderate in the low tide. Each sample was washed and dried in a laboratory. Sieve analysis was carried out using 200g of sediments. The samples in the channel included big materials and the fragments of shells. Then, before the sieve analysis, dried samples were

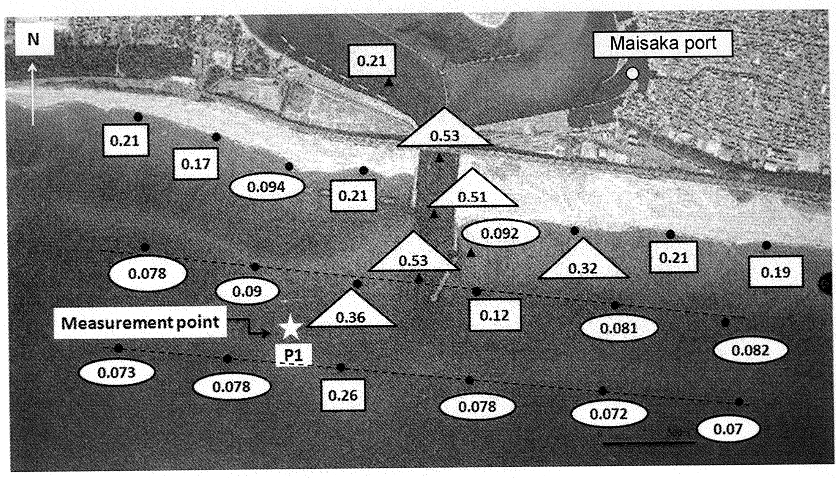


Fig. 2 Distribution of d_{50} around Imagire-guchi.

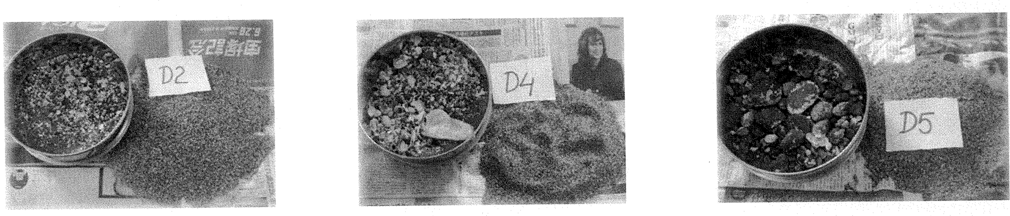


Photo-1 Sediment samples mixed with shell and big materials (in the channel).

separated into two components by 1.4mm sieve (Photo-1). The materials which pass 1.4mm sieve were used in sieve analysis.

Fig. 2 shows the distribution of median grain size (d_{50}) around Imagire-guchi. The samples are separated into three groups by the size of d_{50}, which is less than 0.1mm (ellipse), from 0.1 to 0.3mm (rectangular) and greater than 0.3mm (triangle). Sediment size is getting smaller with going offshore. Along the channel, grain sizes are bigger than others. In the channel, strong offshore-going current was generated repeatedly due to tidal oscillation. It is inferred that fine sediment less 0.1mm is flushed out offshore. On the offshore lateral line, the d_{50} at the position off the channel is bigger (0.26mm) than d_{50} at other positions on the same line. This is the reason that strong offshore-going current may reach around this position. The pattern of d_{50} distribution will give us information on current distribution and potential for sediment transport around the inlet.

(2) Waves, current and bottom turbidity off the channel of Imagire-guchi

Measurements of waves, currents and turbidity were conducted on February 2nd 2010 off the channel of Imagire-guchi ("P1" in Fig. 2) to investigate effects of waves and currents on turbidity generation. Turbidity is measured as surrogate data of suspended sediment concentration. The depth at P1 was about 6m at the beginning of measurement. A water pressure sensor, a magnetic current meter and an optical turbidity sensor were installed at 0.3m above the seabed to measure sea surface elevation, current velocity (East-West and North-South components) and turbidity, respectively. These data were obtained continuously with the sampling frequency of 2 Hz from 9:00 to 17:00. The predicted tide level at Maisaka port (Fig. 2) was high tide at 8:06 and low tide at 14:14, respectively. At the measurement location, the lowest tide level was measured around 13:40 (Fig. 3). The wave condition were calculated from the data of sea surface elevation every 20 minutes. The turbidity and current velocities were averaged every 1 minute and plotted in Fig. 3. Turbidity data were collected in FTU (Formazine Turbidity Unit) by the optical type turbidity meter (Compact-CLW made by Alec Electronics Co. Ltd).

4. RESULTS AND DISCUSSION

(1) Correlation between turbidity and currents in temporal variation

The time series of water depth, wave height and period, turbidity, current velocities and intensity (squared value) of current components during the measurement are shown in Fig. 3. The water depth went down about 0.8m at the maximum. And the lowest tide level was observed at 13:40 (Fig. 3(a)). During this observation, wave height and period did not change significantly (Fig. 3(b)). The turbidity gradually increased during the measurement, but high turbidity occasionally occurred (Fig. 3(c)). The strong currents indicate the south east (offshore-going) direction. These currents are generated due to the ebb tide along the eastside jetty. But East-West component started to change the direction periodically around 14:00. The current direction is slightly unstable under the flood tide although the current direction is mostly stable in the ebb tide (Fig. 3(d)).

The generation of high turbidity over 5 FTU is observed occasionally (circles in the time series of turbidity in Fig. 3(c)). This may correspond to the

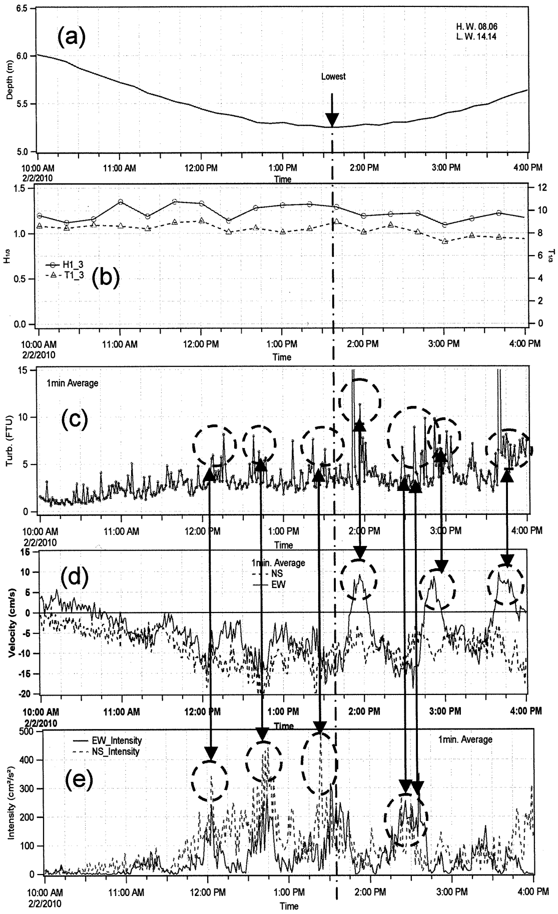
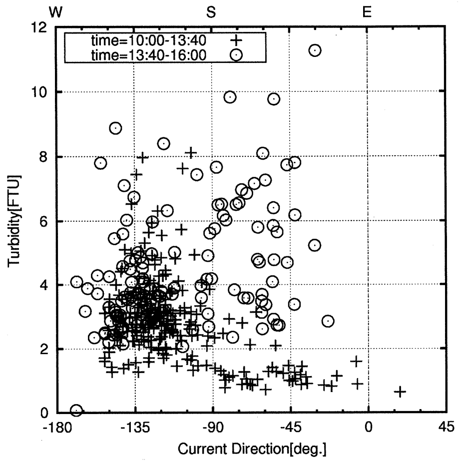
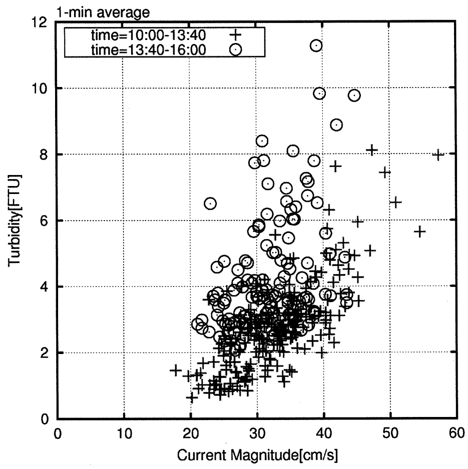


Fig. 3 Time series of measurements: (a) Water level, (b) Waves ($H_{1/3}$, $T_{1/3}$), (c) Turbidity, (d) Current velocity of East-West and North-South components and (e) Intensity of current components.



(a) Turbidity vs. current direction.



(b) Turbidity vs. current magnitude.

Fig. 4 Relationship between turbidity and currents (direction and magnitude).

current variation. When the tide level is going down (ebb tide) to the lowest level (13:40), the generation of high turbidity corresponds to the high intensity of current components. The relationship between NS component and turbidity is clearer than that between East-West component and turbidity. On the other hand, it is clear that the high turbidity is generated when East-West component changes the direction from the west (-) to the east (+) after the lowest tide (flood tide) in Fig. 3(d). However the turbidity generation from 14:30 to 15:00 will be affected by the intensity and the direction change of current. Around Imagire-guchi, the generation mechanism will be different in the ebb tide condition and the flood tide condition.

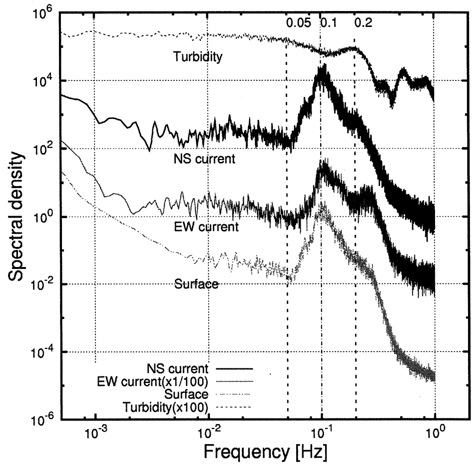


Fig. 5 Fourier spectra of turbidity, currents (East-West and North-South components) and surface elevation.

(2) Change of correlation between turbidity and currents due to tidal condition

Fig. 4 shows the scatter plots to investigate the correlation between turbidity and currents. Symbols are distinguished before and after the lowest tide level (13:40). Until the lowest tide, most of current directions are around -135 degree (south-west) and turbidity is less than 5 FTU except for few data. On the contrary, current directions are scattered in the range between -30 to -170 degree with turbidity higher than 5 FTU when the tide level is rising. In the comparison of current magnitude with turbidity, the range of magnitude of current is much similar in the ebb tide and the flood tide. However, turbidity level is clearly different. Many of turbidity caused in the flood tide are higher than that in the ebb tide. From these figures, it is clear that at the beginning of the flood tide condition, current direction is fluctuated and turbidity becomes higher than the ebb tide condition though current direction, magnitude and turbidity level are relatively stable in the ebb tide condition. Not only current velocity but also the current direction has an effect on turbidity generation around the inlet.

(3) Characteristics of spectral distribution

Fig. 5 shows that the spectral distribution of turbidity, currents (East-West and North-South components) and surface elevation. The spectra of the currents and surface elevation have peaks at 0.1 Hz corresponding to wave motions. The spectrum of the turbidity, however, indicates a peak around 0.2 Hz. The NS current also has a small peak around 0.2 Hz though the East-West current shows a clear peak higher than 0.2 Hz.

Based on the spectral distribution, current data (East-West and North-South components) are divided into 2 parts, i) $f < 0.05$ Hz (low frequency), ii) $f > 0.05$ Hz (high frequency). Fig. 6 indicates the relationship between the turbidity and rms (root-mean-square) values of current velocities. In taking time-average over wave period, mean current velocities of high frequency components become close to zero. And it is difficult to find the relation between turbidity generation in currents because these currents result from wave motion and variations are periodically. In Fig. 6(b), the rms velocity of high frequency component shows high correlation with turbidity. The linear regression lines for all data are drawn in each figure. This means that large variations in current velocity due to wave motion may be an important factor of turbidity generation such as suspension of sediment from a bottom.

5. CONCLUSIONS

Several conclusions are apparent from this study:

a. Strong offshore-going current has a great influence on sediment transport around Imagire-guchi.
b. Sediment size is getting smaller with going offshore and along the channel, grain size are bigger than others.
c. The relationship between north-south component and turbidity is clearer than that between East-West component and turbidity.
d. The high turbidity is generated when east-west component changes the direction from the west (-) to the east (+) after the lowest tide (flood tide).
e. The current direction is slightly unstable under the flood tide although the current direction is mostly stable in the ebb tide.
f. Large variations in current velocity due to wave motion may be an important factor of turbidity generation such as suspension of sediment from a bottom.

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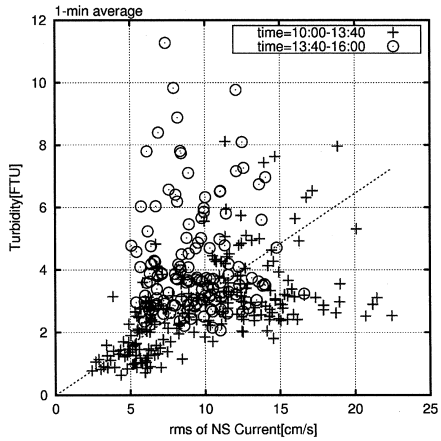
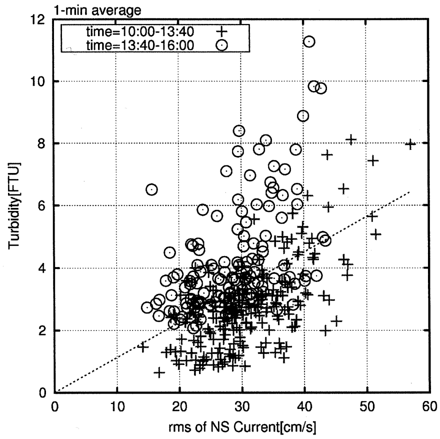


(a) Low frequency component ($f < 0.05$Hz).



(b) High frequency component ($f > 0.05$Hz).

Fig. 6 Correlation between turbidity and rms velocities of NS current.

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