BEACH AND RIVER MOUTH MORPHOLOGY RESPONSE AFTER THE 2011 TSUNAMI

Tohoku University Student Member ○ Hoang Cong VO
Tohoku University Regular Member Yuta MITOBE
Tohoku University Fellow Member Hitoshi TANAKA

1. INTRODUCTION

The tsunami waves, which were triggered by the massive earthquake on March 11, 2011, have caused the significant changes of coastal and riverine morphology in the northeast of Japan. The changes of the coast in Miyagi Prefecture have been presented by Tanaka et al. (2012). According to that study, on Sendai Coast, the serious erosion of the sandy beach, the breaching at old river mouth places, and flushing of sand spit at the river mouth have been observed. After the tsunami, morphology of many places were getting on the restoration process, although that can be fast or slow depending on the different hydrologic regimes and available sediment supply (Tanaka et al., 2012). There have been some studies done on the recovery of morphology after the tsunami. For examples, after the 2004 Indian Ocean tsunami; Choowong et al. (2009) reports the natural recovery of beach areas at Khuk Khak and Bang Niang tidal channels of Khao Lak area, Phang-nga, Thailand by using the satellite images and field surveys; Liew et al (2010) presents the rapid recovery of the Aceh coast, northwest Sumatra, Indonesia by using high-resolution IKONOS images and field visits. These studies investigate the recovery of the beach areas base on the aspect of geomorphology, without considering of movement of longshore sediment. In this study, the recovery of the beach morphology around a river mouth and sandy beach breaching is presented by using aerial photographs with considering the longshore sediment movement.

2. STUDY AREA AND DATA COLLECTION

This study focuses on two areas of Sendai Coast (Fig. 1), northeast of Sendai City, Miyagi Prefecture. Area 1 is the beach of about 1000m on the right side of Nanakita River mouth, which located about 2.5km south of Sendai Port. And area 2 is the beach of about 1500m at Akaiko area which located about 7.5km south from the Natori River mouth.

Aerial photographs of this area have been taken frequently and immediately after the tsunami. There was a photo taking activity on March 6, 2011, about one week before the tsunami. While, the first batch of photo taking after the tsunami was on June 8, 2011. In order to get more detail on the subsequent response of morphology, aerial photographs, which taken on March 12 and May 26, 2011 by Geospatial Information Authority of Japan (GSI) and aerial photographs taken on March 14, 24, 27; April 6; May 3 by Google Earth, have been collected.

3. RESULTS AND DISCUSSION

(1) Propagation of erosion of shoreline at the Nanakita River mouth and diffusion coefficient

The shoreline on the right side of the Nanakita River mouth has been suffered significant changes. The sandy beach was seriously eroded and the sand spit at the river mouth has been flushed away. After the tsunami, in response to the new equilibrium state, the beach on the right side of river mouth was getting erosion. The erosion was propagating from the river mouth to the south of the beach (Fig. 2(a), 2(b)). The changes of the beach this area and its subsequent recovery process have been presented by Hoang et al. (2014). This study also introduces a new approach to evaluate the diffusion coefficient. It has been evaluated to be as 13.2m^2/h from the analytical solution of one-line model and the measured data of erosion distance of the beach on the right of the Nanakita River mouth and its corresponding time.

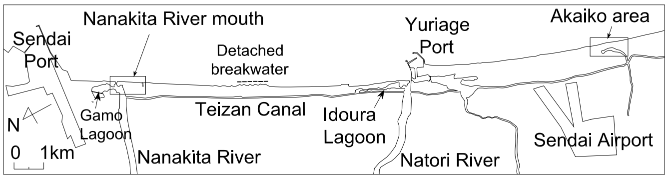
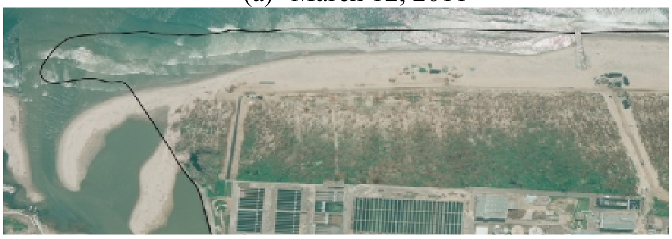


Fig. 1. Study area

(a) March 12, 2011



(b) July 6, 2011

Fig. 2. Morphological changes on the right side of Nanakita River mouth before and after the 2011 tsunami (black line is shoreline position on March 6, 2011)

(2) Analytical shoreline evolution at Akaiko area

The recovery process of breaching at Akaiko is reproduced using the analytical solution of one-line model. The analytical solution for expressing the shoreline position variation in the case of squared beach nourishment has been given by Larson et al. (1987).

$$y_s(x,t) = \frac{1}{2} y_0 \left[erf\left(\frac{a-x}{2\sqrt{\varepsilon t}}\right) + erf\left(\frac{a+x}{2\sqrt{\varepsilon t}}\right) \right] \quad (1)$$

where, y_s is the shoreline position, x is the space coordinate along the axis parallel to the trend of the shoreline, a is the beach nourishment width, t is the time, Y_0 is the cross-shore distance of the beach nourishment region from the initial shoreline, erf is an error function, and

(a) March 14, 2011 (Google Earth)

(b) April 6, 2011 (Google Earth)

Fig. 2. Morphology changes at Akaiko beach after the 2011 tsunami (black line is shoreline position on August 14, 2009)

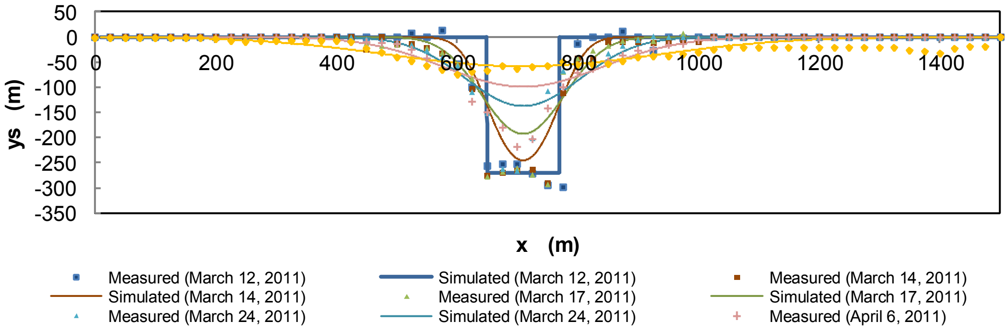


Fig. 3. Analytical shoreline evolution at the Akaiko area compared with the measured data

ε is a diffusion coefficient given by the following formula.

$$\varepsilon = 2K\left(H^2 c_g\right)_B / D \tag{2}$$

where, K is a constant parameter, H is the wave height, c_g is the wave group velocity, B denotes quantity at the breaking point, and D is the depth of closure. In eq. (2), both K and D are uncertainty and the wave data is not available after tsunami due to the destruction of wave gauge induced by the tsunami. Hirao et al. (2012) has computed the diffusion coefficient for this area by utilizing the constant wave height and period from wave climate statistics and other parameters from the previous studies (before the tsunami). Fig. 2 shows the morphology of the beach at Akaiko area before and after the tsunami. The beach was eroded and the breaching occurring at the place was to be a lagoon. Fig. 3 shows the comparison between analytical result and the measurement for the breaching at Akaiko area. The value of diffusion coefficient using in this computation is adopted from Hoang et al. (2014). The comparison after 3 months shows the good agreement between the analytical result and measurement. The assumption of constant width of the channel and the constant value of ε can be the reason of the disagreement during the early period.

4. CONSLUSIONS

In this study, the evolution of shoreline at the river mouth and breaching area on the sandy beach has been presented. The recovery of shoreline at the breaching area has been reproduced by the analytical solution of one-line model. Result shows the good agreement between analytical result and measurement.

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