MORPHOLOGICAL RECOVERY OF TSUNAMI-INDUCED COASTAL BREACHING ON YAMAMOTO COAST

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1. INTRODUCTION

The 2011 tsunami caused severe damages of coastal morphology in the northeast area of Japan. Due to the breaching of sandy beach induced by the tsunami, shoreline had concave shape form. The breaching is bounded by headlands which were constructed to prevent the erosion in this coast. Therefore, the effect of coastal structures needs to be considered in the recovery of morphology.

Analytical solutions of one-line model, Eqs.(1) and (2), which describe the evolution of concave shoreline in cases without and with rigid boundaries at both ends, were introduced by Larson et al., 1987 and Hoang et al., 2015, respectively. However, discussion on the applicability of these solutions is still lack so far. Furthermore, they are also very useful for engineering application as beach nourishment (e.g., Dean, 2003).

Taking all together, this study investigates the recovery of concave shoreline bounded by headlands on Yamamoto Coast through analysis of satellite images and analytical solutions of one-line model.

2. STUDY AREA AND DATA COLLECTION

This study mainly focuses on the beach of about 1000m in length on Yamamoto Coast which is located in the south of Miyagi Prefecture, Japan.

Satellite images, which are utilized in this study, are downloaded from Google Earth. Shoreline positions were extracted from the wet/dry line based on the difference of color intensity between two sides.

3. MORPHOLOGICAL RECOVERY

The morphology 3 days after the tsunami is shown in **Fig. 1(b)**. A longshore canal can be seen clearly from this image. This canal was created from erosion behind the seawall (Udo et al., 2015). Wide beaching (110m width) of sandy coast also can be observed. The recovery of morphology in this area was rather fast (**Figs. 1(c)**, **(d)** and **(e)**). Extracted shoreline positions (**Fig. 1(f)**) present the advancement of shoreline in the concave portion while the retreat on adjacent beaches. This behavior is similar to the one of concave shoreline recovery presented in Hoang et al., 2015.

4. BACKFILLING OF SEDIMENT

The backfilling of sediment into concave portion can be expressed in term of proportional recovery of shoreline position at central line of concave portion or proportional area of sediment filled into concave portion. Analytical solutions, which describe proportional recovery of shoreline at central line for cases without and with rigid boundaries are given as Eqs.(3) and (4) based on Eqs.(1) and (2), respectively. When considering the proportional area of sediment filled into concave portion, Dean, 2003 and Hoang et al., 2015 proposed analytical solutions of the one-line model for cases without and with rigid boundaries as Eqs. (5) and (6), respectively.

$$y = \frac{1}{2}Y_0\left[erfc\left(\frac{B-2x}{4\sqrt{\varepsilon t}}\right)+erfc\left(\frac{B+2x}{4\sqrt{\varepsilon t}}\right)\right] \quad (1)$$

$$y = Y_0\left[1-\frac{B}{L}-\frac{2}{\pi}\sum_{i=1}^{\infty}\frac{1}{i}\sin\frac{i\pi B}{L}exp\left(-\frac{4\varepsilon i^2\pi^2 t}{L^2}\right)\cos\frac{2i\pi x}{L}\right] \quad (2)$$

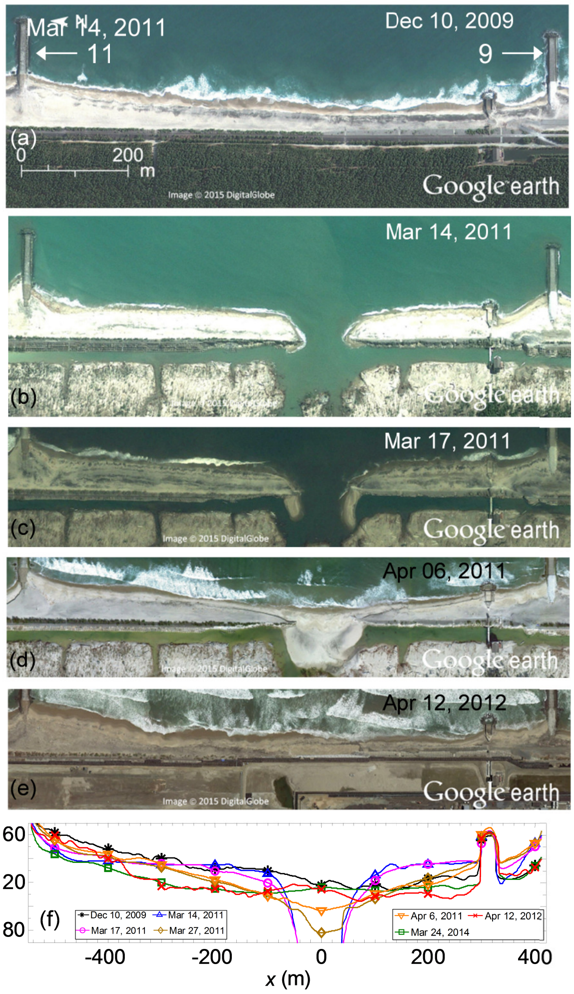


Fig. 1 Selected satellite images (Google Earth), detected shoreline positions, and oblique photograph of breaching on Yamamoto Coast

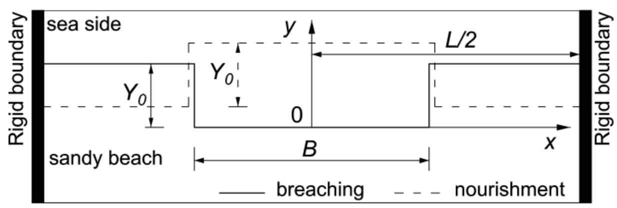
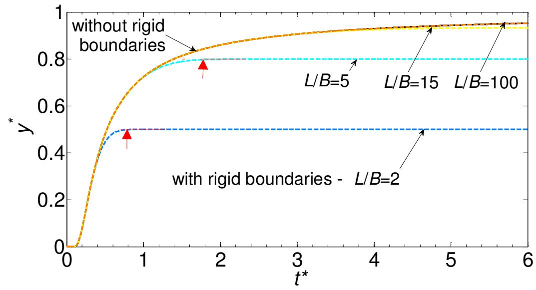
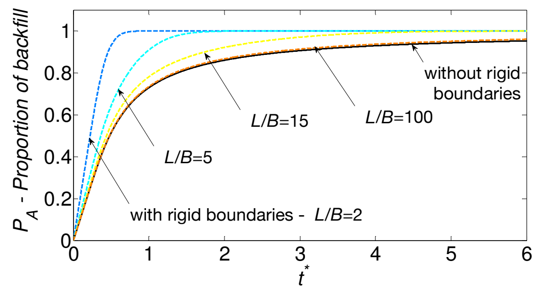


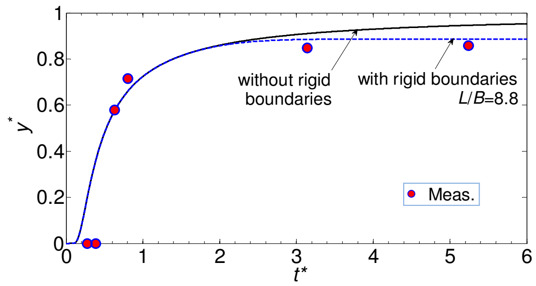
Fig. 2 Schematic diagram of concave shoreline on beach bounded by headlands (rigid boundaries)



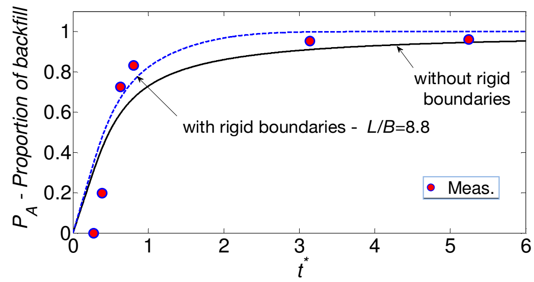
(a) Relationship between t^* and y^*



(b) Relationship between t^* and P_A



(c) Relationship between t* and y^*



(d) Relationship between t* and P_A

Fig. 3 Relationship between t^* and y^*, and t^* and P_A

where ε is diffusion coefficient; t is time; *erfc* is the complementary error function; x, y, Y_0, B, and L are defined as in **Fig. 2**.

$$y^{*}=erfc\left(\frac{1}{4T^{*}}\right) \tag{3}$$

$$y^{*}=\left[1-\frac{1}{L^{*}}-\frac{2}{\pi}\sum_{i=1}^{\infty}\frac{1}{i}sin\frac{i\pi}{L^{*}}exp\left(-\frac{4i^{2}\pi^{2}T^{*2}}{L^{*2}}\right)\right] \tag{4}$$

where dimensionless parameters are defined as below $y^*=yc/Y_0$; $T^*=\sqrt{\varepsilon t}/B$; $L^*=L/B$; y_c is shoreline position at the central line (x=0)

$$P_A=1-\frac{2T^{*}}{\sqrt{\pi}}\left[exp\left(-\frac{1}{2T^{*}}\right)^{2}-1\right]-erf\left(\frac{1}{2T^{*}}\right) \tag{5}$$

$$P_A=\frac{2L^{*2}}{\left(L^{*}-1\right)\pi^{2}}\sum_{i=1}^{\infty}\frac{1}{i^{2}}sin^{2}\frac{i\pi}{L^{*}}\left[1-exp\left(-\frac{4i^{2}\pi^{2}T^{*2}}{L^{*2}}\right)\right] \tag{6}$$

Fig. 3(a) shows the relationship t^* and y^* for case recovery of concave shoreline. When considering a particular L/B, t^* and y^* obtained from cases of without and with rigid boundaries are overlapping each other while t^* is small. This indicates that the evolution of shoreline hasn't been influenced by rigid boundaries yet. However, when t^* is getting larger they are much different; the influence of rigid boundaries are shown clearly. In case of large t^*, if L/B is getting larger, t^* and y^* obtained from case with rigid boundaries is asymptotic with the one of case without rigid boundaries. **Fig. 3(b)** shows t^* and P_A for case of concave shoreline recovery. When L/B is getting larger, the relationship obtained from case with rigid boundaries is asymptotic with the one of case without rigid boundaries. It's noted that in **Figs. 3(a)** and **(b)** the relationships obtained from case with rigid boundaries get stable very early (no further significant recovery). This is distinct difference between two analytical solutions. Moreover, measured data is presented in **Figs. 3(c)** and **(d)**. Good agreement with theoretical results of case with rigid boundaries is obtained, especially when t^* is large. By making slightly modification, mentioned theory can describe the remaining of sediment in the nourished area of rectangular platform beach nourishment.

5. CONCLUSIONS

Concave portion on Yamamoto Coast has been almost fully backfilled within a few months. The relationships t^* and y^*, and t^* and P_A for case with rigid boundaries get stable very early compared to case without rigid boundaries. This is distinct difference between them. When t^* and L/B are large, t^* and y^*, and t^* and P_A for case with rigid boundaries are asymptotic the ones of case without. Good agreement between measured data and theoretical results can be obtained.

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