COASTAL EMBANKMENT AND ITS FUNCTIONS ON TSUNAMI MITIGATION

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1. INTRODUCTION

Numerical model is presently a valuable tool to assess the tsunami risks. The Great East Japan earthquake and tsunami of 2011 had caused many sea dikes and breakwater damages along Suzaki coast. There have been many studies on the effect of construction solutions such as coastal embankment, breakwater, as well as non-structural solutions such as pines trees, mangroves forests for reducing tsunami energy when it spreads in coastal areas. But the fact that most of these solutions only make significant in the case of relatively small tsunami events; in more extreme cases need a deep understanding about tsunami wave and a higher and stronger of coastal embankments. This present study aims to device and analyze the effectiveness of coastal embankment on tsunami mitigation.

2. STUDY AREA

Suzuki coast is located in the westward end of the Ishinomaki coast and near the Naruse River. Suzaki coast is a sandy coast with length of about 2.8 km. The dominant drift on this coast is from the east to the west (Takahashi and Tanaka, 2005). A sea dike system runs along Suzaki beach and located far from the shoreline at a range between 100m and 140m.

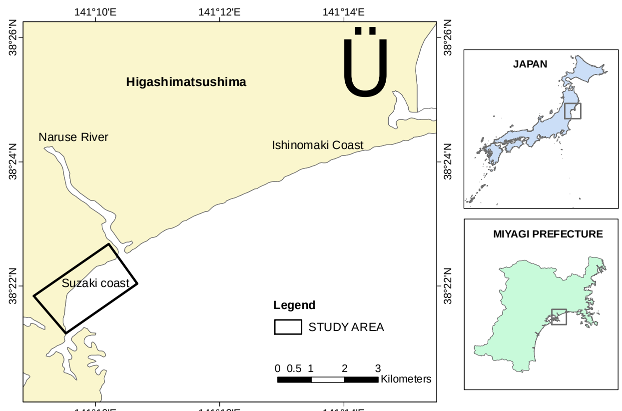

Figure 1. Map of the study area

3. METHODOLOGY

The present study is based on the pre and post tsunami topographic survey data conducted in December 2010 and August 2011 along with the filed observation data along the Suzaki coast of Miyagi Prefecture, Japan. NEWFLUME model (Lin and Liu, 1998) was applied to simulate the effect of tsunami on coastal embankment along the coast of Suzaki. Two cases were simulated. The first case simulated the tsunami propagation on beach without the embankment and the other case with the embankment.

Figure 2. Field observation along the Suzaki coast

4. MODEL SETUP

To find out the causes of morphological change due to tsunami impact on coastal embankment, the domain was set up with two cases with and without embankment for numerical model.
The domain was set based on the surveyed bathymetry cross-section data along the coast of Suzaki. The domain was created to represent the average bathymetric slope, distance from the shoreline to coastal embankment. The information of sea dike such as high and width were provided by the official government. The computational domain is shown in Fig. 3 below.

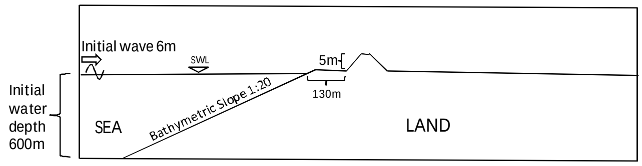

Figure 3. Domain setup for numerical model

A solitary wave train with a wave height of 6m and apparent period of 17mins was sent from the left-hand boundary where the constant water depth is 600m. A beach with the slope of 1/20 is located at the other end of the domain. A sea dike with height of 5m from the ground surface is located at 130m from the shoreline.

5. BOUNDARY AND INITIAL CONDITIONS

Appropriate boundary need to be specified for the model. For rigid boundary conditions, the values of k and ε are expressed as functions of distance from the boundary and the mean tangential velocity outside of the viscous sublayer. For the free surface boundary condition, the zero-gradient are imposed for both k and ε .
The initial condition for the mean flow is treated as still water with no wave or current motion (Lin and Liu, 1998). An initial tsunami wave condition at x = 0 was generated by using solitary wave equations as follows:

Keywords: Great East Japan earthquake and tsunami 2011; coastal embankment, variability of bathymetry, turbulence flow.

$$\zeta(t) = H\,\mathrm{sec}\,h^2\left(\left(\frac{3H}{4d^3}\right)^{1/2}(-ct) \right)$$

in H is the wave height, d is the constant depth, and c = $[g(d+H)]^{1/2}$ is the wave celerity at constant water depth. The volume of fluid (VOF) is used to track the free surface locations through the wave breaking process.

6. RESULTS AND DISCUSSIONS

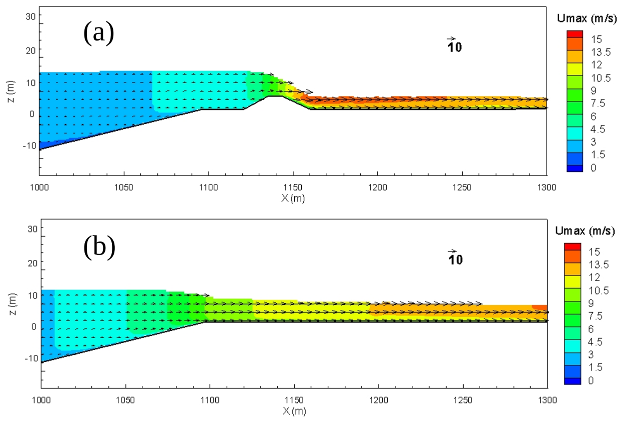

Figure 4. Maximum depth-averaged tsunami velocity in two cases with (a) and without coastal embankment (b)

Fig. 4 shows that due to the effect of coastal embankment the maximum depth-averaged tsunami velocity (U_{max}) before the embankment was reduced comparison with the case without canal. However, after the embankment, the maximum depth-averaged velocity was observed increasing significantly comparison with the case without embankment.

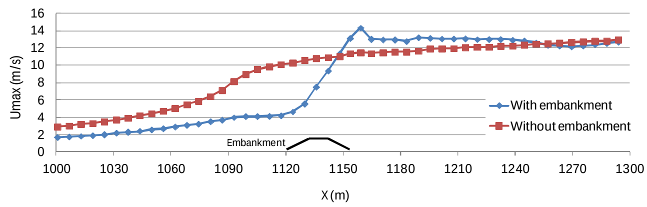

Figure 5. Maximum tsunami depth-averaged velocity profile in two cases (with and without embankment)

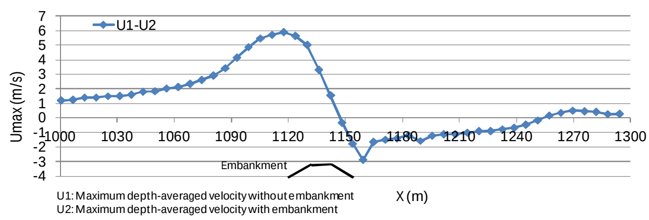

Figure 6. Maximum tsunami depth-averaged velocity reduction due to embankment.

In order to estimate difference maximum tsunami depth-averaged velocity reduction, with and without embankment tsunami depth-averaged velocity was subtracted. It can be seen from Fig. 6 that the maximum depth-averaged velocity reduced 6m/s.

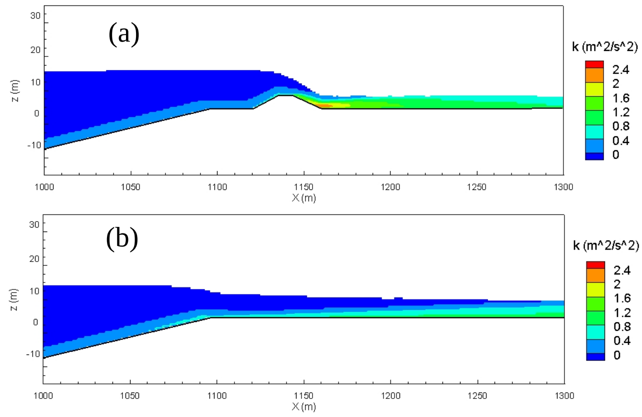

Figure 7. Turbulence kinetic energy in the case with (a) and without embankment (b)

Fig. 7 shows that the maximum turbulence kinetic energy induced by surface layer was 2 m^2/s^2 which was located after the embankment. Moreover, it can be seen that the turbulence kinetic energy production was increased at the back side of embankment and much higher than the kinetic energy production in the case without embankment.

7. CONCLUSION

The results revealed that the coastal embankment was significant in reducing tsunami energy. Moreover, the coastal embankment also plays an important role in terms of coastal morphological change. However, in the largest tsunami event, the coastal embankment should be increased in both dimension height and width in order to withstand and be more effective.

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REFERENCE

Lin, P., & Liu P. L.-F (1998). A numerical study of breaking waves in the surf zone. *J. Fluid Mech.* 359, pp. 239-264.

Takahashi, T. & Tanaka, H. (2005). Change in morphology and sediment budget in the vicinity of Ishinomaki Port. *Proc. 3rd Asian and Pacific Coastal Engineering Conf.*, pp. 931-942.