Numerical Analysis of the 2011 Tohoku Tsunami in Tokyo Bay Focusing on High Water Marks in Ports

Retno Utami Agung Wiyono and Jun Sasaki
Graduate School of Urban Innovation, Yokohama National University
Faculty of Urban Innovation, Yokohama National University
Yokohama, Kanagawa, Japan

ABSTRACT

The March 2011 earthquake off the Pacific coast of Tohoku was followed by great tsunami waves. The objectives of the present study are to apply the unstructured-mesh model FVCOM to tsunami propagation in Tokyo Bay and ports in the bay with high spatial resolution and to understand the mechanisms governing the tsunami properties in the bay. Through comparisons with the observed tide gauge data, it is found that the model can well reproduce tsunami propagation in the bay. The mechanisms causing difference in amplification of tsunami waves among in the ports of the bay (Chiba Port, Funabashi Fishery Port, Kisarazu Port, Yokohama Port, Kurihama Port and Yokosuka Port) are well identified.

KEY WORDS: Tsunami propagation; FVCOM; Tokyo Bay; ports and harbors; numerical simulation.

INTRODUCTION

The 2011 earthquake off the Pacific coast of Tohoku had an epicenter at 142.8 °E, 38.05 °N and occurred at 2:46 pm JST on March 11, 2011. This moment magnitude of 9.0 earthquake was followed by great tsunami waves. The tsunami traveled along the Japanese Pacific Coast from Tohoku area to Tokyo Bay, approximately 350 km away from the epicenter.

Tokyo Bay, which is surrounded by the Boso Peninsula (Chiba Prefecture) to the east and the Miura Peninsula (Kanagawa Prefecture) to the west, has the total area of 1,320 km². As the watershed of the bay, the governments have made considerable efforts to protect the area against natural disasters, including earthquakes, storm surges, and tsunamis. Nakabayashi (2006) inferred that over 40 years have passed since the Great Kanto Earthquake of 1923, hence after 20 years Tokyo would come into the dangerous part of the 69-year cycle. This made clear to local administrations that the disaster potential of earthquake was correspondingly high.

In Tokyo Bay area, the local government had explained that the expected major water-related disaster in the bay was storm surge. Disaster prevention structures, including seawalls, have been designed against storm surges which are taller in the bay head, including Tokyo Port, and shorter in the southern part of the bay, including Yokohama Port (Sasaki et al., 2012). Sasaki et al. (2012) summarized that tsunamis had been generally considered less dangerous than storm surges in the bay before the occurrence of the 2011 tsunami because the worst case of tsunami model used by most of local governments was the 1923 Taisho Kanto earthquake tsunami, which did not cause major damage especially at the bay head.

Studies on the effect of tsunami on ports have been carried out by researchers around the world. Narayan et al. (2005) studied the effect of the 2004 Indian Ocean Tsunami on Nagapattinam Port, while Tomita et al. (2006) studied the tsunami effect on Beruwala fishery harbor, both of which are located in Sri Lanka.

Tsunami is sometimes amplified in ports. One of the best examples of strong tsunami amplification is that observed in Port Alberni (located at the head of long Alberni Inlet on the Pacific coast of Vancouver Island, Canada) to the 1964 Alaska Tsunami (Rabinovich, 2009), which was caused by resonance response of a port. Thus, the study of ports has significant importance to disaster management.

The objective of the present study is to understand the mechanism of the 2011 Tohoku Tsunami properties in ports in Tokyo Bay by application of the unstructured-mesh model FVCOM developed by Chen et al. (2003). Application of an unstructured-mesh model is chosen since the spatial scale of the ports is much smaller than that of the major tsunami propagation area.

The behavior of 2011 Tohoku Tsunami in Tokyo Bay has been studied using field survey and numerical simulations by Sasaki et al. (2012). However, the amplification of tsunami wave in each port has not been discussed yet. To clarify the mechanism of tsunami amplification in each port, analytical solution may not be always applicable because of the special feature in each port. Thus, numerical approach is required. In this paper, numerical simulation will be carried out by resolving Chiba Port, Funabashi Fishery Port, Kisarazu Port, Yokohama Port.