Chapter 6

Coastal Science

Field of expertise: Coastal Engineering

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Summary

The 2011 Great East Japan Earthquake and Tsunami caused widespread land subsidence and breaches in coastal embankments. This caused inundation damage in a wide area and large-scale beach erosion, which had a great impact on the coastal regions. This chapter describes the damage to the coastal embankments and beach erosion at the time of the earthquake and tsunami, the subsequent restoration and recovery process, and outlines the impact of the earthquake and tsunami on coastal management since then.

Keywords: beach erosion, coastal embankment, land subsidence, beach restoration, coastal environment, coastal management

Introduction

The coast is a space that exists at the boundary between the sea and the shore. It fosters a rich environment, and also exists as a place for recreation. At the time of the Great East Japan Earthquake, beaches all over Japan, especially sandy beaches, had already been severely eroded due to rapid development after the war, and not enough countermeasures had been taken. In this chapter, we describe the impact of the Great East Japan Earthquake and Tsunami on coastal management and future prospects, illustrating the example of Yamamoto Coast in southern Sendai Bay, Miyagi Prefecture.

1: Problems Revealed by the Great East Japan Earthquake and Tsunami

What happened?

After the 2011 earthquake and tsunami, the first thing I saw was the image of a tsunami invading the Sendai Plain. The southern coast of Sendai Bay (about 60 kilometers of coast that extends from Sendai City, Miyagi Prefecture, to the Fukushima Prefecture border) suffered significant erosion damage, mainly in the southern part, as shown in the photos from March 2011, Figure 6-1 (Udo et al., 2015). In some beaches, much of the coastal forest was washed away by the tsunami. In particular, on the Yamamoto coast (see Figure 6-1(d), September 2006), where the

coast was already severely eroded, coastal levees were breached everywhere and there was erosion up to several hundred meters inland. Topographic analysis before and after the earthquake and tsunami shows that the eroded sediment was deposited in the sea at a depth of about 5 to 10 meters by receding waves.

Comparing the aerial photographs of March and June 2011 in Figure 6-1(d), the topography that had been gouged at a sharp angle changed to a rounded shape in the months after the earthquake and tsunami, indicating some recovery of the beach. According to the results of the structure analysis by ground-penetrating radar, the recovery rate was the greatest immediately after the earthquake, with a maximum of 18 meters/month, and decreased to 2-3 meters/month one year later.

The reality of the damage

Due to the earthquake and tsunami, 426 coastal areas (about 190 kilometers) out of 515 coastal areas (about 300 kilometers of coastal embankments and seawalls) in Iwate, Miyagi, and Fukushima prefectures were damaged, resulting in widespread devastation. Figure 6-2 (Tojo & Udo, 2018) shows the coastal erosion caused by the earthquake and tsunami, and subsequent recovery in Iwate and Fukushima Prefectures. The size of the circle indicates the scale of erosion by the earthquake and tsunami, and the blue color of the circle indicates the percentage of shoreline recovery four years after the earthquake and tsunami. There are long sandy beaches in the Sendai coast in Miyagi Prefecture, and erosion was limited in the beaches that maintained sufficient beach width before the earthquake. On the other hand, the size of the circles in Figure 6-2 is larger on the beaches where beach erosion had already progressed at the time of the earthquake, and on the beaches along the Sanriku coast in southern Iwate and northern Miyagi prefectures, where short, pocket beaches are scattered, indicating that significant erosion occurred. In these areas, the percentage of red in the circles is large, and since sand supply from the surrounding areas could not be expected, there was little recovery afterwards.

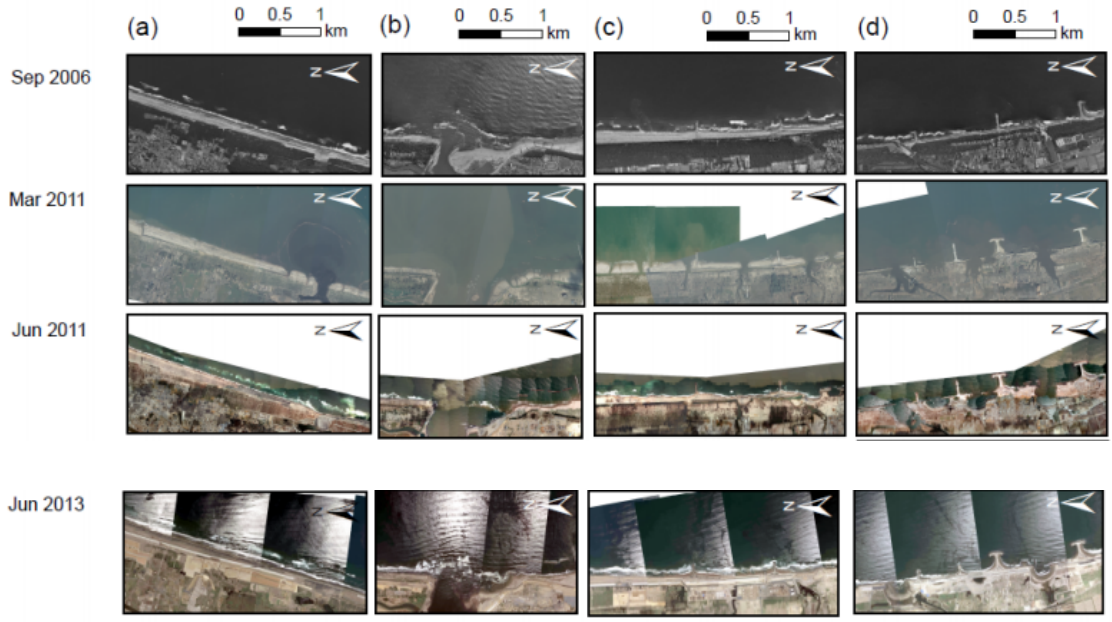

Figure 6-1. Aerial photographs of the southern coast of Sendai Bay from September 2006, March 2011, June 2011, and June 2013 (Udo et al., 2015)

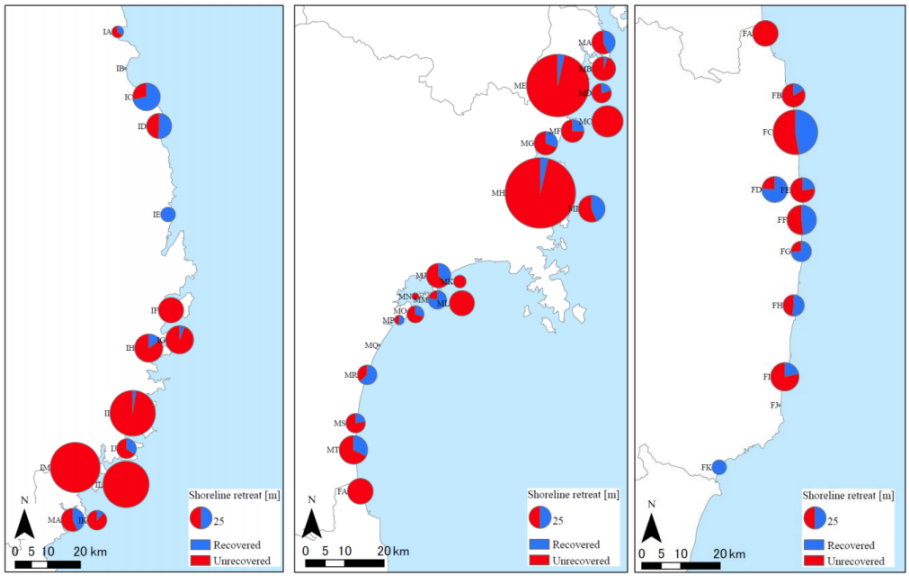

Figure 6-2. The amount of beach erosion before and after the earthquake and tsunami from Iwate Prefecture to Fukushima Prefecture and the state of beach recovery up to 4 years after the earthquake and tsunami (Tojo & Udo, 2018)

2: Paradigms Destroyed by the Earthquake and Tsunami

Conventional wisdom and necessary responses

Of the approximately 1,700 kilometers of coastline in the three prefectures of Iwate, Miyagi, and Fukushima, there is approximately 300 kilometers of coastline with embankments or seawalls, approximately 190 kilometers was completely destroyed, making it necessary to hasten preparations for coastal disasters such as storm surges and waves during typhoon season in the affected coastal areas (https://www.thr.mlit.go.jp/sendai/kasen_kaigan/fukkou/kouzishi.html). By the end of September 2011, emergency restoration corresponding to the height of storm surges and waves was almost completed for a section about 50 kilometers long, behind which facilities essential for recovery and reconstruction are located. After this emergency restoration, discussions on coastal restoration and reconstruction proceeded at a rapid pace, but in the initial stage, the discussions were mainly focused on disaster prevention that took the landscape and environment into consideration.

In addition to widespread land subsidence and tsunami inundation, the southern coast of Sendai suffered extensive damage to embankments, and emergency restoration was undertaken along approximately 20 kilometers of coastline. The first step (protection against the recent maximum storm surge) was completed by June 2011, and the second step (additional protection against the recent maximum storm wave in critical sections) was completed by August of the same year. Even on the coast where rapid topographical recovery was observed immediately after the earthquake and tsunami, the recovery gradually slowed. Construction of a levee that can cope with storm surges, which have a higher risk than the tsunami, proceeded while the topography had not yet recovered. On the Yamamoto Coast, erosion was evident even before the earthquake and tsunami, and the Ministry of Land, Infrastructure, Transport and Tourism had been implementing coastal improvement projects under its direct jurisdiction since 2000. In the overall plan of the project, 4 million m^3 of beach nourishment was planned before the earthquake and tsunami, and 138,000 m^3 of beach nourishment had been completed by the end of 2012. Due to the severe

erosion by the tsunami, the beach nourishment project needs further nourishment and is expected to take several more decades to complete.

3: A New Approach

As time passed since the disaster, the importance of not only disaster prevention, but also of the landscape and environment, such as the positioning of sandy beaches in the living environment, had been widely recognized, and several cases made great efforts for reconstruction planning by holding study sessions among residents about the future state of the coast. It is also worth mentioning that there has been a high demand for the environment, such as the conservation of sandy beaches, on the affected coasts.

The long-term coastal erosion problems experienced after the end of World War II have made it known that it is extremely difficult to restore eroded beaches, but it seems that until the disaster, it was not expected that a temporary event such as a tsunami could cause such large-scale erosion that would require a considerable revision of coastal maintenance plan. Climate change also threatens to increase future coastal disaster risks, and according to the results of the authors' beach loss prediction, up to 90% or more of the beaches in Japan are expected to disappear by sea level rise under climate change (Udo & Takeda, 2017). Since it is difficult to predict the scale and timing of tsunamis, it is impossible to incorporate the amount of beach loss due to tsunamis into future projections, but when considering long-term countermeasures, the discussion is becoming a premise for the impact of relatively low frequency sudden disasters such as tsunamis.

4: Achievements and the Future

A new approach to disaster science

In terms of emergency response to the widespread damage of the Great East Japan Earthquake and Tsunami, the post-disaster response can be evaluated as swift and accurate. On the other hand, in thinking about the restoration and reconstruction of the coastal areas, it was recognized again that the coastal environment and its usage are equally important as coastal disaster reduction, and residents seek to balance these functions.

In the formulation of coastal project plans, cost-benefit analysis is generally conducted to examine the investment effects of the project. In the calculation of the benefits, it is preferable to consider all the benefits of disaster reduction, environment, and utilization, which are the legal objectives of the Coastal Act, but the evaluation of environmental benefits is particularly difficult, and further development of the evaluation methods are required. We hope that more research will be conducted to properly assess the value of the coasts in order to leave a better coastal environment for future generations, while also coping with various disaster risks including climate change.

Conclusion - from the authors

Japan has the sixth longest coastline in the world and is constantly exposed not only to tsunami risks, but also to storm surges caused by typhoons and others. It is also concerned that the coastal environment in Japan will become more severe in the future due to the rise in sea level and the increase in intensity of typhoons caused by climate change. However, if we only pay

attention to disaster reduction, the precious natural environment may be lost. While preparing for various coastal disaster risks, it is important to carry out coastal management that balances disaster reduction, environment, and utilization.

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