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Special Contribution

2011 Great East Japan Earthquake Tsunami and Future Tsunami Disaster Mitigation

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The Great East Japan Earthquake Tsunami on March 11, 2011, caused unprecedented damage in northeast Japan. In the following, the characteristics and damage of the tsunami are described. It has been proved that coastal structures can reduce inundation depth and resulting damage even though the structures themselves are partially damaged. A new policy that has been adopted for recovery of the damaged area and for preparation for future tsunamis, especially Nankai Trough earthquake tsunami, is introduced. In the policy, development of resilient coastal structures plays a key role.

Keywords: Great East Japan Earthquake, Nankai Trough, tsunami, two-level tsunami disaster mitigation, resilient coastal structure

1. Tsunami Generated by Great East Japan Earthquake

Japan was attacked by the Great East earthquake on March 11, 2011 [1]. In particular, the tsunami generated by the earthquake caused devastating damage in the coastal area of northeast Japan. Figure 1 compares the maximum tsunami run-up heights in each city, town or village among the past three major tsunamis in the region. Red, blue and grey bars correspond to the Great East Japan earthquake tsunami, Meiji Sanriku earthquake tsunami in 1896 and Showa Sanriku earthquake tsunami in 1933, respectively. The heights of the Great East Japan earthquake tsunami are far higher than the other two tsunamis. Figure 2 compares the city of Rikuzen-takada, one of the most seriously damaged areas, before and after the tsunami [2], [3]. The city, which had 23,000 populations, was totally inundated and 1,800 people were killed or missing. The total number of deaths and missing in Japan is 22,118 as of March 1, 2017.

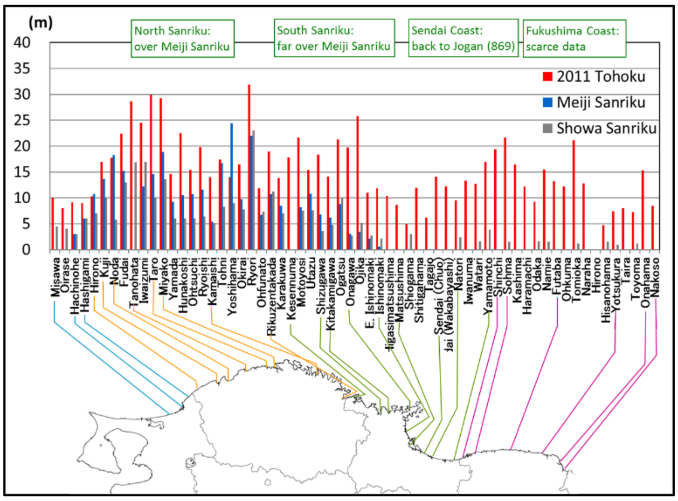

Figure 1 Run-up height of the Great East Japan earthquake tsunami in comparison with Meiji and Showa Sanriku tsunami

Figure 2 Damage due to tsunami (Rikuzen-takada City, Iwate Prefecture)

2. Damage and Effectiveness of Coastal Structures

Coastal structures were constructed as the first line of coastal defense. But, many of them were damaged by the tsunami.

Figure 3 shows the process of breaching of coastal dikes. In each photo, the right side is the bay side, and the left side the land side. When the tsunami came from the bay, compressive force act on the sea-side. But, the seaward surface withstood the pressure. However, when the tsunami overflowed beyond the dike, negative pressure acts on the landward side due to centrifugal force and flow separation. The negative pressure peeled off the surface concrete. Then the sediment was exposed to the flow and gradually flew out. Finally, the seaward concrete lost the support from the sediment and broken.

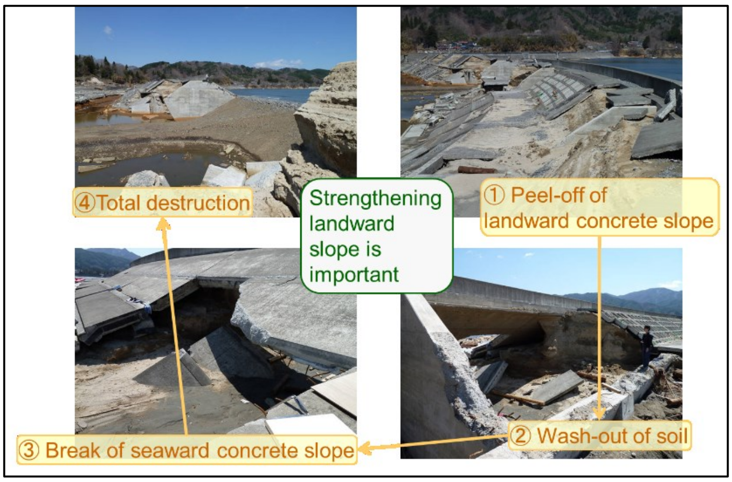

Figure 3 Process of breaching of armored sloping dikes

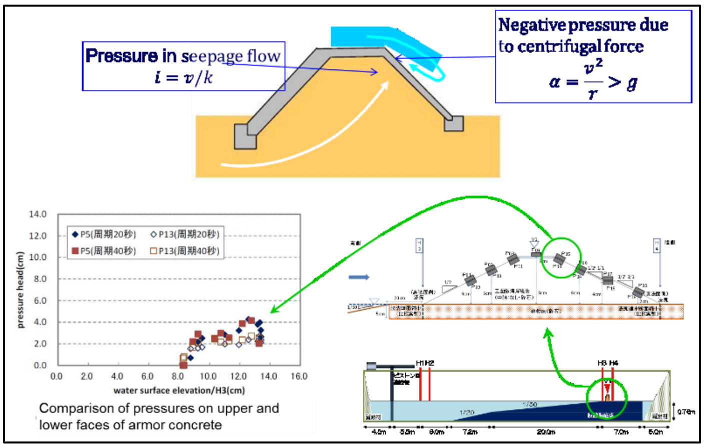

Figure 4 Possible reason for peeling of seaside concrete

This lead the dike to total breaching. Actually, experimental result shows the surface pressure on the seaward concrete drops significantly as shown in Fig. 4 [4]. This will trigger the breaching of coastal dikes. Therefore, the design standard has been modified to increase the thickness of concrete cover. Many other mechanisms for damage of coastal structures have been found through investigation after the tsunami.

In spite of the serious damage on the coastal structures, their effectiveness was also confirmed. In Kamaishi bay, offshore breakwaters were constructed for tsunami protection, but were seriously damaged by the tsunami. However, since 80% of the projected area of the structure remained, the arrival time was delayed by 6 minutes and the inundation depth was reduced by about half.

In Sendai Plain, the tsunami overflew and damage coastal dikes, but the inundation depth and area behind the dikes are similar to the result of computer simulation on assuming all dikes are sound rather than that without dikes. This means the overflow rate can be reduced significantly if sufficient projected area of structures is maintained.

3. New Policy for Tsunami Disaster Reduction

In recovering and reconstructing the damaged area, the first step is to establish a policy to construct the coastal structures that are the first line of the tsunami defense. Before the Great East Japan earthquake tsunami, the maximum recorded hazard level had been generally used as the design external force on the coastal structures. However, this is neither economical nor resilient to prepare for extremely rare and extraordinary hazard. In addition, high coastal structures disconnect the continuity of the land and sea, which results in serious adverse impact on the daily human life as well as the coastal ecology. A series of committees organized by Japanese Government established a policy of two-level tsunami disaster mitigation. For tsunamis of the maximum level, which is termed as level 2 tsunami and has a frequency of once in the order of one thousand years, we save all human lives by all means, mainly by evacuation. The Great East Japan earthquake tsunami is classified at this level.

For a lower tsunami with relatively high frequency, we design and construct coastal structures to protect land from inundation to protect assets as well as human lives. This is called level 1 tsunami and has the frequency of once in about one hundred years, i.e., once in a lifetime. This means that structures may experience tsunamis over the design level.

Therefore, the design standard requires coastal structures be resilient to avoid total corruption even by tsunamis of over-design level. In the area damaged by Great East Japan earthquake tsunami, reconstruction of coastal structures has almost completed according to the policy.

Figure 5 summarizes this tsunami disaster mitigation policy. Even when a tsunami over the design level attacks, coastal structures can defend until the highest part of the tsunami arrives. During this period, people are to evacuate to the safest places among high ground and tsunami evacuation buildings, towers, and shelters. In addition, even if the tsunami overflows, the coastal structures can decrease flow rate and inundation depth, and as a result reduce damage.

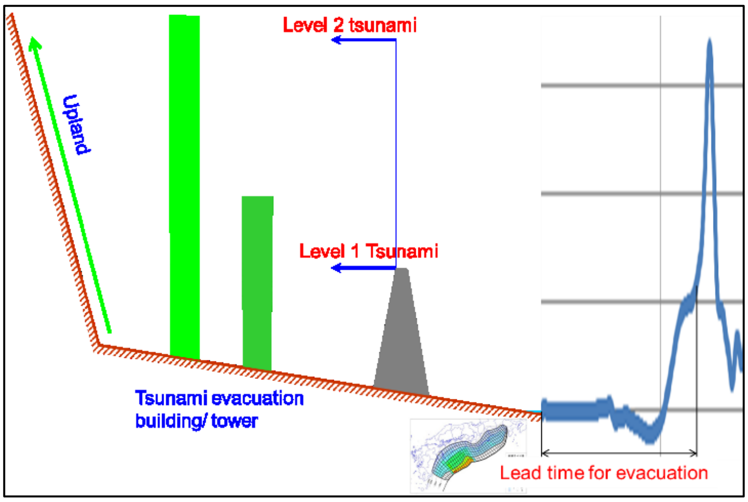

Figure 5 Tsunami disaster mitigation policy

4. Preparation for Future Nankai Trough Earthquake Tsunami

The policy is now being applied not only to the damaged areas but also to all other areas in Japan. Kochi prefecture is being threatened by a giant tsunami generated by the Nankai Trough earthquake. The highest run-up height is simulated as high as 34m. However, in central and eastern coast, the crown heights of the coastal dikes and seawalls are enough to protect from level 1 tsunamis because they have already been constructed for protection against storm surges which are very severe due to frequent attack of strong typhoons. But, to meet the two-level tsunami mitigation policy, they must be improved to avoid subsidence due to liquefaction and to increase resilience. Reinforcement by double sheet piles is suitable for this purpose. Figure 6 shows the sketch of improvement of the dike [5].

When a tsunami of the maximum level attacks, improved structures can save enough time for evacuation. During the time, people can climb up high lands or tall buildings. In the area where they are not available, tsunami evacuation towers as shown in Figure 7 have been constructed. Thus, the two-level tsunami disaster mitigation policy is being implemented in Kochi.

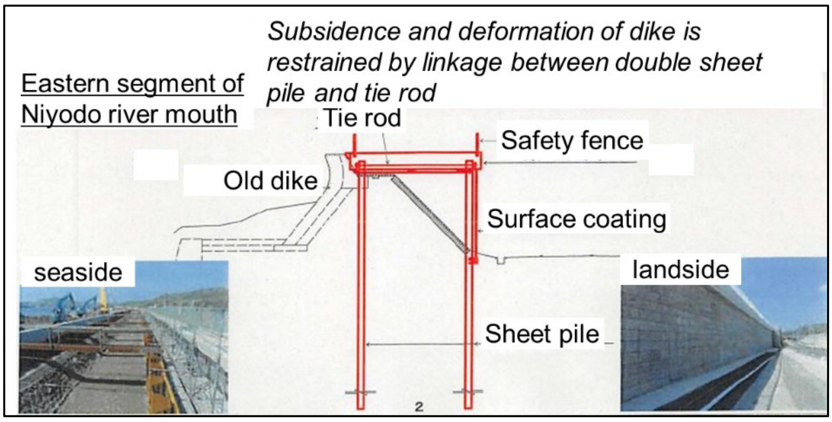

Figure 6 Reinforcement of coastal dikes by piles

5. Conclusion

The first priority in tsunami disaster mitigation is to save all human lives. In parallel to this, economic damage should be minimized. In this respect, the two-level tsunami disaster mitigation policy is effective and flexible to implement. If regional economy does not allow to construct high quality coastal structures, level 1 tsunami can be modified to be lower so that the policy becomes feasible to implement. Finally, development of resilient coastal structures is a key to establish successful disaster mitigation system.

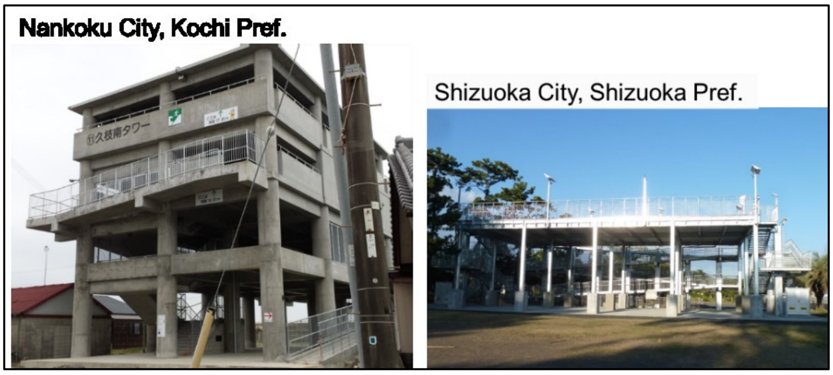

Figure 7 Tsunami evacuation tower

REFERENCES

[1] Sato, S. ed., "Special Anniversary Issue on the 2011 Tohoku Earthquake Tsunami," Coastal Engineering Journal, Vol. 54, No. 1 (12 papers), 2012.

[2] Joint Survey Group for Great East Japan earthquake tsunami, http://www.coastal.jp/ttjt/, April 30, 2011.

[3] Watanabe, H., "List of Disastrous Tsunamis in Japan,", Univ. Tokyo Press, 238p. 1998. (in Japanese)

[4] Kotake, Y. and M. Isobe, "Experimental study on pressure distribution along landward slope of coastal dike due to tsunami overflow," J. JSCE, Ser. B2, Vol. 68, pp. 891-895, 2012. (in Japanese)

[5] by courtesy of Seacoast Office, Water and Disaster Management Bureau, Ministry of Land, Infrastructure, Transport and Tourism.

◆A brief CV of Dr. Masahiko Isobe

Masahiko Isobe obtained doctoral degree in 1981 in the field of coastal engineering at the University of Tokyo. He worked at Yokohama National University from 1981 to 1987 as Assistant Professor and Associate Professor. He also worked at the University of Tokyo from 1987 to 2013 as Associate Professor, Professor and Vice President. Then he moved to Kochi University of Technology as Vice President, and has been serving as President since 2015. Based on his research career, he took a leadership role at national level in recovering from the damage due to the Great East Japan Earthquake Tsunami.