Tsunami Damage Rate of Breakwaters

(Research period: FY2021)

Coastal Disaster Prevention Div. Coastal, Marine and Disaster Prevention Dept.
Head Kazuhiko Honda Research Engineer Fumiya Doukai

(*Keywords*) *tsunami fragility curve, the 2011 Tohoku Earthquake and Tsunami, port facility, damage*

1. Introduction

The 2011 Great East Japan Earthquake and Tsunami had a devastating effect on the population of the region and destroyed and swept away buildings, structures, and property. The tsunami caused severe damage to port facilities such as breakwaters, coastal dikes, warehouses, and cargo handling equipment, and it seriously disrupted port operations.

With the cooperation of port management bodies and the Ports and Harbours Bureau of MLIT (Japan's Ministry of Land, Infrastructure, Transport and Tourism), we have gathered data on the tsunami damage to each port facility. In this paper, we will use the results of this collected data on tsunami damage to report not only statistics on damages caused by the tsunami but also the tsunami fragility curve of the front-line breakwaters.

Fig. 1. Map of eastern Japan

2. Damage to Ports

Fig. 1 is a map showing eastern Japan and the major ports from Aomori Prefecture to Ibaraki Prefecture. Fig. 2 shows the estimated reconstruction costs of damaged public facilities in these major ports. The total cost is approximately 300 million yen. Very large tsunamis struck the bay-mouth breakwaters and front-line breakwaters in the ports of Hachinohe, Kamaishi, Ofunato, and Soma, causing extensive damage to these breakwaters. Hence, the cost of repairing damaged protective facilities for those ports is much higher.

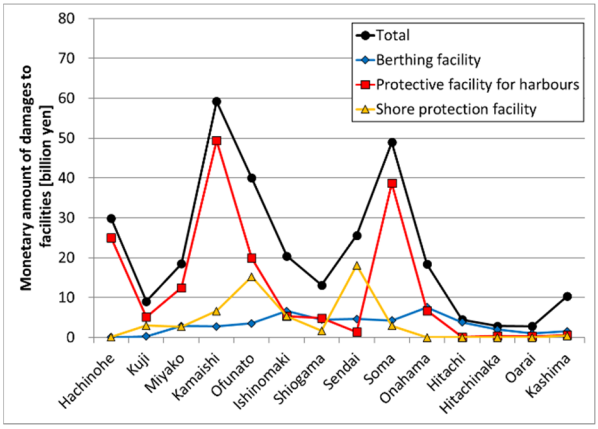

Fig. 2.1. Monetary amount of damages to facilities

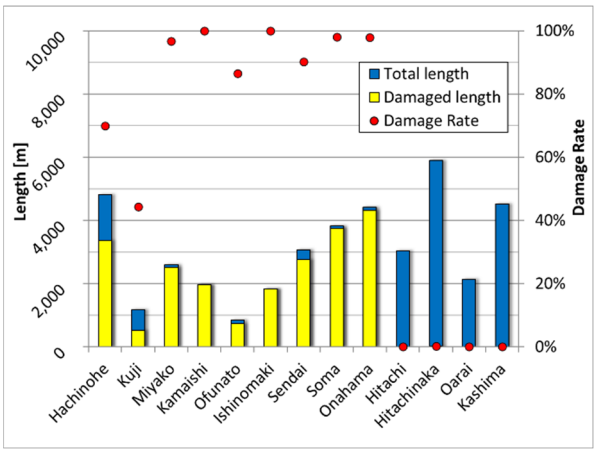

Fig. 3. Damage to front-line breakwaters

3. Damage to Breakwaters

Fig. 3 shows the damage rate of front-line breakwaters in these major ports. It was calculated as the length of the damaged portion of the breakwaters divided by the total length.

Fig. 4 shows the damage rate of the front-line breakwaters in Fig. 3 according to η_{max} (the maximum tsunami height in front of the breakwater) in each port. The value of η_{max} is the maximum value of the tsunami height along the front-line breakwaters in each port.

In this case, the strength against the tsunami force of the front-line breakwaters is not considered. That is why the three ports with almost the same tsunami height have different values for the damage rate. Therefore, in order to estimate the formula for the fragility, we should consider the design strength of the front-line breakwaters.

The main cause of damage to front-line breakwaters in Ishinomaki Port and Onahama Port was ground motion. In other ports, however, the main cause of such damage was the tsunami. Even in Ishinomaki Port and Onahama Port, where the tsunami height was not as large, the damage rate of the front-line breakwater is higher.

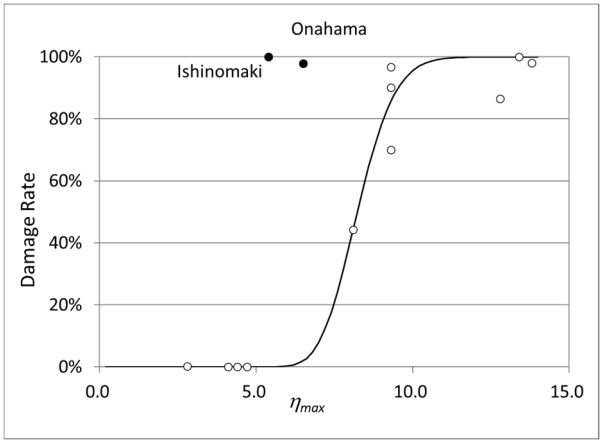

Fig. 4. Tsunami fragility curve (η_{max})

The design significant wave height represents stability against external forces, and can be an indicator of the strength against tsunami force. Fig. 5 shows the damage rate of the front-line breakwaters in Fig. 3 according to the parameter η_{max} divided by $H_{1/3}$ (the design significant wave height of the breakwater) in each port. Each part of a breakwater has a different design significant wave height, so the value of $H_{1/3}$ is the maximum value of the design significant wave height of the front-line breakwaters in each port.

The front-line breakwaters in Ofunato Port were designed against the force due to the design tsunami, because the force due to the design significant wave height is less than that of the design tsunami.

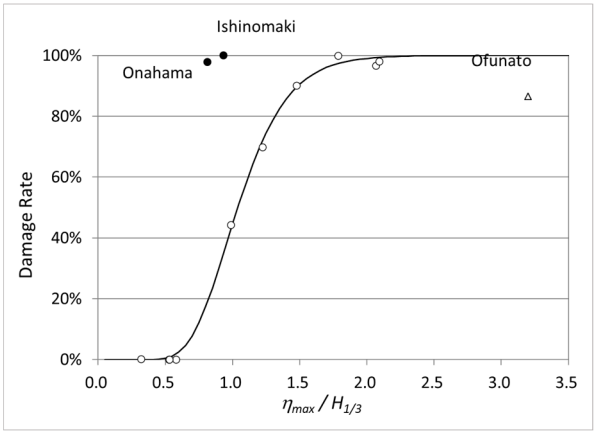

Fig. 5. Tsunami fragility curve ($\eta_{max} / H_{1/3}$)

4. Discussion

The tsunami fragility curve can generally be used to estimate the damage rate of facilities. Based on the results of this paper, it is possible to evaluate the damage rate of the target facility due to the possible tsunami generated by a Nankai Trough Earthquake. In this paper, we also proposed the tsunami fragility curve of warehouses in ports.

It should be noted that this tsunami fragility curve is not for each individual part of the front-line breakwater but for estimating the damage rate that is calculated as the length of the damaged breakwaters divided by the total breakwater length, and that the damage included not only severe damage but also comparatively slight damage.

☞Reference:

1) Technical Note of NILIM, No. 1173

https://www.ysk.nilim.go.jp/kenkyuseika/kenkyusyosiryou.html