Tsunami-Resistant Design Guideline for Breakwaters

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(Key words) Design tsunami, Technical Standards and Commentaries for Port and Harbour Facilities in Japan, hydraulic model experiment

1. Introduction

The Great East Japan Earthquake damaged many breakwaters, primarily because the giant horizontal force of the tsunami acting on the breakwater and the overflow of the breakwater by the tsunami scoured the foundation mound behind the breakwater, destabilizing the breakwater. If a breakwater is a tough structure which is not overturned even when it is deformed by a large-scale tsunami, damage behind the breakwater will be mitigated, because its toughness will restrict the flow rate of the tsunami behind the breakwater, delaying the arrival of the tsunami in the land behind the breakwater. So breakwaters must be tough structures, which are as resistant as possible to overturning, even by a tsunami that is larger than the design tsunami.

The Ports and Harbours Bureau, National Institute for Land and Infrastructure Management, and the Port and Airport Research Institute of the Ministry of Land, Infrastructure, Transport and Tourism have cooperatively conducted a comprehensive study of the results of surveys of damage to breakwaters and of the results of a series of hydraulic model experiments conducted since the earthquake disaster, have organized basic concepts of the design of tough breakwaters, then in September 2013, they partially revised the Ministerial Ordinance for the Technical Standards for Port and Harbor Facilities and other technical standards, defined design tsunami and prescribed toughness against tsunami for structures such as breakwaters, seawalls etc., and at the same time, the Ports and Harbours Bureau has proclaimed the Tsunami-Resistant Design Guideline For Breakwaters. Below the major revisions to technology standards and major contents of this Guideline are introduced.

2. Basic concepts

Past concepts of tsunami-resistant design of port and harbour structures have been revised from their foundations. Two levels of tsunami are hypothesized and based on its concept, the aim is, for tsunamis which occur frequently, to provide disaster protection using structures to do all possible to protect human lives and property, and for the largest class of tsunami, which occur extremely rarely but have catastrophic damage when they do occur, the aim is to minimize damage under the goal of, at the very least, protecting human lives. If a structure has toughness which prevents its overturning even as it is deformed under a tsunami large enough that it exceeds tsunami which occur frequently, it will restrict the quantity of water flowing into the area behind the structure, delaying the arrival of the tsunami behind the structure, and thereby reducing damage. So structures that can provide this toughness are necessary in cases of a tsunami higher than the design tsunami.

3. Definition of the design tsunami

The definition of a design tsunami considering tsunami resistant design is clearly stipulated as a tsunami which is unlikely to occur during the design service life of the facility but would have severe impacts on the facility if it did occur. The design tsunami used for performance verification and a tsunami with strength greater than the design tsunami are considered to be at least the tsunami scale which occurs relatively often with a recurrence period from several decades to one hundred years plus several decades, and is set appropriately for the degree of importance of the facility. The Guideline stipulates that the design tsunami is set as the tsunami with design external force from the highly frequent tsunami to the maximum class of tsunami according to the importance of the structures behind the breakwater based on a regional disaster prevention plan or a basic plan for coastal preservation.

4. Breakwater performance verification

The overall stability of a breakwater in the case where the tsunami and the earthquake motion preceding the tsunami act on the breakwater first sets the initial section under actions other than the tsunami or other waves. Next, the section specifications are set based on the wave design for the design tsunami. Finally, for a tsunami with scale greater than that of the design tsunami, the section of the tough structure is set based on an overall judgment made considering the importance of the facility and cost-benefit performance. The structure analysis factor when stability under the design tsunami is verified can be set with reference to a value in Table 1, because according to the example of damage shown in Figure 1, damage occurs when the slip safety factor is lower than approximately 1.2.

Figure 1. Occurrence/non-occurrence of Damage to a Breakwater in the Overflow Depth – Slip Safety Factor Relationship

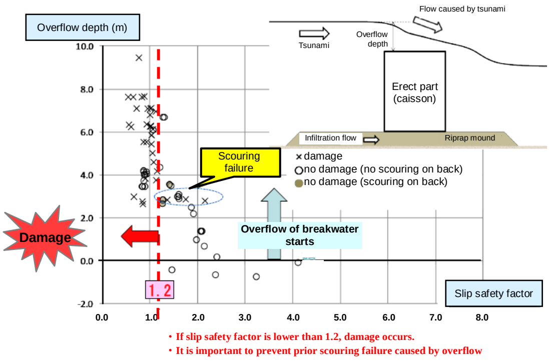
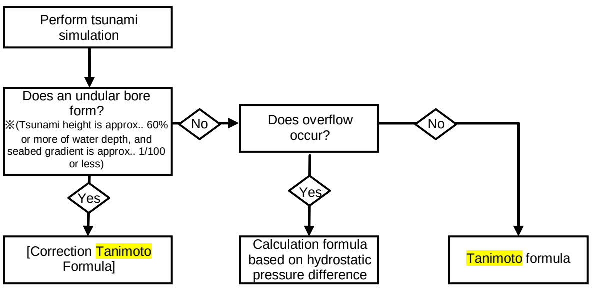


Table 1. Reference Values of Structural Analysis Factor

Item verified	Structural analysis factor
Slip of erect part	1.2
Overturning of erect part	1.2
Bearing capacity of foundation	1.0

The tsunami wave force calculation method used is the appropriate wave force formula obtained by the procedure shown in Figure 2, considering whether or not a tsunami simulation is done, and whether or not an undular bore or overflow occurs.

Figure 2. Tsunami Wave Force Calculation Procedure for Breakwaters



5. Toughness of a structure against tsunami

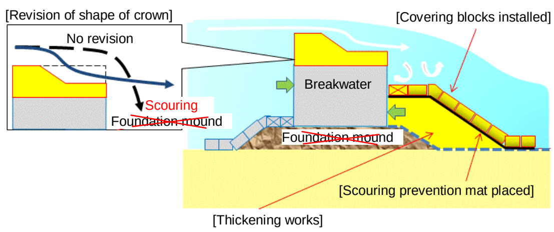
Among breakwaters, seawalls, etc., highly important facilities which, if damaged, would have a severe impact on human life, property, and public economic activities, are required to have toughness which will maintain stipulated stability under tsunami with action of a scale exceeding that of the design tsunami.

Required performance is stipulated so that in a facility which, if damaged, might have a severe impact on human life, property, and public economic activities, even in the case where a tsunami with strength of a scale exceeding that of the design tsunami occurred at a location where the said breakwater is installed according to the structure, severe impact on the stability of the structure of the said facility of damage from the action caused by the action of the tsunami etc., can be delayed as long as possible.

It is stipulated that a breakwater, which is a facility prepared for accidents, have a structure devised to ensure the maximum possible stability so that even when it is subject to the action of a tsunami which scale greater than that of the design tsunami for that location, it displays its disaster mitigating effects and ensures calmness in the port immediately after the disaster.

The Guideline stipulates that as a result of taking supplementary measures according to the importance of the facility and cost-effectiveness etc. at weak points revealed by full studies of the form of damage and weak points in the structure of breakwaters according to the scale of the tsunami while using hydraulic model experiments, the breakwater must be a structure with toughness which prevents it from overturning while deforming, and to the greatest possible degree, maintains its overall stability under a tsunami of a scale exceeding that of the design tsunami.

Figure 3. Breakwater scouring countermeasures



6. Future research

The partial revisions to technology standards and the Tsunami-Resistant Design Guideline for Breakwaters, were prepared based on comprehensive study of survey and research etc. done immediately after the earthquake, but not all of the many challenges have necessarily been clarified. In the future, as new knowledge is obtained, it must be reflected in the Guideline, and we must promote further research and technology development in the field of tsunami-resistant design.

Photo 4. Breakwater Model Experiment

[Sources]
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