Considering a Coastal Dike Structure Resistant to High Waves
– Toward Implementation at Actual Sites –

(Research period: FY 2021 – FY 2023)

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(Keywords) coastal dike, high waves, resilient structure, scouring

1. Background and Purpose of Research

The Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is promoting improvement of coastal dikes and other facilities to a structure (resilient structure) that reduces damage even in the event of a tsunami or waves exceeding the planned scale. Since an early date, NILIM has carried out studies on resilient structures for waves that exceed the design wave, and confirmed the effectiveness of multiple improvement methods by small-scale experiments in the past. However, concrete design methods (e.g., a method for setting the embedded length of steel sheet piles, etc.) are needed for implementation at actual sites. In the research described here, we conducted a large-scale hydraulic model experiment to clarify the process from scouring of the front (seaward) side of a dike until failure and the relationship between the scour depth and the necessary embedded length of steel sheet piles, whose effectiveness was confirmed in the past small-scale experiments, and also confirmed the estimation accuracy of the scour depth obtained using a calculation model.

2. Large-Scale Hydraulic Model Experiment

In this research, we conducted a large-scale hydraulic model experiment (**Fig.-1**) [1], in which waves acted on a model of a coastal dike, and confirmed the process by which the function of the dike was reduced and lost as a result of wave overtopping, and also acquired data on the scour depth and scour profile on the seaward side of the dike. As a result, it was found that the backflow of withdrawing waves that have run up on the outer slope shielding on the seaward slope of the dike generates a vortex on the front side of the dike, and scouring proceeds because that vortex picks up the sand in front of the dike (**Photo-1**).

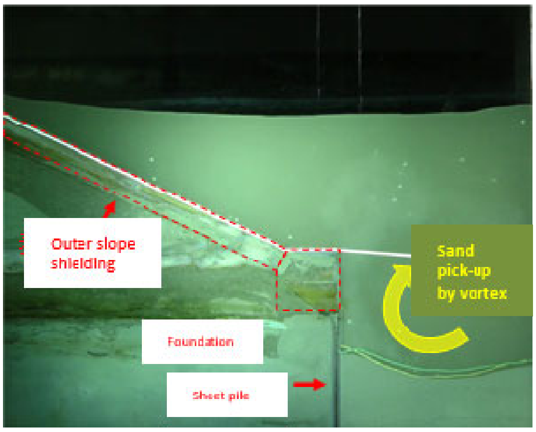

Photo-1 Condition of scouring at seaward side of dike

If scouring proceeds, it was also found that a crevice forms between the crown shielding and the outer slope shielding (**Fig.-2**). In this case, water penetrates from that crevice and causes large-scale deformation of the structure within a short time, and the dike transitions to a state in which it cannot maintain its function.

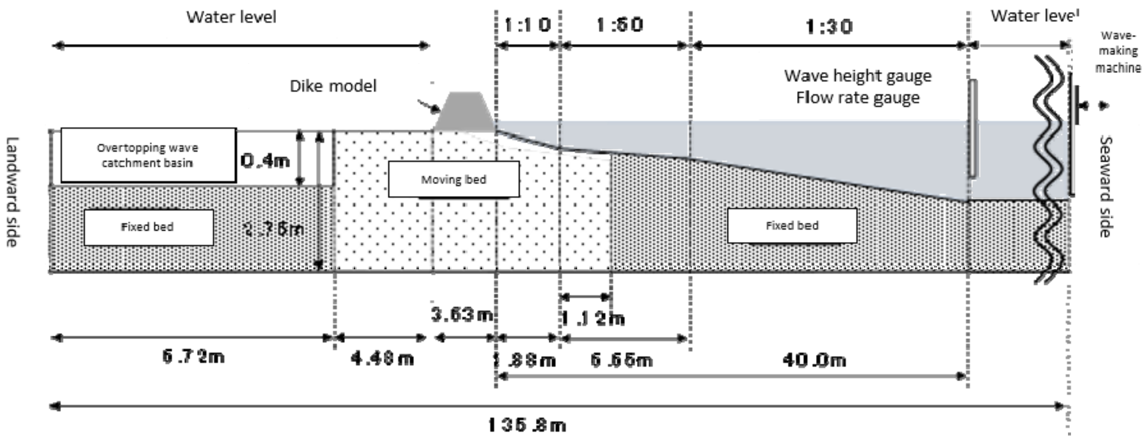

Fig.-1 Water channel and topographical conditions of large-scale hydraulic model experiment

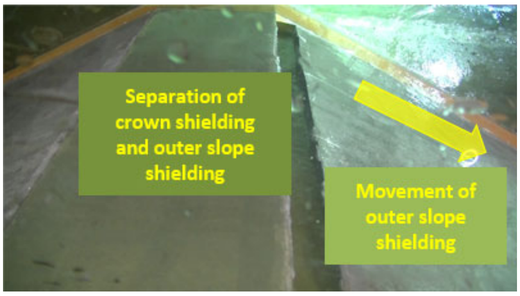

Photo-2 Crevice between crown shielding and outer slope shielding

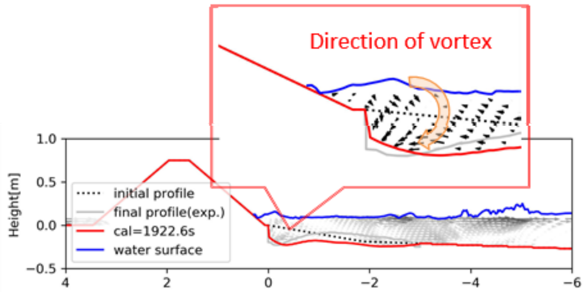

Fig.-2 Example of reproduction by calculation

Since the large-scale hydraulic model experiment confirmed that the main cause of failure of coastal dikes is scouring of the seaward side of the dike, an understanding of the scour depth on the dike front side is considered essential for the implementation of resilient coastal dikes at actual sites. However, there are limitations on large-scale hydraulic model experiments due to the constraints of cost and time, and no technique for estimating the scour depth at the front side of dikes has been established. Therefore, for implementation at actual sites, it is necessary to develop a technique that enables easy estimation of the scour depth in the field by a calculation model or a simple formula.

3. Estimation of Scour Depth by Calculation Model

Based on the situation in 2., the key point for resilient structures is the scour depth at the front side of a dike. Therefore, a model [2] for calculating the scour depth at the front side of a dike was studied. **Fig.-2** shows the velocity vector during wave-making obtained by the calculation model, and **Fig.-3** shows the overlay of the large-scale hydraulic model experiment and the waveform at the dike front side after wave-making. These results confirmed that the model is capable of reproducing the vortex which is the primary factor in the progress of scouring at the dike front side. Although it was not possible to reproduce the sediment zone at distances of more than 1 meter from the dike, the difference between the maximum scour depth in the experiment and the calculation was less than 3 cm, indicating that the scouring that occurs at the dike front side can be roughly reproduced by the model.

4. Future Development

If the calculation model that successfully reproduced the large-scale hydraulic model experiment can be constructed, application to diverse bottom sediment conditions and dike structures will be possible, and it will become possible to design resilient structures for coastal dikes with various coastal conditions. At present, the model has only been verified in experiments under limited conditions, but in the future, we intend to confirm its validity through large-scale hydraulic model experiments to examine the effects of differences in the sediment particle size and type of dike structure on the condition of scouring, carry out a study on methods for setting the parameters of the calculation model, and confirm its reproducibility as research toward the implementation of resilient coastal dikes throughout Japan.

☞For more information:

1) Fukuhara, Himeno, Kato et al.: Experimental Study on Resilient Structures Using Steel Sheet-Pile for Coastal Dikes Against Unexpected High Waves, Journal of the Japan Society of Civil Engineers, Vol. 79 No. 17, 23-17128, 2023.
2) Tomoaki Nakamura and Norimi Mizutani: Numerical Analysis of Tsunami Overflow Over a Coastal Dike and Local Scouring at the Toe of its Landward Slope, Journal of the Japan Society of Civil Engineers Ser. B3 (Ocean Engineering), Vol. 70, No. 2, I_516-I_521, 2014.

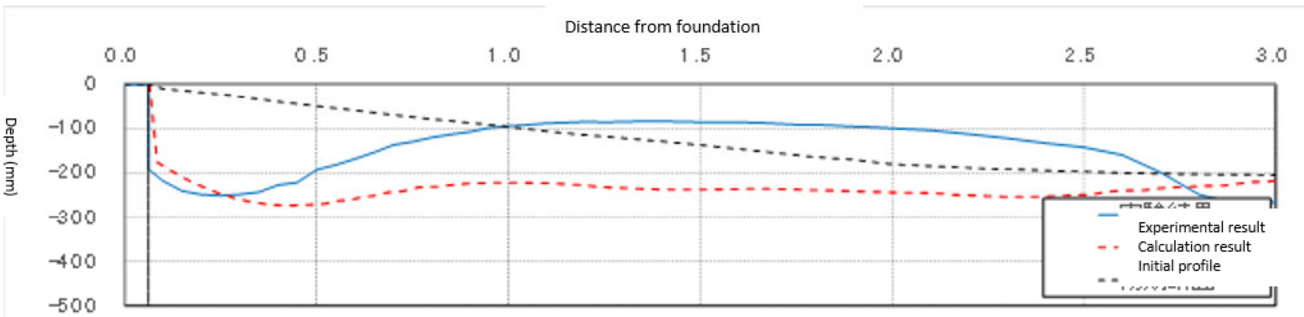

Fig.-3 Results of topographical change in large-scale hydraulic model experiment (solid blue line) and calculation (dotted red line)