Development of Resilient Levees That Are More Effective Than Crisis Management-type Structural Countermeasures

(Research period: FY2019 to FY2021)

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Keywords: water overtopping, resilient levee, crisis management-type structural countermeasures

1. Introduction

As an initiative to strengthen levees against overtopping, measures to cover the surface of levees with sheets or blocks (called "Armored Levee" or "Frontier Levee") were implemented on a trial basis from around 1988 to 2003, but due to maintenance and management issues and high costs, these measures were not developed throughout the country.

Then, after the flooding in Joso caused by the torrential rains in the Kanto and Tohoku regions in 2015, under a basic understanding that "there is a limit to the capacity of facilities and that a major flood that cannot be prevented by facilities will surely occur," crisis management-type structural countermeasures have been introduced to delay the progress of levee erosion and collapse by adding asphalt pavement to the levee crown and block covering on the back slope toe in the sections where the river channel and levees have not been developed, despite the high risk of flooding, from the perspective of upstream/downstream balance, etc.

Then, the 2019 Eastern Japan Typhoon caused serious inundation damage, which indicated the need for "resilient river levees" that are more effective than crisis management-type structural countermeasures to mitigate damage caused by overtopping[1].

Accordingly, the NILIM started to develop technologies for "resilient river levees" and plans to prepare guidance for studying the structure of resilient levees by organizing the findings to date and the results of the experiments described below.

2. Consideration of resilient structure

(1) Circumstances of development

In the 2019 Eastern Japan Typhoon, water overtopped at one of the sites where crisis management-type structural countermeasures were constructed. While the countermeasures were considered effective since the levee was not broken, erosion occurred on the back slope that was not covered with blocks (**Photo 1**), and the need for slope protection was recognized once again.

Photo 1: An example of back slope erosion at a site where crisis management-type structural countermeasures were used (left bank of 6.2 kp of the Toki River in the Arakawa River system)

(2) Proposal for a resilient structure based on existing knowledge

After organizing the existing knowledge of armored levees, frontier levees, and crisis management-type structural countermeasures, we determined a resilient structure would be more effective and reasonably priced. Specifically, in addition to the slope toe and crown, the slope was also protected, and the slope protection work consisted of anti-absorption sheets held with blocks or soil cover.

(3) Issues in study of structure and response

1) Evaluation of hydrodynamic forces acting on blocks placed on the slope

To study the stability of blocks against overflow, it is necessary to understand the hydrodynamic force acting on the blocks due to the overflowing water. However, there was an issue in that it is difficult to evaluate the hydrodynamic force acting on the blocks because the water flowing over the back slope is different from the flow of water on the river surface where the blocks are usually installed, and is a shallow flow with a complex flow due to the protrusions of the blocks. Therefore, an experiment was conducted by changing the shape of the protrusions of the blocks to directly measure the hydrodynamic force acting on the blocks by the overflowing water using a force-measuring device and a force gauge (**Photo 2**).

The results showed that when the height of the block protrusion is relatively high compared to the block thickness, the force tends to be greater than the hydrodynamic force acting in deep water flows such as those at the river surface, which, as information, served us in evaluating the stability of the block against overflow water.

Photo 2: Experiment of hydrodynamic force measurement

2) Evaluation of pull-out resistance of sheets

When the back slope is long, it is difficult to cover the slope from the shoulder to toe with a single anti-absorption sheet, so a sheet seam is formed in the middle of the slope. Since these seams are weak areas and there is a concern that the sheets may shift or rise, we are considering inserting the sheets into the levee to hold them strongly. In examining the stability of sheets, since the pull-out resistance of the sheets was unknown, we conducted an experiment to directly measure the pull-out resistance (**Figure, Photo 3**).
As a result, we found a relationship between the vertical load and the pull-out resistance of the sheet inserted into the levee, and obtained knowledge for determining the length of insertion of the sheet into the levee.

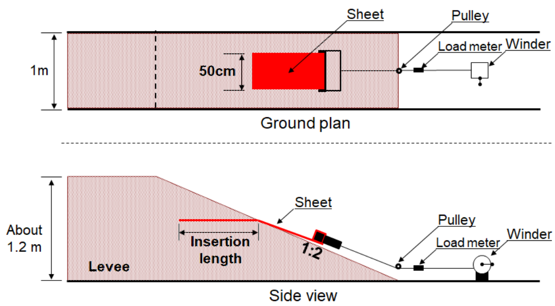

Figure: Outline of the experimental model for measuring pull-out resistance

Photo 3: Pull-out resistance measurement experiment

3) Protruding shape of slope block and water splashing at the slope toe

The slope toe protection works must prevent scouring of the slope toe due to overtopping water. Depending on the shape of the block protrusion on the slope protection works, overtopping water may splash and jump over the slope toe protection works, causing water flow to directly hit the landside, which may impair the scour suppression effect of the slope toe protection works. Therefore, we conducted an experiment to confirm how water splashes when blocks with high protrusions of the soil covering type are used (**Photo 4**).
As a result, we obtained knowledge regarding the necessary width of the top edge in slope toe protection works based on the way water splashes.

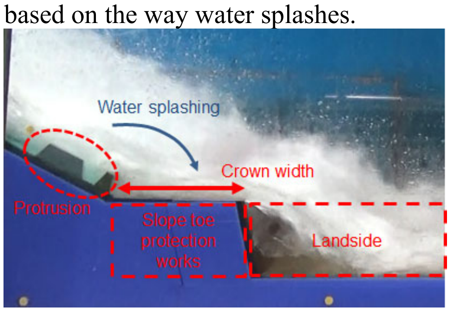

Photo 4: Experiment to confirm how water splashes

3. Future development

Considering the uncertainty of levee soil and variation of construction, it is necessary to continue to study a structure that is more effective through field testing and levee model overtopping experiments. The findings will be reflected as appropriate in a guidance to be prepared in the future.

☞See the following for details.

1) Water and Disaster Management Bureau, MLIT: Technical Workshop on River Levees Based on the Damage Caused by the 2019 Typhoon No. 19, 2020.
https://www.mlit.go.jp/river/shinngikai_blog/gijutsu_kentoukai/index.html