Development of River Embankment Structure Highly Resistant to Overtopping under Public Private Partnership

(Research period: FY2023 ~ FY2025)

MIYOSHI Tomohiro, Senior Researcher　　FUKUOKA Chiaki, Researcher
KONO Tsutomu, Visiting Researcher　　MATSUO Takaki, Visiting Researcher
SEZAKI Tomoyuki, Head
River Department, River Division

(keywords) highly resistant river embankment, overtopping, reliability

1. Introduction

Most of the embankments have been made of earth due to the construction cost being relatively inexpensive as well as the fact that the construction material can be obtained easily. Also, it has a history of not deteriorating easily. However, embankments made of earth are vulnerable to overtopping.

Therefore, MLIT is developing a river embankment with a highly resistant structure (hereinafter referred to as “highly resistant river embankment”). It has damage mitigation qualities such as not easily collapsing or taking a longer time before collapsing even when it is overtopped. Considering the fact that it is technically difficult, at this this point in time , to keep embankments from not collapsing when it is overtopped (the 2008 report of Japan Society of Civil Engineers), our evaluation criteria for technical development is to extend the time to collapse as long as possible even when there is overtopping for 3 hours with an overflow water depth of 30cm.

In this article, I will introduce the history of technical developments until now and an overview of research for a method to efficiently ensure reliability for the highly resistant river embankment that NILIM is currently working on.

2. Development of river embankment structure highly resistant to overtopping

(1) Development of highly resistant river embankment by NILIM

So far, we have implemented “risk management type hardware measures” paving the top-end or placing blocks at the bottom of the city-side slope, to reinforce embankments against overtopping in vulnerable areas along rivers all over Japan. The purpose is to delay scouring of slope bottoms and collapsing of top-ends that could potentially accelerate the process from the start of overtopping to embankment collapse. This measure has strengthened existing embankments at a relatively low cost. I will show the situation after overtopping at the place where the risk management type hardware measures have been taken in Photo-1.

We can confirm that no scouring of the slope bottom occurred, and top-end pavement worked as an overhang reducing erosion of the embankment. On the other hand, the city-side slope, which is only covered with vegetation, may be eroded once overflow water depth becomes greater and the speed of the flow increases. It may eventually collapse if overtopping continues for a long time.

Taking this into account, we have devised a highly resistant river embankment (Photo-2) (hereinafter referred to as “block structure”) The structure consists of covering the city-side slope of the embankment with soil draw-out retaining material and concrete blocks used for protecting the slope. The structural details have gone through repeated waterway experiments. The results of this research and development were summarized in technical documents (draft) [1)] and publicly disclosed. We have already made pilot works of this structure at around 14 places all over Japan and we keep monitoring changes after the works.

(2) Technical development of highly resistant river embankment through open call

MLIT made an open call for “technology for highly resistant river embankment” to overtopping to promote technical development from March 2025 to September 2025, in addition to the block structure on which NILIM made research and development.

Photo-1 Erosion of inner slope at the area where the risk management type hardware measures have been taken

Among the proposals made, there were those made by companies that had not worked on embankment technologies before, so it helped to expand embankment technologies. The technologies applied (16 proposals in total) were evaluated as 4 in category B, 1 in Category C and 11 in category D (refer to Table-1. The technologies applied and evaluated as Category B or higher may be used on-site.) Among these proposals, there were a lot of technologies referring to the technical documents (draft) [1)] that NILIM publicly disclosed, and there were certain technologies for which experiments were made renting the large-scale experimental waterway that NILIM had, so NILIM's research results and facilities were effectively used. In addition, there were some approaches to aid applicants' technical development such as arranging discussions between those who requested to meet with members of evaluation committee.

3. Research on methods to improve reliability

In the development of highly resistant river embankment structures, we have made it mandatory to verify the proposal with experiments, using actual scale models. Technologies that received high evaluations can be said to possess "laboratory-level reliability," meaning they function effectively under ideal conditions. The highly evaluated technologies are, as the next stage, adopted in on-site pilot works, where they are tested to determine whether they can perform sufficiently under on-site circumstances having uncertainty —in other words, whether they possess "field-level reliability."

Photo-2 Example of highly resistant river embankment

Table-1 Evaluation category

Evaluation category	① Not to damage the function of existing embankments		② If having a function against overtopping or not
	Safety at planned water height level or lower	Items to be reflected and considered in design	
Category A	Equivalent to earth embankment or more	Equivalent to earth embankment or more	Yes, it has
Category B	Equivalent to earth embankment or more	Though not regarded as equivalent to earth embankment, continuous technical development is expected having a room for improvement	Confirmed at experiment results, etc. (on-site uncertainty, etc. is yet to be confirmed)
Category C	Though not regarded as equivalent to earth embankment, continuous technical development is expected having a room for improvement	Though not regarded as equivalent to earth embankment, continuous technical development is expected having a room for improvement	Confirmed at experiment results, etc. (on-site uncertainty, etc. is yet to be confirmed)
Category D	Having some issues in technology	Having some issues in technology	Having some issues in technology

The on-site uncertainty to which we are referring here can be minor work defects, material's deterioration over time due to carelessness at work, un-uniformity of earth quality for embankment, changes, land subsidence that has been affected or wind and rainfall over time. However, in case of the on-site pilot works, though it is considered efficient to improve the structure based on flood experience repeatedly occurred at an affected areas such as reinforcement of river-side slope, it takes time to verify a low probability of overtopping function of the embankment so it is not efficient.

Consequently, we make verification using a hydraulic experiment, systematically summarizing the causal relationship between on-site uncertainty and destruction of embankment in drawing, and selecting on-site uncertainty, from that which is assumed to lead to embankment collapse. For example, in block structure, we "dig down" destruction modes attributed to various on-site uncertainties by making experiments setting such status as making unevenness under the block assuming the occurrence of gully erosion, due to a long period of rainfalls for initial status of the experiment (refer to Photo-3). With this, we can confirm that the highly resistant river embankment would be vulnerable to some kind of uncertainty, the damage mechanism at such time and the structure to overcome such vulnerability and things to take note of for the maintenance and management. These verifications are also made for technologies highly evaluated in the open call previously mentioned, obtaining cooperation from the applicants themselves. From the research results, we would like to identify risks that are difficult to find under ideal circumstances, and to publicly propose a process to improve reliability in making countermeasures.

Photo-3 Experiment image having gully erosion at embankment slope

☞ Detailed information is as follows.

1) Technical documents (draft) to study structure for highly resistant river embankment https://www.nilim.go.jp/lab/fbg/download/gijutsusiryo.pdf

2) On technical development for highly resistant river embankment Japanese Geotechnical Society report, March 2025