Aiming for coastal dikes that are not collapsed by earthquake before arrival of tsunami (Study period: Fiscal 2015 and 2016)

- Creation of technical note on seismic performance evaluation of coastal dikes mainly made of soils -

KATO Fuminori, Head (Dr. Eng.) TAKESHITA Tetsuya, Senior Researcher
River Department, Coast Division

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1. Introduction

When "Technical standards for coastal protection facilities" was revised in 2015, evaluation of the seismic performance of coastal facilities against "earthquake motion that causes design tsunami" was newly introduced. In addition, an administrative notification of coastal authorities in 2015, titled "Basic concept of engineering documents to be followed in design of coastal dikes," provides as follows.

[Structure mainly made of concrete]
→ Technical documents for fishing port facilities and harbor facilities shall be basically followed.
[Structure mainly made of soils]
(Except for the structure mainly made of concrete above)
→ Technical documents for designing river levees shall be basically followed.

Further, it is required to explain the concept of the Technical standards above, common methods, etc. for coast administrators to evaluate seismic performance properly. Because ground conditions and required performance differ between coastal dikes and river levees and no detailed description about "earthquake motion that causes design tsunami" is found in the seismic performance evaluation guidelines, etc. for river structures.
For this reason, Coast Division of NILIM collected case data on earthquake disasters involving coastal dikes etc. and established a workshop of academic experts (see **Table 1**) to organize the concepts of seismic performance evaluation, etc. for coastal dikes mainly made of soils, and completed "Technical note on seismic performance evaluation of coastal dikes mainly made of soils" in July 2017.

2. Outline of technical note on seismic performance evaluation of coastal dikes mainly made of soils

(1) Organization of critical conditions against earthquake action

We organized critical conditions against earthquake motion in coastal dikes in reference to the content of seismic performance in **Table 2**, "Basics of design for civil engineering and building" (2002, MLIT), and existing papers on seismic performance and critical conditions of banking structures (see **Figure 1**).

Table 1 Members of the workshop on seismic performance evaluation for coastal dikes mainly made of soils

IAI Susumu	Professor, Disaster Prevention Research Institute, Kyoto University
ICHII Koji	Associate Professor, Division of Social Environment and Space, Graduate School of Engineering, Hiroshima University
YASUDA Susumu	Vice president and professor of the Department of Science and Engineering, Tokyo Denki University
KATAOKA Shojiro	Head, Earthquake Disaster Management Division, Road Structures Department, NILIM
SASAKI Tetsuya	Team Leader, Soil Mechanics and Dynamics Research Team, Geology and Geotechnical Engineering Research Group, Public Works Research Institute

* In random order (honorifics omitted, as of March 2017), Coast Division excluded

Table 2 Seismic performance which should be filled for each earthquake motion

Earthquake motion	Seismic performance
Level 1 earthquake motion (Earthquake motion with a probability of occurrence once or twice during the service period of the dike)	The required structural safety is secured and the function of coastal facilities is not impaired.
Earthquake motion that causes design tsunami (Design tsunami: Tsunami that occurs with a relatively high frequency --- about once during several tens of years to a hundred and several tens of years.) <Added when the standards were revised>	Even when an earthquake causing design tsunami has an intensity exceeding level 1 earthquake ground motion, disaster caused by the earthquake is minor and the required structural safety is secured against tsunami coming after the earthquake and the function of coastal facilities is not impaired.
Level 2 earthquake motion (Earthquake motion with the greatest strength considered for the site at present and in future)	Disaster caused by the earthquake is minor and prompt recovery of functions after the earthquake is possible. (only those determined to require higher seismic performance)

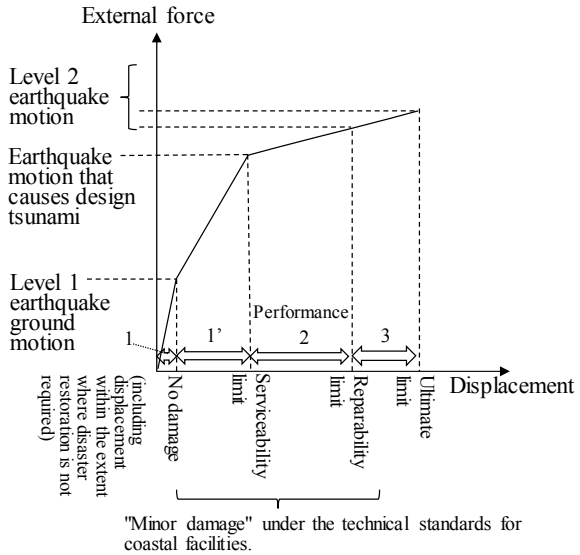

Figure 1 Image of critical conditions in coastal dikes mainly made of soils

We also classified the seismic performance of each earthquake motion into "safety performance" and "performance to achieve objectives" and organized data for each of them together with evaluation standards (see **Table 3**).

(2) Organization of conditions for applying various evaluation methods

We also organized conditions of application, etc. for the static analysis method and the dynamic analysis method, which enable calculation of settlement, as methods used for seismic performance evaluation of coastal dikes in addition to the seismic coefficient method (method of evaluation with safety factor assuming circular slip) (see **Table 4**). We also described the use of the simple analysis method, with which settlement can be calculated simply, in order to reduce the burden of coast administrators since both the static and dynamic analysis methods require much effort to calculate settlement. Note that the basic concept for setting evaluation standards and external forces for seismic performance evaluation is consistent with that of methods applied to river levees (see **Figure 2**).

(3) Information useful for seismic performance evaluation

In addition to the above, we organized the following in the part of Reference Material as information useful for seismic performance evaluation.

- Microtopography that should be considered in seismic performance of coastal dikes
- Important points in conducting a ground investigation
- Examples for earthquake disasters and seismic performance evaluation, etc.

3. Future schedule

For coast administrators, we distributed this technical note in 2017 and explained in the meeting of personnel in charge in each regional block. In the future, we continue to support the efforts of coast administrators to conduct seismic performance evaluation of coastal dikes using this technical note. Additionally, in future revision of "Technical standards and commentaries for coastal facilities and commentary (2004)," which is a commentary of "Technical Standards for Coastal Facilities," this technical note will be used as one of reference materials together with other findings concerning coastal facilities.

☞See the following for details.

1) Technical Note of NILIM, No. 977

Table 3 Organization of seismic performance

Earthquake motion	Safety performance	Performance to achieve objectives
Level 1 earthquake motion (Performance 1)	Secure the required structural safety. → No damage from the effect of seismic force. [Evaluation standard] Safety factor concerning the seismic coefficient method	The function of coastal dike is not impaired. - Function to prevent sea water invasion (storm surge / tsunami) - Function to prevent wave overtopping (waves) - Erosion control function [Evaluation standard] Safety factor concerning the seismic coefficient method
Earthquake motion that causes design tsunami (Performance 1')	Secure the required structural safety against tsunami (design tsunami) coming after the earthquake → Minor damage (Displacement within the extent where stability of the coastal dike and the functions on the right are not impaired by the action of tsunami.) [Evaluation standard] The crown height is beyond the water level of design tsunami. Structure where parapet work (and continuous armor, etc.) can withstand the action of tsunami	The function of coastal dike is not impaired by the tsunami (design tsunami) coming after the earthquake. → Function to prevent sea water invasion (limited to tsunami) [Evaluation standard] The crown height is beyond the water level of design tsunami. Displacement of the parapet work after the earthquake is under the tolerance determined from the thickness of parapet work, etc.
Level 2 earthquake motion (Performance 2)	(only those determined to require higher seismic performance) → Minor damage (Displacement within the extent where prompt recovery on the right is possible) [Evaluation standard] Same as on the right	(only those determined to require higher seismic performance) Prompt recovery of functions after the earthquake is possible. [Evaluation standards] To be set individually, such as "HWL + 1/10 stochastic wave."

Table 4 Evaluation methods and conditions of application

Earthquake motion	Evaluation method	Outlines (conditions of application, etc.)
Level 1 earthquake motion	Seismic coefficient method	Deemed to be no damage when safety factors (inertia force, liquefaction) are met (same as before).
Earthquake motion that causes design tsunami	Simple analysis method	Method of easily calculating settlement, which is used for screening of coastal dikes for static / dynamic analysis method should be conducted preferentially.
Level 2 earthquake motion	Static analysis method	Method of analyzing the impact of earthquake statically, not considering destruction by inertia force.
	Dynamic analysis method	Method of analyzing seismic behavior dynamically, enabling the analysis of inertia force and liquefaction.

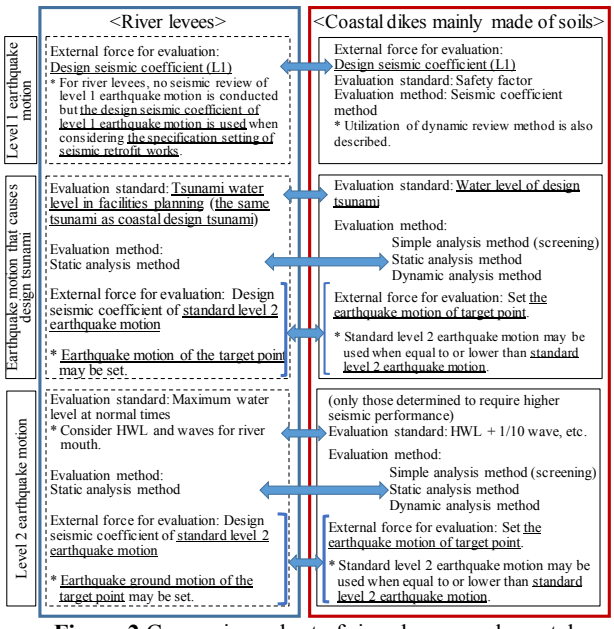

Figure 2 Comparison chart of river levees and coastal concerning seismic performance evaluation