Case Studies and Dynamic Centrifuge Tests to Evaluate Earthquake Related Damage of Special Levees of Rivers

KAJIO Tatsushi, Researcher; KATAOKA Shojiro, D.Eng, Senior Researcher; KANEKO Masahiro, Head
Earthquake Disaster Prevention Division, Research Center for Disaster Management

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1. Introduction

For a river levee, a soil embankment is in principle constructed. In some cases, however, special levees (Independent type structure: Concrete retaining wall [“retaining wall”]), steel sheet pile ["sheet pile"], or parapet structure) are constructed due to land conditions, etc. Most of these special levees have a complicated structure due to extension / alteration works, etc. Since such special levees are expected to demonstrate complicated behavior during an earthquake, it is required to implement advanced earthquake-proof diagnoses and measures. Thus, considering that the first step to solve this issue is to understand their behavior during an earthquake, we collected data on the cases of damage of special levees in order to analyze the causes and conducted dynamic centrifuge tests to clarify the damage mechanisms.

2. Case study on the condition of special levees and seismic damage

The special levees in the river sections under the direct administration of MLIT (209 locations, about 190 km in total) are mostly composed of parapet structures (approx. 80%), followed by retaining walls (approx. 20%), and sheet piles (less than 10%). Moreover, about 70% of them are concentrated in the three major metropolitan areas, so it is important to ensure earthquake resistance.

Twenty nine damage cases on special levees located in the sections under the administration of MLIT, prefectural control, etc., were compiled. It was observed that major damage occurred where the thickness of the liquefaction layer was more than approx. 3 m for the retaining walls and more than approx. 2 m for the sheet piles, as shown in Fig.1.,which shows the relationship between displacement and the liquefaction layer during an earthquake. Thus, the liquefaction layer is considered to be the main cause of damage.

3. Implementation of centrifuge tests

Model tests were conducted by setting a 1:50 scale model (Fig. 2) on the dynamic centrifuge of the cooperating Public Works Research Institute (PWRI) and subjecting it to excitation under centrifugal acceleration of 50 G. In these tests, the thickness of liquefaction layer was changed to 3 types for both retaining walls and sheet piles.

The mechanism of damage of special levees was identified from the centrifuge tests. The pore water pressure of the liquefaction layer increased under excitation, following which the ground lost the effective stress and was liquefied, causing flow force to be directed to the frame. The flow force made the balance of applied force unstable, consequently causing horizontal/vertical displacement and/or rotation (tilt) of the frame. In addition, the displacement of the retaining walls and the sheet piles showed the same tendency as the compiled damage case: horizontal displacement increased as the liquefaction layer became thicker, and vertical displacement was minimal in the cases where the foundation of the retaining walls and the sheet piles were supported by the non-liquefaction layer.

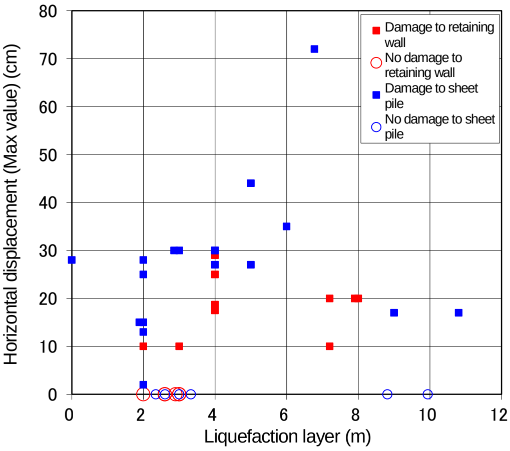

Figure 1: Relation between Horizontal Displacement in Frame and Thickness of Liquefaction Layer in Damage Cases

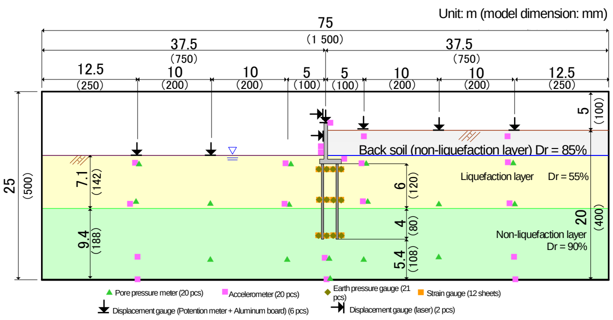

Figure 2: Schematic Diagram of the Model (Case where the liquefaction layer is 7.1 m below the river bed.)

4. Future study

We plan to study seismic retrofit methods using two-dimensional static analysis and promote studies that will resultantly propose effective seismic retrofit methods by implementing model tests .