The First JSCE-ASCE Joint Symposium on Infrastructure Resilience
Auditorium, JSCE, Tokyo, May 22-23, 2019

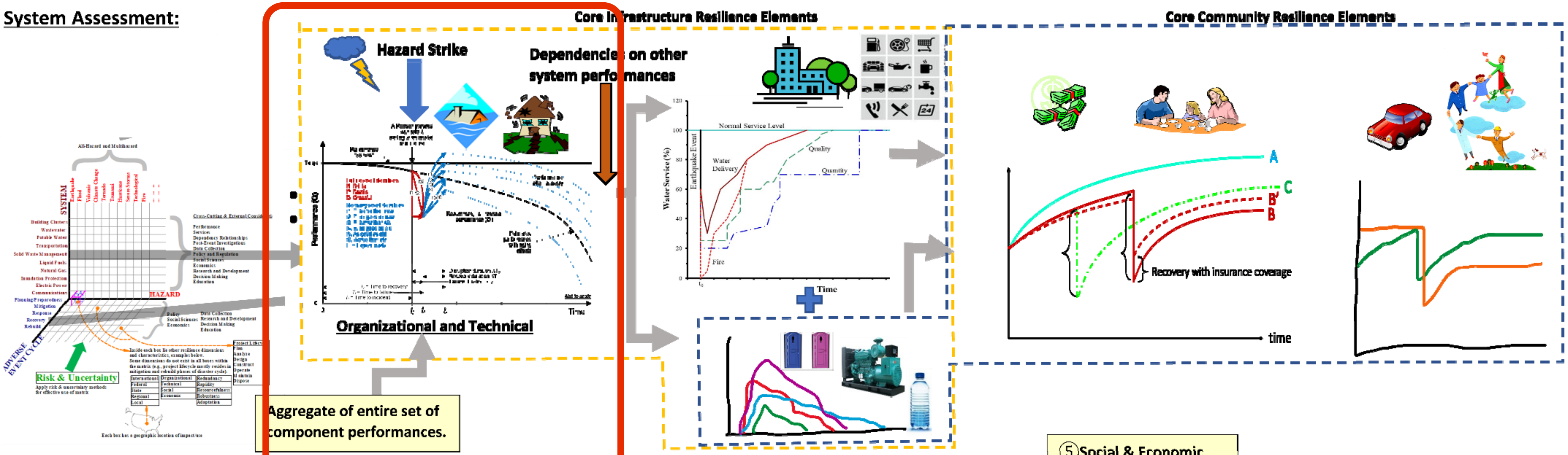
Resilience in Geotechnical Engineering

Residual Performance of Geo-structures

Ryosuke Uzuoka
Disaster Prevention Research Institute
Kyoto University

Performance or Functionality

System Assessment:



①**Infrastructure Resilience Domain:** Define the dimensions most relevant to engineered systems

②**Building and Lifeline System Performance or Functionality** (representing a single system and change in performance over time)

③**System Service Provision & Operability** (Davis, 2014)
+
④**Continuity of [inoperable] Services Temporarily Lost** alternatives, substitution, stockpiles, etc.)

⑤**Social & Economic activity** supported directly and indirectly by infrastructure systems

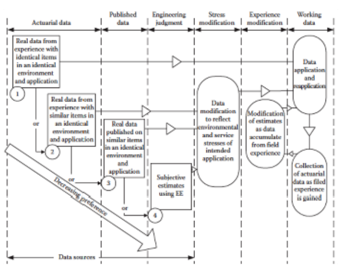
⑥**Community:** wellbeing, equity, livability, etc.

Management:

⑦**Establish Community Performance Targets** (e.g., NIST 2015)

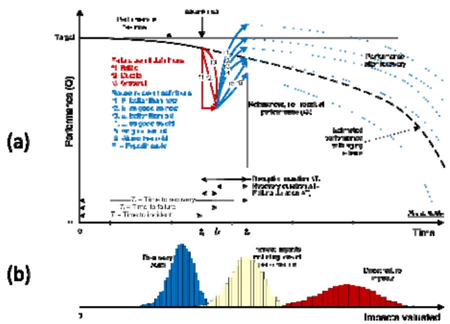
⑧**Define Infrastructure System Performance Targets** to support the social and economic needs of a community.

Data needs, sources and expert opinion elicitation (Ayyub, 2001): collect in support of all resilience elements.

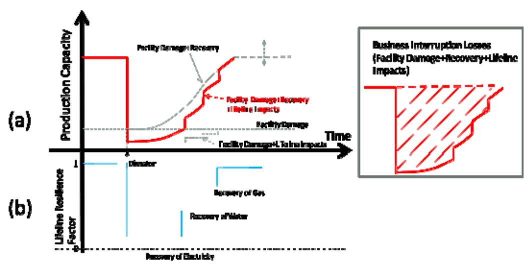


Management tools
Implement programs to operationalize resilience using characteristics (Davis et al, 2018)
Resilience standards and codes (Burton et al, 2018; Honda, 2017)
Insurance
Loss estimation methodologies
Business Continuity Plans, Continuity of Operations Plans
Emergency and incident management
Asset management
Risk management
Hazard Scenarios
Life cycle cost analysis/ assessment

Economics of resilience
(Gilbert & Ayyub, 2016)
(a) performance profile
(b) Economic valuations of direct losses, recovery costs, and indirect impacts
-Develop cost effective mitigation alternatives



Regional Social and Economic Losses from facility and lifeline losses (Kajitani and Tatano, 2009)
(a) Losses from facility and lifeline systems
(b) Lifeline restorations



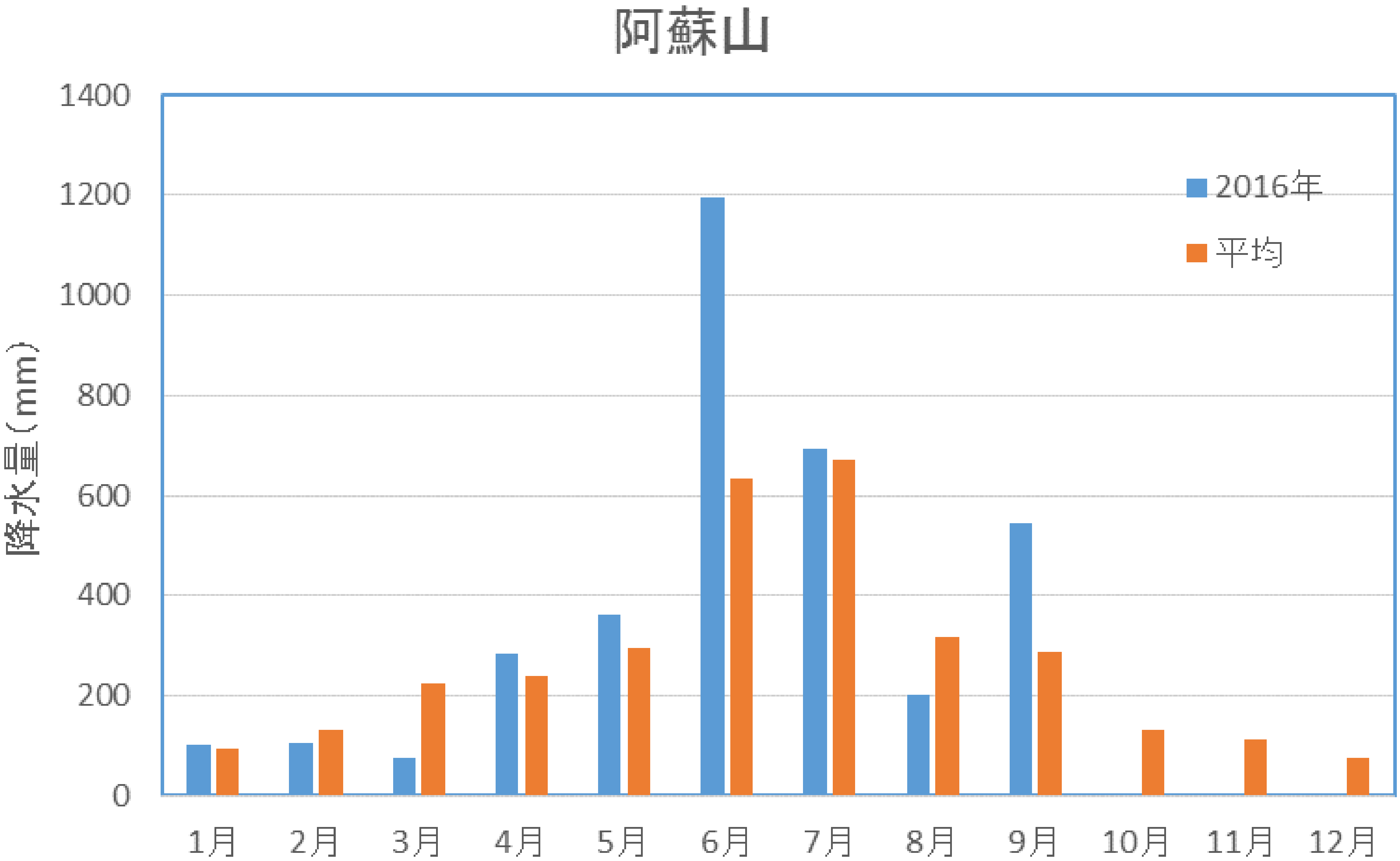
Geo-hazard

- Heavy rainfall
  - Landslide, Debris flow, Slope failure
  - Flood, River levee failure
  - Earth-filled dam failure, Road embankment failure
  - Landslide dam
- Earthquake
  - Landslide, Debris flow
  - Landslide dam
  - Embankment failure
    - Road, River levee, Housing land, Earth dam
  - Liquefaction
- Combined geo-hazard
  - Earthquake after rainfall
  - Rainfall after earthquake

Landslides:
Measuring volume of the sediment movement in the recovery process

Geo-structure such as embankment:
Evaluating residual performance in the recovery process

Precipitation in Kumamoto 2016



Main shocks on 2016.4.14 and 4.16

(JMA)

South Aso, Kumamoto (2016.4.20)

(http://www.gsi.go.jp/BOUSAI/H27-kumamoto-earthquake-index.html)

South Aso, Kumamoto (2016.7.5-24)

(http://www.gsi.go.jp/BOUSAI/H27-kumamoto-earthquake-index.html)

Mashiki, Kumamoto (2016.6. 21)

地震後堤体にクラックがあり，トンパックが置いてあったが流された（熊本県，岡二三生京大名誉教授）。

Mashiki, Kumamoto (2016.10.21)

The 19th International Conference on Soil Mechanics
and Geotechnical Engineering
Seoul 2017

Evaluation of seepage behavior for deformed levee after earthquake

Yasuhiro Ikami, Tokushima University, Japan
Ryosuke Uzuoka, Kyoto university, Japan
Katsutoshi Ueno, Tokushima University, Japan

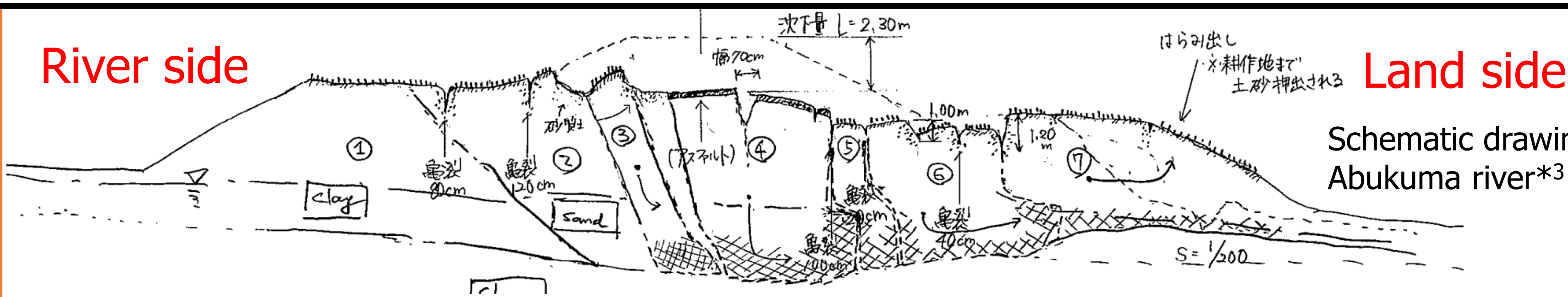
Introduction

Damaged river levees in japan, 2011

Earthquake, tsunami and heavy rainfall caused extensive damages of river levees, and combined influences against river levee have been pointed out before 2011*1.

Seismic performance design in Japan*2

Seismic limit state of deformed river levee has been assessed with comparing the crest settlement and normal high water with Japanese standard.



Schematic drawing at Abukuma river*3

Seepage performance of deformed levee should be evaluated by not only the crest settlement but also the whole behaviour of deformed levee, because the deformed levee after earthquake has many cracks and the deformed configuration is various.

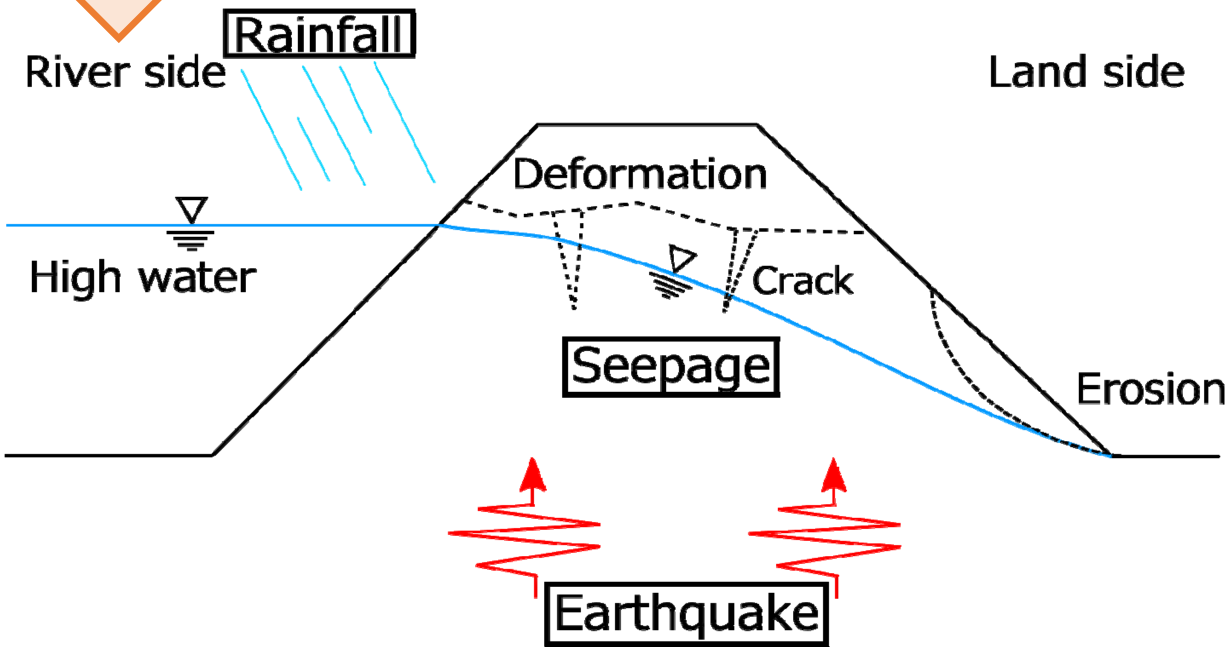
*1 Japanese Geotechnical Society special committee in 2007. 2009

*2 and *3 Ministry of Land, Infrastructure, Transport and Tourism. 2016 and 2011

Objective

To evaluate performance of deformed levee under plural external forces such as earthquake and high water.

In this study, we performed seepage tests for deformed levee by shaking and non-deformed levee in centrifugal model test and numerical simulation.



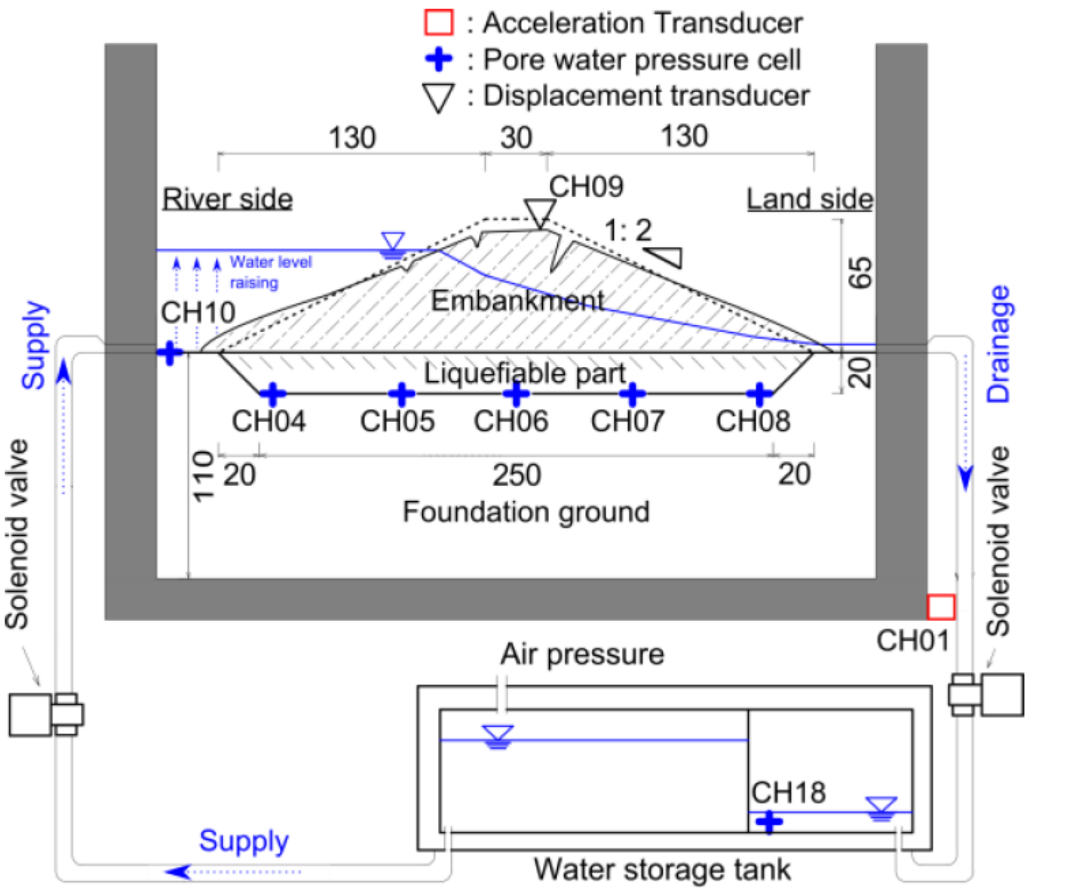
Plural external forces

Earthquake:
Crack, Lateral flow at toe of slope …

×

High water:
Seepage, Erosion …

Centrifuge model test



Unit: mm *Model scale

Internal dimensions of rigid container:
375mm long, 175mm wide, 200mm deep.

Foundation ground (mortar) is impermeable.

Test procedures

A. Gravitational force field, 1G

1. Preparation of pore fluid water and sample
2. Preparation of liquefiable part and embankment

B. Centrifugal force field, 25G

3. Saturation of liquefiable part
4. Shaking tests (M-1,-2, L-1)
5. Seepage tests (All cases)

Test cases and samples

*Model scale

Test code	Relative density of settlement part (%)	Degree of compaction of embankment (%)	Shaking conditions	
			Input frequency (Hz)	Shaking duration (sec)
N-1	48.4	78.6	-	-
M-1	50.3	79.6	17	1.5
M-2	46.3	80.2	17	1.5
L-1**	51.0	77.6	17	2.0

**L-1 is additional case

Mixed sand

Toyoura sand: Keisha No.7= 8: 2

Pore fluid water

Methylcellulose

kinematic viscosity is 25cSt.

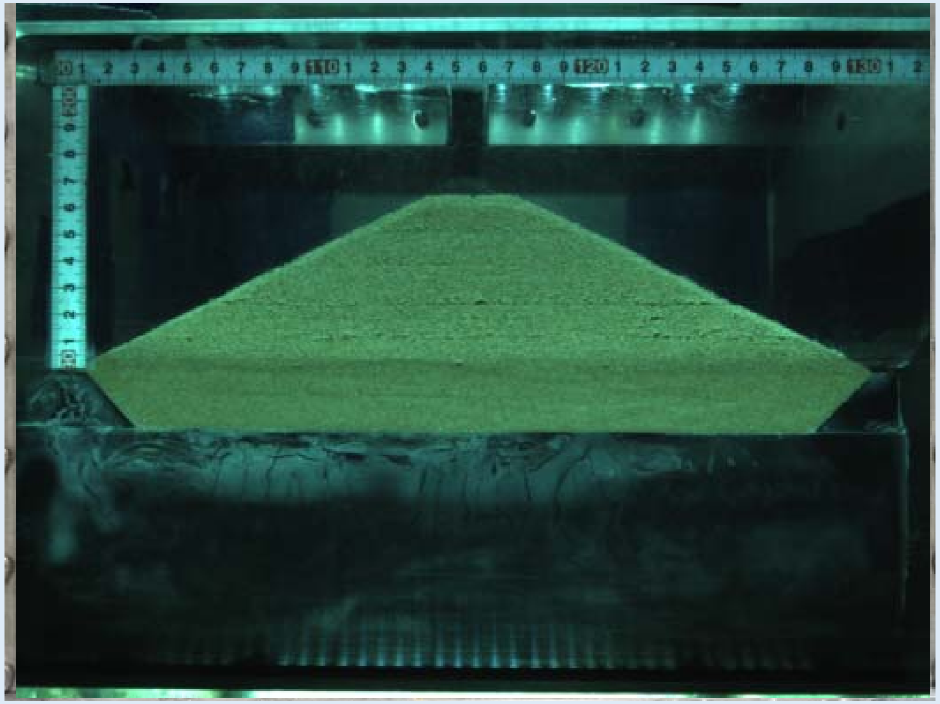
physical parameter of embankment and liquefiable part

ρ_s $(\mathrm{g/cm^3})$	2.569
w_{opt} (%)	13.2
ρ_{dmax} $(\mathrm{g/cm^3})$	1.61
ρ_{dmin} $(\mathrm{g/cm^3})$	1.33

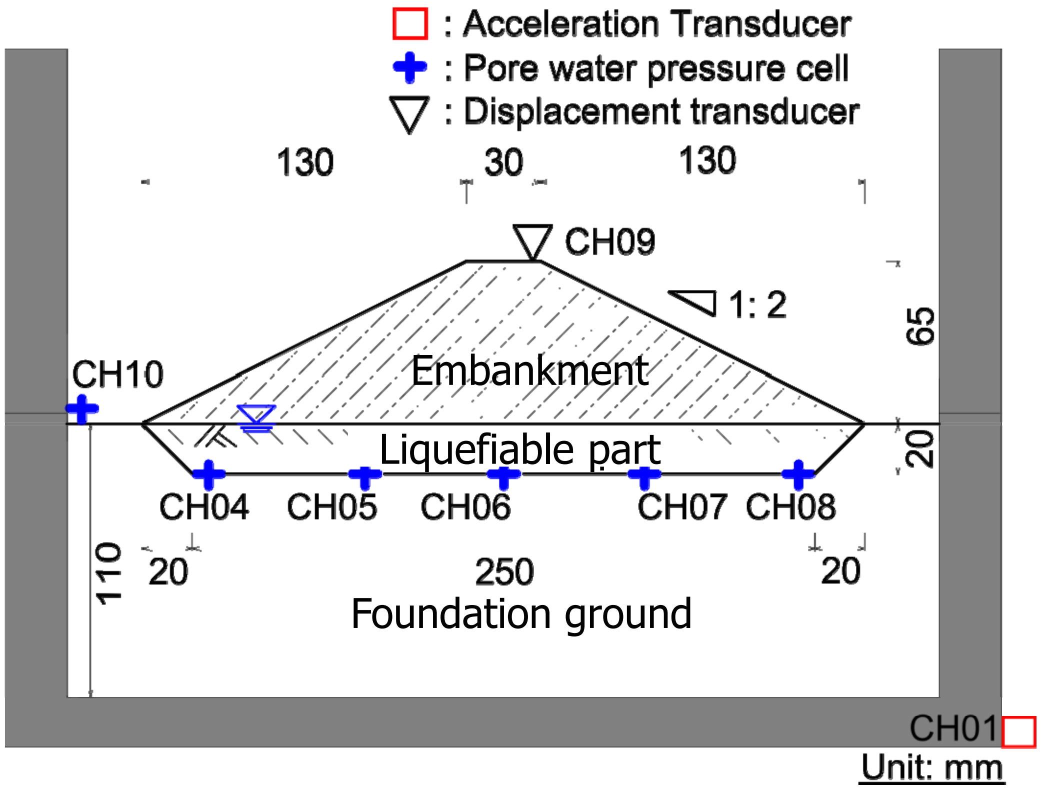
Preparation of experimental model

Mixed sand (Toyoura sand: Keisha No.7 = 8: 2)

Preparation process of model 1~25G



*Model scale



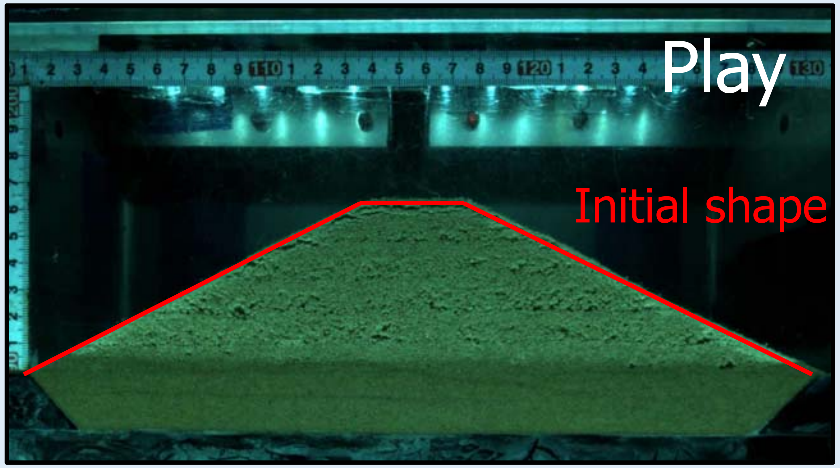
- The liquefiable part was established with the relative density of 50% on mortar foundation.
- The thickness of liquefiable part was 20mm.
- The embankment was compacted with the degree of compaction of 80% on the liquefiable part.

Shaking tests

Test code: L-1 (additional case)

Side view

25G



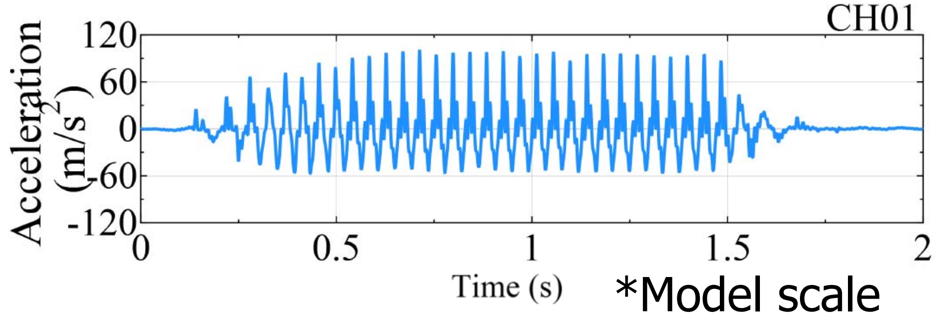
River side | Land side

View of slope at land side

(Top of slope)

(Toe of slope)

Input acceleration



*Model scale

Conditions after shaking:

Some cracks occurred at the slope.

Crest settlement in all cases

*Model scale

Test code	Crest settlement (mm)
M-1	10.5
M-2	7.1
L-1	19.8

Seepage tests

Test code: L-1 (additional case)

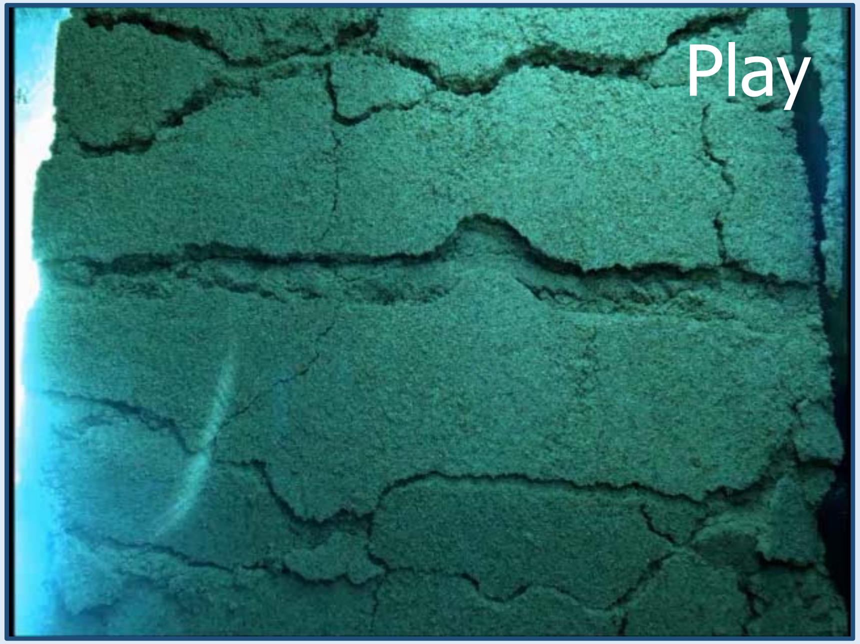
Side view

(32.0 speed) 25G

River side Land side

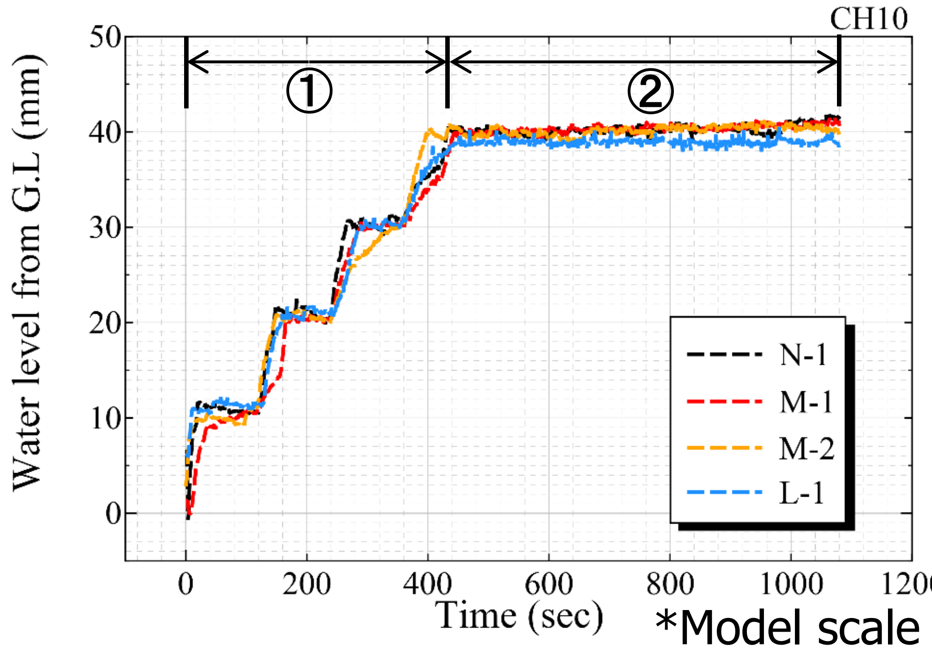
View of slope at land side

(Top of slope)



(Toe of slope)

Water level at river side



*Model scale

① Raising water level process

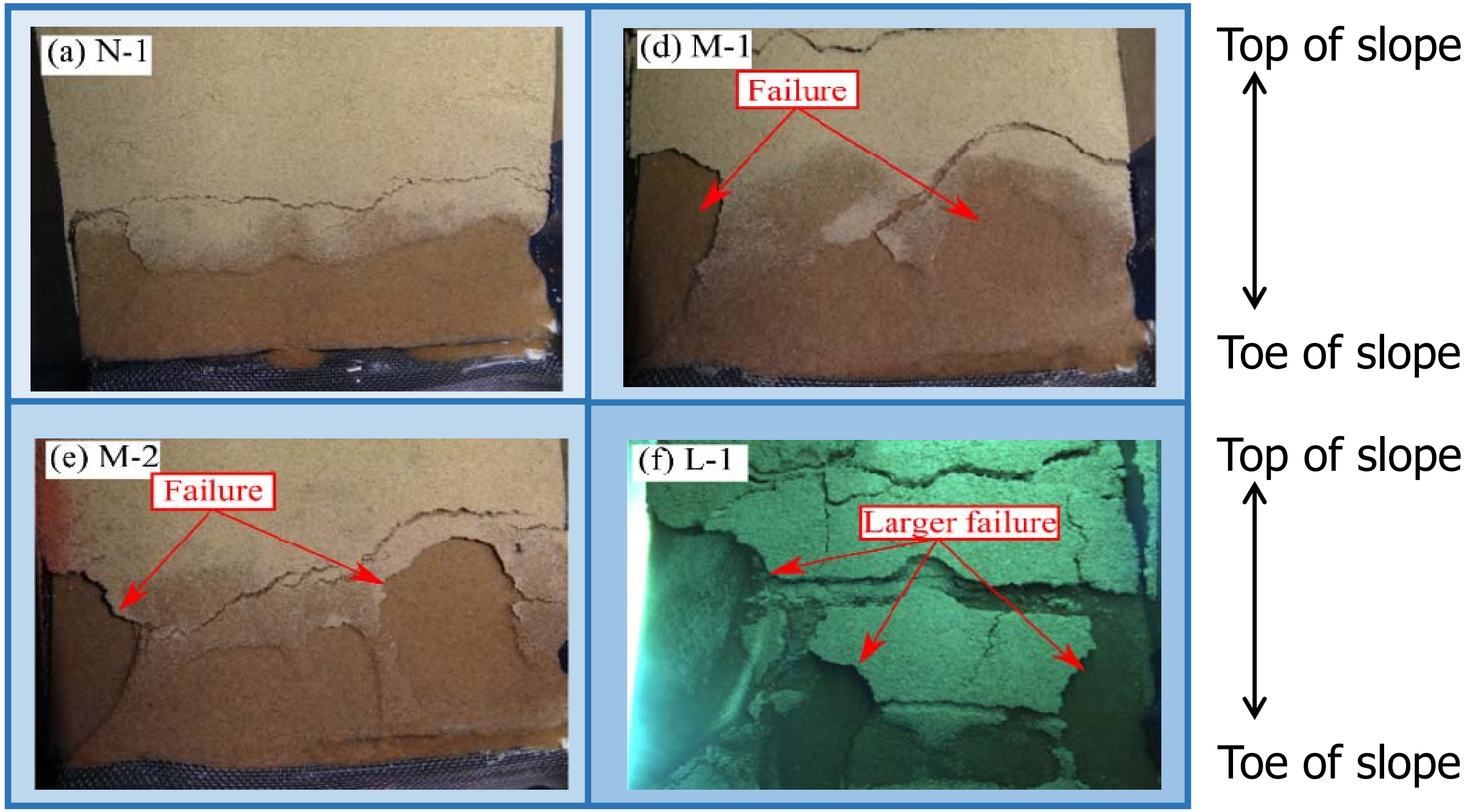
- The water level rose per 120sec.
- The final water level at river side was 40mm.

② Keeping water level process

- The high water level was kept in 600sec.

Result of Seepage tests

Conditions of the slope at land side after seepage tests



N-1

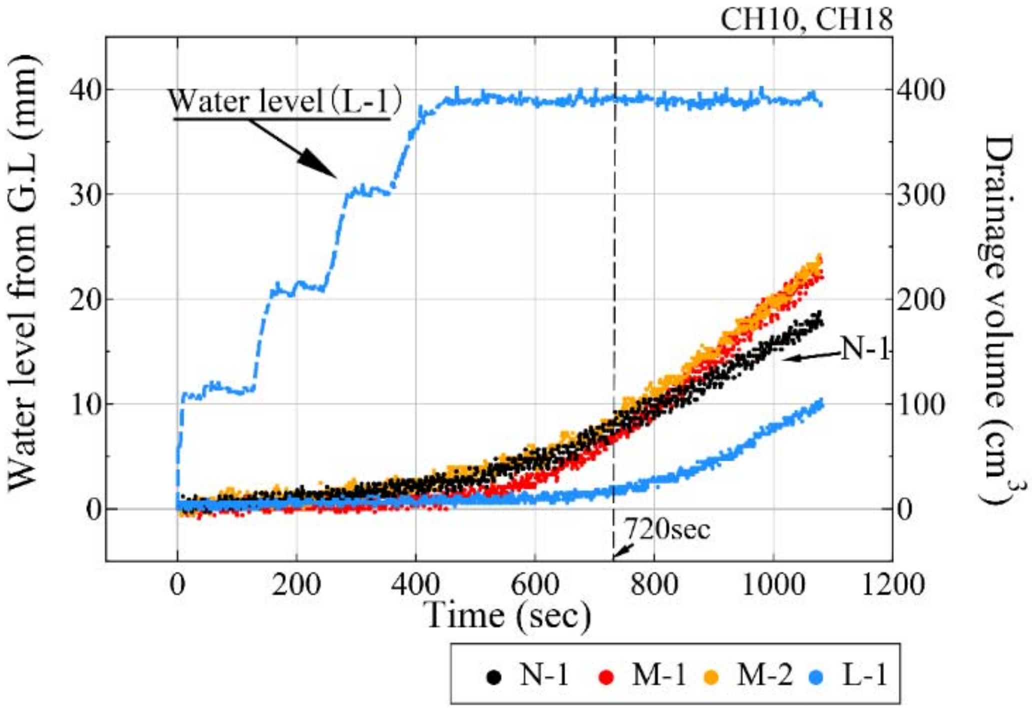
- Major failure by seepage was not observed.
- Some fine particles were flowed out of embankment.

M-1, M-2, L-1

- Cracks became larger and localized failure at the foot was observed.
- The seepage failure occurred from the cracks induced by shaking.

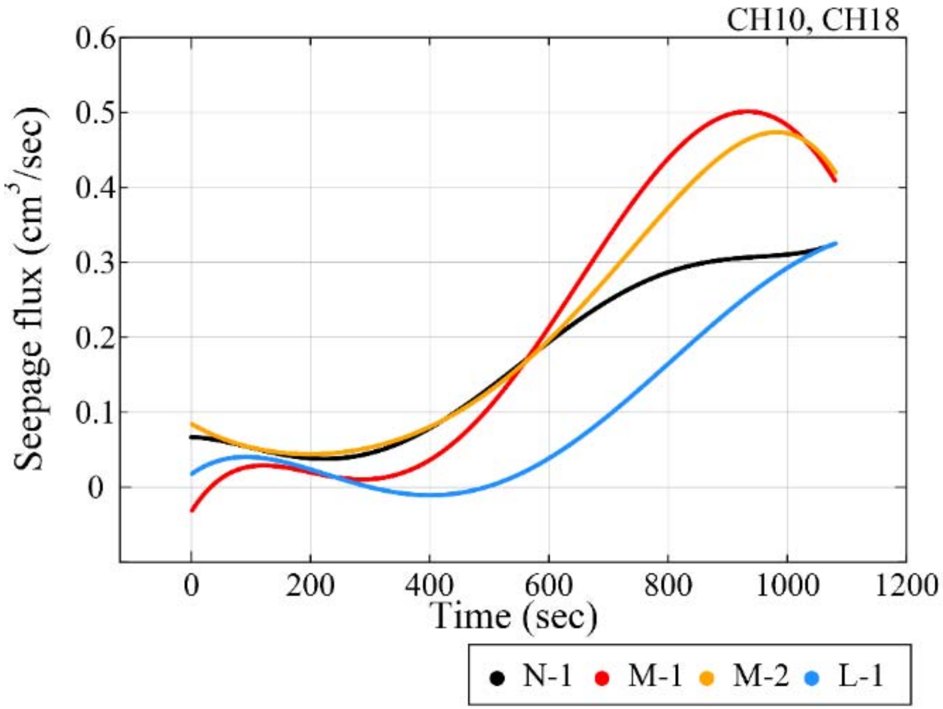
Result of Seepage tests

1. Seepage amount from land side



2. Seepage flux

*Model scale



1.
- The seepage amounts became larger than that of case N-1 after about 720sec.(M-1 and M-2)
- The seepage amounts were smaller than that of case N-1 through the experiments.(L-1)

2.
- The seepage flux became larger than that of case N-1 without shaking after about 600sec.(M-1 and M-2)

It is possible that the localized failure at the toe of slope caused larger seepage flux through embankment.

Summary

In this study, we performed seepage tests and analyses for deformed levee by shaking and non-deformed levee.

- In the shaking cases of M-1, M-2 and L-1, localized seepage failure from the cracks by shaking was observed at the toe of embankment slope on the land side.
- Seepage flux in the cases of M-1 and M-2 became larger than the case without shaking (N-1) near the end of experiments.
- Seepage flux in the case of L-1 tended to increase at the end of seepage test.

It is possible that the localized seepage failure from the cracks by shaking causes larger seepage flux through embankment.

Thank you for your attention.