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Effects of Seepage and Erosion History on Liquefaction Resistance of Fine-Grained Mixed Sand

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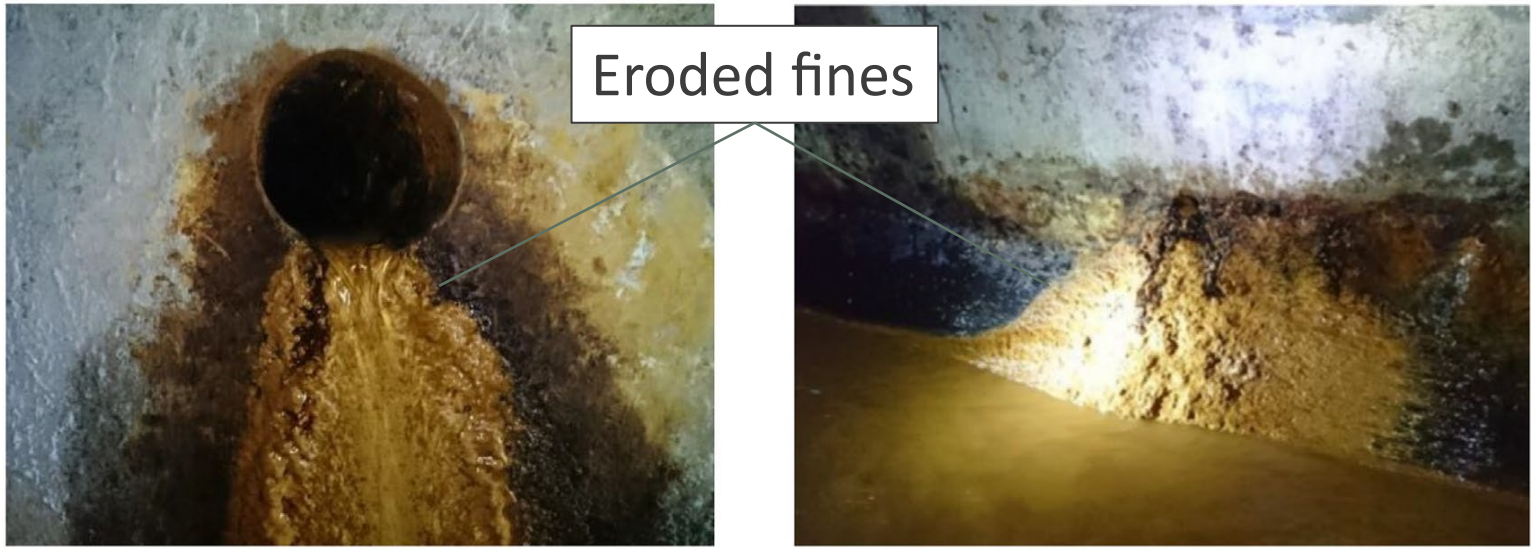
INTRODUCTION

In the 2018 Hokkaido Eastern Iburi Earthquake

→ The large-scale liquefaction failure occurred at the reclaimed landfill.

Source : Google maps

An investigation after the accident revealed that a large amount of fine particles had eroded from the damaged part of the culvert.



Picture 1: Layers of muddy cake inside underground drainage pipes.

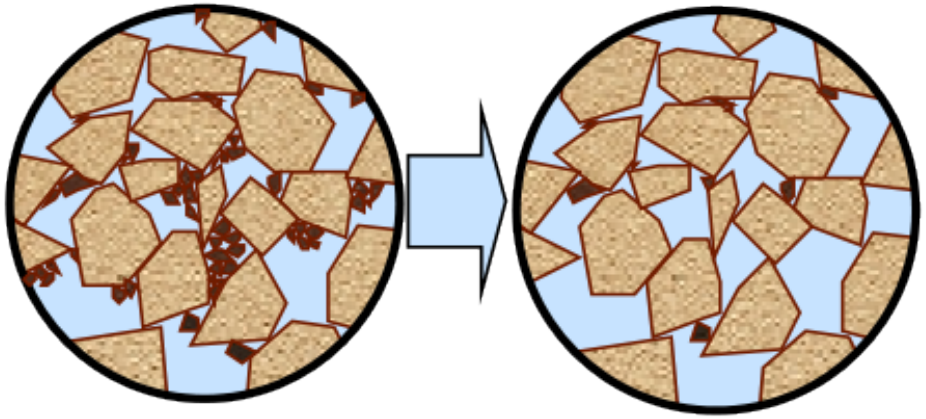
(Sarmah and Watabe, 2023)

INTRODUCTION

Suffusion

The detachment and migration of fine particles through voids connected by the matrices of coarse particles.

Fine particles move due to seepage.

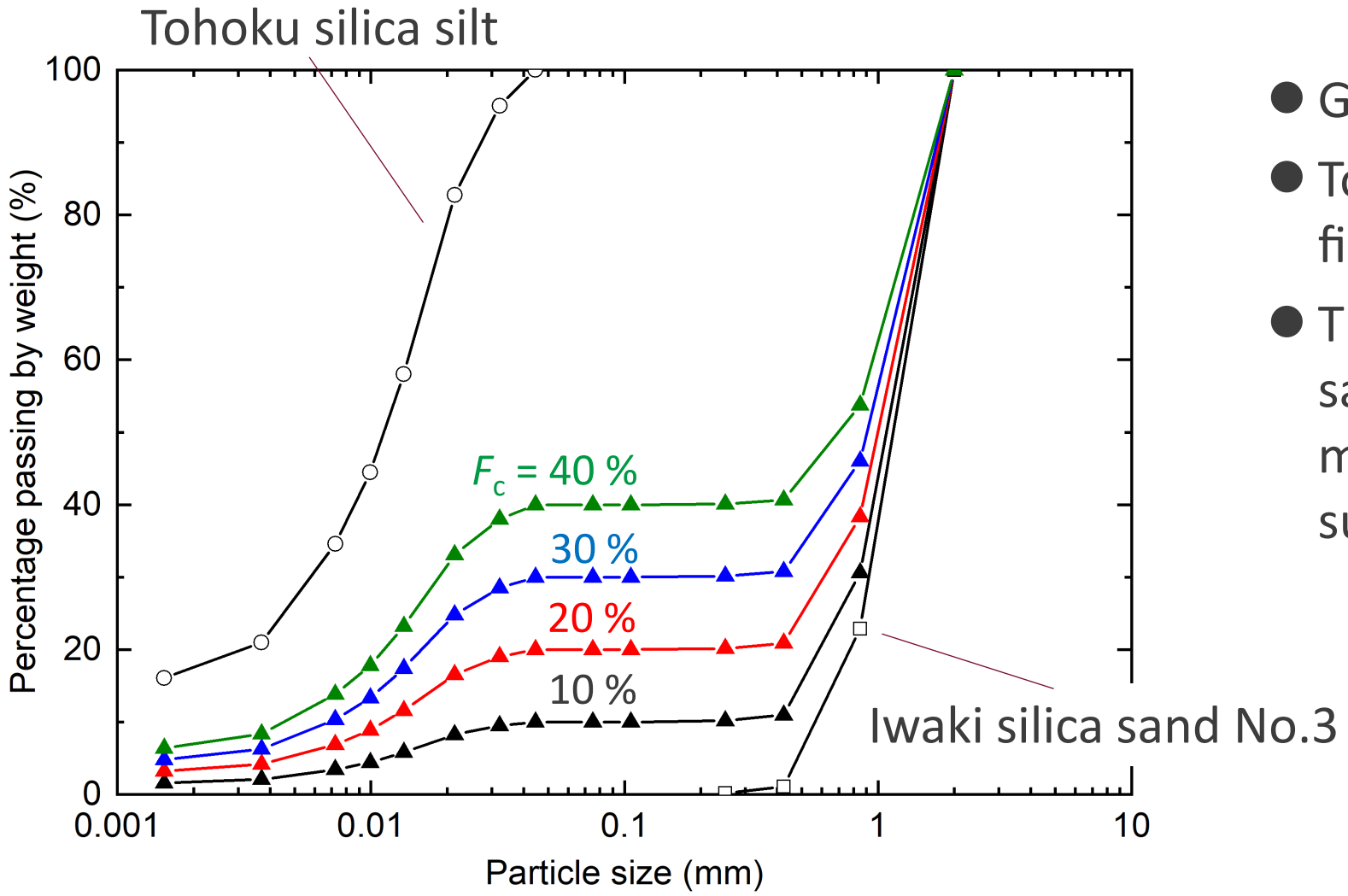


Geotechnical Issue

Does the suffusion affect the triggering of soil liquefaction?

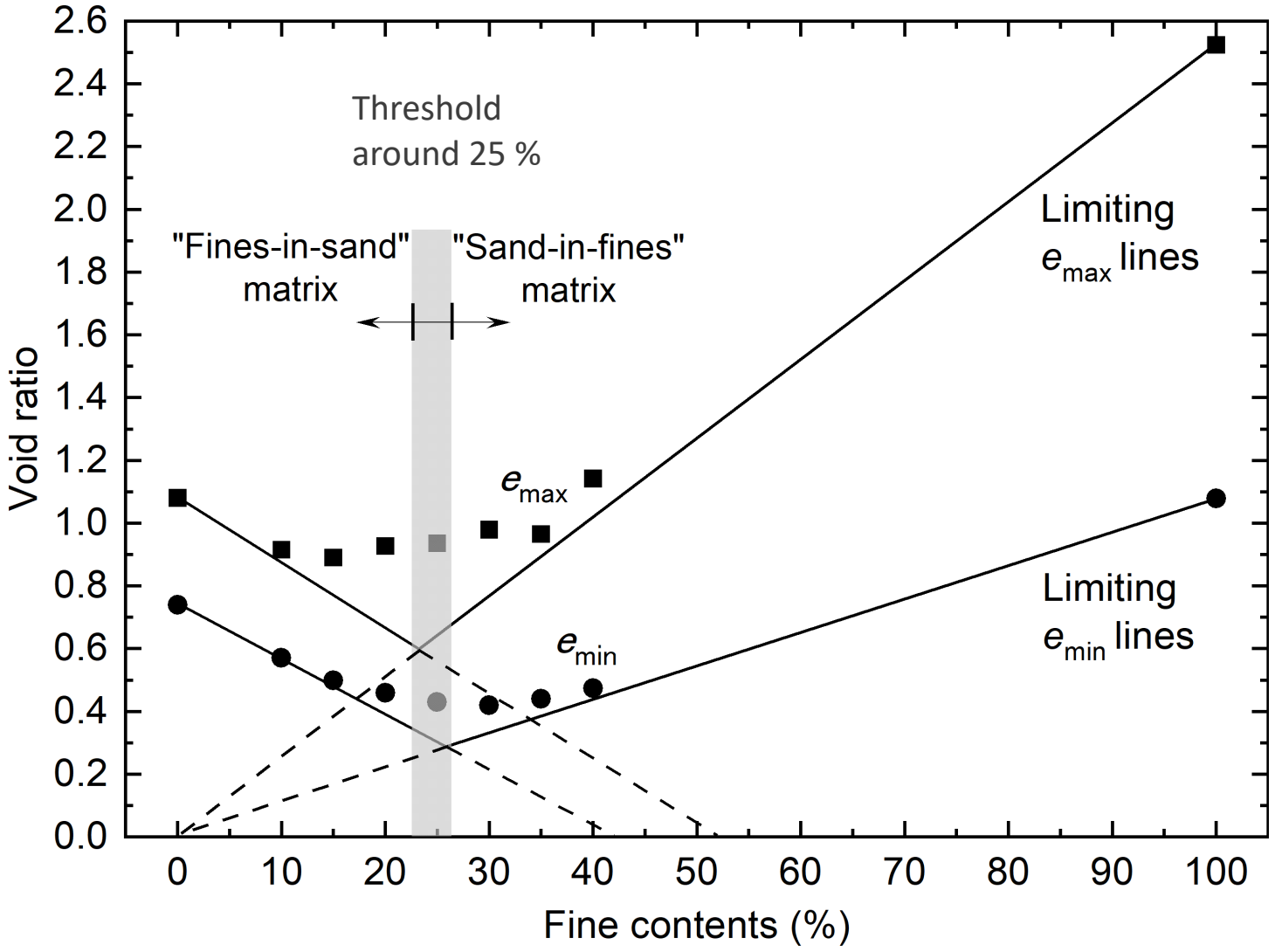
In this study, a series of undrained cyclic triaxial tests were conducted on soil specimens affected by seepage and erosion history.

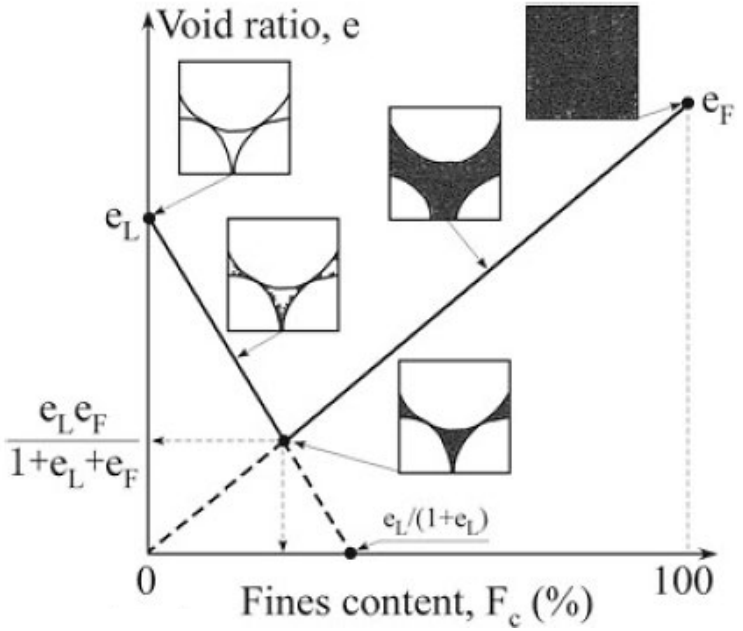
EXPERIMENTAL MATERIALS



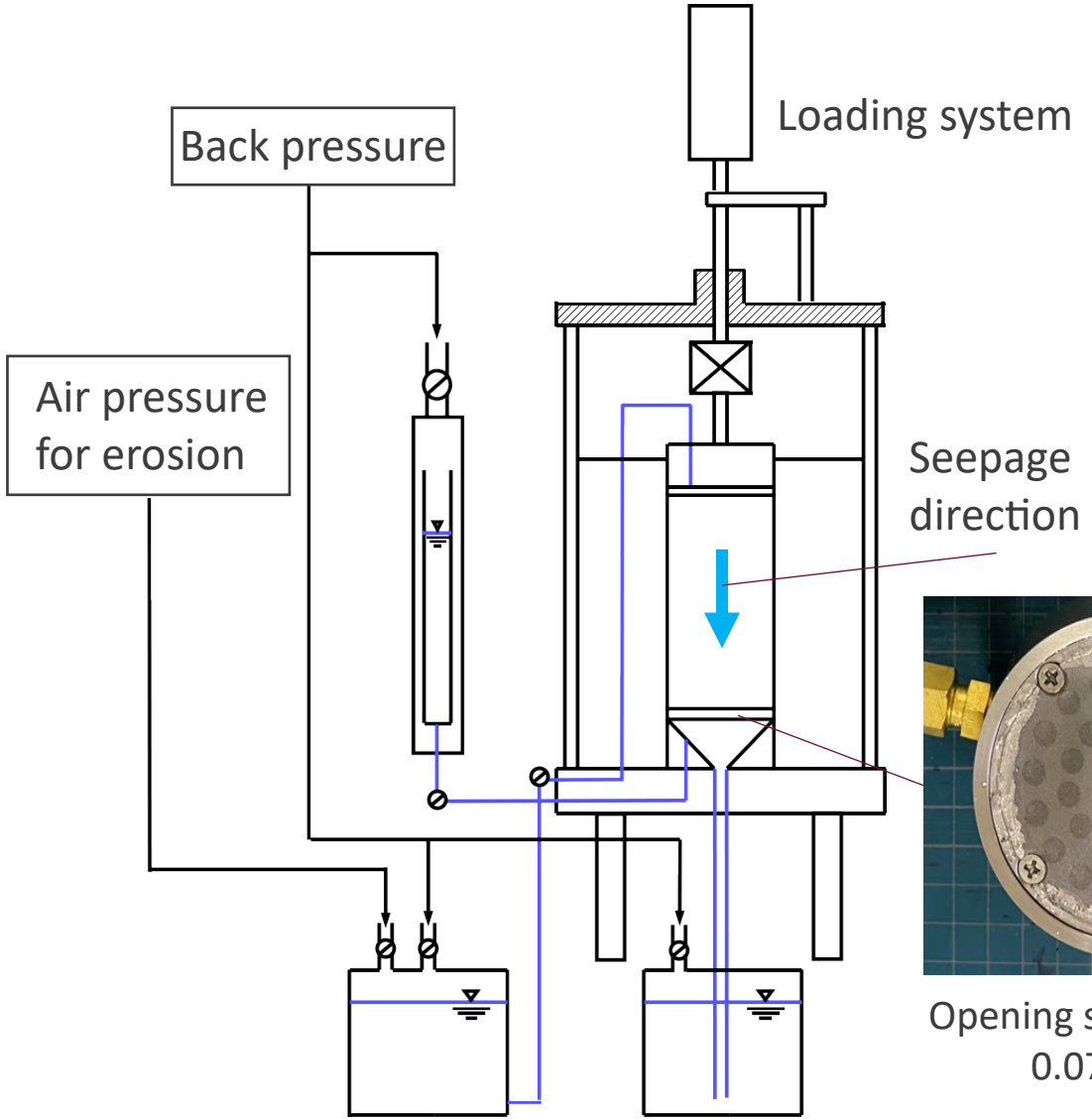
- Gap-graded Soils
- Tohoku silica silt used as fine-grains is non-plastic.
- These experimental samples are those that meet the conditions for susceptibility to suffusion.

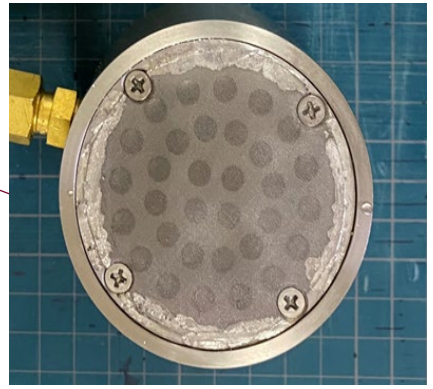
EXPERIMENTAL MATERIALS





EXPERIMENTAL APPARATUS





Opening size of mesh: 0.075 mm

Features of this experimental apparatus

- Seepage direction is downward.
- The mesh placed at the bottom of the specimen allows only fine particles to pass through.
- Because the specimen can be subjected to seepage flow under back pressure, the specimen can maintain a high degree of saturation.

Specimen conditions

- Specimen size: ϕ60mm × H120mm.
- Relative Density: 65%

Experimental conditions

- Cyclic undrained shear test
- Effective confining stress: 100 kPa
- Cyclic stress ratio: 0.1

EXPERIMENTAL METHODS

Three test procedure

NE (No Erosion)

- Bottom boundary of specimen: Filter paper

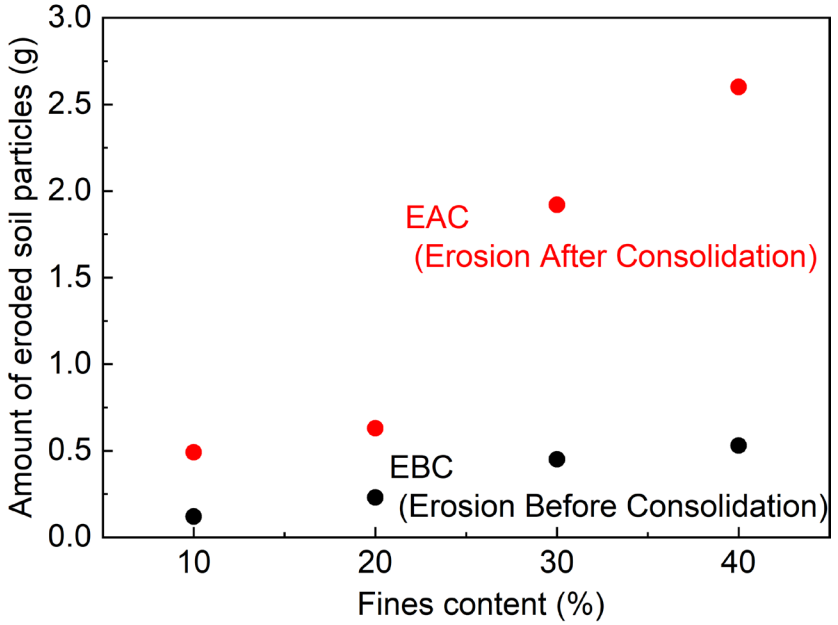
EBC (Erosion Before Consolidation)

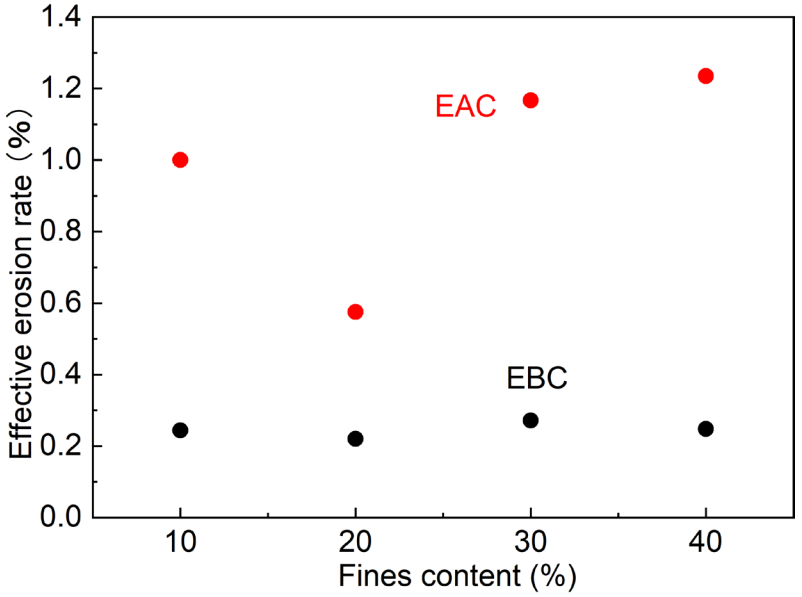
- Bottom boundary of specimen: Wire mesh (Opening size: 0.075 mm)

EAC (Erosion After Consolidation)

- Bottom boundary of specimen: Wire mesh (Opening size: 0.075 mm)
- Hydraulic gradient for erosion: 5

RESULT 1 – Status of Suffusion





Effective erosion rate

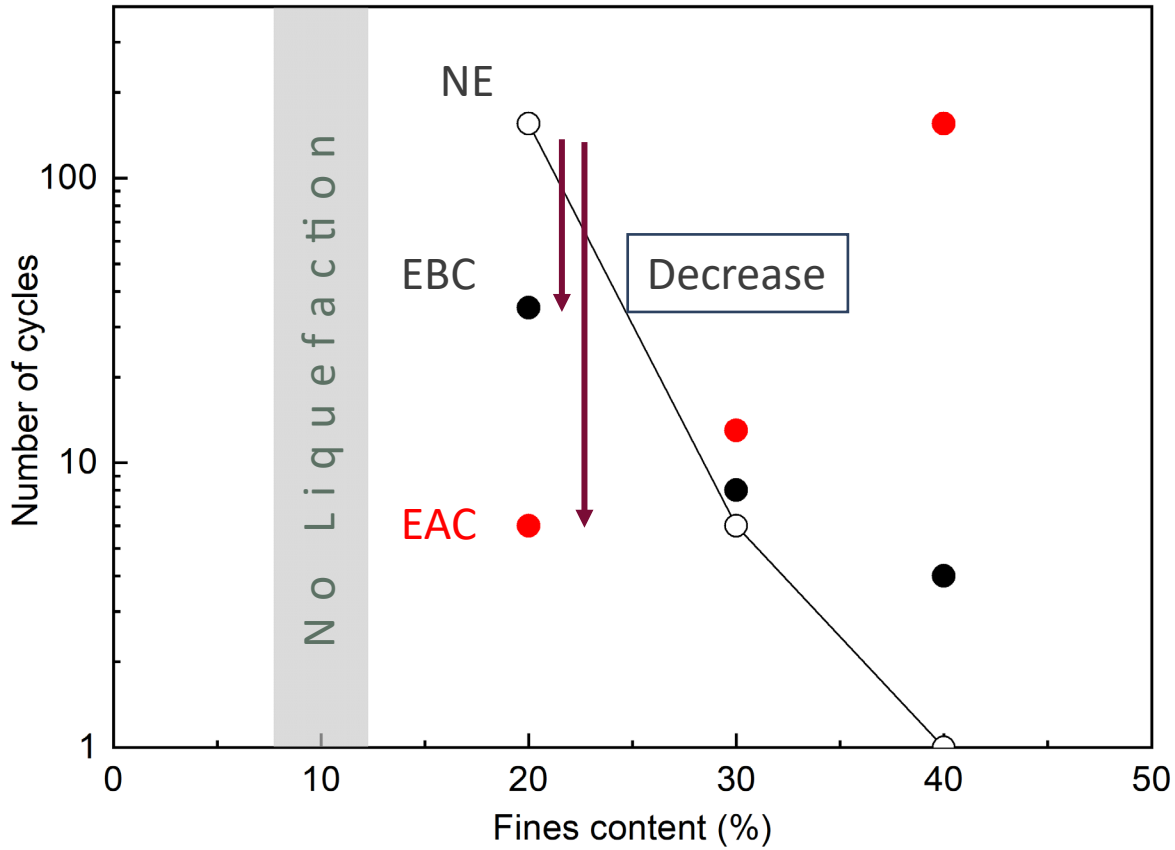
$$\frac{m_{s,\,erosion}}{m_{f,initial}} \times 100\ (\%)$$

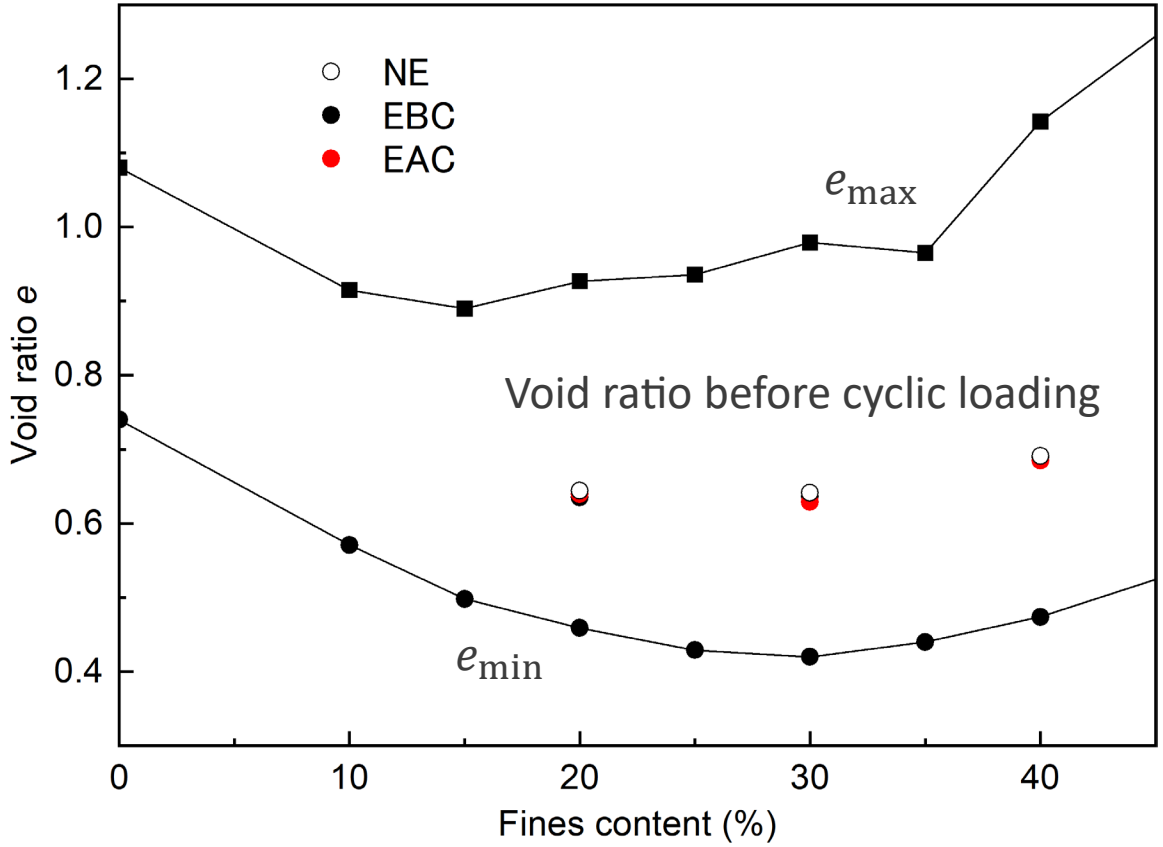
$m_{s,\,erosion}$:
Amount of eroded soil particles (g)

$m_{f,initial}$:
Initial amount of fines among the specimen

- The amount of eroded soil particles was greater in the case of EAC than in EBC.
- The higher the fines content, the more soil particles were eroded.
- In the case of EBC, the effective erosion rate was 0.2-0.3 %. When the bottom boundary of the specimen was mesh, a small amount of soil particles eroded during the seepage process for saturation.
- In the case of EAC, maximum effective erosion rate is about 1.2%.

RESULT 2 - Liquefaction Resistance -

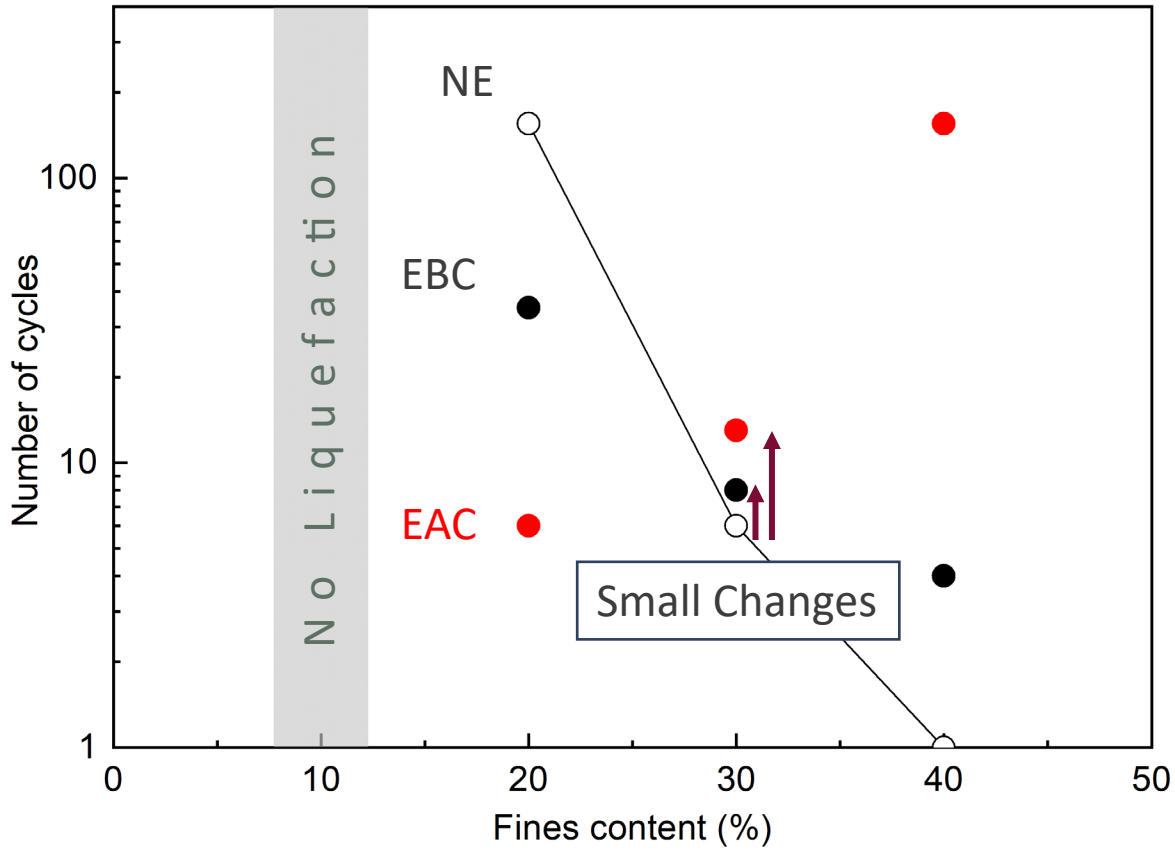


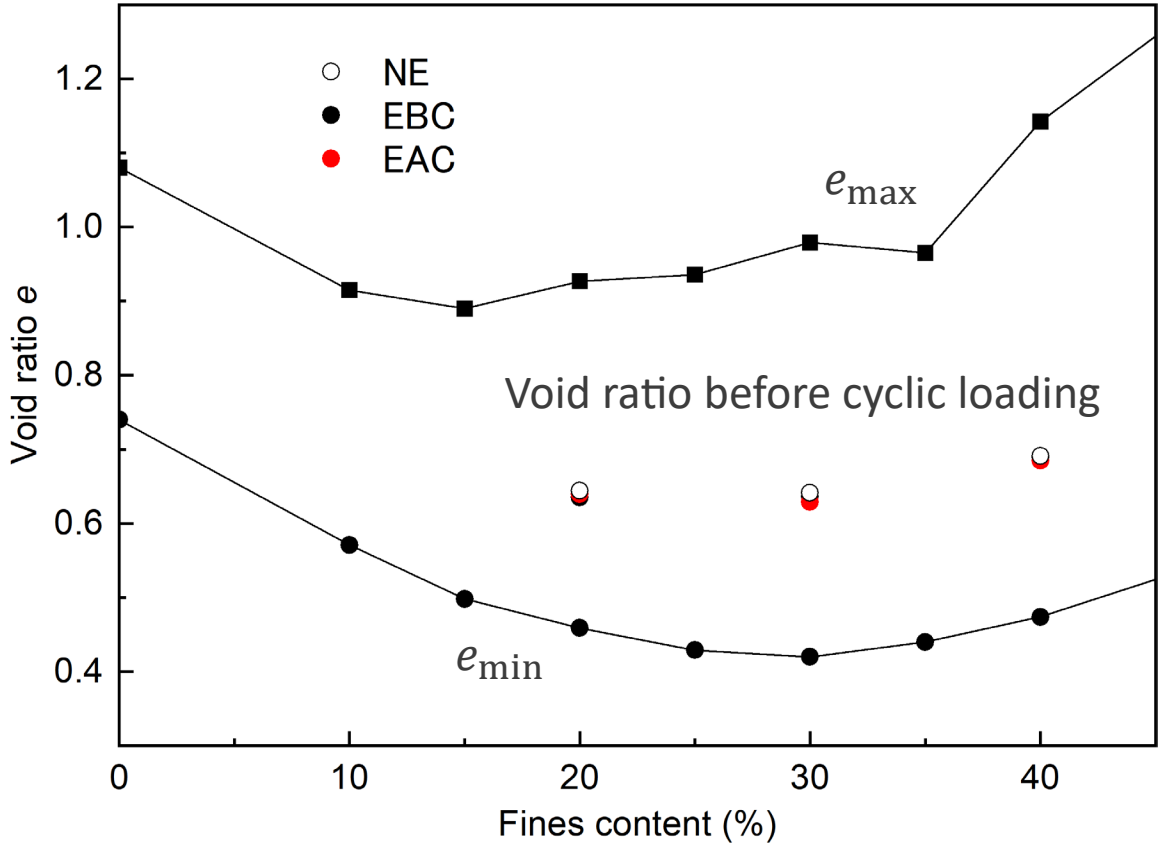


F_c = 20%

- The liquefaction resistance of the EBC and EAC was reduced compared to the NE.
- The change in liquefaction resistance is greater for EAC compared to EBC.

RESULT 2 - Liquefaction Resistance -

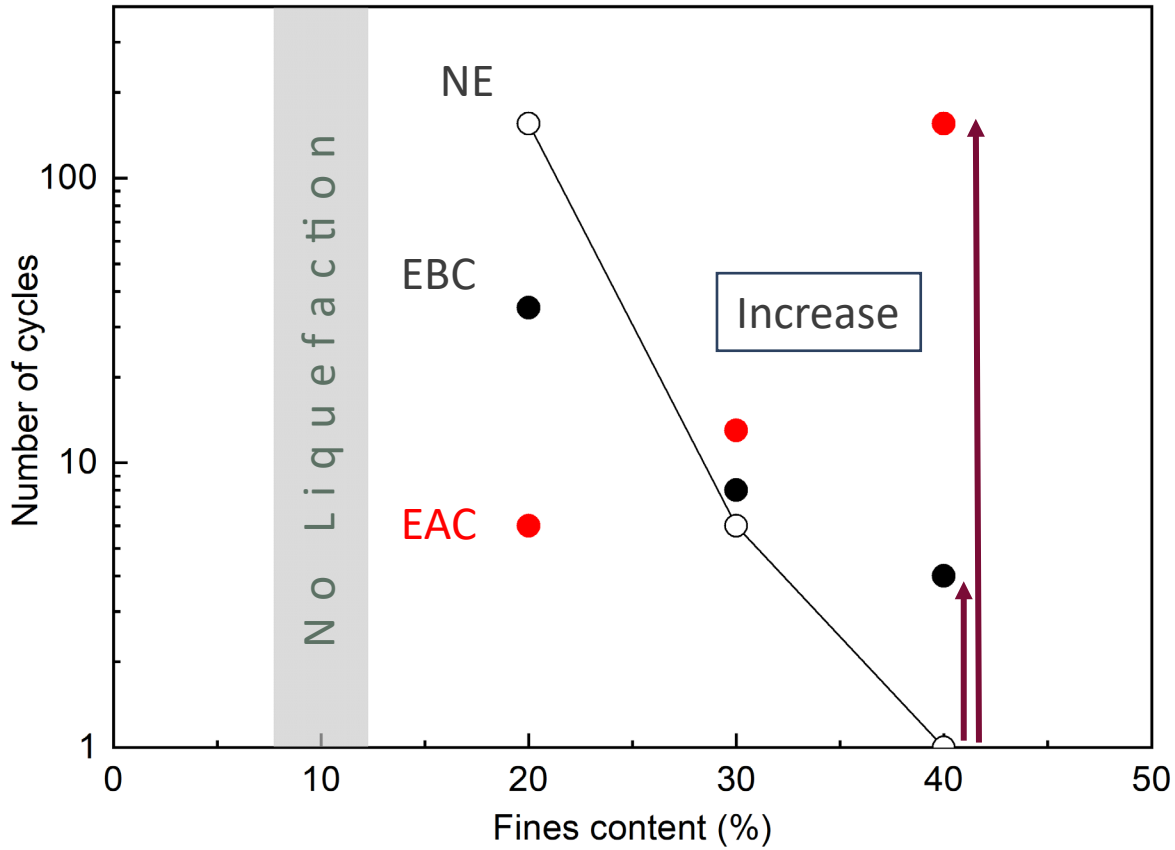


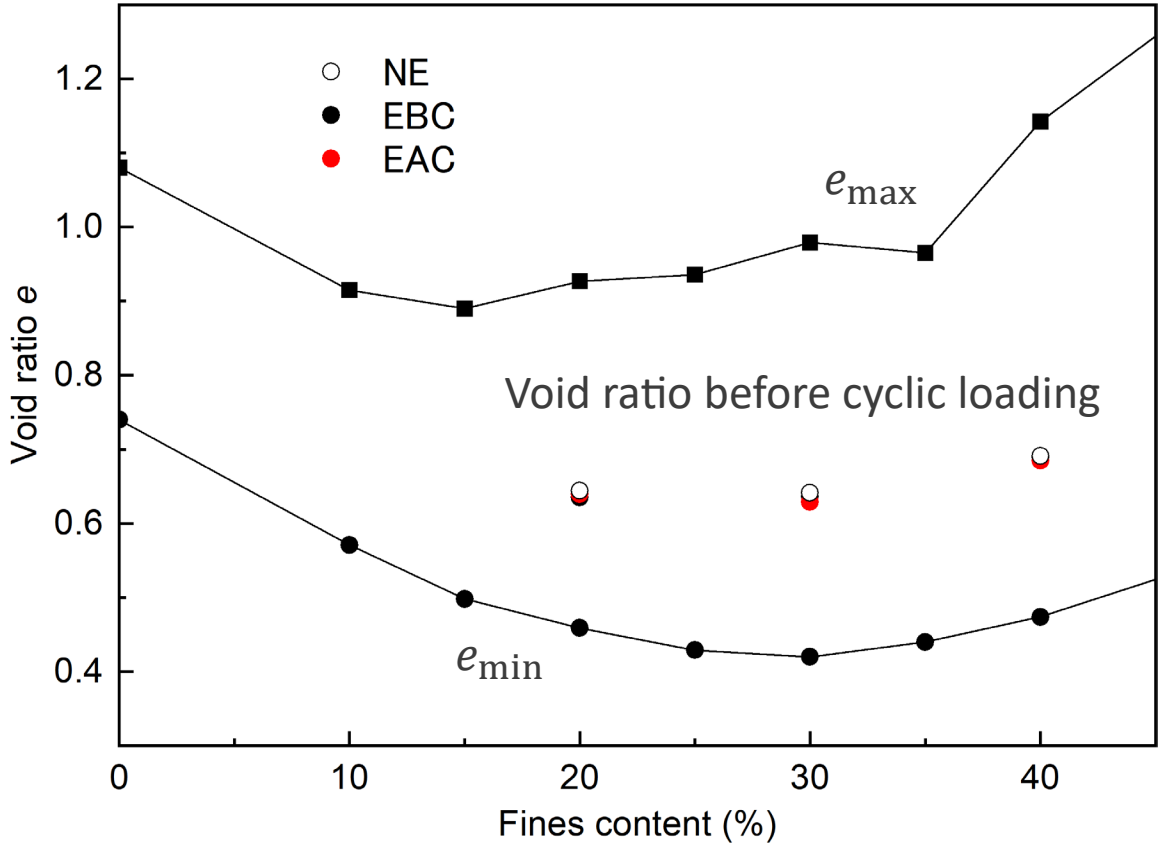


F_c = 30%

- The liquefaction resistance of the EBC and EAC was increased compared to the NE.
- However, changes in liquefaction resistance are small.

RESULT 2 - Liquefaction Resistance -





F_c = 40%

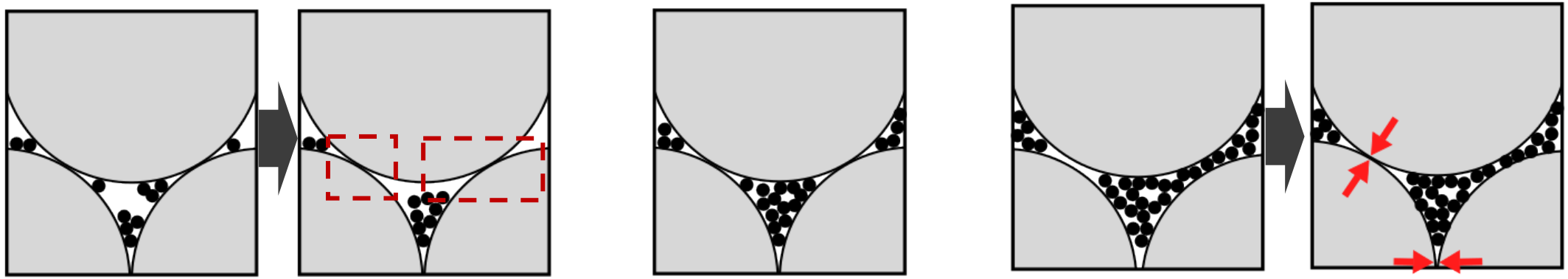
- The liquefaction resistance of the EBC and EAC was increased compared to the NE.
- The change in liquefaction resistance is greater for EAC compared to EBC.

DISCCUSION

$F_c = 20\ \%$ 30 % 40 %

Fines-in-sand matrix

Sand-in-fines matrix



F_c = 20% Liquefaction resistance decrease.

⇒ Support for fine particles between coarse particles may have been lost.

F_c = 40% Liquefaction resistance increase.

⇒ The loss of fine particles between coarse particles may have increased contact between coarse particles.

CONCLUSION

A series of undrained cyclic triaxial tests were conducted on soil specimens affected by seepage and erosion history, and examined the effects of suffusion on liquefaction resistance.

- The effects of suffusion on liquefaction resistance was found to vary depending on the fines content.
- The difference in the effect of suffusion on liquefaction resistance is due to differences in the skeletal structure of soils with different fines content.