香港科技大學
THE HONG KONG UNIVERSITY OF SCIENCE AND TECHNOLOGY

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Revealing the liquefaction mechanism and anisotropy behaviour of root-reinforced soils: an energy-based approach

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Abstract

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Sharing is encouraged

Outline

- ❑ Introduction and background of research
- ❑ Methodology
  - Materials and sample preparation
  - Test plan
  - Energy based method interpretation
- ❑ Results and discussion
  - Effect of roots on liquefaction resistance
  - Root effects on anisotropic behaviour of soil upon cyclic loading
- ❑ Conclusions

Introduction (liquefaction and landslides)

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Indonesia, Palu (2018)
7.5 M_w
2100 fatalities
(Combination of flow liquefaction and landslide)
The New York Times footage on YouTube

Japan, Hokkaido (2018)
6.6 M_w
41 fatalities
(Earthquake after Jebil typhoon)
The Ashai Shimbun/Getty image

Methodology (Sample preparation)

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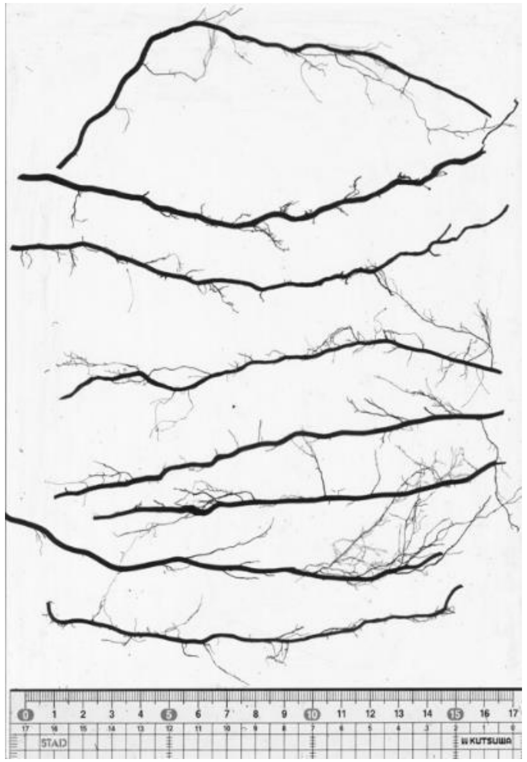
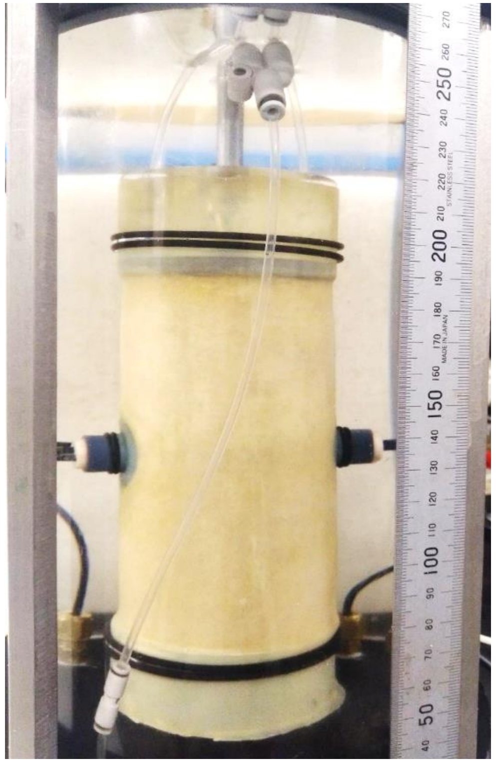


EPSON scanner
(Model: STD4800,)
Pro-WinRHIZO

Attach the roots on the pedestal
Deposited sand



Put membrane and install bender elements

Artificial sample

- Toyoura sand
- Diameter of 75 mm and 152 mm height
- *Dry deposition*
- *Dr = 64% and e=0.73*
- Void ratio of the soil matrix in all of the rooted specimen was the same as bare specimens
- Advantage:
  - Root distribution
  - Repeatability

Methodology (Test plan)

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Strain-controlled test

- Different Root Volume Ratio (RVR)
- Different Cyclic Stress Ratio (CSR)

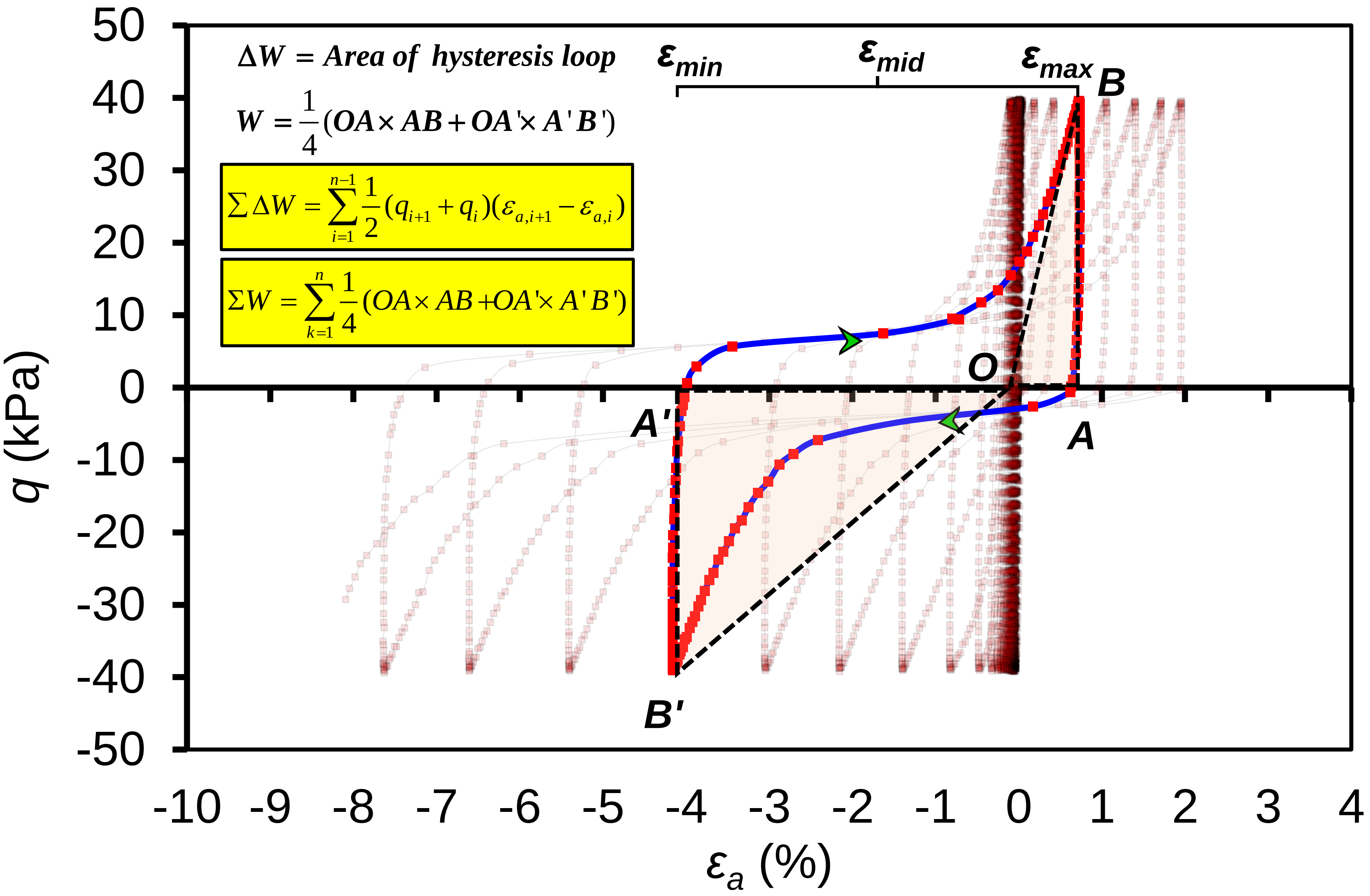
$$RVR = \frac{Volume\ of\ roots}{Volume\ of\ soil} \qquad CSR = \frac{q_{cyc}}{2\sigma'_{3c}}$$

Test procedures

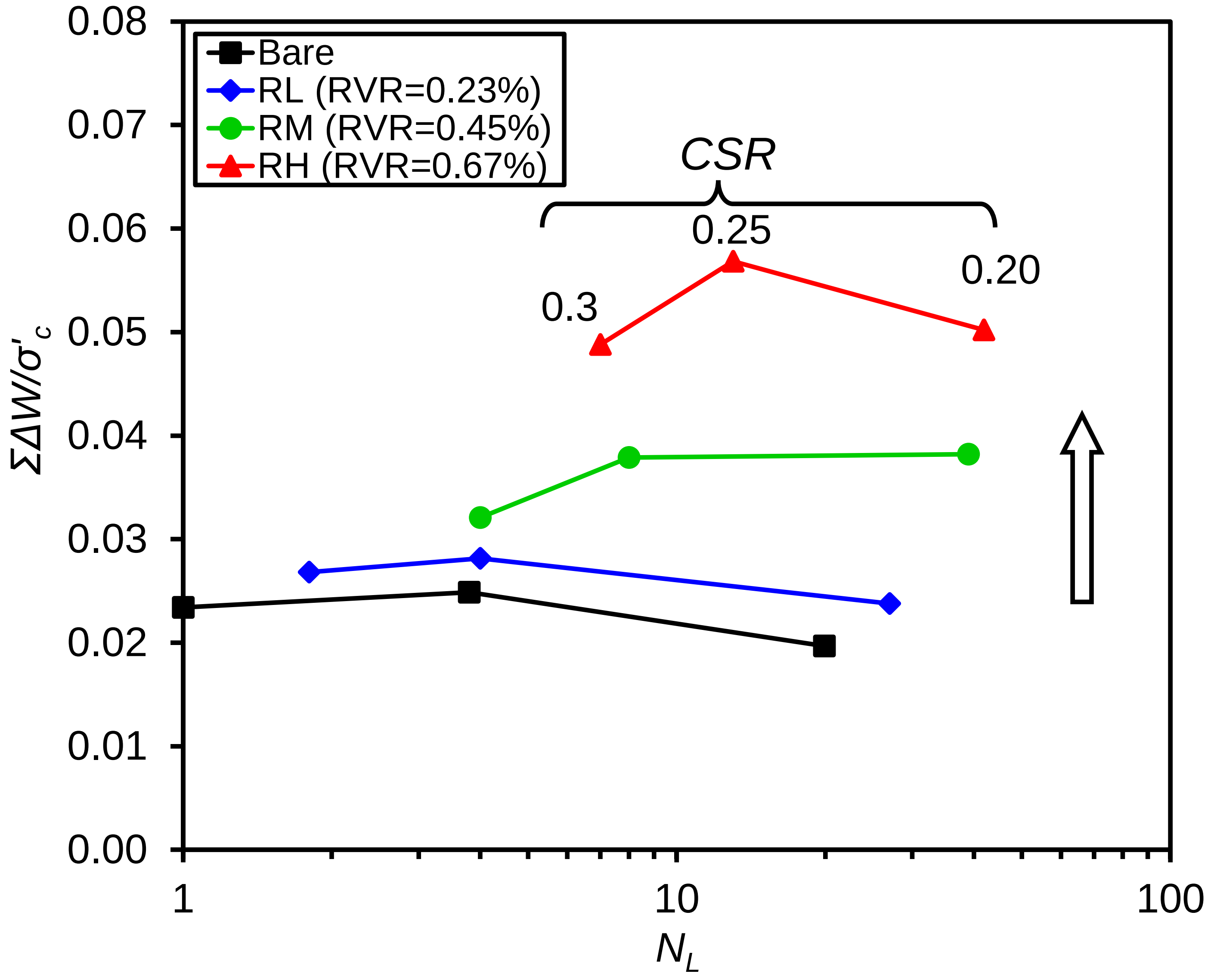
- Back-pressure saturation
- Drained consolidation at a given confining pressure
- Undrained cyclic shearing at a frequency of 0.05 Hz

Test	Sample type	RVR (%)	p_c' (kPa)	e	CSR
B-CSR0.20	Bare	0.00	100	0.726	0.20
RL-CSR0.20	Rooted	0.23	100	0.733	0.20
RM-CSR0.20	Rooted	0.45	100	0.735	0.20
RH-CSR0.20	Rooted	0.67	100	0.740	0.20
B-CSR0.25	Bare	0.00	100	0.727	0.25
RL-CSR0.25	Rooted	0.23	100	0.731	0.25
RM-CSR0.25	Rooted	0.45	100	0.734	0.25
RH-CSR0.25	Rooted	0.67	100	0.739	0.25
B-CSR0.30	Bare	0.00	100	0.729	0.30
RL-CSR0.30	Rooted	0.23	100	0.732	0.30
RM-CSR0.30	Rooted	0.45	100	0.735	0.30
RH-CSR0.30	Rooted	0.67	100	0.740	0.30

Methodology (EBM interpretation)

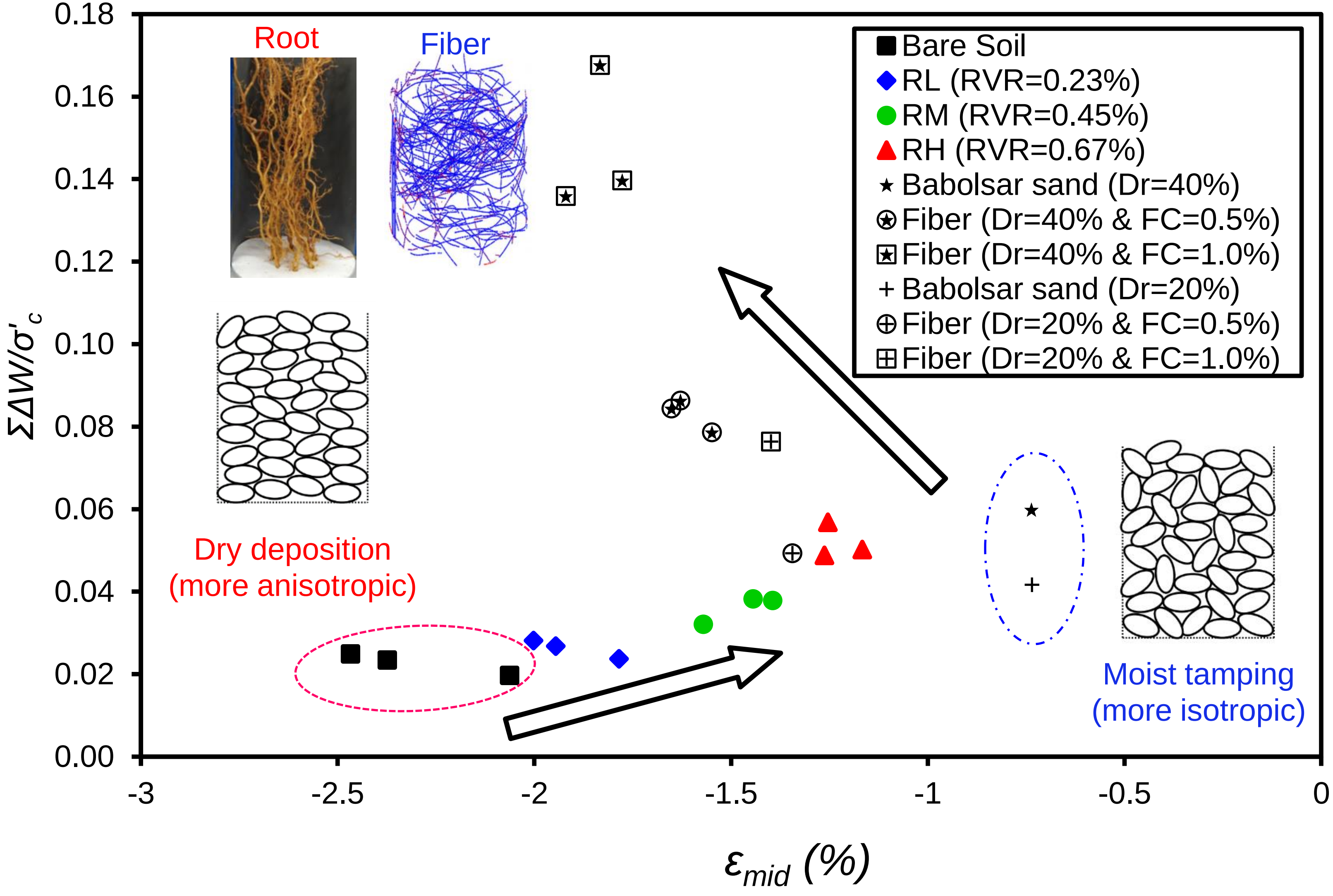


Result (liquefaction resistance)



- Roots increase the **energy required** to reach liquefaction state
- Soils with **higher RVRs** dissipated **more energy**
- For **low RVRs**, energy dissipation is **independent** of N_L and CSR

Result (anisotropy)



- Roots **reduce** soil anisotropy
- Fibers **increase** soil anisotropy
- Depending on
  - Initial soil fabric anisotropy
  - Distribution of reinforcement element

Conclusions

- The cumulative dissipated energy is independent of N_L and *CSR* at low root volume ratios (*RVRs* < 0.22%), but not for the case for higher *RVRs*
- The dissipated energy of rooted soil is uniquely correlated with the cyclic resistance ratio at the cycle number of 15 (CRR_{15}) and this relationship is independent of *RVRs*
- Roots reduces anisotropy of soil produced by the dry deposition method
- The dissipated energy is linearly correlated with the cumulative strain energy with a gradient of approximately 2 that recycling and recovering of strain energy is minimal in these reinforced soils.

Reference

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Technical Note

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ASCE

Energy-Based Assessment of Liquefaction Resistance of Rooted Soil

Ali Akbar Karimzadeh[1]; Anthony Kwan Leung[2]; and Pedram Fardad Amini, Aff.M.ASCE[3]

Abstract: Plant roots have been shown to improve the soil resistance to liquefaction upon cyclic loading. However, the effect of roots and their orientations on any changes in soil anisotropy and the mechanisms of dissipated energy involved at liquefaction state are not clear. This study applied the energy-based method to evaluate the liquefaction behavior of rooted soils of varying root volume ratios (RVRs). Results of 12 undrained cyclic triaxial tests on rooted soils published in the literature were reinterpreted under this energy framework. The assessment showed that the normalized cumulative dissipated energy ($\sum \Delta W/\sigma_c'$, where σ_c' is the effective confining pressure) of rooted soil at liquefaction state can be related to the cyclic resistance ratio at 15 cycles (CRR_{15}). It was discovered that roots that were predominantly orientated in the direction perpendicular to the major principal stress of extension path reduced soil anisotropy. Additionally, the $\sum \Delta W/\sigma_c'$ was linearly correlated with the normalized cumulative strain energy ($\sum 4W/\sigma_c'$) with a gradient of approximately 2, which implies that any recycling and recovering of strain energy was minimal in rooted soils. **DOI: 10.1061/(ASCE)GT.1943-5606.0002717.**

Author keywords: Energy-based method; Rooted soil; Anisotropy; Cyclic triaxial test.

Karimzadeh, Ali Akbar, Anthony Kwan Leung, and Pedram Fardad Amini. "**Energy-Based Assessment of Liquefaction Resistance of Rooted Soil**." *Journal of Geotechnical and Geoenvironmental Engineering* 148.1 (2022): 06021016.

Thank you very much for your attention!