THE UNIVERSITY OF MELBOURNE

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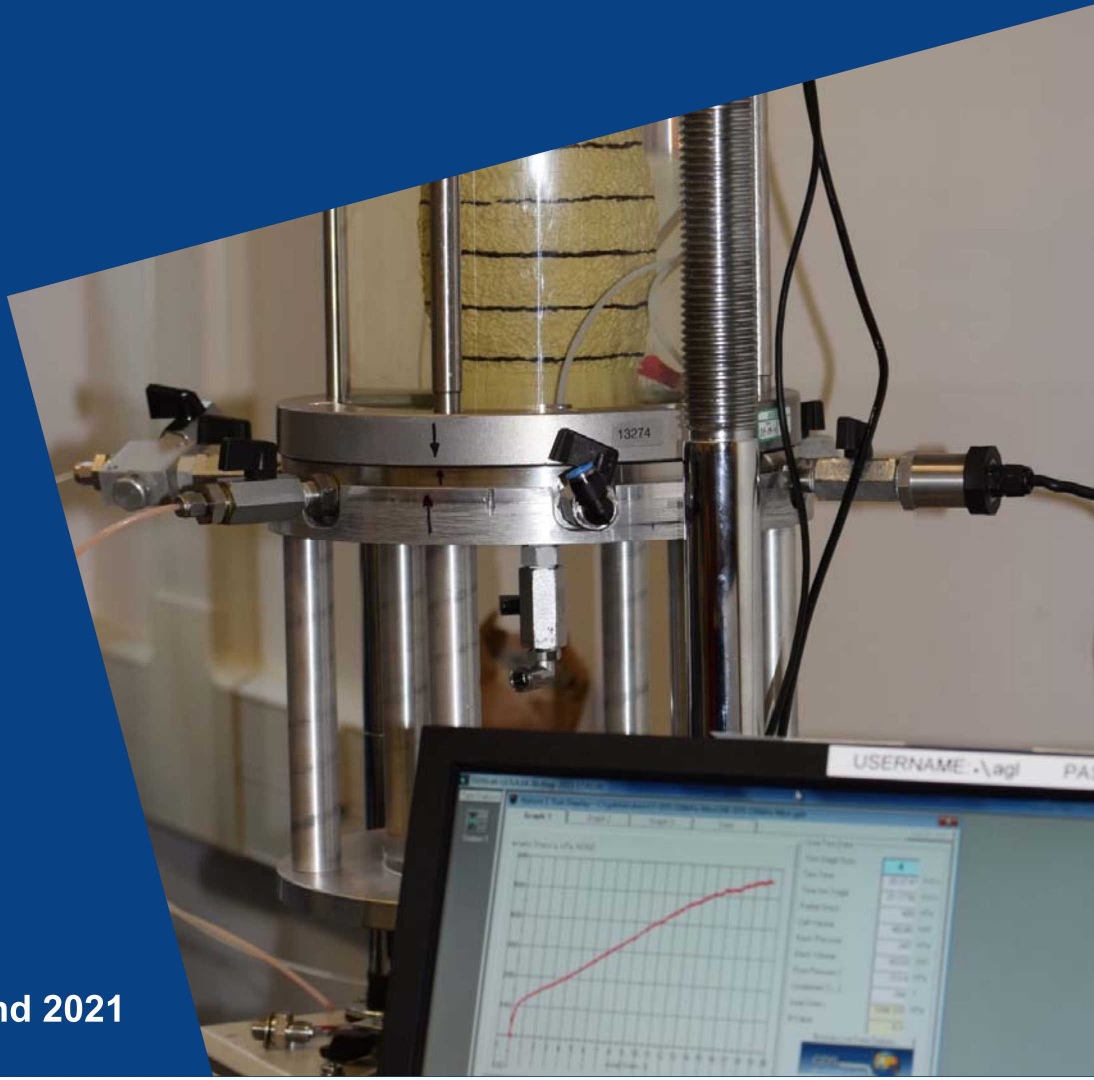
Post-erosion mechanical response of internally unstable soil under monotonic and cyclic loadings



Amir Mehdizadeh

Mahdi Disfani

EWG-IE 2021 ONLINE WORKSHOP February 2nd 2021

Erosion: A Persistent Problem

Major Melbourne dam needs repair to lower risk of catastrophic flood

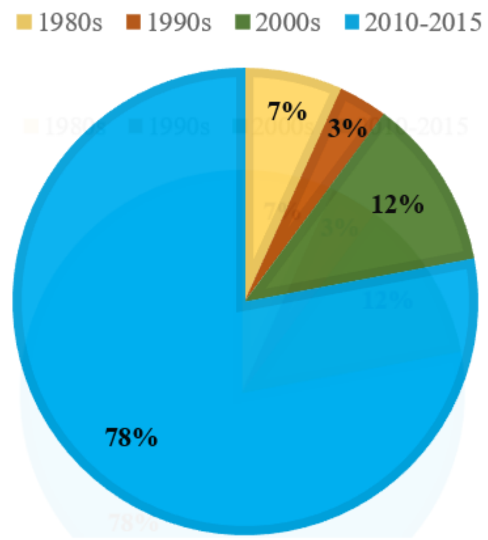
THE AGE

3 June 2019

A 2018 collaborative research project resulted in an improved understanding of the phenomenon of *internal erosion in embankment dams and general erosion in unlined spillways* (Melbourne Water, 2018)

Shortcoming of the Current Knowledge

- Effect of initial fine content on internal erosion
- Effect of hydraulic gradient on internal erosion
- Effect of soil gradation on internal erosion
- Effect of confining pressure on internal erosion
- Effect of seepage direction on internal erosion
- Investigation of granular filter criteria (Internal stability)
- Effect of seepage length on internal erosion
- Effect of particle shape on internal erosion
- Effect of relative density on internal erosion
- Effect of seepage duration
- Effect of specimen dimensions and erosion path on soil response during internal erosion
- Post-erosion behaviour (drained or undrained)



Contribution of each decade in the experimental investigation of internal erosion

Impact of Erosion on Soil's Behaviour

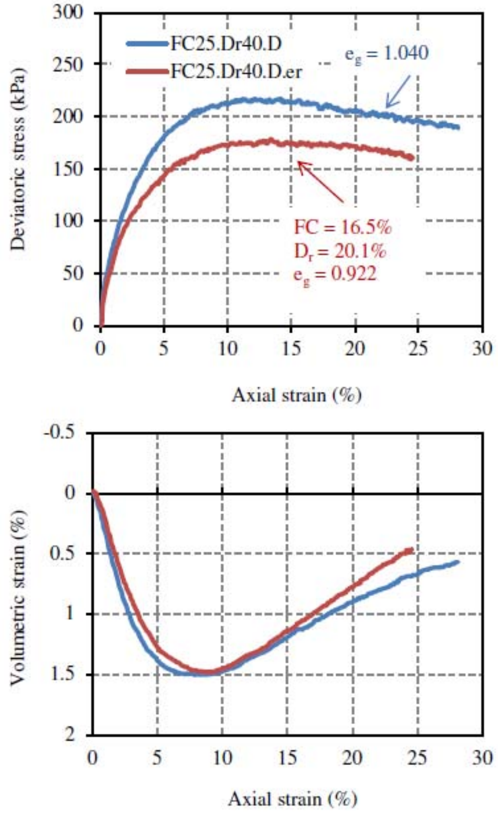


Figure 8. Drained triaxial tests on the non-eroded and eroded soils.

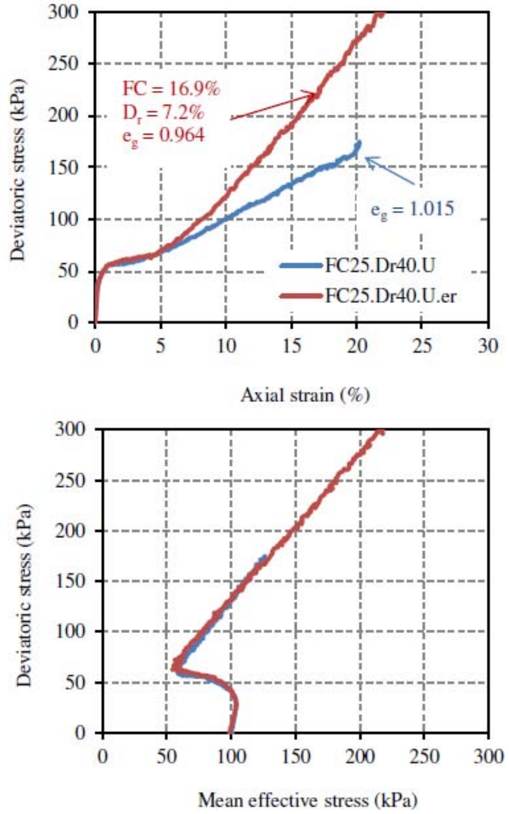
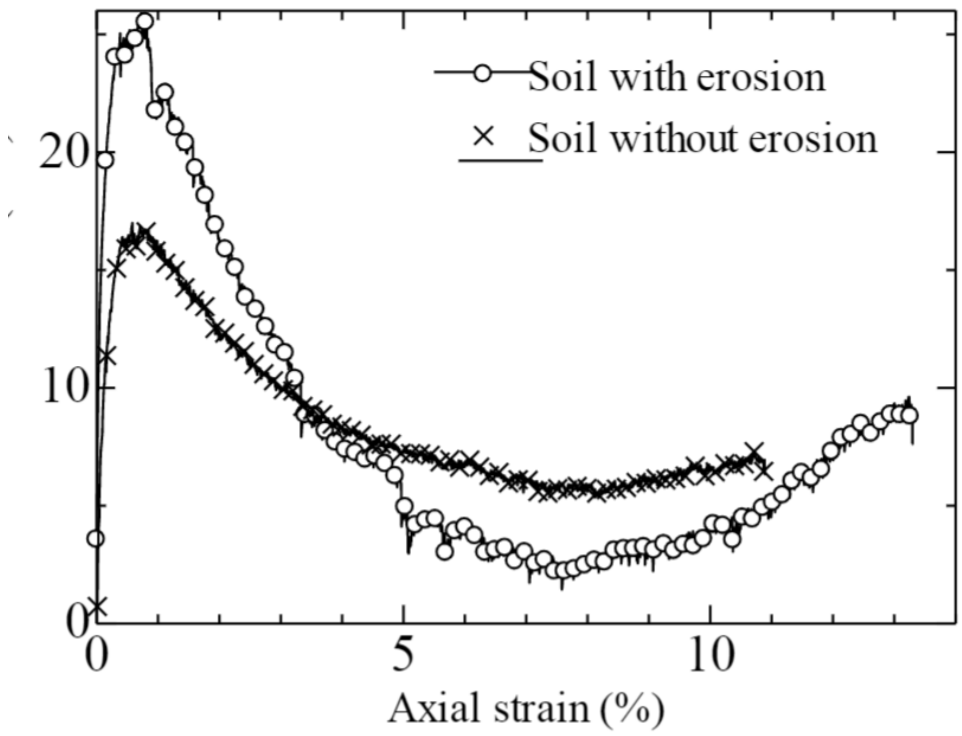


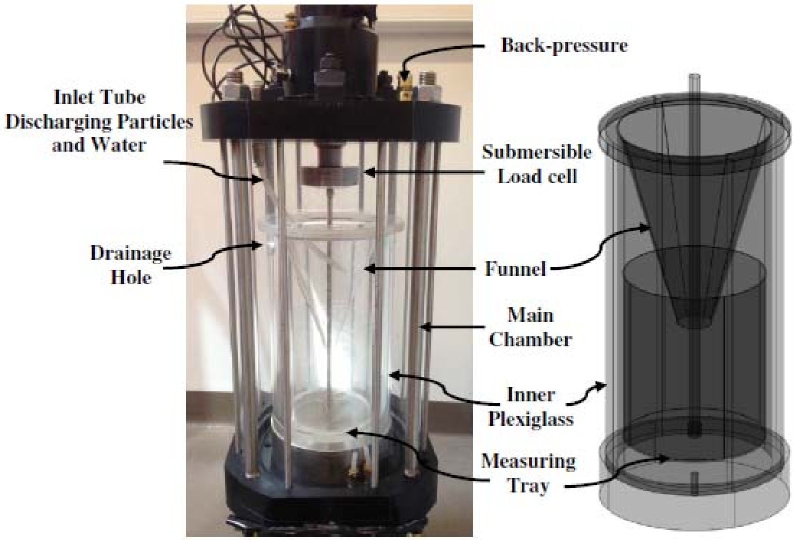
Figure 9. Undrained triaxial tests on the non-eroded and eroded soils.

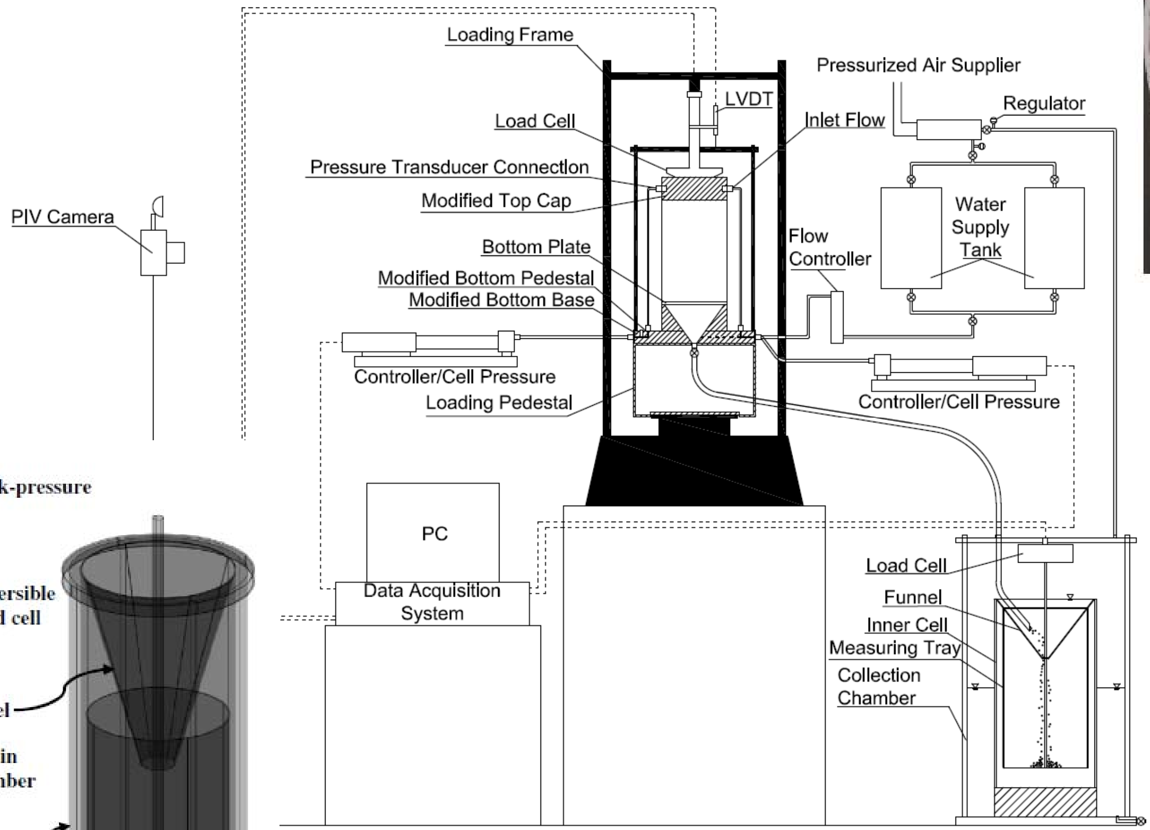
Nguyen et al, 2020

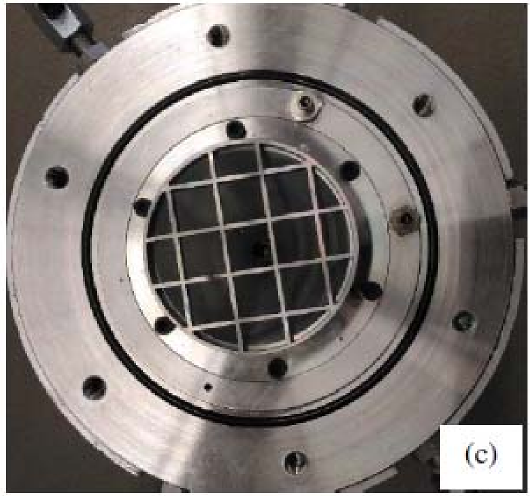


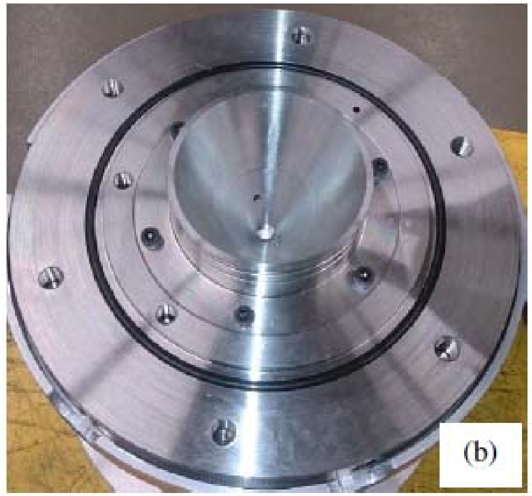
Ke and Takahashi, 2014

Our Experimental Approach

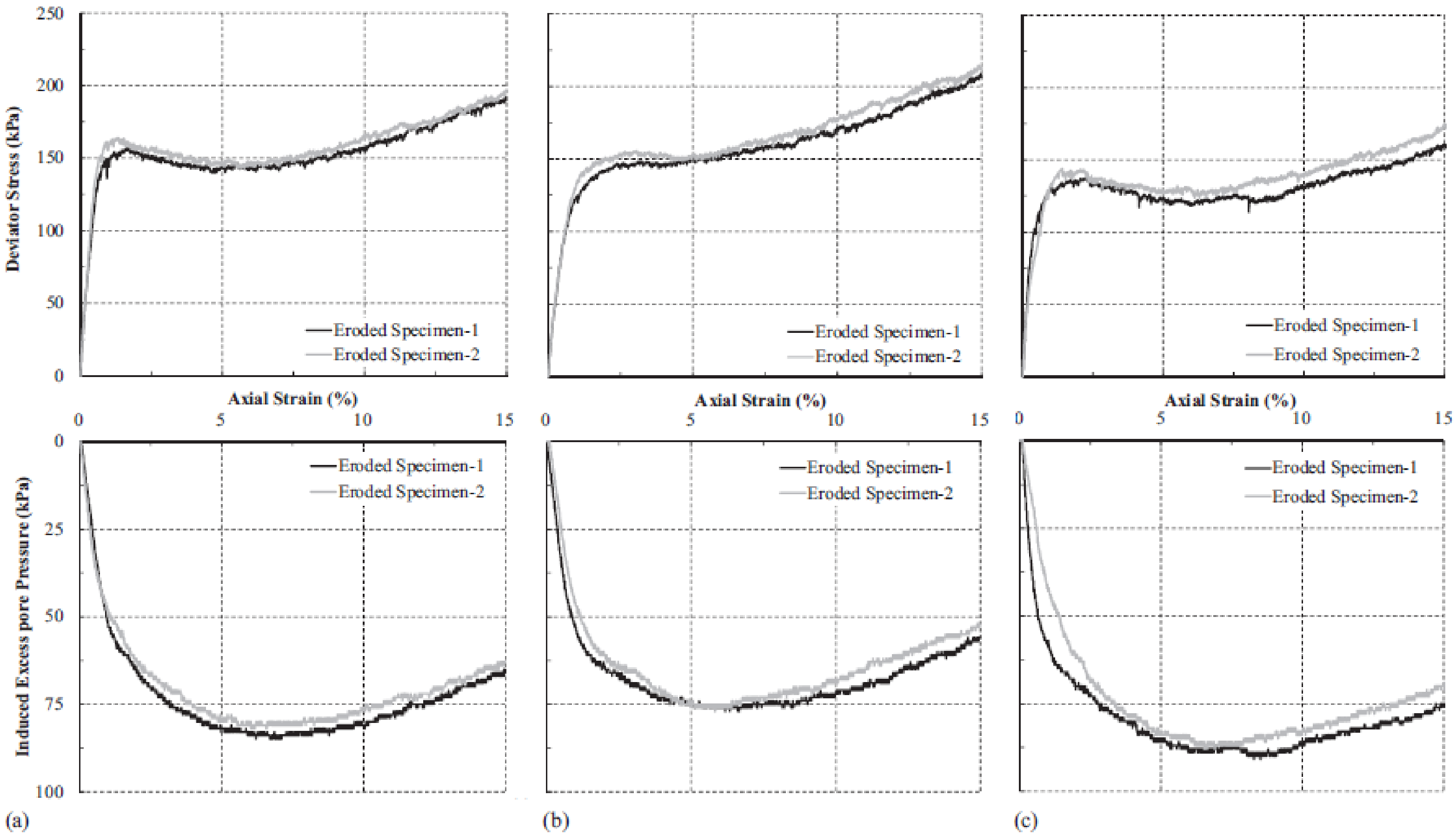




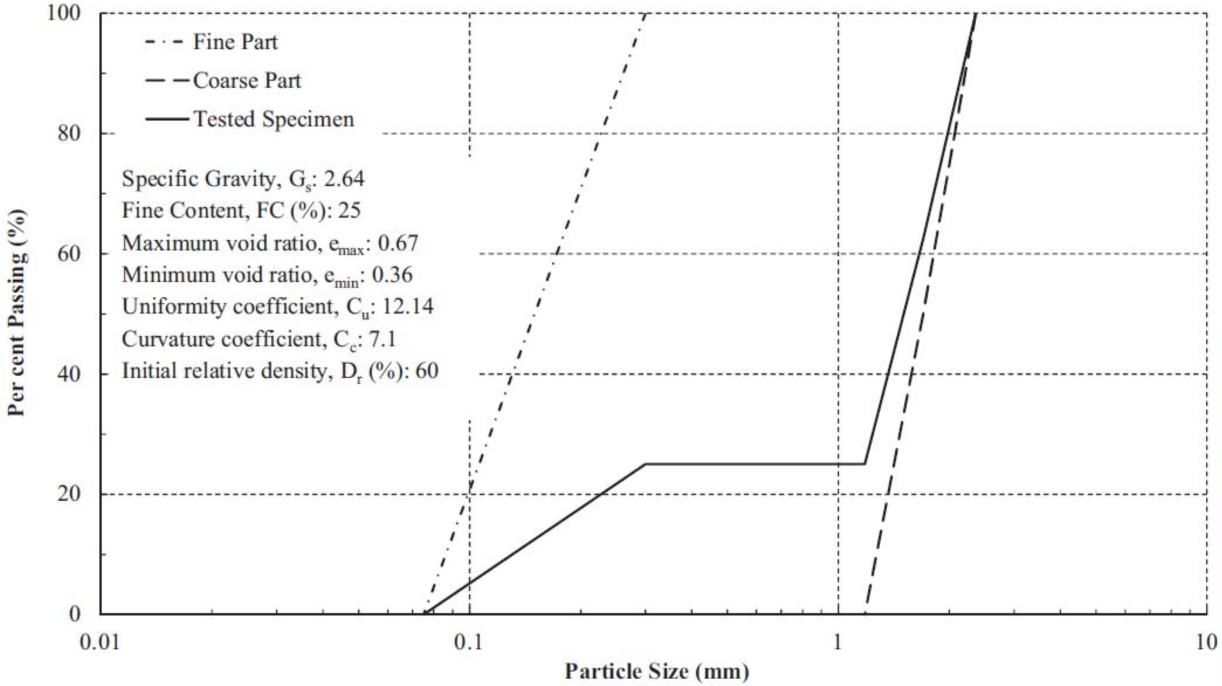


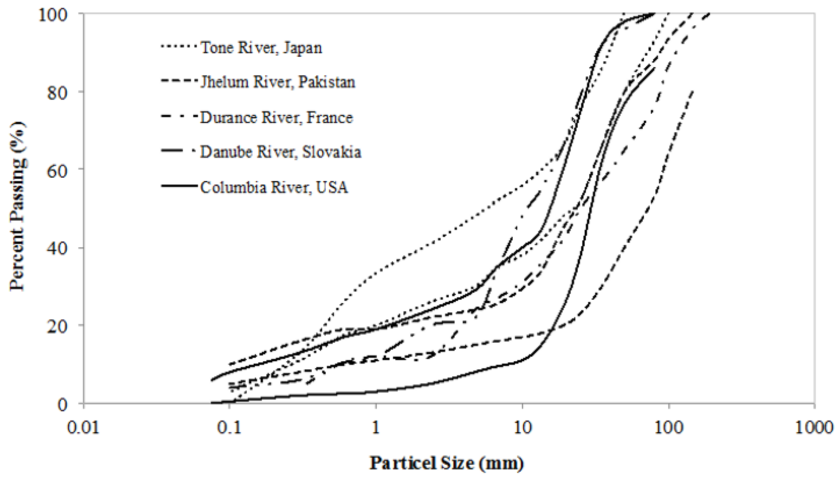


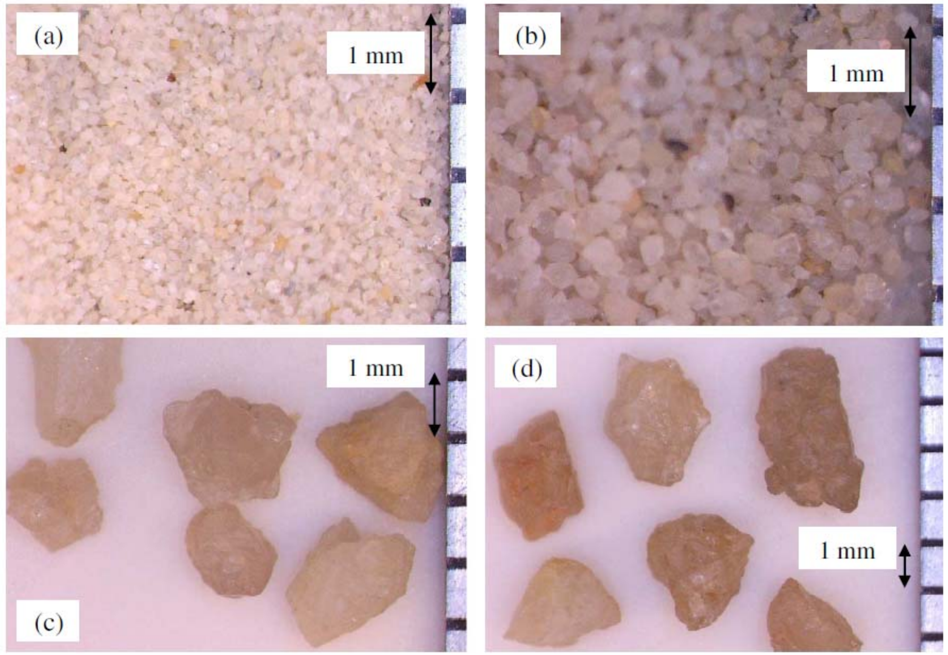
Repeatability of Experiments



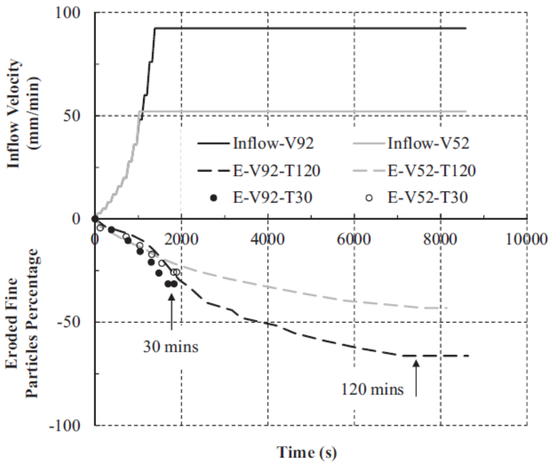
Soil Properties

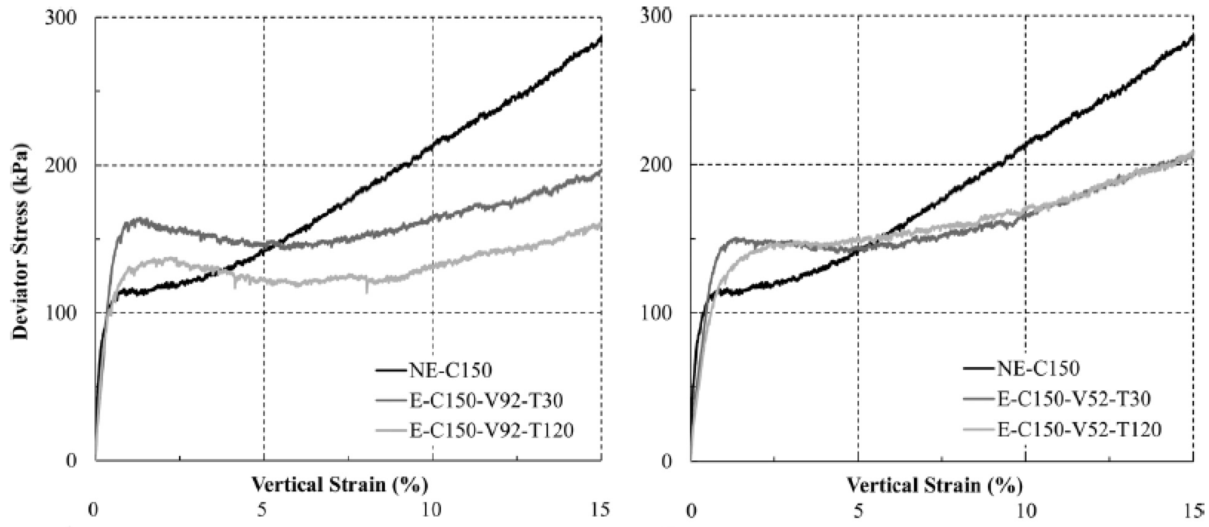






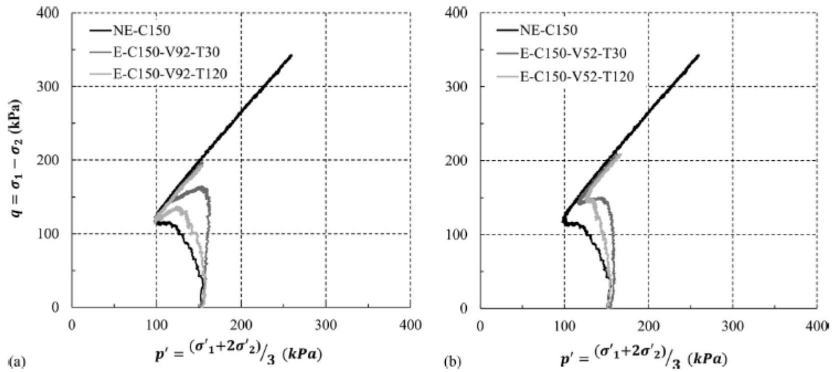
Post-Erosion Undrained Behaviour





Specimen identification	Initial coarse fraction (g)	Initial fine fraction (g)	FC_i (%)[a]	Eroded fine (g)	Survived fine (g)	FC_f (%)[b]	Eroded percentage
E-C150-V92-T30	905.25	301.75	25	95	206.75	18.6	31.5
E-C150-V92-T120	905.25	301.75	25	200	101.75	10.1	66.3
E-C150-V52-T30	905.25	301.75	25	78	223.75	19.8	25.8
E-C150-V52-T120	905.25	301.75	25	130	171.75	15.9	43.1
NE-C150	905.25	301.75	25	0	301.75	25	0.0

Note: C = consolidation pressure; E = eroded; NE = noneroded; T = erosion duration; V = seepage velocity.
[a]Initial fine content.
[b]Final (residual) fine content.

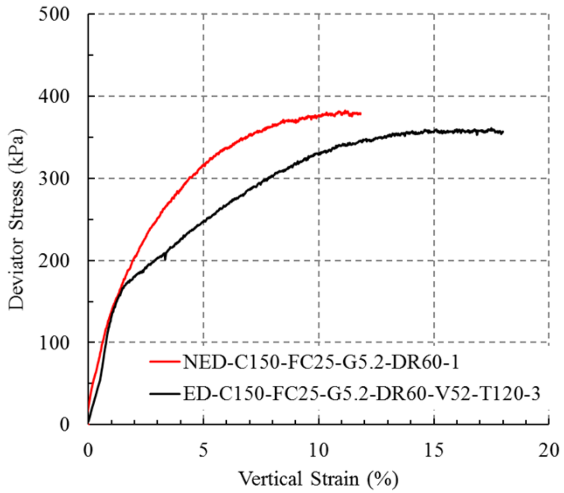


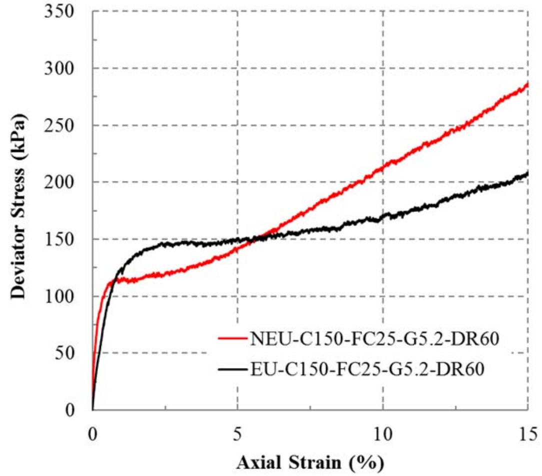
Post-Erosion Drained and Undrained Behaviour

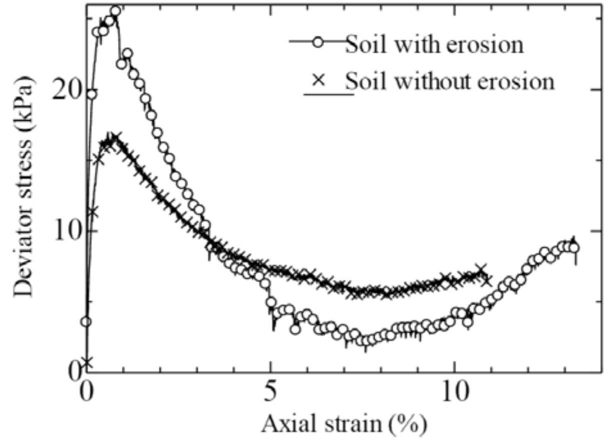
Ke and Takahashi, 2014

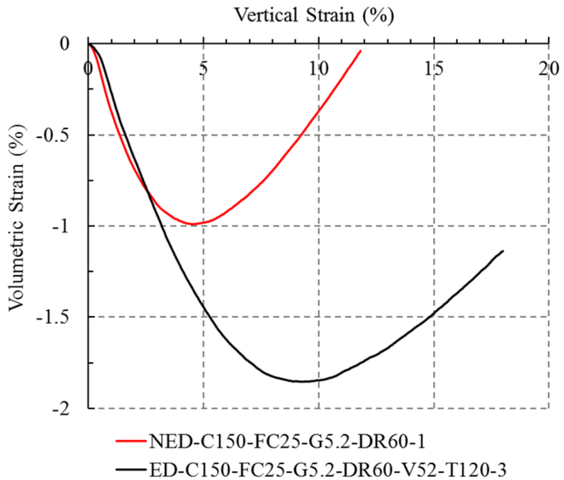
FC_i: 25 %

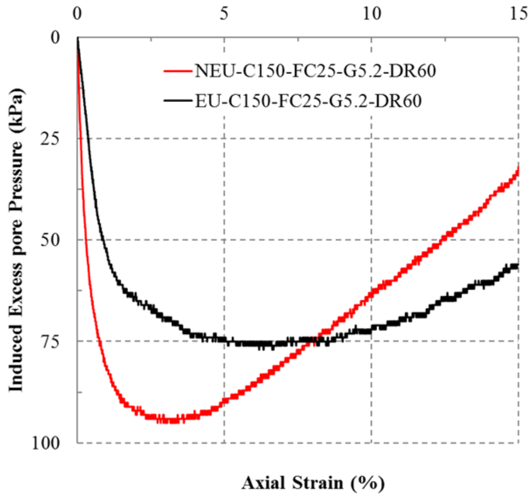
FC_f: 15 ~ 16%

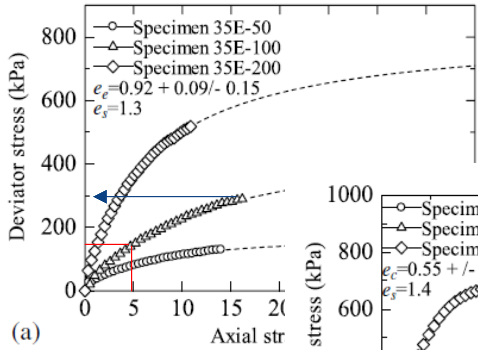


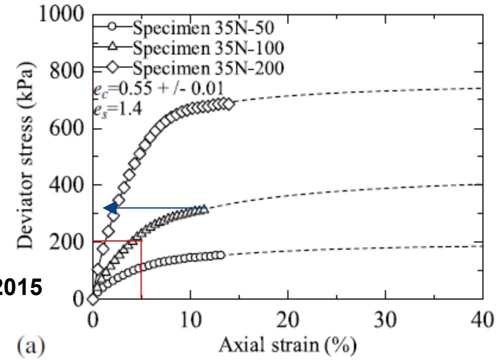






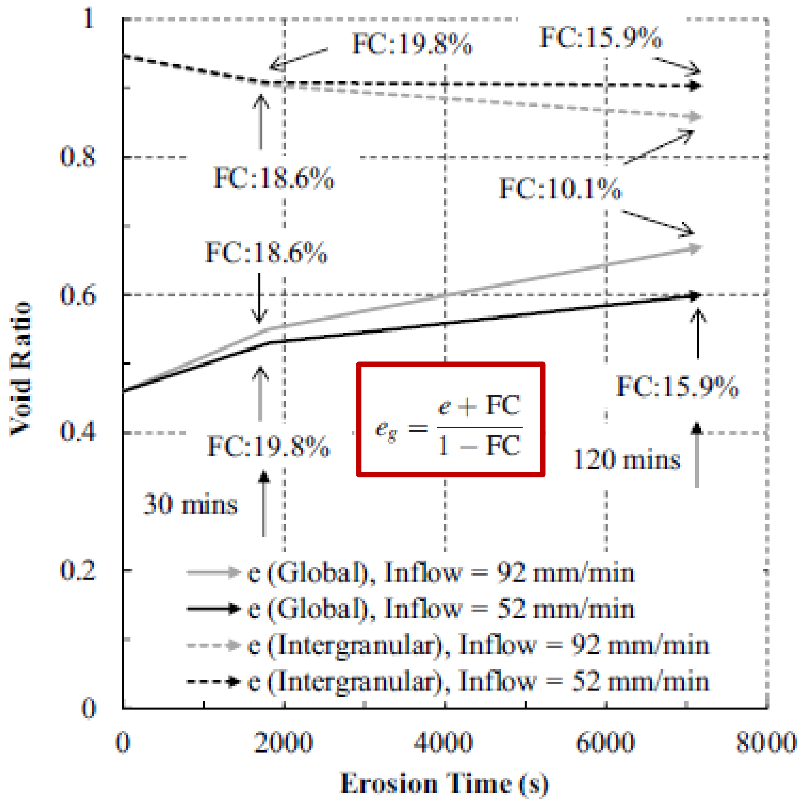


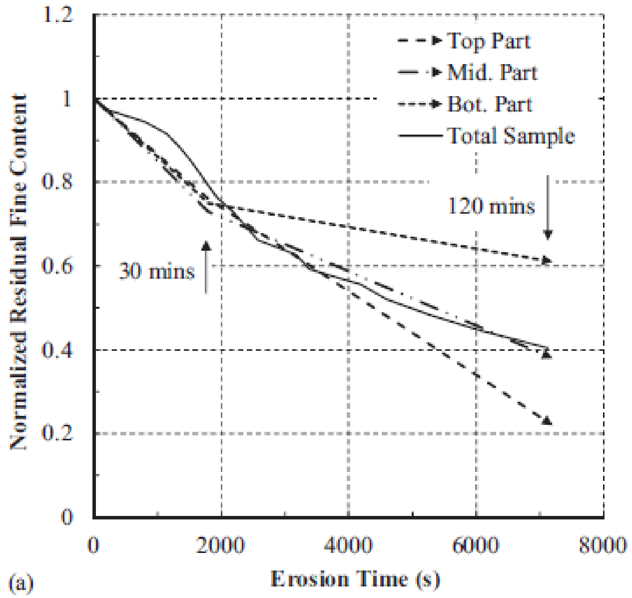


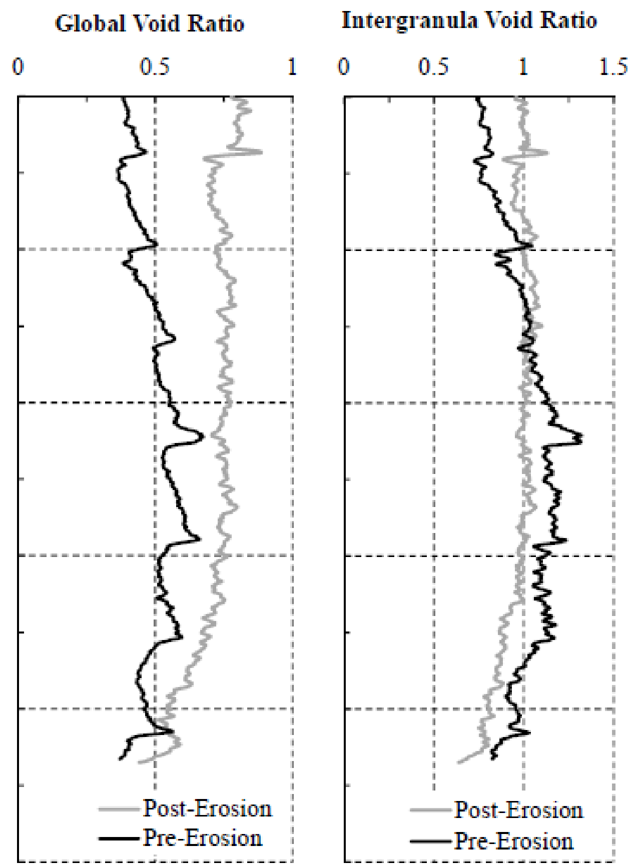


Ke and Takahashi, 2015

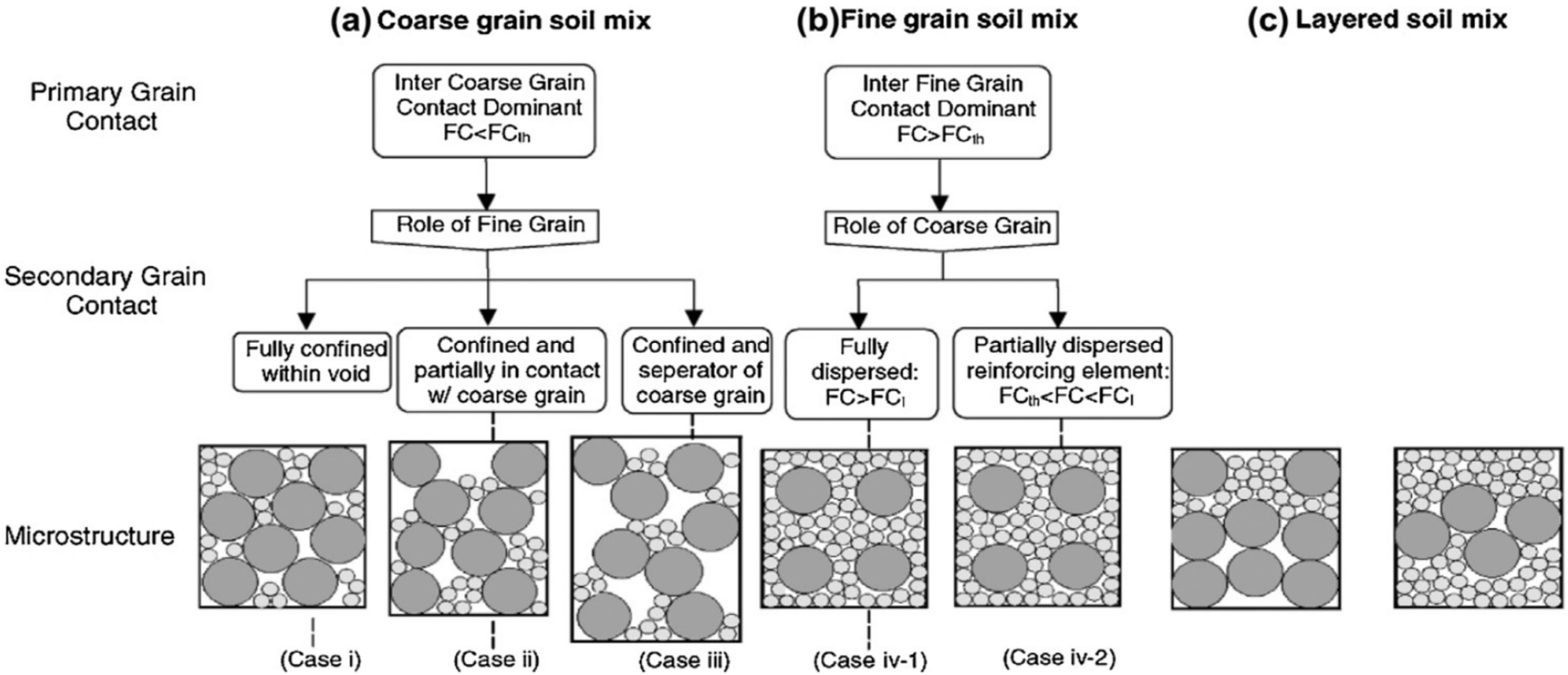
Post-Erosion Undrained Behaviour







Role of Fine Particles!



(Thevanayagam, 2007)

Post-Erosion Undrained Behaviour

$$e_{c\,\mathrm{eq}} = \frac{e + (1-b)\mathrm{FC}}{1-(1-b)\mathrm{FC}};\ 0 < b < 1$$

Thevanayagam et al. (2002)

where b = portion of FC participating in the soil stress matrix [i.e., b = 0 when fine particles are completely free and inactive (filler), and b = 1 when all of the fine particles are involved in the soil skeleton]

$$b = \left\{1 - \exp\left[-0.3\frac{\left(\frac{\mathrm{FC}}{\mathrm{FC}_{\mathrm{Crit}}}\right)}{k}\right]\right\}\left(r\frac{\mathrm{FC}}{\mathrm{FC}_{\mathrm{Crit}}}\right)^{r}$$

Rahman et al. (2008)

→

$$\mathrm{FC}_{\mathrm{Crit}} = 0.4\left(\frac{1}{1+e^{\alpha-\beta\chi}} + \frac{1}{\chi}\right);\ \text{for } 2 \le \chi \le 42$$

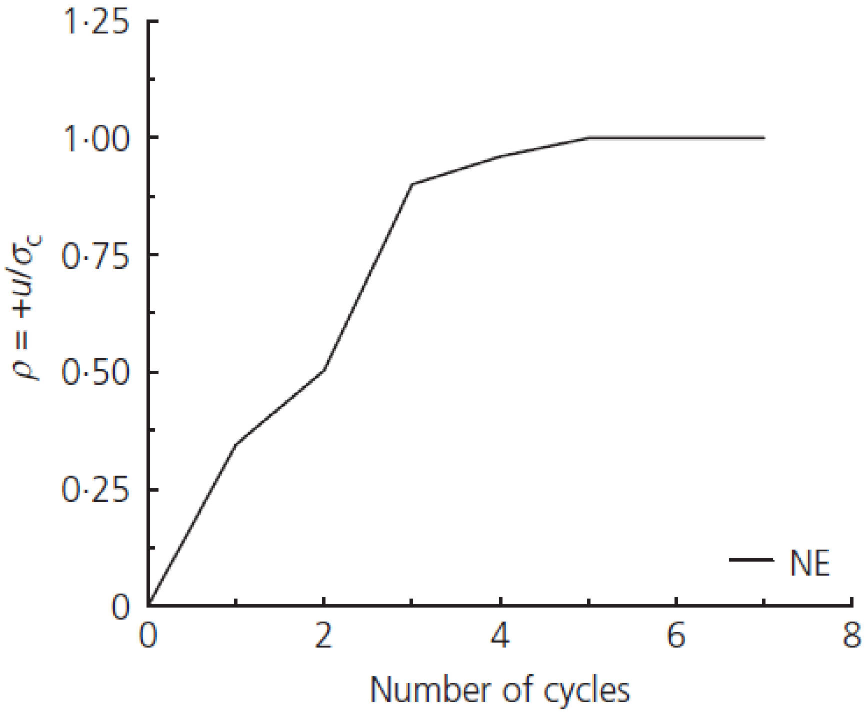
Rahman and Lo (2008)

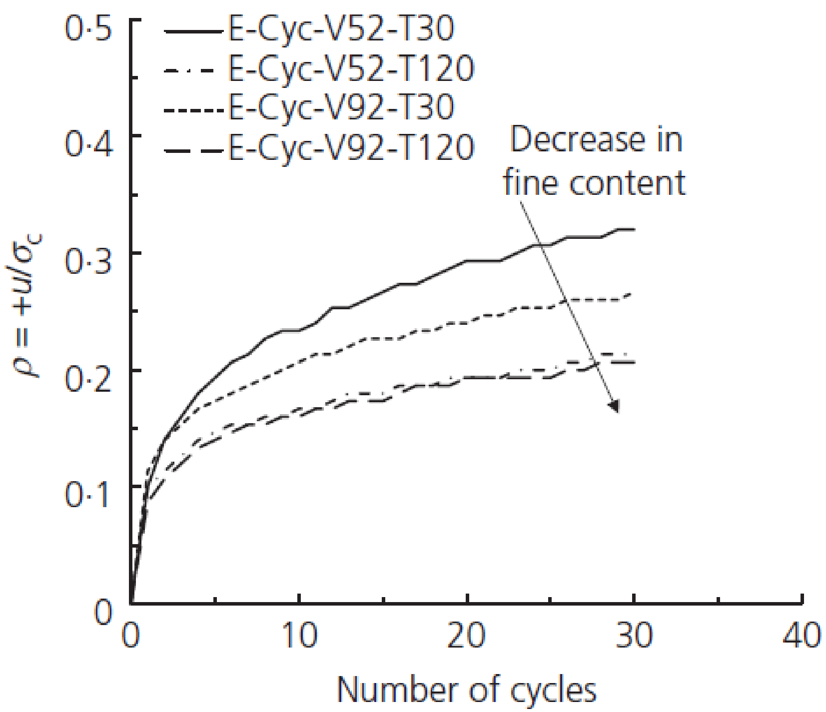
where $\chi = D_{10}/d_{50}$; a = 0.5; and b = 0.13

where $r = 1/\chi$; and $k = 1 - r^{0.25}$

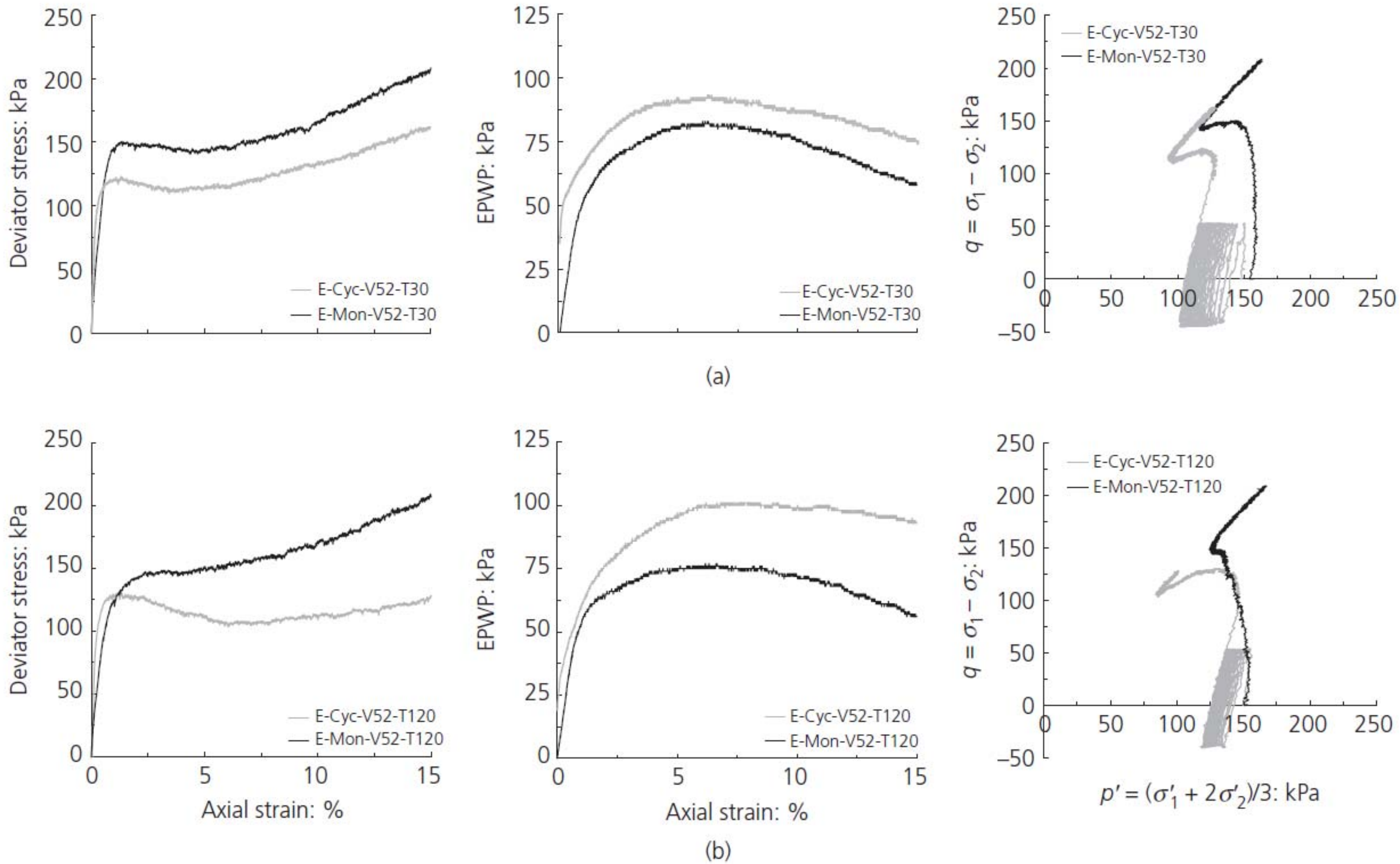
FC_{Crit} and b are equal to 31%and 0.34, respectively, for the soil specimen reported in this paper.

Impact of Suffusion on the Cyclic and Post-Cyclic Behaviour

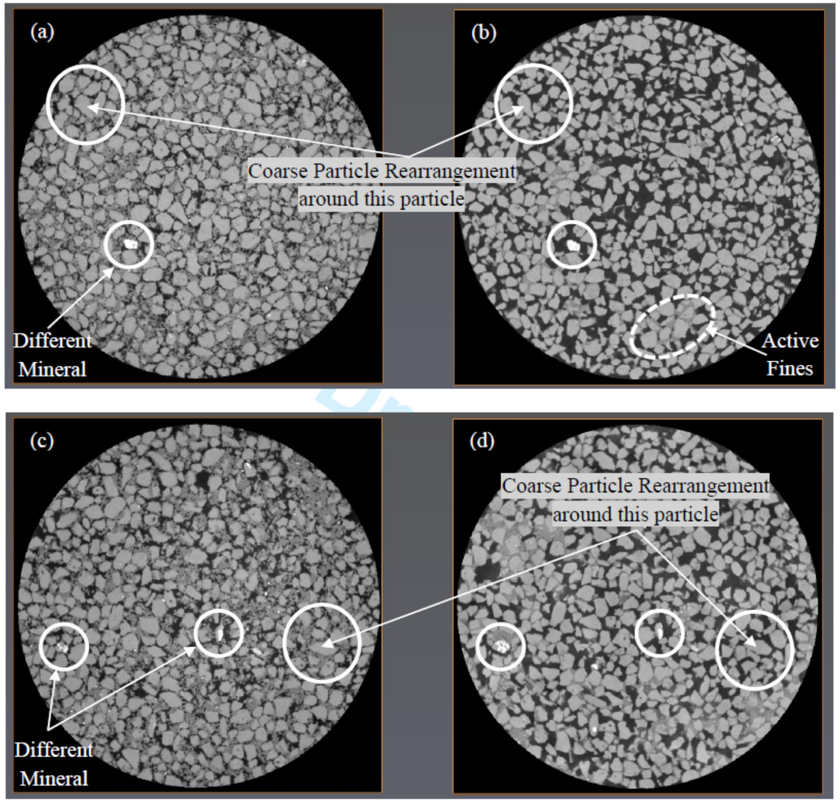




Impact of Suffusion on the Cyclic and Post-Cyclic Behaviour



Coarse Particle Rearrangement



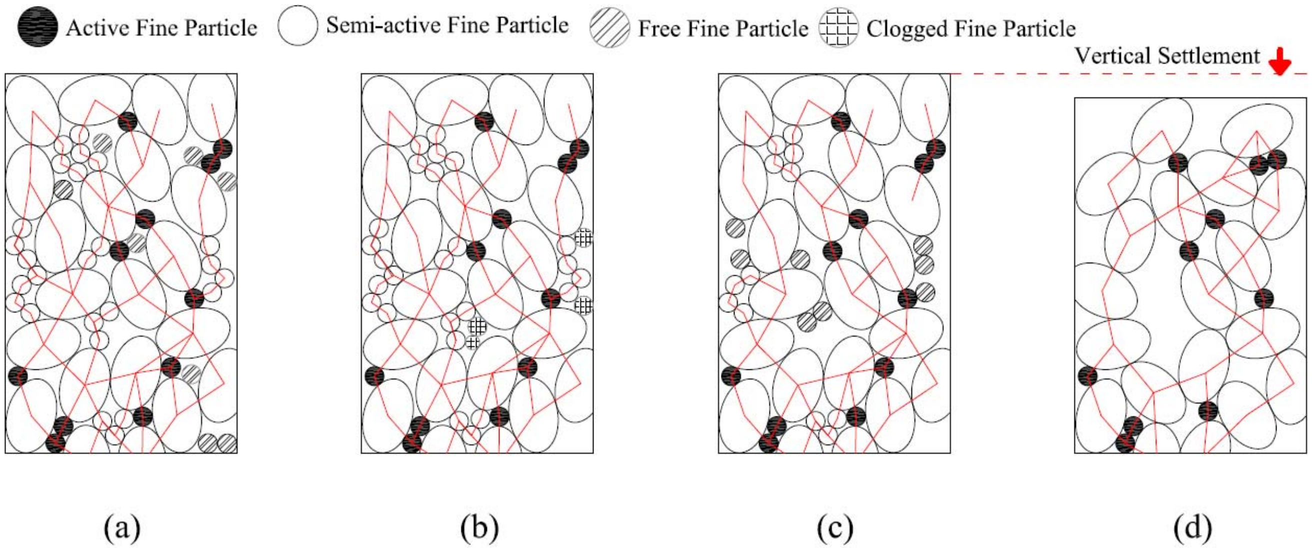


Figure5. Progress of internal erosion (a) Initial condition, (b) Erosion of the free fines, (c) Erosion of the semi-active fines and providing new free fines and (d) Particles rearrangement and vertical deformation with residual active fines

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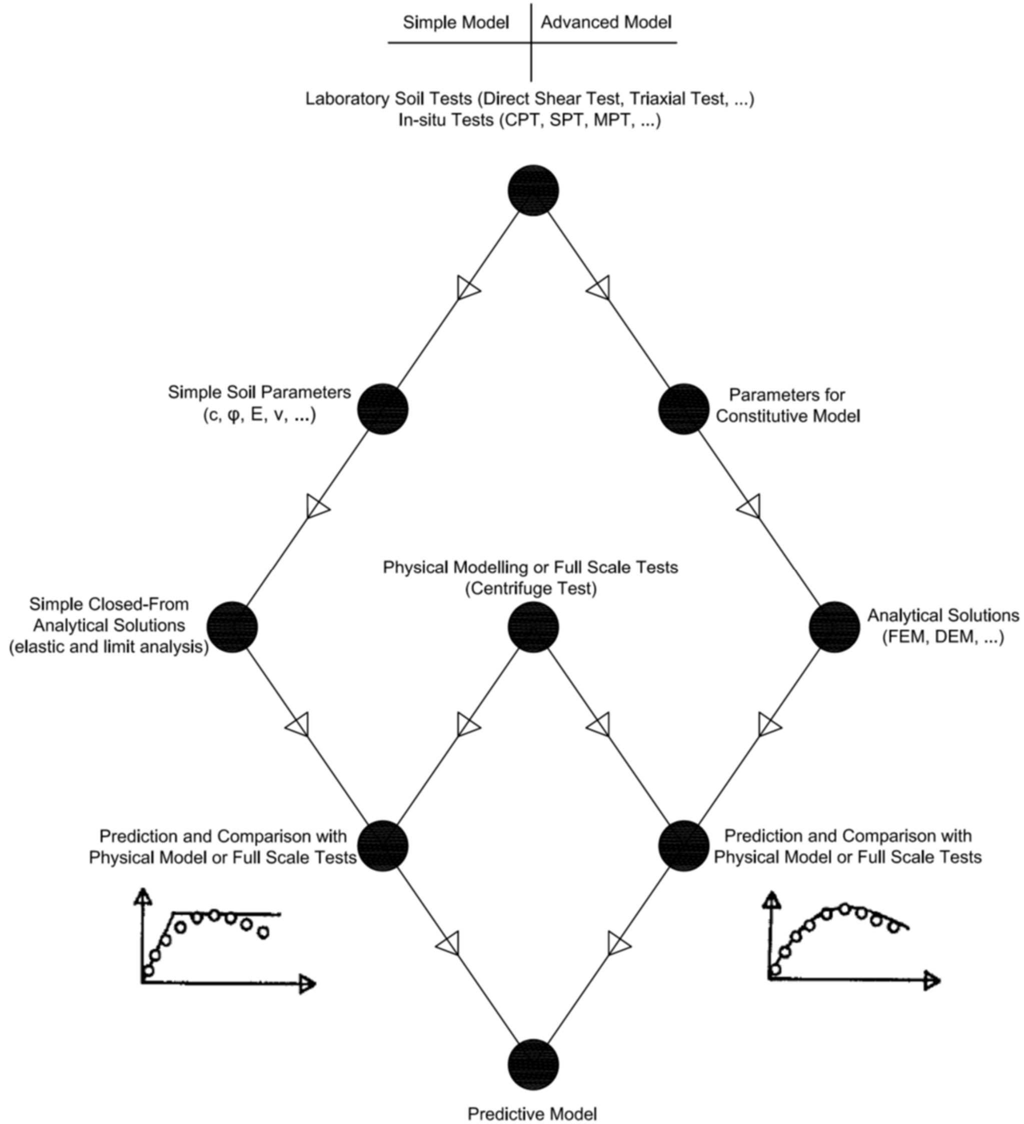
What do we need now?

A constitutive soil model to predict the post-erosion behaviour considering various parameters (e.g. residual fine content (active fines in particular), intergranular void ratio, relative density, …)



(After Lade, 2005)

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EWG-IE 2021 ONLINE WORKSHOP
February 2nd 2021

Thank you

Questions?

Acknowledgment:

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Thomas Shire
The University of Glasgow