Phase I Report: LEAP-Asia-2018

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The present report summarizes the numerical simulations performed at the University of British Columbia (UBC) as part of Phase I of the LEAP-Asia-2018 numerical exercise. The objective of the simulations was to calibrate a constitutive model with the results of the cyclic torsional shear tests conducted at Kyoto University (KyU) for Ottawa F65 sand. The KyU tests were carried out on saturated samples reconstituted to target relative densities (D_r) of 50 and 60%, vertical effective stress of 100 kPa, and under isotropic stress condition. The sampled where then cyclically sheared at stress ratios (CSR) ranging from 0.10 to 0.20.

The SANISAND class of constitutive models was chosen for the numerical simulations to represent the cyclic response of sand. The version used in this study is based on the 2004 formulation of the model with fabric change effects [1], with additional features for overshooting correction scheme [2] and accounting for the response in the semifluidized regime [3]. This version is referred hereafter with the generic name of SANISAND. The calibration targeted capturing the stress paths and stress-strain loops for both levels of D_r and all different levels of CSR, all with a single set of parameters.The model was numerically implemented in the finite difference program FLAC^{3D} [4], and used for the simulations presented in this study. The undrained cyclic tests were simulated using a single-element zone in the above simulation platform, and cyclically sheared under constant-volume conditions. Table 1 presents the calibrated SANISAND model parameters. The following section showcases the model performance against the KyU cyclic torsional shear tests, and the resulting liquefaction strength curves.

Details of the numerical simulation results are uploaded in the shared dropbox folder "UBC/Phase1".

Table 1: SANISAND model parameters for Ottawa F65 sand used for Phase 1 of the project.

Parameter	**Symbol**	**Values**
Elasticity	G_0	125
	ν	0.05
CSL	M	1.26
	c	0.8
	e_0	0.780
	λ	0.0287
	ξ	0.8
Yield surface	m	0.02
Dilatancy	n^{d}	2.5
	A_0	0.5
Kinematic hardening	n^{b}	2.3
	h_0	6.0
	c_{h}	0.968
Fabric dilatancy	$z_{\max}$	25
	c_{z}	2000
Overshooting correction	$\bar{e}^{p}_{ep}$	0.01%
	n	1
Semifluidized regime	c_l	80
	n_l	8
	χ	3
	α	8
	$p_{\mathrm{th}}/p_{\mathrm{atm}}$	0.10
	$p_{\mathrm{in,ref}}/p_{\mathrm{atm}}$	0.18

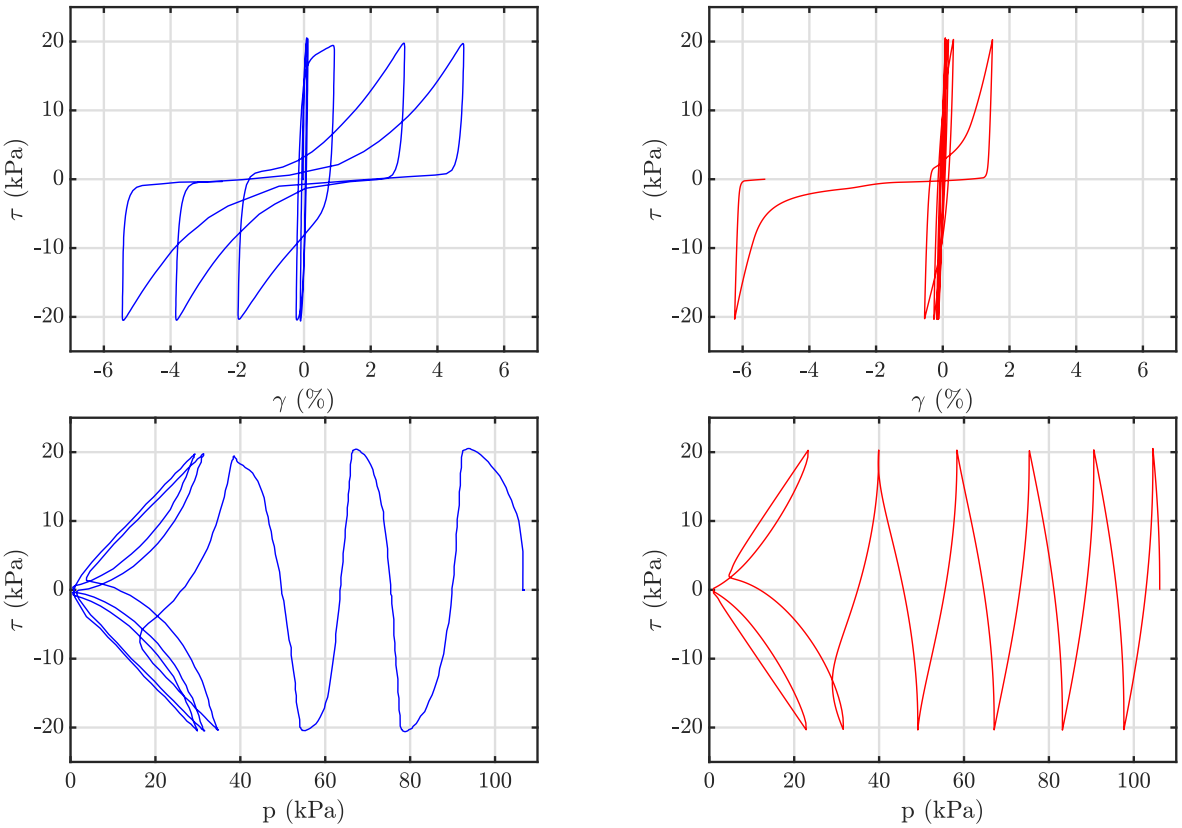

Figure 1: KyU experiments (left) and UBC simulations (right) for cyclic torsional shear tests at $D_r = 50\%$, CSR = 0.19.

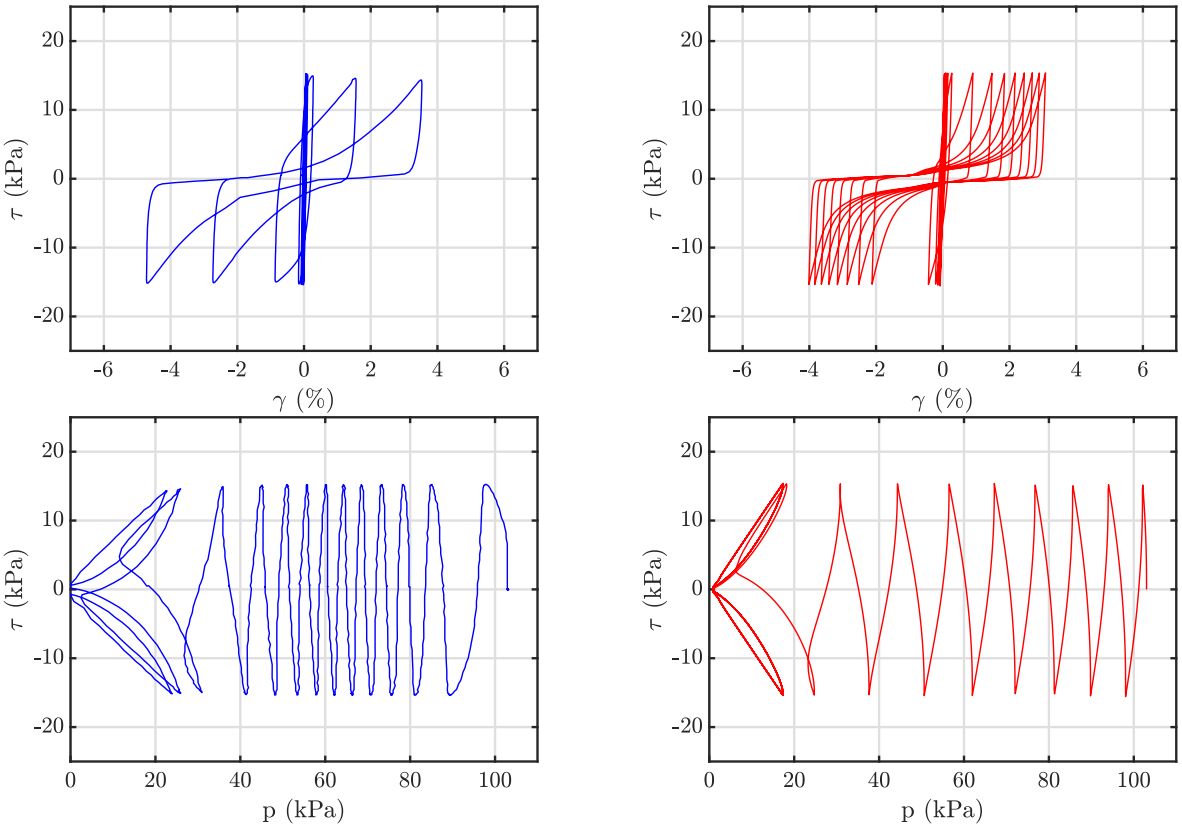

Figure 2: KyU experiments (left) and UBC simulations (right) for cyclic torsional shear tests at $D_r = 50\%$, CSR = 0.15.

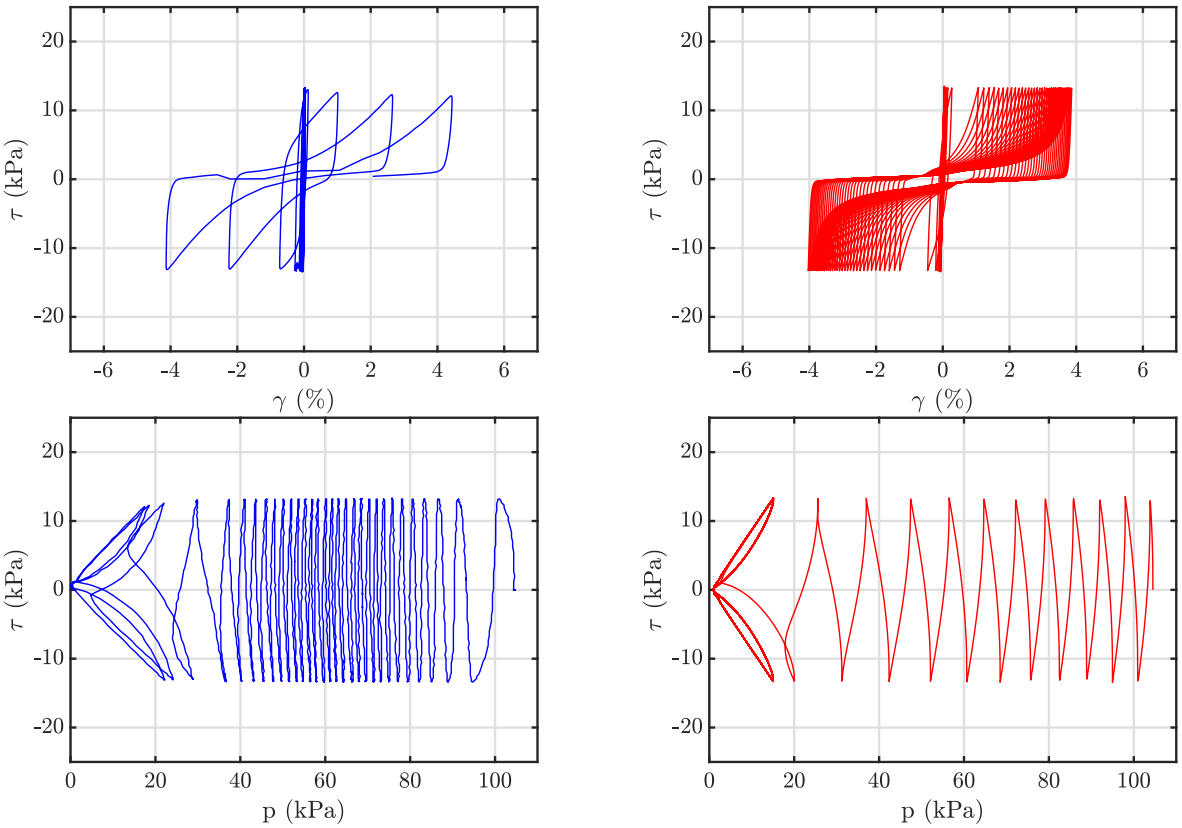

Figure 3: KyU experiments (left) and UBC simulations (right) for cyclic torsional shear tests at $D_r = 50\%$, CSR = 0.13.

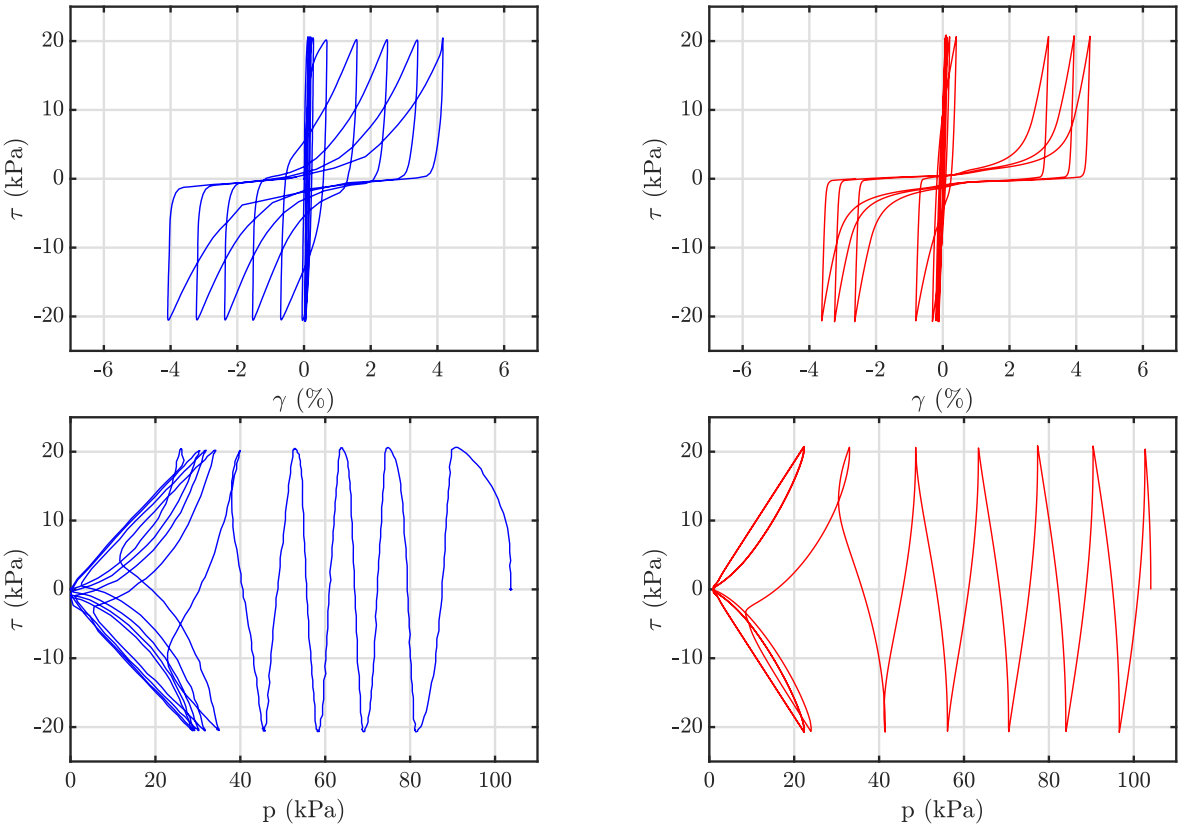

Figure 4: KyU experiments (left) and UBC simulations (right) for cyclic torsional shear tests at $D_r = 60\%$, CSR = 0.20.

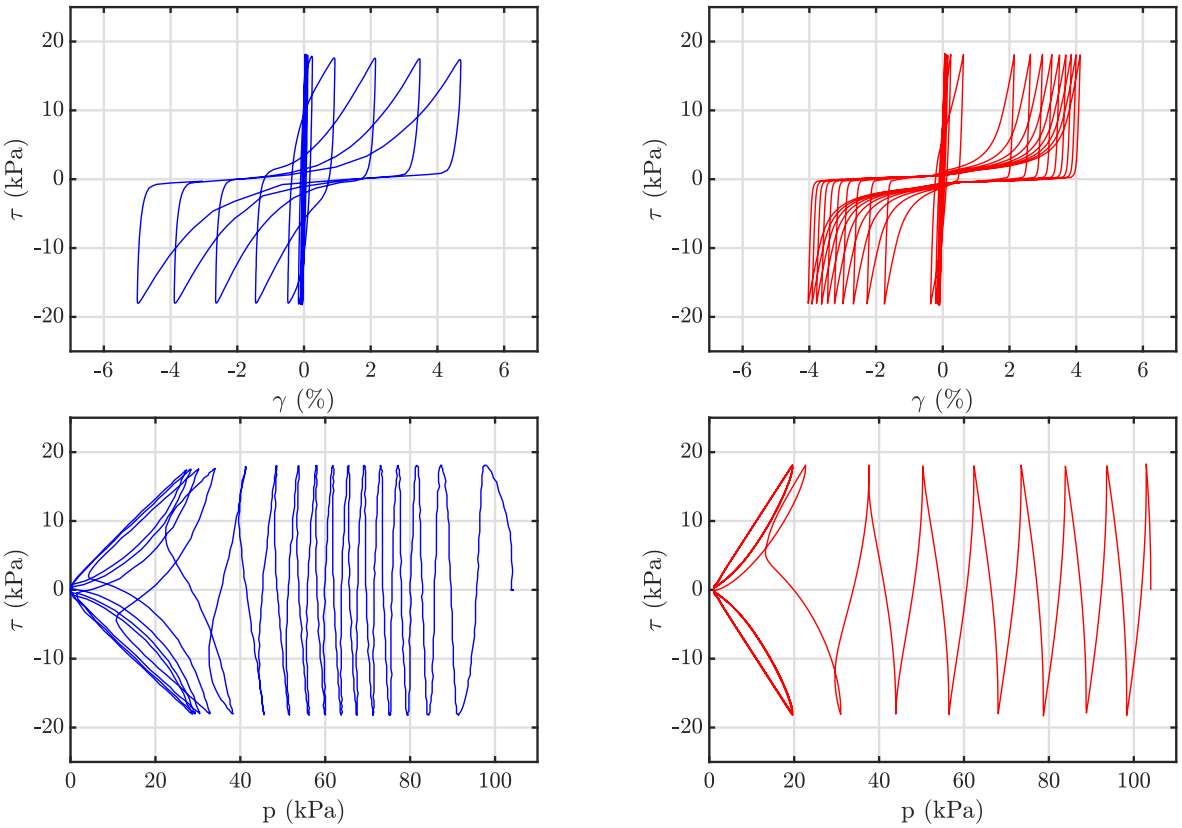

Figure 5: KyU experiments (left) and UBC simulations (right) for cyclic torsional shear tests at $D_r = 60\%$, CSR = 0.18.

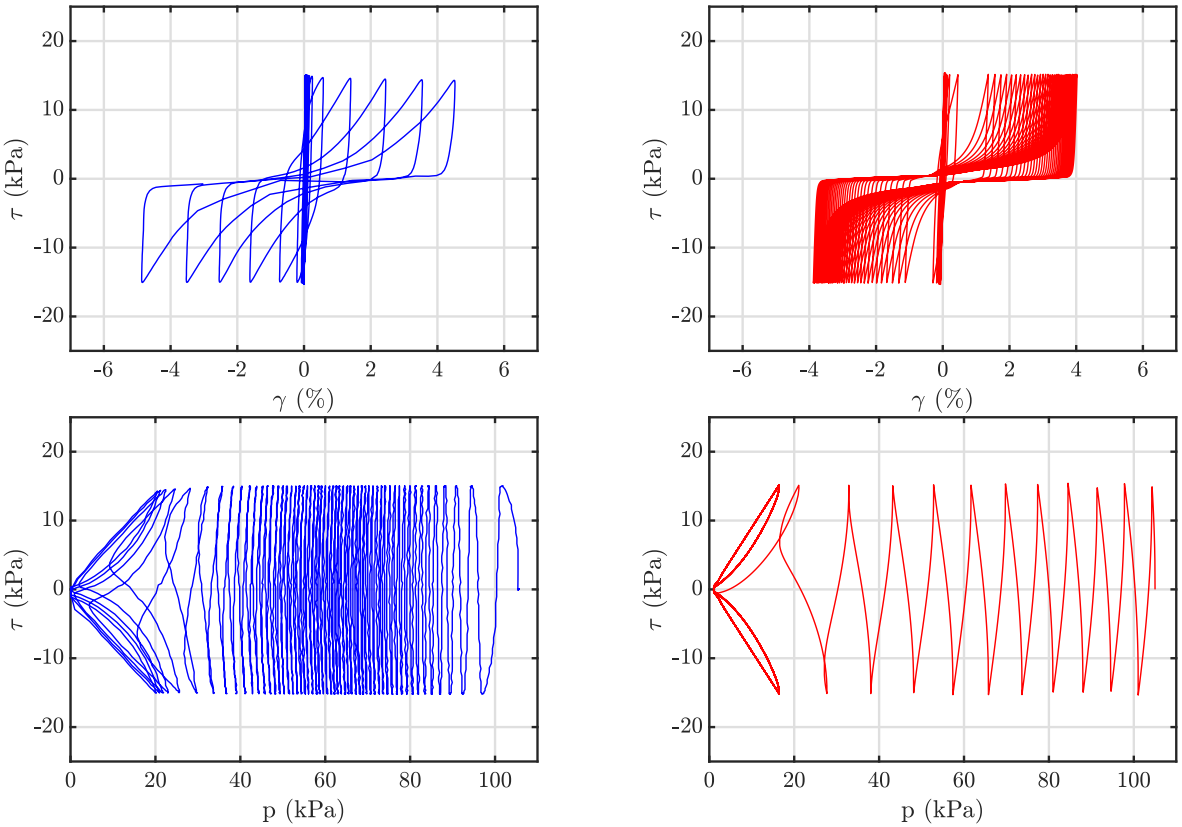

Figure 6: KyU experiments (left) and UBC simulations (right) for cyclic torsional shear tests at $D_r = 60\%$, CSR = 0.15.

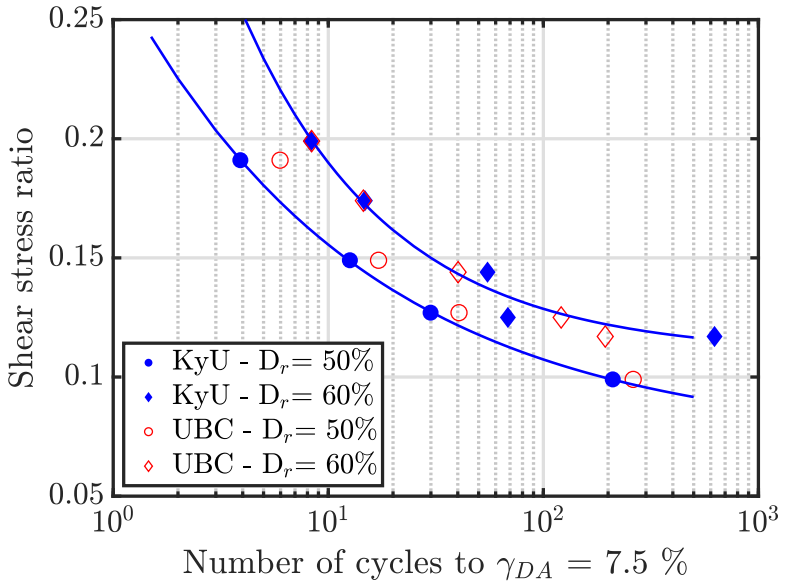

Figure 7: Summary of experiments and simulations showing the cyclic shear stress ratios and the corresponding number of cycles to reach double amplitude shear strain of 7.5%. The lines represent the interpolated liquefaction curves based on the experimental data for each of the two relative densities.

References

[1] Y. F. Dafalias and M. T. Manzari, "Simple plasticity sand model accounting for fabric change effects," *Journal of Engineering mechanics*, vol. 130, no. 6, pp. 622–634, 2004.

[2] Y. F. Dafalias and M. Taiebat, "Sanisand-z: zero elastic range sand plasticity model," *Géotechnique*, vol. 66, no. 12, pp. 999–1013, 2016.

[3] A. Barrero, "Multi-scale modeling of the response of granular soils under cyclic shearing," Ph.D. dissertation, University of British Columbia, BC, Canada, 2019.

[4] Itasca, *FLAC3D: Fast Lagrangian Analysis of Continua in 3 Dimensions, Version 5.01*, Itasca Consulting Group Inc., Minneapolis, Minnesota, USA, 2013.