Micromechanical assessment of the phase transition in cyclic liquefaction of granular materials

Ming Yang[1,2,*] Mahdi Taiebat[2,**] Farhang Radjaï[3,***]

[1]Northwestern University, Evanston, USA [2]University of British Columbia, Vancouver, Canada [3]University of Montpellier, Montpellier, France

Introduction

- Cyclic liquefaction of granular materials
- Long-term evolution of contact network
- Jamming transition between solid-like and fluid-like

Protocols

- Bi-periodic boundary
- Isotropic compression with $p_0 = 100$ kPa
- Constant-volume cyclic shear with a constant $\dot{\gamma}$

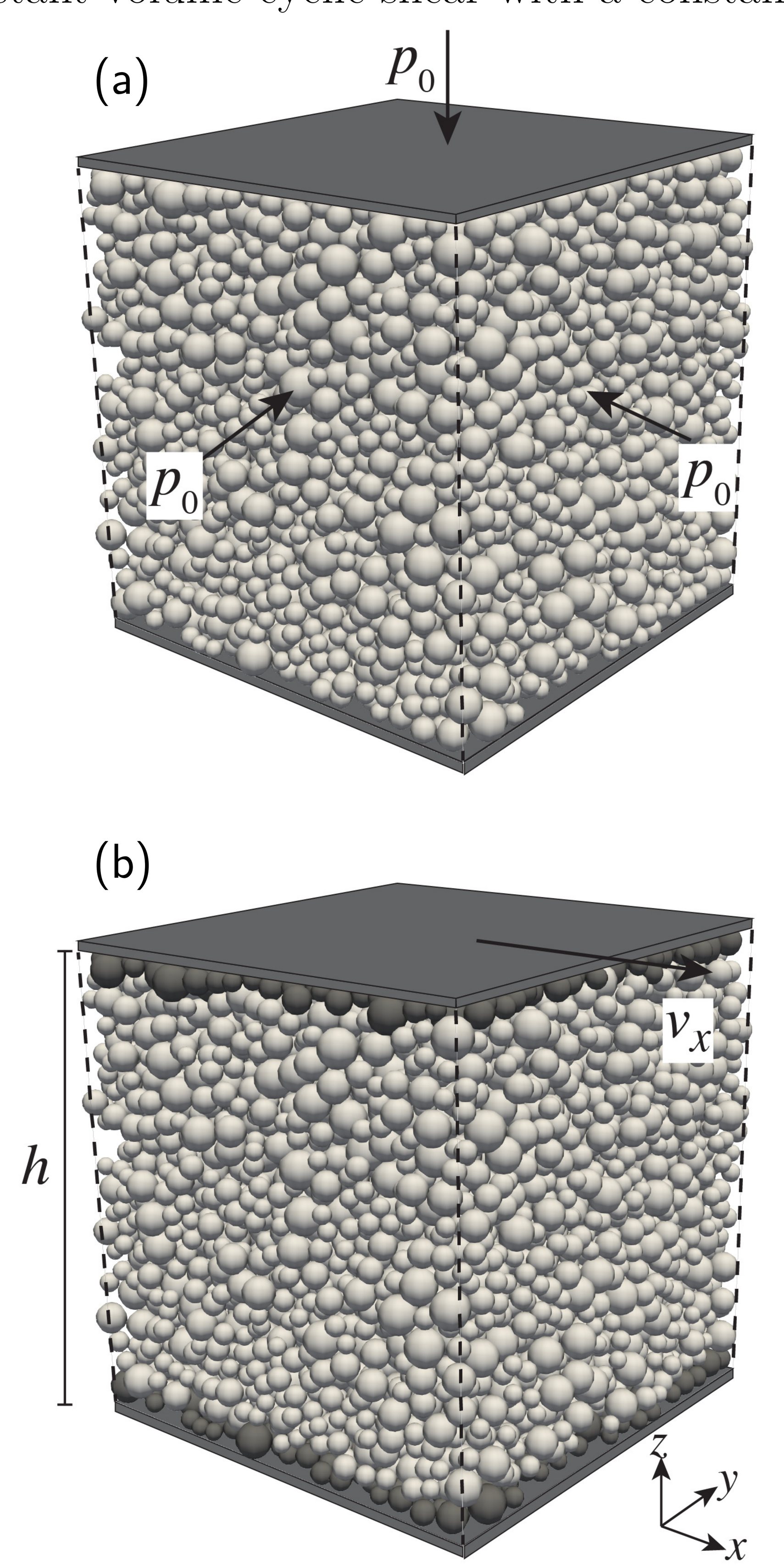

Figure 1: Particle arrangements and boundary conditions for a sample composed of 8000 spheres: (a) at the end of sample preparation; (b) during constant height cyclic shearing. Gray particles are glued to the top and bottom walls of the bi-periodic cell.

Contact info: *myang@northwestern.edu
**mtaiebat@civil.ubc.ca
***franck.radjai@umontpellier.fr

Macro

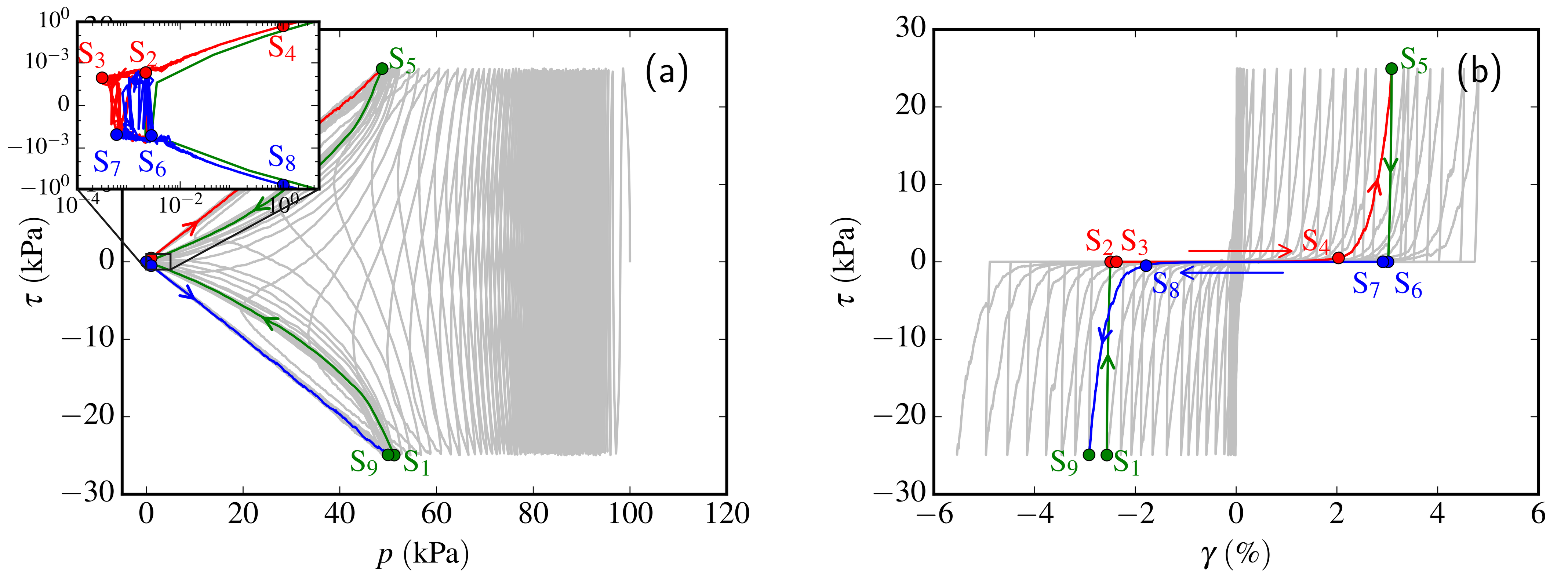

Figure 2: Macroscopic response of a constant-volume cyclic simple shear test: (a) stress path; (b) stress-strain curve. A post-liquefaction cycle C is highlighted. Points S_1 (or S_5, S_9), S_2(or S_6), S_3(or S_7), and S_4(or S_8) correspond to selected states of $|\tau| \simeq \tau^{amp}$ (shear stress amplitude), $\tau \simeq 0$, p reaching the lowest, and $p/p_0 \geq 0.01$ (exiting the fluid-like state), respectively.

Micro/Meso

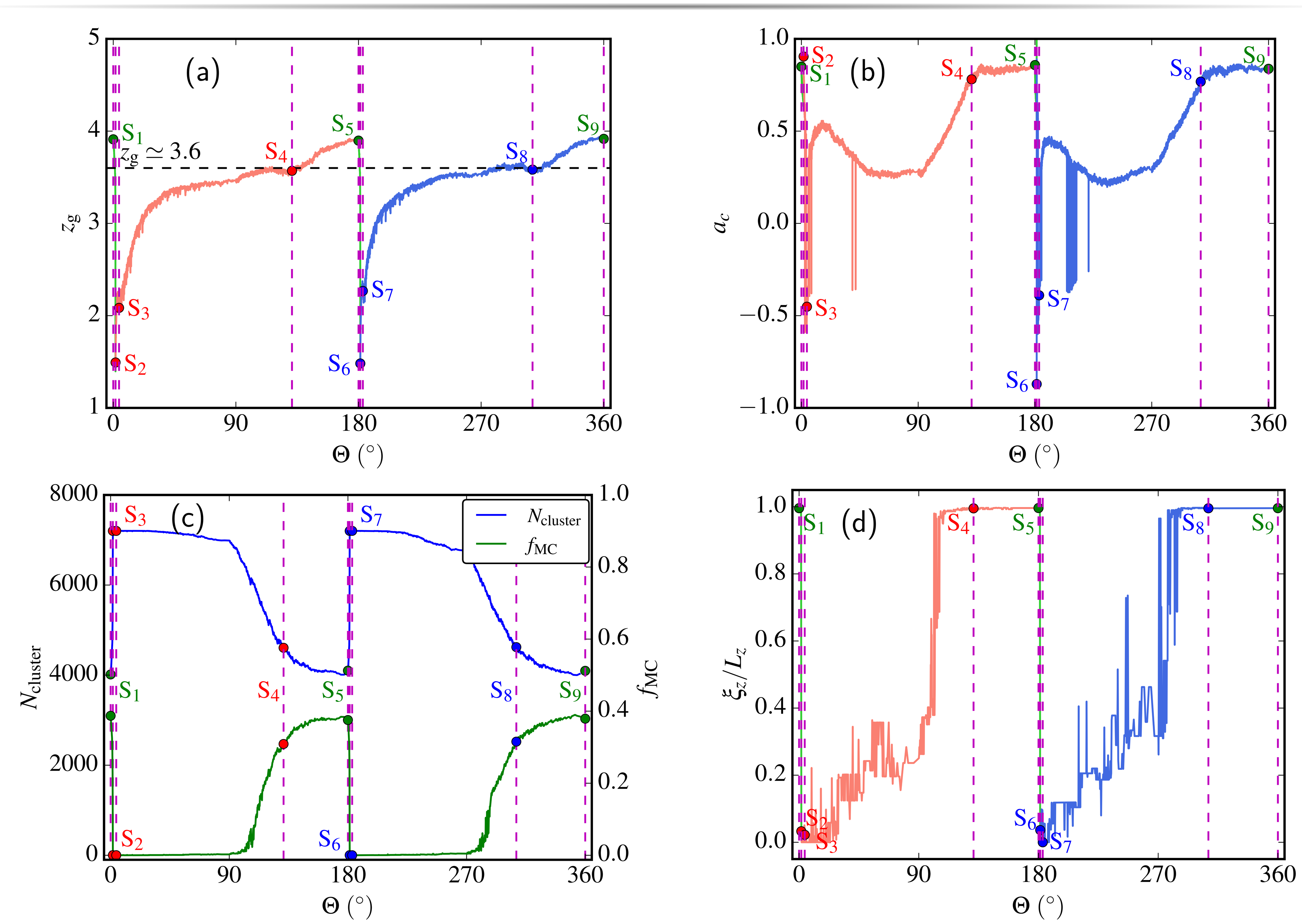

Figure 3: Evolutions of micro- and meso-scale descriptors in post-liquefaction cycle C: (a) coordination number $z_g = 2N_c/(N_p - N_p^0)$; (b) contact normal fabric anisotropy $a_c = \text{sign}(S_c)\sqrt{(3/2)\mathbf{a}_c : \mathbf{a}_c}$ with $S_c = \mathbf{a}_c : \mathbf{s}/(\sqrt{\mathbf{a}_c : \mathbf{a}_c}\sqrt{\mathbf{s} : \mathbf{s}})$ and $\mathbf{s}$ deviatoric stress tensor; (c) particle k-cluster ($f_n \geq k\langle f_n \rangle$) with $k = 1$; (d) percolation index ξ_z/L_z with $k = 1$ (largest k-cluster versus system dimensions).

Linking Micro/Meso to Macro

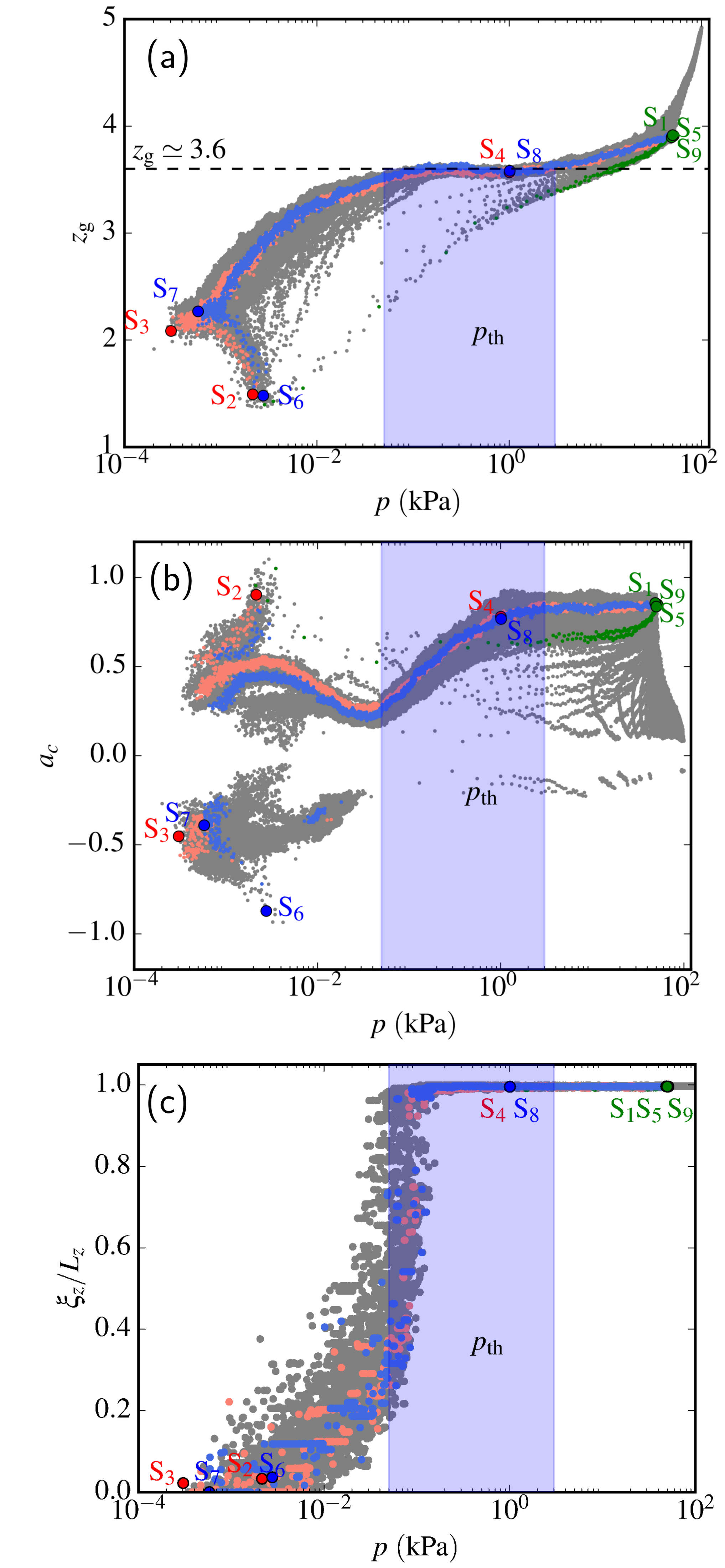

Figure 4: Micro- and meso-scale descriptors versus mean stress during cyclic shearing: (a) coordination number z_g; (b) fabric anisotropy a_c; (c) percolation index ξ_z/L_z. p_{th} ranges between 0.05 and 3 kPa.

Conclusion

- Jamming transition: $z_g \simeq 3.6$, $\xi_z = 1$, evolving a_c

1. M. Yang, M. Taiebat, P. Mutabaruka, F. Radjaï, Physical Review E **103**, 032904 (2021)
2. M. Yang, M. Taiebat, F. Radjaï, Computers and Geotechnics (2022), in review