

COMPACTION OF COHESIVE GRANULAR MATERIALS

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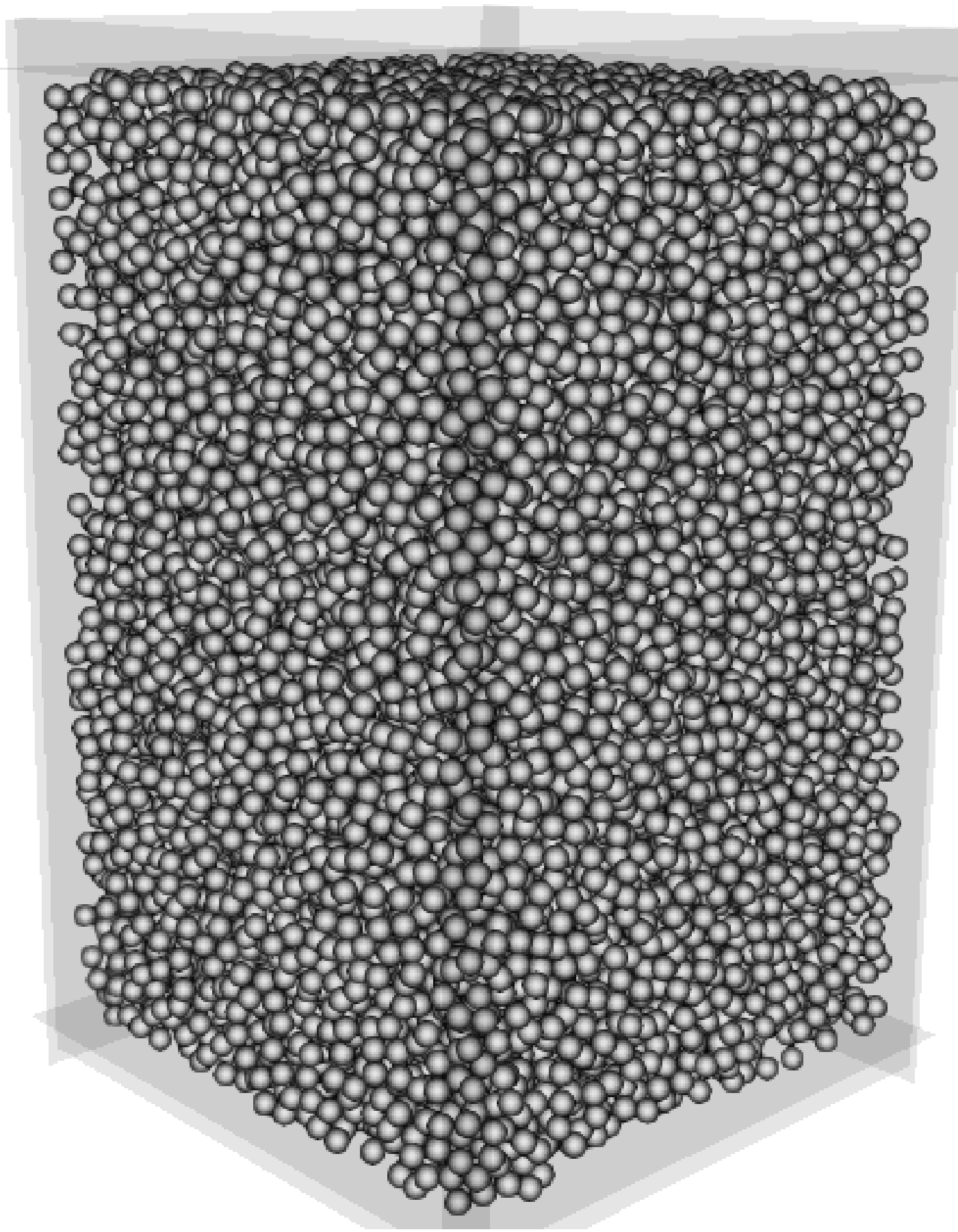


INTRODUCTION

Cohesive granular materials play a key role in nature and industry. Cohesive interactions between particles have various physico-chemical origins such as capillary bonding, Van der Waals forces, and a cementing matrix [1]. Despite extensive experimental and numerical work on these materials, their mechanical behavior under the action of external loading is still poorly understood [2].

In this work, we use the Discrete Element Method (DEM) to perform an extensive parametric study of isotropic compaction of a cohesive material in which the cohesive action between two particles is modeled as a constant adhesion force.

DEM SAMPLE



- 3D sample filled with monodisperse spherical particles
- **Elasto-cohesive contact law**

$$f_n(\delta_n) = -k_n\delta_n - N^c$$

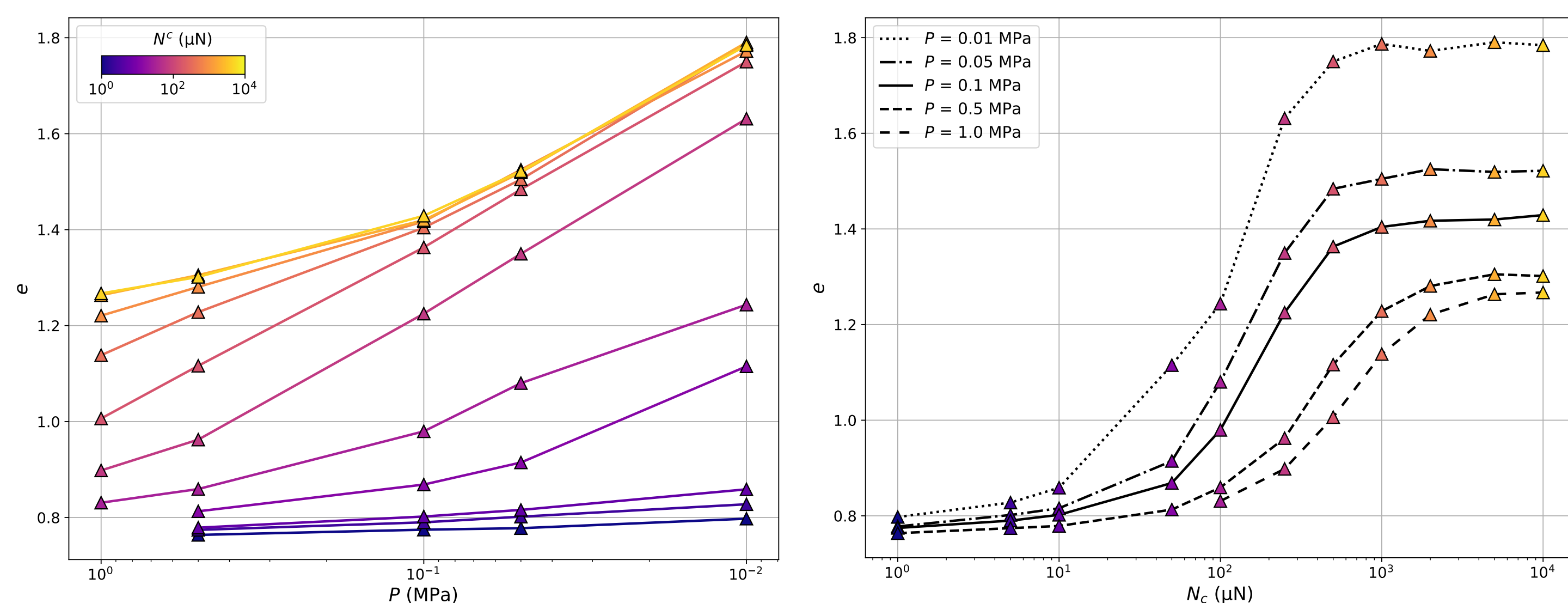
- Isotropic confining pressure P

Parameters	Values
Adhesion force N^c [μN]	$[1, 10^4]$
Normal stiffness k_n [N/m]	$\{10^4, 10^5, 10^6\}$
Particle size D [μm]	$\{5, 10, 20\}$
Pressure P [MPa]	$\{0.01, 0.05, 0.1, 0.5, 1\}$

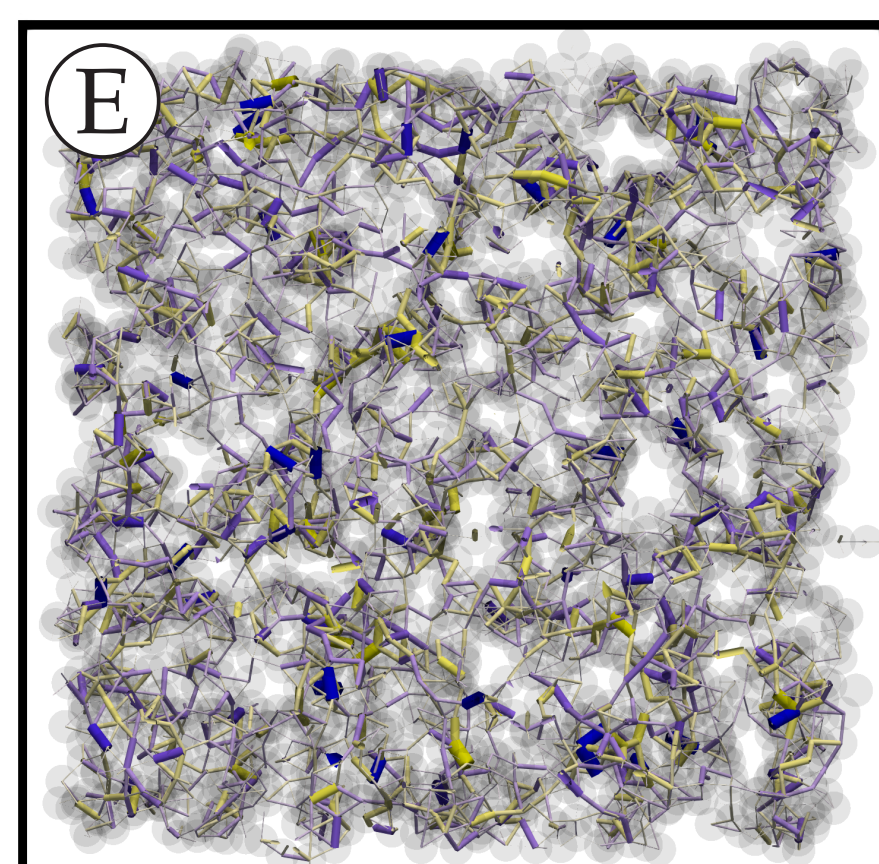
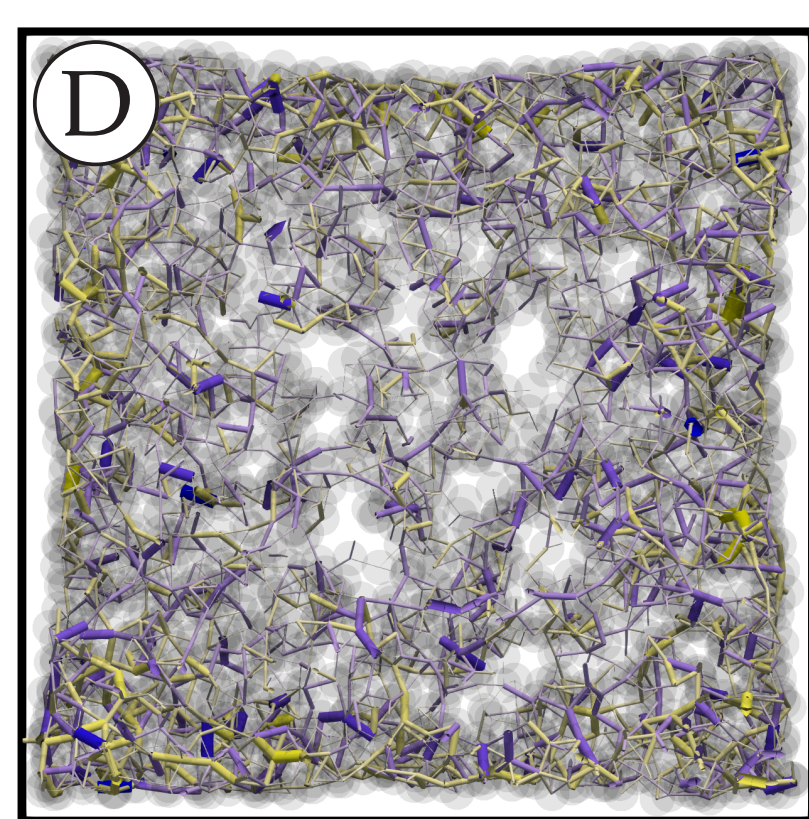
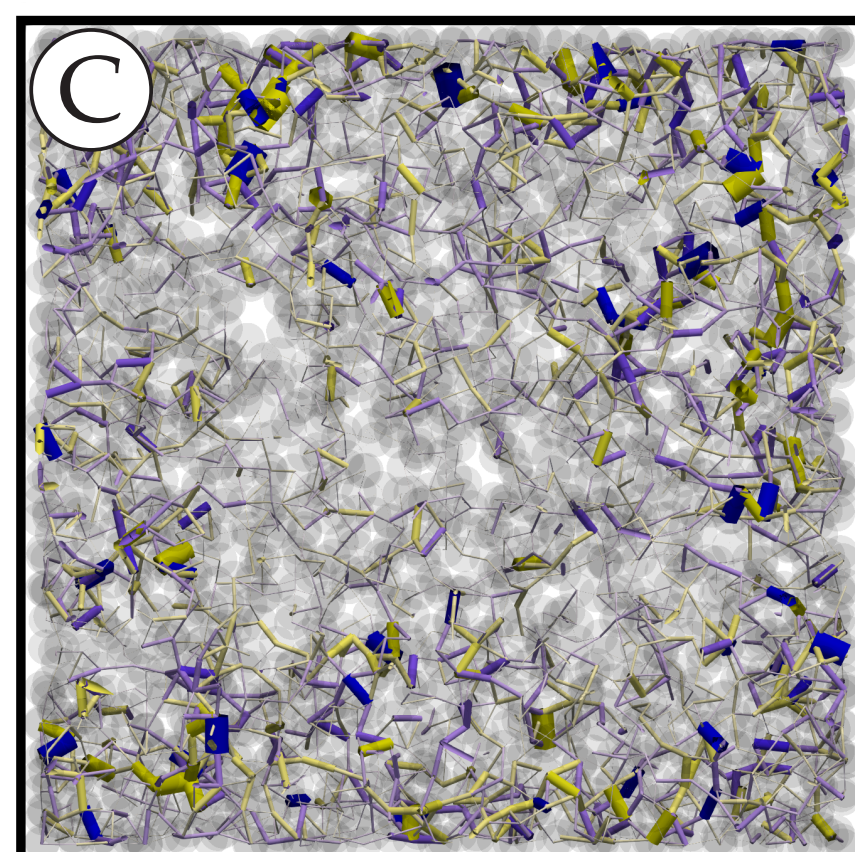
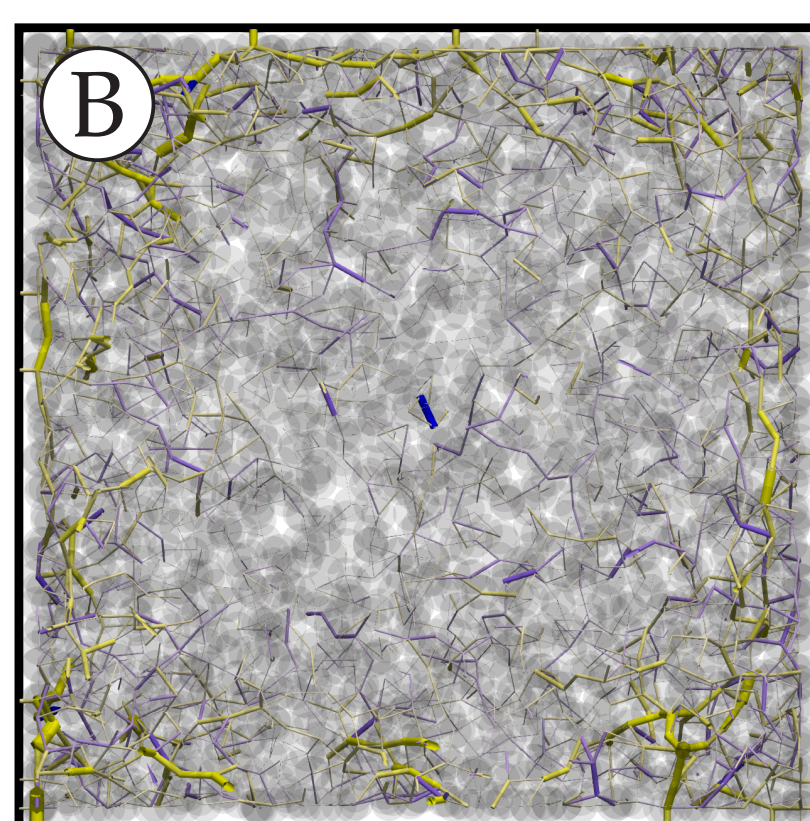
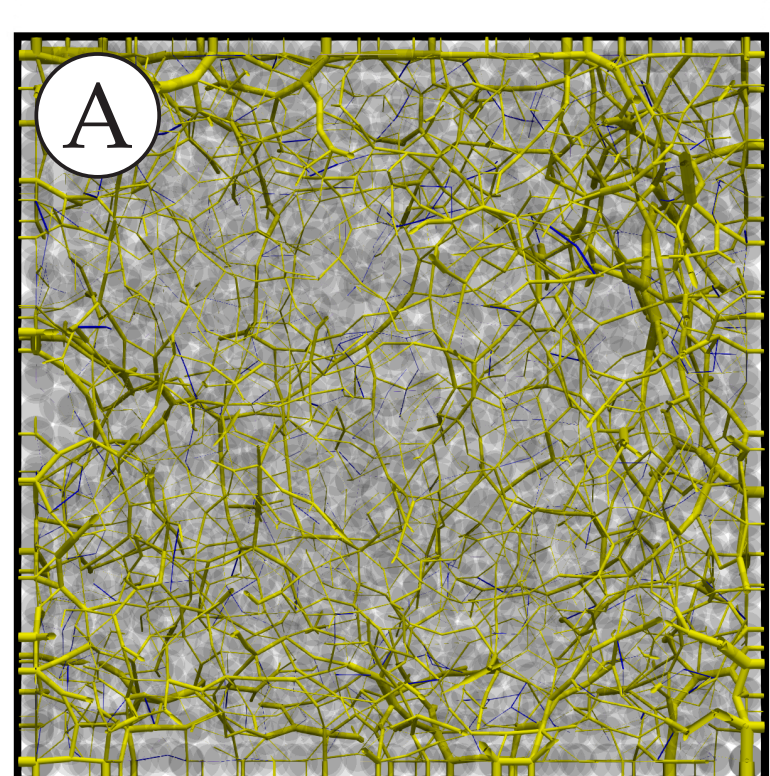
RESULTS

$$e = \frac{1}{\phi} - 1$$

Evolution of void ratio e as a function of confining pressure P for different values of adhesion force N_c (left) and as a function of confining pressure for different values of adhesion force (right).



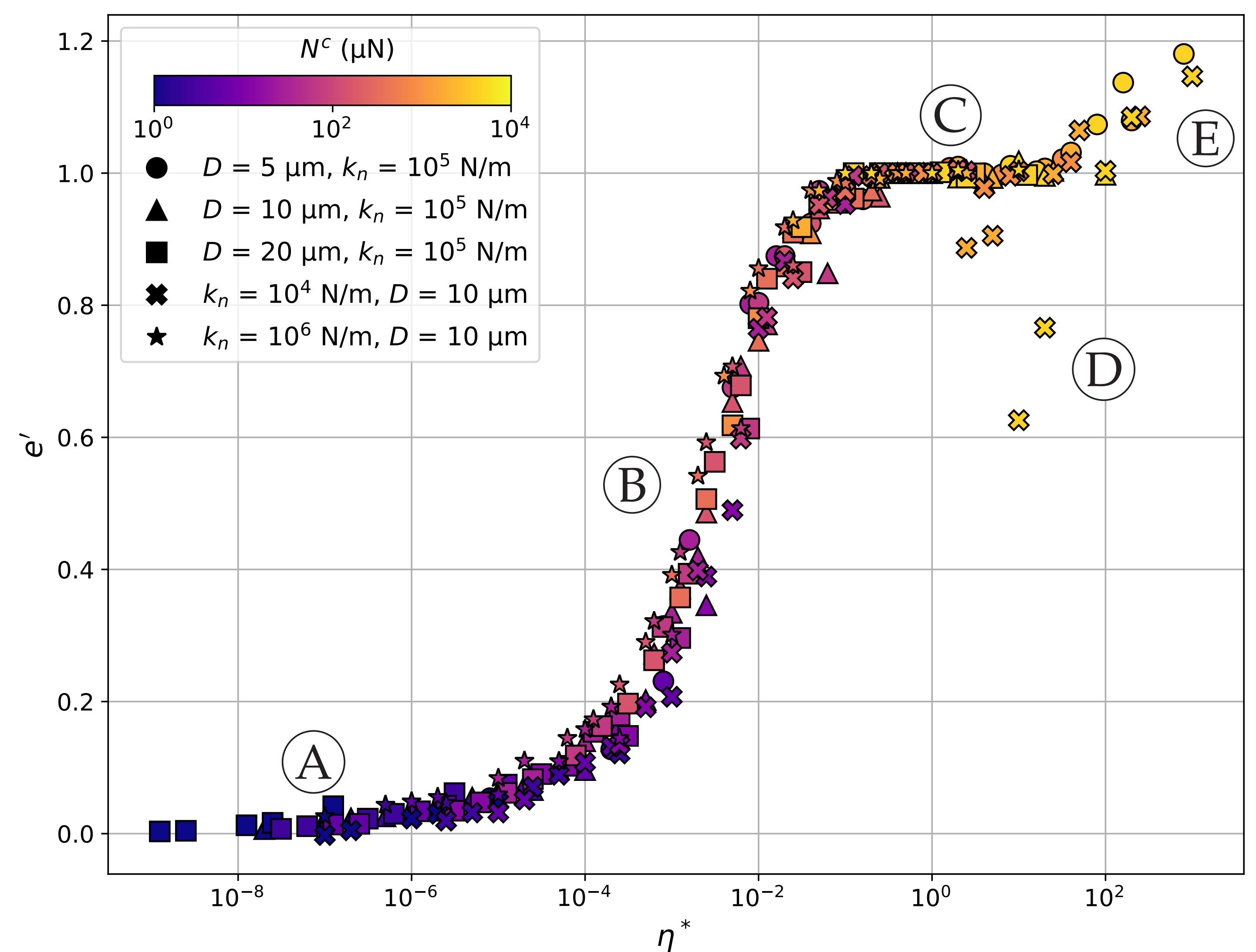
MICROSTRUCTURES



D: Highly cohesive chains of particles on the edges of the sample tend to concentrate the compressive forces.

E: Pressure is not strong enough to correctly compress the sample.

SCALING



$$e' = \frac{e - e_{min}}{e_{max} - e_{min}}$$

$$\eta^* = \frac{N_c^2}{P k_n D^3}$$

Relative void ratio e' as a function of the dimensionless number η^* , depending on all material parameters and applied pressure. All data points collapse on the same curve except a few points (D & E) that represent special particle configurations induced by rigid walls (see below).

CONCLUSION

We introduced a new dimensionless number that represents the compaction state of a granular material under isotropic compression. A compaction law is proposed as a generic function of this number that combines all system parameters. We also showed that finite size and wall effects can lead to deviations from this state due to stress concentration and gradients at the boundary of the system.

REFERENCES

- [1] S. Mandal, M. Nicolas, and O. Pouliquen. Insights into the rheology of cohesive granular media. *Proceedings of the National Academy of Sciences*, 117(15), 2020.
- [2] F. A. Gilabert, J.-N. Roux, and A. Castellanos. Computer simulation of model cohesive powders: Plastic consolidation, structural changes, and elasticity under isotropic loads. *Phys. Rev. E*, 78:031305, 2008.