

Influence de la granulométrie dans le comportement mécanique de la terre crue

Ahmad Morsel^{1,2}, & Claire Silvani²

1. INSA Lyon, GEOMAS, UR7495, Villeurbanne 69621, Lyon, France

2. Université de Lyon, LabEx IMU, UMR5259, Villeurbanne 69621, Lyon, France

Context – Problem – Objectives

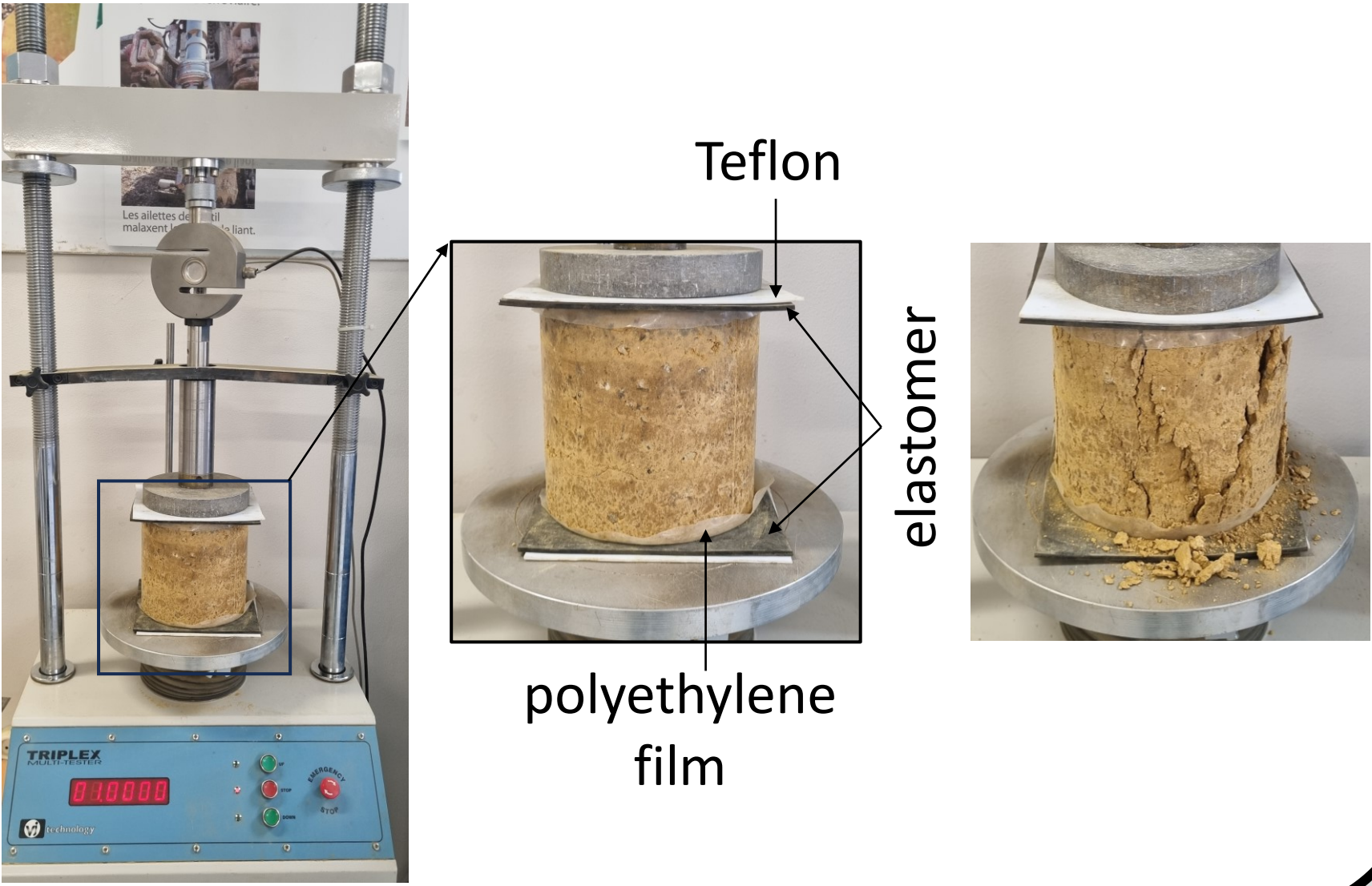
Context

Rammed earth as a construction material fits perfectly into the circular economy concept, since the soil is usually taken from excavation work (a waste) and is upcycled to build an earth-en architecture without adding any other components.



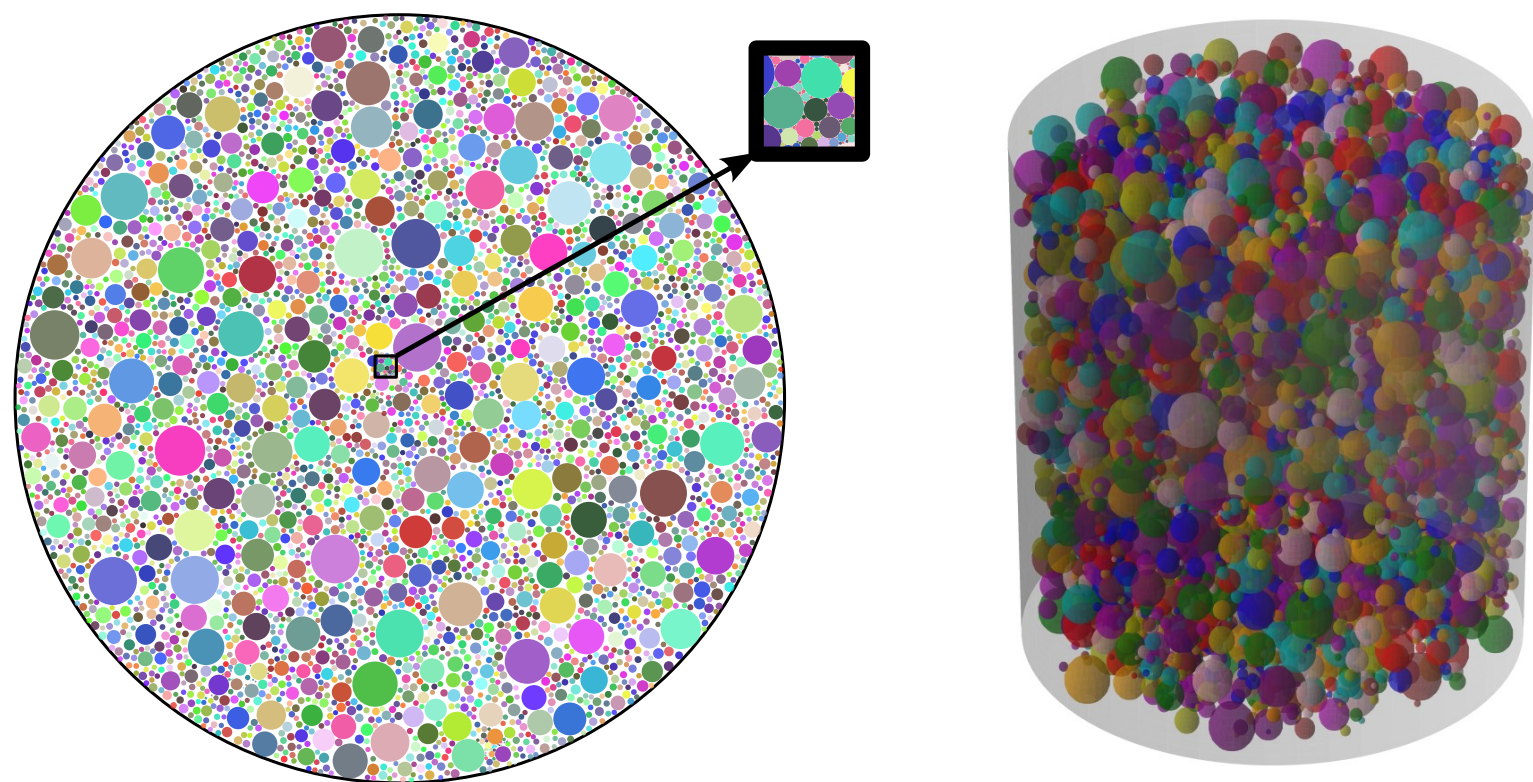
Problem

Compressive strength of rammed earth is highly sensitive to its internal structure, particularly the arrangement of particles and the **distribution of grain sizes**. The issue becomes even more complex when different types of soil are used...



Objectives

- Evaluate the effect of **particle size distribution** on the mechanical characteristics of rammed earth materials.
- Improve **compressive strength** to ensure structural stability and enhance durability.
- Investigate the effect of **fractal dimension** on the compressive strength of rammed earth samples.



Materials Characterizations



CLM

STA

SPC

Volume-weighted mean diameter

$$d[4, 3] = \frac{\sum n_i d_i^4}{\sum n_i d_i^3}$$

Surface area-weighted mean diameter

$$d[3, 2] = \frac{\sum n_i d_i^3}{\sum n_i d_i^2}$$

Specific Surface Area

$$SSA = \frac{6}{\rho_s \cdot d[3, 2]}$$

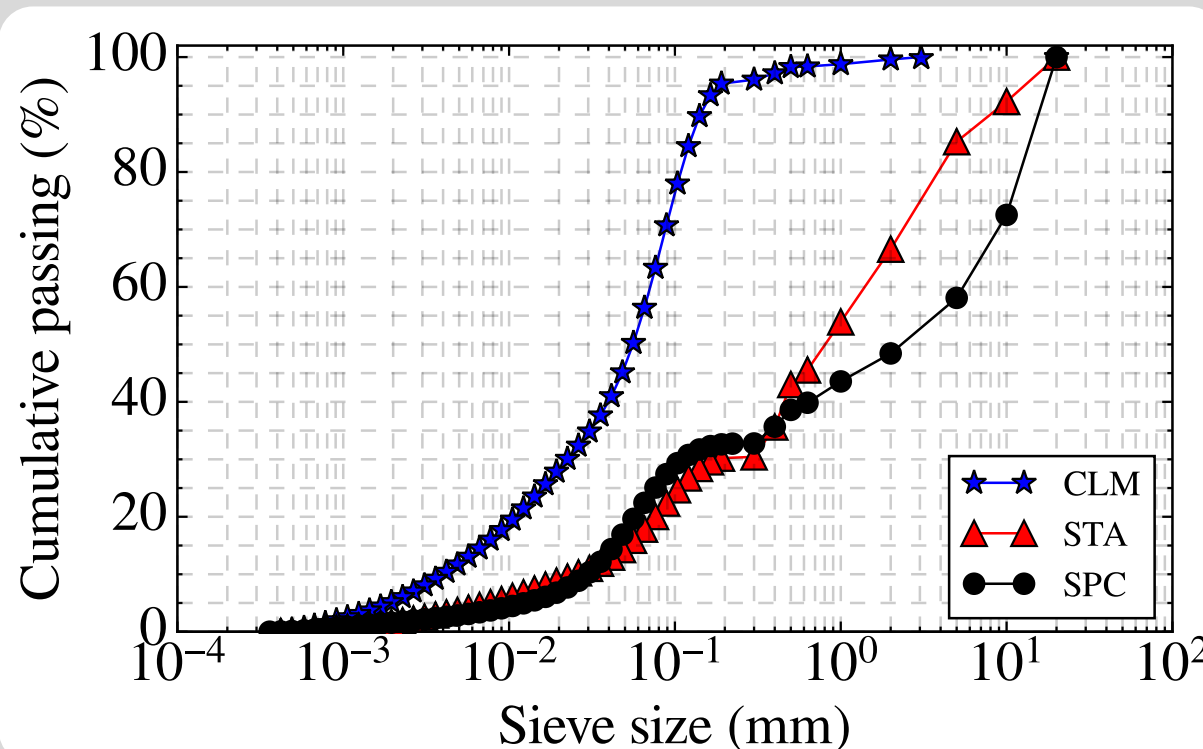
Coefficient of Uniformity

$$C_u = \frac{d_{60}^2}{d_{10} \cdot d_{30}}$$

Coefficient of Curvature

$$C_c = \frac{d_{60}}{d_{10}}$$

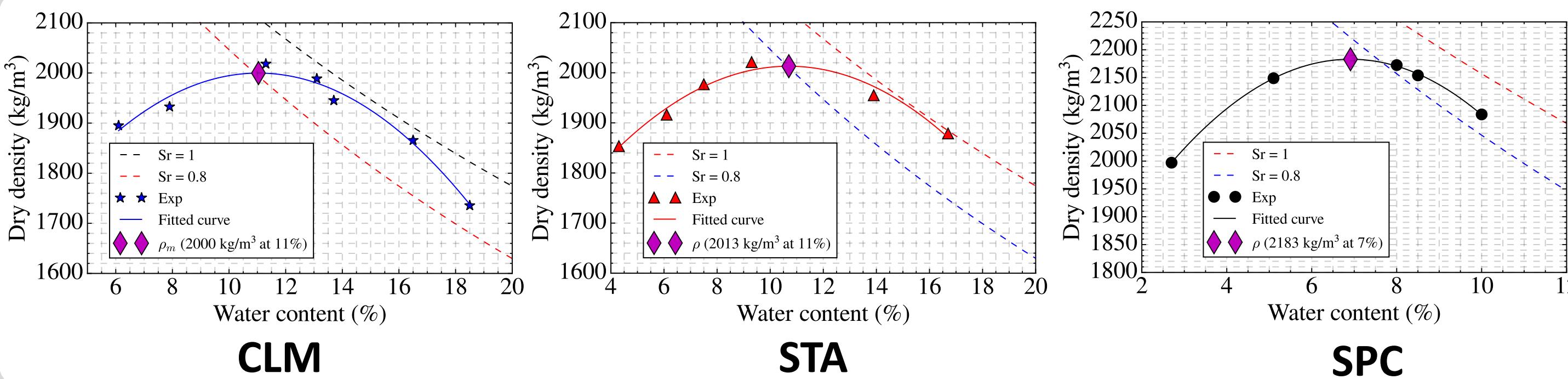
Sieve test



Parameter	CLM	STA	SPC
$d[4, 3]$ (μm)	41.04	50.77	45.44
$d[3, 2]$ (μm)	9.54	7.85	9.07
$d_{v,0.1}$ (μm)	6.32	3.26	5.41
$d_{v,0.5}$ (μm)	36.98	45.36	40.19
$d_{v,0.9}$ (μm)	80.17	109.18	90.15
Porosity (%)	26.4	25.8	19.8
SSA (m ² /g)	0.2315	0.2817	0.2430
C_u (-)	18.16	13.64	11.56
C_c (-)	1.26	1.26	1.17

n_i number of particles
 $d_{v,0.1}$ 10%, 50%, & 90% of the volume is composed of particles smaller than this size, respectively
 $d_{v,0.5}$
 $d_{v,0.9}$
 ρ_s particle density

Modified Proctor test



CLM

STA

SPC

Apollonian packing concept

- It is mathematical concept that describes the process of filling space with spheres to maximize packing density while maintaining a **fractal structure** [1]. This methods based on the **power law** distribution that describes the relationship in which one quantity varies as a power of another:

$$N(d) \propto d^{-D}$$

d diameter of the particle
 $N(d)$ cumulative number of particles
 D fractal dimension (equal to 2.5)

- mass m_i of particles of size d_i is given by:

$$m_i = m_{\text{total}} \cdot \frac{d_i^{0.5}}{\sum_{j=1}^{N(d)} d_j^{0.5}}$$

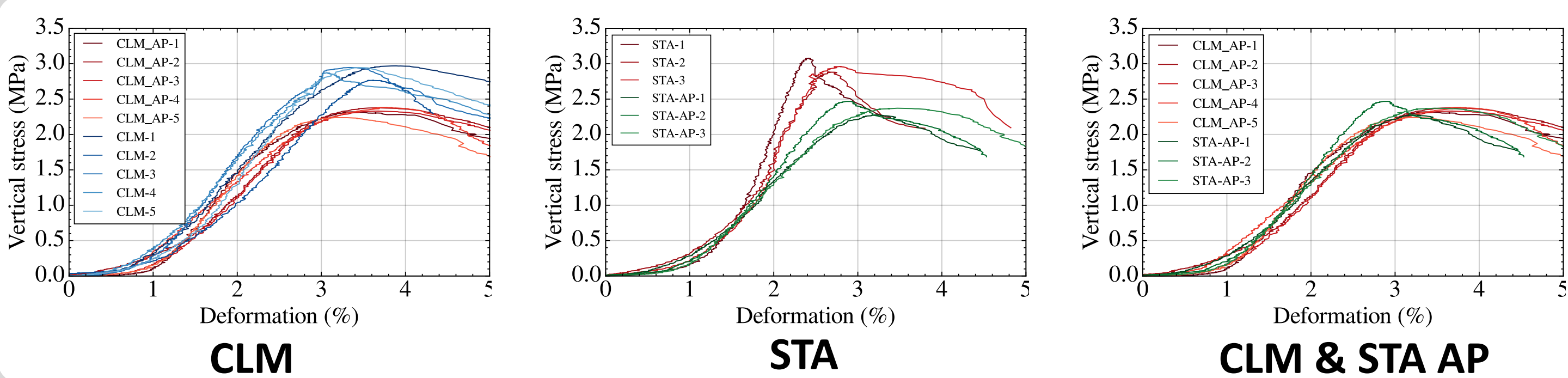
m_i mass of particles of size d_i
 m_{total} total mass of the soil

Application

Apollonian Packing (AP) is used to model dense granular systems in soils ($D \approx 2.6-2.9$) [1]. Another study estimated the lower bound of the fractal dimension for 3D Apollonian packing as $D \approx 2.48-2.52$, validating theoretical predictions and enhancing understanding of polydisperse space-filling structures [2].

Results

Compression test



As the fractal dimension increases, the compressive strength increases

Conclusions & Perspectives

- Apollonian packing** offers a promising framework for organizing particles based on fractal dimension.
- Higher **fractal dimension** correlates with increased compressive strength in rammed earth samples.
- CLM and STA soils, despite different origins, show similar compressive strength(under Apollonian application).
- Verify whether SPC soil follows the same fractal dimension–strength relationship observed in CLM and STA soils.

References

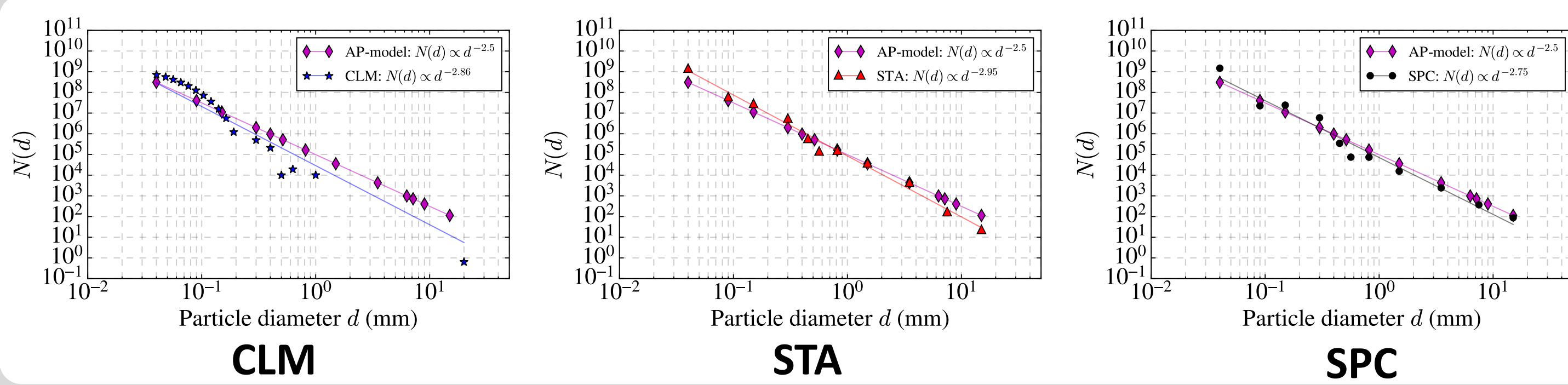
- S. V. Anishchik and N. N. Medvedev. Three-dimensional Apollonian packing as a model for dense granular systems. Physical Review Letters, 75:4314–4317, 1995. doi: [10.1103/PhysRevLett.75.4314](https://doi.org/10.1103/PhysRevLett.75.4314).
- A. Amirjanov and K. Sobolev. Fractal dimension of Apollonian packing of spherical particles. Advanced Powder Technology, 23(5):591–595, 2012. doi: [10.1016/j.appt.2011.06.006](https://doi.org/10.1016/j.appt.2011.06.006).

Contact

Ahmad Morsel (ahmad.morsel@insa-lyon.fr); Claire Silvani (claire.silvani@insa-lyon.fr)

Results

Fracture dimension



CLM

STA

SPC

Different soils have different fractal dimensions