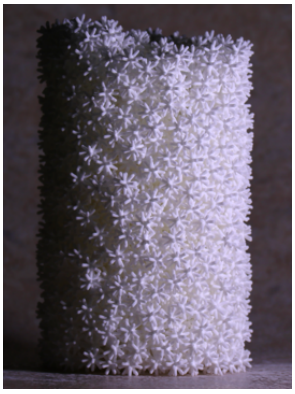
Master 2 Internship –
Exploring Geometric Cohesion in Star-Shaped Meta-Grains
LMGC – Université de Montpellier & IMT Mines Alès.



Granular materials like sand or concrete owe their strength to adhesion between grains. A new paradigm, *geometric cohesion*, has recently emerged: assemblies of non-convex grains can spontaneously form stable, self-supporting structures purely due to mechanical interlocking, without any glue. Understanding how grain shape controls this effect opens the way to designing smart meta-granular materials with tunable properties (Fig. 1).

Objective:

The goal of this internship is to investigate how assemblies of star-shaped grains behave under shear, combining numerical simulations and simple experimental exploration. Due to the complexity of full 3D calculations, the numerical part of the project will be carried out in 2D, enabling systematic exploration of grain shapes and configurations in a time-efficient way. In parallel, simple experiments can be performed on small 3D grains that have already been fabricated, providing qualitative validation of the numerical trends and insight into geometric cohesion.

Tasks:

1] Numerical Study (2D DEM): Simulate small assemblies of 2D star-shaped grains under quasi-static shear, Explore how geometric parameters (number and length of arms, orientation) influence stress transmission and packing behavior, Compute basic mechanical observables (stress-strain curves, coordination number) to identify trends.

2] Experimental Exploration: Use small 3D star-shaped grains already available to perform simple shear or compression experiments. Observe qualitative interlocking patterns and emergent cohesion, complementing the numerical study.

3] Analysis and Comparison: Compare numerical and experimental results to understand correlations between grain geometry and macroscopic behavior under shear. Prepare a report summarizing findings and recommendations for potential 3D extensions or PhD-level work.

Expected Outcomes:

- A database of 2D simulations and small-scale experiments highlighting the effect of star-shaped grain geometry on shear response.
- Hands-on experience with DEM simulations, 3D printing, and experimental granular mechanics.
- Insights into the onset of geometric cohesion under shear.

Practical information:

• **Duration:** 5-6 month

• **Locations:** Montpellier (LMGC)/Alès (IMT Mines Alès),

• **Research Axis and Hosting Team:** the project will be conducted within the *Milieux Divisés* research axis of the *Laboratoire de Mécanique et Génie Civil (LMGC)*. The supervising and collaborating team includes: Emilien Azéma (PR), Mathieu Renouf (CR), Jonathan Barés (IR), and Rémy Mozul (IR) at LMGC/Université de Montpellier & Arnaud Regazzi (Ass.Pr), Patrick Ienny (Pr), and Sylvain Buonomo (IR) at LMGC/IMT Mines Alès.

• **Opportunity:** Possibility to continue into a fully funded PhD via the ANR Exo2GeCo project, building on this internship work.

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