



HAL
open science

Relation between free surface shape and local vertical force in the relaxation of granular materials poured into a container

Agnès Duri-Bechemilh, Frederic Mabilh, Bernard Cuq, Thierry Ruiz

► To cite this version:

Agnès Duri-Bechemilh, Frederic Mabilh, Bernard Cuq, Thierry Ruiz. Relation between free surface shape and local vertical force in the relaxation of granular materials poured into a container. Colloque STPMF - Science et Technologie des Poudres et Matériaux Frittés, Apr 2015, Nancy, France. hal-02916060v1

HAL Id: hal-02916060

<https://hal.science/hal-02916060v1>

Submitted on 3 Jun 2020 (v1), last revised 17 Aug 2020 (v2)

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.



Distributed under a Creative Commons Attribution - ShareAlike 4.0 International License



Thème 3 Propriétés et caractérisations

Relation between free surface shape and local vertical force in the relaxation of granular materials poured into a cell

Agnès Duri*, Frédéric Mabilie, Bernard Cuq and Thierry Ruiz

UMR IATE

<http://umr-iate.cirad.fr/>

2 Place Pierre Viala - 34000 Montpellier – FRANCE



* duri@supagro.inra.fr

**How is the local force distribution
inside an ensiled granular medium?**

How is the local force distribution inside an ensiled granular medium?

- “ Where does it come from?
- “ What is its impact on silo draining, storage or powder mixing ?



Global vertical stress at the bottom of a cylindrical grain column

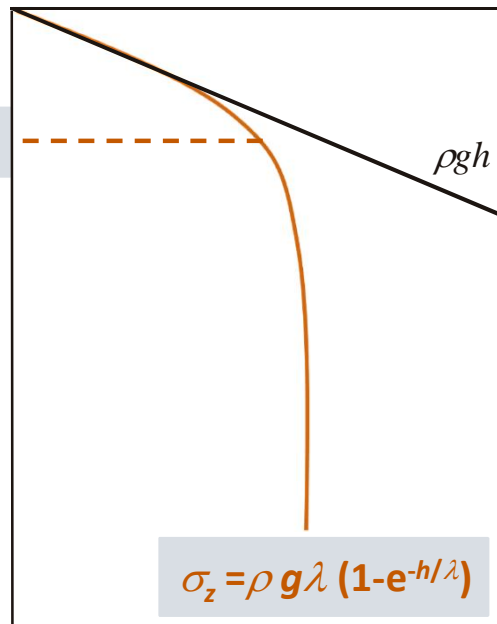
Main hypothesis:

Lateral uniformity of the weight

Global vertical stress

$$\lambda_J = D/4\mu K$$

Height h of grain in the column

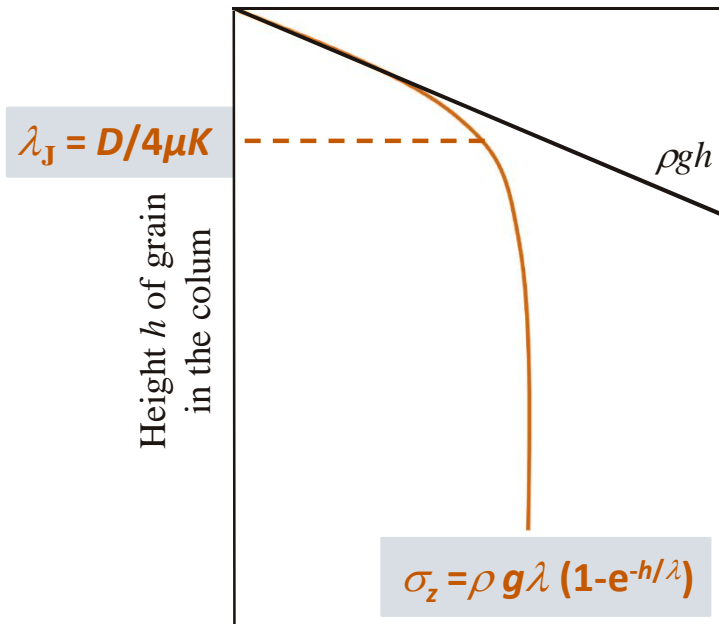


Global vertical stress at the bottom of a cylindrical grain column

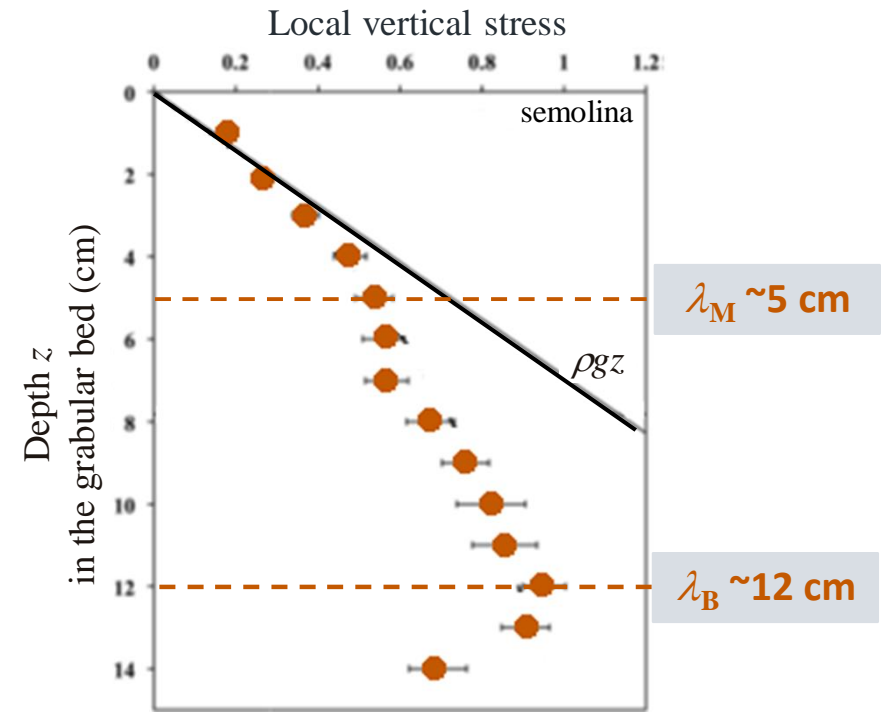
Main hypothesis:

Lateral uniformity of the weight

Global vertical stress



Local vertical stress inside a rectangular grain column



Mandato *et al.*, Powder Tech. 238, 56-63, 2013

Global vertical stress at the bottom of a cylindrical grain column

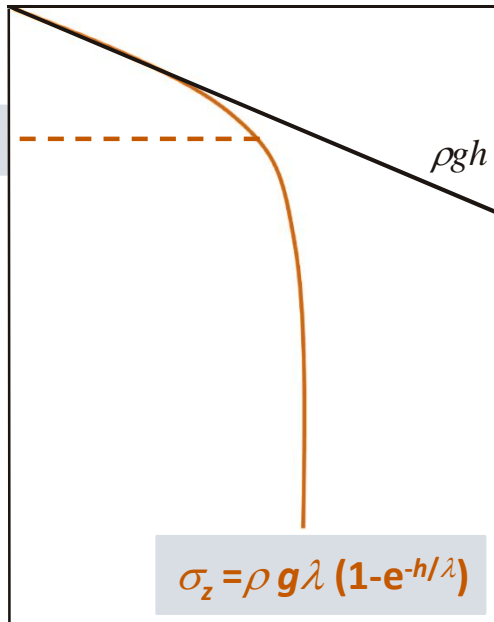
Main hypothesis:

Lateral uniformity of the weight

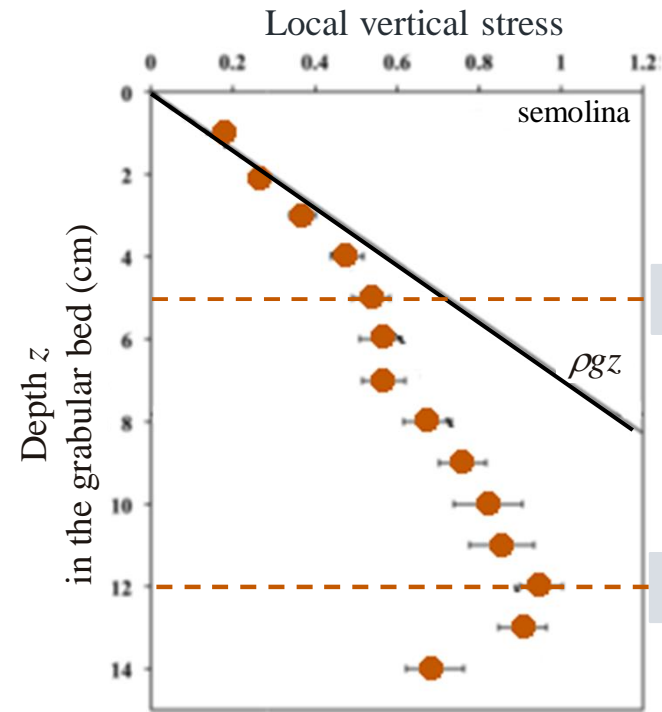
Global vertical stress

$\lambda_J = D/4\mu K$

Height h of grain in the column



Local vertical stress inside a rectangular grain column



Mandato *et al.*, Powder Tech. 238, 56-63, 2013

\neq

Understanding the origin
of the local mechanical static state

Understanding the origin
of the local mechanical static state

- “ Mandato’s device.
- “ Powders of same nature but with contrasted physical properties.
- “ Study the powder implementation in a cell.

2D rheological device

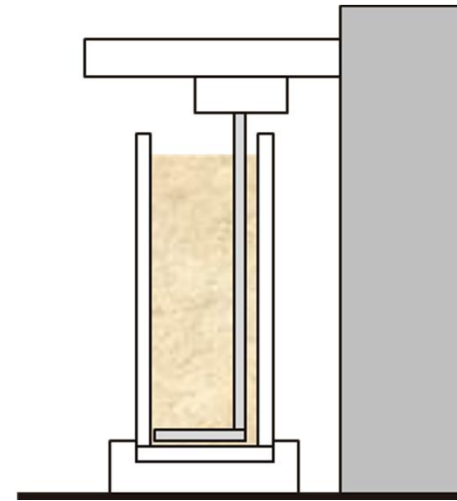
Mandato's device



cell
(51 x 100 x 160 mm)

blade sensor
(45 x 20 mm)

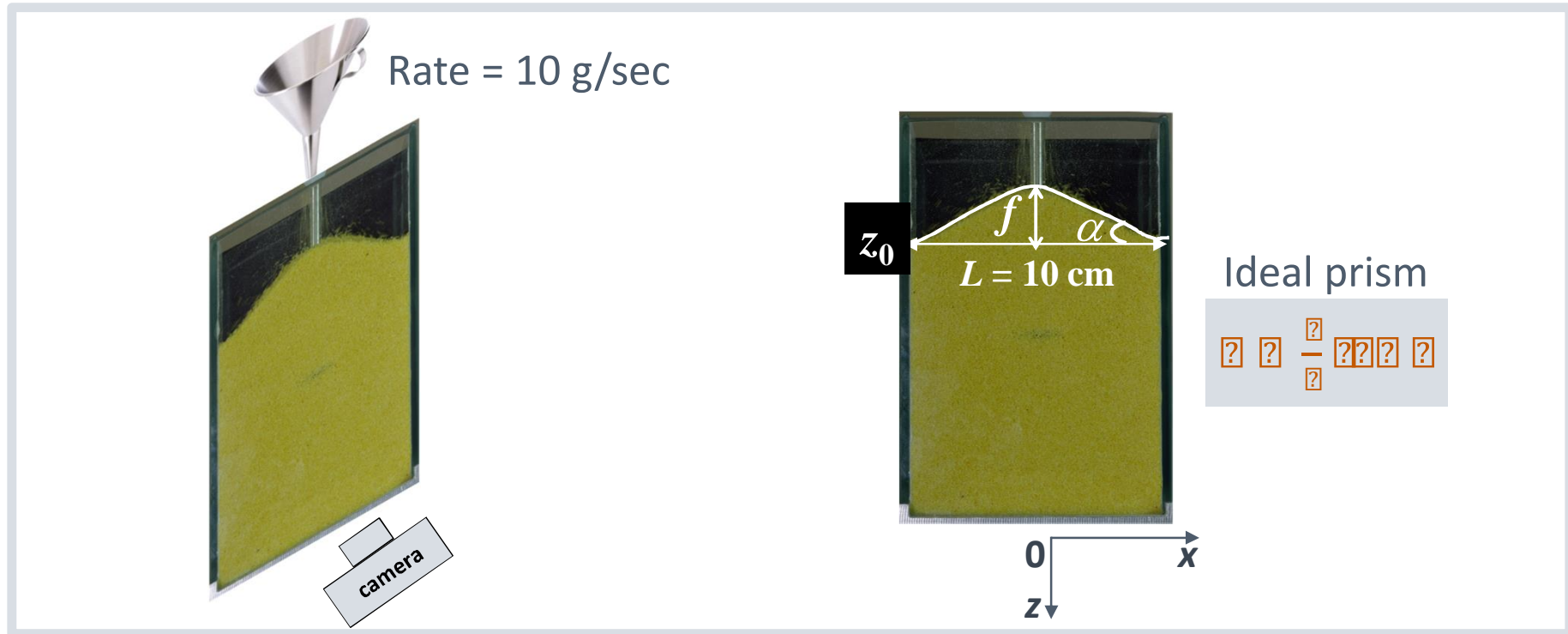
Front view



*Side view
of the texture analyser*

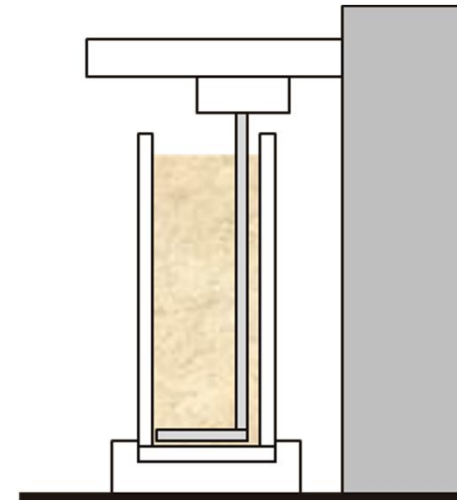
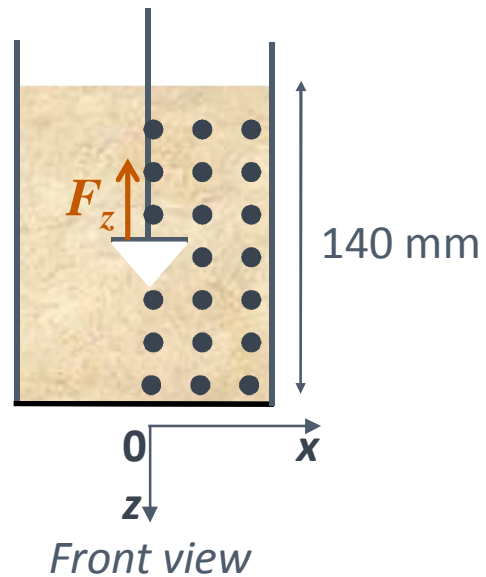
2D rheological device

Measurement of the free surface profile of the heap

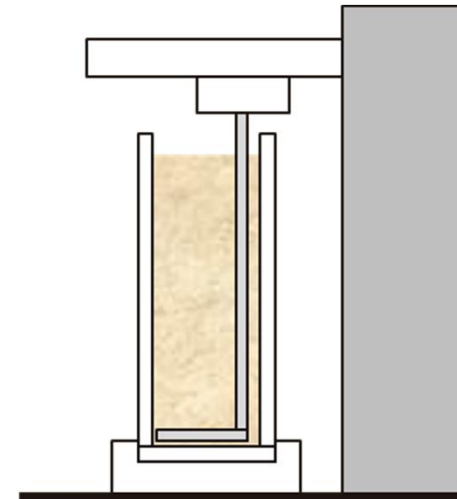
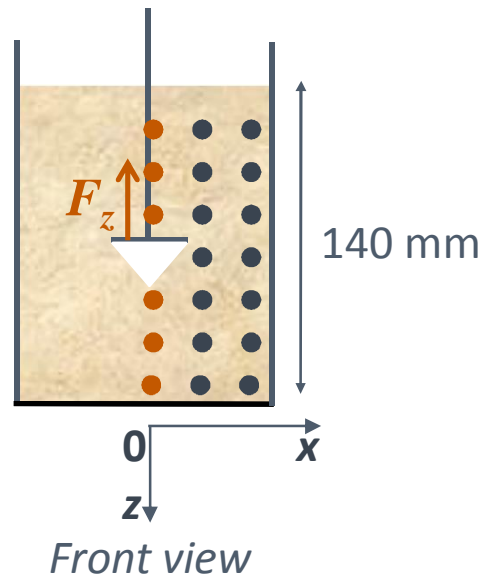


Measurement of:

- " f , the deflection
 - " α , the angle of repose
- } $0 < z \leq 140 \text{ mm}$

2D rheological deviceMeasurement of the local vertical force profile

Measurement of the local vertical force
inside the granular bed

2D rheological deviceMeasurement of the local vertical force profile

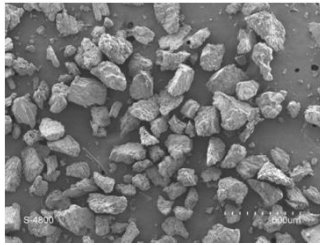
Side view
of the texture analyser

Measurement of the local vertical force
inside the granular bed
 $x = 0 \text{ mm}$ & $0 < z \leq 140 \text{ mm}$ (position in the bed)

Objective

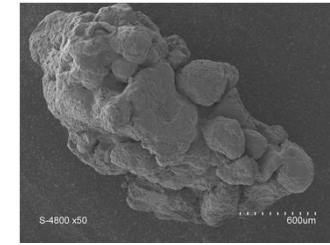
Method

Material



Semolina

Wheat-based powders



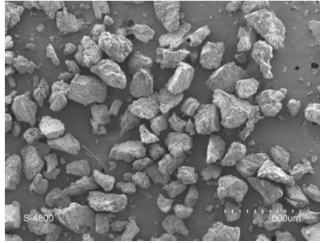
Couscous grain

A range of 5 wheat-based powders : native and agglomerated particles

Objective

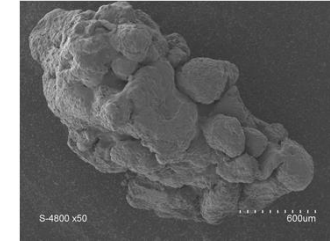
Method

Material



Semolina

Wheat-based powders



Couscous grain

A range of 5 wheat-based powders : native and agglomerated particles

Sample Name	d_{50} (μm)	$d_{90}-d_{10}$ (μm)	Bed compactness Φ
Fine semolina	210	320	0.416
Medium semolina	300	430	0.446
Fine couscous	680	640	0.580
Medium couscous	950	520	0.570
Large couscous	1100	400	0.580

Example of heap formation



Couscous moyen

Objective

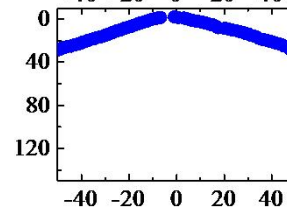
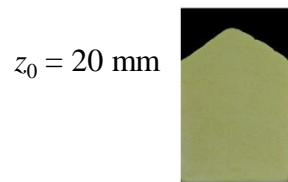
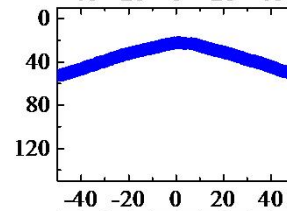
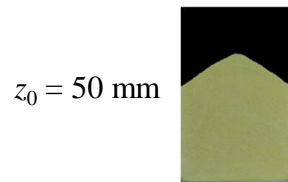
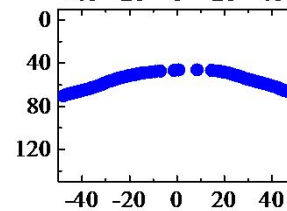
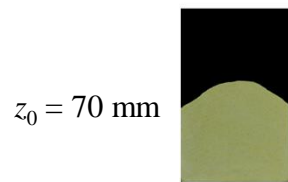
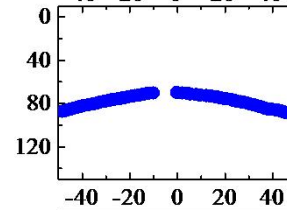
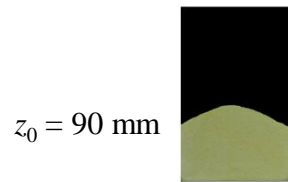
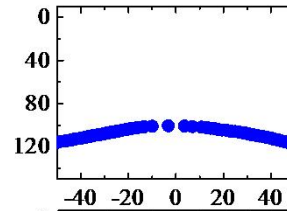
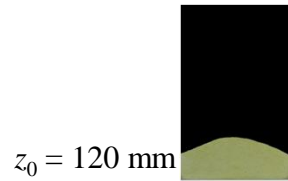
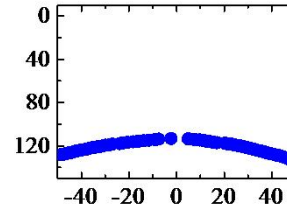
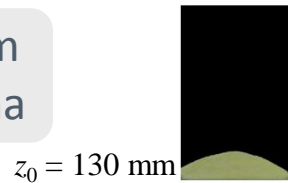
Method

Material

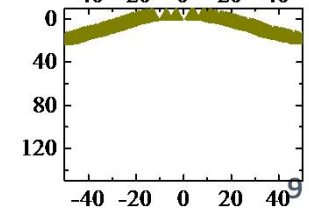
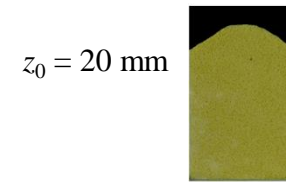
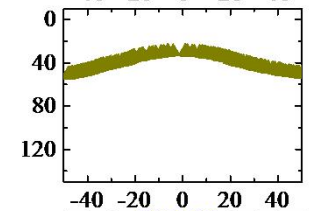
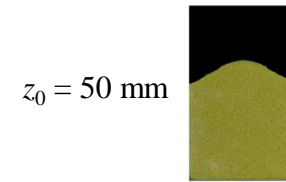
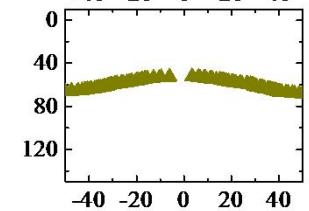
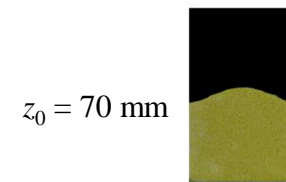
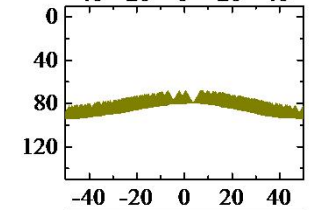
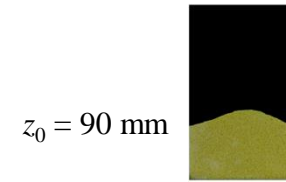
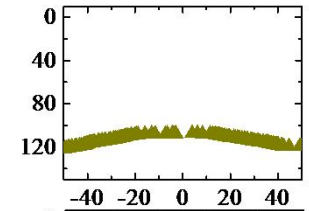
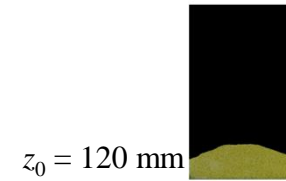
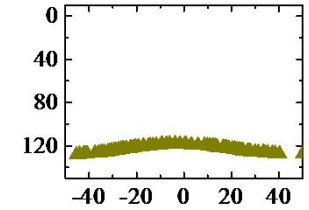
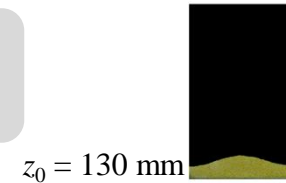
Results

Examples of free surface profile

Medium semolina

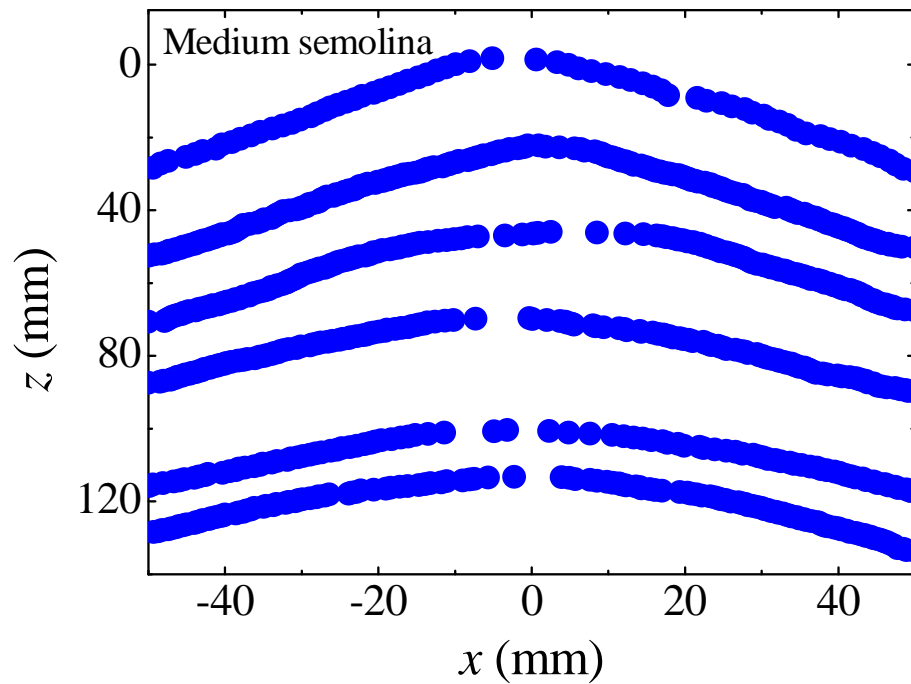


Large couscous



Examples of free surface profile evolution of the heap

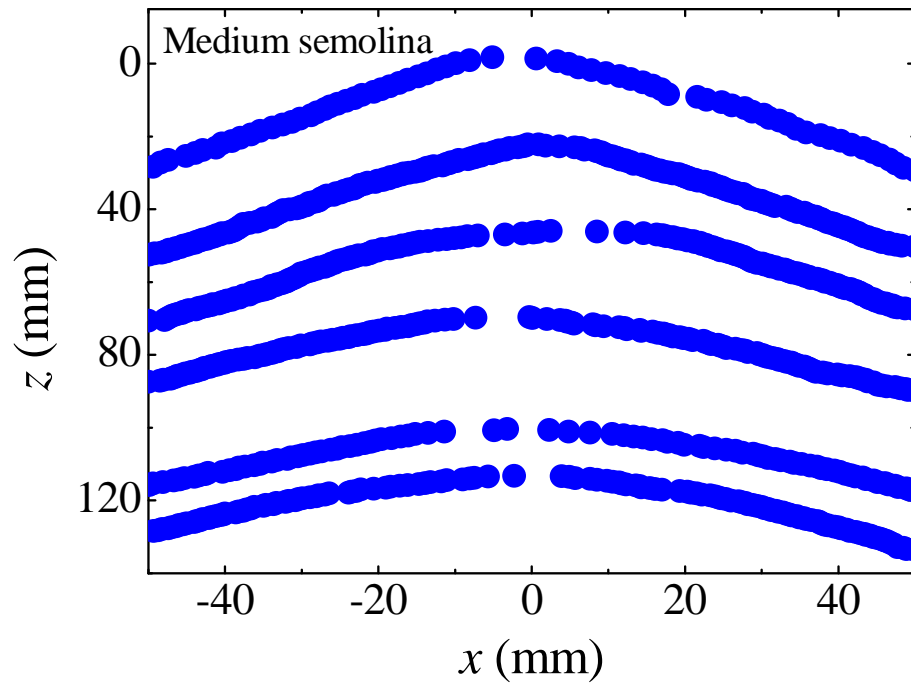
As a function of z_0



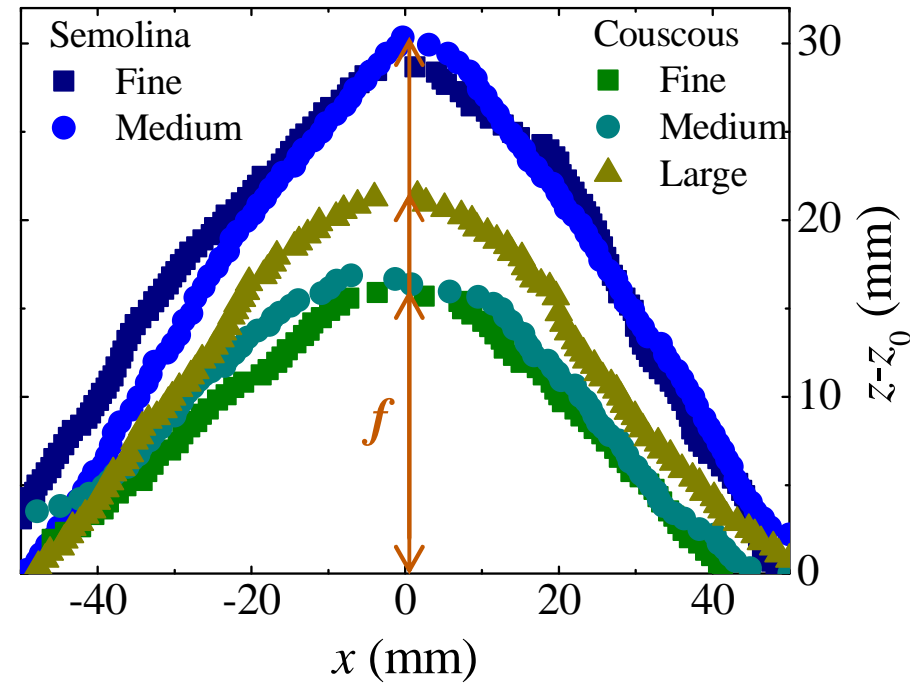
The shape of the free surface profile evolves with z_0

Examples of free surface profile evolution of the heap

As a function of z_0

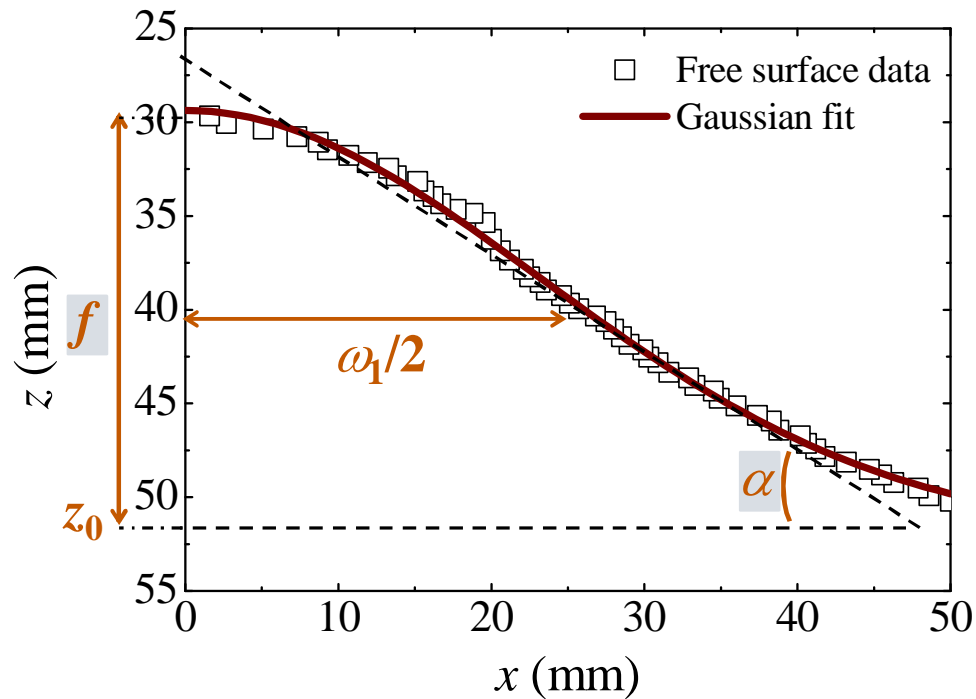


As a function of particle



The shape of the free surface profile **evolves** with z_0 and between **native** and **agglomerated** particles

Free surface profile analysis



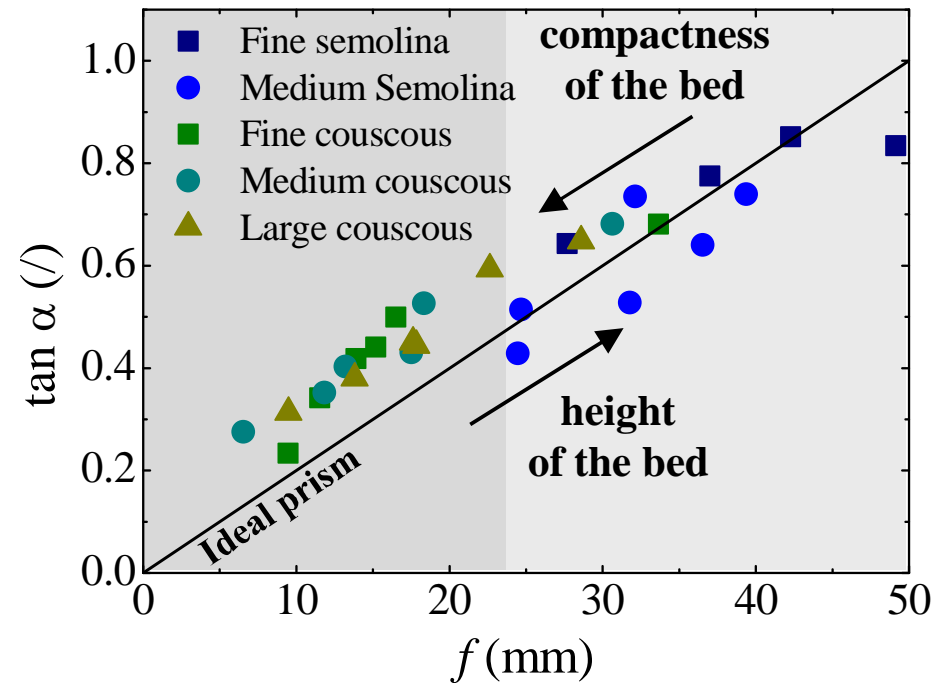
Gaussian fit

$$f(x, z) = z_0(z) + \frac{f}{\omega_1^2} \exp\left(-\frac{x^2}{\omega_1^2}\right)$$

- f is the deflection
- $2 \sigma = \omega_1 / \sqrt{\ln(4)}$
- ω_1 is the width of the gaussian fit

$$z(x) = z_0 + \frac{f}{\omega_1^2} \tan^2\left(\frac{x}{\omega_1}\right)$$

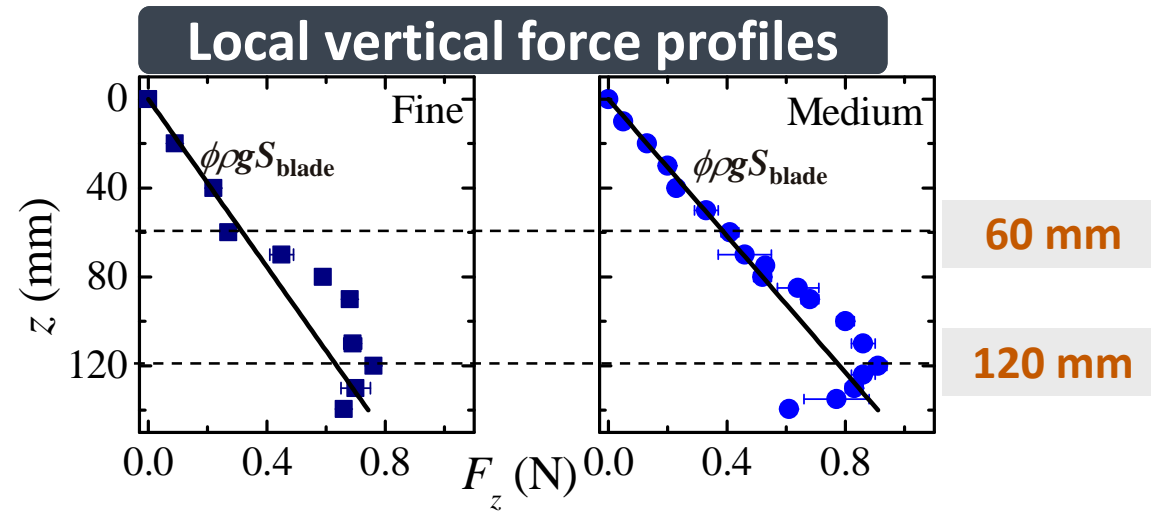
Fit parameter evolution of the heap



Two significant regimes:

- “ Semolinas – sloping heap of high amplitude \leftrightarrow low bed compactness
- “ Couscous – plane heap of low amplitude \leftrightarrow high bed compactness

Semolina

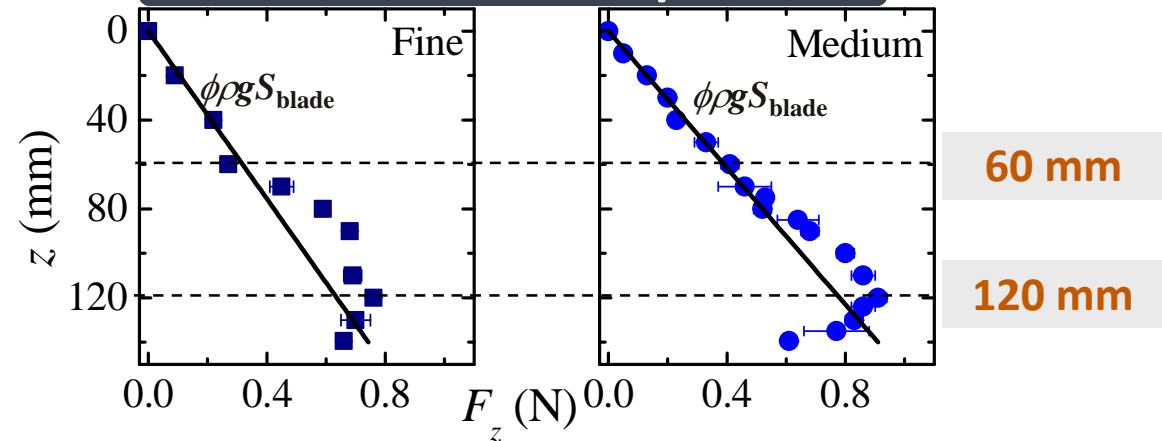


60 mm

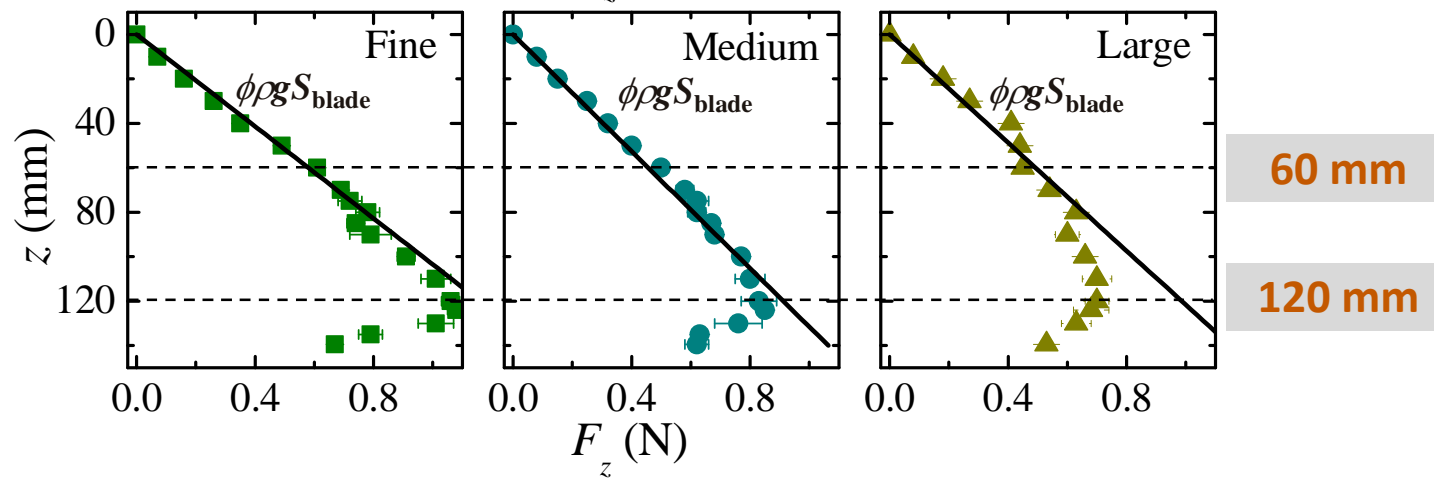
120 mm

Local vertical force profiles

Semolina

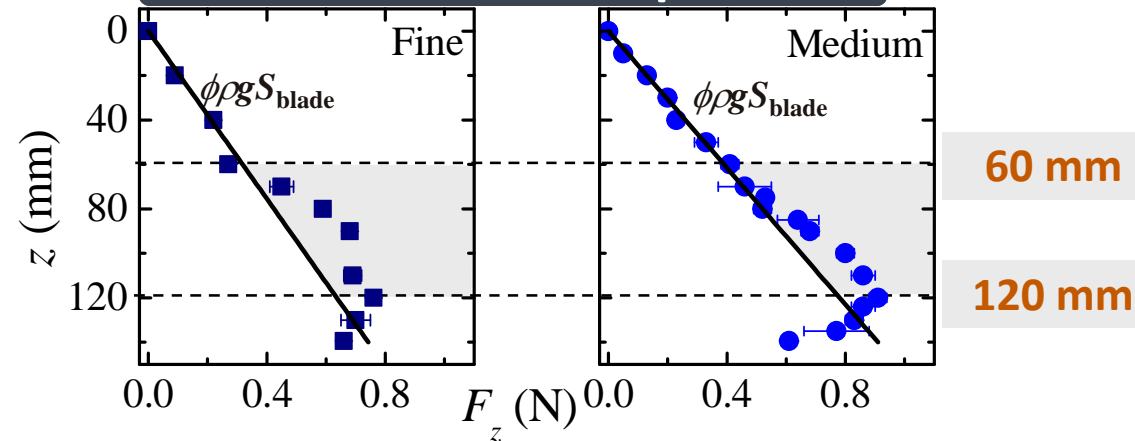


Couscous

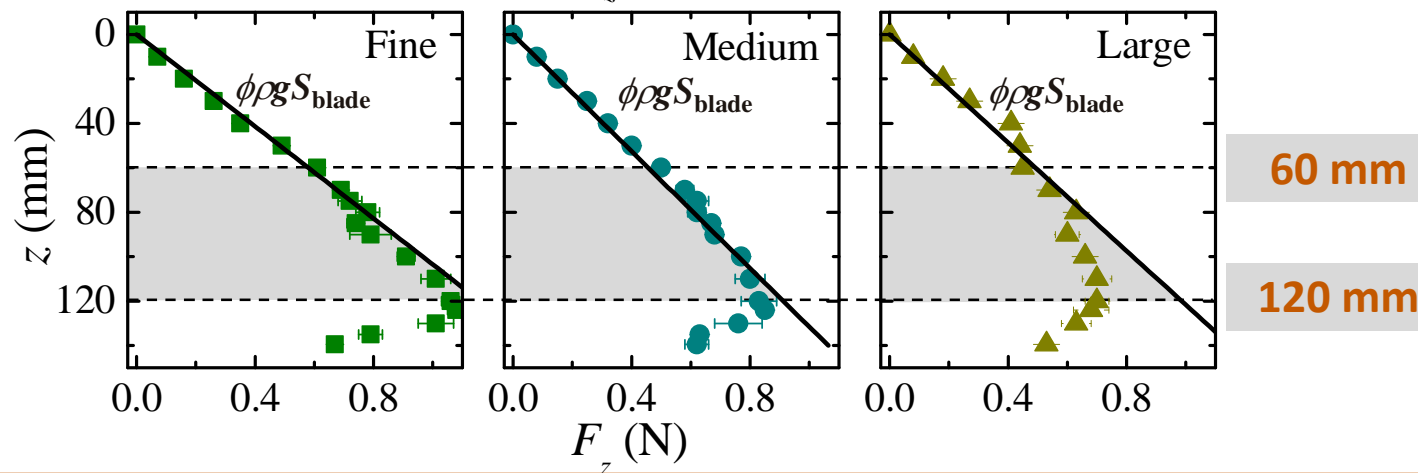


Local vertical force profiles

Semolina



Couscous



Two distinct regimes for $60 \text{ mm} \leq z \leq 120 \text{ mm}$:

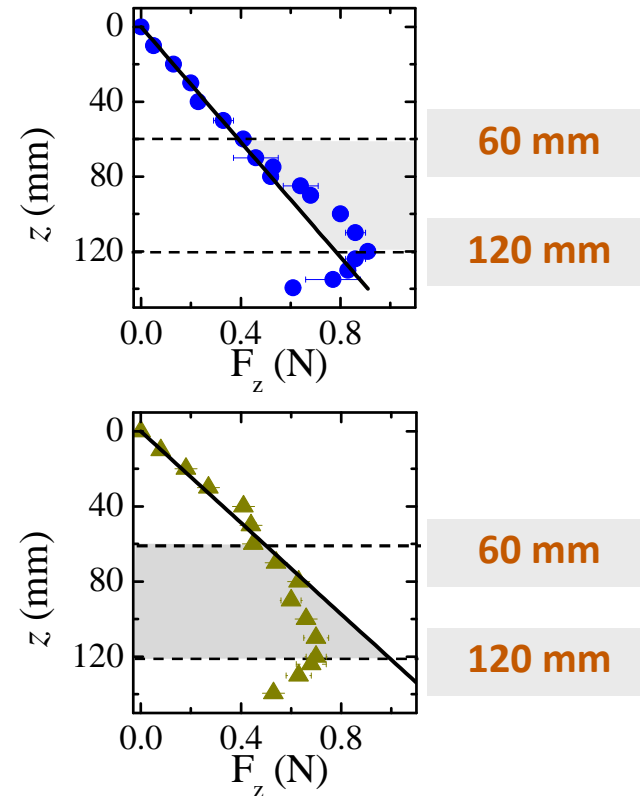
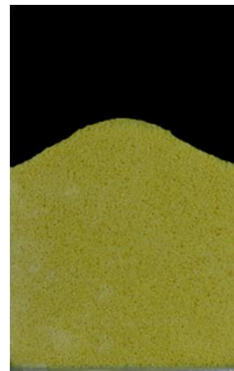
- “ Semolinas – local vertical force profile $>$ pseudo-hydrostatic profile
 \leftrightarrow low bed compactness
- “ Couscous – local vertical force profile $>$ pseudo-hydrostatic profile
 \leftrightarrow high bed compactness

Free surface profile of the heap / Local vertical force profile

Medium
semolina



Large
couscous



Two distinct regimes for $60 \text{ mm} \leq z \leq 120 \text{ mm}$:

- “ Semolinas – sloping heap \leftrightarrow low lateral deflection of the local vertical force
- “ Couscous – plane heap \leftrightarrow high lateral deflection of the local vertical force \leftrightarrow Local Janssen's profile

Conclusions

- “ **2D rheological device** for measuring the **local vertical force** inside **ensiled granular media** and capturing their **free surface implementation** of the powder bed.
- “ **Correlation** between the history of the **bed implementation** and the **local force distribution** inside an ensiled granular medium:
 - The **more sloping** the **powder heap** is, the **more high** the **intensity** of the **local force** is, with regard to its pseudo-hydrostatic state (for $60 \text{ mm} \leq z \leq 120 \text{ mm}$).

Conclusions

- “ **2D rheological device** for measuring the **local vertical force** inside **ensiled granular media** and capturing their **free surface implementation** of the powder bed.
- “ **Correlation** between the history of the **bed implementation** and the **local force distribution** inside an ensiled granular medium:
 - The **more sloping** the **powder heap** is, the **more high** the **intensity** of the **local force** is, with regard to its pseudo-hydrostatic state (for $60 \text{ mm} \leq z \leq 120 \text{ mm}$).

Influence of **powder properties** on the **local vertical force profiles**

→ **Poster of Duri et al.**



Thème 3 Propriétés et caractérisations

Thank you for your attention

**Relation between free surface shape and local vertical force
in the relaxation of granular materials poured into a container**

Agnès Duri*, Frédéric Mabilie, Bernard Cuq and Thierry Ruiz

UMR IATE

<http://umr-iate.cirad.fr/>

2 Place Pierre Viala - 34000 Montpellier – FRANCE



* duri@supagro.inra.fr

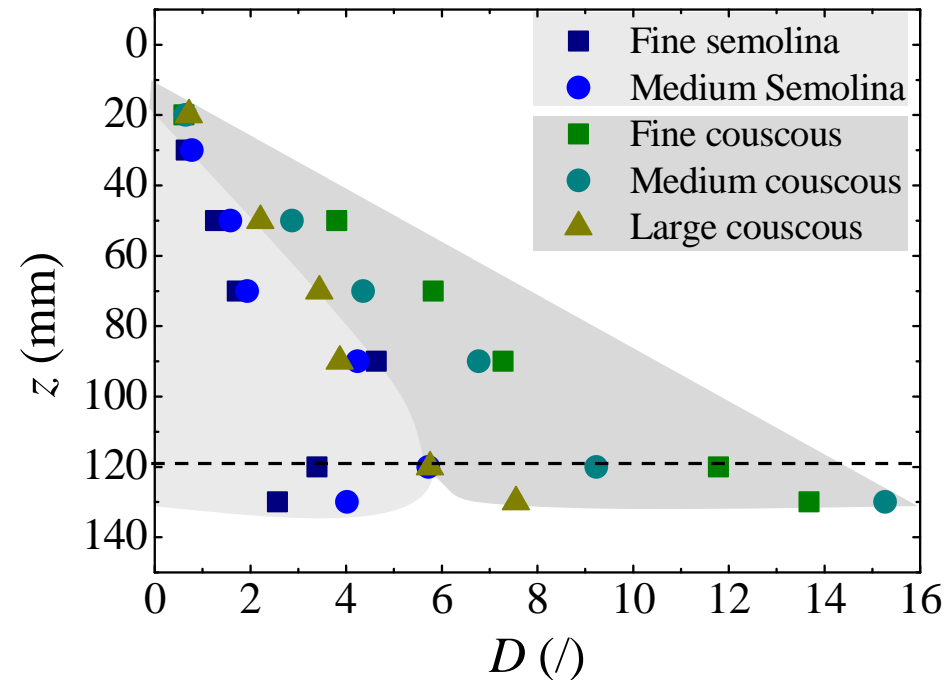
Adimensional D parameter

$$D = \frac{f}{F S^2}$$

f is the deflection

F is the local vertical force

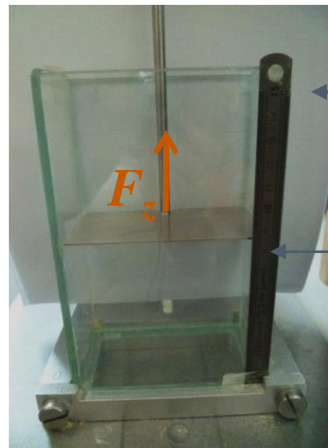
S is the the slope of the local hydrostic profile



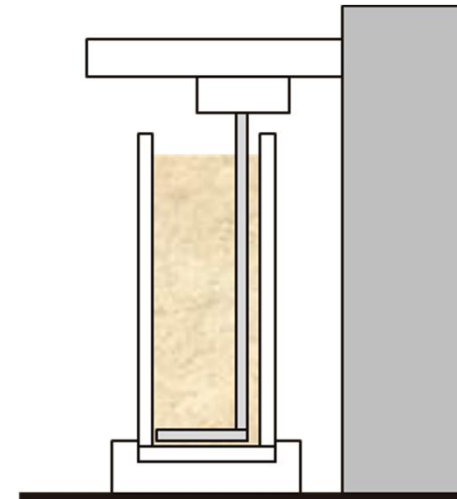
Two significant regimes:

“ $0 \text{ mm} \leq z \leq 120 \text{ mm}$ – linear trend of D – $\text{Slope}_{\text{semolinas}} > \text{Slope}_{\text{couscous}}$

“ $z \geq 120 \text{ mm}$ – bottom effect \rightarrow Deviation of D – Left semolinas & Right couscous

2D rheological deviceGlobal vertical force*Front view*

cell
(51 x 100 x 160 mm)
blade sensor
(50.5 x 98.5 mm)

*Side view
of the texture analyser*

Measurement of the **vertical force**
at the **bottom** of the cell
 $0 < z \leq 14$ cm (height of the bed)