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Influence of the stabilization process on the mechanical properties of a honeycomb

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From Knowledge to Market

Influence of the stabilization process on the mechanical properties of a honeycomb

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A joint initiative of

Context and Objectives

Context of the study:

- **The physical protection of personnel and assets against the effects of various explosive charges**
  - Increasing the distance between the explosive and the target
  - Mitigating the detonation process (*__water mist__*, aqueous foam, confinement bell,…)
  - Mitigating the blast load (physical barrier, *__water curtain__*, sacrificial cladding…)

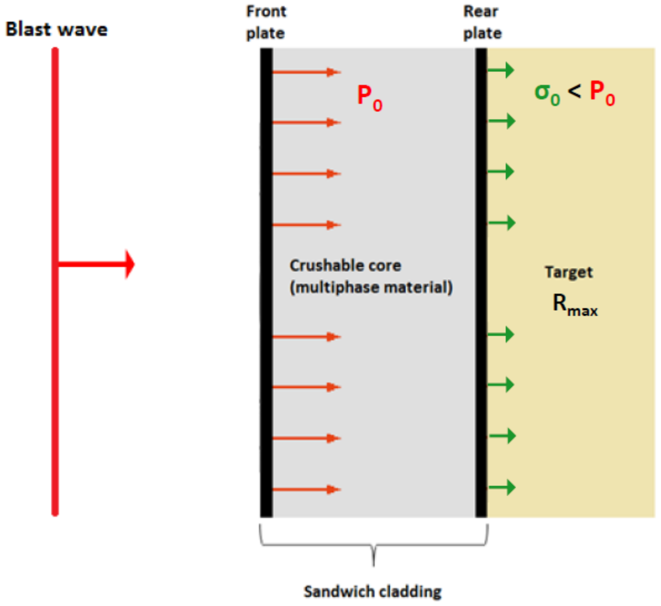
Objectives:

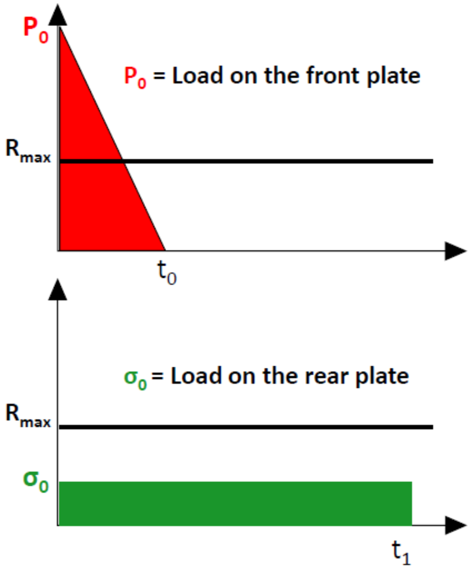
- **Improving our knowledge on the sandwich cladding:**
  - Exploiting fluid-structure interaction *(Blanc L., ISIEMS 2019)*
    - → reduction of transmitted load impulse
  - Using the absorption capacity of cellular materials
    - → reduction of transmitted load
  - Improving our database of absorbers *(Blanc L. ISSW 2019)*

Schunck T., ISSW 2017

Schunck T., ISSW 2019

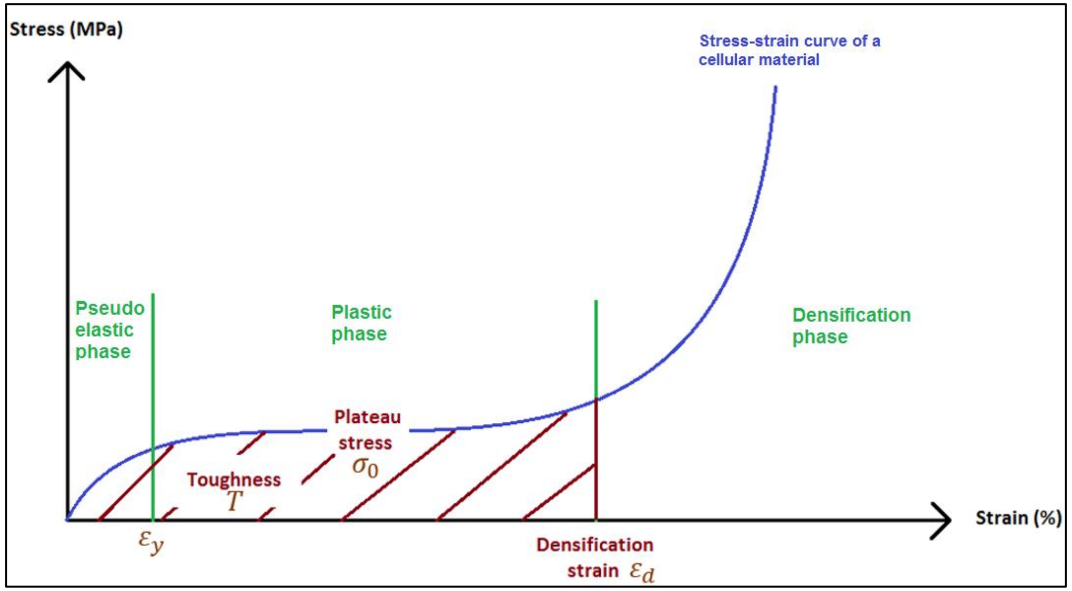
Context and Objectives : Sandwich cladding

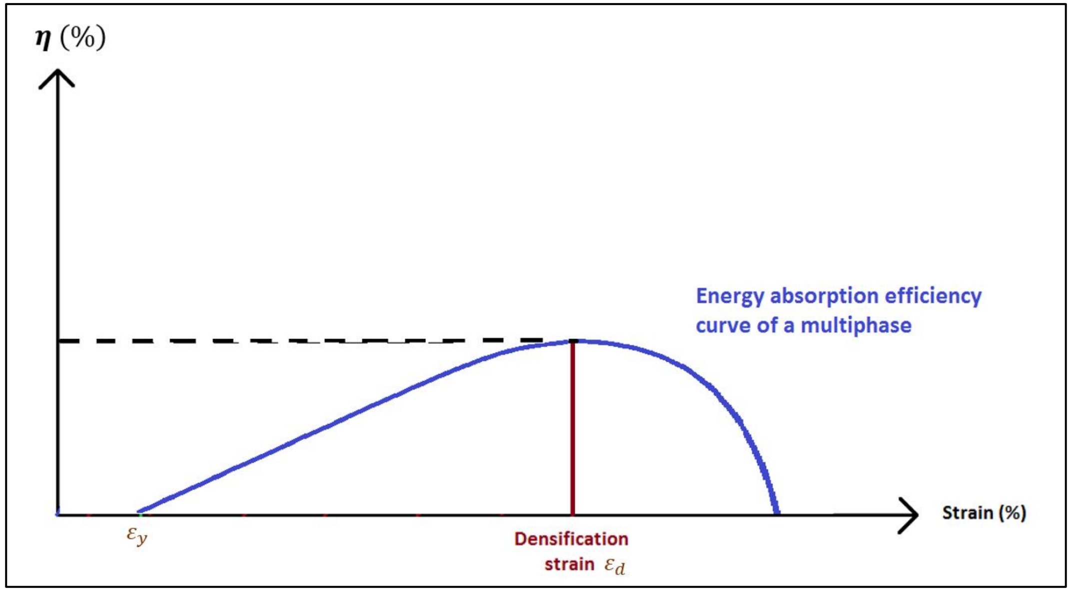




- **Sandwich Cladding: a blast mitigation technique**
  - The rigid front plate is put into displacement by a shock wave (Assumption: load $P_0 > R_{max}$)
    ⟶ Conversion of the blast energy into kinetic energy.
  - Front plate kinetic energy E_k is absorbed by the compression of the core until zero velocity or impact on the rear plate
  - Through the compression, the core applies a load $\sigma_0 < P_0$ to the rigid back plate over a longer time span.
- **Objective:**
  - choose the crushable core so that $\sigma_0 < R_{max}$
  - choose the thickness of the core so that all the kinetic energy is absorbed

Methodology





Li Q.M., Magkiriadis I., Harrigan J.J., 2006, *Compressive strain at the onset of densification of cellular solids*, Journal of Cellular Solid 42, Issue 5, pp. 371-392

$$\eta(\varepsilon) = \frac{1}{\sigma(\varepsilon)} \int_{\varepsilon_y}^{\varepsilon} \sigma(\varepsilon) d\varepsilon$$

$$\sigma_0 = \frac{\int_{\varepsilon_y}^{\varepsilon_d} \sigma(\varepsilon) d\varepsilon}{\varepsilon_d - \varepsilon_y}$$

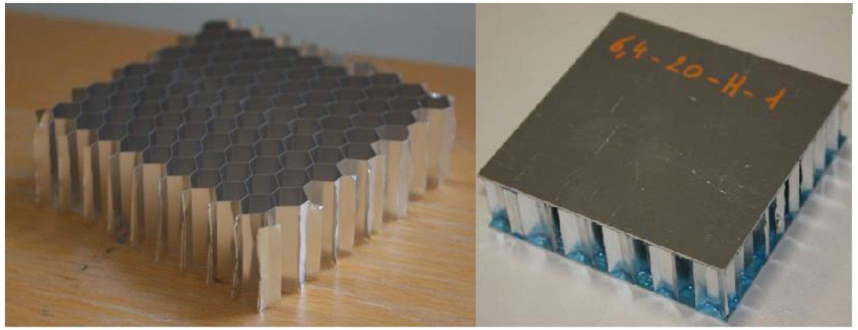
$$T = \int_0^{\varepsilon_d} \sigma(\varepsilon) d\varepsilon \approx \sigma_0 \cdot \varepsilon_d$$

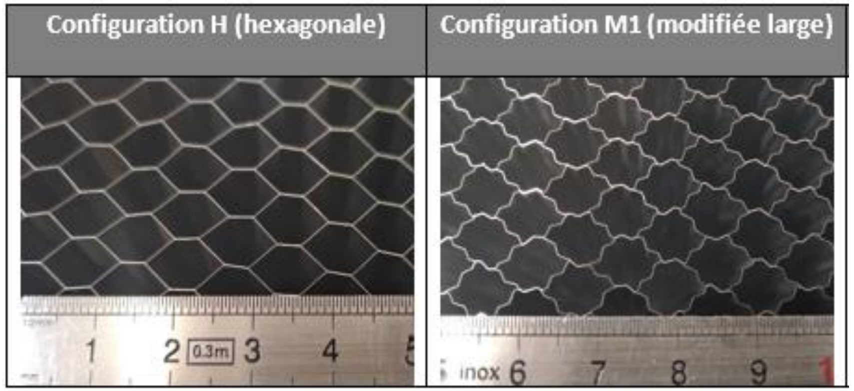
Bulk modulus computation is chosen following this equation

→ <u>Choice based on results and not before the investigation</u>

$$K = \frac{0.70 \cdot PCS - 0.30 \cdot PCS}{\varepsilon_{0.70 \cdot PCS} - \varepsilon_{0.30 \cdot PCS}}$$

Material and experimental set-up





<u>Honeycomb :</u>

- Squared area (75 x 75 mm^2)
- Height varying from 20 to 100 mm
- Cell size varying from ϕ6.4 to ϕ9.5
- Sheet thickness varying from 40 to 60 µm
- Density of 42 $kg.m^{-3}$
- Half of the samples are stabilized with two 0.8 mm thin aluminium sheets glued with "prepreg epoxy Hexcel Redux 609"
- Varying cell topology

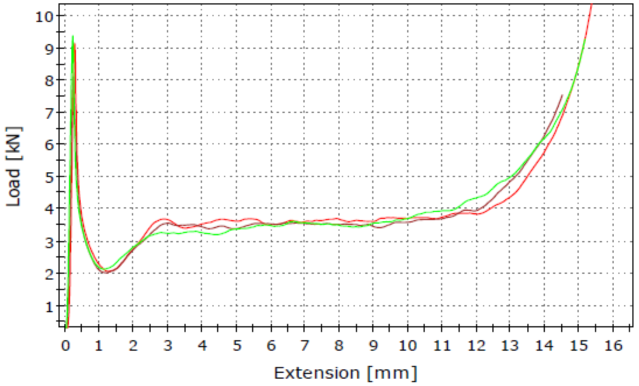
<u>Quasi-static tests : INSTRON 250kN 5985</u>

- Measurement through traverse displacement
- Strain-rate at 0.5 mm/min to compute the bulk modulus K (Norm ASTM C365M)
- Strain-rate at 25 mm/min to compute the platau stress σ0 (Norm ASTM D7336M)
- Automatic change in strain-rate once the stress decreased to 80 % of the ultimate force prior to failure
- Compliance test performed and included in the analysis

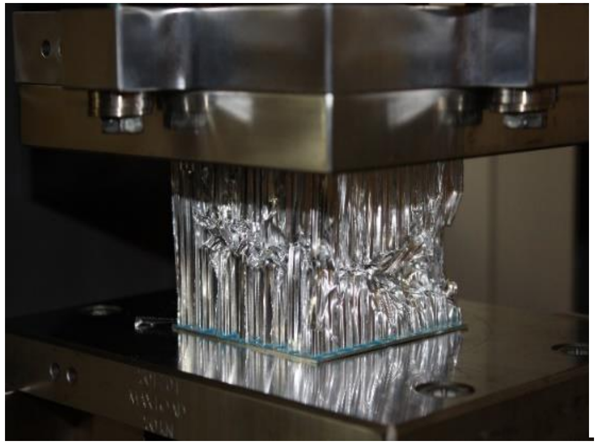
Experimental and numerical Results

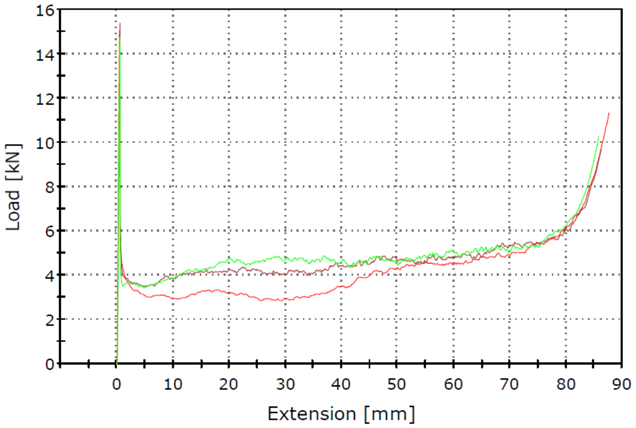
Experimental :

- Repeatability and Dispersion of the results :
  - Low dispersion < 5%: Influence of the structural default on the measured Plastic Collapse Stress



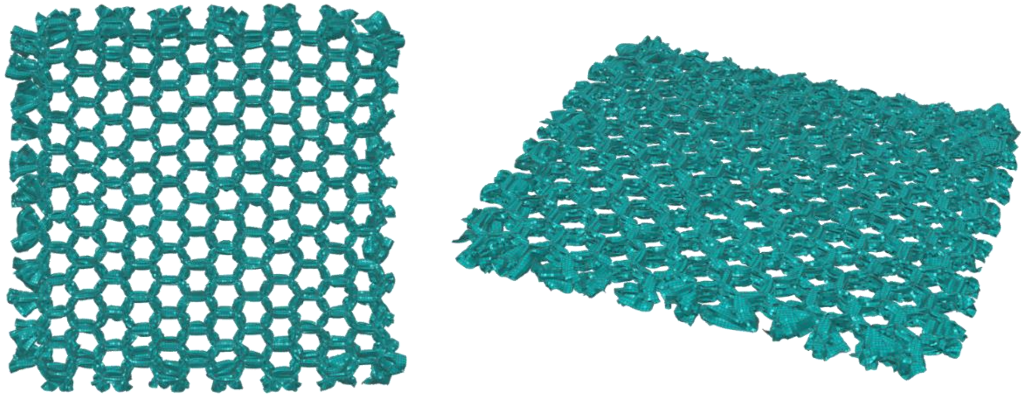
  - High dispersion = 10 %: Catastrophic failure and its influence on the toughness of the sample

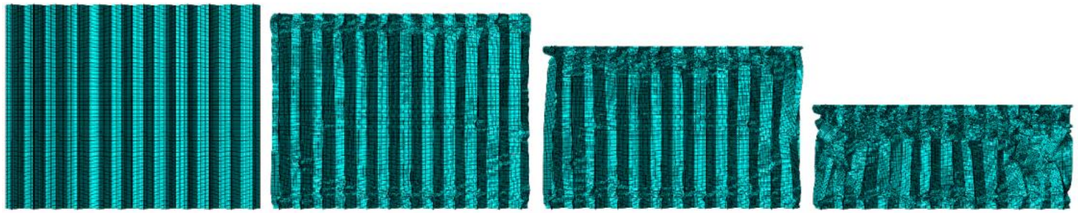




Numerical:

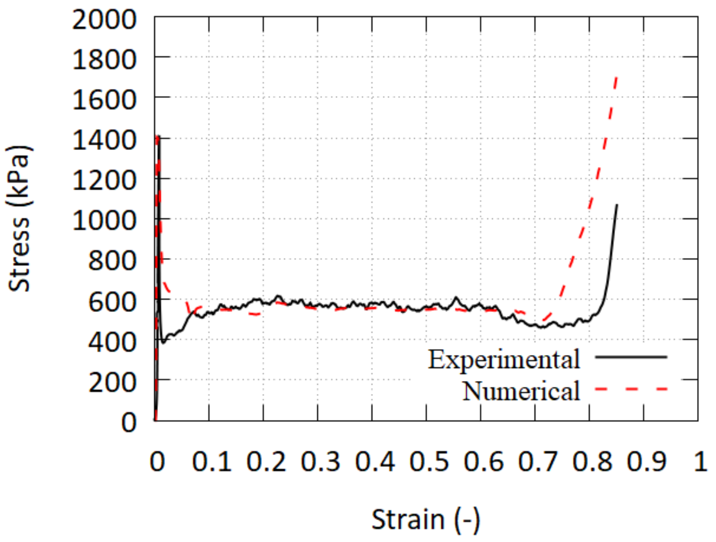
- Full modelization with a 0.5 mm mesh
- Stabilization modelled through boundary conditions

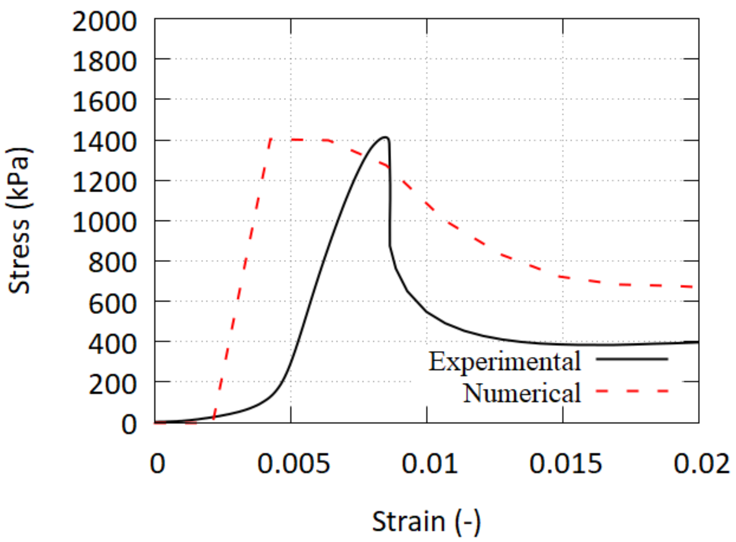




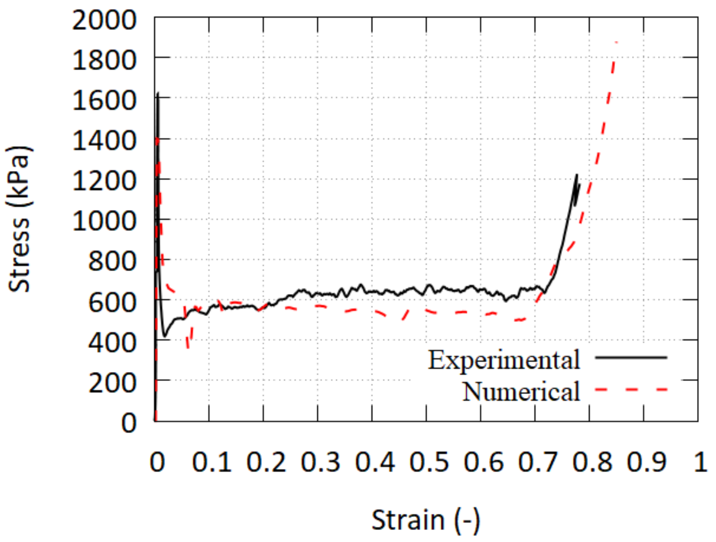
Experimental and numerical comparisons: 60 mm high Honeycomb

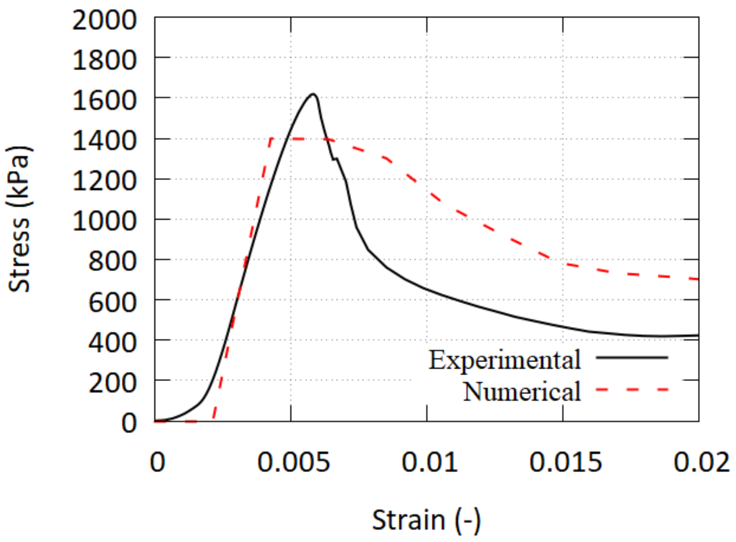
<u>Non-Stabilized Honeycomb :</u>
- Good description of the crushing behavior, including the bulk modulus





<u>Stabilized Honeycomb :</u>
- Good description of the crushing behavior, including the bulk modulus

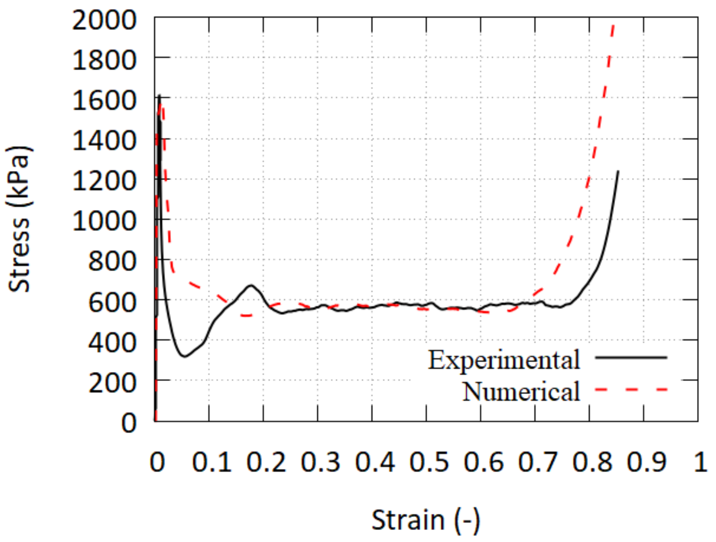


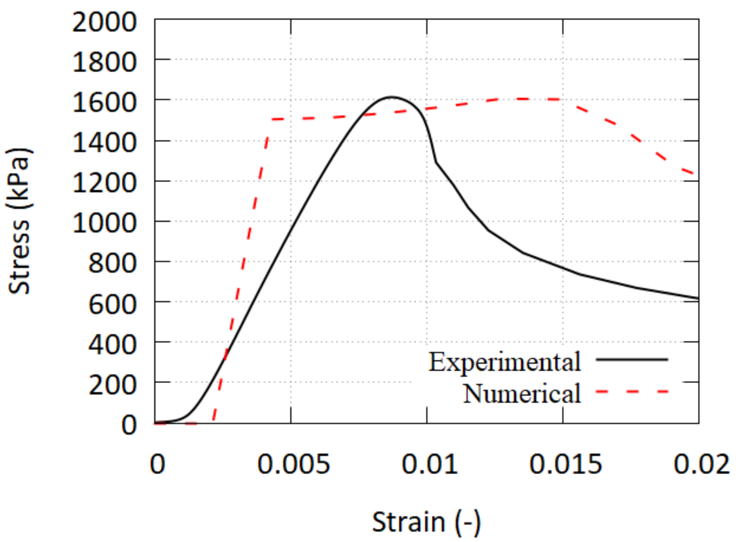


Experimental and numerical comparisons: 20 mm high Honeycomb

<u>Non-stabilized Honeycomb :</u>

- Good description of the crushing behavior, except for the bulk modulus

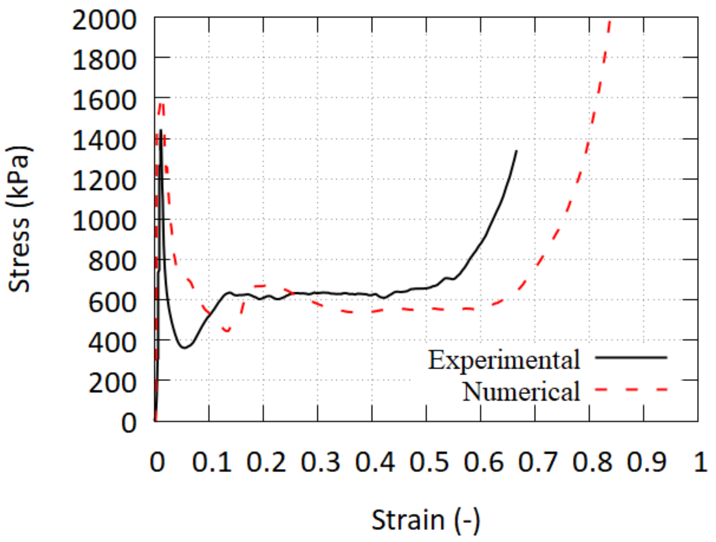


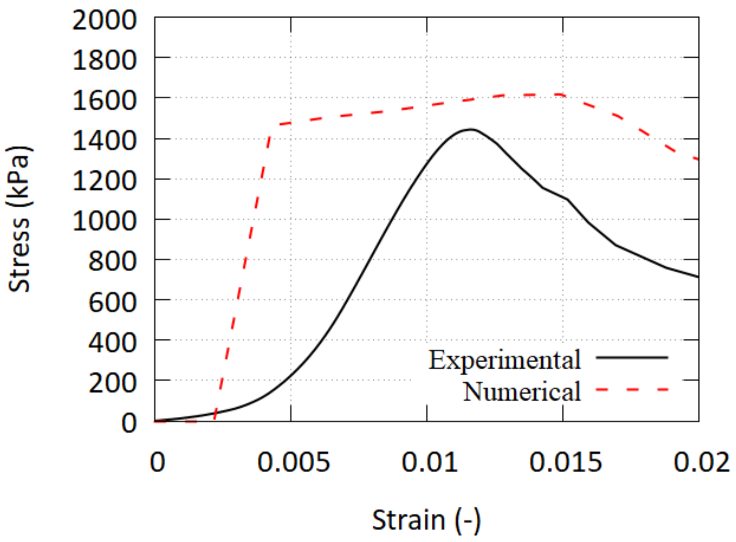


<u>Stabilized Honeycomb :</u>

- Bad description of the crushing behavior, especially the elastic and densification phases

→ Stabilisation needs to be better parametred in numerical simulations





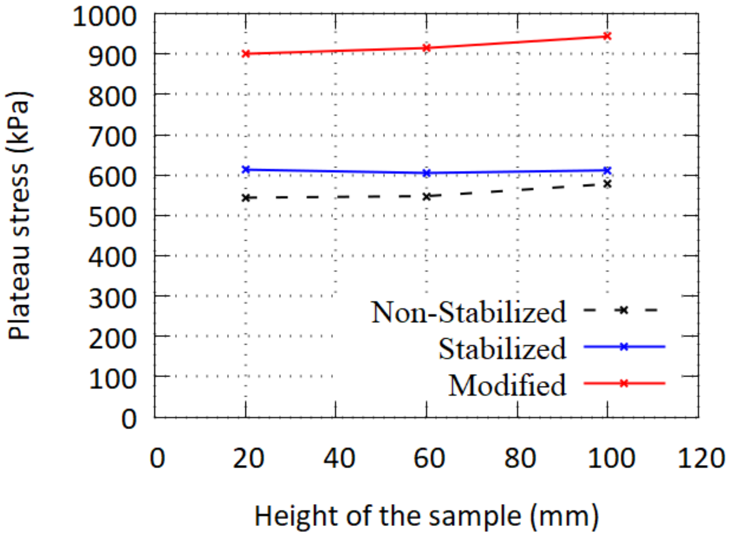
Analysis of materials parameters:

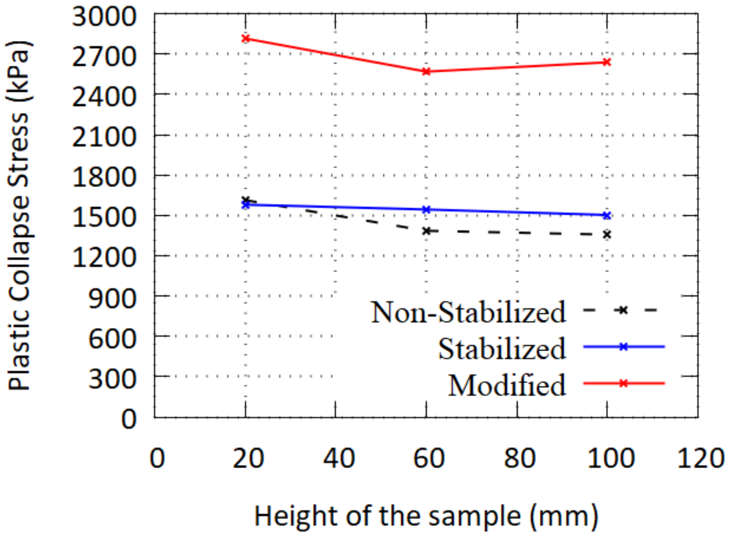
Influence of the stabilization process :

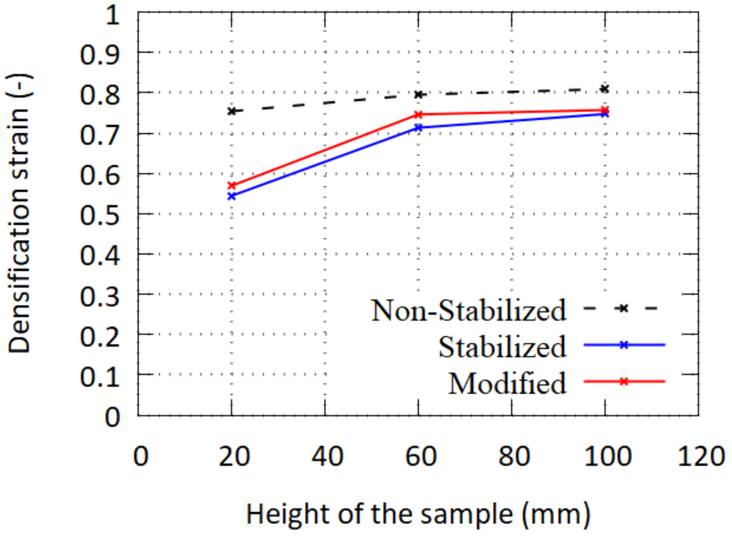
- **Higher plateau stress**
- **Higher plastic collapse stress** except when the height is low enough to have similar boundary conditions with or without the glue
- **Lower densification strain**, simply because the material has less room to deform with the glue. The difference decreases when the ratio height of glue over Height of honeycomb decreases
- **Lower toughness**, because of its definition and how the densification strain is influenced.

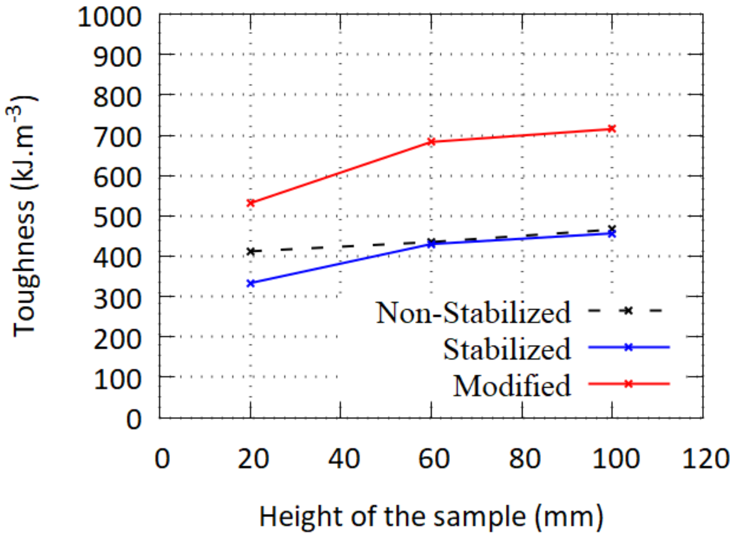
Influence of the height of the Honeycomb :

- **No influence on the plateau stress**
- **No influence on the plastic collapse** stress BUT …
  … as the height increases, we are more likely to find default in the material
- **Influence on the densification strain**, especially on stabilized sample.
- **Influence on the toughness** following the trend found for the densification strain.





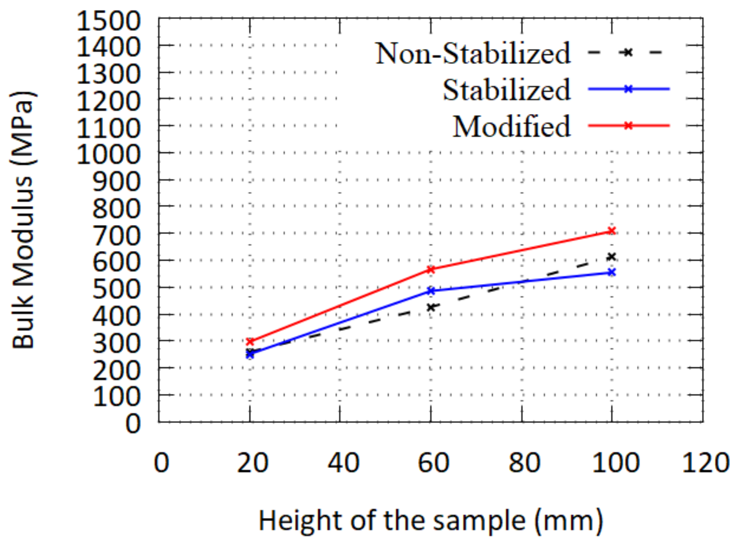




Analysis of materials parameters:

Bulk modulus of the Honeycomb :

- Increase with the height of the honeycomb, since the ratio F/Δl is known to be constant.
- Be careful if the material is homogenized in a numerical model using the bulk modulus
- Be careful when using the Bulk modulus of a material in civil engineering application (safety coefficient, etc…)
- The influence of the stabilization process is unclear yet on the bulk modulus

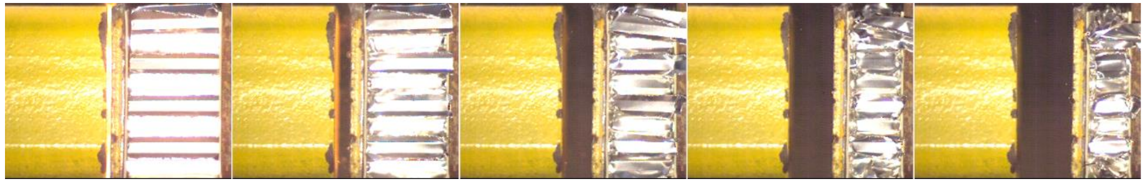


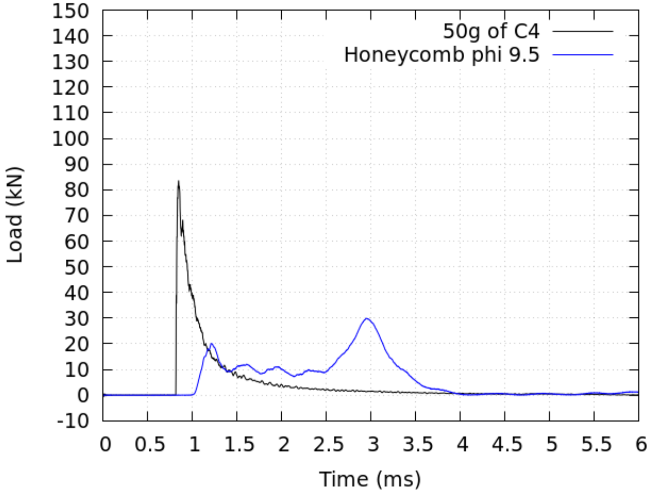
Conclusion

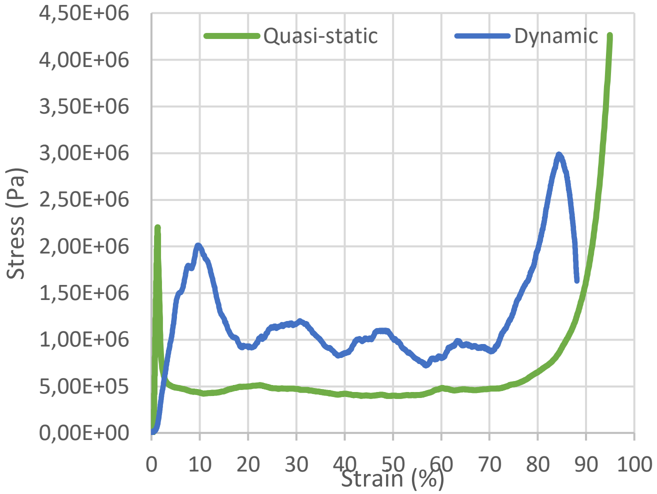
- New tests will be performed to further increase our accuracy when measuring the bulk modulus of honeycomb

- While slightly discussed, we will focus in the future on the influenced of the topology
    - The modified honeycomb presented far better characteristics than the classical hexagonal honeycomb, at equivalent density

- Dynamic tests will be performed on these honeycomb using our Explosive Driven Shock Tube







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THANK YOU!

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Q&A

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