

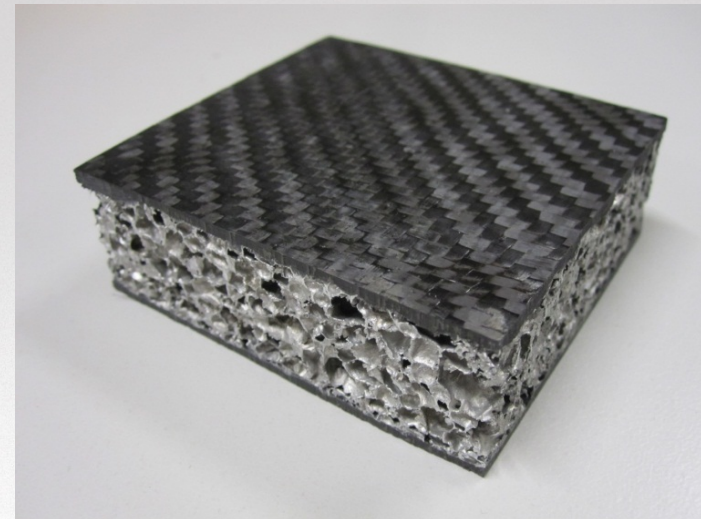


# Lightweight Modular Vehicle Platform (LMVP)

## Composite Sandwich Panels - Deformation and Energy Absorption

**Martin Vcelka**  
**Swinburne University**

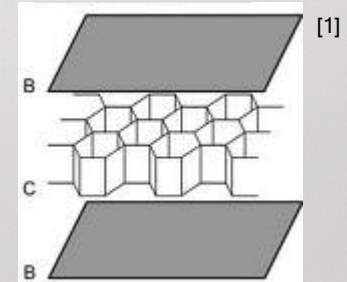
Supervisors : Tracy Ruan  
Yvonne Durandet  
Chris Berndt





# Outline

- Energy Absorption
  - Materials
  - Motivation
  
- Composite Sandwich Constituent Testing
  - Face sheets
  - Foam
  - Deformation Modes
  
- Composite Sandwich Panel Structural Testing
  - LVI
  - Research Components
  - Applications



$$P = \begin{bmatrix} 2(\alpha_4 + \alpha_6) & -2\alpha_4 & -2\alpha_6 & 0 & 0 & 0 \\ -2\alpha_4 & 2(\alpha_4 + \alpha_5) & -2\alpha_5 & 0 & 0 & 0 \\ -2\alpha_6 & -2\alpha_5 & 2(\alpha_6 + \alpha_5) & 0 & 0 & 0 \\ 0 & 0 & 0 & \alpha_7 & 0 & 0 \\ 0 & 0 & 0 & 0 & \alpha_8 & 0 \\ 0 & 0 & 0 & 0 & 0 & \alpha_9 \end{bmatrix} \quad [3]$$

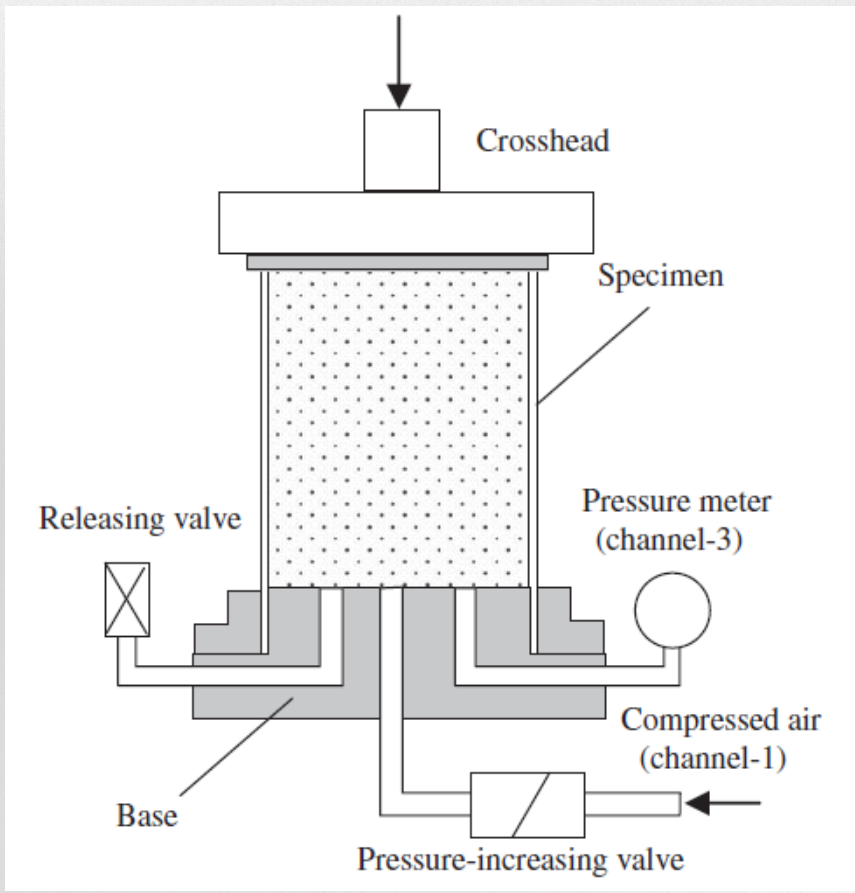
[1] www.wn.com

[2] www2.tbo.com

[3] Vinson.R., "The Behavior of Sandwich Structures", Technomic Publishing, Lancaster, 1999

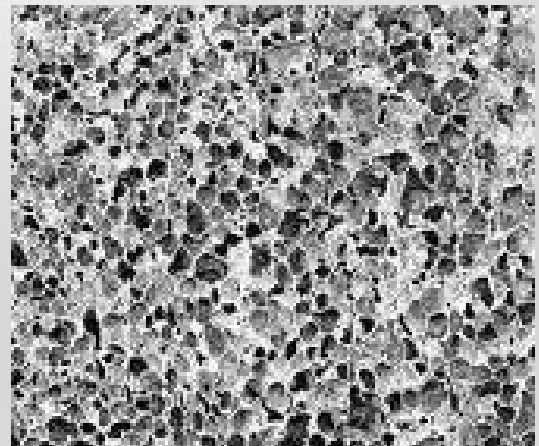


# Energy Absorption



Pressure Filled Hollow Tube

Aluminium Foam



Metallic Hollow Spheres



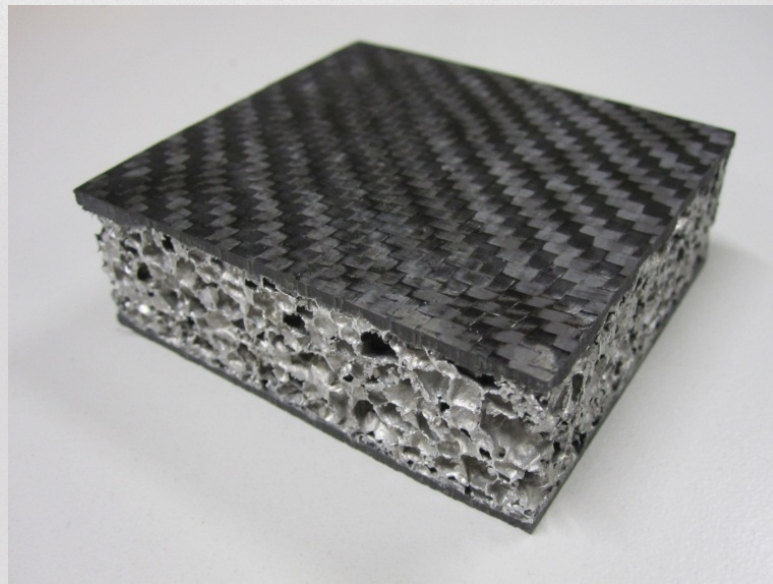
# Research Outline



[1]



[1]



$$\begin{Bmatrix} N_x \\ N_y \\ N_{xy} \end{Bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ & A_{22} & A_{26} \\ \text{sym.} & & A_{66} \end{bmatrix} \begin{Bmatrix} \epsilon_x^0 \\ \epsilon_y^0 \\ \gamma_{xy}^0 \end{Bmatrix} + \begin{bmatrix} B_{11} & B_{12} & B_{16} \\ & B_{22} & B_{26} \\ \text{sym.} & & B_{66} \end{bmatrix} \begin{Bmatrix} \kappa_x \\ \kappa_y \\ 2\kappa_{xy} \end{Bmatrix}$$

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[1]

$$\delta = \frac{PL^3}{48(EI)_{eq}} + \frac{PL}{4(AG)_{eq}},$$

where  $(EI)_{eq}$  is the equivalent flexural rigidity

$$(EI)_{eq} = \frac{E_f b t_f d^2}{2} + \frac{E_f b t_f^3}{6} + \frac{E_c b c^3}{12} \approx \frac{E_f b t_f d^2}{2}$$

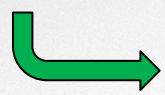
and  $(AG)_{eq}$  is the equivalent shear rigidity

$$(AG)_{eq} = \frac{b d^2 G_c}{c} \approx b d G_c,$$

[3]



[4]



[1] Swinburne University – Martin Vcelka  
 [2] J.M. Berthelot, Composite materials: mechanical behaviour and structural analysis, Springer, New York, 1999.  
 [3] Christos C. Chamis, "Polymer Composite Mechanics Review 1965 to 2006", *Journal of Reinforced Plastics and Composites* 2007; 26; 987  
 [4] Styles, M., "The effect of core thickness on the flexural behaviour of aluminium foam sandwich structures," *JCS*, vol. 80, pp. 532-538, 2007.

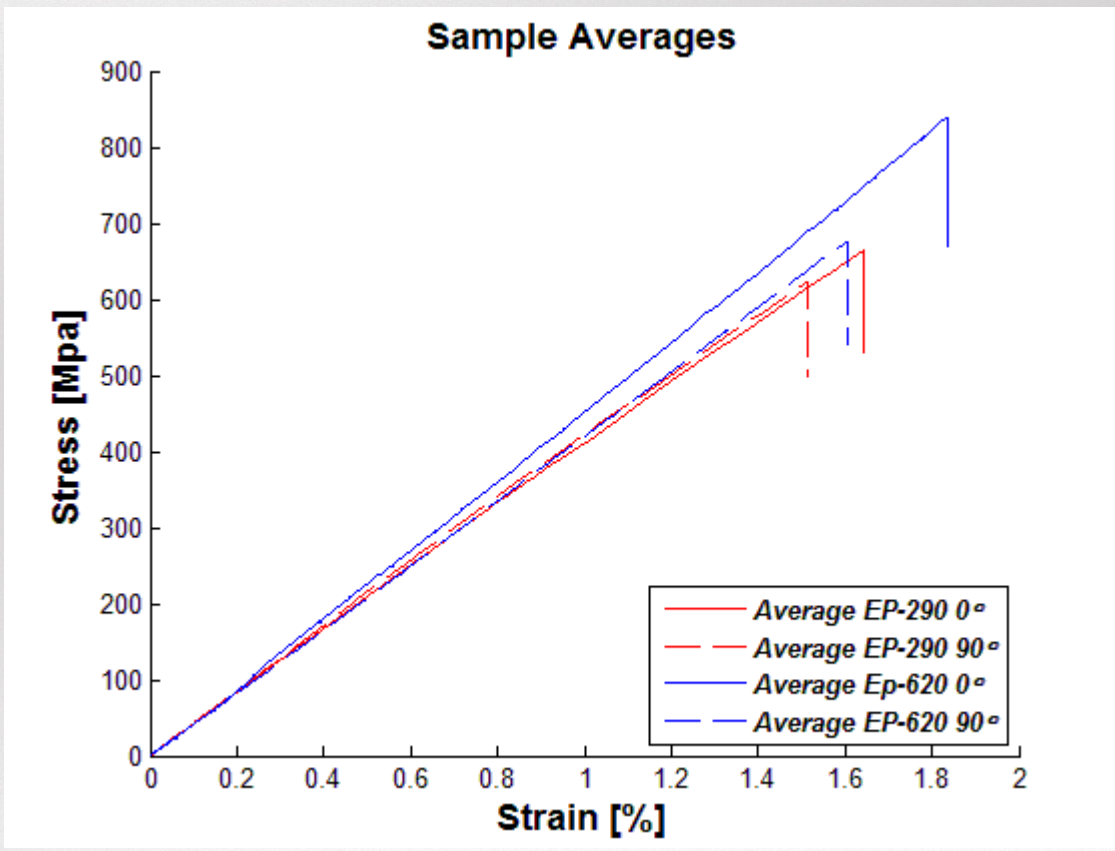


# Carbon Fibre Tensile Testing



[1]

MTS Universal Testing Machine



Average Tensile Strengths

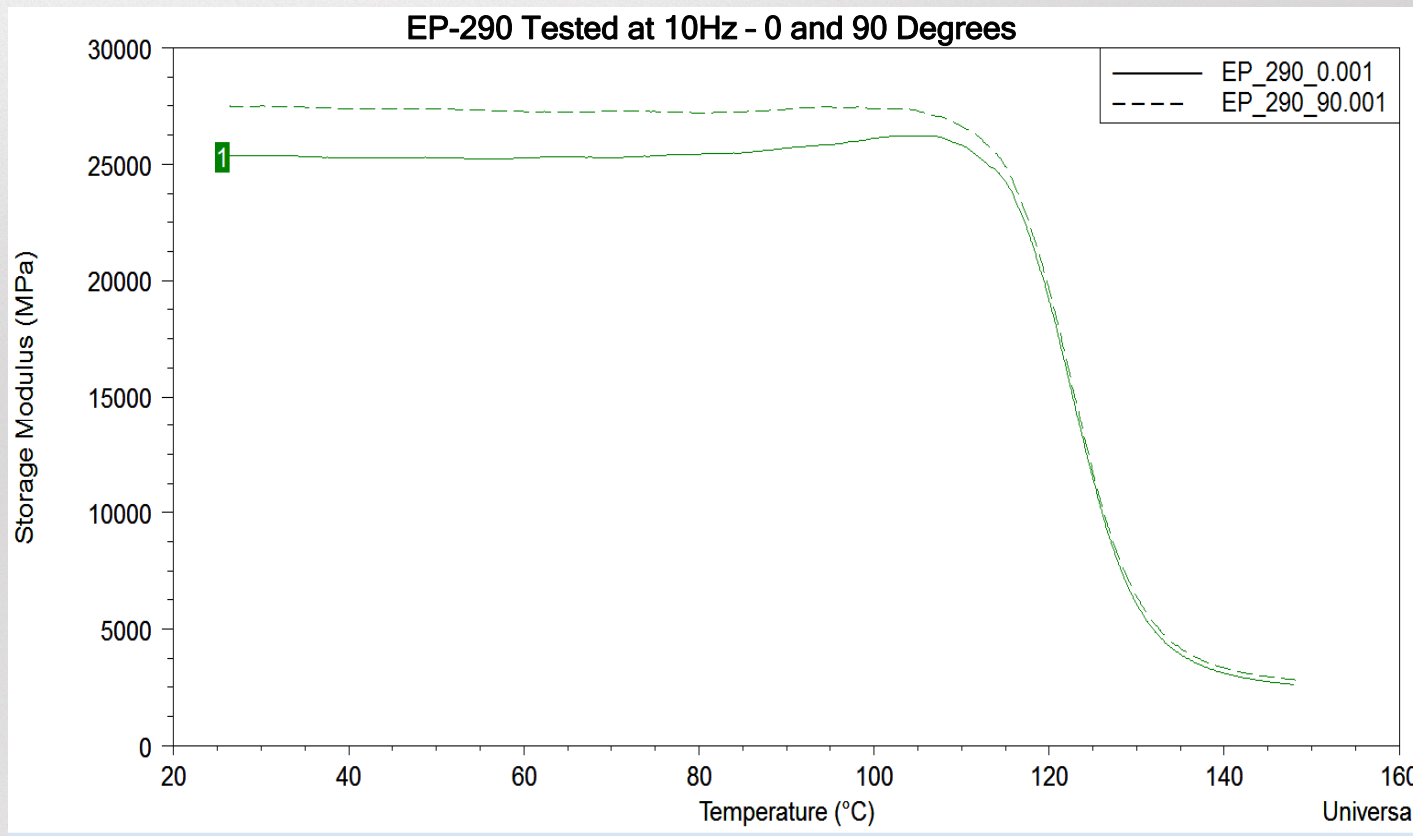


# Dynamic Mechanical Analysis



[1]  
→

DMA - Three point bending configuration



EP-290 Storage Modulus



# Constitutive Model

- The yield stress is expressed as:

$$Y = \sigma_p + \gamma \frac{\hat{\varepsilon}}{\varepsilon_D} + \alpha_2 \left( \frac{1}{1 - \left( \frac{\hat{\varepsilon}}{\varepsilon_D} \right)^\beta} \right)$$

[1]

where  $\sigma_p$ ,  $\alpha_2$ ,  $\gamma$  and  $\beta$  are material parameters from a curve fit of the stress-strain data from uni-axial compression of foam samples.

- The densification strain  $\varepsilon_D$  is determined by:

$$\varepsilon_D = -\ln \left( \frac{\rho_f}{\rho_{f0}} \right)$$

[2]

Where  $\rho_f$  and  $\rho_{f0}$  are the densities of the foam and virgin metal material respectively.

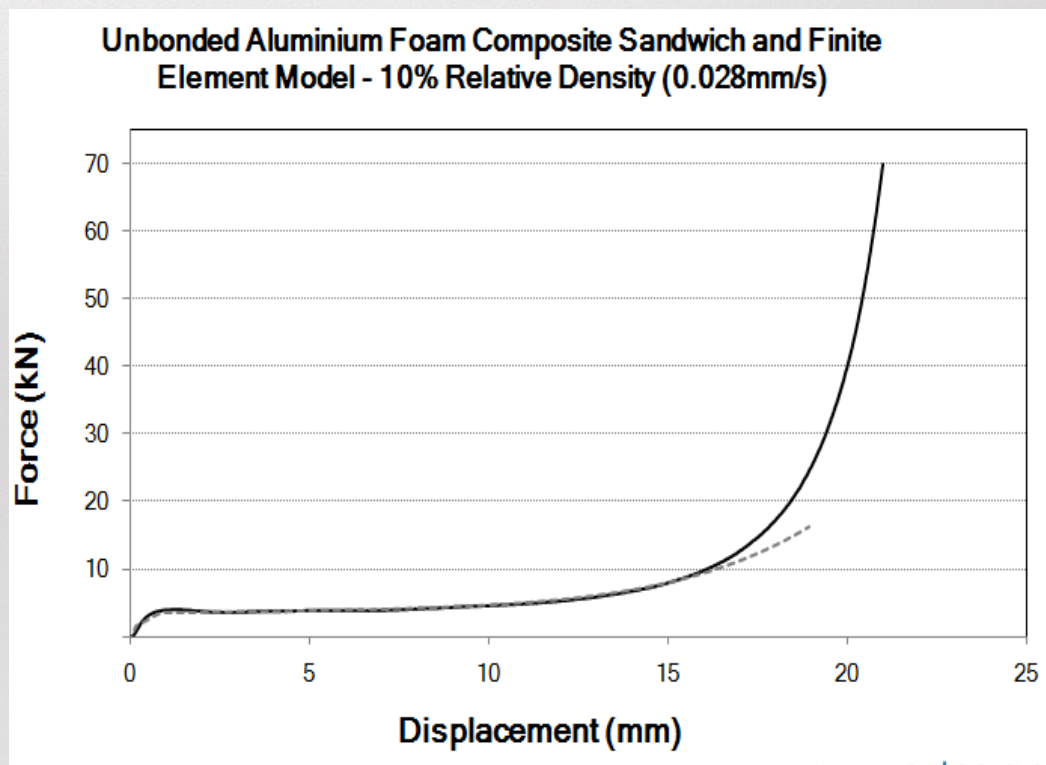


# Compression Testing

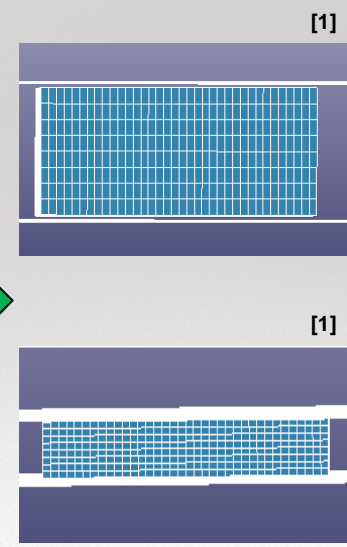


Experiment

[1]



Results

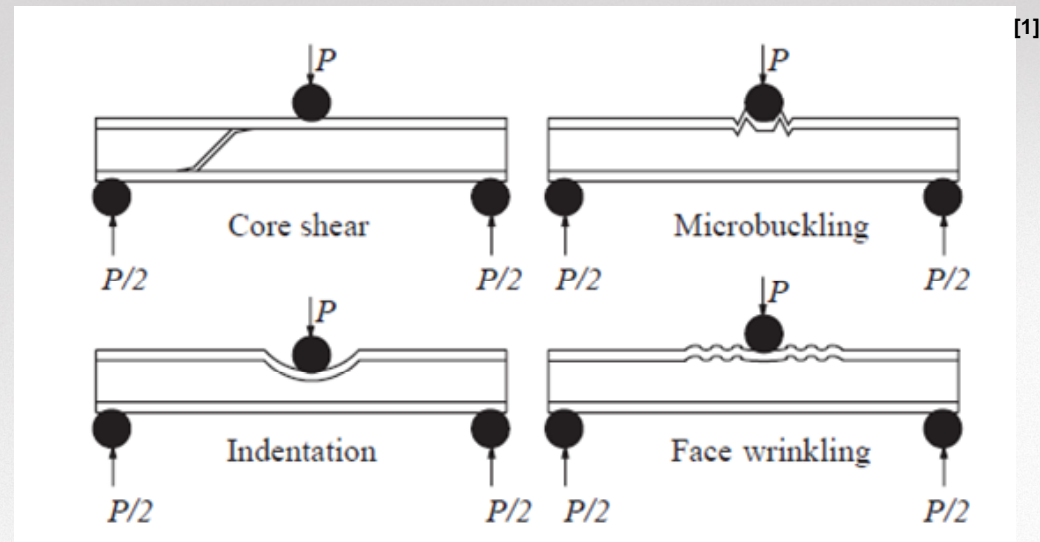
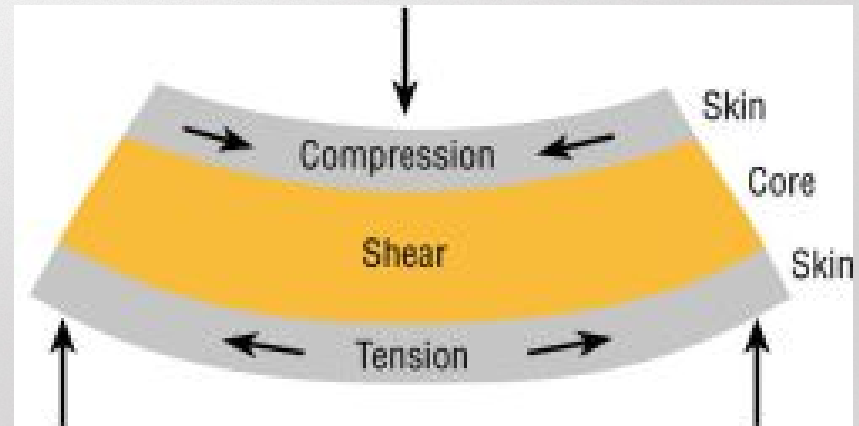


FEA



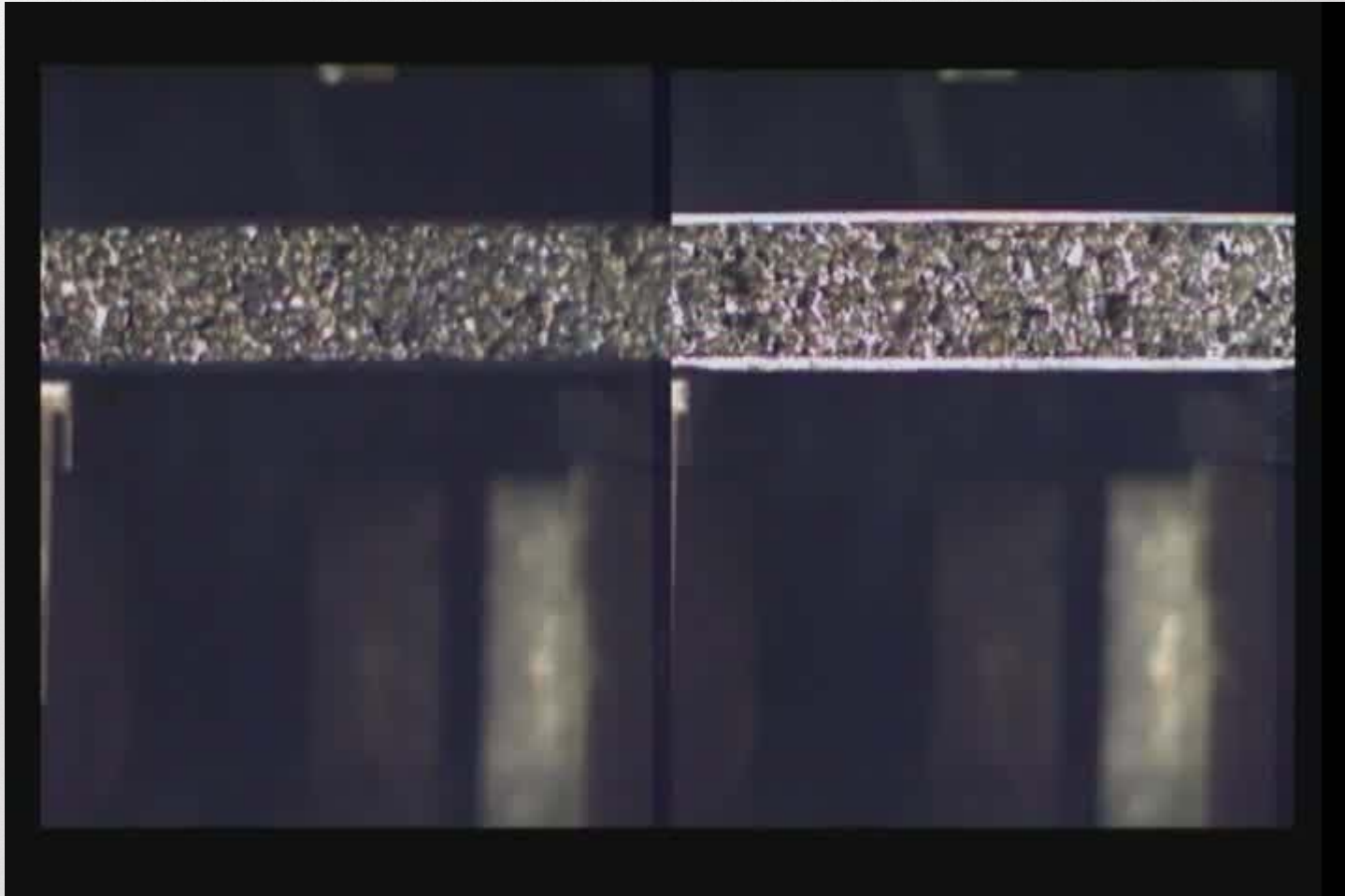
# Deformation

- A Sandwich Beam can be likened to an I-beam.
  - Face sheets as flanges
  - Core as shear web
- Four main modes of collapse in three and four-point bending:
  - Face yield
  - Face wrinkling
  - Core shear
  - Indentation





# *Low Velocity Impact*

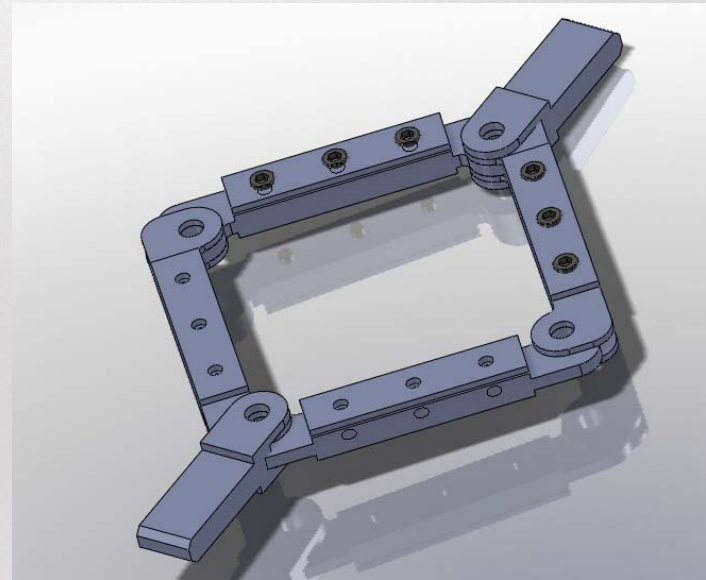


[1]



# Further Work

- **Experiments**
  - Picture frame testing
- **FEA**
  - Parametric Studies
- **Analytical Model**



[1]

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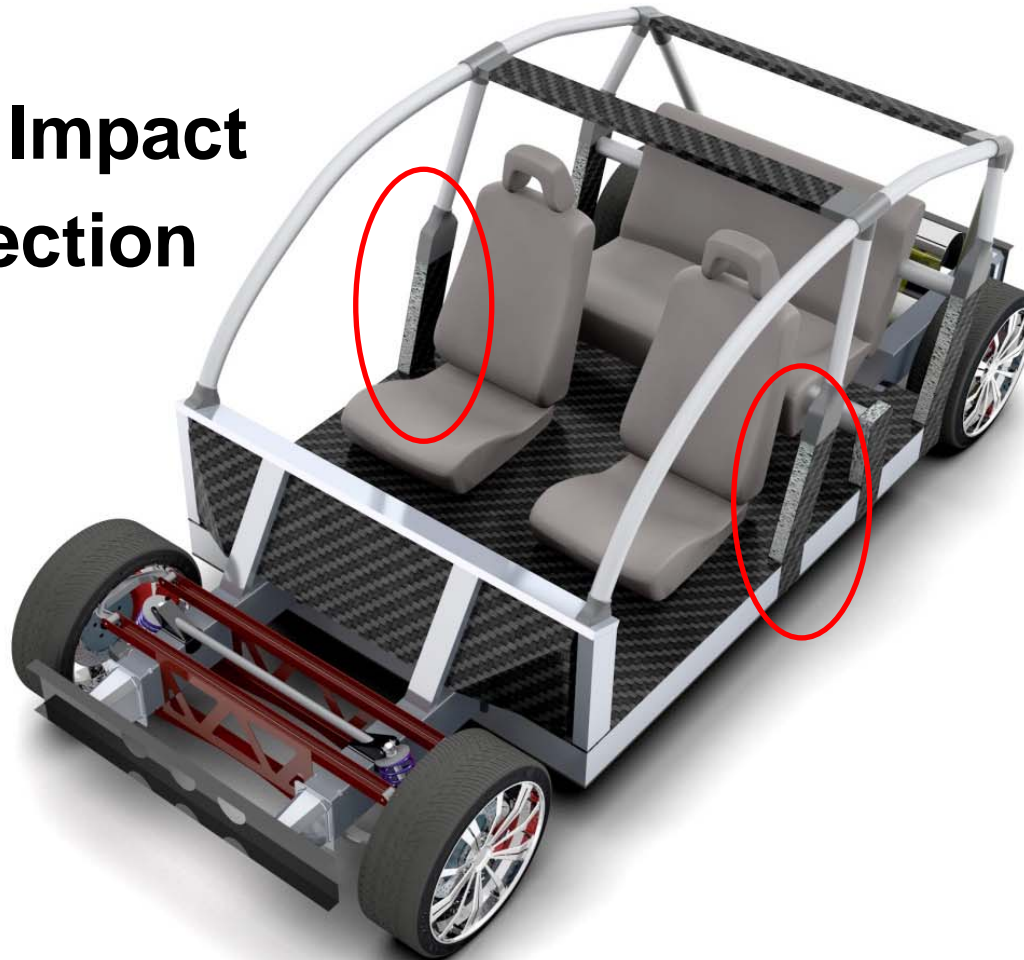


[3]



# Lightweight Modular Vehicle Platform (LMVP)

## Side Impact Protection



[1]



## *Conclusion*

- Very light and stiff structure that can be tuned for load case.
- Carbon Fibre face sheets have very different deformation modes compared to metallic face sheets.
- Care must be taken to consider the interface between core and face sheet for accurate FEA modelling
- Possibility for many Automotive Industry applications and use in wide variety of parts.



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## A – Extensional stiffness

$$\begin{Bmatrix} N_x \\ N_y \\ N_{xy} \end{Bmatrix} = \begin{bmatrix} A_{11} & A_{12} & A_{16} \\ & A_{22} & A_{26} \\ \text{sym.} & & A_{66} \end{bmatrix} \begin{Bmatrix} \varepsilon_x^0 \\ \varepsilon_y^0 \\ \gamma_{xy}^0 \end{Bmatrix} + \begin{bmatrix} B_{11} & B_{12} & B_{16} \\ & B_{22} & B_{26} \\ \text{sym.} & & B_{66} \end{bmatrix} \begin{Bmatrix} \kappa_x \\ \kappa_y \\ 2\kappa_{xy} \end{Bmatrix}$$
  

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**B - Coupling**

**D – Flexural stiffness**