
Stronger, Lighter, Smarter
The Sandwich Concept
Elass Meeting – Pornichet -June 2017
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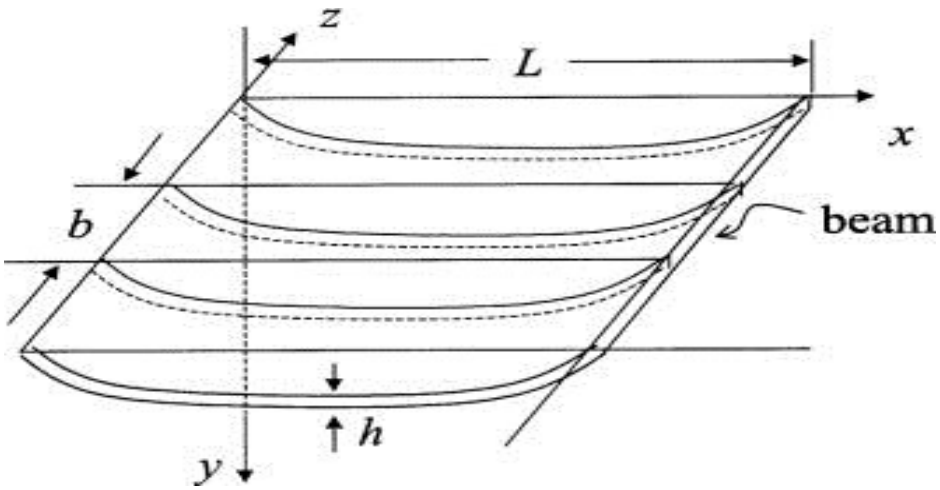
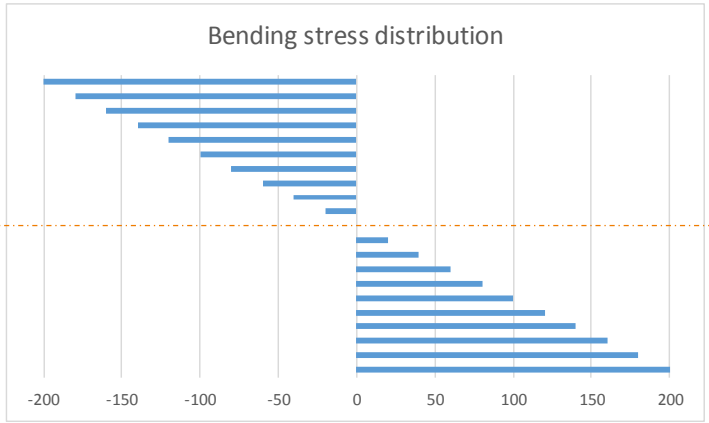
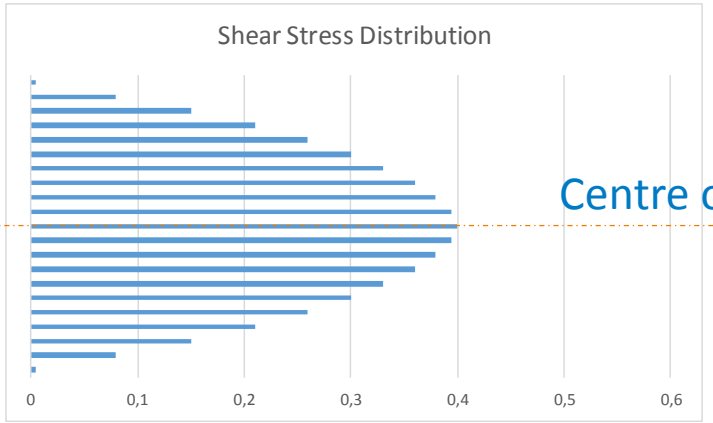
From Panel to Beam



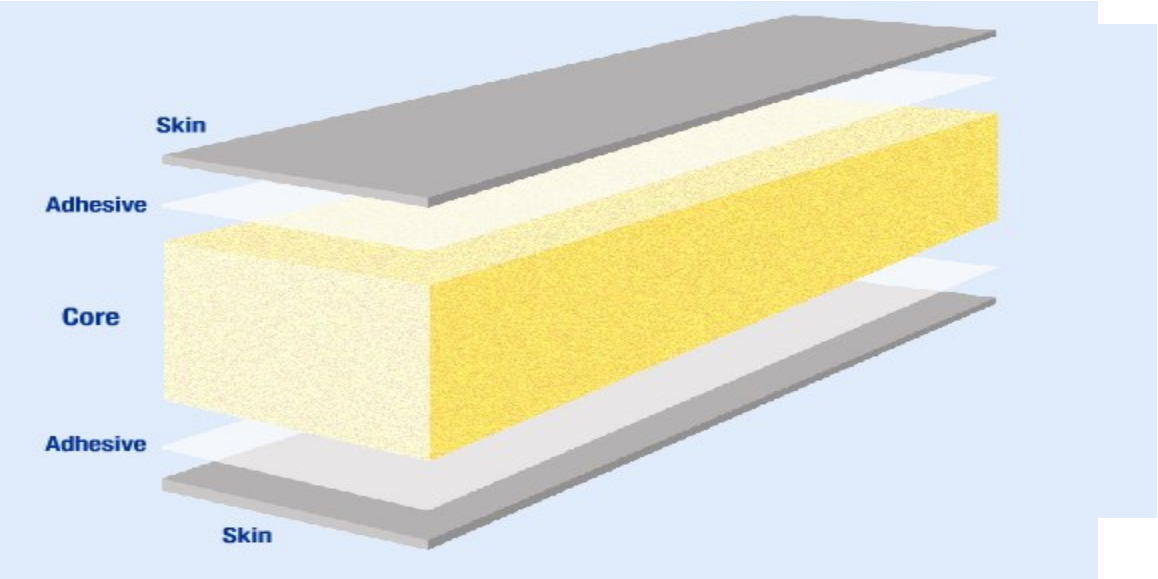
Stress distribution in a homogenous cross section



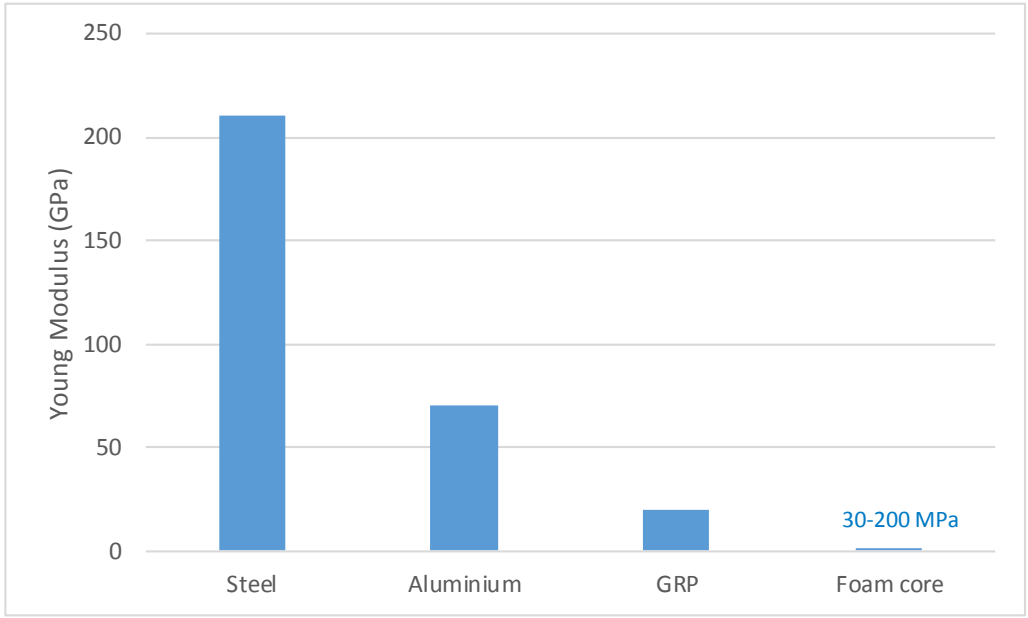


Centre of bending

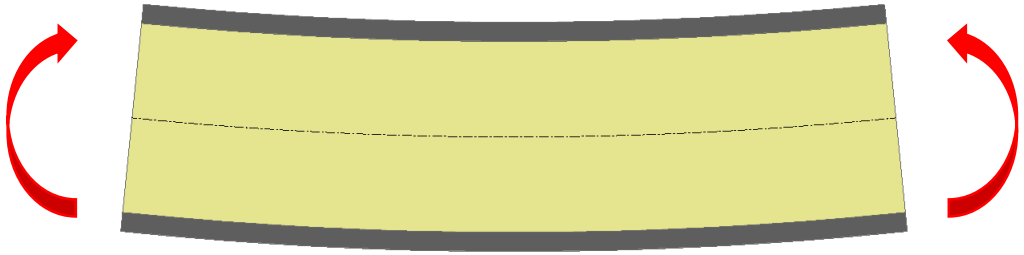
Structural Sandwich



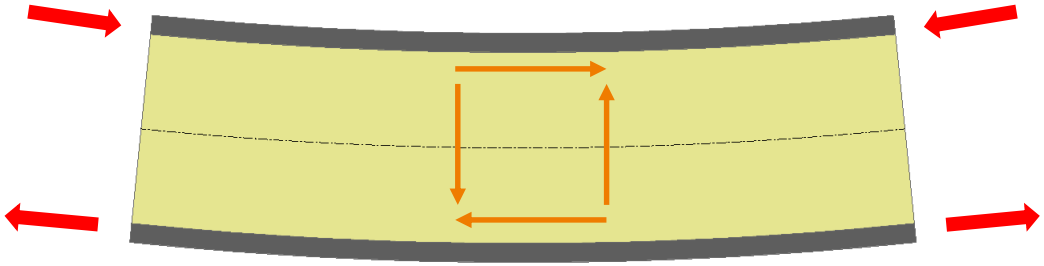
Young Modulus of skin material is MUCH HIGHER than modulus of core $E_f >> E_c$



Bending of a sandwich



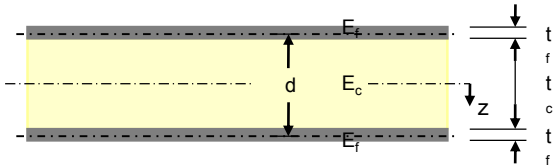
Bending of a sandwich



Top skin subjected to compression and bottom skin subjected to tension whereas the core is subjected to shear

Sandwich – Flexural Rigidity

$$D = \int E z^2 dz = 2 \cdot \frac{E_f t_f^3}{12} + 2E_f t_f \left[\frac{d}{2}\right]^2 + \frac{E_c t_c^3}{12}$$



Stiffness contribution from the two skins bending around their individual neutral axis

Sandwich – Flexural Rigidity

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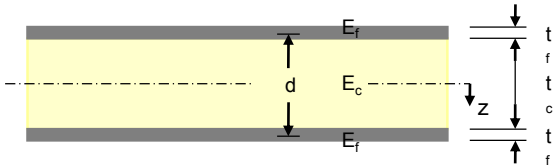

Stiffness contribution from the two skins being removed from the centre of bending – Steiners theorem

Sandwich – Flexural Rigidity

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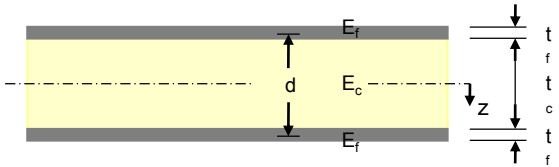


Stiffness contribution from the core material bending around its own neutral axis

Sandwich – Flexural Rigidity - Example

$$D = \int E z^2 dz = 2 \cdot \frac{E_f t_f^3}{12} + 2E_f t_f \left[\frac{d}{2}\right]^2 + \frac{E_c d^3}{12} \qquad D = \frac{E_f t_f d^2}{2}$$

14.5 % + 85.2 % + 0.3 % = 3615.9 Nmm²/mm (width)

1800 g/m² 0/90 biaxial glass — E_f = 17.8 GPa
20 mm H60 — t_f = 1.70 mm
1800 g/m² 0/90 biaxial glass — E_c = 58.5 MPa

Assume that the skins are very thin in relation to the core thickness and that the core material is weak/soft in relation the the skins.

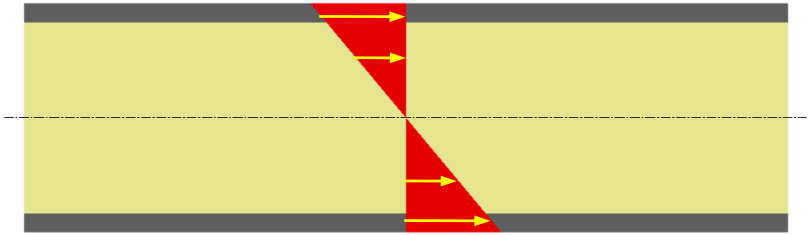
Sandwich – 3 ways to increase flexural rigidity

$$D = \frac{E_f t_f d^2}{2}$$

1. Increase the stiffness of the skins, change from glass to carbon fibres / aluminium or steel
2. Increase the thickness of the skins
3. Increase the core thickness

- Increasing the core thickness is by far the most weight efficient way to increase rigidity of a sandwich!

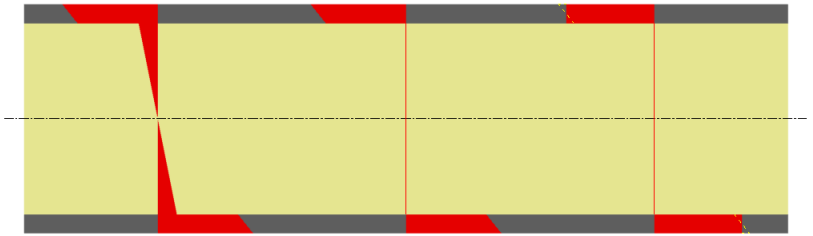
Bending of a sandwich – strain distribution



Hooke's Law: $\sigma_i = E_i \cdot \varepsilon_i$

But … $E_f >> E_c$

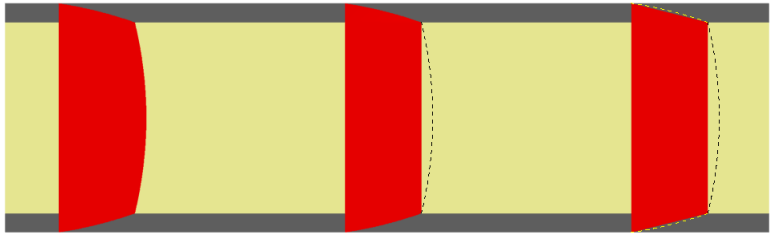
Bending of a sandwich – stress distribution



No approximations $E_c << E_f$ $E_c << E_f$ and $t_c >> t_f$

$$\sigma_f = \frac{M_x y}{D} \cdot E_f \approx \frac{M_x}{t_f\, d}$$

Bending of a sandwich – shear distribution



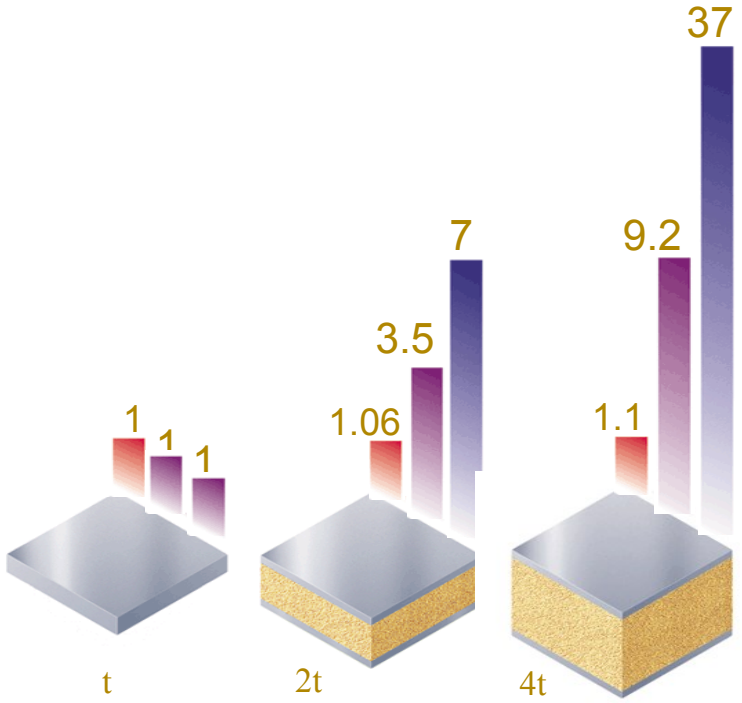
No approximations $E_c << E_f$ $E_c << E_f$ and $t_c >> t_f$

$$\tau_i(z) = \frac{T_x \cdot B(z)}{D},\ \tau_c(z=0) = \frac{T_x}{D}\left(E_c \cdot \frac{t_c}{4} + E_f \cdot t_f \cdot \frac{d}{2}\right) \qquad E_c << E_f$$

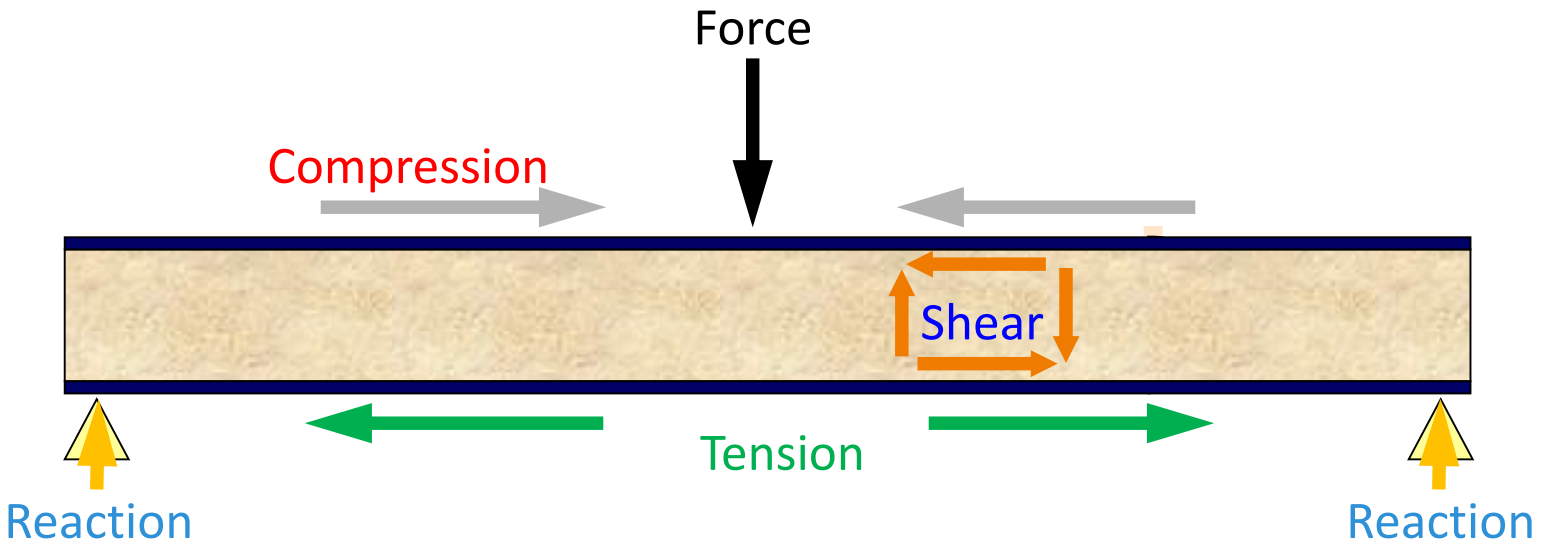
$$\tau_c \approx \frac{T_x}{d}$$

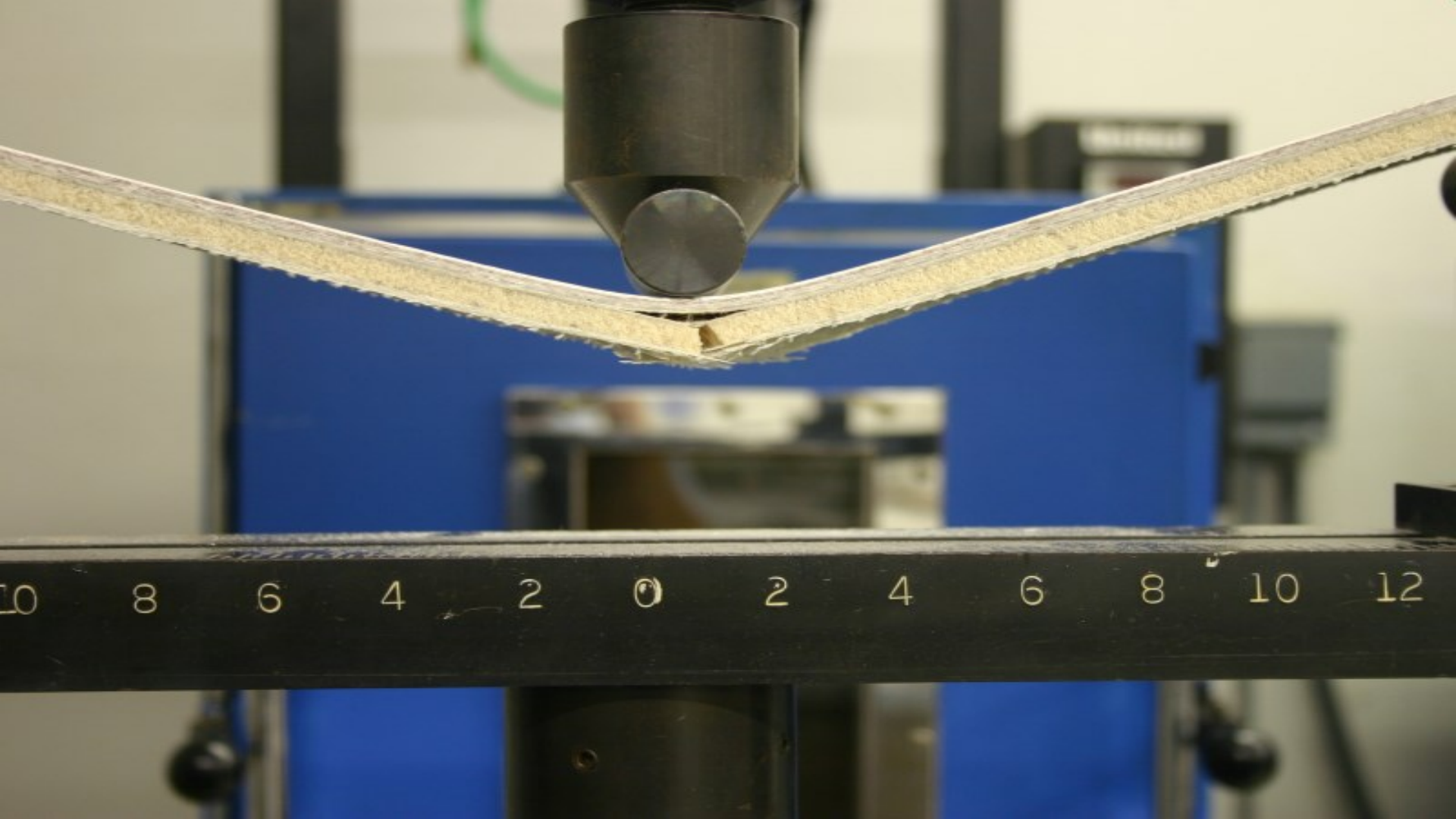
The Sandwich Concept

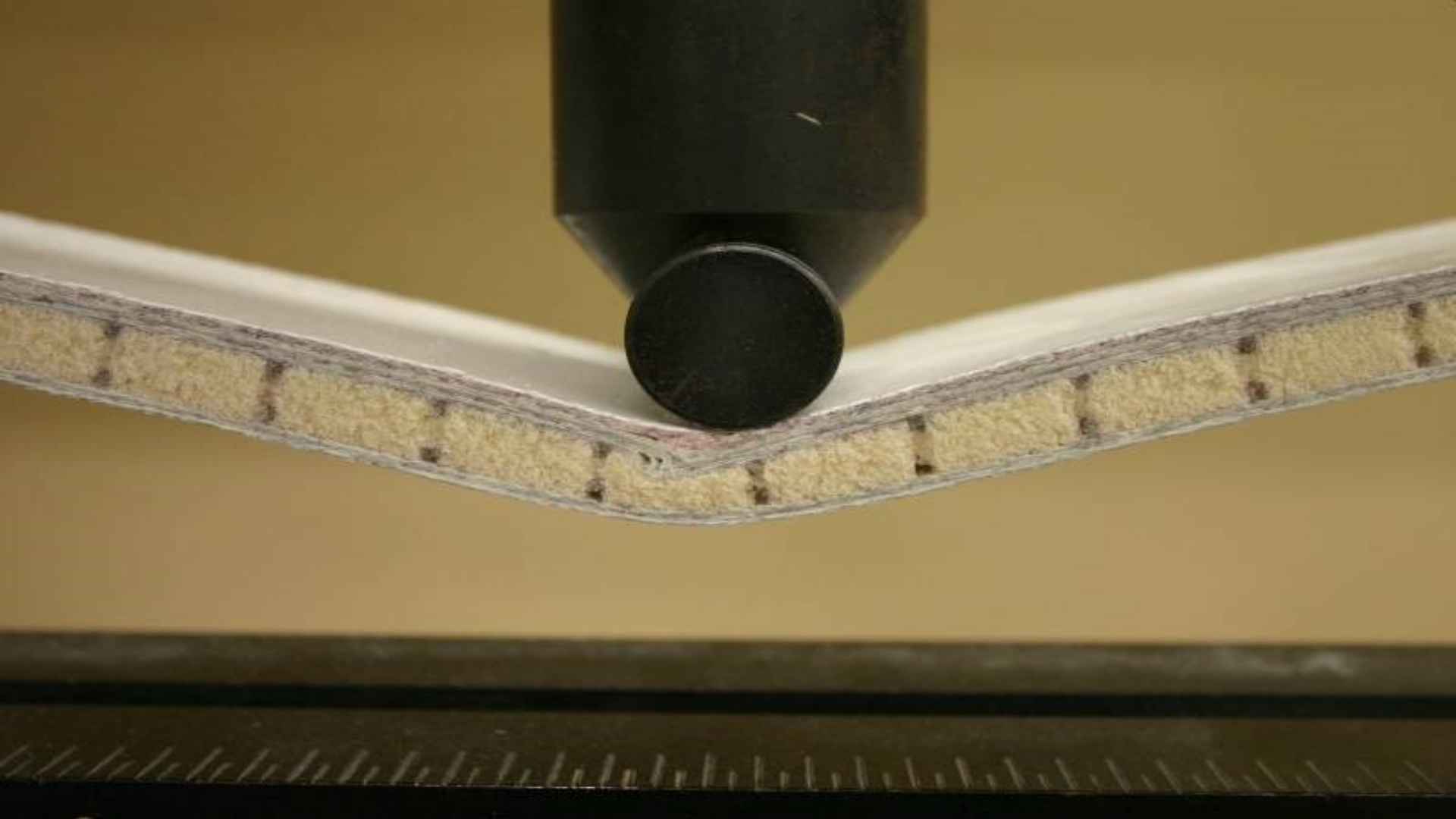
- Weight
- Strength
- Stiffness

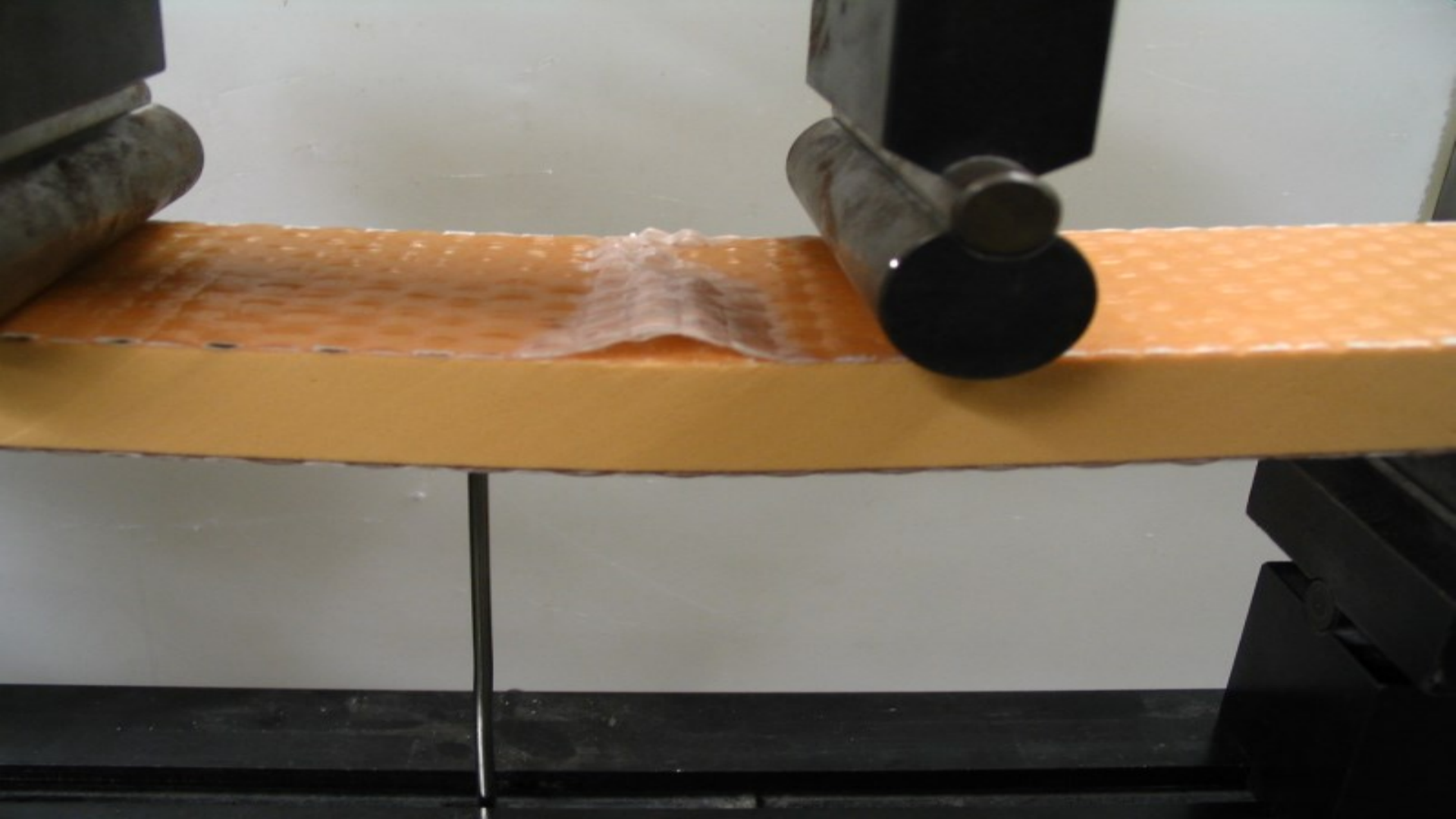


Design of Sandwich Structures

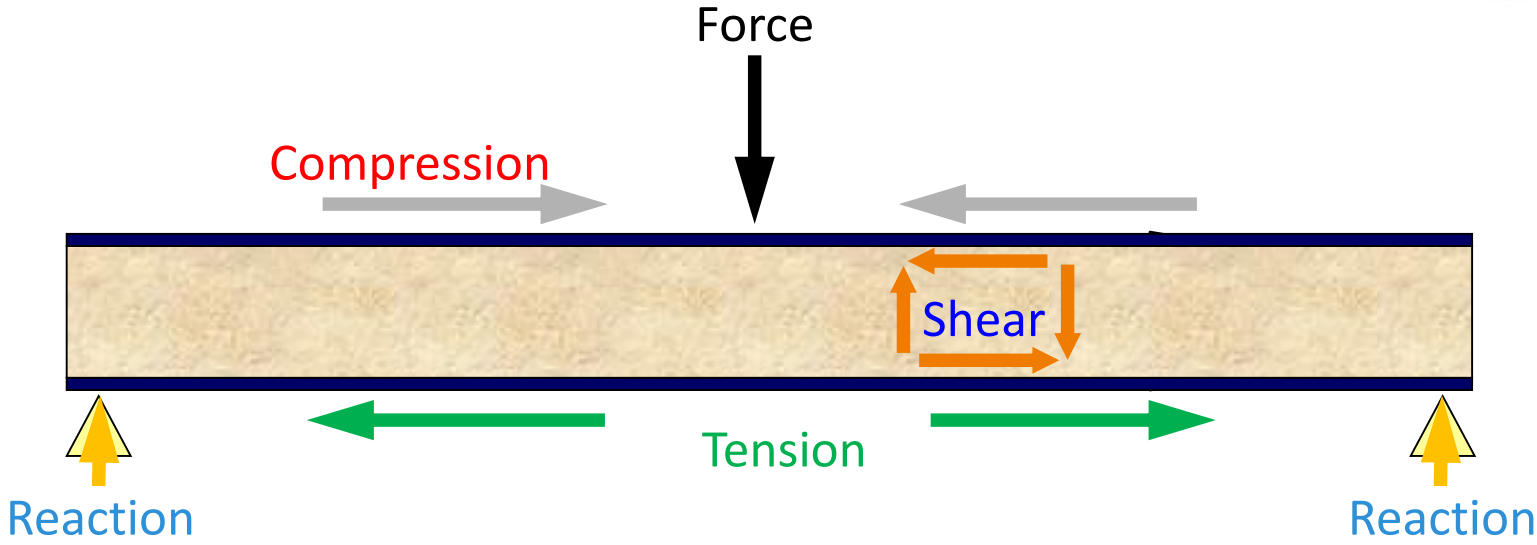



10 8 6 4 2 0 2 4 6 8 10 12





Main properties of Sandwich



Skins:

- Tensile and compressive strength
- Stiffness of the skin in compression

Core:

- Shear strength
- Compressive stiffness
- Shear stiffness
- Compressive strength

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