Composite Sandwich Structure Design Requirements

Composite Engineer's Viewpoint
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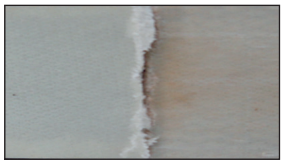
Part 6 – Failure Modes and Analysis

This article covers Sandwich Panel Failure Modes and Analysis – Face Sheet Failure, Face Sheet Dimpling, Face Sheet Wrinkling, Core Shear Failure, Core Buckling Instability and Global Buckling.

The principal failure modes in composite sandwich structures are illustrated below. The basic design equations for the listed failure modes are provided and the important material and geometric properties indicated.

Face Sheet Failure

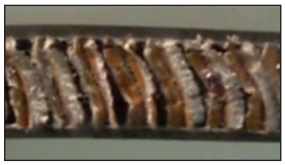


$$\sigma_{axial} = \frac{P}{2}\frac{1}{t_f}$$

For sandwich panels with $t_c > 4t_f$, then:

$$\sigma_{axial} = \frac{M}{ht_f}$$

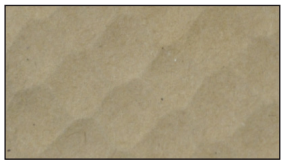
Core Shear Buckling (Instability)



$$\sigma_{c_{buckling}} = \frac{G_c t_c h_c}{2dt_f} \quad \text{hollow}$$

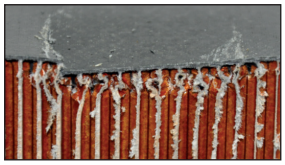
$$\sigma_{c_{buckling}} = \frac{G_c h_c}{2t_f} \quad \text{solid}$$

Face Sheet Dimpling



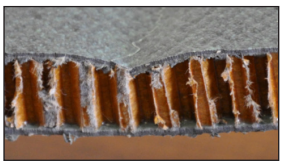
$$\sigma_{cr_{dimpling}} = \frac{2\sqrt{E_1 E_2}}{(1-\upsilon_{21}\upsilon_{12})}\left(\frac{t_f}{s}\right)^2$$

Core Crush



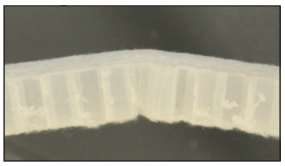
$$\sigma_{c_{crush}} = \frac{V}{A_{c_{eff}}}$$

Face Sheet Wrinkling



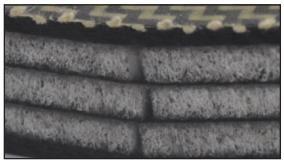
$$\sigma_{cr_{wrinkling}} = \sqrt{\frac{2}{3}\frac{\sqrt{E_1 E_2}E_c}{(1-\upsilon_{21}\upsilon_{12})}\frac{t_f}{h_c}}$$

Global Buckling



$$\sigma_{cr_{buckling}} = \frac{\pi^2}{4(1-\upsilon_{21}\upsilon_{12})}\sqrt{E_1 E_2}\left(\frac{t_c}{b}\right)^2 K$$

Core Shear Failure



$$\tau_c = \frac{V}{hb}$$

Skin Separation (wrinkle)

$$\sigma_{cr_{wrinkling}} = \sqrt{\frac{2}{3}\frac{\sqrt{E_1 E_2}E_c}{(1-\upsilon_{21}\upsilon_{12})}\frac{t_f}{t_c}}$$

Failure Modes of Sandwich Structures

Where:

P = edge running load (N/m)
t_f = skin thickness
M = edge running moment (N.m/m)
V = transverse applied load (N)
h = distance between the skin centroids
E_c = core axial Young's Modulus
E_1 = orthotropic skin longitudinal Young's Modulus
E_2 = orthotropic skin transverse Young's Modulus
υ_{21} = orthotropic skin major Poisson's ratio
υ_{12} = orthotropic skin minor Poisson's ratio
s = distance across cell space
h_c = core depth
G_c = Core shear modulus
b = panel width
d = total panel thickness (2tf + hc)
t_c = core wall thickness
$A_{c_{eff}}$ = core effective cross-section area
K = edge constraint factor

In the next issue of Connection magazine, we will discuss Sandwich Panel Bending Behaviour – specifically the factors that influence the bending performance of sandwich panels with composite

All articles published in Engineer's Viewpoint are available on the Composites Australia website (www.compositesaustralia.com.au/industry). Rik welcomes questions, comments and your point of view by email to rikheslehurst@gmail.com