The honeycomb sandwich construction is one of the most valued structural engineering innovations developed by the composites industry.

Used extensively in aerospace and many other industries, the honeycomb sandwich provides the following key benefits over conventional materials:

- Very low weight
- High stiffness
- Durability
- Production cost savings

Hexcel began developing honeycomb over 40 years ago, and now supplies a range of high performance honeycombs, prepregs and Redux® film adhesives - all ideally suited to the manufacture of honeycomb sandwich constructions. Hexcel is also the leading supplier of lightweight honeycomb sandwich panels.

This guide explains how to design and manufacture honeycomb sandwich panels, from materials selection and analysis of mechanical properties, through to production methods, and includes basic sample calculations for simple constructions.

More complex calculations may require computer modelling which, although mentioned briefly, is beyond the scope of this publication.

December 2000
Publication No. AGU 075b

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BENEFITS OF HONEYCOMB SANDWICH CONSTRUCTIONS

The facing skins of a sandwich panel can be compared to the flanges of an I-beam, as they carry the bending stresses to which the beam is subjected. With one facing skin in compression, the other is in tension. Similarly the honeycomb core corresponds to the web of the I-beam. The core resists the shear loads, increases the stiffness of the structure by holding the facing skins apart, and improving on the I-beam, it gives continuous support to the flanges or facing skins to produce a uniformly stiffened panel. The core-to-skin adhesive rigidly joins the sandwich components and allows them to act as one unit with a high torsional and bending rigidity.

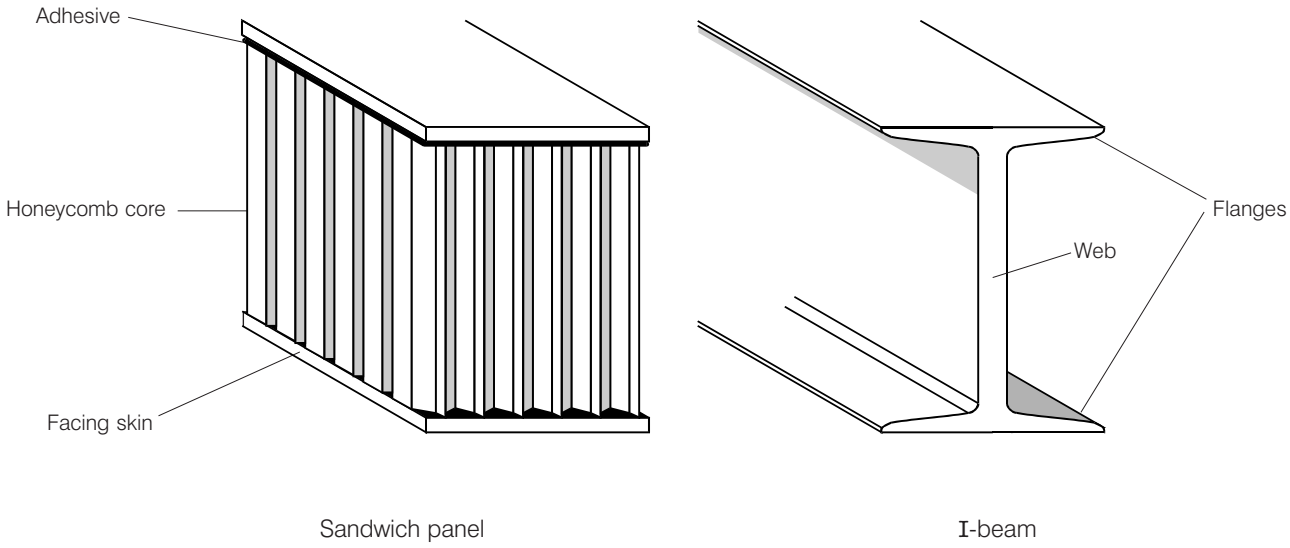


Figure 1 shows the construction of a sandwich panel compared to an I beam.

	Solid Material	Core Thickness t	Core Thickness 3t
	t	2t	4t
Stiffness	1.0	7.0	37.0
Flexural Strength	1.0	3.5	9.2
Weight	1.0	1.03	1.06

Figure 2 shows the relative stiffness and weight of sandwich panels compared to solid panels.

MATERIALS SELECTION

Honeycomb Sandwich Materials

The honeycomb sandwich construction can comprise an unlimited variety of materials and panel configurations. The composite structure provides great versatility as a wide range of core and facing material combinations can be selected. The following criteria should be considered in the routine selection of core, facing, and adhesive.

Structural Considerations

Strength:
Honeycomb cores and some facing materials are directional with regard to mechanical properties and care must be taken to ensure that the materials are orientated in the panel to take the best advantage of this attribute.

Stiffness:
Sandwich structures are frequently used to maximise stiffness at very low weights. Because of the relatively low shear modulus of most core materials, however, the deflection calculations must allow for shear deflection of the structure in addition to the bending deflections usually considered.

Adhesive Performance:
The adhesive must rigidly attach the facings to the core material in order for loads to be transmitted from one facing to the other. Suitable adhesives include high modulus, high strength materials available as liquids, pastes or dry films. As a general rule, a low peel-strength, or relatively brittle adhesive should never be used with very light sandwich structures which may be subjected to abuse or damage in storage, handling or service.

Economic Considerations:
Composite sandwich panels can provide a cost effective solution. Value analysis should include assessment of production and assembly costs; and installation costs including supporting structure.

Environmental Considerations

Temperature:
As in any materials system the thermal environment will play an important role in the selection of materials.
All systems are basically operational at Room Temperature and materials are readily available to give performance up from -55°C to 170°C.
Material selection should also take account of available manufacturing facilities, especially cure temperature capability.

Flammability:
Materials used in bonded sandwich construction are usually classified into three categories:

1) Non-burning - which means that the product will not burn.

2) Self-extinguishing - which means that the material will burn while held in a flame but will extinguish when the flame is removed.

3) Flammable. Flammable materials are sometimes further defined by determining the flame spread rate under specified conditions.

Heat Transfer:
The transfer of heat through a sandwich panel is dependent upon the basic principles of convection, conduction and radiation. Metallic cores with metallic facings maximise heat flow characteristics.

Moisture/Humidity:
Some core and facing materials offer excellent resistance to degradation due to moisture and humidity.

Adhesive Solvents and Outgassing:
Some adhesives give off gases or solvent vapours during cure which can interact with resin systems in some non-metallic cores, or with the node adhesive in some metallic honeycombs. The entire bonding process must be checked to ensure that no reduction in mechanical properties has occurred due to incompatibility of the materials or process actually used. All of Hexcel's Redux® film adhesives are compatible with this type of construction.

Honeycomb Materials

HexWeb honeycomb is available in a wide range of materials including:-

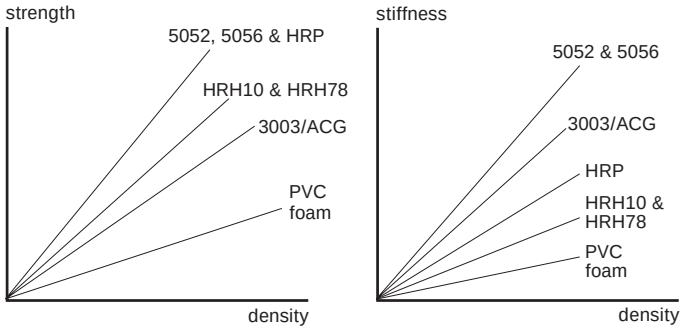
Aluminium, Nomex (Aramid), Korex, Kevlar, Fibreglass, Carbon.

For details please consult The HexWeb Honeycomb Selector Guide and the HexWeb Honeycomb Attributes and Properties Manual.

Selected mechanical properties for Aluminium and Nomex honeycombs are shown in Appendix I.

Mechanical Performance

Honeycomb strength and stiffness (compression and shear) is proportional to density. Relative performance of the material types is shown in comparison to PVC foam.



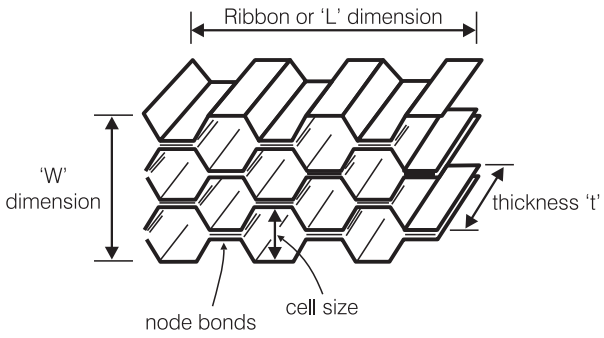
Key: Aluminium - 3003/ACG; 5052; 5056
Nomex - HRH10; HRH78;
Fibreglass - HRP

Cell Size

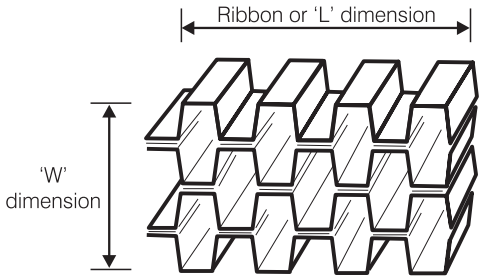
A large cell size is the lower cost option, but in combination with thin skins may result in telegraphing, i.e. a 'dimpled' outer surface of the sandwich. A small cell size will give an improved surface appearance, and provides a greater bonding area, but at higher cost.

Cell Shape

Normally supplied with hexagonal cell shapes, a few honeycomb types can be supplied with rectangular cell shapes (W:L approximately 2:1), and designated OX.



hexagonal cell size
= measured across flats



OX cell size
= nominal hexagonal cell size before expansion to rectangular shape.

Hexagonal cells give minimum density for a given amount of material.
Rectangular cells give easier forming in the W direction (with less anticlastic curvature than is exhibited by hexagonal cell honeycomb).

Skin Materials

The table in Appendix II shows properties of typical facing materials for sandwich panel construction.

Skin considerations include the weight targets, possible abuses and local (denting) loads, corrosion or decorative constraints, and costs.

Facing material thickness directly affects both the skin stress and panel deflection.

Hexcel Composites offers a wide range of prepreg materials. Refer to the Prepreg Matrix Selector Guide to identify systems most likely to suit your application, where fibre reinforced composites are thought appropriate.

Adhesive Materials

For honeycomb sandwich bonding, the following criteria are important:

1. Fillet Forming

To achieve a good attachment to an open cell core such as honeycomb, the adhesive should flow sufficiently to form a fillet without running away from the skin to core joint.

2. Bond Line Control

Every endeavour should be made to ensure intimate contact between the parts during bonding, as the adhesive needs to fill any gaps between the bonding surfaces.

Adhesives are often supplied supported by a carrier cloth, for the purpose of helping them to remain in place where the parts are squeezed particularly tightly together.

Hexcel Composites offers a wide range of film adhesives. Refer to the REDUX® Film Adhesive Selector Guide to identify the most suitable material for your application.

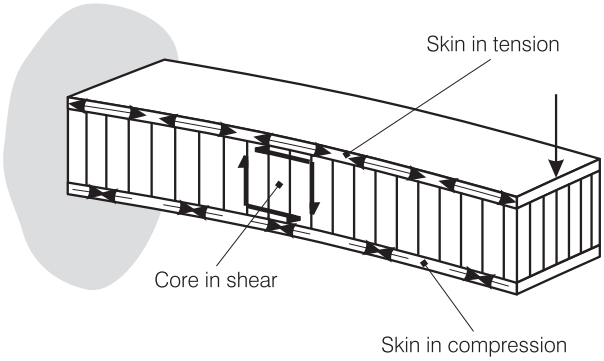
SANDWICH DESIGN

How a Sandwich Beam Works

Loads

Consider a cantilever beam with a load applied at the free end. The applied load creates a bending moment which is a maximum at the fixed end, and a shear force along the length of the beam.

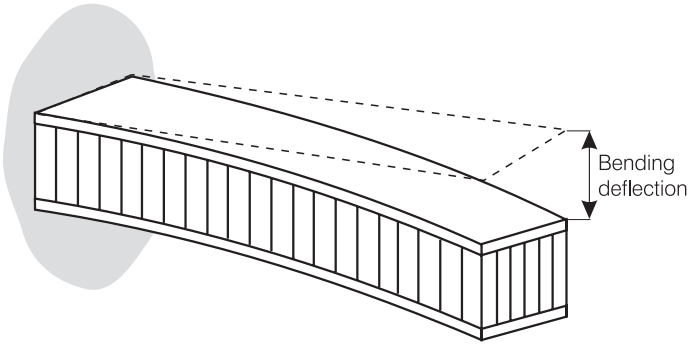
In a sandwich panel these forces create tension in the upper skin and compression in the lower skin. The core spaces the facing skins and transfers shear between them to make the composite panel work as a homogeneous structure.



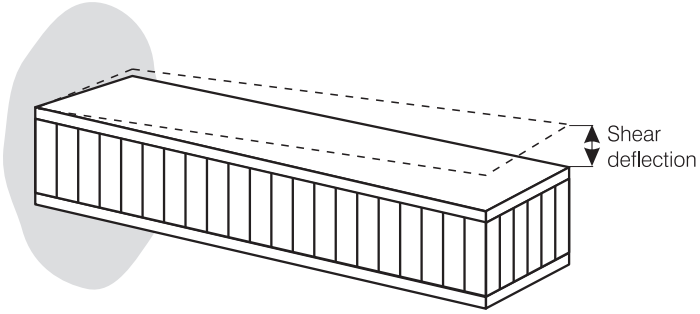
Deflections

The deflection of a sandwich panel is made up from bending and shear components.

The bending deflection is dependant on the relative tensile and compressive moduli of the skin materials.



The shear deflection is dependant on the shear modulus of the core.



Total Deflection = Bending Deflection + Shear Deflection.

Under different sets of applied loads and supporting conditions, the material stresses and deflections can be calculated as shown on page 9 onwards.

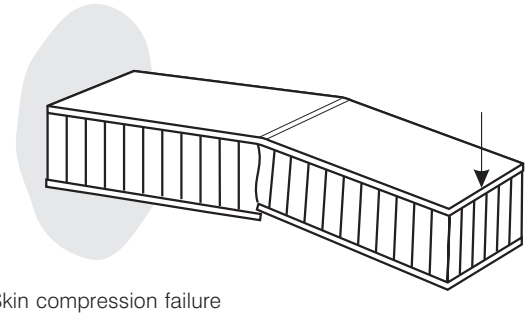
Failure modes

Designers of sandwich panels must ensure that all potential failure modes are considered in their analysis. A summary of the key failure modes is shown below:

1. Strength

The skin and core materials should be able to withstand the tensile, compressive and shear stresses induced by the design load.

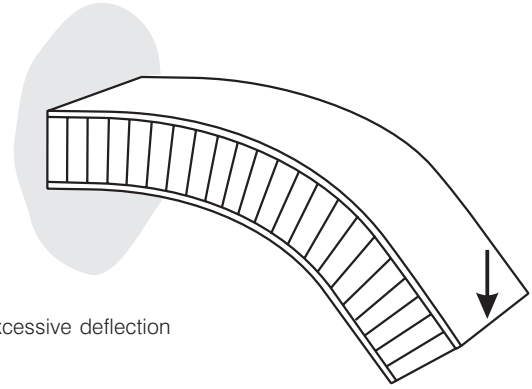
The skin to core adhesive must be capable of transferring the shear stresses between skin and core.



Skin compression failure

2. Stiffness

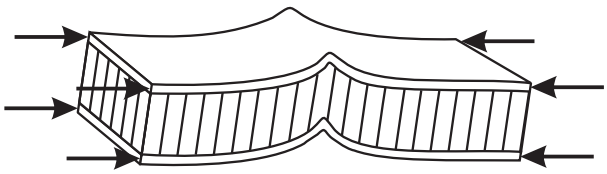
The sandwich panel should have sufficient bending and shear stiffness to prevent excessive deflection.



Excessive deflection

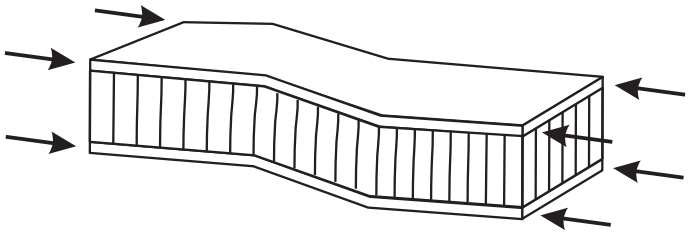
3. Panel buckling

The core thickness and shear modulus must be adequate to prevent the panel from buckling under end compression loads.



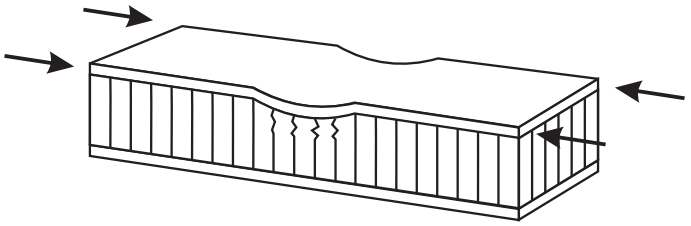
4. Shear crimping

The core thickness and shear modulus must be adequate to prevent the core from prematurely failing in shear under end compression loads.



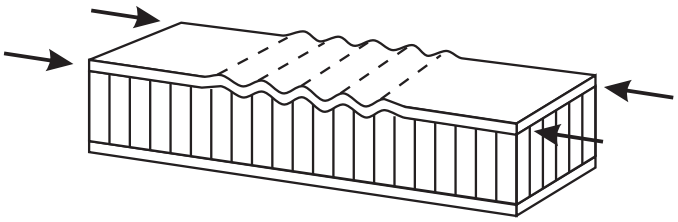
5. Skin wrinkling

The compressive modulus of the facing skin and the core compression strength must both be high enough to prevent a skin wrinkling failure.



6. Intra cell buckling

For a given skin material, the core cell size must be small enough to prevent intra cell buckling.



7. Local compression

The core compressive strength must be adequate to resist local loads on the panel surface.