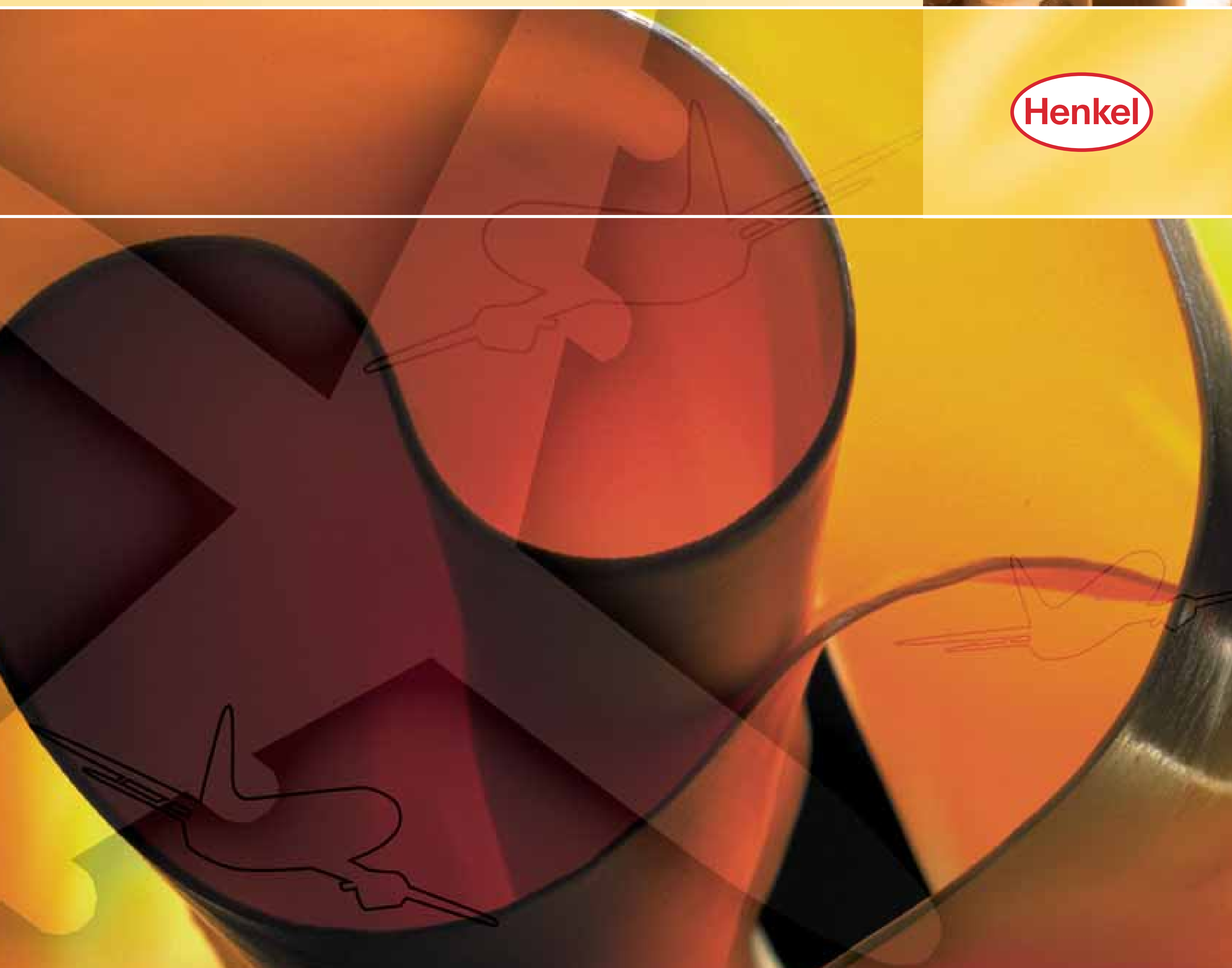
Hysol®

SynCore® Design Guide

An Aerospace Technology Guide



Henkel

Efficiency in Advanced Composites

INTRODUCTION TO STRUCTURAL SANDWICH CONSTRUCTION

Structural sandwich construction comprises a combination of alternating dissimilar, homogeneous or composite materials that are intimately fixed in relation to each other so as to use the properties of each to specific advantage for the whole assembly. This construction can be viewed as a special form of a laminated composite. Face sheets that are thin, strong and hard are laminated over a core that is relatively thick, soft, lightweight, and weak. This construction results in a laminate that is lightweight and much stronger and stiffer than the simple sum of the properties of the individual elements. The primary advantage of sandwich construction is the possibility of stressing each material in the laminate to its practical limit, resulting in an efficient structural design.

An analogy can be drawn between structural sandwich composite design and a structural I-beam. The I-beam gains its efficiency by having a large proportion of its total material placed in the flanges, which are situated far from the center of bedding or the neutral axis (*Figure 1*). The material in the connecting web of the beam must be sufficient to allow the flanges to retain their relative positions and to resist the shear load. A structural sandwich works on the same principle. The face sheets are equivalent to the flanges of the I-beam, and the core material takes the place of the web.

It should be emphasized from the outset that sandwich construction possesses an advantage over solid construction against bending loads and compression loads, which are critical in buckling. Direct tensile loads are carried by the face sheets only. The core material generally has negligible strength in tension compared to the face sheet material. Other advantages of sandwich construction include improved acoustic fatigue and simplicity of manufacture compared to ribbed structures.

In addition to the shear loads, the core also gives continuous support to the facing sheets and stabilizes them against wrinkling and buckling. Therefore, the core must be strong and stiff enough to resist the transverse tension and compression loads applied by the face sheets. In direct compression, the same resisting force is required to provide lateral restraint against buckling. Finally, the bond between the core and face sheets must be strong enough to transmit the tensile and shear stresses between the face sheets and the core.

I-Beam Analogy

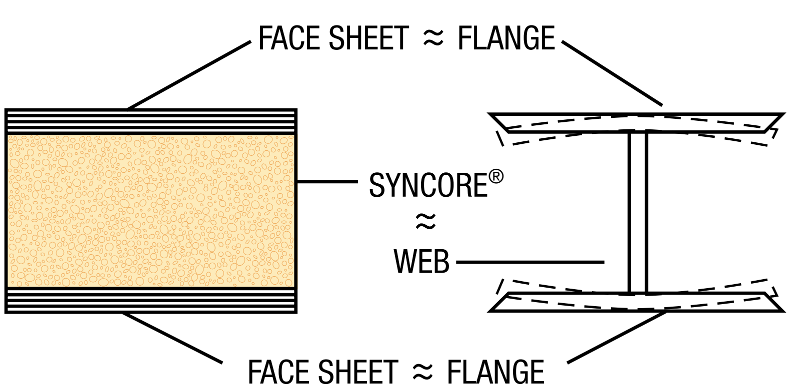


Figure 1

By using thin, stiff facings over a lightweight core, the stiffness of a given amount of facing material can be increased at a much greater rate than the resulting increase in weight (*Figure 2*). The same amount of face sheet material applied to both sides of a SynCore® film can increase the stiffness by 600 percent while the weight increases by only 60 percent. The flexural strength of this example would increase by 250 percent. The strength under direct tensile loads remains practically the same. (*Figure 3*).

A major advantage of structural sandwich construction is the ability to choose from a wide variety of face sheet, core materials, and combinations. Face sheet material is evaluated for its strength and stiffness. The most common materials are laminated plastics, metals (such as aluminum and titanium), and composites. The core material must be lightweight and relatively inexpensive compared to the facing material. Honeycomb formed from various materials (such as paper, aluminum, or cellular plastics), and syntactic films (such as SynCore®) are widely used. Each combination of facing and core material possesses unique advantages and disadvantages.

Generally, sandwich type construction has the following advantages over solid or rib reinforced construction: higher strength-to-weight ratios, smoother surfaces, greater structural stability, higher load carrying capacity, increased fatigue life, and better sonic fatigue endurance. The basic principle of spacing face sheets was formulated over 150 years ago, and practical structures were built during World War II. The necessity to use labor and materials more efficiently has spurred the use of this construction method, and SynCore® represents an evolution of this highly efficient structural approach.

Comparison of SynCore® Sandwich vs. Solid Laminate Construction

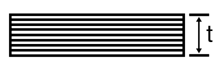
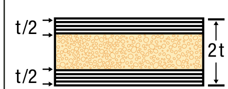
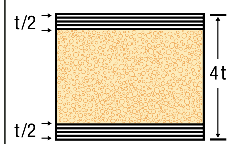
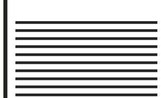
	Solid Laminate	2+ SynCore® Sandwich	4+ SynCore® Sandwich
Diagram			
Relative Stiffness	1	7.0	37.0
Relative Strength	1	3.5	9.3
Relative Weight	1	1.6	2.6

Figure 2

Comparative Advantages of Syntactic Core vs. Composite Laminate Construction

Panel	1	2	3	4
Configuration				
Laminate	10 plies – woven fabric (wt.)	4 plies wf SynCore® (30 mils) 4 plies wt.	3 plies wf SynCore® (50 mils) 3 plies wt.	2 plies wf SynCore® (100 mils) 2 plies wt.
Thickness *(mils/mm)*	130/3.30	134/3.40	138/3.51	152/3.86
Weight *(lbs./ft.²)*	1.01	0.91	0.80	0.74
Weight Savings *(%)*	0 (control)	9.9	20.8	26.7
Flexural Rigidity *[in.(lb./in.)]/[m(N/m)]*	1965/221	2127/240	2157/243	2246/253
Flexural Rigidity *(% of Control)*	100	108	110	114

wf = Woven fabric
wt = 13 mil woven graphite prepreg modulus 10.73 x 10^{-6} psi
SynCore® = SynCore® HC 9872.1™

Figure 3

SYNCORE® SYNTACTIC FILM CORE

Description of SynCore®

SynCore® is a low density syntactic material that is supplied in a film form. It combines a matrix resin system with low density, high strength glass microballoons. A Kevlar® or glass backing scrim is attached to the SynCore®, which helps prevent tears and wrinkles during handling and lamination. Typical room temperature properties are shown in (*Table 1*).

SynCore® is produced as a controlled thickness film that enables precise control of final part thickness.

SynCore® is generally used where a core thickness of 0.125 inch/3.18 mm or less is desired. SynCore® is relatively flexible and will follow the contour of the mold surface.

SynCore® is used with reinforced thermoset or thermoplastic prepreg face sheets (*Figure 4, page 4*). In the uncured state, SynCore® may be cut and assembled into the laminate in the same manner as prepreg broadgoods. Once assembled, the prepreg/SynCore® sandwich laminate is bagged using typical vacuum bag layup procedures (*Figure 5, page 4*) and cured using the recommended cure cycle for the prepreg material. Optional processing methods are frequently used; however, they are not addressed in this guide. Also see the Application Instructions at the end of this document.

Typical Engineering Properties of SynCore® at Room Temperature

	American Engineering Units	Metric Units
Shear Strength	6,800 psi	46.9 MPa
Compressive Strength	8,800 psi	60.7 MPa
Tensile Strength	4,800 psi	33.1 MPa
Shear Modulus	150,000 psi	1,034 MPa
Compressive Modulus	375,000 psi	2,586 MPa
Tensile Modulus	400,000 psi	2,758 MPa
Flatwise Tensile Strength	4,800 psi	33.1 MPa
Thermal Conductivity	0.069 BTU/hr. ft.^{2}-°F/ft.	0.12 W/mk
Elongation of Failure, Tension	1.2%	–
Typical Density Range	38 to 44 lb./ft^3	609 to 705 kg/m^3
Coefficient of Thermal Expansion	5 to 15 (10^{-6} in./in./°F)	2.5 to 8.5 (10^{-6} m/m/°C)
Dielectric Constant *(Non-conductive)*	1.7 to 2.0	–

NOTE: Specific product properties are detailed in Table 3.

TABLE 1

Advantages of SynCore®

SynCore® is a unique family of low density, syntactic films. It may be handled, formed, co-cured and supplied in continuous rolls or sheets of controlled thickness and width.

SynCore® possesses the following general advantages for use as a core material to be used with prepreg composite face sheets:

1. SynCore® may reduce material costs by replacing plies of graphite, Kevlar®, or fiberglass prepreg.
2. SynCore® reduces density, since there is a significant weight reduction compared to laminates of equal stiffness and strength made entirely of prepreg. SynCore® also cuts weight by eliminating subassemblies (such as rib stiffeners) in many applications (*Figure 3, page 2*).

3. SynCore® reduces manufacturing costs since it is co-curable with the prepreg face sheet laminate and requires less time to lay up than an all prepreg laminate of comparable thickness. Also, since SynCore® is a homogeneous material, details may be efficiently nested, cut and assembled with no attention to orientation, thus allowing a significant reduction of scrap material.
4. SynCore® is easily applied in the laminate stacking sequence. It readily conforms to the tool or mold surface.
5. Syncore® is compatible with the standard cure cycle of the resin used in the prepreg face sheets.
6. SynCore® represents a viable hybrid construction method between honeycomb stiffened panels and solid laminate construction.
7. The cured SynCore® sandwich panel may be inspected per typical composite laminate NDI procedures requiring no additional inspection steps.

Conventional honeycomb core structures are generally limited to thicknesses in excess of 0.25 inch/6.35 mm if expensive machining is to be avoided. Also, honeycomb is difficult to mold into complex shapes and varying geometries. In addition, honeycomb structures have relatively low impact resistance, poor lateral strength, significant manufacturing and in-service problems due to corrosion, and are difficult to repair properly. The limited bond area of the honeycomb core causes poor peel and transverse properties. Inspection of the completed structure is difficult and expensive. The inclusion of fasteners and inserts are a significant problem.

For these reasons, many engineers are reluctant to use honeycomb structures even though their theoretical properties are initially attractive.

In contrast, SynCore® offers the following advantages versus conventional honeycomb core:

- *Can be used in thin core sections (0.010 inch/0.254 mm minimum thickness)*
- *Ideally suited to complex composite shapes*
- *Provides continuous support to the face sheets*
- *High compressive, transverse, tensile and lateral strength*
- *No face sheet wrinkling problems*
- *Simplified manufacturing procedures*
- *No in-service corrosion/moisture ingression problems*
- *Ease of inspection and in-service repair*
- *Simultaneous co-cure with composite face sheets*
- *Conforms easily to complex geometries*

Conversely, SynCore® is usually not used for thick sections greater than 0.25 inch/6.35 mm since its density is somewhat greater than conventional honeycomb core. In some applications, SynCore® and honeycomb have been used successfully in the same structure. Thus, SynCore® and honeycomb can be viewed as complementary products, each solving different design problems and enhancing both the efficiency and cost effectiveness of structures.

SynCore® Sandwich Construction

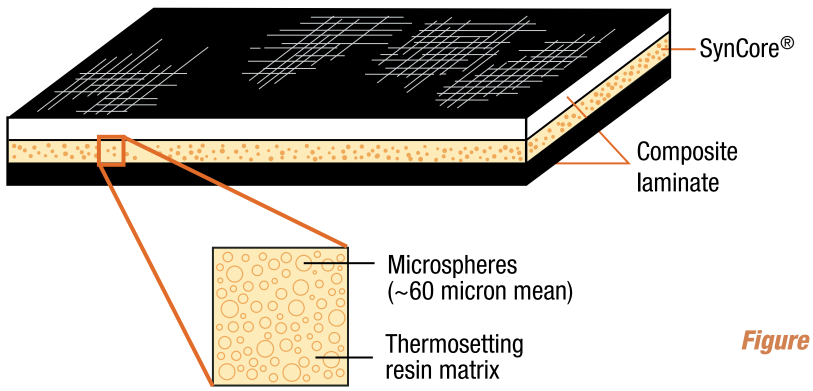
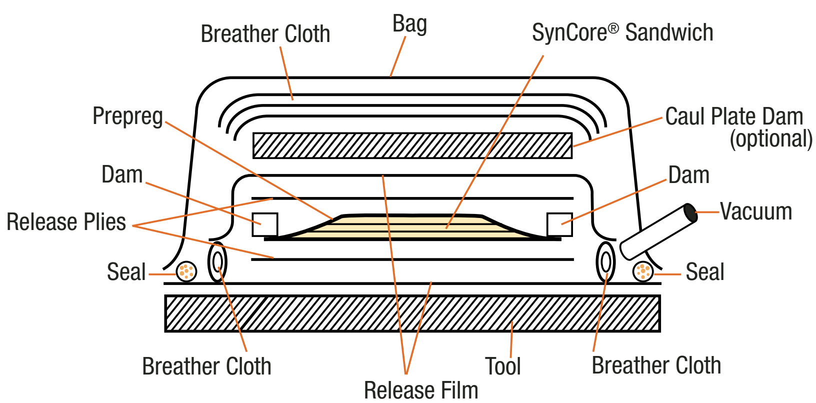


Figure 4

Typical SynCore® Sandwich Bagging Procedure



NOTE: Since SynCore® drops in viscosity during cure, it is important to have SynCore® pinched off by a prepreg ply to make an effective dam. Exposed edges are not recommended due to problems related to resin flow.

Figure 5

Density Comparison

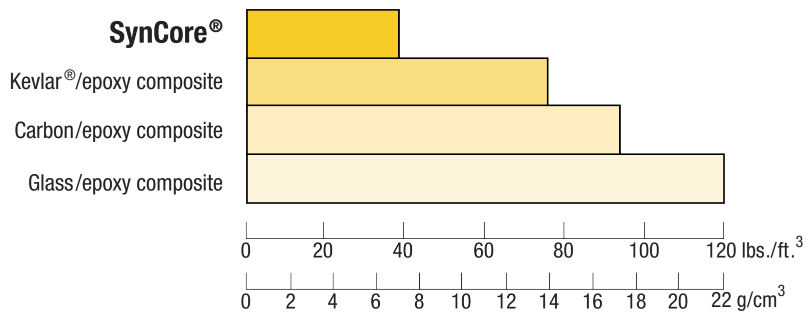


Figure 6

SynCore® Facts

1. SynCore® is shipped and handled in the same manner as prepreg. It is shipped refrigerated with a shelf life of six months at 0°F (-18°C) and with a minimum out time of 15 days at 77°F (25°C).
2. SynCore® is available in a variety of thicknesses to suit a broad range of applications. Usage will generally be with carbon fiber and Kevlar® prepreg materials, where it is effective in lowering product costs and weight while adding stiffness and impact strength. It is also used with hybrid fibers, S-glass, and Boron fibers.
3. SynCore® is an aerospace approved material: *(Reference)*
   - *Boeing® BMS 8-324*
   - *BF Goodrich® RMS-084*
   - *British Aerospace BAER 3107*
   - *Boeing® Long Beach DMS-2235*
   - *Boeing® Long Beach DMS-2320*
   - *Bell 299-947-360*
4. Standard SynCore®:
   - *Resin:* Epoxy
   - *Thickness:* 0.010 to 0.060 inches (0.254 to 1.524 mm)
   - *Typical Density:* 42 lbs./ft.^{3} (673 kg/m^3)
   - *Typical Widths:* 12 and 24 inches

SynCore® Applications

AEROSPACE

- High stiffness-to-weight skin panels that feature reduced weight with decreased deflection compared to a solid laminate design
- Allows increased spacing between structural frames, which offers further benefits, including reduced part count (frames and fasteners), reduced assembly time and labor, more space available for systems installation, and improved access for maintenance and inspection
- Close-out material for honeycomb edges and tapers
- Filler for fillets and build-up of complex shapes and thicknesses
- Duct lining material to eliminate porosity
- Honeycomb stabilization
- Acoustic vibration absorption
- Prepreg ply filler to use in complex shapes to minimize prepreg wrinkling in compound curves

ELECTRONICS

- Electrical insulating filler and repair material
- Extender in circuit board laminates or as a material of construction between plies of glass fiber prepregs

AUTOMOTIVE

- Structural laminates
- Firewall linings and hood insulation

RESIN TRANSFER MOLDING

- Core filler material for molded parts as an extender for resin and reinforcement
- Stiffening core

SPORTS AND RECREATIONAL

- Core material for poles, rods, shafts, rackets, paddles and oars for lighter weight and improved performance

Design of SynCore® Structures

GENERAL DESIGN CRITERIA

Structural sandwich design may be considered to consist of determining the thickness of facing sheets and core required to resist the movement, shear and axial stresses induced by the loads applied to the structure. As previously stated, the axial tensile and compressive stresses caused by axial and flexural loads are carried almost entirely by the sandwich face sheets. The core resists the shear loads and provides support to the face sheets to increase their critical buckling stresses under bending or axial compression.

The basic design principles for sandwich construction can be summarized in the following conditions, which are illustrated in (*Figure 7*).

1. ***Tension and Compression:*** The sandwich facings must be thick enough to resist the design tensile and compression loads without exceeding the allowable face sheet stress. The core must be thick enough to remain below the allowable core shear stress (*Figure 7A*).
2. ***Deflection:*** The combination of face sheet and core thicknesses must be sufficient to prevent excessive deflection (*Figure 7B*).
3. ***General Buckling and Shear Crimping:*** The core must be thick enough and have sufficient shear modulus and strength such that overall buckling of the structure (*Figure 7C*) or shear crimping (*Figure 7D*) does not occur.
4. ***Face Sheet Wrinkling:*** The core must have a high enough elastic modulus, and the sandwich a large enough flatwise tensile and compressive strength such that wrinkling of the face sheets does not occur (*Figure 7E*). This condition does not usually apply to SynCore® construction since the SynCore® provides continuous support to the face sheets, and the compressive and tensile strengths of SynCore® are relatively high.
5. ***Face Sheet Dimpling:*** If the core is of cellular (honeycomb) construction or made of corrugated material, the cell size must be small enough so that dimpling of the face sheets does not occur (*Figure 7F*). This condition does not apply to SynCore®, which provides continuous support to the face sheets.

Localized loads are frequently the source of honeycomb sandwich panel failure. The structure must be able to sustain local concentrated loads, reactions, attachments, and other discontinuities. The effects of several localized normal loads are shown in (*Figure 8, page 7*). The honeycomb sandwich must be reinforced in these areas by thickening the face sheets or using solid inserts to prevent core failure or local facing failure. The effects of such localized loads are difficult to calculate accurately, and their evaluation by tests may be required. Due to the relatively high physical properties of SynCore®, most of these concerns will not usually be a factor in SynCore® sandwich structures.

Design Principles for Sandwich Construction

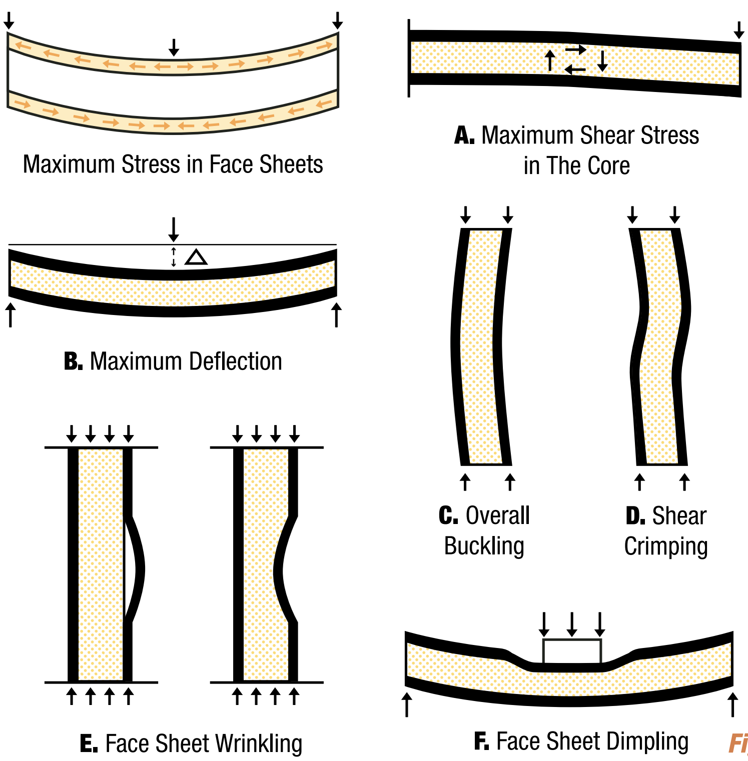


Figure 7

SynCore® Summary

SynCore® is an ideal core material for composite sandwich structures. The following advantages can be cited versus conventional honeycomb structures:

- *Ease of conformity to complex shapes*
- *No face sheet wrinkling or dimpling*
- *Lay up and co-cure with composite face sheets*
- *Compatible with standard aerospace cure schedules*
- *Ideal for thin sandwich structures*
- *High tensile, compressive and lateral strengths*
- *Ease of in-service repairs*
- *Ease of manufacture and inspection*

Application Instructions

As with all composite materials, and particularly when applied in unique complex structure, attention should be given to establishing a processing scheme that represents the application. It is recommended to place a layer of prepreg over the edge of the SynCore® to effectively restrain it from flowing during cure. In most applications it is not recommended that SynCore® be exposed to the edge of the laminate. If it is, then it is important to effectively dam or pinch off the edge, otherwise the SynCore® will flow out of the part during cure. The most common method of restricting excess flow is to place damming material at the edge of the SynCore® ply to effectively create a dam. These techniques should be followed to maintain accurate thickness control around the edge of the part.

Unique applications may require more comprehensive processing guidelines. The potential user should contact a Henkel Technical Representative for help in establishing processing parameters for any applications.

Effects of Localized Normal Loads

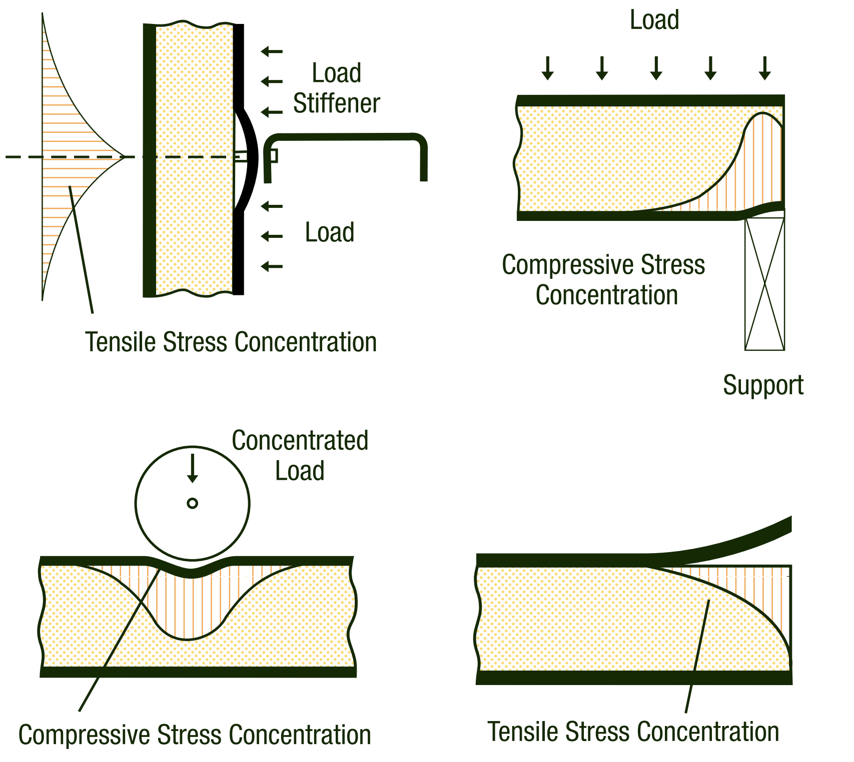
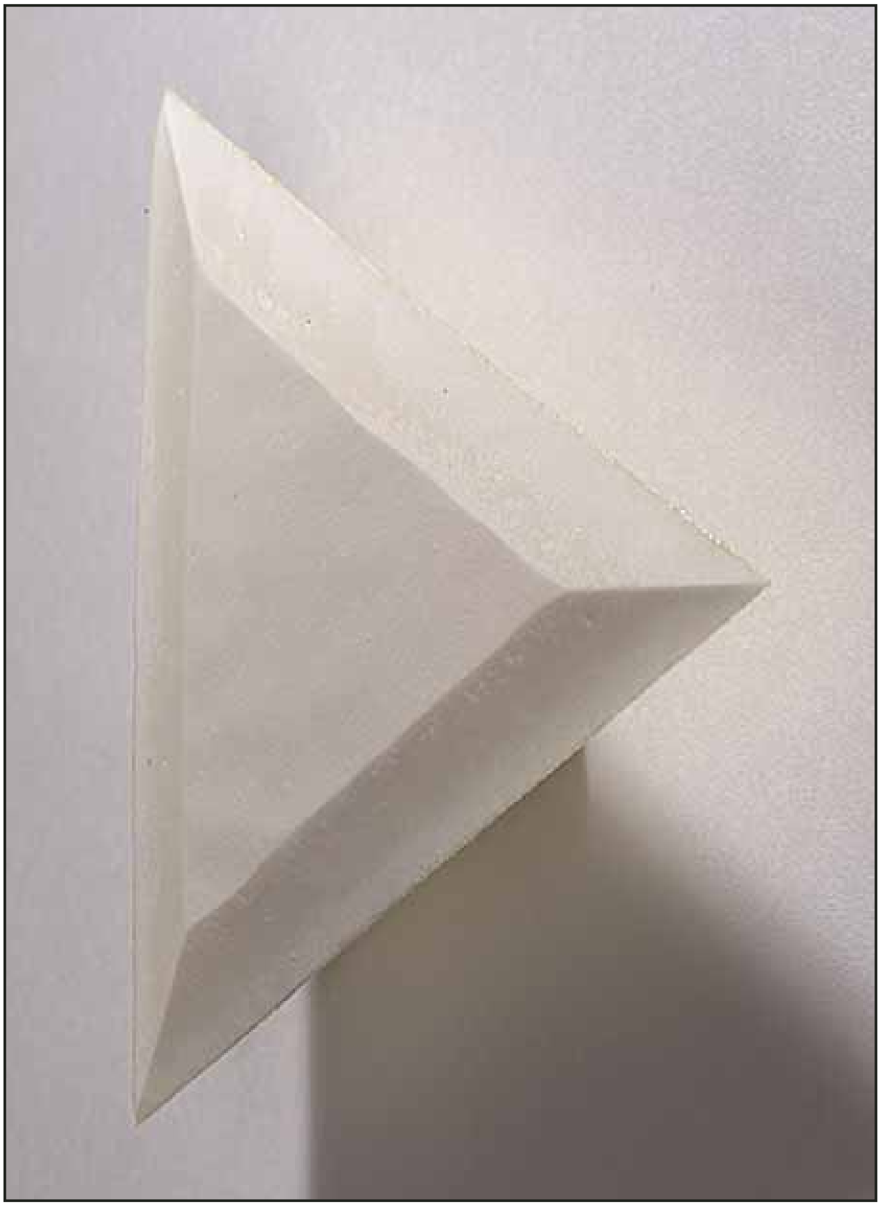


Figure 8

SYNCORE® SHAPES

Until recently, SynCore® was used in very select areas, such as the edges of wing access doors. The aerospace group of Henkel has developed a method for providing SynCore® film in precut forms. Prior to developing this capability, the use of SynCore® was limited to very simple square-edged parts, like access doors and honeycomb edge close-out areas. Workers cut the sheets into shapes with simple knives and templates.

The challenge from SynCore® users was to provide a wide variety of shapes with very defined beveled edges. Henkel focused on combining equipment solutions that would enable the design of SynCore® to exact dimensions from aerospace drawings electronically transmitted by the customer. The new product form allows customers to use automated fiber placement equipment, which reduces fabrication costs. Automated tape heads slide up the SynCore® bevel, similar to a ramp during automated tape-laying operations.



How to Choose SynCore® for Your Application

Matrix Resin (Type)	Service Temperature	SynCore® (Type)
Epoxy	180°F to 200°F (82°C to 93°C)	SynCore® 9823.1™
Epoxy	280°F to 300°F (138°C to 149°C)	SynCore® 9872.1™
High Crush Strength Epoxy	280°F to 300°F (138°C to 149°C)	SynCore® HC 9875™

TABLE 2

Typical Physical Properties of SynCore®

Typical Properties	SynCore® 9823.1™	SynCore® 9872.1™	SynCore® HC 9875™
Density	42 pcf / 673 kg/m^3	42 pcf / 673 kg/m^3	60 pcf / 961 kg/m^3
Shear Strength	8,900 psi / 61.4 MPa	6,800 psi / 46.9 MPa	7,000 psi / 48.2 MPa
Shear Modulus	145 ksi / 1,000 MPa	150 ksi / 1,034 MPa	n/a
Compression Strength	9,000 psi / 62.0 MPa	8,000 psi / 55.2 MPa	21,800 psi / 150 MPa
Compression Modulus	200 ksi / 1,380 MPa	375 ksi / 2,590 MPa	n/a
Tensile Strength	4,000 psi / 27.6 MPa	4,800 psi / 33.1 MPa	5,000 psi / 34.5 MPa
Tensile Modulus	380 ksi / 2,600 MPa	400 ksi / 2,760 MPa	580 ksi / 4,000 MPa

TABLE 3

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