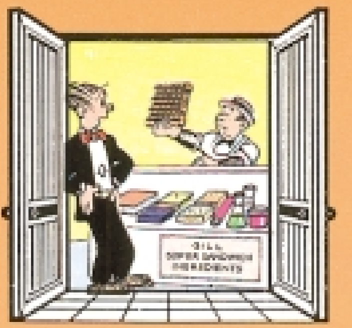
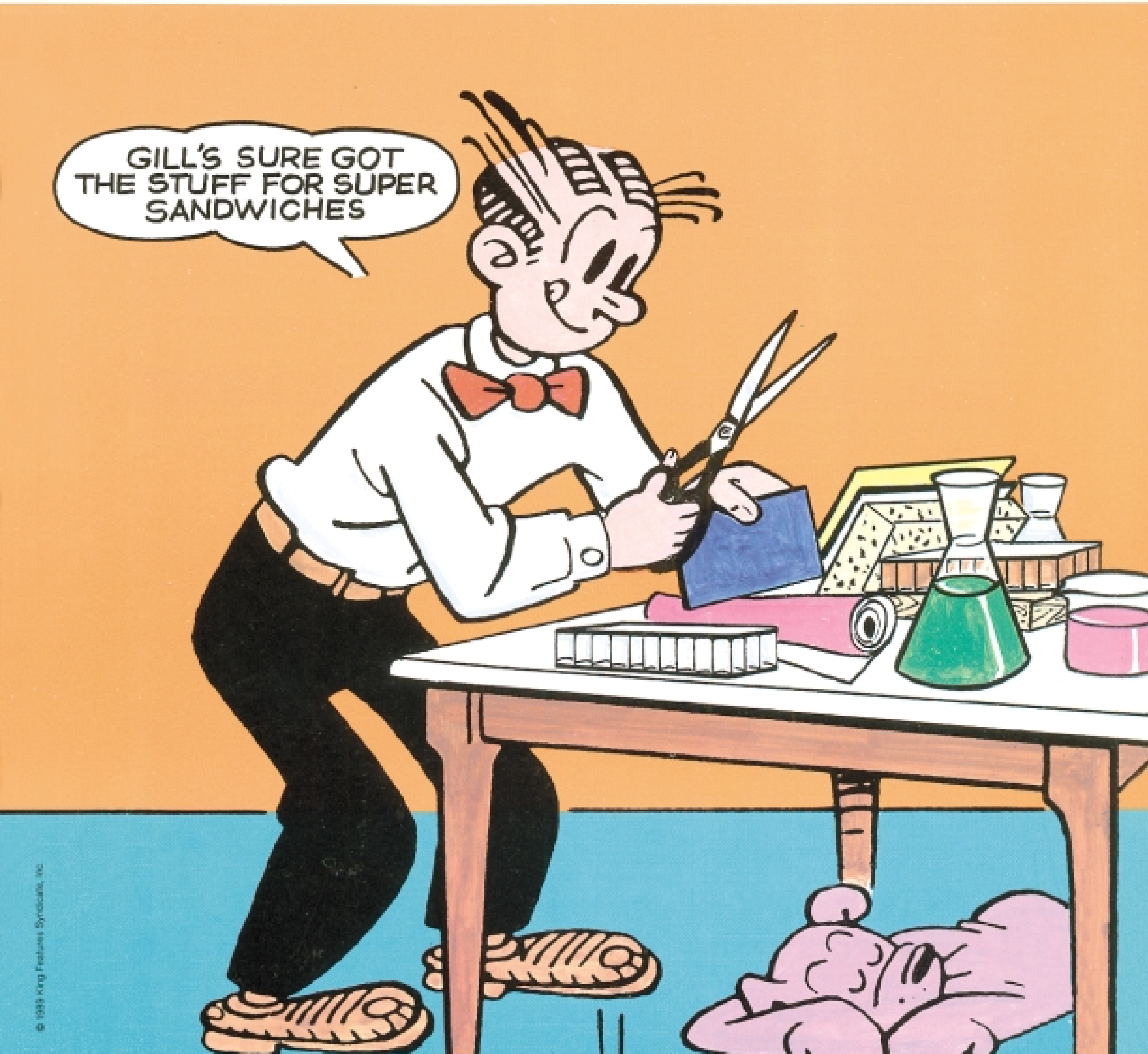
VOLUME 28
SUMMER 1991
NUMBER 3

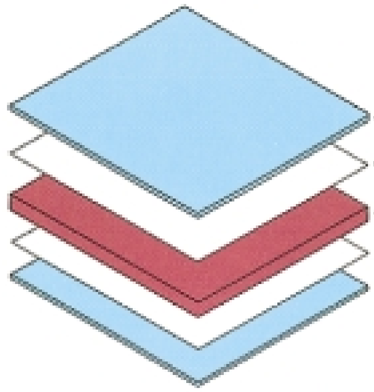


THE M.C.GILL DOORWAY

M.C. GILL CORP., 4056 EASY ST., EL MONTE, CA 91731 • PHONE 818-443-4022 • TELEX 67-7467 • FAX 818-350-5880

SANDWICH PANEL REVIEW...PART 2





Introduction:

This issue of the M.C. Gill Doorway is Part 2 of our Sandwich Panel Review series. The overall series updates data and information contained in a three-part effort conducted in 1984 and 1985. Part 1 of this Review dealt with a general overview of sandwich panels, a discussion of different constructions, a pictorial of how sandwich panels are made, and a listing of sandwich panels M.C. Gill has in stock and ready for shipment. If you did not receive Part 1 and would like a copy, please contact the Marketing Services Department at the address on the cover.

In Part 1, we listed the three components of a sandwich panel, i.e., top and bottom facings, core, and adhesive. Just as Dagwood could go into great detail concerning the different ingredients of his many sandwich concoctions, we will cover the various types of facings, cores, and adhesives in this issue.

As will become apparent in the following pages, there are so many variables as to which type of sandwich panel is the right one for a given end use application. Moreover, it is important to understand that simply having a hot platen press used to bond components purchased elsewhere does not qualify one as a super sandwich laminator. There is no substitute for experience, properly designed equipment, qualified personnel and rigid quality control.

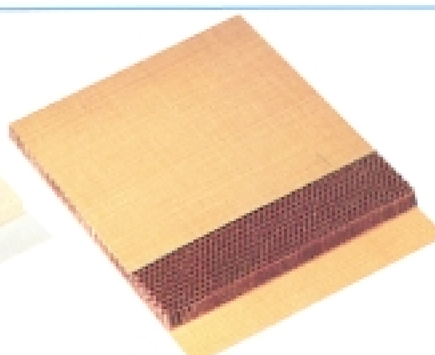
Sandwich Panel Facings

In sandwich panel design, the facings are the main load-bearing element. Under load, the bottom facing is in tension and the top facing in compression. The facings must be strong enough to carry the intended loads and have the proper characteristics to withstand the various service environments they encounter. However, strength is not the only consideration that plays a part in selecting types of faces. The end user must also think about such other factors as weight, corrosion resistance, cost, dent or puncture resistance, weatherability, fire resistance, smoke and toxic emissions, and appearance. Different types of facings include aluminum, fiber reinforced composites, steel, titanium, and plywood and pressed hardboard. The mechanical properties of typical facing materials are shown in the table on page 4.

ALUMINUM ALLOYS

Aluminum alloys are primarily used in aircraft applications, utilizing their high rigidity-to-weight ratio. Each alloy has its advantages: generally the higher the yield strength, the lower the corrosion resistance. A 2024T3 alloy offers a good compromise between strength and susceptibility to corrosion for aircraft uses. We recommend an annodized corrosion treatment in preference to the "acid etch then zinc chromate prime" technology.

WOVEN FRP-POLYESTER FACINGS



UNIDIRECTIONAL FRP-PHENOLIC FACINGS

WOVEN FRP-POLYESTER FACINGS

Aluminum offers good stiffness properties and core shear. It will corrode without proper treatment, is subject to denting and permanent distortion, and although non-burning and non-smoking, aluminum does have high heat contribution and conduction.

FIBER REINFORCED PLASTICS

FRP laminates are widely used as facing material for sandwich panels. They have lower specific gravity, greater corrosion resistance, and lower dielectric properties (low radar signature) than aluminum. Sandwich panel design using FRP faces is a rapidly changing field.

The following are some of the more popular FRP facing materials. They can be unidirectional — where all fibers run in the same direction to provide higher impact resistance and specific strengths in specific directions. Or they can be woven — where fibers are woven in cloth patterns to provide ease of cutting and trimming, delamination resistance and bidirectional strengths.

E-glass — Originally called electrical glass, E-glass was used in 99 percent of the reinforced plastics made in 1984. It is the lowest cost reinforcement. This material performs well in electrical applications, but its usage ranges far wider as a result of its high mechanical strength properties combined with good chemical and heat resistance. Generally, when people say "fiberglass," they are talking about E-glass.

S-2 glass® — This reinforcement is the high impact contender for advanced composites. It has the same low rigidity of E-glass, but has 50 percent higher tensile strength and puncture resistance. Hollow fiber versions are in early developmental stages.

Carbon, or graphite — This material is synonymous with the term "advanced composites." Although glass is used in 99 percent of reinforced plastic applications, it is graphite that has dominated the trade literature for the past few years. Graphite makes parts that have lightness and rigidity unattainable by other means. It is very stiff, and has low density and low thermal expansion. Graphite composites are considered to have excellent fatigue strength and high wear resistance. This reinforcement's shortcomings are its poor impact strength and its high cost. Galvanic corrosion with aluminum is a big problem also, especially with fastening systems because graphite sets up an electronic couple with alumimum and the latter is quickly corroded.

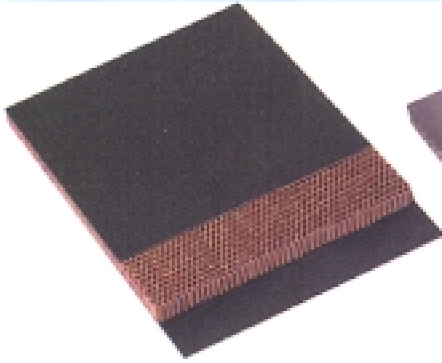
STEELS AND TITANIUM

Low carbon steels are low cost and very stiff, but are heavy and prone to corrosion. Titanium is strong and light, but expensive and hard to bond. Stainless steel has high strength and rigidity, but bonding to core material is difficult.

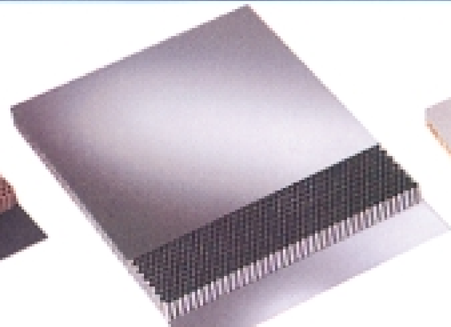
PLYWOOD AND PRESSED HARDBOARD

These materials are used in low-cost architectural or non-structural applications, not so much to improve properties as to keep costs to a minimum in undemanding applications.

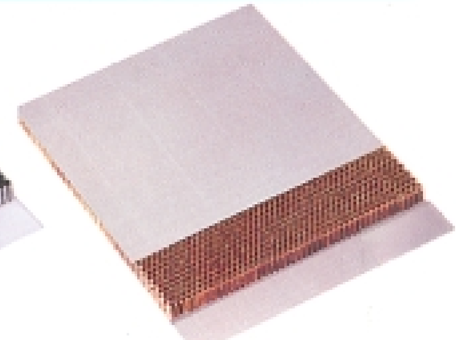
The M.C. Gill Corporation uses primarily aluminum and composite facings but on customer request will use any conventional materials as facings for sandwich panel requirements.



UNIDIRECTIONAL GRAPHITE-PHENOLIC FACINGS



ALUMINUM FACINGS



UNIDIRECTIONAL FRP-EPOXY FACINGS

TABLE 1

MECHANICAL PROPERTIES OF TYPICAL SANDWICH FACING MATERIALS

Facing Material	Yield Strength f_f (psi x 10^3)	Modulus of Elasticity E_f (psi x 10^6)	Wt. per Mil Thickness (lb/ft^2)	Comments
Aluminum-2024-T3	42	10	0.014	Good strength, moderate cost
Aluminum-3003-H16	20	10	0.014	Moderate strength, good weathering
Aluminum-6061-T6	21	10	0.014	Workable, corrosion resistant
Aluminum-7075-T6	60	10	0.014	High strength and dent resistant
Mild carbon steel	50	28	0.040	Low cost, high weight, hard to cut with hand tools
Stainless steel-316	60	29	0.040	Heavy, expensive, hard to bond and fabricate with hand tools
Titanium: Annealed Ti-75A	70	15	0.0235	Low corrosion, high cost, hard to bond
Fiberglass laminates				
Epoxy-Gillfab 1040	30	3.3	0.01	Std. epoxy, 180°F service temp.
Epoxy-Gillfab 1045	30	3.3	0.01	High strength, 250°F service temp.
Phenolic-Gillfab 1002	30	3.0	0.01	Good strength, 350°F service temp.
Polyester-Gillfab 1074	33	3.0	0.01	Good strength, most fire-resistant
Polyimide-Gillfab 1028	22	2.5	0.01	400°F service temp.
Polyester-mat-Gillfab 999	16	1.8	0.01	Low cost
Polyester-woven rovings-Gillfab 1027	25	2.0	0.01	Low cost
Kevlar-epoxy-Gillfab 1313	18	2.5	0.0068	Moderate strength, light weight
Kevlar-phenolic-Gillfab 5055	16	2.0	0.0068	Light weight, low smoke
Graphite-epoxy-Gillfab 1089	65	16.0	0.008	Watch for galvanic corrosion, high cost, strength, stiffness
Graphite-phenolic	60	15.0	0.008	Watch for galvanic corrosion, high cost, strength, stiffness
Douglas fir plywood	2.6	1.5	0.003	Low cost, poor weathering, heavy
Tempered hardboard	2.0	0.6	0.0045	Low cost, low strength, heavy

In the Embraer EMB-120 highly rigid (black) sandwich flooring is installed in the aisle; less rigid (yellow) panels under the seats.

Fiberglass faced/balsa core sandwich panels for flooring resist high abuse in Federal Express 747 cargo compartments.

British Aerospace employee installing graphite faced/Nomex honeycomb flooring in the BAe 146 passenger area.

Sandwich Panel Cores

In the aircraft and aerospace industries end grain balsa wood, honeycomb and foam are the core materials of choice. As discussed in the following paragraphs, each has its advantages and disadvantages. The end user must weigh the pros and cons of the core material with the specific end use before specifying type, or, if the user is unsure, we will be pleased to assist in the selection.

END GRAIN BALSA WOOD

Because of its light weight and low cost, balsa wood is widely used as core material for sandwich panels in the aircraft and marine industries. Balsa can be considered a cellulose aligning foam, with cylindrical cells 95 percent closed and 100 percent aligned.

"End grain" simply means that the grain of the wood is perpendicular to the panel surface — like a butcher's cutting block. Thus, the compressive and shear strength of the wood achieves its optimum utilization with this configuration. Under a microscope, balsa is seen to have a vertical, 95 percent closed-cell structure that is much better aligned than foams.

Because balsa comes from trees, not all balsa wood is the same and it is imperative that the panel fabricator is experienced in specifying and inspecting the balsa used in sandwich panels. The balsa wood we use comes from trees that grow along the rivers of central Ecuador and is the finest available. Lumber selection and sorting, along with tight controls on kiln drying and bonding into blocks, are required to maintain the highest quality standards.

End grain balsa wood can be difficult to laminate, but again experience is the key. There is no substitute for proper handling and preparation of the balsa wood before and during the panel fabrication.

More than thirty years ago, M.C. Gill recognized the many advantages of balsa wood. This type of sandwich core exhibits high strength, low cost and remarkable endurance in heavy duty, high abuse applications.

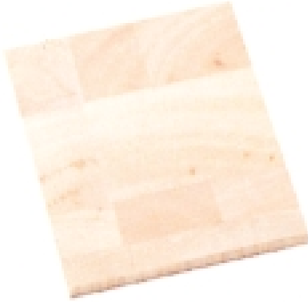
End grain balsa wood is available in either 9.5 pcf (pounds per cubic foot) or 6.25 pcf density. Because balsa wood is a natural product these densities are averages. For example, a 9.5 pcf density may range between 7 and 14 pcf. The load-bearing properties are lessened with the lower 6.25 pcf density. It is normally used where the panel is installed in a vertical position or where loads are less severe.

Among balsa wood's many features are:

- High compressive strength — over 1500 psi (pounds per square inch) for 9.5 pcf balsa and over 900 psi for 6.25 pcf balsa
- Resilient, high fatigue nature — has integrity, is resistant to point loading, and is not brittle
- Good core shear strength — 200 psi for 9.5 pcf balsa and 160 psi for 6.25 pcf balsa
- Better thermal insulation than unfilled honeycomb

To illustrate the strength difference between 6 and 9 pcf balsa, tests on identical 0.400" thick panels with 0.011" 2024T3 aluminum facings on both sides showed the 6 pcf balsa had 16 percent greater deflection under load, 6 percent lower ultimate load, but the overall panel weight was reduced by 15 percent.

In aircraft, many of our end grain balsa floor panels have achieved a service life of well over 20,000 hours flight time as center aisle flooring on flights of short duration and, therefore, demanding service. Mother Nature gave balsa wood inherent toughness, light weight and good strength. We like to think she had the M.C. Gill Corporation in mind.


END GRAIN BALSA WOOD


NOMEX HONEYCOMB


ALUMINUM HONEYCOMB

HONEYCOMB

Although bees have been manufacturing honeycomb much longer than we have, it is the core material that first comes to most people's minds when thinking of sandwich panels. Its initial applications came in the aircraft industry during World War II and has since spread to such industrial uses as manufactured housing, office partitions, marine bulkheads, and others where its combination of high stiffness-to-weight ratio are utilized.

Having used honeycomb in the manufacture of sandwich panels since 1955, the M.C. Gill Corporation knows what good quality consists of and the company utilizes its experience in the selection of adhesives, resins, reinforcements, and processing to achieve the proper combination for any given application.

Honeycomb core is manufactured from fiber reinforced plastic, aramid paper, graphite, metallic foils such as aluminum and stainless steel, and kraft paper.

The strength and stiffness of honeycomb is determined by its density, that is, its cell size, cell wall thickness and the material used in the honeycomb. High density produces high strength with greater weight.

Versatility a Prime Attribute. Resin impregnated paper honeycomb is the least expensive and is used where high strength and moisture resistance are not required. Aramid (or Nomex®), FRP and metal (primarily aluminum) honeycomb are most widely used in high performance applications. A wide range of cell size configurations and densities can be produced to meet varying performance levels. As a result, honeycomb core can be tailored to specific applications and specifications.

Honeycomb core is truly a versatile, high performance core material. Cell sizes vary from 1/8" to 1.0" and overall densities may range from 1.0 pcf to more than 11.0 pcf. Slice thicknesses can be specified up to 12" and down to 0.038." It can also be milled or crushed for contoured panels. Generally, the smaller the cell size, the higher the cost at a given density. Conversely, smaller cell sizes provide 1) less honeycomb mark-off (dimpling of the facings), 2) a better bonding surface, and 3) under heavy loads, less wrinkling of facings, giving higher facing stress.

Is it Aluminum or is it Nomex? Aluminum honeycomb features good temperature resistance, low water absorption and relatively low cost. However, aluminum honeycomb is poor in burn-through resistance, and unless properly treated, high in corrosion. Nomex honeycomb is much higher in cost and has low resistance to water absorption, but offers superior fatigue resistance and radar transparency. The panel strength is influenced by the particular honeycomb configuration used.

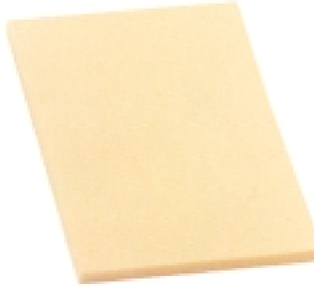
The M.C. Gill Corporation specializes in aluminum and Nomex honeycomb core panels, where the high performance requirements of our customers can be met consistently. We have produced both materials with our own equipment since 1983, thus providing better quality control and availability.

CRUSHED HONEYCOMB

Crushed honeycomb panels can be roll-formed, routed, sawed, drilled, or riveted using standard metal shop practices, which makes them very popular in shops accustomed to fabricating plate metal. In general aviation these thin sandwich panels are often used as flooring and interior sidewalls. In the larger commercial jets they sometimes find use as flooring in containerized baggage compartments. Crushed core panels can be substituted for solid sheet thickness for thickness at a weight saving of one-third and no sacrifice in mechanical properties.

The acquisition of our 60" span horizontal band saw in the late 1980's has enabled us to develop the capability to provide honeycomb as thin as .040" without crushing it. The computer controlled saw slices Nomex honeycomb and foam to within a ±.005" tolerance across each slice and reduces the chance for

CRUSHED ALUMINUM



FOAM

FOAM FILLED I-BEAM

operator error because it controls speed and repositions the blade after each cut. The ability to produce very thin slices results in a lighter weight lower cost panel that can be substituted for crushed honeycomb in applications such as shelving and flooring, or where the panels do not have to be formed.

FOAM

Foam core sandwich panels have a long history of use as thermal insulation materials in the construction industry. In other areas their use has been restricted by flammability and smoke emission requirements, low tensile strength, fatigue failure and their friable (crumbly) nature. In recent years, these drawbacks have been overcome to varying degrees with new types of foam although their high smoke generation in a fire greatly reduces their use in transportation vehicles. Foam core panels are still restricted almost exclusively to vertical non-structural surfaces due to their lower fatigue levels.

Polymethacrylimide

This relative newcomer to the field of high performance rigid foams exhibits mechanical properties well above PVC or urethane in the same densities. Available in densities as low as 1.9 pcf, it is resistant to most solvents and chemicals, and has good structural properties at temperatures up to 350°F. However, it is much more water absorbent than other foams mentioned here. It burns, is more expensive, and is difficult to bond.

Poly Vinyl Chloride (PVC)

These foams are actually half PVC and half urethane, with the urethane providing cross-linking and increased temperature stability. The PVC decreases brittleness and increases fire resistance. Densities range from 2.5 pcf to 17 pcf. PVC foams exhibit somewhat stronger characteristics than urethane foams of the same density, particularly friability.

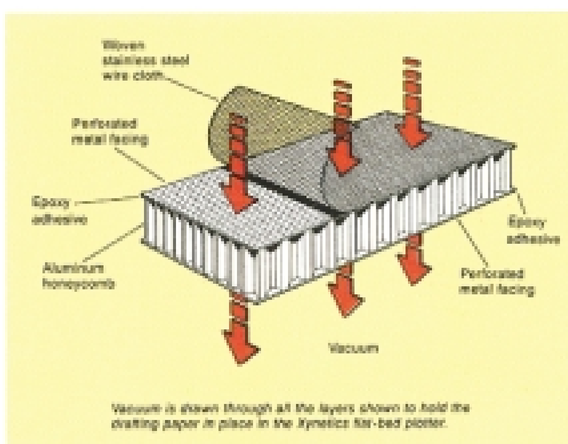
Polystyrene

The lower density styrofoam is rarely used in high performance applications. It exhibits fair mechanical values in sandwich panel structures, but has unacceptable flammability and smoke emission characteristics for many end uses, particularly in the aircraft industry. Because it is soluble in many solvents and has low temperature resistance, it is very difficult to bond with high strength adhesives. Polystyrene foams are used primarily in such applications as recreational vehicles, truck bodies, cargo containers, and sign and display boards. it is low in price compared to higher performance foams.

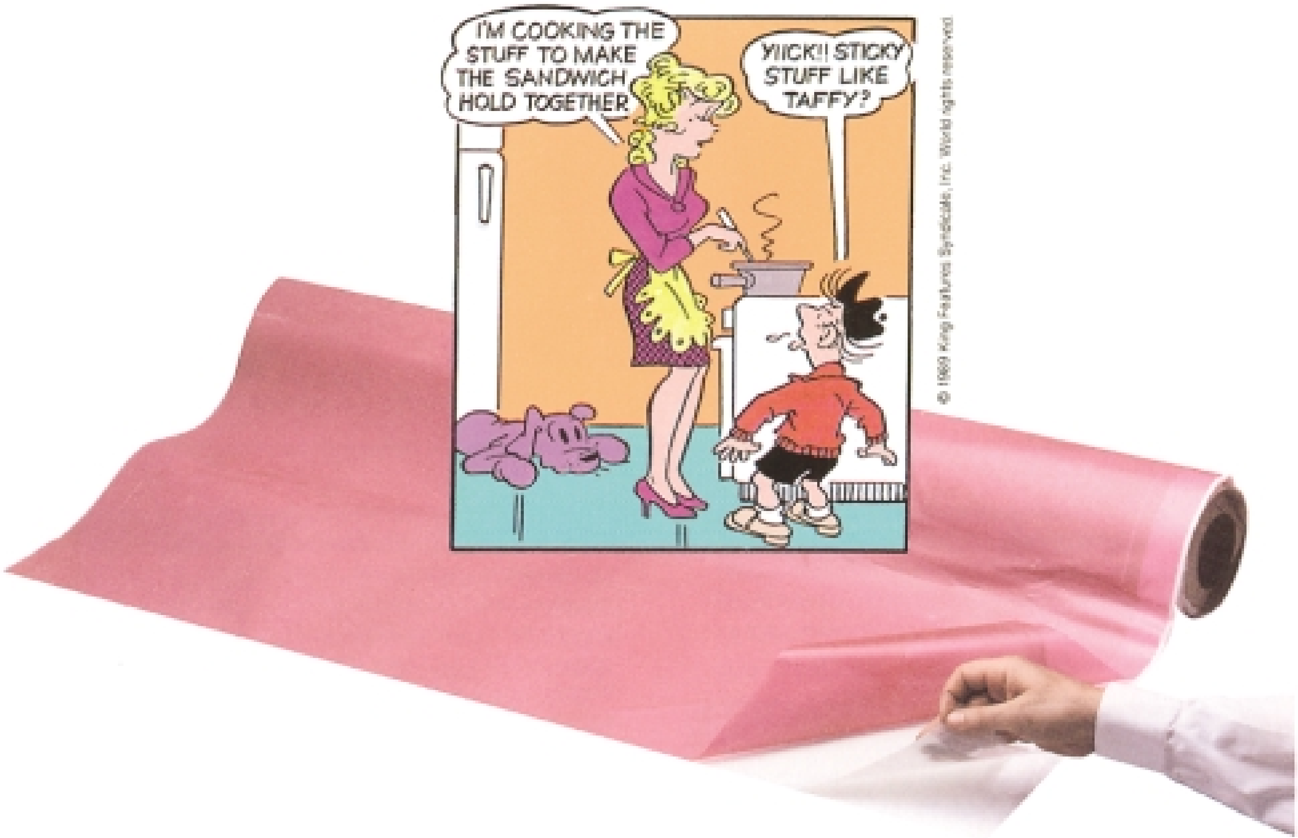
Polyurethane

Polyurethane foam is available in both rigid and flexible foams. Only the rigid foam is considered here because flexible foam is not a viable sandwich panel core. This foam is resistant to a wide range of solvents and chemicals including resin systems used for FRP sandwich panel facings. Densities range from 2 to 30 pcf. Typical uses include low density thermal insulation panels second to none and edge close outs in sandwich panels. Urethane foams are relatively fire retardant, but have high smoke emissions in a fire. These foams are rather friable and panels are subject to impact damage and fatigue failure.

A 1½" thick aluminum honeycomb panel with perforated metal facing is used as the base for a vacuum table by Xynetics Division, General Signal Corporation, Santa Clara, CA.



Vacuum is drawn through all the layers shown to hold the drafting paper in place in the Xynetics flat-bed plotter.



Adhesives

The stickiest component for a purchaser of sandwich panels to specify is the quality or reliability of the adhesive used because, as a wise man once said, "A sandwich panel is no better than the adhesive bonding it together."

For Dagwood, that adhesive may be butter, mayonnaise, mustard, or catsup, but for purposes of this discussion there are four general adhesive types available.

- Modified epoxy. Usually the best choice and many formulations are available for different end uses.
- Vinyl phenolic. Very durable but it is difficult to process.
- Contact elastomeric (rubber base). It may be satisfactory in non-structural applications but must be evaluated for cold flow or creep.
- Urethane. Normally used in construction but has water resistance problems.
- 300°F to 350°F service epoxy. Expensive, but produces durable bonds to 350°F.

Urethane and contact-type bonding adhesives are used with lower cost, continuous surface core materials while modified epoxies are used with honeycomb and the higher performance cores required by the aircraft and aerospace industries. The M.C. Gill Corp. uses all types, depending on the compatibility of adhesive with core and facings, the bond and peel strengths required and customer preference or specification. Environmental laws have severely restricted the processing of vinyl phenolic and solvent based elastomeric in the United States.

Elastomeric contact adhesives are applied to both facings and core, then laminated in a low pressure, low temperature hot press.

Epoxy adhesives are usually applied as heat-curing films and are placed between core and facings when the panel components are assembled. Initial heating of the press momentarily liquifies the epoxy. As the press continues to heat, the epoxy is cured to a tough rigid film, bonding core and facings together. Some epoxies are used in liquid or paste form.

Panels that look and feel the same may have flatwise tensile strength variations that range from 40 to 1200 psi. Because of the difficulty of "inspecting quality," M.C. Gill concluded in 1977 that we would make our own epoxy adhesives to ensure that every inch of every roll of adhesive would exceed minimum requirements. The company's epoxy adhesives are formulated to satisfy customers' needs, and our consistently uniform quality has improved dramatically since we started using our own adhesives.

Adhesive Specifications

All M.C. Gill epoxy adhesives meet the two most common adhesive specifications: MMM A 132, Type 1, Class 2 and 3, and Mil A 25463 A. However, we are not satisfied to merely meet the minimum requirements. As a result, we test our adhesives to the most current durability tests as well as spot checking during each run to ensure consistency.

The following tabulation shows the more commonly used adhesives (all modified epoxies) that we manufacture, and is included here to assist our customers in deciding which adhesive they might choose to specify.

M.C. GILL MANUFACTURED ADHESIVES

Part Number	Weight (psf)	Uses/Features
A-187 and A-197	.031 .038	For one-step or primary bonding of FRP facings to Nomex honeycomb core. Fire resistant.
A-198	.045	Marginal for secondary bond but very strong in one-step bonding. Qualified to McDonnell Douglas DPS 1.99-9.15. Fire resistant.
A-196	.070	Standard for end grain balsa wood panels. Fire resistant.
A-193	.060	Standard for aluminum honeycomb core panels. Not fire resistant.
A-175	.085	Very high bond strengths. Not fire resistant.
A-176	.068	Light weight version of A-175. Not fire resistant.

Factors Affecting Epoxy Adhesive Bond Strengths

Sometimes a customer has a certain honeycomb sandwich panel configuration in mind, but doesn't know what to expect in terms of bond strengths. When bonding a honeycomb sandwich panel there are a number of factors that will affect its bond strength. Foremost among these are 1) Type of adhesive, 2) Adhesive weight, 3) Type of core, 4) Cell size, 5) Surface preparation of the facings, 6) Processing techniques, and 7) Variations in processing.

Adhesive Weight

A key variable in selecting epoxy adhesives is the weight of the adhesive per square foot. For purposes of illustration, we have taken an aluminum honeycomb core/aluminum faced panel. The core is 1/4" 5052 cell, .003N 6.0 pcf density; facings are each .020" 2024T3 aluminum; adhesive is Gillbond A-193.

Adhesive Weight (psf)	Flatwise Tensile (psi)	Climbing Drum Peel in-lbs/3"
.045	650	35
.060	1000	60
.085	1200	90

The .045 psf adhesive is usually enough to bond fiberglass or graphite facings to honeycomb core but experience has taught us that it will not provide a dependable bond for aluminum faces bonded to aluminum honeycomb core; therefore, we use an .060 psf epoxy. Where superior strength is required, we recommend using the .085 psf adhesive. The strength and reliability increase dramatically but at some sacrifice of weight.

Bond Strength

The type of core governs the bond strength achievable. Unless the core has good flatwise tensile strength, the panel will not have high bond strength. For example, foam core has minimal strength, regardless of type; balsa core will bond satisfactorily if processed properly; and bondability of honeycomb core varies with type, foil and cell size.

All fiberglass sandwich panels enclose communications equipment atop Los Angeles Water & Power Building. The panels, installed 28 years ago, have surpassed their planned service life of 20 years by 40%.

Surface Preparation and Workmanship

Surface preparation and workmanship are essential to high quality bonding. Like a chain, a bond is no better than its weakest link and processing techniques must be maintained at a high level. Seemingly insignificant changes can cause drastic changes in the bond. Therefore, uniformity is paramount. No one can do a good job without adequate equipment, procedures, and controls. Many "adhesive failures" are really surface preparation or uncontrolled process variations (it must be 100% clean).

Although many materials can be used as facings, four of the more common are aluminum, FRP, titanium and stainless steel. For aluminum panel facings, chemical treatment is the only reliable preparation technique. As opposed to solvent or mechanical cleaning, chemical treatment changes the nature of the aluminum's surface to make it more receptive to adhesion. Aluminum is usually acid-etched or flash annodized.

Generally, in two step bonding, fiberglass reinforced plastic facings are pressed with a peel ply which keeps the bonding surface clean until it is removed just prior to lay up of the panel. If there is no peel ply, the surface can be wiped clean with a solvent such as MEK; lightly abraded and then wiped clean; or sandblasted.

One method of preparing stainless steel is to sandblast it and then dip it in a solution of sulfuric acid to clean it, but the material must be carefully inspected after sandblasting for kinks or other possible damage. A second method is to dip it in a solution of nitric acid. Primers are sometimes used to coat facing surfaces to improve bondability.

Titanium is a difficult facing material to bond, but one method is to dip it in a solution of hydrofluoric, hydrochloric, and nitric acids. Another is to prime the surface to facilitate bonding.

Space limitations preclude a complete discussion of all the different surface preparations for not only the above four but the many other facing materials. The subject is touched on here primarily to alert the reader of its importance and to emphasize that only an experienced laminator with the proper equipment and personnel is qualified to do it.

Smoke and Toxic Emissions in a Post-Crash Fire

As noted in the introductory remarks in Part 1 of this series, we felt it necessary to update our earlier series on panels, in part because we've moved up several notches on the sandwich panel learning curve. Many of those notches have been related to heat release, smoke evolution, and toxic emission characteristics in a post-crash fire.

Given the tragic aircraft crashes that transpired during the 1980's and early 1990's the drawbacks related to the incorporation of epoxy resin systems in sandwich panels have become the increasing concern to the FAA, airframe manufacturers, airlines and the M.C. Gill Corporation. Hazards to passengers and airplane crews caused by fire in post-crash conditions have drawn increasing public attention and congressional scrutiny. New standards were established by the FAA in 1988 for heat release rates of certain aircraft components.[3] **Note:** Flooring panels are not required to pass the heat release tests at this point in time. However, in response to customer interests, the M.C. Gill Corp. has developed and tested a number of panels that will pass the tests.

These heat release values for samples tested are reported in terms of kilowatts (kw) of heat per square meter (m^2) for the peak heat release and in terms of kilowatt-minutes (kw-min) per square meter for the two-minute integrated heat release. In 1986, the FAA established, as criteria, release rates of 100 kw/m^2 for the peak test and 100 kw-min/m^2 for the integrated test (usually expressed as 100/100). These standards became effective August 20, 1988, and became even more stringent in 1990 when they dropped to 65/65. To put this measurement in perspective, a one square foot piece of red oak flooring will yield readings of 130/130 under identical test conditions — twice the maximum values currently allowed by the FAA.

In order to manufacture products that will enable airlines and airframe manufacturers to comply with these standards, M.C. Gill Corp. has developed new products and "reintroduced" existing ones that utilize phenolic resin systems in their construction. Phenolic resins are inherently non-burning and exhibit very low smoke evolution and toxicity in a fire compared to virtually any other organic polymer (see the Summer 1988 Doorway for a pictorial comparison of the differences in smoke emissions from polyester resin and phenolic resin). Phenolics do have drawbacks but many are manufacturing oriented and not related to end use. As shown in Table 2, many M.C. Gill products are well within the FAA's 1990 guidelines, and likely would pass any future standards the FAA might adopt.

The Information in Table 2 identifies the construction of our better selling sandwich panels. Two of the panels (4017 and 4105) that pass heat release requirements use fiberglass reinforced epoxy facings, and are both well under the latest FAA standard.

Research efforts to develop and test new flooring panels for the commercial aircraft industry are on-going. As requirements change, response time will not only be rapid, but thorough. Many composite flooring panels have been tried and successful new panels will require exceptional effort.

[3] Smoke and toxic emissions are fire-associated dangers in a post-crash environment, but as of this writing the FAA has not established test procedures and minimum standards, as it has with heat release rates.

TABLE 2

PROPERTIES OF SELECTED M.C. GILL SANDWICH PANELS

PRODUCT	Core type and density	Adhesive	Top facing	Bottom facing	Panel thickness (inches)	Panel weight (lb/ft^2)	Flex strength 20" span 2 pt. load: Ult. load (lbs)	Flex strength 20" span 2 pt. load: Defl. @ 100 lbs (inches)	Heat Release (Total $kw/min/m^2$ Peak kw/m^2)	Climbing drum peel strength (in-lbs/3" width): Top	Climbing drum peel strength (in-lbs/3" width): Bottom
TEST METHOD ►							Mil Std 4018		FAR 25.853 (a-1) App F, Part 4	Mil Std 4018	
4004	1/8" cell, 9 pcf Aramid honeycomb	Modified epoxy	.015" Unidir. FRP phenolic	.015" Unidir. FRP phenolic	.390	.70	325	.65	24/21	21	21
4017 Ty 1	1/8" cell, 9 pcf Aramid honeycomb	.030 psf epoxy	.015" epoxy Unidir. FRP	.015" epoxy Unidir. FRP	.400	.64	260	.85	53/59	30	30
4017 Ty 2	1/8" cell, 5 pcf Aramid honeycomb	.030 psf epoxy	.015" epoxy Unidir. FRP	.015" epoxy Unidir. FRP	.400	.52	240	.85	53/59	30	30
4022	1/8" cell, 8 pcf Aramid honeycomb	Modified epoxy	.020" FRP phenolic	.020" FRP phenolic	.400	.84	306	.72	14/19	25	25
4030	3/16" cell, 5, 7 pcf Aluminum honeycomb	Modified epoxy	.020" 2024T3 aluminum	.020" 2024T3 aluminum	.500	.90	484	.15	0.5/0	40	40
4105	3/16" cell, 6 pcf Aramid honeycomb	Modified epoxy	.025" woven FRP epoxy	.025" woven FRP epoxy	.375	.67	371	.681	58/58	27	27
4109 Ty 1	1/8" cell, 8 pcf Aramid honeycomb	Modified epoxy	.014" Unidir. GRP phenolic	.014" Unidir. GRP phenolic	.390	.52	325	.40	40/49	21	21
4109 Ty 2	1/8" cell, 4 pcf Aramid honeycomb	Modified epoxy	.014" Unidir. GRP phenolic	.014" Unidir. GRP phenolic	.390	.42	325	.40	41/50	18	18
5007A	End grain balsa 9.5 pcf	Modified polyester	.040" woven FRP polyester	.020" woven FRP polyester	.400	1.04	400	.41	78/62	18	10
5007B	End grain balsa 9.5 pcf	Modified polyester	.040" woven FRP polyester	.020" woven FRP polyester	.400	1.03	420	.43	N/A	28	20
5007C	End grain balsa 9.5 pcf	Modified polyester	.045" woven FRP polyester	.030" woven FRP polyester	.400	1.3	525	.36	N/A	30	22
5040	End grain balsa 9.5 pcf	Phenolic Mod. elastomer	.020" 2024T3 aluminum	.012" 2024T3 aluminum	.400	.75	295	.31	3.6/0	50	50

PRODUCT	Flatwise compressive strength (psi)	Flatwise tensile strength (psi)	Core shear 4" span 2 pt. load (psi)	In-plane shear strength (psi)	2 lb. Gardner impact (in-lbs)	Insert shear strength (lbs)	Roller cart (test cycles to failure)	30 day 100% humidity soak (% of dry results): 20" flex strength	30 day 100% humidity soak (% of dry results): Climbing drum peel	Specifications
TEST METHOD ►	Mil Std 4018	Mil Std 4018	Mil Std 4018	BMS 4-17D	Model 1IK3	Shurlok 5107-A3	BMS 4-17D	Mil Std 4018	Mil Std 4018	
4004	1600	N/A	N/A	N/A	100	N/A	N/A	100%[1]	100%[1]	McDonnell Douglas DWG 7954401
4017 Ty 1	1500	700	700	4,140	65	950	128 lbs — 120,000 158 lbs — 35,000	80%[1]	80%[1]	McDonnell Douglas DWG BZZ 7002 Lockheed LAC-C-28-1386
4017 Ty 2	600	550	430	4,140	65	980	98 lbs — 80,000	80%[1]	80%[1]	McDonnell Douglas DWG BZZ 7002 Lockheed LAC-C-28-1386
4022	1200	350	437	7,200	26	N/A	N/A	N/A	N/A	McDonnell Douglas 9D0059 Lockheed LAC-C-22-1339 & LAC-C-28-1041
4030	600	700			40	N/A	N/A	N/A		Lockheed LAC-C-28-1145 Ty 5, 7, 9, 10 E-systems TMS 11-903
4105	916	501	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Airbus Industrie TL53/5000/79
4109 Ty 1	1200	N/A	355/190[2]	N/A	20	650	100 lbs. — 100,000	100%[1]	100%[1]	McDonnell Douglas DWG 7954400 BAER 3231
4109 Ty 2	470	N/A	235/120[2]	N/A	20	650	N/A	100%[1]	100%[1]	McDonnell Douglas DWG 7954400 BAER 3231
5007A	1500	900	240[3]	12,200	44	1200	128 lbs — 120,000 158 lbs — 35,000	70%	80%	Airbus Industrie TL53/5000/79
5007B	1500	1000	250[3]	9,200	40	1000	128 lbs — 120,000 158 lbs — 50,000+	70%	80%	United Airlines SHE 2902
5007C	1500	1000	260[3]	14,700	54	1150	128 lbs — 120,000 158 lbs — 35,000	70%	80%	
5040	1500	275	185[3]	14,000	34	1200	128 lbs — 40,000	85%	70%	

NOTES: N/A means not available.
FRP means glass reinforced plastic.
GRP means graphite reinforced plastic.

1. Tested after 30 days at 140°F and 95-100% relative humidity.
2. First number is ribbon direction/second number is transverse direction.
3. 12" span.

Trivia

Next to the bible, the Guinness Book of Records is the best selling copyrighted book in the world.

★ ★ ★ ★

The tallest living woman in the world is 7 feet 7¾ inches.

★ ★ ★ ★

In 1844, the Y.M.C.A. was founded in London.

★ ★ ★ ★

Supermarkets cash more checks than banks.

★ ★ ★ ★

Percentage of women in dental office jobs:

- Receptionists—99%
- Dental assistants—98%
- Dental hygienists—97%
- Dentists—9%

★ ★ ★ ★

Hulk Hogan's real name is Terry Bollea.

★ ★ ★ ★

In 1933, the first drive-in movie theater opened in Camden, NJ.

★ ★ ★ ★

The sooner you leave the hospital after surgery, the less chance you'll get an infection.

★ ★ ★ ★

An electric eel generates up to 500 volts (an electric chair generates 2,000 volts).

★ ★ ★ ★

Madrid's 1811 earthquake rang Boston's church bells.

M.C. GILL CORP. • SINCE 1945

THE FUNNY SIDE

Looking over the rim of the volcano, the American tourist remarked, "Kind of reminds one of hell doesn't it?" The guide threw up his hands and exclaimed, "These Americans, they've been everywhere!"

★ ★ ★ ★

When grandpa was a kid, he had his own private tanning salon. Only then, it was called a woodshed.

★ ★ ★ ★

Show business: Fraudville.

★ ★ ★ ★

Music criticism: Sound judgements.

★ ★ ★ ★

Eavesdropping: Ear, there, and everywhere.

★ ★ ★ ★

Coffee lover: Caffiend.

★ ★ ★ ★

Procrastination: All in a day's shirk.

★ ★ ★ ★

Four businessmen invested in a hunting lodge deep in the woods where every year they would meet for a couple of weeks. "We want to rough it," they told their wives. "No hot water, no modern conveniences, and above all, no women!" One year the wives decided to follow their husbands as a surprise. "You gals better beat it quick!", an old guide advised them. "This year they brought their wives with them."

★ ★ ★ ★

Don't worry if your child gets excited over nothing. He may grow up to act in TV commercials.

★ ★ ★ ★

Fresh out of boot camp, the proud Marine stood at attention, awaiting his colonel's scrutiny during graduation exercises. The colonel noticed a loose thread dangling from the young man's uniform. "Soldier," he barked, "your jacket is frayed." Undaunted, the new Marine replied, "Sir, begging the colonel's pardon, but this here jacket ain't 'fraid of nothing."