STRUCTURAL COMPOSNTES

A structural composite is a multi-layered and normally low-density composite used in applications requiring structural integrity, ordinarily high tensile, compressive, and torsional strengths and stiffnesses. The properties of these composites depend not. only on the properties of the constituent materials, but also on the geometrical design of the structural elements. Laminar composites and sandwich panels are two of the most common structural composites.

1- Laminar Composites

A laminar composite is composed of two-dimensional sheets or panels (plies or laminae) bonded to one another. Each ply has a preferred high-strength direction, such as is found in continuous and aligned fiber-reinforced polymers. A multi-layered structure such as this is termed a laminate. Laminate properties depend on several factors to include how the high-strength direction varies from layer to layer.

In this regard, there are four classes of laminar composites: unidirectional, cross-ply, angle-ply and multidirectional. For unidirectional, the orientation of the high-strength direction for all laminae is the same (Figure a); cross-ply laminates have alternating high-strength layer orientations of 0° and 90° (Figure b); and for angle-ply, successive layers alternate between +θand -θ high-strength orientations (e.g., ±45°) (Figure c). The multidirectional laminates have several high-strength orientations (Figure d). For virtually all laminates, layers are typically stacked such that fiber orientations are symmetric relative to the laminate midplane; this arrangement prevents any out-of-plane twisting or bending.

In-plane properties (e.g., modulus of elasticity and strength) of unidirectional laminates are highly anisotropic. Cross-, angle-, and multidirectional laminates are designed to increase the degree of in-plane isotropy; multidirectional can be fabricated to be most isotropic; degree of isotropy decreases with angle- and cross-ply materials.

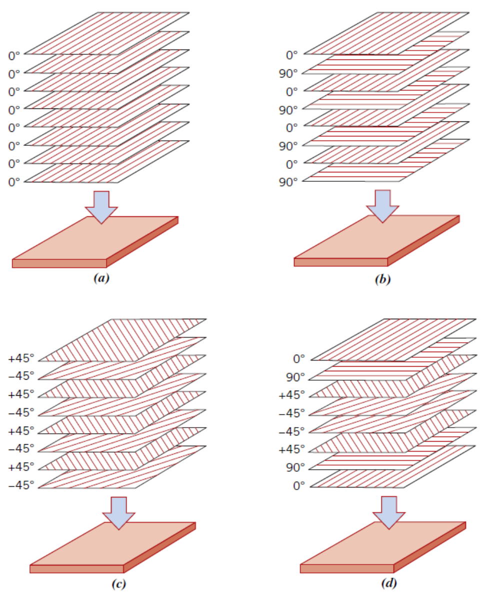


Figure Lay-ups (schematics) for laminar composites. (*a*) Undirectional; (*b*) cross-ply; (*c*) angle-ply; and (*d*) multidirectional.

A multi-layered structure having the desired configuration is produced during lay-up as a number of tapes are laid one upon another at a variety of predetermined high-strength orientations.
Overall strength and degree of isotropy depends on fiber material, number of layers, as well as orientation sequence.

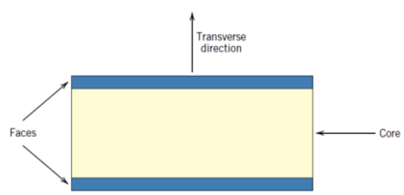
Most laminate fiber materials are carbon, glass, and aramid. Subsequent to lay-up, the resin must be cured and layers bonded together; this is accomplished by heating the part while pressure is being applied.
Laminations may also be constructed using fabric material such as cotton, paper, or woven-glass fibers embedded in a plastic matrix. In-plane degree of isotropy is relatively high in this group of materials.

Techniques used for post-lay-up processing include autoclave molding, pressure-bag molding, and vacuum-bag molding.

Applications that use laminate composites are primarily in aircraft, automotive, marine, and building/civil-infrastructure sectors. Specific applications include the following: aircraft—fuselage, vertical and horizontal stabilizers, landing-gear hatch, floors, fairings, and rotor blades for helicopters; automotive-automobile panels, sports car bodies, and drive shafts; marine—ship hulls, hatch covers, deckhouses, bulkheads, and propellers; building/civil-infrastructure—bridge components, long-span roof structures, beams, structural panels, roof panels, and tanks.

2-Sandwich Panels

A class of structural composites, are designed to be lightweight beams or panels having relatively high stiffnesses and strengths. A sandwich panel consists of two outer sheets, faces, or skins that are separated by and adhesively bonded to a thicker core (Figure).

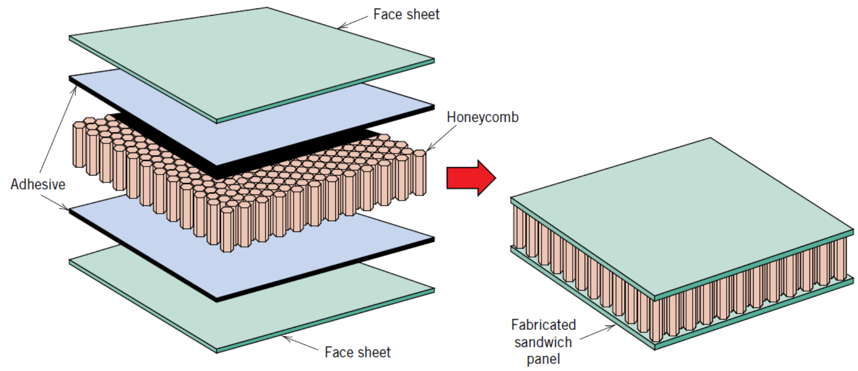


Schematic diagram showing the cross section of a sandwich panel

- *The outer sheets* are made of a relatively stiff and strong material, typically aluminum alloys, steel and stainless steel, fiber-reinforced plastics, and plywood; they carry bending loads that are applied to the panel. When a sandwich panel is bent, one face experiences compressive stresses, the other tensile stresses.
- *The core material* is lightweight and normally has a low modulus of elasticity. Structurally, it serves several functions.
  1- Provides continuous support for the faces and holds them together.
  2- Must have sufficient shear strength to withstand transverse shear stresses and also be thick enough to provide high shear stiffness (to resist buckling of the panel). Tensile and compressive stresses on the core are much lower than on the faces. Panel stiffness depends primarily on the properties of the core material and core thickness; bending stiffness increases significantly with increasing core thickness.
  3- it is essential that faces be bonded strongly to the core.

  The sandwich panel is a cost-effective composite because core materials are less expensive than materials used for the faces.
  Core materials typically fall within three categories: rigid polymeric foams, wood, and honeycombs.

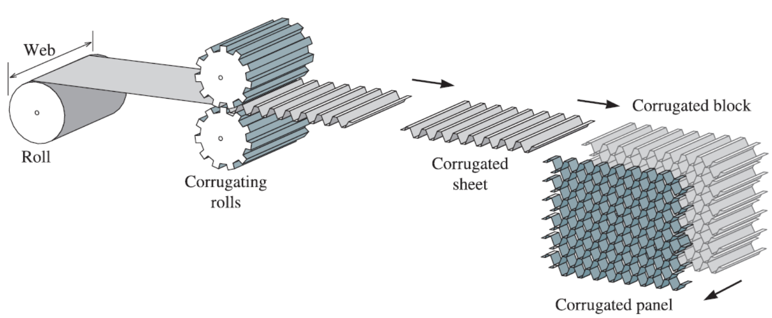
Sandwich panels are used in a wide variety aircraft, construction, automotive, and marine applications, including the following: aircraft—leading and trailing edges, radomes, fairings, nacelles (cowlings and fan-duct sections around turbine engines), flaps, rudders, stabilizers, and rotor blades for helicopters; construction-architectural cladding for buildings, decorative facades and interior surfaces, insulated roof and wall systems, clean-room panels, and built-in cabinetry; automotive—headliners, luggage compartment floors, spare wheel covers, and cabin floors; marine—bulkheads, furniture, and wall, ceiling, and partition panels.



Schematic diagram showing the construction of a honeycomb core sandwich panel.

3-Honeycomb Structure

thin foils that have been formed into interlocking cells (having hexagonal as well as other configurations), with axes oriented perpendicular to the face planes; Figure shows a cutaway view of a hexagonal honeycomb core sandwich panel. Mechanical properties of honeycombs are anisotropic: tensile and compressive strengths are greatest in a direction parallel to the cell axis; shear strength is highest in the plane of the panel. Strength and stiffness of honeycomb structures depend on cell size, cell wall thickness, and the material from which the honeycomb is made. Honeycomb structures also have excellent sound and vibration damping characteristics because of the high volume fraction of void space within each cell. Honeycombs are fabricated from thin sheets. Materials used for these core structures include metal alloys— aluminum, titanium, nickel-based, and stainless steels; and polymers—polypropylene, polyurethane, kraft paper (a tough brown paper used for heavy-duty shopping bags and cardboard), and aramid fibers.



Producing Laminar Composites

Several methods are used to produce laminar composites, including a variety of deformation and joining techniques used primarily for metals. Individual plies are often joined by *adhesive*, as is the case in producing plywood. Polymer-matrix composites built up from several layers of fabric or tape prepregs are also joined by adhesive bonding; a film of unpolymerized material is placed between each layer of prepreg. When the layers are pressed at an elevated temperature, polymerization is completed and the prepregged fibers are joined to produce composites that may be dozens of layers thick.