Design Research Seminar

Title: Honeycomb Structures for Use In Automotive Industry

Guide:
Prof. K Ramachandran

Submitted by:
Tanmay Ohri

Mobility & Vehicle Design

IDC, IIT-B

Acknowledgement

I would like to thank my guide, Prof. K Ramachandran, for providing me the opportunity to take up this research project. I would like to thank him for his feedback and support. I would also thank my classmates and friends for all the necessary inputs and help in this project.

Tanmay Ohri
(126390005)
Mobility & Vehicle Design
IDC

Approval Sheet

The project titled ‘Honeycomb Structures for Use In Automotive Industry’, is approved for partial fulfilment of the requirement for the degree of ‘Master of Design’ in Mobility and Vehicle Design.

Guide .....

Date .....

Declaration

I declare that this written submission represents my ideas in my own words and where others' ideas or data has been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Student's signature
Tanmay Ohri

Introduction

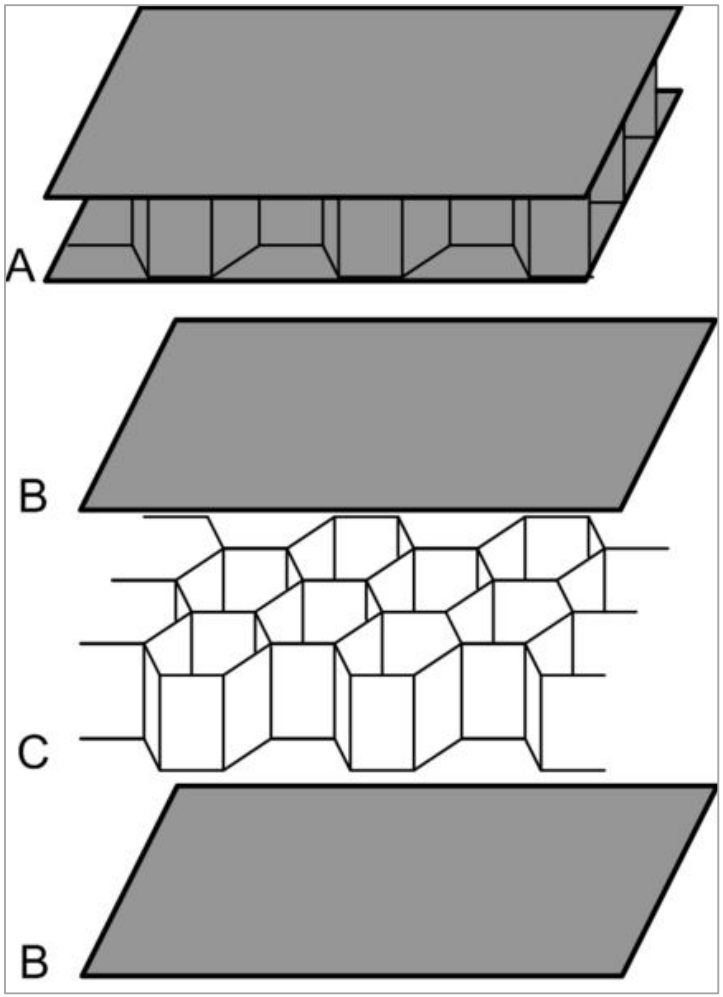
Honeycomb structures are natural or man-made structures that have the geometry of a honeycomb to allow the minimization of the amount of used material to reach minimal weight and minimal material cost. The geometry of honeycomb structures can vary widely but the common feature of all such structures is an array of hollow cells formed between thin vertical walls. The cells are often columnar and hexagonal in shape. A honeycomb shaped structure provides a material with minimal density and relative high out-of-plane compression properties and out-of-plane shear properties.

Man-made honeycomb structural materials are commonly made by layering a honeycomb material between two thin layers that provide strength in tension. This forms a plate-like assembly. Honeycomb materials are widely used where flat or slightly curved surfaces are needed and their high strength-to-weight ratio is valuable. They are widely used in the aerospace industry for this reason, and honeycomb materials in aluminum, fiberglass and advanced composite materials have been featured in aircraft and rockets since the 1950s. They can also be found in many other fields, from packaging materials in the form of paper-based honeycomb cardboard, to sporting goods like skis and snowboards.

Introduction [1]:

Natural honeycomb structures include beehives, honeycomb weathering in rocks, tripe, and bone.

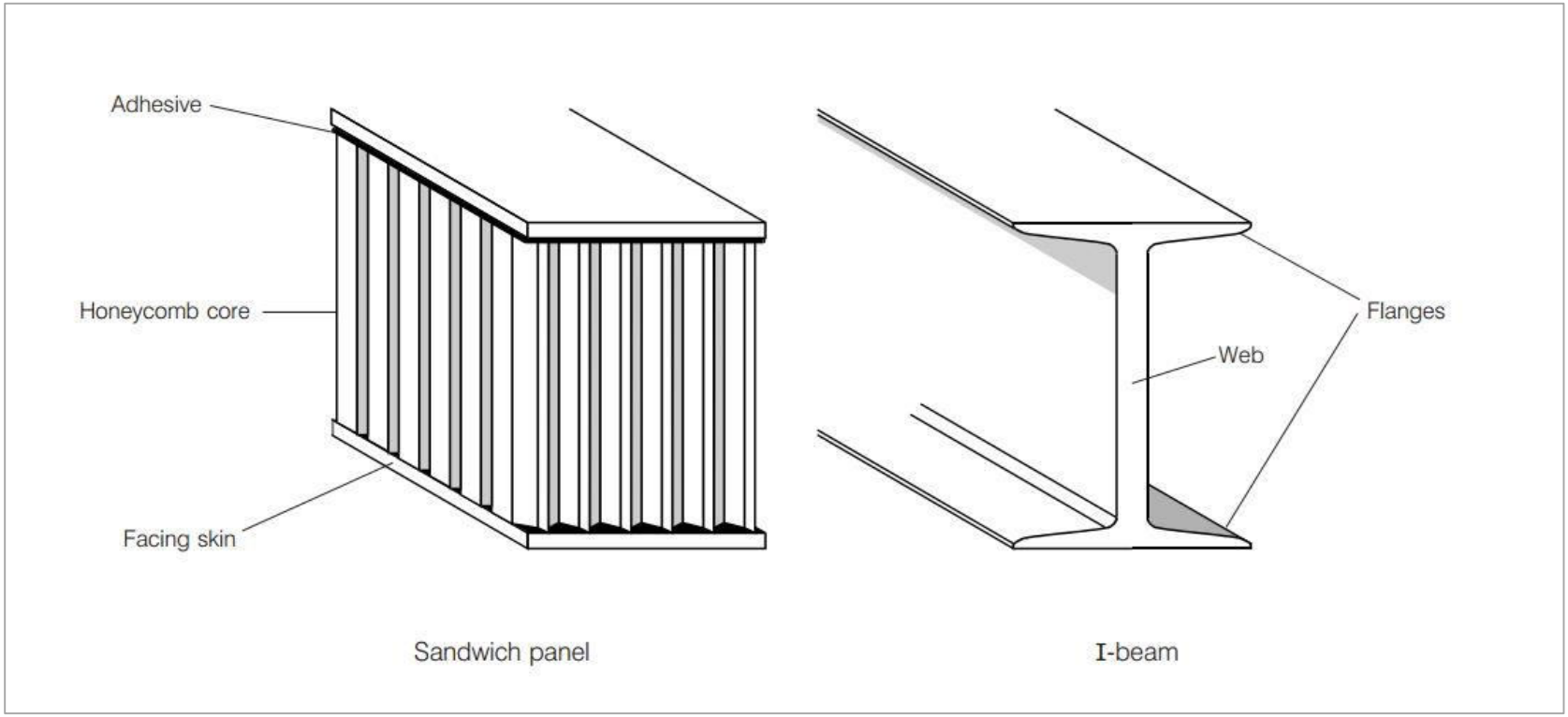
Man-made honeycomb structures include sandwich composites with honeycomb cores. Man-made honeycomb structures are manufactured by using a variety of different materials, depending on the intended application and required characteristics, from paper or thermoplastics, used for low strength and stiffness for low load applications, to high strength and stiffness for high performance applications, from aluminum or fiber reinforced plastics. The strength of laminated or sandwich panels depends on the size of the panel, facing material used and the number or density of the honeycomb cells within it. Honeycomb composites are used widely in many industries, from aerospace industries, automotive and furniture to packaging and logistics. The material takes its name from its visual resemblance to a bee's honeycomb – a hexagonal sheet structure.



A - Composite sandwich panel, B – Face sheets, C – Honeycomb core

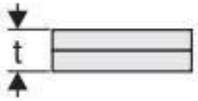
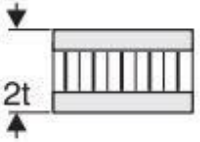
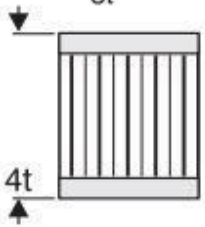
Comparison of Honeycomb Sandwich Panel with Solid Panel

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. [2]



Comparing Sandwich panel to an I-Beam

For the same dimensions (length and breadth) of panel used made up of a solid material, the honeycomb sandwich panel offers many times greater stiffness with very minute addition to the weight of the panel. An approximate relation has been shown in the figure below:

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

Relative comparison of solid panel and sandwich panel

Choice of 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.

Honeycomb cores may be of following types: [3]

- Aluminum: Aluminum honeycomb is a lightweight core material offering excellent strength and corrosion resistance for industrial, architectural and transportation applications. It can also be perforated.
- Aramid fiber: It's a special material used by Plascore, manufactured using DuPont Nomex or Kevlar paper or equivalent, and can be coated with a heat resistance phenolic resin for high performance racing and aerospace applications.
- Thermoplastic: Polycarbonate and polypropylene honeycomb exhibit a unique cell structure and excellent corrosion resistance that makes these cores ideal for sandwich panels, molded parts, wind tunnels, grilles and directional flow.
- Stainless Steel: Stainless steel honeycomb is used for joiner panels, bulk heads, train doors, floors and any area where honeycomb would be subjected to hostile environment. A large variety of cell size and sheet thickness is available.

Apart from the materials used specifically for the honeycomb core, the honeycomb composite panels also have exterior facing skins that sandwich the core from both the faces. 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.

There is also a good variety of skin options available for honeycomb composites like: [2]

- Epoxy UD Carbon tape
- Epoxy UD Glass tape
- Epoxy woven Carbon
- Epoxy woven Aramid
- Epoxy woven Glass
- Phenolic woven Glass
- Aluminum alloy
- Carbon Steel
- Exterior Plywood fir
- Tempered Hardwood Teak

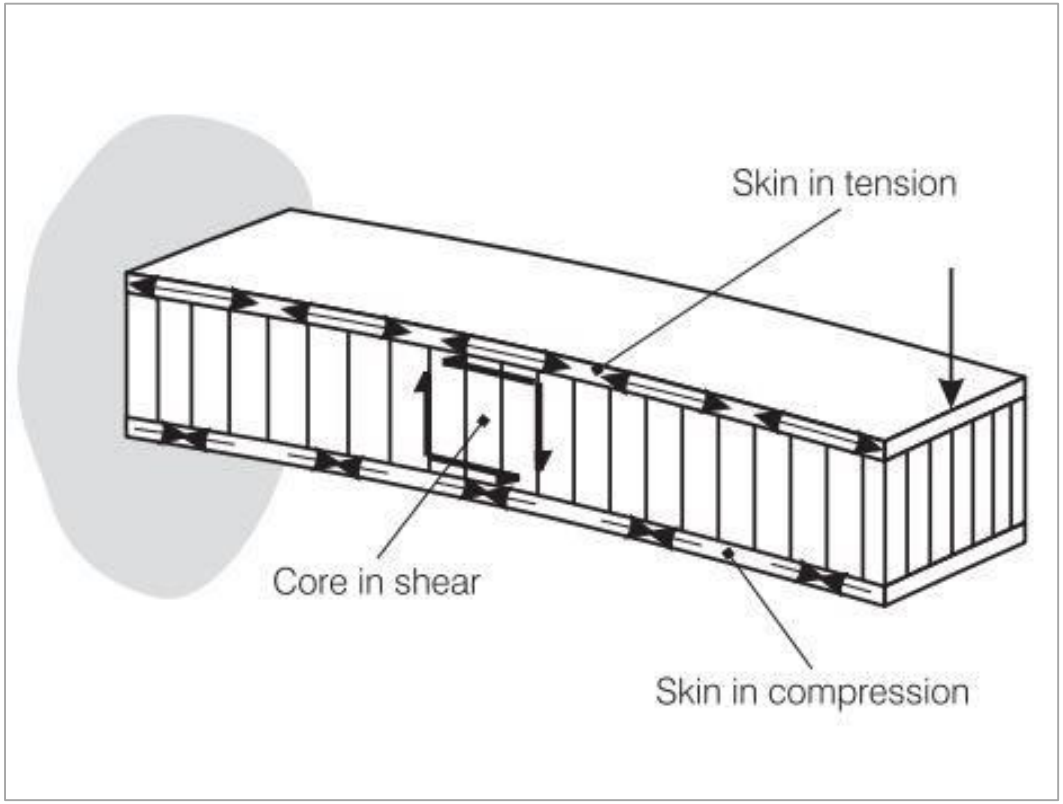
The following factors are to be considered while doing the selection of materials for the honeycomb composite:

- Density range
- Service Temperature
- Moisture/humidity resistance
- Chemical resistance
- Adhesive performance
- Strength
- Stiffness
- Smoke and Fire resistance - flammability
- Air/Fluid Flow medium
- Machinability
- Thermal conductivity
- Radar transparency
- RFI shielding
- Energy Absorption
- Formable
- Economic consideration – Cost

How a Sandwich Beam Works

Sandwich beam under Load: [2, p. 6]

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.

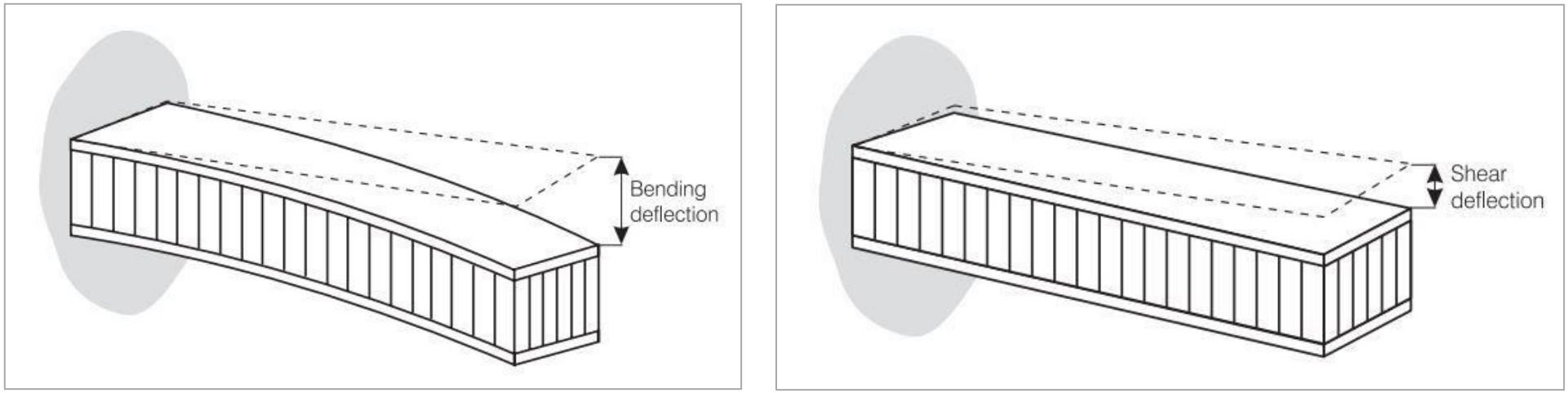


A sandwich beam under load

Sandwich beam under Deflection:

The deflection of a sandwich panel is made up from bending and shear components. The bending deflection is dependent on the relative tensile and compressive moduli of the skin materials. The shear deflection is dependent on the shear modulus of the core.

Total Deflection = Bending Deflection + Shear Deflection.



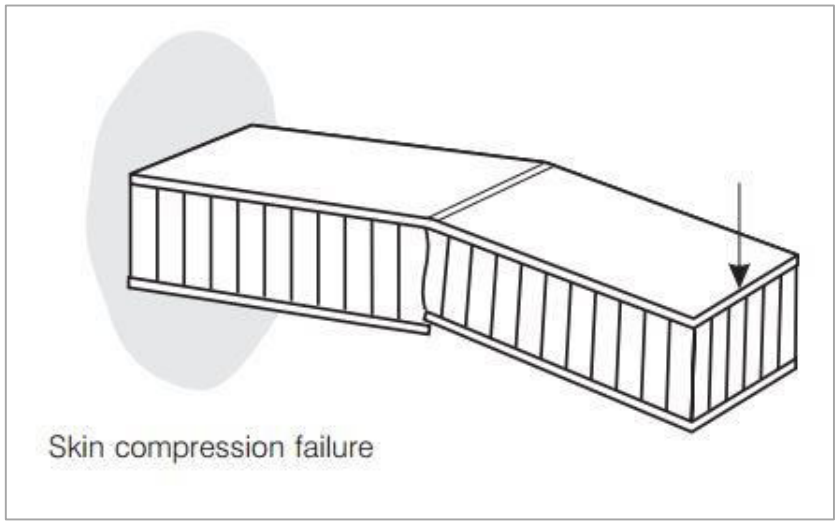
Sandwich beam under bending and shear stress

Failure modes

[2, p. 7] 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:

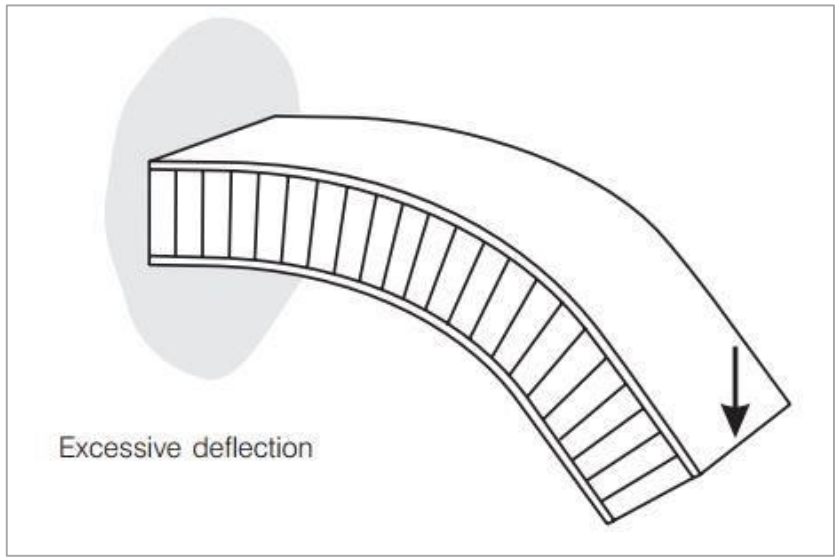
1. Strength

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.



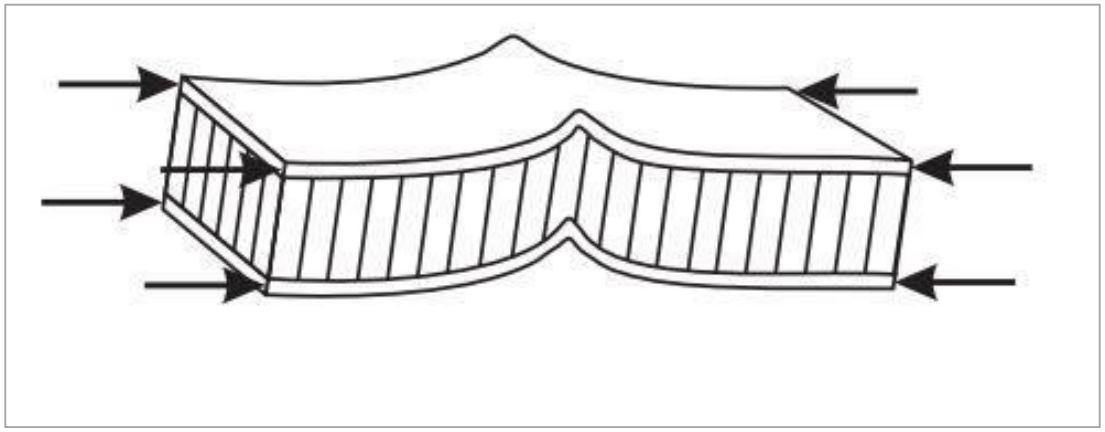
2. Stiffness

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



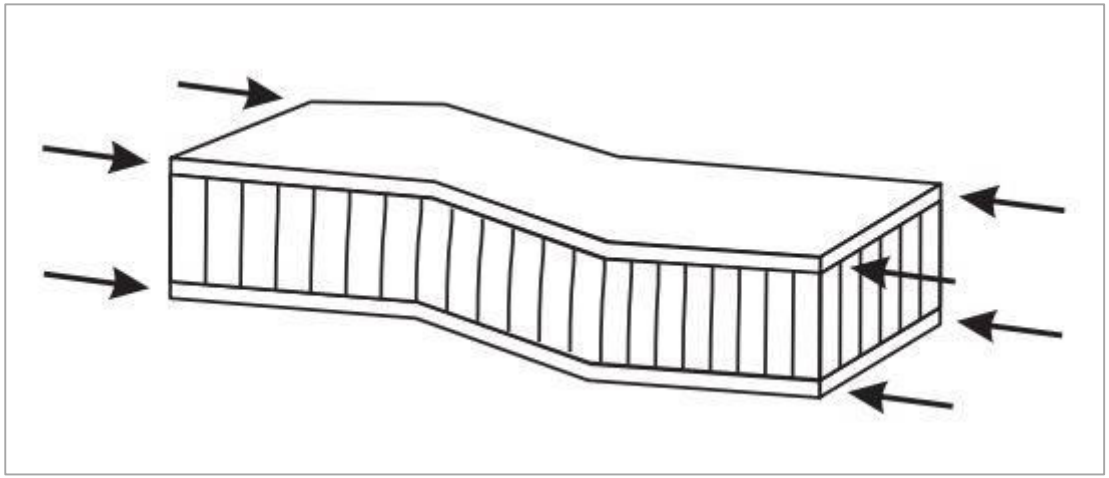
3. Panel buckling

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



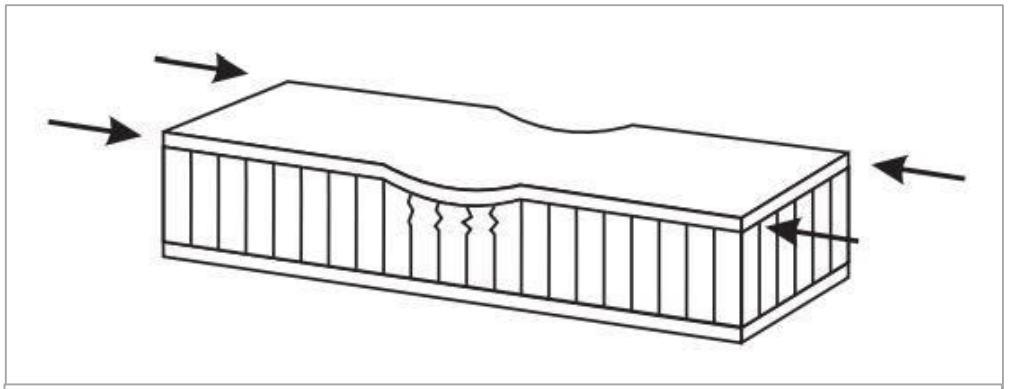
4. Shear crimping

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



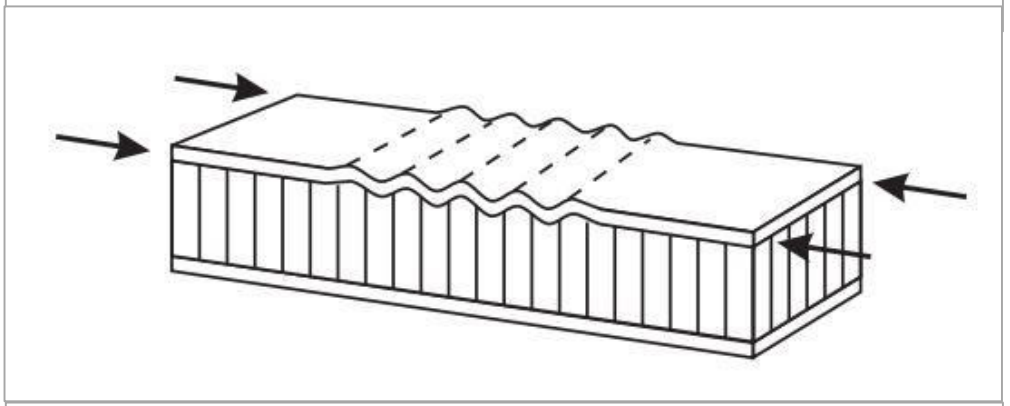
5. Skin wrinkling

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



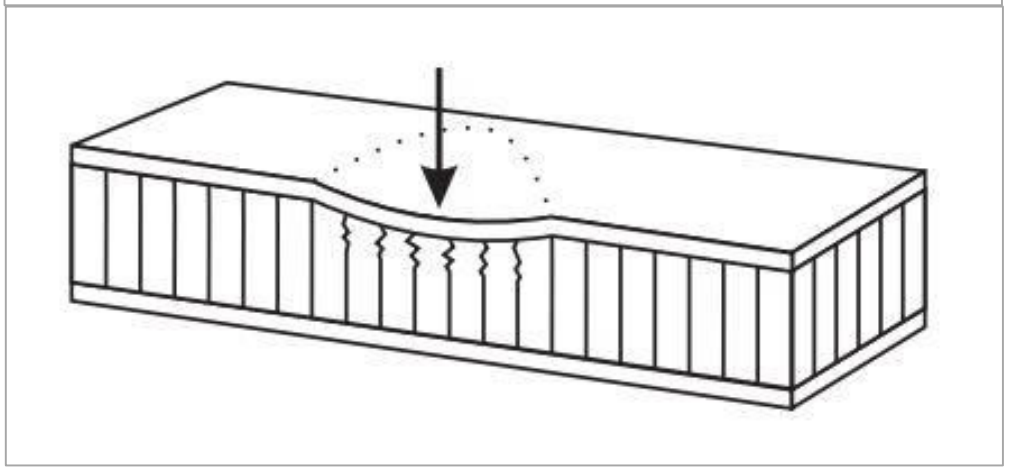
6. Intra cell buckling

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.



APPLICATIONS

Honeycomb structures and composites are majorly used in the following fields:

- Automotive
- Aviation and aerospace
- Energy Absorption
- Exhibitions and showrooms
- Marine
- Rail
- Industrial Equipment
- Light Stones (e.g. Floorings, tiles etc.)
- Sports and leisure
- Building and construction
- Wind Turbines
- Yachting and Ship building

Application Area	Industry	Company/Product
Racing shells	Sport	Vespoli, Janousek Racing Boats
Aerospace manufacturing	Aerospace	Hexcel
Gliders	Aerospace	Schleicher ASW 19, Solar Impulse Project
Helicopters	Aerospace	Kamov Ka-25, Bell 533, Westland Lynx
Jet aircraft	Aerospace	General Dynamics/Grumman F-111B, F-111 Aardvark
Rocket substructure	Aerospace	Saturn V Instrument Unit, Mars Exploration Rover, S-520
LED technology	Lighting	SmartSlab
Loudspeaker technology	Audio	Loudspeaker Driver design, Woofer
Telescope mirror structure	Aerospace	Hubble Space Telescope
Automobile structure	Automotive	Panther Solo, Dome F105, Bluebird-Proteus CN7, Ferrari F50
Snowboards	Sports	Snowboard

A few examples of use of honeycomb structure composites in the industry: [4]

Possible usage of Honeycomb structures in automobiles:

- Rigid truck boxes
- Caravan body parts
- Vehicle floor covers
- Interior fittings
- Rear parcel shelves
- Spare wheel covers
- Roof linings
- Casing for sound insulation
- Partitions, roof, rear door, side and cabin panels
- Collision heads of automobile crash test rigs
- In specialized vehicles like trailers, vans, caravans
- In medical vehicles ambulance, fire engines, horse boxes

Implementation Processes

Mainly these processes are used to fabricate a honeycomb sandwich composite panel: [5]

- Cutting
- Infusion
- Lamination
- Shaping
- Gluing

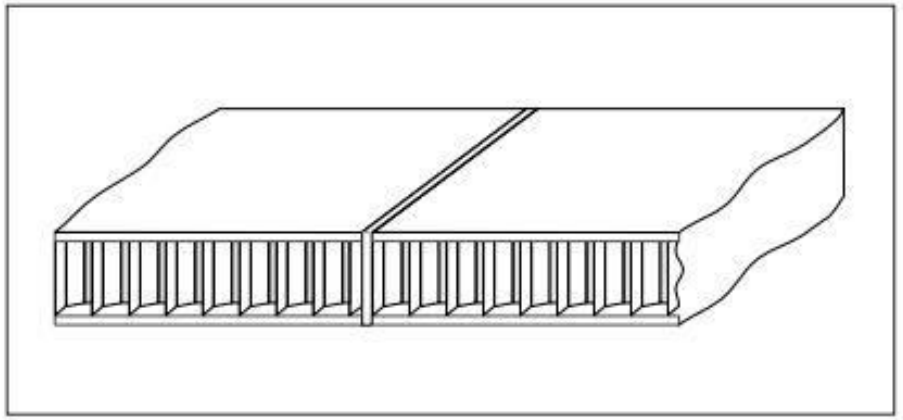
TYPICAL SANDWICH PANEL - JOINTING AND CONNECTION METHODS

[6, pp. 5, 6, 7]

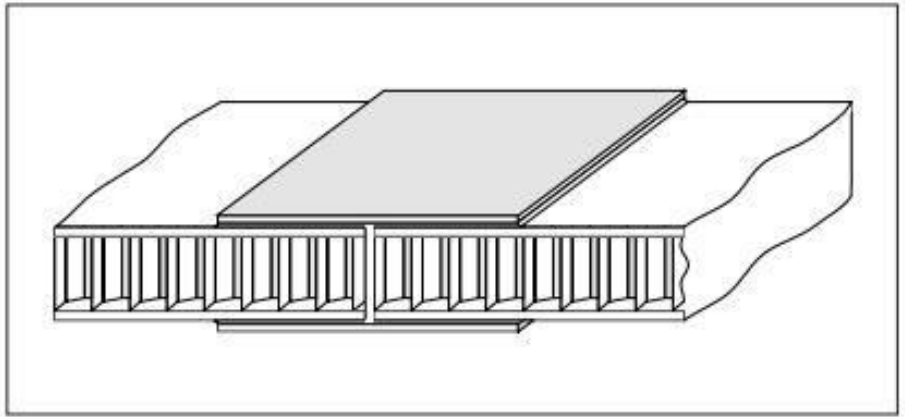
Honeycomb sandwich panels are joined using a variety of methods some of which are illustrated:

Typical Flat Joining Methods –

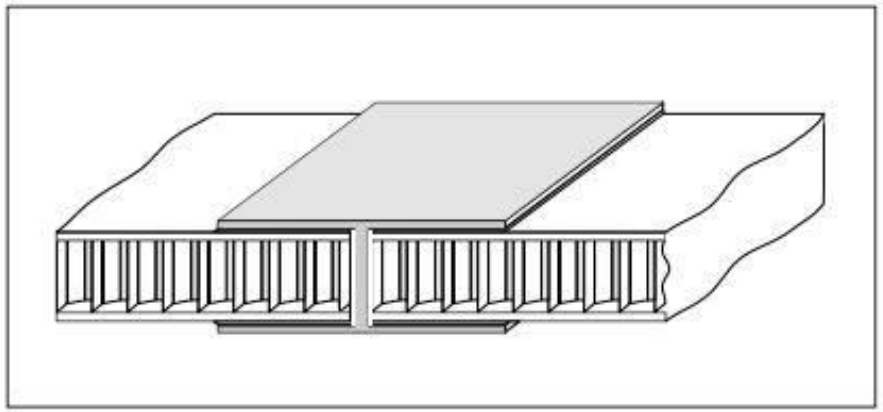
- Flush faced all bonded butt joint - for non-structural applications. Care must be taken to ensure flatness across the joint.



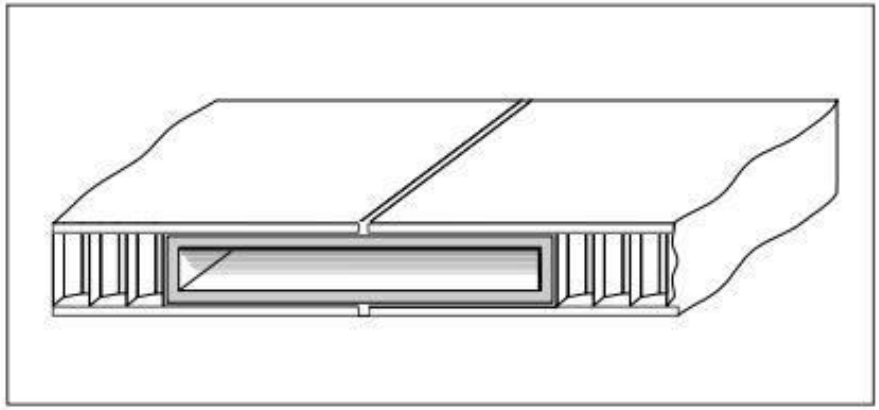
- Bonded face supported butt joint.



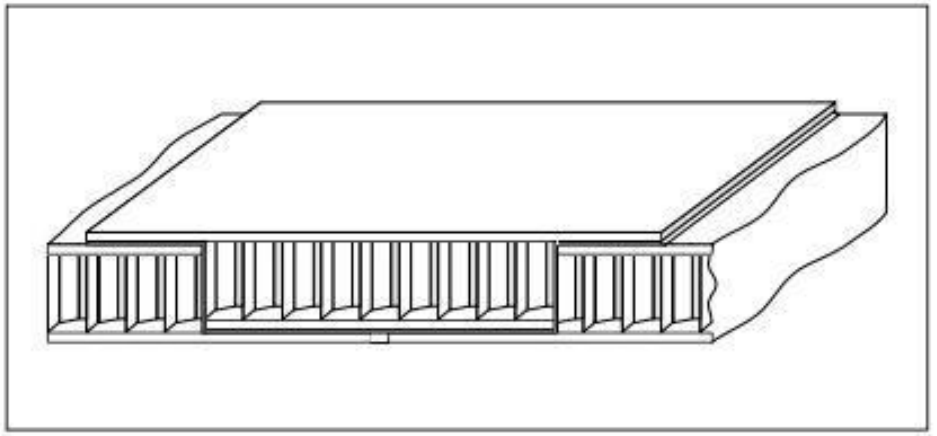
- Bonded butt joint using 'H' section extrusion for volume production.



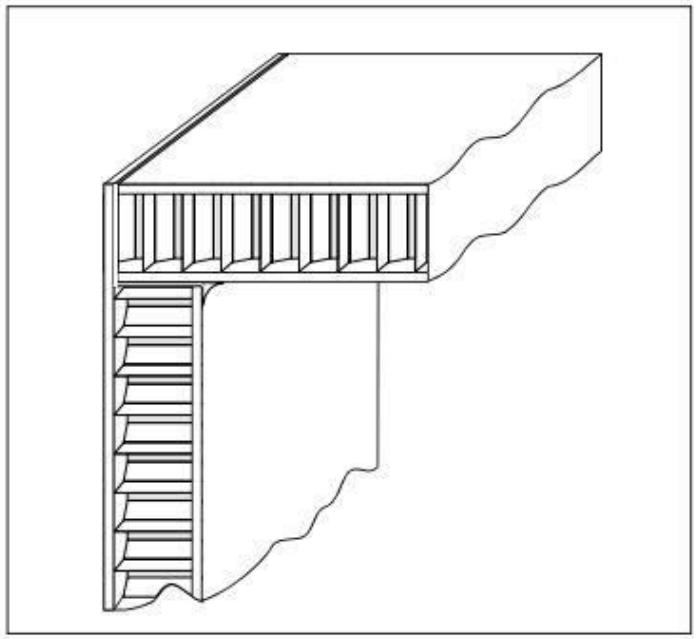
- Flush faced bonded joint, supported by a special internal extrusion (or wood block) - for volume production.



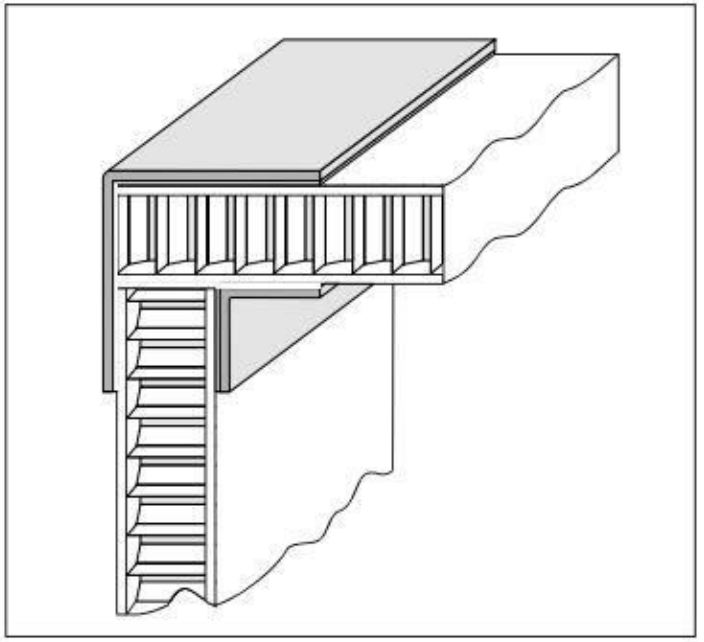
- Panel section insertion method, using same panel material.



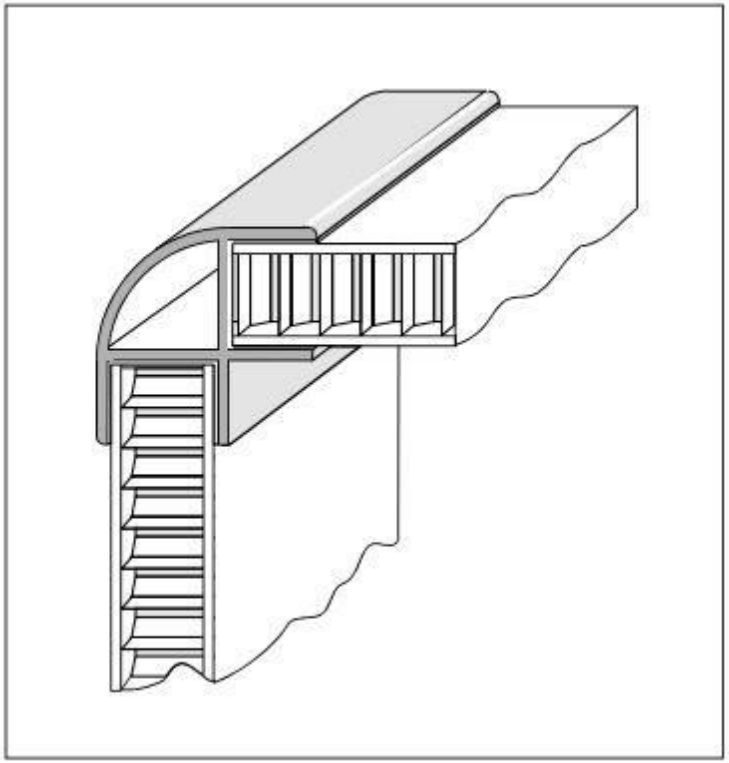
Typical Corner Joints –



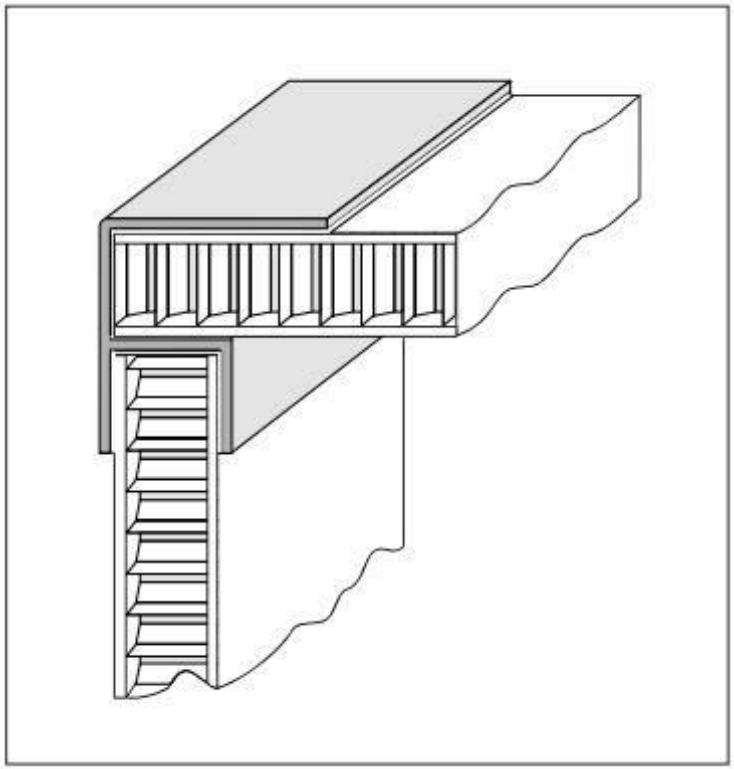
Rebated and bonded. Low strength, and can be difficult to make square.



Supported by bonded L-section extrusions.

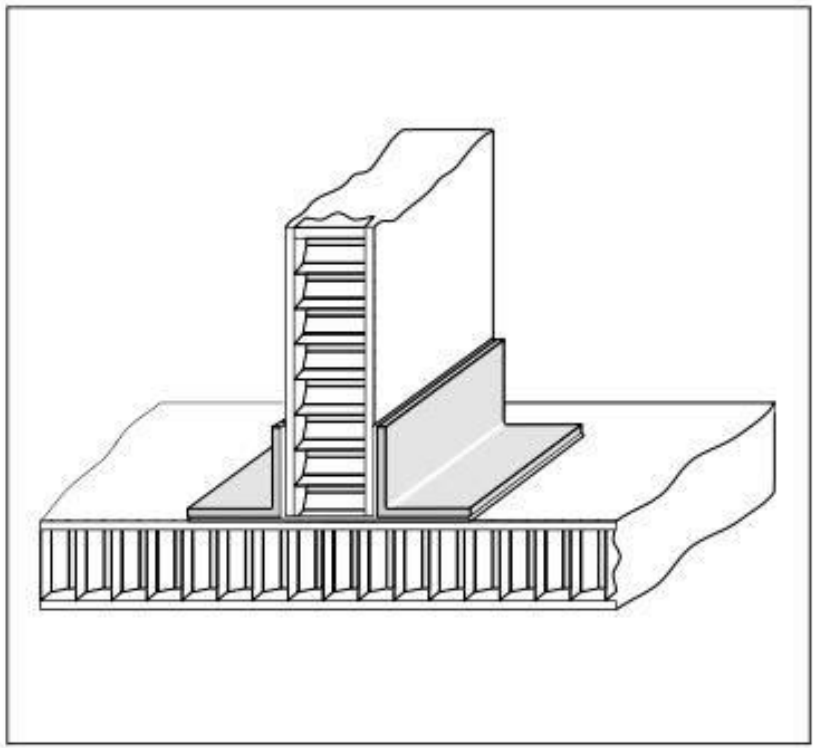


Use of special extrusion, for volume production
of rounded corners.

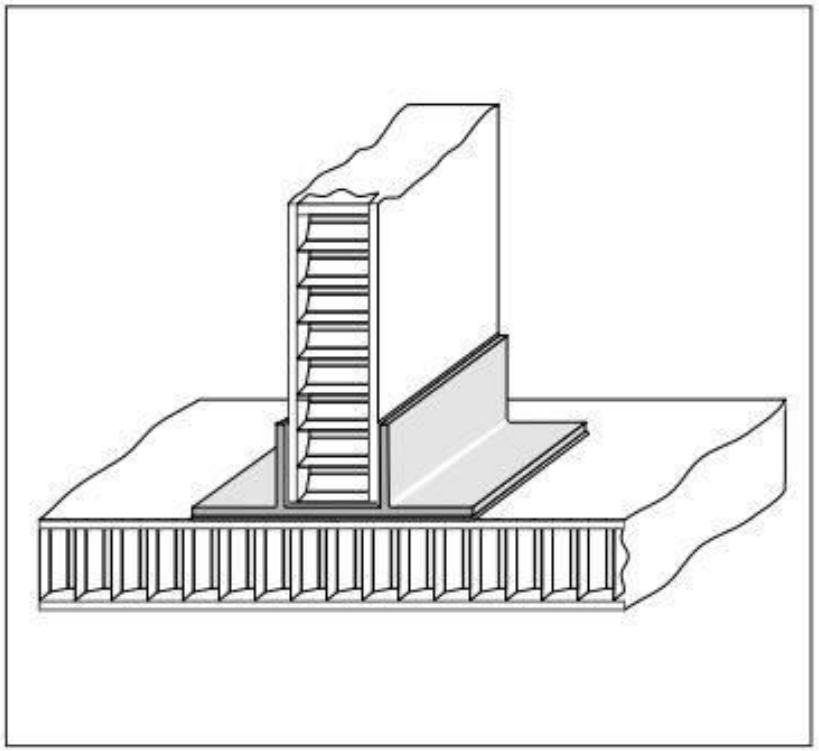


For volume production of square corners.

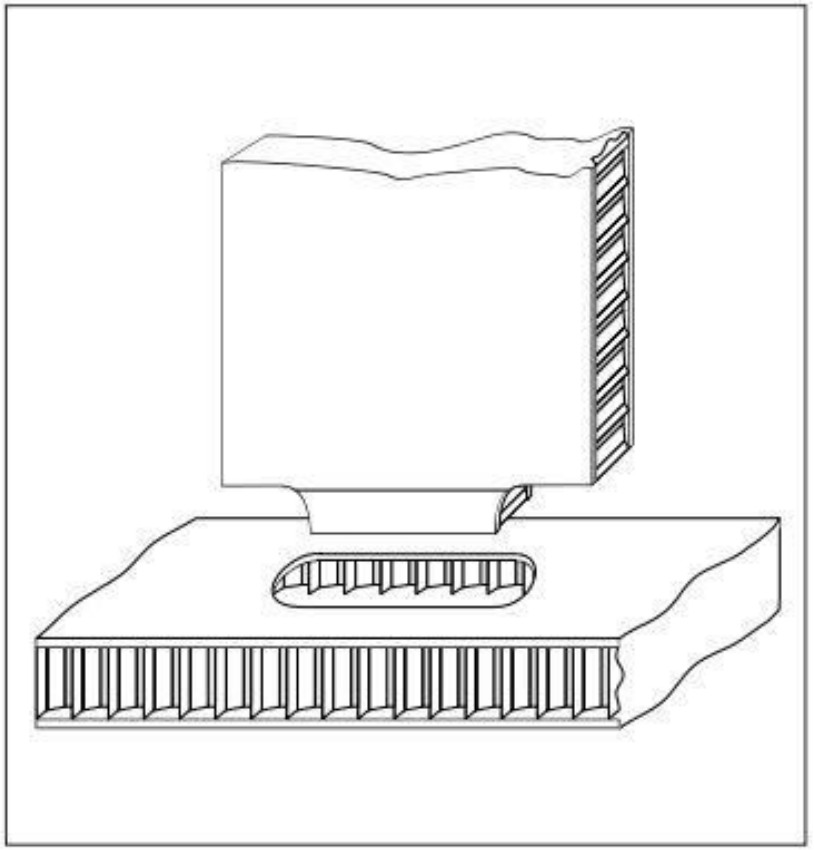
'T' Joints –



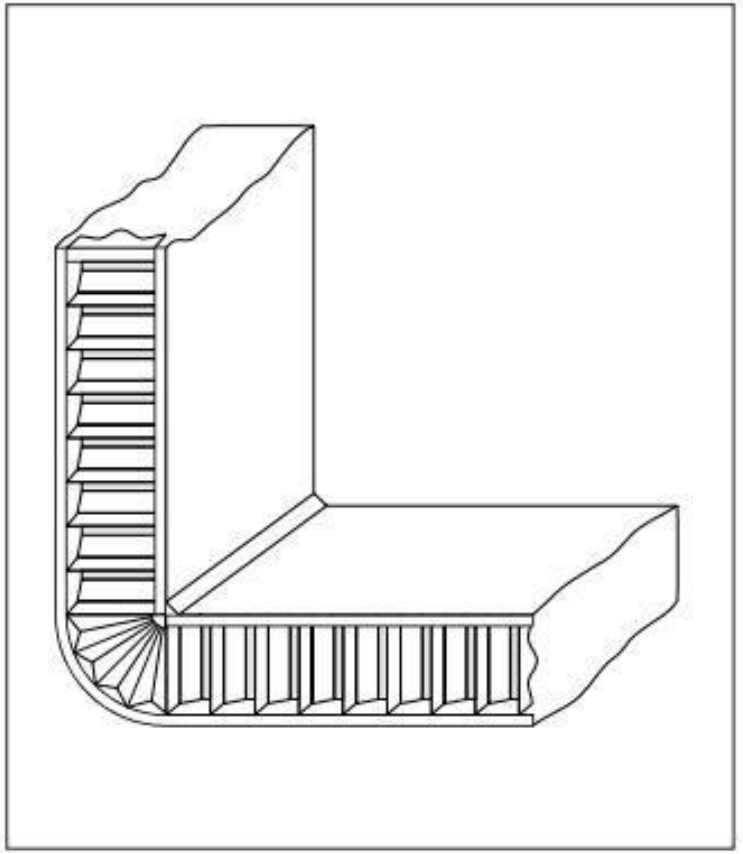
Joint supported by bonded L-sections.



Joint supported by special bonded extrusion – volume production



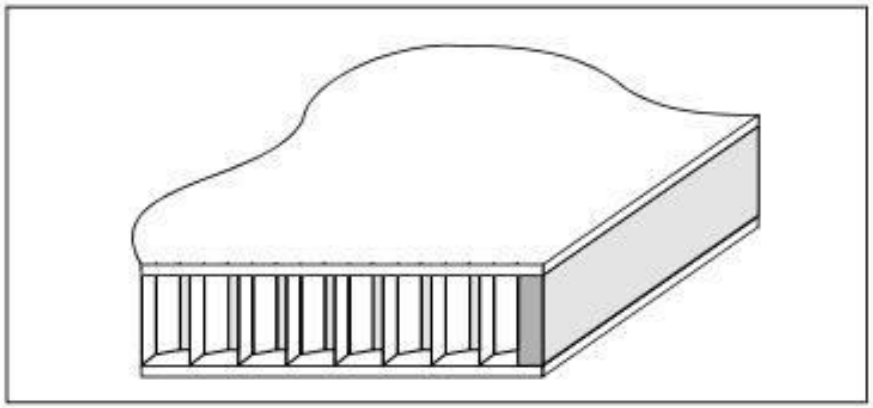
Self-jigging "tongue and groove" method joint.



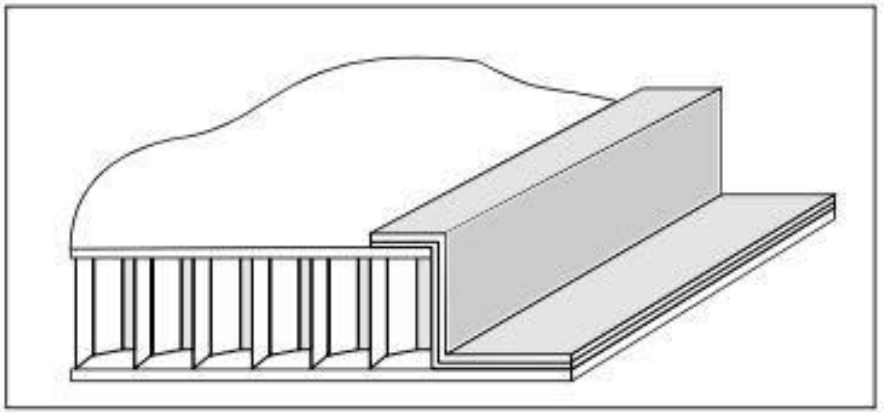
Cut, folded and bonded corner joint for clean radius edges.

TYPICAL SANDWICH PANEL - EDGE CLOSURE METHODS

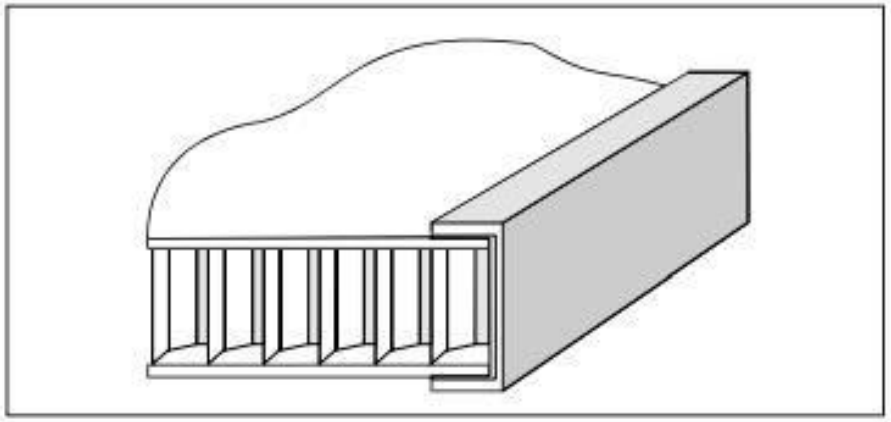
Open edges on sandwich panels can be sealed to prevent moisture ingress, to enhance appearance or permit subsequent fixings. Some typical edge closure methods are illustrated below: [6, p. 8]



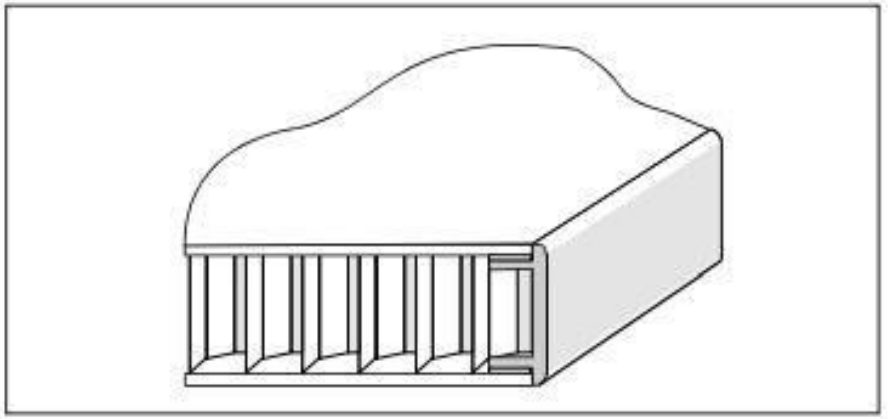
Edge Filler



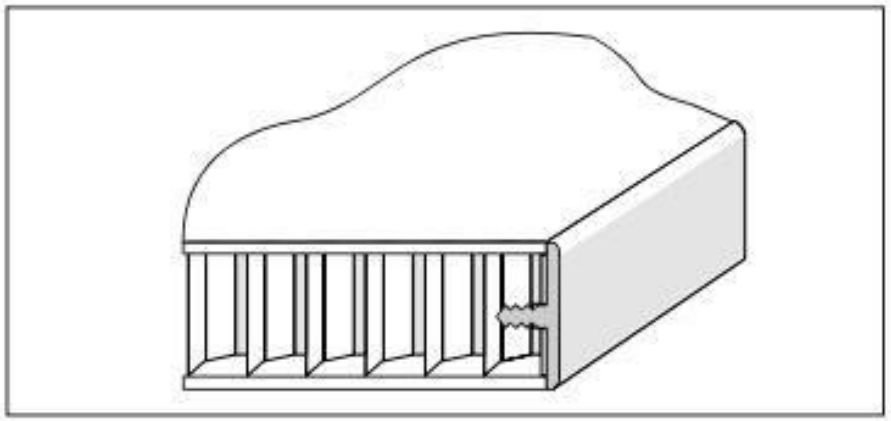
Bonded ‘Z’ Section



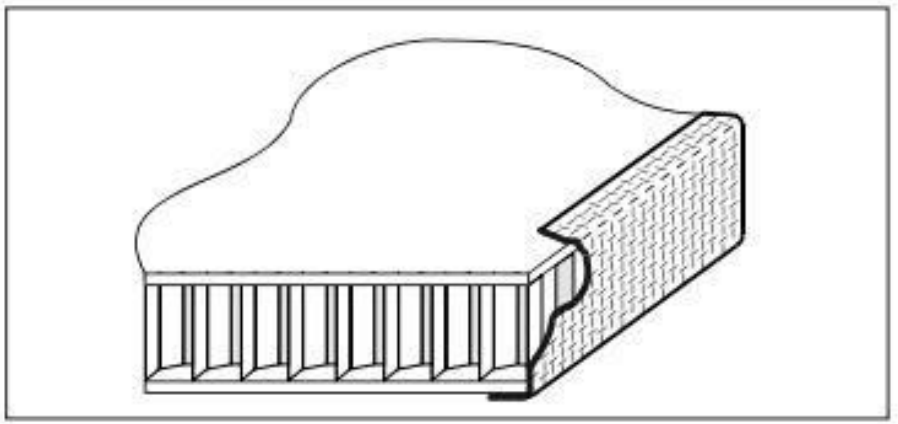
Bonded ‘U’ Section



Bonded edge closure section-thicker panels



Press-fit edge closure section-thinner panels

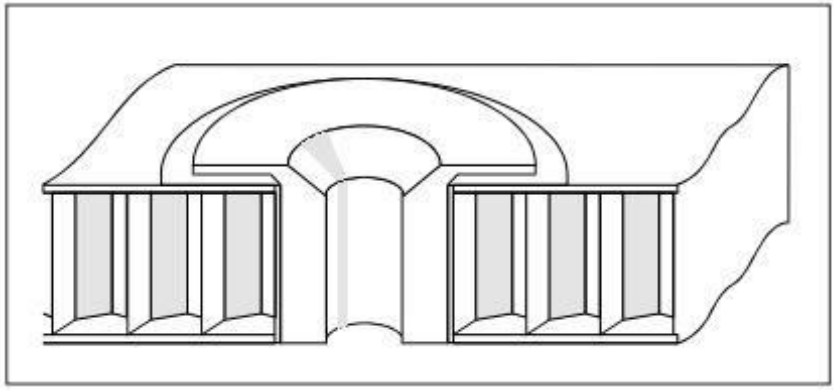


Durable self-adhesive tape

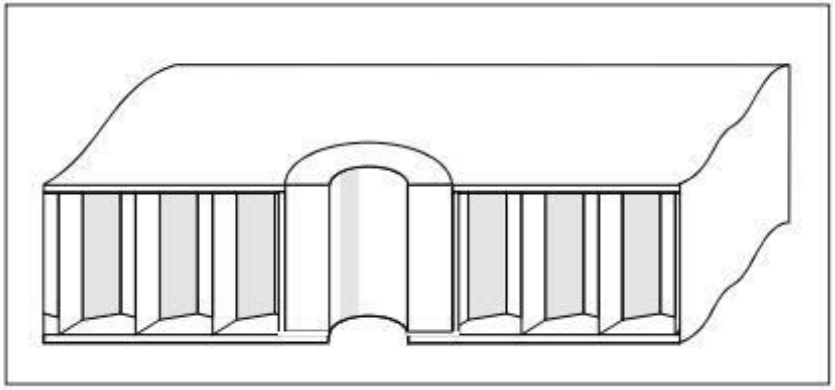
TYPICAL PANEL FIXINGS

[6, p. 9]

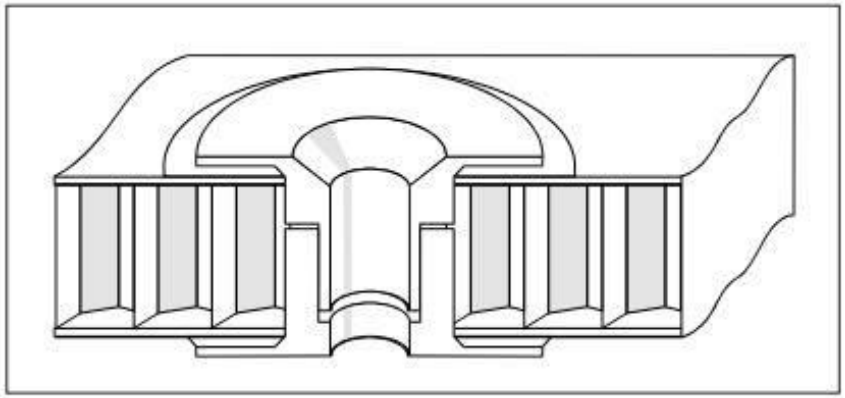
Mechanical fixing to panel faces is achieved in a variety of ways. The choice of method depends on the desired strength, the finish required and the quantity to be produced. To obtain the full strength potential it is necessary to achieve a bonded shear connection to both facing skins.



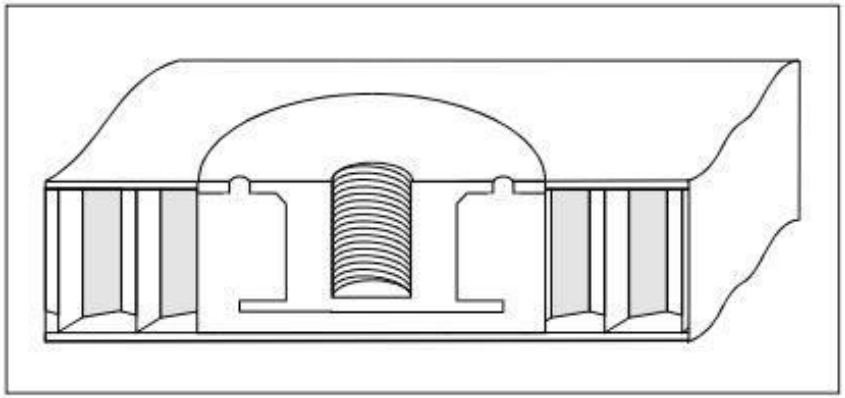
Single part ferrule



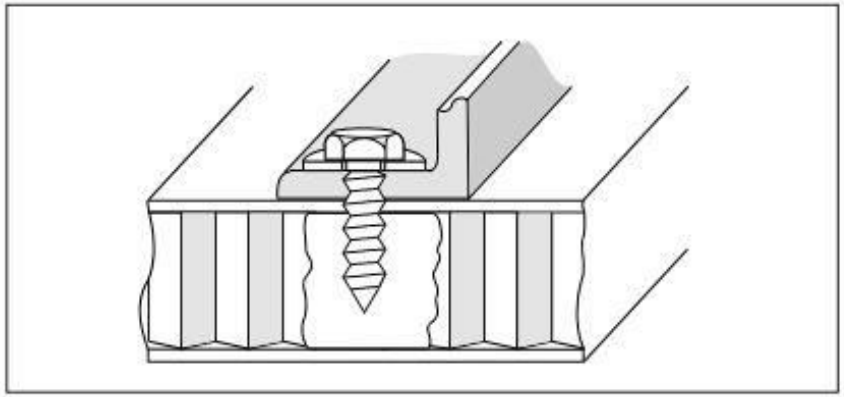
Distance tube



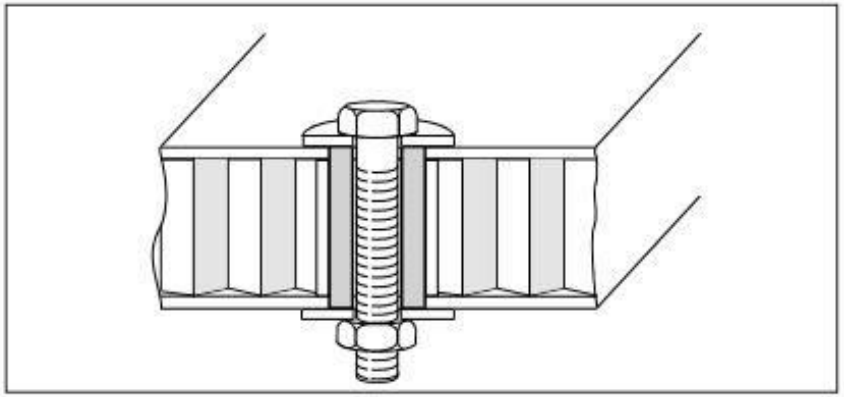
Two part ferrule



Threaded insert



Resin potted area



Through-panel distance tube - penny washer

Cut and Fold Fabrication

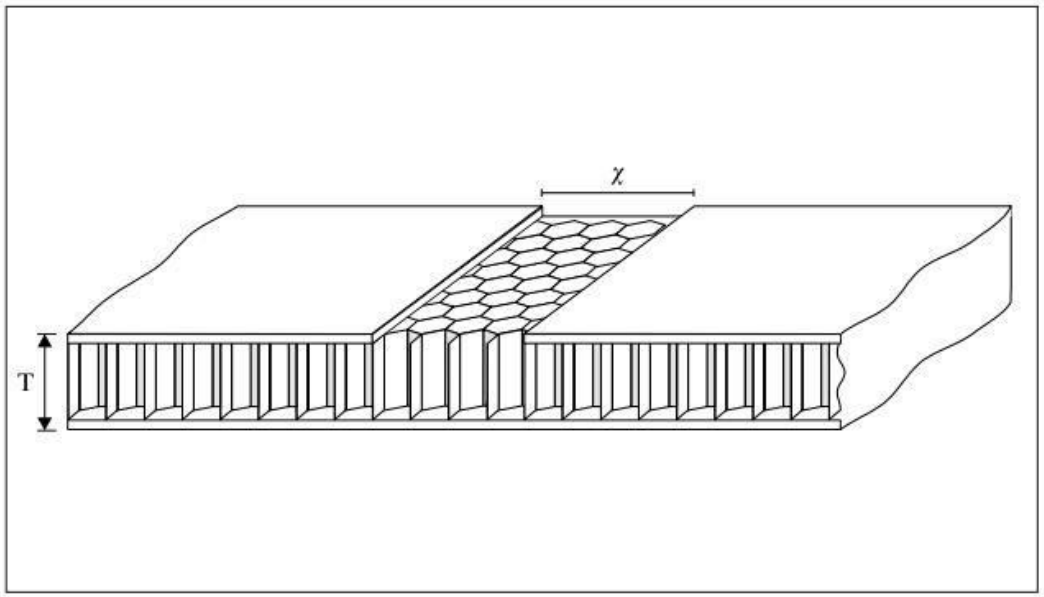
[6, pp. 10, 11]

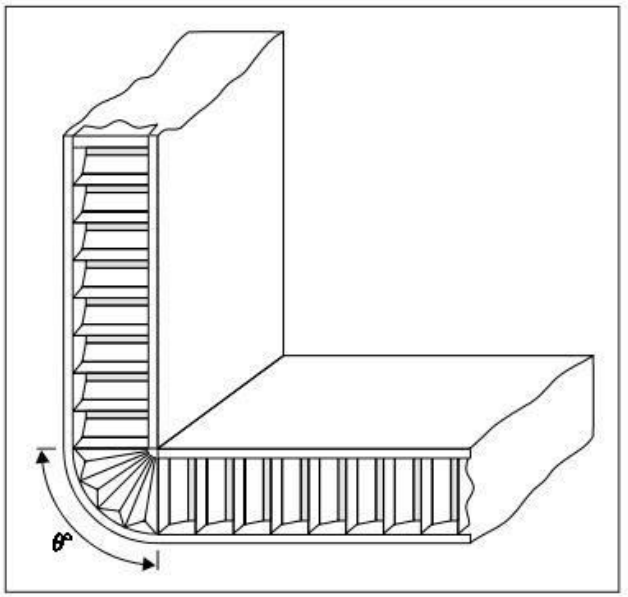
Most Hexcel Composites honeycomb sandwich panels can be fabricated to form mechanically strong components by following the ‘cut and fold’ technique. This method is simple, economical and involves very minimum use of jigs and fixtures.

It requires removal of a strip from the face sheet as shown. The thickness ‘x’ of the sheet needed to be removed depends upon the angle of fold ‘*θ*’ and he thickness of the panel ‘T’.

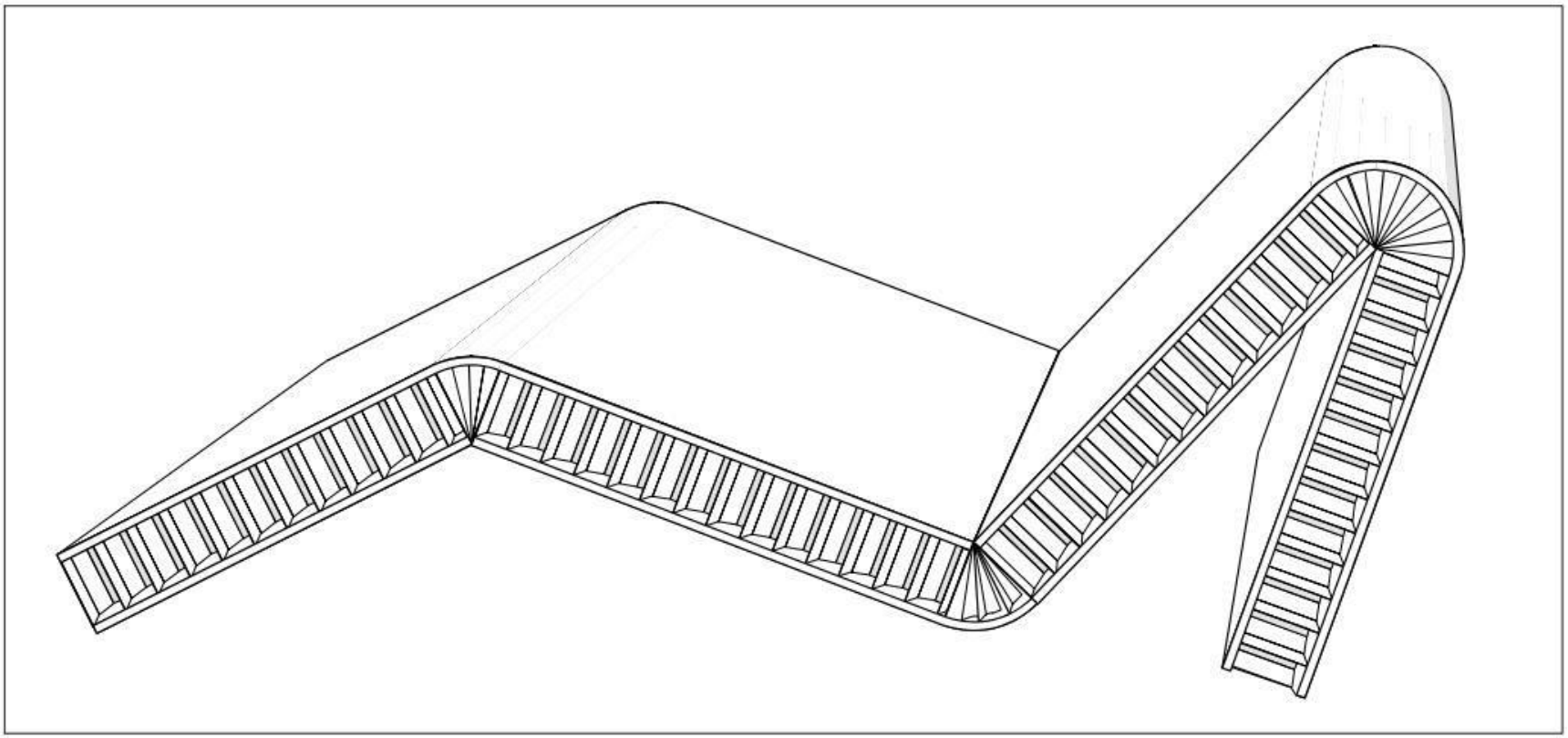
x = (2π x T x *θ*) / *360*

After the strip of skin is removed, adhesive is applied to the exposed core. The component is then clamped until the adhesive cure is complete.





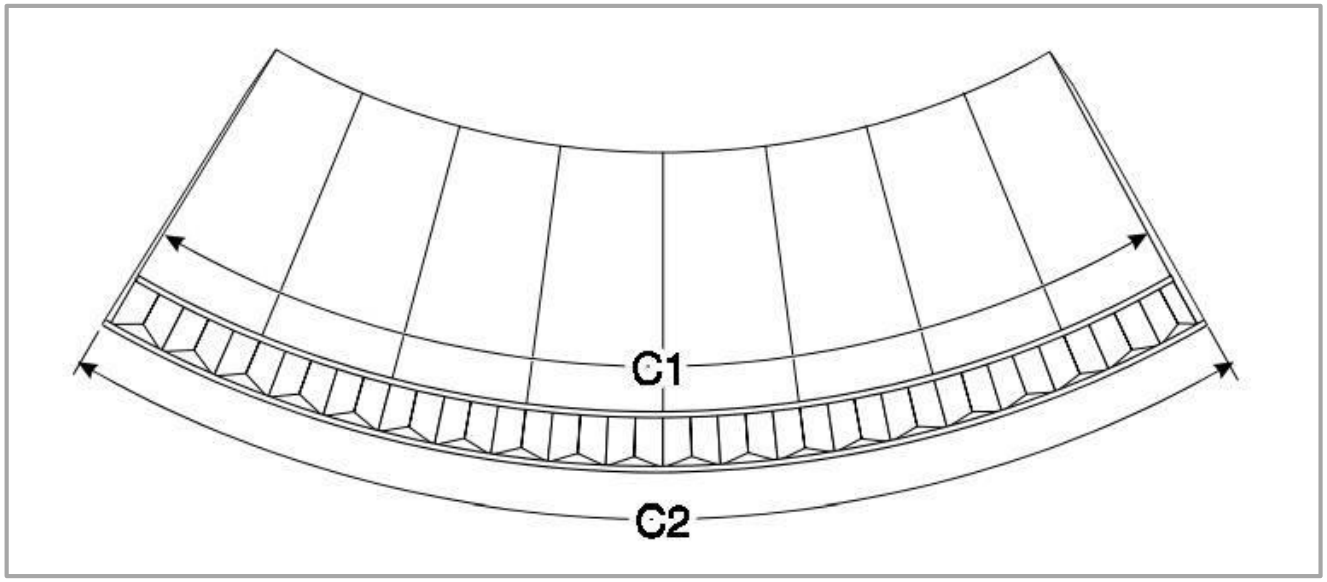
The method can be applied on most of the angles needed.



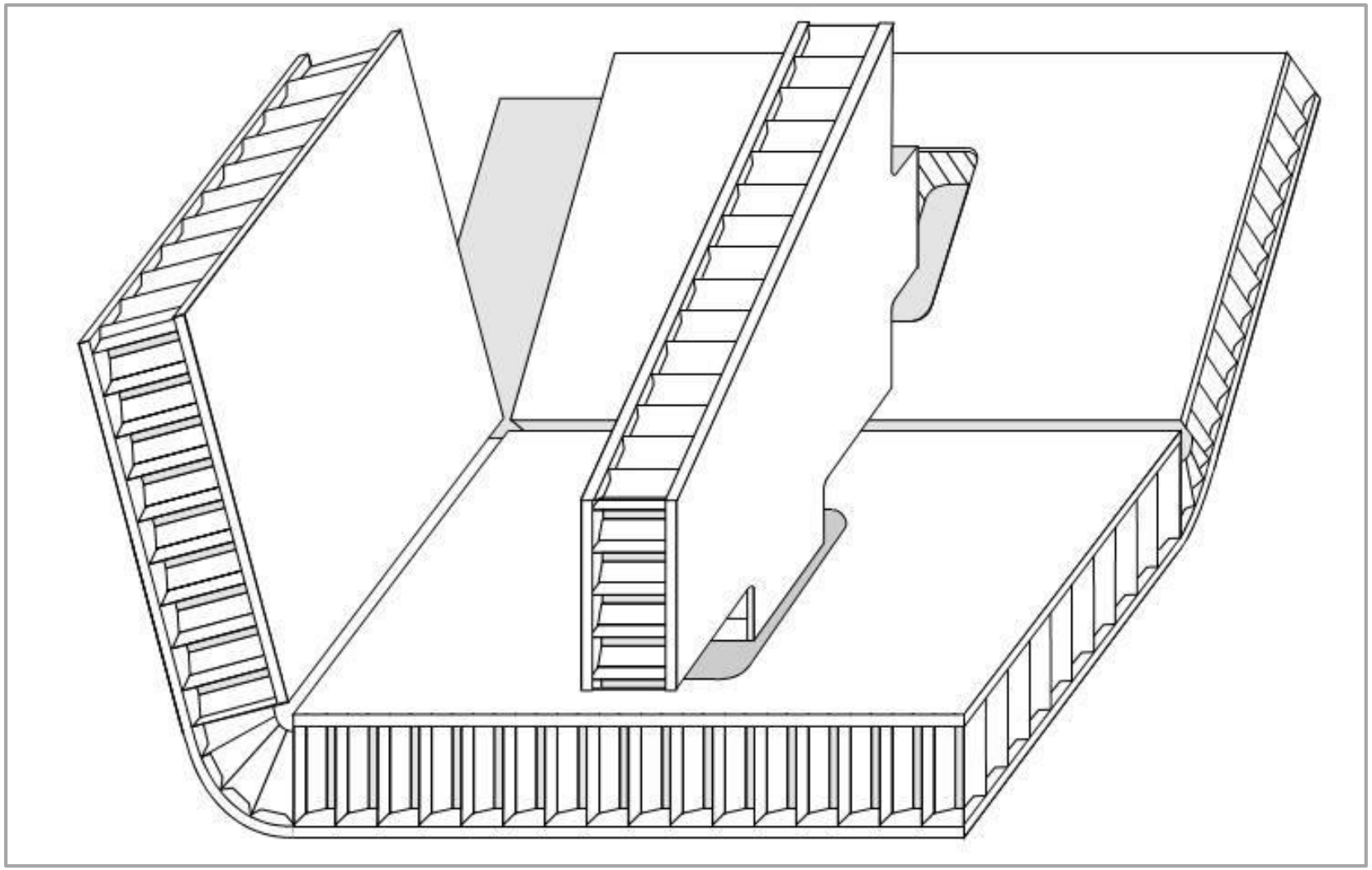
Radius curvature on panel materials can also be achieved using the cut and fold technique. In this case narrow, parallel slots are cut through one facing skin.

The number of slots required is determined by the calculation:

$$\frac{\boldsymbol{Length\ of\ outer\ circumference\ (C2)\ -\ length\ of\ inner\ circumference\ (C1)}}{\boldsymbol{thickness\ of\ cutter}}$$



Honeycomb sandwich panels can be cut, folded and bonded to form prefabricated production components with the minimum of tooling.



MANUFACTURE

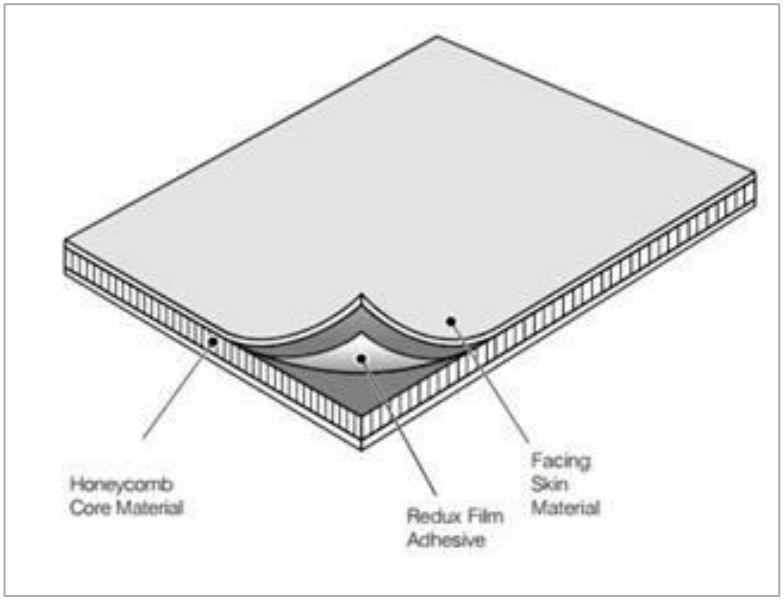
The basic well-established Honeycomb Sandwich components production methods are: [2, pp. 21, 22]

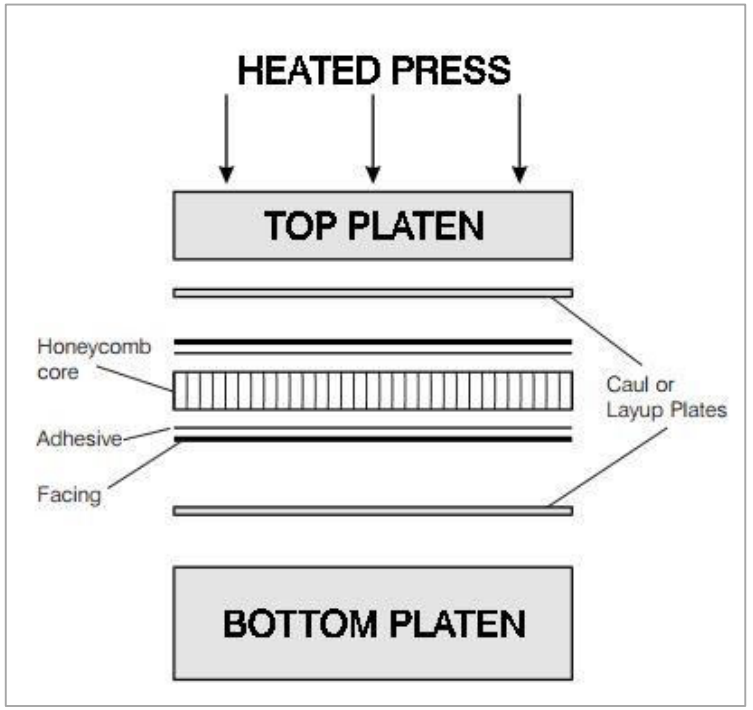
- **Heated Press:** generally used for the production of flat board or simple preformed panels.
- **Vacuum Bag Processing:** used for curved and complex form panels.
- **Matched Mould Processing:** used generally for batch production of finished panels.

Heated Press:

The panels are assembled ready beforehand for curing as a single shot process. The facing skins are prepared and the core as well and subsequently bonded together with an adhesive. This method is suitable for metallic and pre-impregnated facing skin.

Integrally bonded items such as extruded bar sections and inserts may be included and located by the honeycomb core or with simple tooling.

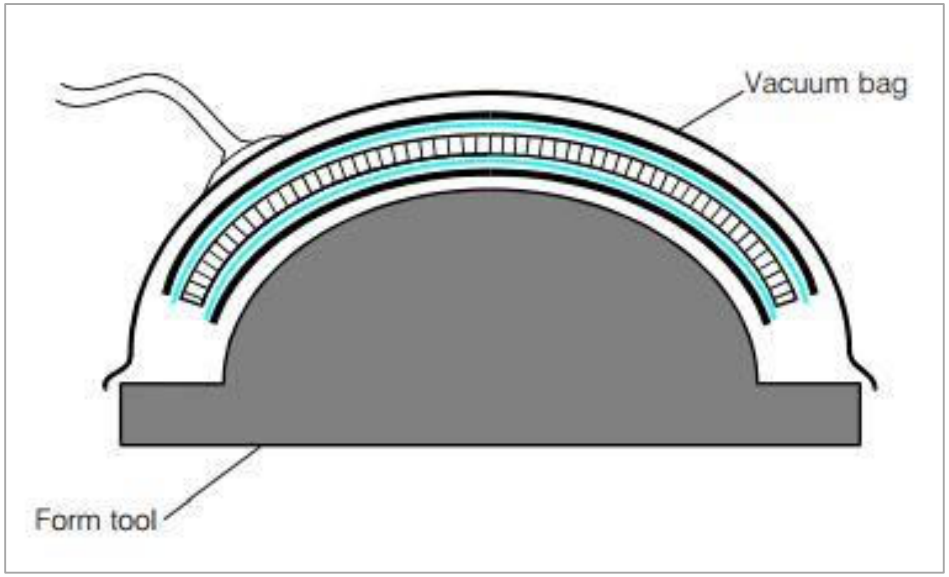


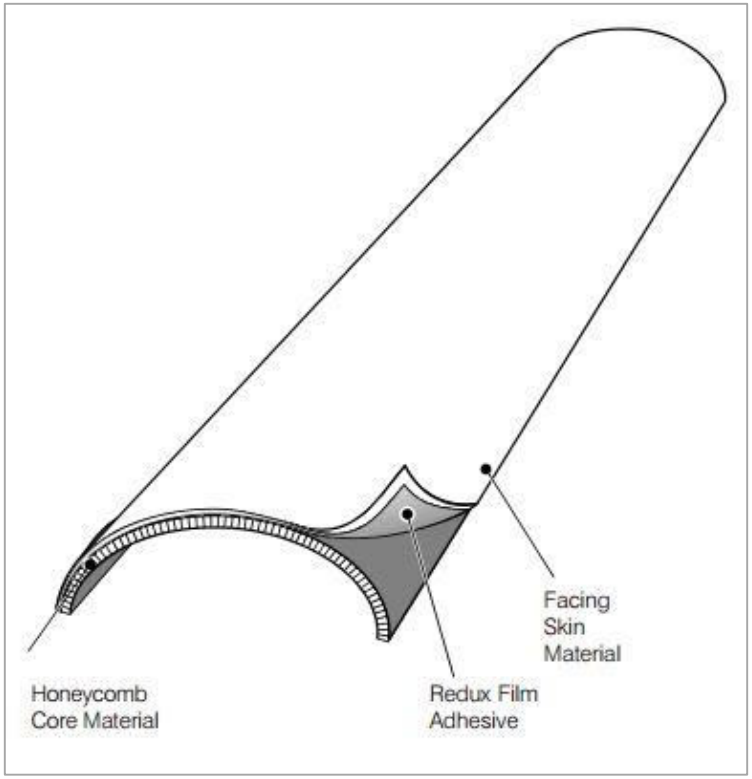


Vacuum Bag Processing:

The component should be assembled for cure as a single shot process, the necessary consolidation is obtained using a vacuum. This can be cured in an oven, and additional pressure can be applied if an autoclave is used.

This method is suitable for items with prepreg or preformed composite or metallic facing skins. When flexible or formed honeycomb core and film adhesives are used complex items may be produced.

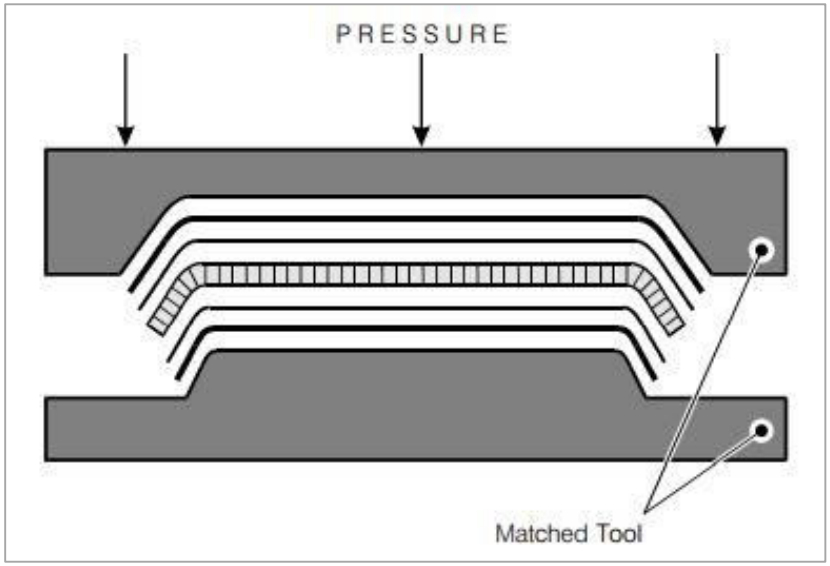


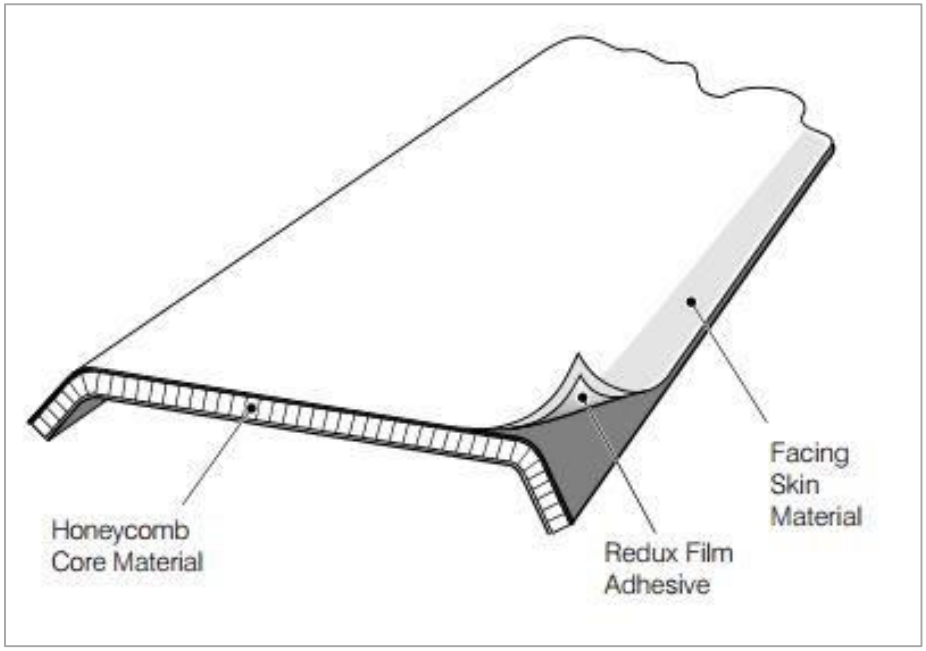


Match Mould Processing:

Most suited to those single shot cure process where a key objective is to achieve production items with high levels of tolerance and surface finish. The heat and pressure cure cycle in this case is applied using a variety of methods.

Typical methods are the use of heated tools with external mechanical pressure or non-heated tools placed in a press or oven to achieve the full cycle. Using a room temperature curing adhesive cold bonding may be considered if the sandwich construction is too large to be processed or heating is difficult.





Possibility of curved surfaces and different forms:

The above mentioned way is one of the simplest methods of achieving the desired fabricated part from the honeycomb sandwich panels. As shown in the diagrams, various curvatures and radii are possible with the same panel giving us abundant possibilities to play with the form of the desired object.

Manufacturers

Some of the leading firms that deal with manufacture and fabrication of panels made of honeycomb are:

- Nidaplast composites
- Plascore Inc
- ThermHex
- HexCel composites
- Gurit
- Renolit

References

[1] wikipedia, "compositeswiki.org/honeycomb-structures," 18 December 2013. [Online].

[2] HexCel, "Honeycomb_Sandwich_Design_Technology," [Online]. Available: http://www.hexcel.com/Resources/DataSheets/Brochure-Data-Sheets/Honeycomb_Sandwich_Design_Technology.pdf. [Accessed 18 Dec 2013].

[3] Plascore, "www.plascore.com," Plascore, [Online]. Available: http://www.plascore.com/product-honeycomb-cores.php. [Accessed 16 December 2013].

[4] Wikipedia, "Honeycomb structure," [Online]. Available: http://en.wikipedia.org/wiki/Honeycomb_structure. [Accessed 10 December 2013].

[5] N. composites, "Nidaplast composites," [Online]. Available: http://www.nidaplast.com/en/composites/implementation-processes. [Accessed 18 December 2013].

[6] HexCel, "www.hexcel.com," [Online]. Available: http://www.hexcel.com/Resources/DataSheets/Brochure-Data-Sheets/Sandwich_Panel_Fabrication_Technology.pdf. [Accessed 17 Dec 2013].