SANDWICH STRUCTURE

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This paper deals with the theory, functions and certain design considerations of the sandwich. The various materials used in the construction of sandwiches are mentioned and the honey-comb is explained. Their merits, drawbacks and applications in various fields are given.

Excellent stiffness-to-weight ratio, simplified design techniques, easy fabrication and economy are the principal advantages claimed for the selection of sandwich structures in the aircraft, missile, shipping, and automobile industries. The sandwich structure came into existence during the World War II, using the plywood skin and Balsa wood core for the fabrication of the wings of the Mosquito bomber and since then the sandwich structures are gaining the attention of aerospace engineers as an engineering material. An example of highstrength to weight ratio of a aluminium faced honeycomb sandwich compared to other structural members is given in Table 1 for the same deflection and over the same span.

The theory and functions of a sandwich may best be compared to that of an *I*-beam, a conventional engineering girder. Here the high strength facings correspond to the flanges of *I*-beam, the main idea being to keep the high strength material as far away as possible from the neutral axis so as to increase the sectional modulus, while the honeycomb is compared to that of web, and they both constitute a single unit in all respects. Now, if we imagine that the web has expanded and occupied all the space between the flanges, the density of the material being diminished so as to keep the total weight of *I*-beam constant, the sandwich structure would ultimately result. The thin facing sheets offer resistance to shearing forces and prevents the local buckling. The adhesives play important.

TABLE 1

STRENGTH TO WEIGHT RATIO OF VARIOUS MATERIALS

Material	Deflection (inch)	Weight (lbs.)
Honeycomb sandwich	0·058	7·79
Nested beam	0·058	10·86
Aluminium plate	0·058	34·20
Steel plate	0·058	68·60
Glass-reinforced plastics laminate	0·058	83·40

role in transmitting the loads uniformly and in forming an integral structure. When loaded as a column, the facings only resist the column forces while the cores stabilize the thin facings to prevent buckling (Fig. 1). The sandwich has an advantage over the *I*-beam, in that the core material that supports the facing material has a continuous area support which helps to develop higher buckling strength.

MATERIALS AND CONSTRUCTIONAL FEATURES

Selection of materials both for the facing sheets and core depends upon the field of application such as aircraft missile, shipping etc. The following are some of the materials generally used in the construction of the sandwich structures :

Facing materials—(a) Aluminium alloys, (b) High strength steel facings, (c) Plywood facings, (d) Reinforced plastics laminates etc.

Core materials—(a) Aluminium honeycomb, (b) Reinforced plastics honeycomb, (c) Plastic foams such as urethane foams, polystyrene foams, (*d*) Balsawood etc.

Adhesives—(a) Redux 775 adhesive film (CIBA), (b) Polyster resins, (c) Epoxy resins.

Honeycomb core materials require some explanation. They can be described as a two-dimensional array of hexogenal structure with length as the third measurement. The smaller the cell size greater will be the strength. The honeycomb can be produced by the following two process—Corrugation process and Expansion process. In the former process a thin sheet is passed through a set of rollers which imparts a permanent set causing the corrugation. It is then cut to the size and arranged in a hexagonal manner thus forming the core of the sandwich. In the second process, the thin sheet is fed past the rollers, and the adhesive is transferred to the sheet along with the preselected printed pattern during

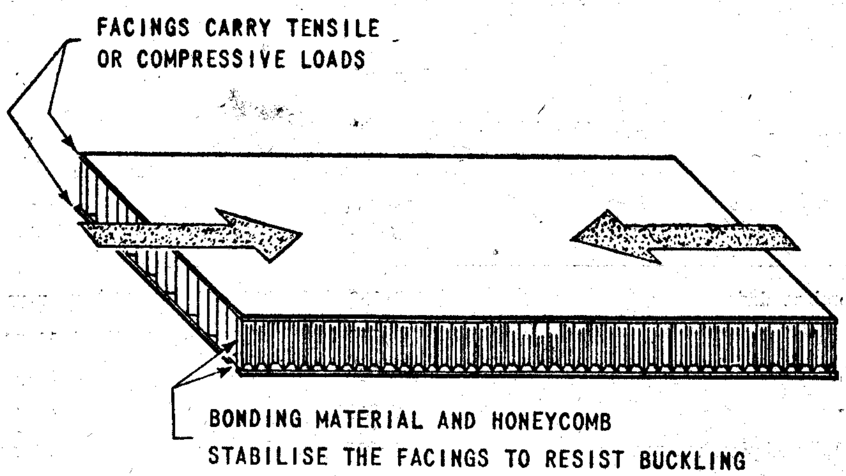

Fig. 1—Sandwich reacting under a compressive or tensile load.

operation. It is piled up to the required size known as HOBE *i.e.* honeycomb before expansion which forms the core for sandwich.

The main constructional features of the sandwich structure for *e.g.* sandwich panel (Fig. 2), which consists of one layer of facing sheet, a thin layer of the bonding material, the core, another layer of the bonding material and finally another facing sheet. After bonding the facing sheet to either side of the core, the entire sandwich is pressed in a suitable press at a pressure of 5 *p.s.i.* and later to accelerate the curing process, kept in an auto-clave at an elevated temperature. After complete curing the sandwich is taken out for further processing, but in the case where Redux 775 adhesive film (CIBA) is used to bond aluminium honeycomb core to the aluminium face sheets, the curing is done at 160°C.

DESIGN CONSIDERATIONS

Consider the design of a rectangular panel loaded as a simply supported beam and with a concentrated load (Fig. 3). The facing stress is obtained from the basic formula $f_t = \frac{M.C}{i}$

In the case of sandwich, $$f_t = \frac{P.\,L}{2.\,b.\,t_f\,(t + t_c)}$$

$$\text{or} = \frac{P.\,L}{4b.\,t_f\,(t - t_f)}\,.$$

By increasing the thickness of the facing sheet, the facing stress can be lowered. The core shear stress is dependant on the density of the material and its structure. Closer the cell size of honeycomb, stronger is the bond and better will be the strength. The core shear stress is calculated using the formula

$$f_c = \frac{P}{b\,(t + t_c)}\;\cdot\; or\;\frac{P}{2b\,(t - t_f)}$$

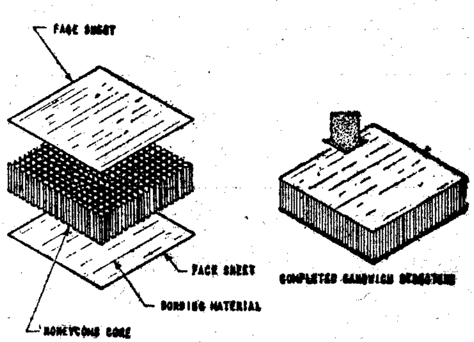

Fig. 2—The essential parts of a honeycomb sandwich.

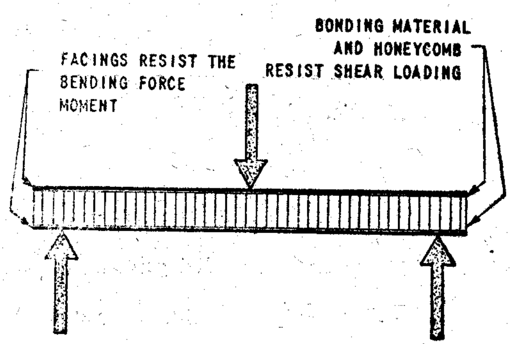

Fig. 3—Function of the parts of the sandwich under a shear load.

The deflection of the beam is determined as

$$W = \frac{PL^3}{48\,D} + \frac{PL}{8\,G_c\,b\,t}$$

Where P = Total load (lbs)

L = Span (inch)

b = Panel width (inch)

t = Total thickness (inch)

t_c = Core thickness (inch)

f_t = Facing stress (psi)

t_f = Facing thickness (inch)

W = Deflection, (inch)

$$D = \frac{E_f\ t_f\ t_c\ t}{2\lambda\ f}$$

G_c = Shear modulus of core (psi)

λ = (1—(Poisson's ratio)^2)

E_f = Modulus of elasticity of facing (psi)

Knowing the densities of facing material and core, the weight of the material is calculated The weight of bonding material is noted and finally the total weight of the panel is determined. The following allowable stresses for different materials for typical aircraft applications may be used while designing for such structures.

TABLE 2

ALLOWABLE STRESSES FOR DIFFERENT MATERIALS

Material	Allowable stresses in pounds per square inch
Aluminium alloys for facing and core	17,000
High strength steel facings	80,000
Plywood facings	2,000
Polystyrene foam	500 psi (varies with density)

MERITS AND DRAWBACKS

The sandwich has the following merits and drawbacks compared to the other material :

Merits—(*i*) High strength to weight ratio, (*ii*) Better resistance to vibration, (*iii*) Heat insulation capacity depending upon the core thickness, (*iv*) Simplified design techniques and easy fabrication, (*v*) In building industry—ease of replacing the floors less construction time, longer life etc.

Drawbacks—(*i*) Higher initial cost, (*ii*) Non-reliability of proper bond between the facing and core, (*iii*) Possibility of crushing of internal cells of honeycomb, (*iv*) Corrosion due to internal condensation of aluminium and mild steel honeycomb cells etc.

APPLICATIONS

The sandwich structures find an important role in the military and commercial fields such as aircraft, missile, shipping, automative, building etc.

Aircraft and missile industry : Many of the parts such as radomes, fuselage, missile wing, control surfaces could be manufactured using sandwich construction. It can also be used as landing mats for the aircraft.

Shipping industry : The boat hulls, deck of the boat, seats etc., could be made of honeycomb panels which not only saves the weight but also pains the buoyancy due to the cellular honeycomb construction.

Portable hutments and bridges : Sandwhich structures can be utilised by Defence Services for portable type of huts used in various types of weather *e.g.* in the Himalayas where it is extremely cold. The polystyrene foam sandwich acts as a thermal insulator and, in addition, the light weight and better strength properties provide portability in this field.

Also the sandwich structures can be used as portable bridges across channels.

Automotive industry : The sandwich structures could be used for the floors of cars the doors, bonnets etc. These structures not only have light weight but also economical and easy in operation.

Building industry : Many of the structural parts such as floors, roofs, partition walls are made of the sandwich construction which offer main advantages such as economy, long life, less construction time, ease of replacing floors, reduction of the total weight of super-structure and good appearance.

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