SANDWICH PANELS

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ABSTRACT

This introductory article gives an insight into the different methods employed in the construction of Sandwich panels, their limitations and future design applications for defence use as a structural element with one of the highest strength-weight ratios yet devised.

INTRODUCTION

Sandwich panel, as the name implies, is of composite construction made up by proper bonding of the three basic elements; upper facing, core and lower facing. Panels thus fabricated out of the thin high strength facing sheets and the fragile core have proved to be an amazing structural element when valued in terms of strength to weight ratio, consistency and durability. The core may consist of low density wood or foamed plastic or best of all, a metal honey comb. Metal honey comb has advantages over other core materials in having very consistent physical properties and in being proof to climatic conditions.

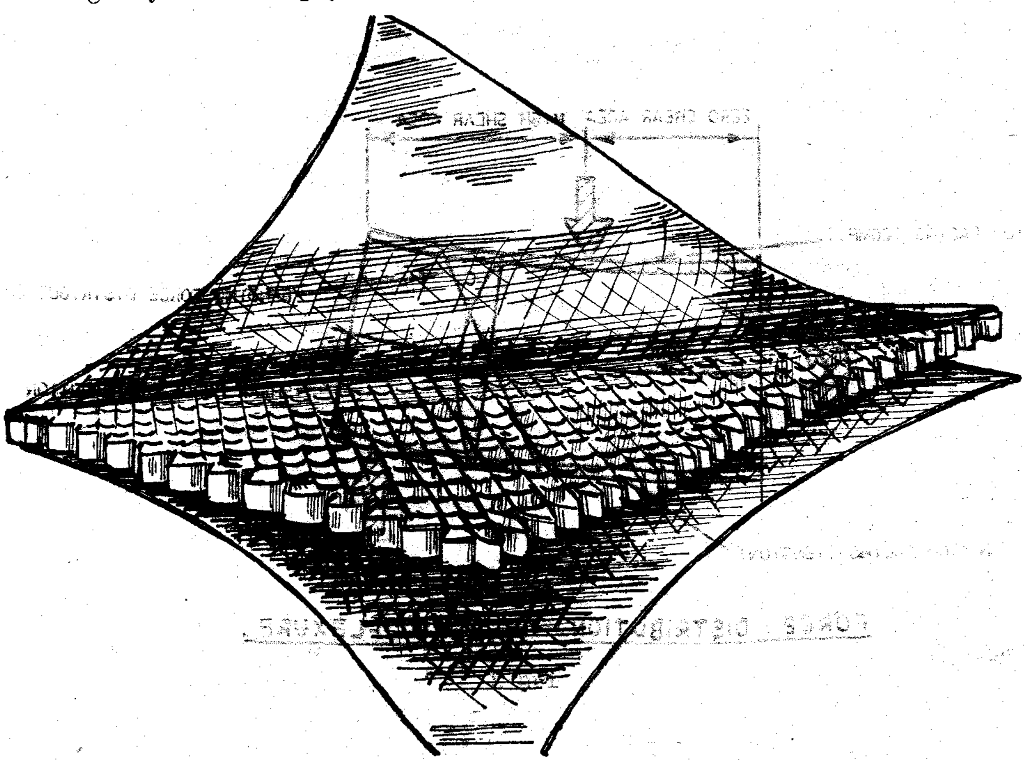
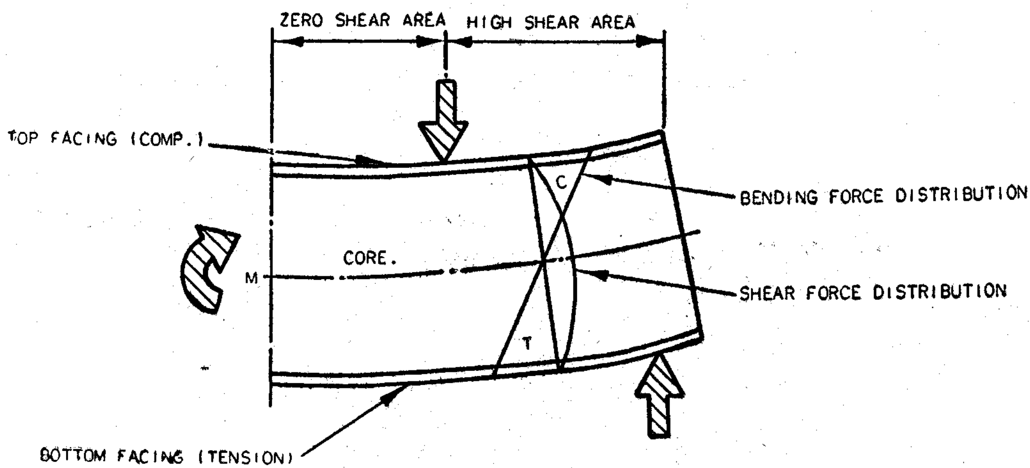


Fig 1

Metal alloys are chosen for the facing sheets, the most popular being aluminium alloys and precipitation—hardenable stainless steels. According to the different methods of bonding, and the different kinds of materials used for the core and facings, sandwich panels vary from each other in the methods of construction and design and high-strength sandwich panels have been made capable of even withstanding skin stresses of 50,000 lbs/Sq". An attempt is made in this article to focus the attention on only 3 common types : Glued honeycomb panels, Braced honeycomb panels and foamed plastic sandwich panels.

Design of sandwich panels

The design of sandwich panel is based on the basic assumption that in beam flexure (See Fig 2) the tensile and compressive forces are taken up mostly by the facings alone and the core is subjected only to very little stress. The two facings thus provide strength under bending loads apart from acting as a protective cover to the fragile core. The core however, is designed to withstand the shear forces causing most of the deflection. In axial loading, the worst case is compression rather than tension, as buckling can occur, and it is well known that the load causing buckling is inversely proportional to the square of column length and the strength of the column is increased by adding lateral guides. The sandwich panel with its honeycomb core incorporates so many lateral guides that the effective length of the column becomes very small, thus strengthening it against buckling.



FORCE DISTRIBUTION IN BEAM FLEXURE.

FIG 2

The chance of failure is thus limited to the compressive yield strength of the material itself. The core cell wall thickness and cell size (See Fig 3) are fixed so that the core, and the bond between the core and facings are able to transmit the shear from face to face. Thus by choosing a proper combination of facing thickness and core cell dimensions, the composite sandwich panels can be fabricated to cater for all structural requirements where a high strength-weight ratio is of paramount importance.

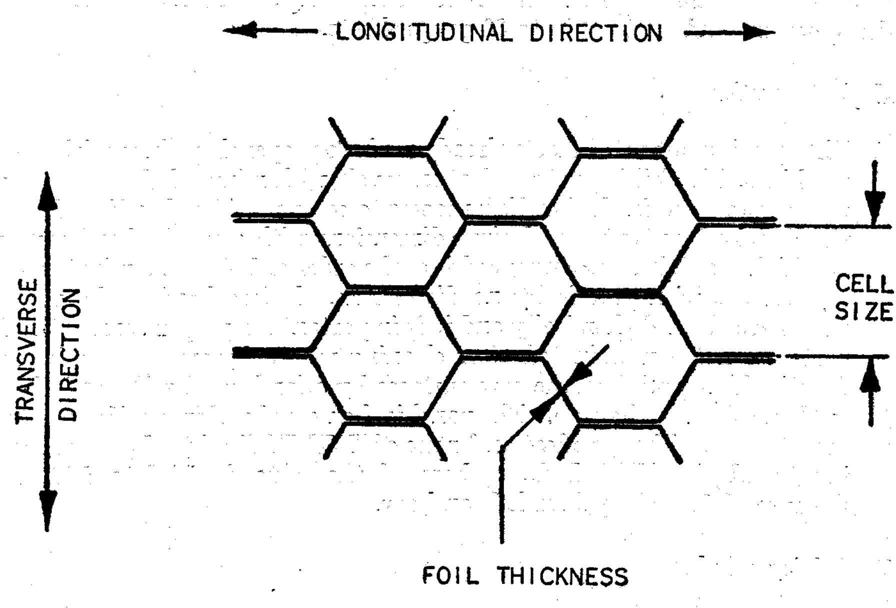


FIG 3. Geometrical form of honeycomb core

Different types of sandwich panels

Considerable progress have been made in the development of the following three different types of sandwich panels; Glued honeycomb panels, Brazed honeycomb panels and Foamed plastic sandwich panels.

Glued honeycomb panels

The main problem in sandwich construction is to achieve an effective bond between the core and the facings. In glued honeycomb panels, this bonding is done by specially prepared glues. CIBA (A.R.L.) Ltd. has done intensive research in the development of glues. According to reports some of their products proved successful in the production of satisfactory honeycomb panels.

The material chosen was aluminium alloy and the normal honeycomb cell sizes varied from $\frac{1}{8}''$ to $\frac{3}{8}''$. The thickness of the foil ranged from $0{\cdot}001''$ to $0{\cdot}003''$. The upper facing used was 20 to 26 gauge and the lower facing being a tension member was thinner than the upper one and made of 26 to 30 gauge sheets.

Method of construction

(*a*) The core is made up of sheets already made to proper shape in special corrugating machines. The foil is perforated at intervals with minute holes to allow volatile matter produced in the bonding process to escape. After bonding the core foils the blocks are cut to desired dimensions with a special band saw running at a high speed. The cutting speed is of the order of 16000 ft. a minute to perform a clean cut with practically no distortions. Before bonding the metal facing sheets are cleaned chemically and it is important for proper connection that the parts are not contaminated after cleaning process by exposure to dust or dirt. Glue is then applied on the core surfaces by a lambswool roller and the facings are bonded on to the core. The panel is then cured under specified pressure and temperature. The specification for use of "REDUX" Film CR for curing according to CIBA (ARL) Ltd., makers of the glue is 145° to 168° C and a pressure of 10 to 50 psi for half an hour.

(*b*) *Edging member*

In the fabrication of a structure the attachment of panels to other members is done through bolts or other normal fixing devices through the edging members, which are incorporated in the panel. The edging members, are normally metal or hardwood blocks and are again bonded to the panels. Apart from effecting connection the panel edgings also protect the core from moisture and other matter.

(*c*) *Inspection of bonds*

It is vitally important that the panels after construction should be thoroughly inspected. To check on the efficiency of bonding over the whole area, the instrument at present used for this purpose makes use of a vacuum cup which is placed over the panel and when the vaccum is applied, if the bonding is not complete, the facing sheets will show signs of distortion which are reflected on a micrometer gauge.

Brazed honeycomb panels

The basic elements of honeycomb panel are the same as discussed above viz.,upper facing, honeycomb core and lower facing. But in the formation of brazed honeycomb panels the honeycomb core is generally of welded construction and the connection between the core and facing is done by using a brazing alloy in sheet or powdered form and brazing in an inert gas atmosphere.

(*a*) *Materials and construction*

The most commonly used metal for brazed sandwich panels is stainless steel due to ease of forming the annealed material, ease of joining and good corrosion resistance. The material can be further strengthened by aging treatments, (temperature varying from 950°F to 1,050°F) or by sub-zero cooling plus tempering (temper at about 850°F). Various alloys are available in the market suitable for facing sheet stock and core material. The honeycomb core is produced in two different ways. In one method the sheets are preformed in special corrugating machines and welded layer by layer where the corrugations meet. In the second method flat sheets are spot welded together at fixed intervals. When a bundle is thus built up the top and bottom sheets are pulled apart thus forming the honeycomb shape. The spacing of the weld points determines the cell size. When the welded bundle is expanded, the honeycomb cells spring back slightly and hence the cell shape is over-expanded to cater for this. Strong brazed joints demand closely controlled dimensions and hence the core is machined prior to brazing to get precise thickness. Most common are high speed disk cutting and electro-mechanical machines. After shaping, the facings and core are chemically cleaned and brazed. The brazing is done in a protective argon atmosphere and furnace heating is widely used in preference to electric blanket devices, quartz tube lamps or salt baths. For high strength requirements the brazed panels are again subjected to heat treatment and aging processes. Edging members are then brazed on to the panels to cater for fastening and joining of different sections.

(*b*) *Inspection of brazed panels*

Inspection of brazed panel joint is a difficult process and a combination of destructive and non-destructive tests are generally followed. Destructive tests include inspection of original materials and also the normal basic tests on test specimens. Non destructive tests are done by the use of X-Ray, ultra-sonics or heat sensitive coatings. Even these methods are time consuming and costly and the problem of speedy and efficient quality control still remains unsolved.

Foamed plastic sandwich panels

In the family of sandwich panels, foamed plastic sandwich panels is gaining popularity, where the stiffening plastic core replaces the conventional corrugated metal core. Most rigid foam cores are available in a range of densities and according to the core material, the mechanical properties like shear strength, tensile strength and bond properties vary sharply.

Although foamed plastic core may be considered isotropic, final properties may vary slightly due to incorrect mixing and hence statistical analysis of specimens are required to check on them.

Core shear failure is the most common form of failure in this type and hence is widely used as a testing standard, but there is consolation that the failure is critical only for simply supported beams and not in case of plate flexure when the panel is supported on all four edges.

The common causes of failure of foamed plastic core can be summarised as follows:—

(*a*) Core shear failure—due to non-homogenous core with weak cells near facings.

(*b*) Adhesion failure—due to poor adhesion properties of foam or due to trapped air at inter-face.

(*c*) Failure due to core compression—due to local compression failure tending to bukle facing.

(*d*) Facing failure—due to thin facings or stress concentration at points.

Different uses of sandwich panels

Sandwich panels have become popular only after the second World War and much of the construction, design and use of these panels are still in the hands of various research agencies. Inspite of this, sandwich panels are accepted and valued by the designers in projects where structural strength and low weight are of importance.

Listed below are a few of the projects incorporating the sandwich panel construction:—

(*a*) A ready use of the sandwich panel is found in the building of aircraft especially for construction of floor wings, fuselages tail planes and trailing edges.

(*b*) The light weight, rigidity and buoyancy of honeycomb panels makes them ideal for construction of boats. The honeycomb core sealed between the two facing sheets forms thousands of water-tight cells and the boat becomes virtually unsinkable. A 13 ft. honeycomb runabout made by CIBA (ARL) Ltd. showed a saving of 40% weight compared to plywood boats of the same size.

(*c*) In the construction of Rover gas turbine car manufactured in 1956, the floor was made of honeycomb panels resulting in economy in weight.

Sandwich Construction Problems

The honeycomb panel structure presents a host of design problems from material selection to joint design—

(*a*) Because of the composite nature of sandwich construction, special design equations have to be evolved and varied experimentally for different loading situations—no small task indeed, considering the variety of materials and joining methods, now used by designers.

(*b*) Even with the use of improved bonding techniques, the main problem still is to guarantee effective connection between the facing sheets and the core. For good bonding it is important to see that the joining parts are thoroughly cleaned by chemical process and even after cleaning, no exposure to dirt or dust is allowed; the components cannot be handled by bare hands.

(*c*) Shaping the cells to correct sizes and shapes involves the use of special corrugating machines or other tedious construction techniques.

(*d*) For maximum strength, the sandwich panel components have to conform to closely controlled dimensions as tolerances of the order of plus or minus 0·002 ins. are advocated at the mating surfaces.

(*e*) Adequate quality control is a problem as thorough inspection of the panel is difficult because the joints are inaccessible. Accordingly a combination of destructive and non-destructive tests are at present followed.

(*f*) The sandwich panels are expensive due to specialised construction, greater rejection rates and tedious inspection techniques. Cost of curved and tapered panels are also disproportionately high, compared to flat panels due to increased forming cost.

The Future

Inspite of the above mentioned disadvantages sandwich panels are becoming popular among modern designers as one of the most sophisticated structural element with one of the highest strength-weight ratios yet produced. Improved techniques of high temperature brazing and good metal to metal adhesives are already erasing the problem of effective connection between the different components of the composite structure. X-Ray, ultrasonics and heat sensitive coating are showing great promise for high speed—low cost inspections. As a result of constant research ; the cost of honeycomb panels are dropping steadily in recent years comparative analysis shows a saving in cost of 40% in the past 4 years.

In various Defence Projects where strength and lightness are preferred even at the expense of economy, sandwich panels could be used with advantage. An immediate application of the sandwich panels may be found in the construction of different watercraft, road expedients and prefabricated landing mats for airfields. Honeycomb panels may be used as an excellent material in the production of practically unsinkable amphibious military vehicle. Also vehicles with aluminium sandwich body panels could be designed so lightweight, that they could be air dropped with ease during operations. Only the progress and the results of present research carried on for the production of better sandwich panels can foretell its future use and adaptability for various Defence needs.

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