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MODAL ANALYSIS OF COMPOSITE SANDWICH PANEL

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ABSTRACT

Use of Sandwich construction for an aircraft structural component is very common to the present day. One of the primary requirements of aerospace structural materials is that they should have low density, very stiff and strong. Sandwich panels are thin-walled structures fabricated from two flat sheets separated by a low density core. We have investigated here is of aluminium honeycomb structure because of excellent crush strength and fatigue resistance. Sandwich panels have a very high stiffness to weight ratio with respect equivalent solid plate because of low density core. FEA modeling is developed by consideration of rotary inertia. The free vibration analysis of sandwich panels is studied. Four noded isoparametric shell element is used for FEA. The effects of sandwich design parameters, such as face thickness, core thickness and pitch, on the global bending and vibration responses are determined. Convergence study is also included for high accuracy of the results. Analytical results are based on classical bending theory. Mode shapes and corresponding natural frequencies are studied for simply supported sandwich panel and cantilever condition.

Keywords: FEA, Mode Shape, Natural Frequencies, Sandwich Construction, Stiffness ratio

INTRODUCTION

Sandwich panels have high strength to weight ratios hence have been successfully used for many years in the aviation and aerospace industries, as well as in marine, and mechanical and civil engineering applications. Also they have attendant high stiffness. The use of the sandwich constructions in the aerospace structures can be traced back to Second World War when British De Havilland Mosquito bomber had utilized the sandwich constructions. In the early use, the sandwich structure was very simple in construction, with simple cloth, fabric or thin metal facings were used and soft wood were used as the core. [6]

The conventional sandwich construction comprises a relatively thick core of low-density material which separates top and bottom faceplates (or faces or facings) which are relatively thin but stiff. The materials that have been used in sandwich construction have been many and varied but in quite recent times interest in sandwich construction has increased with the introduction of new materials for use in the facings (e.g. fiber- reinforced composite laminated material) and in the core (e.g. solid foams).

Sandwich Structure Types:

Detailed treatment of the behavior of honeycombed and other types of sandwich panels can be found in monographs by Plantema [3] and Allen [4].These structures are characterized by a common feature of two flat facing sheets, but the core takes many generic forms; continuous corrugated sheet or a number of discrete but aligned longitudinal top-hat, zed or channel sections. The core and facing plates are joined by spot-welds, rivets or self-tapping screws.[3]

Construction of Sandwich:

Sandwich construction is a special kind of laminate consisting of a thick core of weak, lightweight material sandwiched between two thin layers (called "face sheets") of strong material. This is done to improve structural strength without a corresponding increase in weight. The choice of face sheet and core materials depends heavily on the performance of the materials in the intended operational environment.

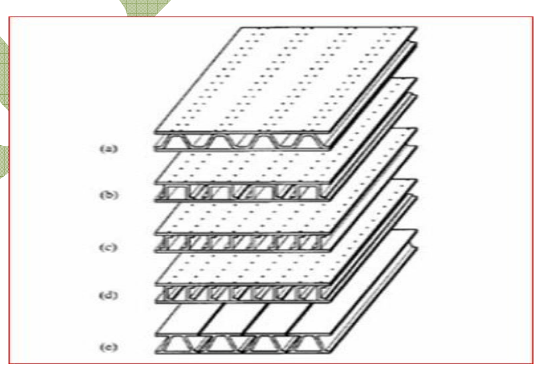

Figure 1.1 Sandwich panel with (a) continues corrugated-core (b) top-hat core (c) zed-core (d) truss-core

Because of the separation of the core, face sheets can develop very high bending stresses. The core stabilizes the face sheets and develops the required shear strength. Like the web of a beam, the core carries shear stresses. Unlike the web, however, the core maintains continuous support for the face sheets. The core must be rigid enough perpendicularly to the face sheets to prevent crushing and its shear rigidity must be sufficient to prevent appreciable shearing deformations. Although a sandwich composite never has a shearing rigidity as great as that of a solid piece of face-sheet material, very stiff and light structures can be made from properly designed sandwich composites.

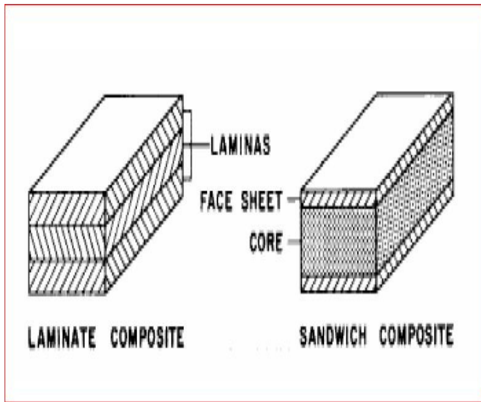

Figure 1.2 Laminate composite and sandwich composite

To see the core effect upon sandwich strength, let us consider the honeycomb-core and the truss-core sandwich composite. The honeycomb sandwich has a ratio of shear rigidities in the *xz*and *yz*planes of approximately 2.5 to 1. The face sheets carry in-plane compressive and tensile loads, whereas the core stabilizes the sheets and builds up the sandwich section. The truss-core sandwich has a shear rigidity ratio of approximately 20 to 1. It can carry axial loads in the direction of the core orientation as well as perform its primary function of stabilizing the face sheets and building up the sandwich section.

MATERIAL PROPERTIES USED IN SANDWICH CONSTRUCTION:

No single known material or construction can meet all the performance requirements of modern structures. Selection of the optimum structural type and material requires systematic evaluation of several possibilities. The primary objective often is to select the most efficient material and configuration for minimum-weight design.

Face Materials:

Almost any structural material which is available in the form of thin sheet may be used to form the faces of a sandwich panel. Panels for high-efficiency aircraft structures utilize steel, aluminium or other metals, although reinforced plastics are sometimes adopted in special circumstances. In any efficient sandwich the faces act principally in direct tension and compression. It is therefore appropriate to determine the modulus of elasticity, ultimate strength and yield or proof stress of the face material in a simple tension test. When the material is thick and it is to be used with a weak core it may be desirable to determine its flexural rigidity.

Core Materials:

A core material is required to perform two essential tasks; it must keep the faces the correct distance apart and it must not allow one face to slide over the other. It must be of low density. Balsa wood is one of the original core materials. It is usually used with the grain perpendicular to the faces of the sandwich. The density is rather variable but the transverse strength and stiffness are good and the shear stiffness moderate. Modern expanded plastics are approximately isotropic and their strengths and stiffness’s are very roughly proportional to density.

In case of aluminium honeycomb core, all the properties increase progressively with increases in thickness of the foil from which the honeycomb is made.

CURRENT APPLICATION:

Aerospace Field:

In Aerospace industry various structural designs are accomplished to fulfill the required mission of the aircraft. Since a continually growing list of sandwich applications in aircraft/helicopter (example-Jaguar, Light Combat Aircraft, Advanced Light Helicopter) includes fuselages, wings, ailerons, floor panels and storage and pressure tanks as shown in figure.

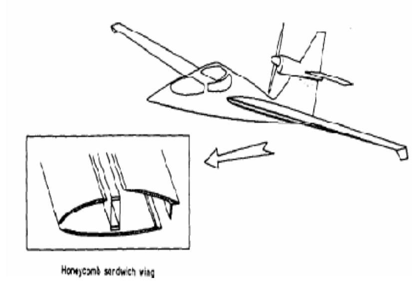

Fig 3.1.1 Application of sandwich structure

Honeycomb sandwich structures have been widely used for load-bearing purposes the aerospace due to their lightweight, high specific bending stiffness and strength under distributed loads in addition to their good energy-absorbing capacity [8]. In a new space-formed system called "Sunflower," the reflector is of honeycomb construction, having a thin coating of pure aluminum protected by a thin coating

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of silicon oxide to give the very high reflectivity needed for solar-energy collection. Thirty panels fold together into a nose-cone package in the launch vehicle.

Fig 3.1.2 Application of sandwich structure

(1. Rotor Blades, 2.Main and Cargo Doors, 3.Fuselage Panels, 4.Fuselage, 5. Boom and Tail section)

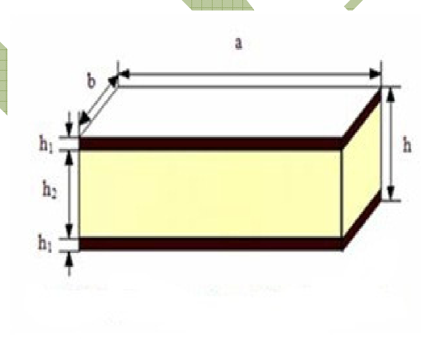
Building Construction:

Architects use sandwich construction made of a variety of materials for walls, ceilings, floor panels, and roofing. Cores for building materials include urethane foam (slab or foam-in-place), polystyrene foam (board or mold), phenolic foam, phenolic-impregnated paper honeycomb, woven fabrics (glass, nylon, silk, metal, etc.), balsa wood, plywood, metal honeycomb, aluminum and ethylene copolymer foam. Facing sheets can be made from rigid vinyl sheeting (fiat or corrugated) ; glass-reinforced, acrylic-modified polyester**;** acrylic sheeting; plywood; hardwood; sheet metal (aluminum or steel); glass reinforced epoxy; decorative laminate; gypsum; asbestos; and poured concrete.

Damped Structures:
An increasing number of vibration problems must be controlled by damping resonant response. By using a symmetric sandwich panel with a visco-elastic core, various degrees of damping can be achieved, depending on the core material properties, core thickness, and wavelength of the vibration mode.

SANDWICH PRINCIPLES:

The basic prerequisite for high-performance structural component parts as used in aerospace applications is light-weight design wherever possible. An essential component of these light-weight structures is load-bearing and buckling optimized shell elements. The classical method to obtain improved buckling properties is using sandwich structures have also proven their worth in a number of fields. The performance of a sandwich structure depends primarily upon the efficiency of surface skins and the distance between them. A great distance between the surface skins produces a correspondingly great geometrical moment of inertia, thus leading to high bending stiffness. Since this arrangement subjects the core of the sandwich to a relatively small amount of stress, it can be reduced in weight significantly. Extremely thin-walled sandwich structures present the problem of how force is introduced and the sandwich structure's sensitivity towards impact loads. This means that a minimum wall thickness is required for the surface skins to be able to ensure that it is adequate to the purpose.



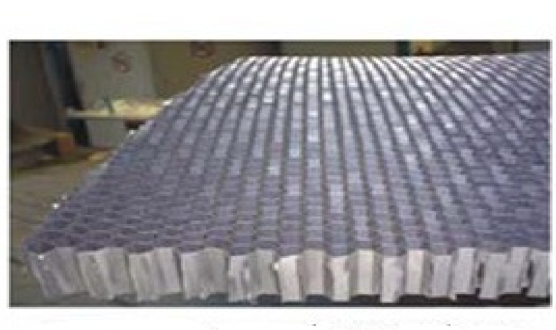


Fig 4.1 Typical geometry of sandwich plate *Fig 4.2 Aluminium honeycomb core*

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Face Sheets:
The face sheets provide the flexural rigidity of the sandwich structure. It should also possess tensile and compressive strength. [1]
Cores:

The purpose of the core is to increase the flexural stiffness of the panel. The core in general has low density in order to add as little as possible to the total weight of the sandwich construction. The core must be stiff enough in shear and perpendicular to the faces to ensure that face sheets are distant apart. In addition the core must withstand compressive loads without failure.[7]

Aluminum Honeycomb:

These cores are available in variety of materials for sandwich structures. These cores can be formed to any shape or curve without excessive heating or mechanical force. Honeycombs have very high stiffness perpendicular to the faces and the highest shear stiffness and strength to weight ratios of the available core materials. The most commonly used honeycombs are made of aluminum or impregnated glass or aramid fiber mats such as nomex and thermoplastic honeycombs.

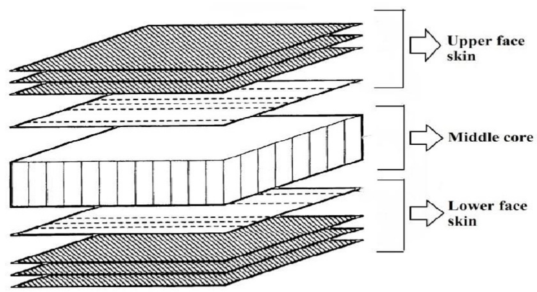
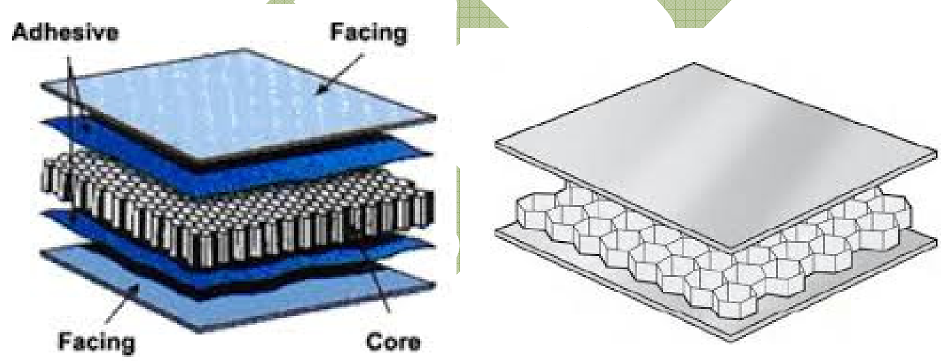


Fig 4.3.1Typical sandwich structure

Composite material is the combination of two or more constituent materials, and forms a light weight and high strength structure. The matrix and reinforcement material make the material stiffer and stronger. A typical sandwich structure, the below shown figure is a special class of composite material in which a thick foam core is attached by two thin, stiff, skin and a thick core which is lighter in weight. Honeycombs have a higher strength-to-weight ratio than foam, but foams may be used in several forms of structural constructions, for the same characteristics. Also, the compression strength of a foam core prevents the thin facesheet/skin from failure due to buckling. It is mainly a thermoset, polymer, light weight and strong structure.



FINITE ELEMENT MODELING

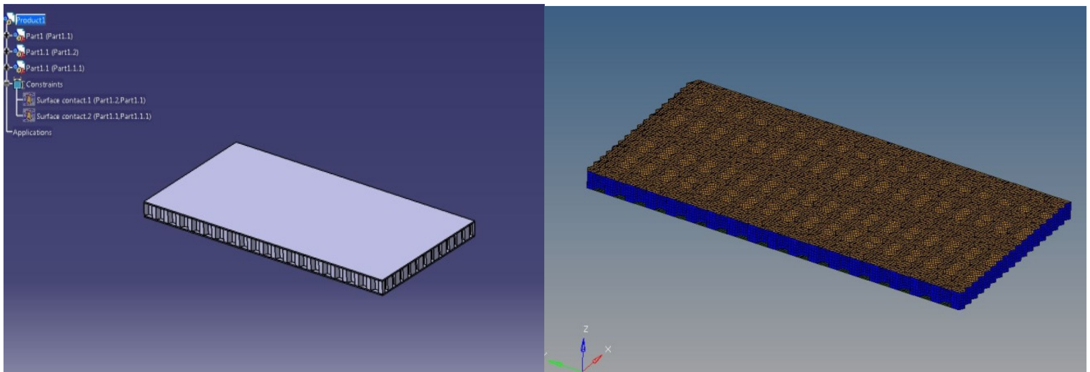
Introduction:
The Finite Element Method is essentially a product of electronic digital computer age. Though the approach shares many features common to the numerical approximations, it possesses some advantages with the special facilities offered by the high speed computers. In particular, the method can be systematically programmed to accommodate such complex and difficult problems as non homogeneous materials, non linear stress-strain behaviour and complicated boundary conditions. It is difficult to accommodate these difficulties in the least square method or Ritz method and etc. an advantage of Finite Element Method is the variety of levels at which we may develop an understanding of technique. The Finite Element Method is applicable to wide range of boundary value problems in engineering. In a boundary value problem, a solution is sought in the region of\ body, while the boundaries (or edges) of the region the values of the dependant variables (or their derivatives) are prescribed. [4]

Advantages of FEM:
The advantages of finite element method are listed below:
1. Finite element method is applicable to any field problem: heat transfer, stress analysis, magnetic field and etc.
2. In finite element method there is no geometric restriction. The body or region analyzed may have any shape.
3. Boundary conditions and loading are not restricted. For example, in a stress analysis any portion of the body may be supported, while distributed or concentrated forces may be applied to any other portion.[5]

Limitations of FEM:

The limitations of finite element method are as given below:
1. To some problems accurate results are not obtained to the approximations used
2. For vibration and stability problems the cost of analysis by FEA is prohibitive.
3. Stress values may changes from fine mesh to its counterpart.

CAD model of composite panel



Meshing in Hyper mesh:

The CAD model is imported to hyper mesh and the geometry cleanup is done. The appropriate element size is selected according to the geometry features. Then using quad element the aluminium honeycomb is meshed and then the composite plates maintaining the connectivity. The meshed model is checked for element criteria.

Application of Material Properties:

Element type	Quad 4
Element size	3
No of elements	59316
No of nodes	50562

Table: 1

Material properties Aluminium core:

Property	Value
Young's Modulus, E	68.9 GPa
Poisson's Ratio ,ν	0.33
Density, ρ	2700 kg/m^3
Yield Stress, σ_{yield}	214 MPa
Ultimate Tensile Stress, σ_{uts}	241 MPa

Table: 2

Material Properties of Glass Fibers:

Property	Value
Longitudinal Modulus, E_1	59 GPa
Lateral Modulus, E_2	20GPa
Poisson's Ratio ,ν	0.35

Lonitudinal tension strength X_t	2000 MPa
Lonitudinal compression strength X_c	1240 MPa
Transverse tension strength Y_t	82 MPa
Transverse compression strength Y_c	200 MPa
Density, ρ	2.02 g/cm^3
In plane shear S	165 MPa

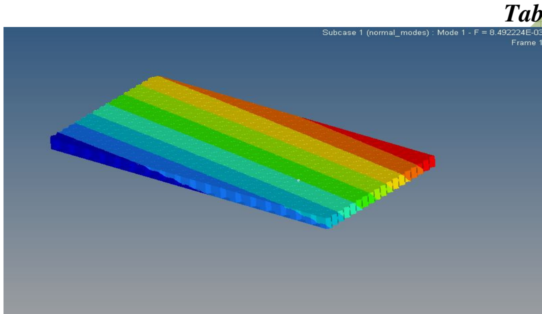
Table: 3

Modal Analysis:

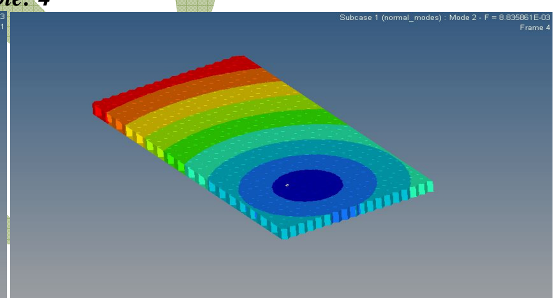
Free modal analysis-Total three modes of vibration are plotted by free modal analysis. The Composite panel natural frequencies can be obtained by modal analysis; the following modes are listed as shown in figure.

Sr.No	Modes	Frequencies(HZ)
1	Mode 1	8.492E-3
2	Mode 2	8.835E-3
3	Mode 3	9.086E-3

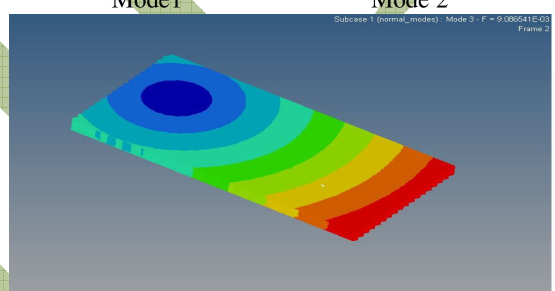
Table: 4



Mode1

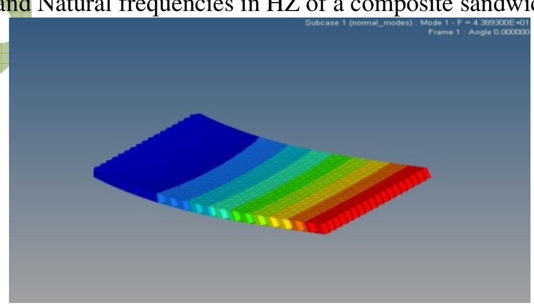


Mode 2

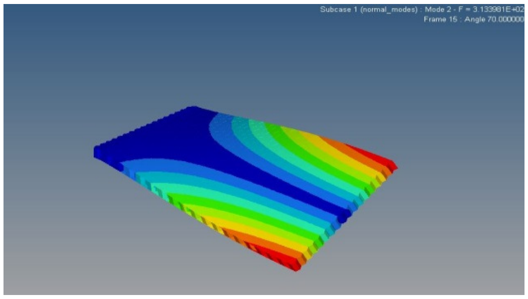


Mode 3

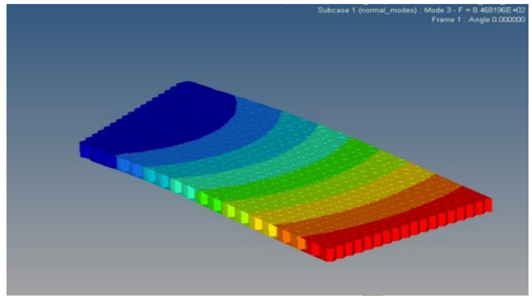
Cantilever Beam Condition: Mode shapes and Natural frequencies in HZ of a composite sandwich panel-



Mode 1



Mode 2



Mode 3

Sr. No	Mode Shapes	Frequencies
1	Mode 1	4.38930E+1
2	Mode 2	3.13398E+2
3	Mode 3	8.46819E+2

Table: 5

CONCLUSION:

The Natural Frequency of a Composite sandwich material for a free-free and cantilever beam condition is calculated.

Sr. no	Mode Shapes	Free-Free Condition	Cantilever Condition	Analytical Results of Cantilever Condition	Error
1	Mode 1	8.492E-3	4.38930E+1 HZ	48.16HZ	8.86%
2	Mode 2	8.835E-3	3.13398E+2HZ	301.860HZ	3.68%
3	Mode 3	9.086E-3	8.46819E+2HZ	845.223HZ	0.188%

Table: 6

Thus, by studying above comparison table we can predict the behaviour of composite sandwich panel made of materials aluminium and carbon fiber plastics. And with this conclusion composite sandwich panel can be used to appropriate application. Also with this analysis optimizing time can be minimized. To increase the higher accuracy, above analytical results can be validated by performing experimentation on Fast Fourier Transformer.

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