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A REVIEW ON HONEYCOMB SANDWICH STRUCTURES AND HYBRID STRUCTURES

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Abstract - A honeycomb structure is a natural or manmade structures with the geometry of a honeycomb which allow minimal use of material to achieve a reasonable weight and cost. The honeycomb structure which is inspired by bees, is widely used in variety of fields like architecture, transportation, mechanical engineering, chemical engineering, nanotechnology, and more recently in biomedicine. In a honeycomb sandwich structure there were two face plates and in between them the core should be placed and it looks like a sandwich. In this study different analysis like buckling analysis, bending analysis, and dynamic analysis are to be done in the corrugated sandwich structures and hybrid structures. By this study we can predict the behaviour of honeycomb structure and hybrid structure and also a comparative study is done between the in-plane and out of-plane compression.

Key Words: **Honeycomb structures , Hybrid structures, Corrugated sandwich structures,**

1.INTRODUCTION

A honey comb core sandwich panel is constructed by adhering two highly rigid thin-face sheets with a low-density honeycomb core, which has less strength and stiffness[5]. The face sheets are of typically thin composite laminates like steel plates, aluminium, glass, carbon or aramid and the honey comb core is made mostly by aluminium. In this between the two face sheets the honeycomb core is placed like a sandwich shape. It is mainly used to achieve high stiffness-to-weight and strength-to-weight ratios A higher thickness of the face sheet affects the frequency of sandwich panels in a complicated way, since it increases exponentially for the first three values of thickness before coinciding to a fixed frequency for a higher value of thickness[1]. An important study is to be done for the dynamic response of the composite honeycomb structures subjected blast loads. According to the traditional honeycombs the auxetic honeycomb sandwich plate, which has meta material property, have better vibration absorptions[7]. In the honeycomb sandwich structure by varying the core the thickness and material of the face sheet, it is possible to obtain various properties and desired performance[5][12] . Several types of core shapes and core material have been applied to the construction of sandwich structures [1] [2]. The basic principle of honeycomb sandwich structure is that the core carries the shear stresses and the face plate carries bending stresses[8]. There were many applications of engineering structure included the using of composite and sandwich structure as beam, plate and shell are used in a mechanical engineering field from many researchers. Where, the papers presented investigations of its application by various techniques as experimental, numerical (by using finite element method) and analytical solution of problem (by derive and solution of general equation of structure) and showed the effect of reinforcement types and volume fraction, in addition to, showing the effect of sandwich honeycomb size[15]. In this study the modelling of corrugated sandwich structure and hybrid structure (I strut + honeycomb , Corrugated + honeycomb) are to be modelled and analyzed. The modal testing and analysis of a honeycomb sandwich plate can be done and on the results, a FEM updation is done so as to efficiently estimate the accurate equivalent properties of the honeycomb core[2]. Due to the use of hybrid structures it give comprehensive thermal and mechanical advantages and also have high strength and specific energy absorption[13]. In addition, the presence of the honeycomb core has a significant contribution on the ballistic impact response of the sandwich structure by reducing the residual velocity, kinetic energy and damage area [9].

1.1 Honeycomb Sandwich Structures

The honeycomb sandwich structures are structures which are in the shape of a sandwich which consist of two face sheets and in between the sheets there were a honeycomb core. One type of honeycomb sandwich structure consist of three components like glass fibre UD, carbon fibre UD and Aluminium 5052 [1] [20]. Metal and non metal materials are used as the upper and lower sheet plate and the honeycomb sandwich structure can be made from various type of materials like metal, ceramic and composite materials etc. [4]. At the present time the sandwich structure is made of two rigid metallic thin face sheets and also with a low density soft core. For the manufacturing of honeycomb core there are of five basic ways they are adhesive bonding, resistance welding, brazing, diffusion bonding and thermal fusion.Among these methods, most common manufacturing method is adhesive bonding. Resistance welding, brazing and diffusion bonding are only used for cores to be used at very high temperatures. There are two basic methods of manufacturing honeycomb core by adhesive bonding.

1. Expansion method
2. Corrugation method [11]

The new design is of using auxetic honeycomb with thin plate [6].In the honeycomb sandwich structures the core have different shapes like triangular, square, hexagonal or circular shapes. The core gives high compressive strength and the face sheet gives shear strength. Hexagonal cells are used most because it has been successfully fabricated by using a variety of technologies and materials [8] [18].

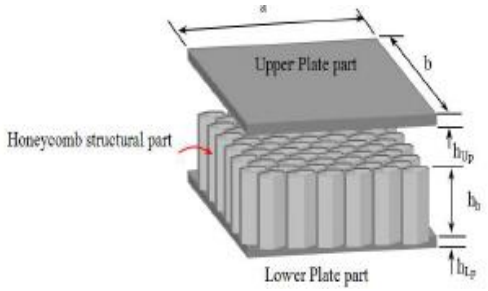


Fig -1: Honeycomb sandwich plate structure

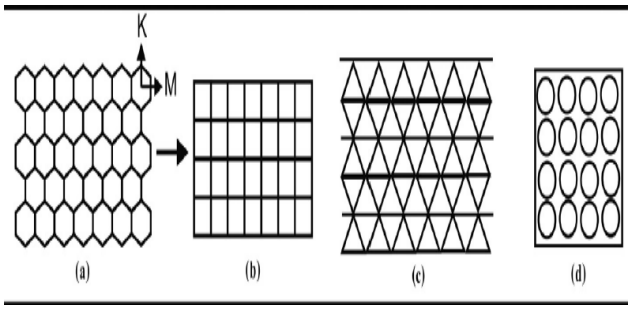


Fig -2: Different core shapes

1.2 Hybrid Structures

The hybrid structures are those structures which have a combination of two core shape . By using the hybrid it give comprehensive thermal and mechanical advantages and also it have high strength and specific energy absorption. There were different combination of hybrid structures one is of using the I type strut and the corrugated core by combining these two we get a hybrid core . The corrugated core is in the shape of 'V' then by combining this with' I' we get a M type or N type core [2].

The honeycomb corrugation hybrid core have two different scale they are of:

a) the macro scale , here the hybrid is considered as a homogeneous continuum solid

b) the micro scale, separately considering the corrugated membes and filling honeycomb [13].

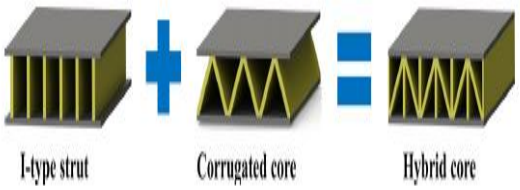


Fig -3: Hybrid core

2. Material properties

The model of the honeycomb sandwich structure is made up of mainly of 3 materials they are of two face sheets and a core between them . The face sheets which are commonly used are of glass fibre UD and carbon fibre UD, The core material is usually Aluminium 5052 . The glass fibre UD and carbon fibre UD are of unidirectional fibres which having zero degree fibre orientation have better compressive strength, modulus of elasticity and shear strength. The Aluminium 5052 have good weldability, good cold formability and medium to high fatigue strength [1] [4] [8].

Table -1: Material Properties

Material	Aluminium 5052	Carbon Fibre UD	Glass Fibre UD
Density (kg/m3)	83	1490	2000
Ex (MPa)	1.48	1.21e + 05	45,000
Ey (MPa)	0.49	8600	10,000
Ez	2129	8600	10,000
υxy	0.58	0.27	0.30
υyz	7.5e _ 05	0.4	0.4
υzx	2.4e _ 04	0.27	0.27
Gx (MPa)	0.72	4700	5000
Gy (MPa)	253	3100	3846.2
Gz (MPa)	524	4700	5000

3. Numerical investigation

3.1. Cell geometry of the model

The analysis is done in finite element method using ANSYS Firstly the model is created using solid works and the thickness of the sheet and meshing is done in Ansys[1] [3]

[8] [10] [13]. The core and the sheets were designed using SOLIDWORKS. For the FEA analysis the thickness of the face sheet is varying it is shown in table 2. The cell geometry of the honeycomb core is given in the figure below.

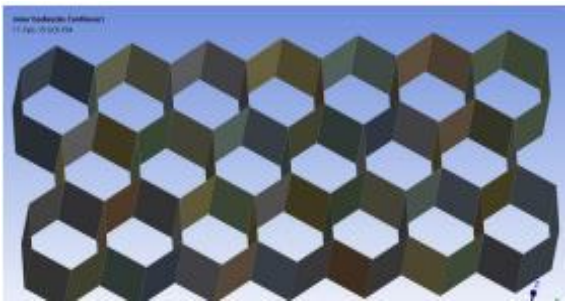


Fig -4: Cell geometry of honeycomb core

Table -2: Natural frequencies for different face sheet thickness

Thickness (mm)	wn1 (Hz)	wn2 (Hz)	wn3 (Hz)	wn4 (Hz)	wxn5 (Hz)	wn6 (Hz)
0.5	73.164	124.63	168.63	173.99	179.64	183.24
1.0	123.40	167.04	179.64	183.24	184.96	185.55
1.5	179.64	180.48	183.23	184.96	188.67	188.91
2.0	179.64	183.24	184.96	188.67	188.91	194.52
2.5	179.64	183.24	184.96	188.67	188.91	194.52

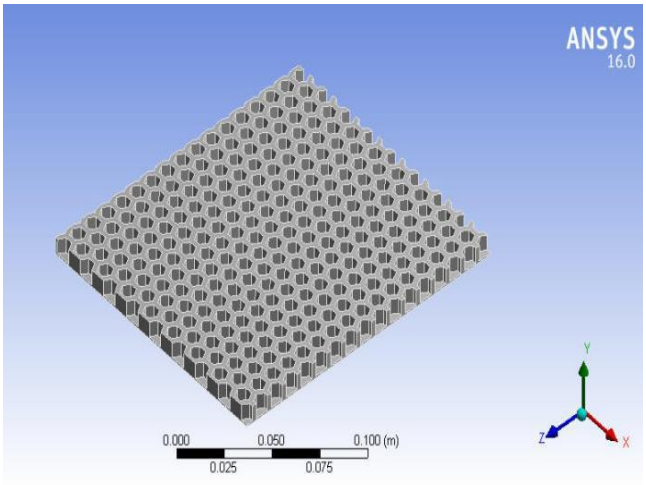
3.2. Boundary conditions

The modal analysis, buckling analysis, bending analysis & static structural analysis is done for the specimen under fixed end conditions. Here the von mises stresses and total deformation should be calculated. By applying various forces we can study the behaviour of the model and also the faces of the plates are in fixed condition. For commonly the varying forces are from 100 Pa to 700 Pa [1] [15].
For evaluating the buckling load as output the finite element analysis or Ansys programme requires a multi input theirfore the input programme requires :

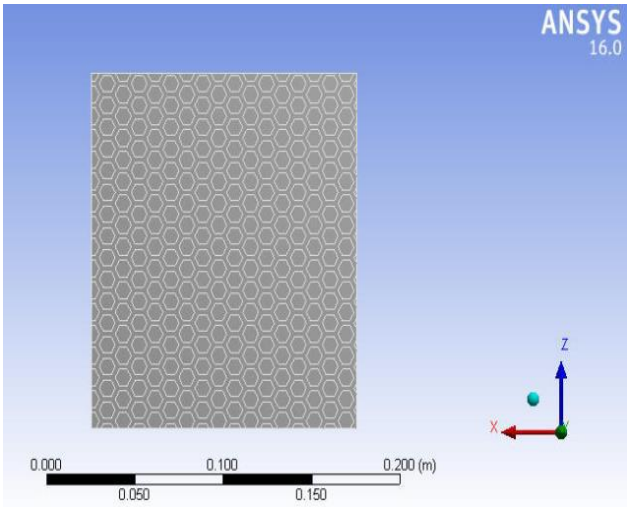
- Mechanical properties of upper and lower sheet plate structure, in addition to, mechanical properties for honeycomb structure plate.
- Dimension, length; width and thickness, for upper and lower sheet plate parts.
- Dimension, length; with; thickness and core size, for honeycomb structure part.
- Boundary conditions for plate structure [15].

4. Finite element analysis of honey comb sandwich structure

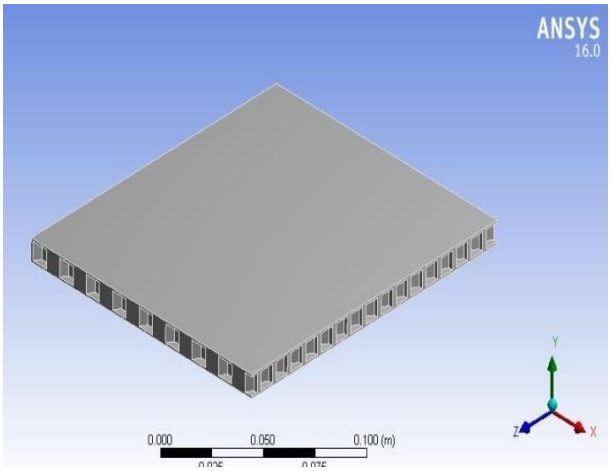
The finite element analysis is used for finding the analytical value of the honeycomb sandwich structure. The software used here is of Ansys 16.0 for the analysis[16]. To make other individual cells here first a unit cell is modelled and it is replicated in X-direction and Y- direction. For assembling the honeycomb core of sandwich panel the individual cells are merged together. To the honeycomb core to develop the full part of honey comb sandwich panel the face sheets are modelled and assembled on it[21].Then the meshing is done. .After meshing the model the boundary condition and load should be assigned. The result from the analyses are of deformation and stresses[1]. The analysis in ANSYS confirms the natural frequency. The analyzing process of each mode in ANSYS is shown in below figure.



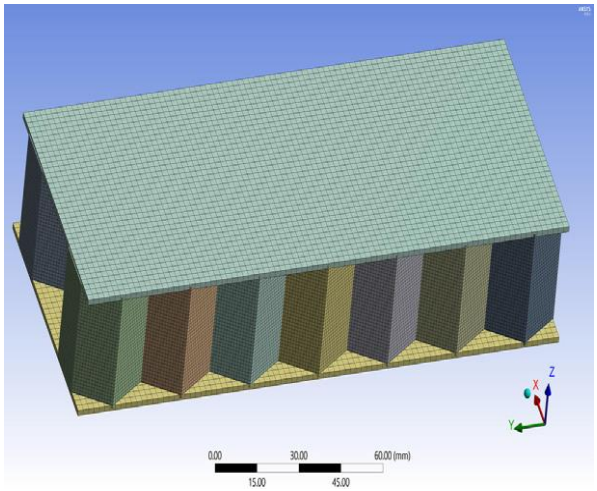
(a) Honeycomb panel before filling the materials



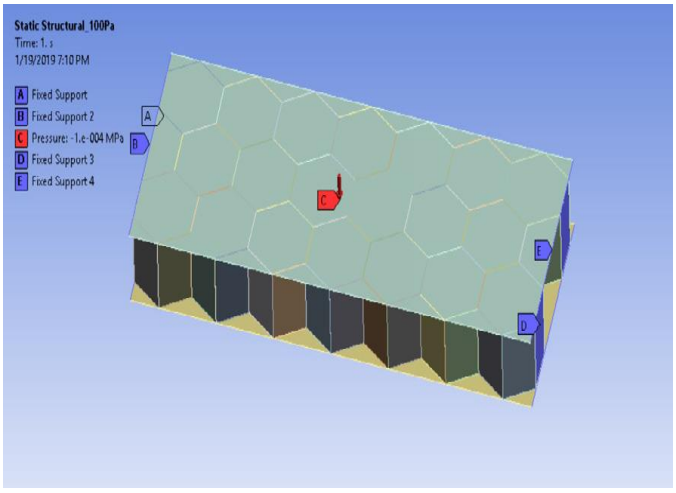
(b) Top view- Honeycomb Sandwich panel



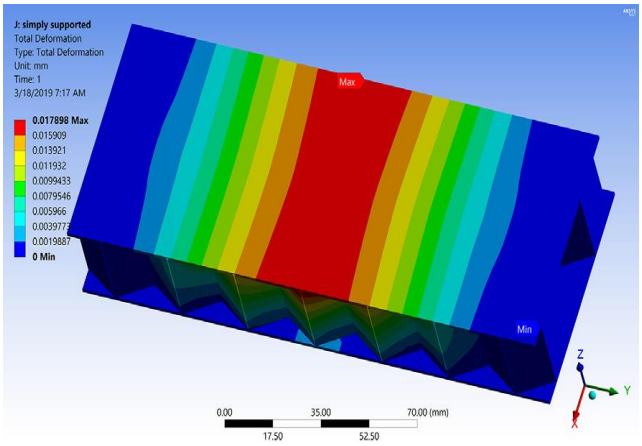
(C) Honeycomb Sandwich panel before analyzing



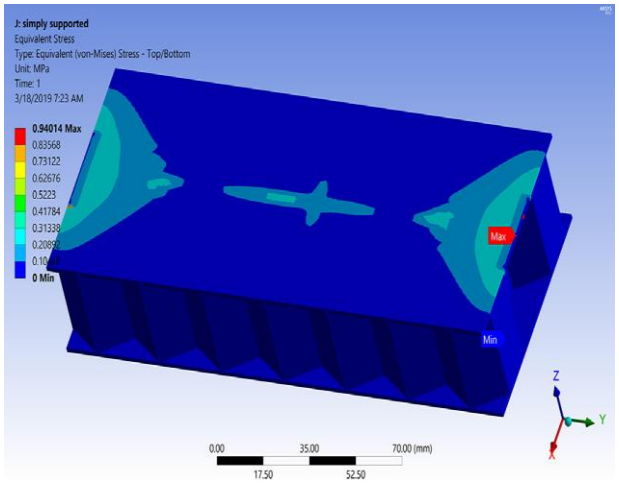
(d) Meshing of honeycomb sandwich structure



(e) Boundary condition of honeycomb sandwich structure



(f) Total deformation at 100pa



(e) Equivalent stress at 100pa

5. Experimental modal testing

The modal testing is mainly used to validate the computational result . The test configuration is shown in the below figure.

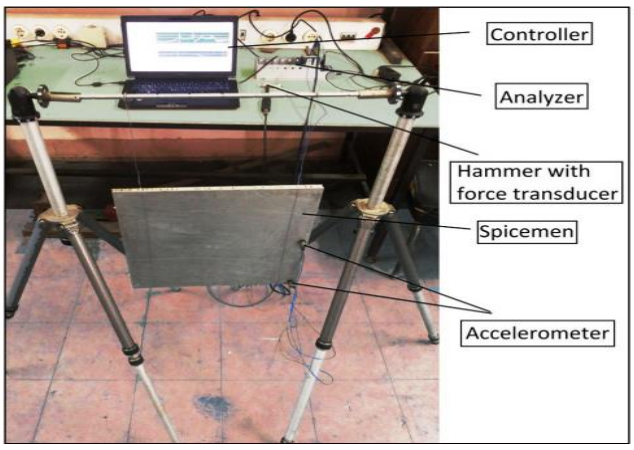


Fig -5: Modal testing configuration

The test includes the following devices:

• A hammer that comprises a force transducer for structure excitation.
• By using special kind of wax the two accelerometers are attached to the plate with response sensing elements. . The location of such accelerometers is determined using numerical modal analysis results in the way that helps to extract the four mode shapes. This location is selected at the points of maximum deformations (corners and sides mid-distance).
• For interpreting hammer force and accelerometers response analyzer is used.
• For controlling the whole test process Laptop with Lab view software is used.

Here from the test eight excitation points are decided at the four corners, and the four mid points of each side. The test procedure implies performing five consecutive hammer impacts at each excitation point in order to take the mean readings[3].The frequency response function (FRF) is recorded and the four natural frequencies are measured as shown in figure.

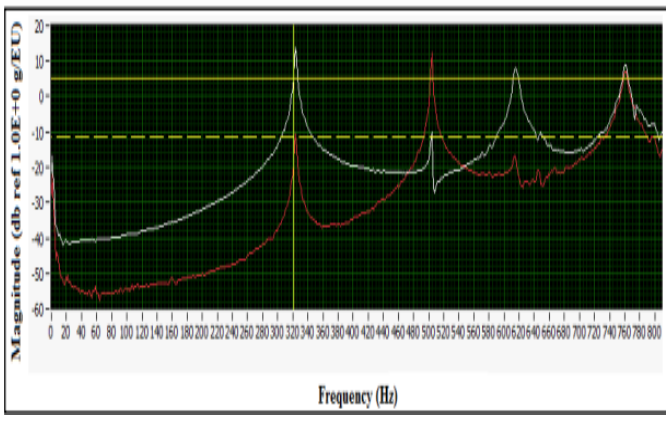


Fig -6: Modal testing FRF

Another experimental test are also used for the analysis of honeycomb sandwich structures they are of mainly Compression and tensile tests [14] [4] and also Drop weight impact test [17] [19]. The figure of the drop weight impact test apparatus is shown below.

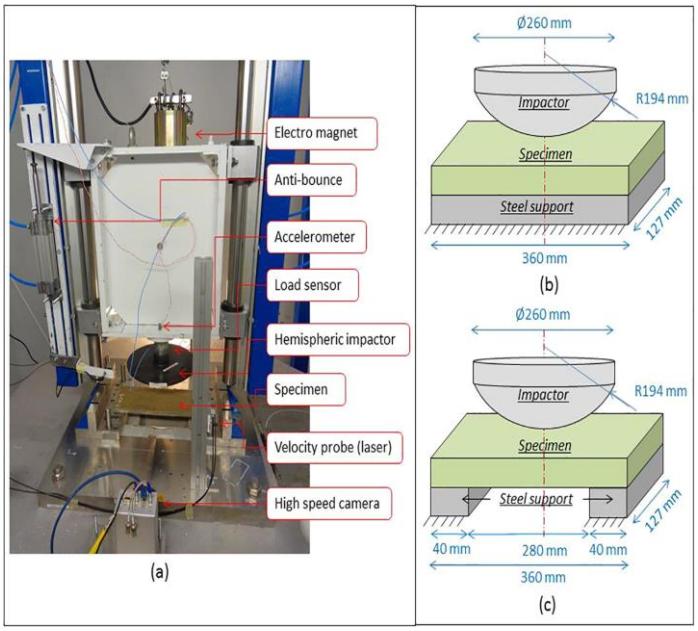


Fig -7: (a) Photography of the drop weight impact test design by Rescoll; (b) Impact boundary conditions with support plan; (c) Impact boundary conditions with bending support.

6. CONCLUSION

For determining natural frequencies under different loading condition in honeycomb structure finite element modeling software Ansys is used. In order to determine deformations and von mises stresses static structural test were conducted.From the experimental setup the FEA method is suitable because it may be used for the comparison of behaviour of various other configuration sandwiched honeycomb structures by changing the parameters of materials. by refining the geometric design, meshing, element type, boundary conditions etc the further results may be improved. It can be understand by the numerical simulation that the honeycomb sandwich structures are good at energy absorption and impact resistance. High rigidity and high strength to weight ratios should be exhibited by the honeycomb sandwich structures. From the above papers it can be understand that the hexagonal cells of honeycomb sandwich structure have less stress distribution and have good stiffness. By increasing the honeycomb structure part thickness lead to modify the structure buckling stiffness and also by increasing the honeycomb core and height lead to modify the mechanical properties. It was observed that the start of plastic deformation could be delayed due to the increase in thickness of the honeycomb core cell it results increase of ultimate strength. While considering the isotropic properties used in honeycomb models among hexagon, octagon, circular shapes the hexagonal shape gave better results and in the hexagonal shape the deformation as well as stresses are minimum. The hybid sandwich structure gives thermal and mechanical advantages and also it gives more strength and specific

energy absorption. Their fore the honeycomb sandwich structure can be used in bridge deck slab, façade cladding and roofing in places with high levels of wind and also it can be used as partition walls.

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