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Investigation of Structural Behaviour of I-Beam Honeycomb Structure

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Abstract:- Honeycomb structures are natural or man-made structures that have the geometry of a sandwich to allow the multilayered materials made of bonding stiffness, high strength skins facings to the low-density core material. The honeycomb sandwich has a high stiffness to weight ratio. So it is used in the structural component. The use of honeycomb composite structure continues to increase rapidly due to the variety of their application, for example, satellite, aircraft, ships automobiles, transportation rails, etc. In this research, an I-Beam honeycomb and hexagonal honeycomb panel are compared and evaluated. Static behavior of sandwich is investigated to determine the permissible load and then a fatigue analysis is carried out to investigate to predict the lifetime. The objective of the work is to find a number of cycles that a structure sustains at a particular mid-point load. If a structure fails at an early stage, efforts will be taken to increase its stiffness and strength as design parameters. A Finite element analysis of sandwich structures is to be carried out with numerical analysis as both preprocessor and post-processor. The finite element analysis results in hexagonal honeycomb compared with I-beam honeycomb panel.

Keywords: *ANSYS, ASTM Standard, Honeycomb Core, Three Point Bending, Fatigue Life.*

I. INTRODUCTION

A cellular structure is made of an interlinked network of solid plates which comprise the edges and face. The simplest form of cellular solid is a 2D array of polygons which packed like the hexagonal cells of the honey bee to fill a plane area. For this reason, we call 2D cellular materials as honeycombs. Usually, the cells are polygon which packed in 3D to form cellular materials which are known as foams. Relative density is one of the most important features of cellular solid, where the density of a cellular material and density of the solid from which the cell walls are made.

Cellular structures which have the wide range of properties available to an engineer. These solids have the properties like mechanical, physical and thermal are measured by the same methods used for fully dense solids. The low-density solids allow the design of rights and stiffness components like sandwich panels. Very large movable structure and floating devices. Cheap reliable thermal insulation is achieved by low thermal conductivity. For cushioning application, foams having low stiffness is used. The best examples are elastomeric foams. Which stand material for seating. The low strengths and large compressive strains make foams attractive for energy-absorbing applications.

II. MECHANICS OF HONEYCOMBS

Polymer, ceramic and metal honeycombs are used in the wide range of applications. Both metal and polymer honeycomb is used in energy absorbing devices in some application. It is used in the load-bearing structure, further understanding of mechanical behavior is important. Studying honeycomb structure helps in the understanding of the mechanics of more complex 3D foams of the honeycomb structure is loaded in the plane, when the applied stress is acting in that plane. Linear elastic deformation and cell wall bending are occurring when the honeycomb structure is blended. Cells tend to collapse after certain limit by elastic buckling, plastic yielding, creep or brittle fracture depending upon the nature of cell wall material. When the cell collapse end. The stiffness and density increase when cells contact each other. The strength and in-plane stiffness are always low.

When a honeycomb is compressed, the cell walls start to bend and cause a linear elastic deformation. Beyond a critical strain, the cells collapse by elastic buckling, plastic yielding, creep or brittle fracture, depending on the nature of the cell wall material. Whenever the opposing cell walls contact each other, cell collapse ends. As the cells close up the structure densifies and its stiffness increases rapidly. The in-plane stiffness and strength are the lowest because the cell walls respond to external loads by bending, and subsequent buckling, yielding, or fracturing. The out-of-plane stiffness and strength are much larger since they require axial deformation of the cell walls. In this chapter, the in-plane strength of hexagonal honeycombs is studied.

III. DATA ANALYSIS

Ashby, M., & Gibson L. explain the analysis for the determination of distributed stresses on the panel under bending load. The mathematical model is identical for all types of bending loading configuration except for the valves of geometrical constants. The normal or compressive stresses in the sheets and core and shear stresses is calculated from the following equations. When a honeycomb, loaded in the two direction, deforms in a linear-elastic way, the cell walls bend. The Young’s moduli in each direction are calculated by the method.

A stress parallel to one side causes one set of cell walls those of length l to bend; one cell wall is shown in the figure.

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Equilibrium requires that the component of force G parallel to other side be zero. The moment tending to bend the cell wall which is treated as a beam of length l, thickness t, depth b, and Young's modulus is:

$$M = \frac{pl\sin\theta}{2} \quad \text{------------- (1)}$$

$$P = \sigma 1(h + l\sin\theta)b \quad \text{------------- (2)}$$

$$\delta = \frac{Pl^3 \sin\theta}{12EsI} \quad \text{------------- (3)}$$

$$E_1 = \frac{\delta \sin\theta}{l\cos\theta} = \frac{\sigma_1 (h + l\sin\theta) b l^2 \sin^2\theta}{12 E_S I \cos\theta} \quad \text{------------- (4)}$$

$$\frac{E_1^*}{E_S} = \left(\frac{t}{l}\right)^3 \frac{\cos\theta}{(h/l + \sin\theta)\sin^2\theta} \quad \text{-------------(5)}$$

$$M = \frac{Wl\cos\theta}{2} \quad \text{------------- (6)}$$

$$\delta = \frac{Wl^3\cos\theta}{12E_sI} \quad \text{------------- (7)}$$

$$\varepsilon_1 = \frac{\delta COS\theta}{h + l\sin\theta} = \frac{\sigma_2 b l^4 \cos^3\theta}{12E_S I(h + l\sin\theta)} \quad \text{------------- (8)}$$

$$\frac{E_2^*}{E_S} = \left(\frac{t}{l}\right)^3 \frac{(h/l + \sin\theta)}{\cos^3\theta} \quad \text{------------- (9)}$$

For regular hexagonal with walls of uniform thickness, both Young's moduli, E1* and E2*, reduce to the same value:

$$\frac{E_1^*}{Es} = \frac{E_2^*}{Es} = 2.3\left(\frac{t}{1}\right)^3 \quad \text{------------- (10)}$$

IV. EXPERIMENTAL PROGRAM

A. Research Methodology

The First level or Preliminary analysis of design uses tools that have to be simple to design the Hexagonal cell structure and I-beam Hexagonal cell structure and then extrude. After that Assembly of the group of Hexagonal cells will be generated for some cases for analysis. The secondary level of design of panel of the rectangle. Numerical codes are based on finite difference methods (FEM) or finite element methods (FDM), with 1D, 2D or 3D models of physical phenomena (structural analysis). They allow precise calculations or optimization up to defining the final geometry as shown in fig.1.

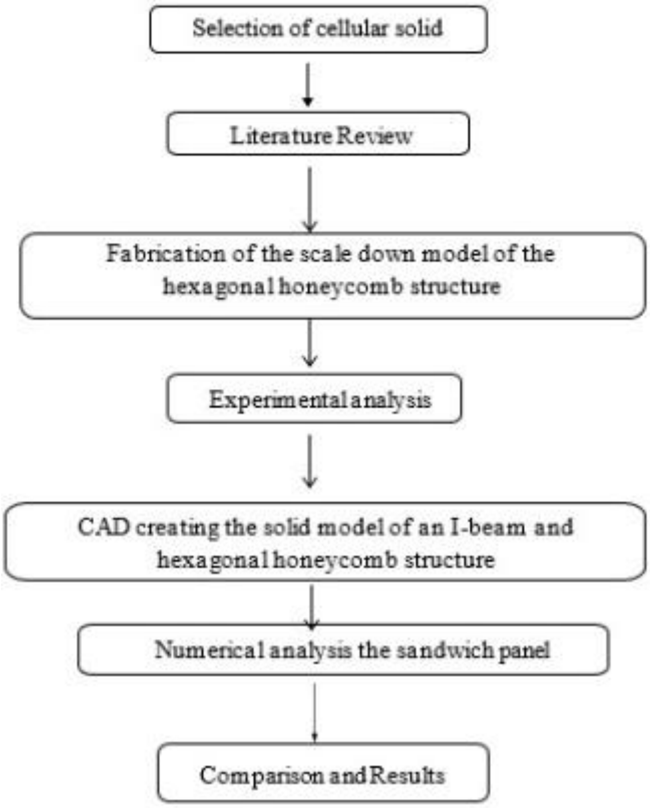

Fig 1: Flow Chart

B. Problem Definition

The concept of the skin of aircraft application with cellular honeycomb core covered by a face sheet in aircraft wing skin has been already studied. In order to improve the mechanical properties frequently an I-beam honeycomb core can be placed on the surface. The design for the wing is carried out using a CAD package (Pro/E or Unigraphics) and the model will be analyzed using an FEA based simulating software.

C. Material Selection

Design of the structure we are analyzed with different type of material like Aluminum 3003, and Aluminum 8081 clear over view on material properties are given in table 1.

Properties	Core wall Aluminum 3003	Face sheet Aluminum 8081
Density	83 kg/m^3	0. 47 kg/m^2
Poisson's ratio	0.33	0.125
Elongation (%)	13	4.8
Tensile Modulus (GPa)	70.3	20
Compressive Modulus (GPa)	1.31	17

Table 1:- Mechanical Properties Of Core And Face

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D. Phases of design

The face-sheet of the sandwich panel was made of Aluminum 8081. Honeycomb Core is made of Aluminum 3003. Geometrical Dimensions of core are given in Table 2 and face sheet as shown in fig.2 & 3.

Item	Specimen	Honeycomb panel (mm)
Core	Cell size (s)	6.35
	Thickness (t)	0.06
	I-beam section	2.032
Honeycomb panel	Thickness	13.5
	Length	200
	Width	28
Flat plate	Thickness	1
Total	Thickness	14

Table 2: Geometrical Dimensions

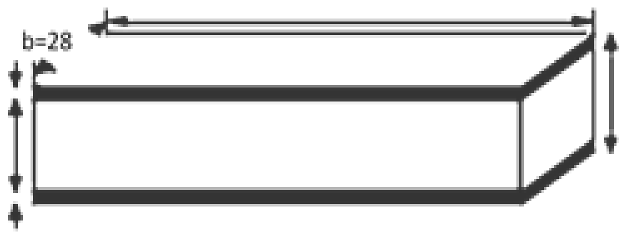

Fig 2:- Sandwich Structure

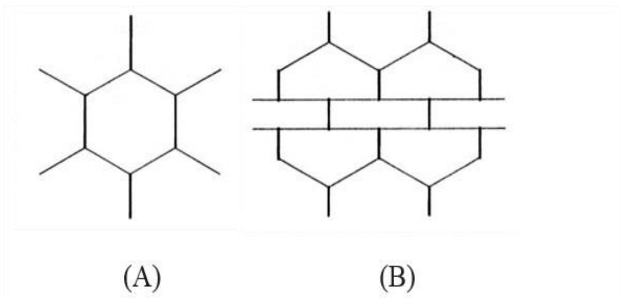

Fig 3:- (A) Honeycomb panel (B) I-beam honeycomb cell

E. Experimental Procedure

Both static and fatigue tests were carried out through a three point bending testing fixture using the Autograph, AG –IS 50KN Shimadza, Chennai. AGSI is an indispensable resource to obtain the information about the characterization of all types of materials and available in Mechanical material testing laboratory. The three point loading configuration based on ASTM C-393 as shown in Fig. 4. The static test was carried out by loading specimen under ultimate stress. The fatigue tests were carried out at several loading levels obtained from 90%, 75% to 60% of ultimate load as shown in Fig.5. The constant amplitude sinusoidal waveform loading was selected. The ratio of minimum applied load to maximum load R was considered 0.1 in all fatigue tests.

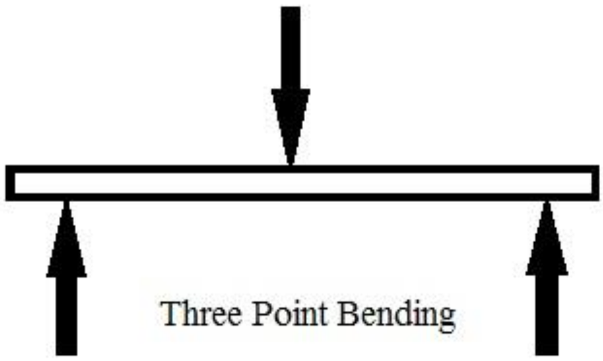

Fig 4:- Three Point Bending using with ASTM C393

Fig 5:- Experimental Setup

V. RESULTS AND DISCUSSION

A. Static Tests

Static tests were carried out to determine the ultimate load and stiffness of the sandwich panel in order to set the amplitude of fatigue loading is given in Table 3. Under static load the ultimate static failure load is recorded and on the basis of the information of static failure load and the geometric parameters the average flexural strength and stiffness of the panel is calculated using the data analysis discussed in section is given in Table 4 & 5. The behavior of the load versus the displacement for tested is shown in Fig.6.

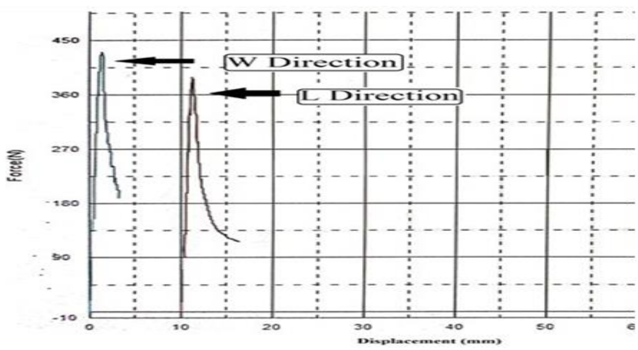

Fig 6:- Static Test

NAME	Max_Force	Max_Stress	Max_Strain	Elastic
Units	N	N/mm^2	%	N/mm2
W	432.250	15.9564	0.55989	2081.40
L	390.750	13.4733	0.50119	2851.67
Mean	411.500	14.7148	0.53054	2466.53

Table 3:- Output Value for Ultimate Strength

W- DIRECTION	HEXAGON HONEYCOMB	IBEAM HONEYCOMB
CASE I (389.025 N)	0.065421	0.039734
CASE II (324.1875N)	0.054518	0.033112
CASE III (259.35 N)	0.026489	0.015328

Table 4: W-Direction (Comparison of hexagon and I-beam honeycomb)

L- DIRECTION	HEXAGON HONEYCOMB	IBEAM HONEYCOMB
CASE I (351.675 N)	0.074414	0.05590
CASE II (293.0625 N)	0.062012	0.046584
CASE III (234.45 N)	0.049609	0.037267

Table 5: L-Direction (Comparison of hexagon and I-beam honeycomb)

B. Fatigue Tests

The purpose of fatigue test is to predict the life of honeycomb as well as the investigation of fatigue modes. The graph between fatigue deflection and the no. of cycles at different loading levels is shown in table 6. It can be seen from the figure that the deflection is almost constant in the start because of the degradation of stiffness. Initiation of failure is considered where the deflection starts to increase abruptly. The slight increase in deflection in the beginning is due to the face yielding. The abrupt increase in deflection is caused by the small indentation and bounding of honeycomb core and face interface at loading area. It was observed that at higher load the initiation of failure occurs near the final failure because of the face yield and final failure is because of compression of face sheet but in case of small load the initiation of failure occurs because of face yield as well as delamination below the loading area and final failure occurs because of indentation.

METHOD OF ANALYSIS	HEXAGON HONEYCOMB	IBEAM HONEYCOMB
NO. OF CYCLES	1,60,000	2,30,000

Table 6:- No of Cycle

VI. DISCUSSION

In structural analysis, the model has been extracted in IGES format. Here the material chosen is aluminum which is subjected to boundary conditions such as the sandwich plate has been fixed and given a point load act on midpoint as 90%, 75% and 60% indented on a sandwich plate. The total deformation along Y-axis. It is found that maximum Deformation in the hexagonal sandwich plate and the I-beam hexagonal sandwich plate.

A. Total Deformation

- *L –DIRECTION*

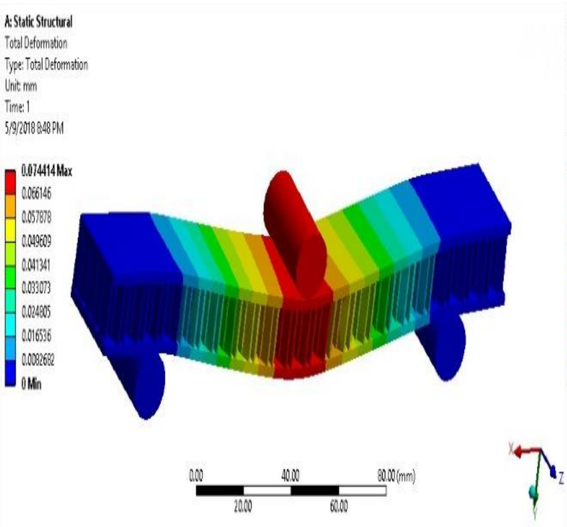

Fig 7(a):- I - beam panel (351.675)

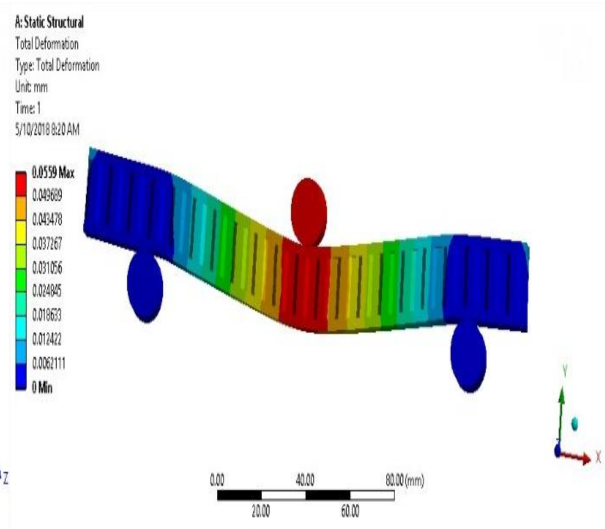

Fig 7(b):- Hexa Panel (351.675)

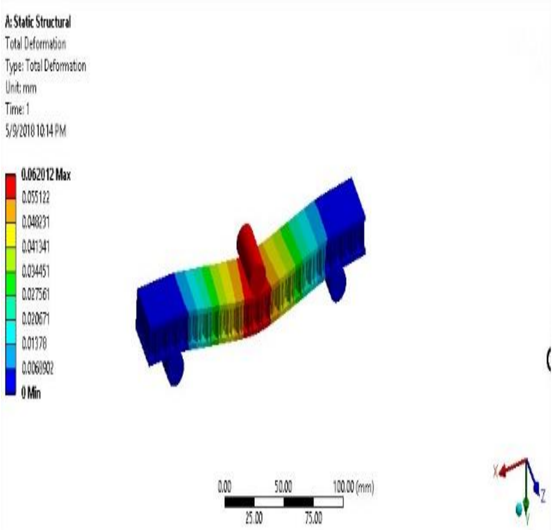

Fig 8(a):- I - beam panel (293.0625)

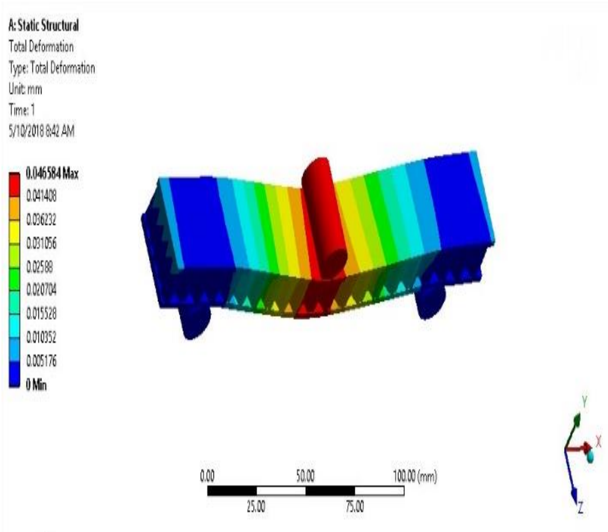

Fig 8(b):- Hexa Panel (293.0625)

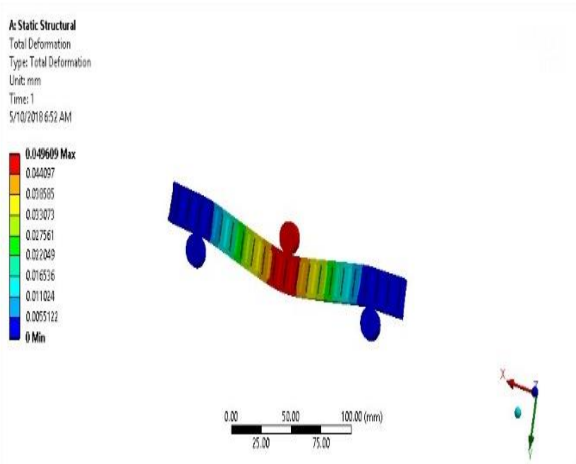

Fig 9(a):- I - beam panel (234.45)

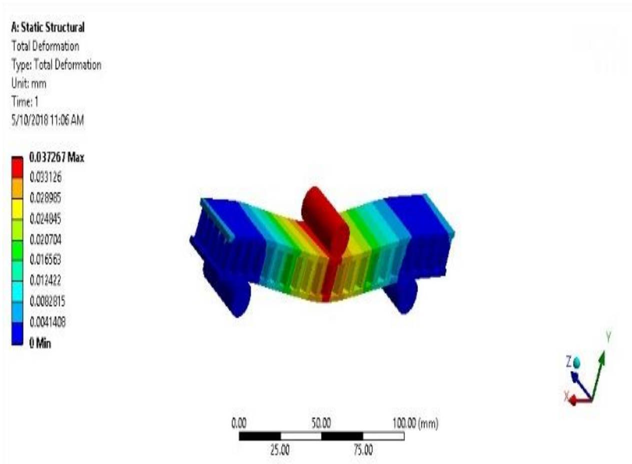

Fig 9(b):- Hexa Panel (234.45)

- *W –DIRECTION*

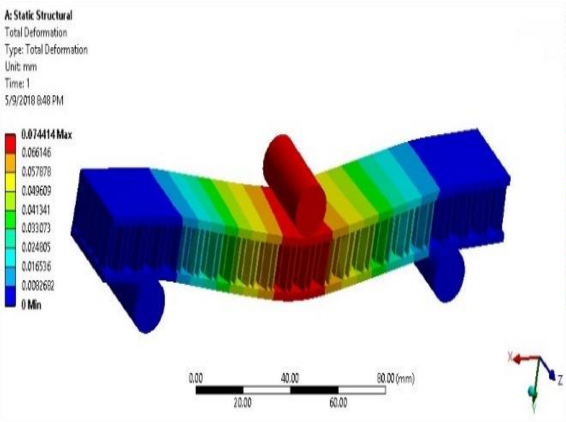

Fig 10(a):- I - beam panel (389.025)

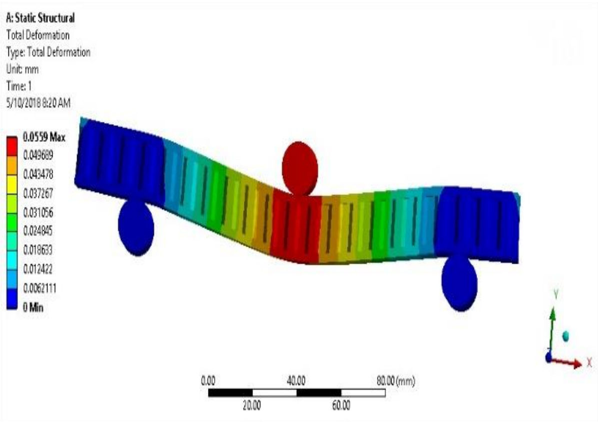

Fig 10(b):- Hexa Panel (389.025)

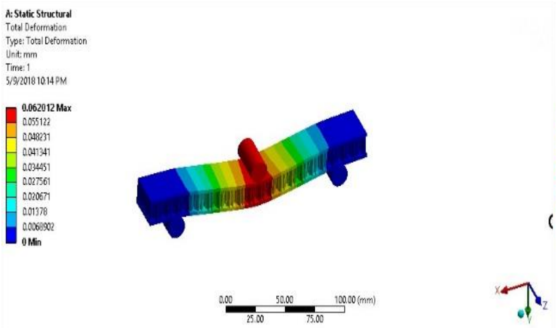

Fig 11(a):- I - beam panel (324.1875)

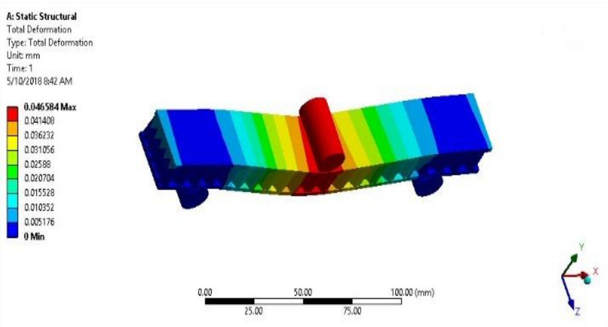

Fig 11(b):- Hexa Panel (324.1875)

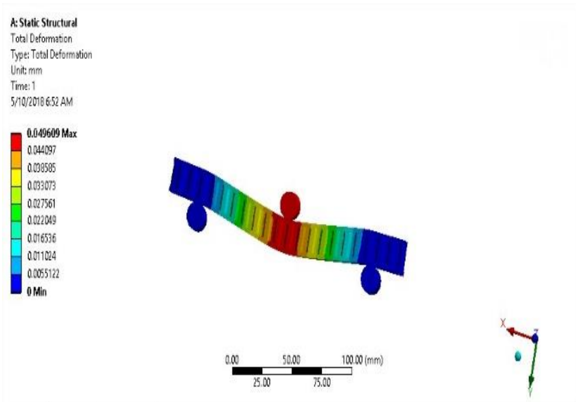

Fig 12(a):- I - beam panel (259.35)

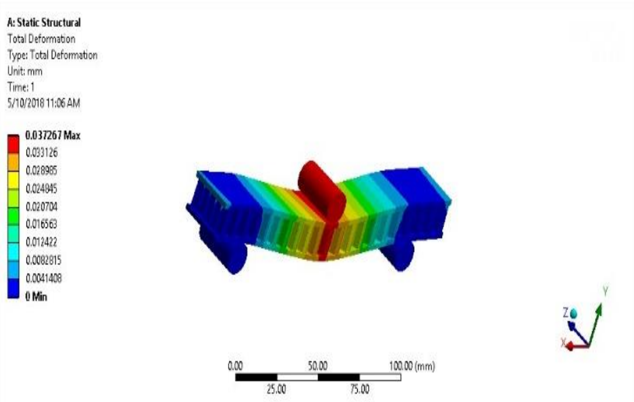

Fig 12(b):- Hexa Panel (259.35)

VII. CONCLUSION

In this research, fatigue analysis is made on three-point bending in two kinds of sandwich panels. Namely hexagonal honeycomb and I-beam honeycomb panel.

- Static analysis of honeycomb panel is made on W and L direction. Then static ultimate strength attains in W and L direction is 432.250 N and 390.750 N.
- The load levels of 90%, 75% and 60% of static ultimate tensile strength are taken as a load to carry the numerical analysis for both hexagonal honeycomb and I-beam honeycomb. The I-beam honeycomb gets low deformation than hexagonal honeycomb.
- Fatigue analysis is analyzed numerically to predict the fatigue life of the panel. The result shows that fatigue life of I-beam honeycomb is greater than hexagonal honeycomb

VIII. FUTURE WORK

In future, The Fatigue analysis of I-beam honeycomb panel should be carried out experimentally and then thermal analysis, impact analysis and dynamic analysis for I-beam honeycomb will be evaluated.

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