Design of Medium Density fiber, Aluminium Composites Panel & Buckling Analysis

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Abstract – **Aluminium Sandwich panel is a structure made of three layers; low density core inserted in between two relatively thin skin layers of aluminium. As this sandwich setup allows achieving excellent mechanical performance at minimal weight, can be used in those applications where high structural rigidity and low weight is required. The typical applications includes packaging, transportation and automotive as well as building & construction. This project work includes the study and analysis of various mechanical properties and buckling analysis of Aluminium and Aluminium Sandwich (Composite) Panel to find it industrial applications viz., in machine cabinets, etc.**

Keywords – **Composite materials, medium density fiber, tensile Test, CAD Analysis**

I. INTRODUCTION

Now a day, many industries required to take the economical advantages of weight reduction. The composite setup of materials allows achieving excellent mechanical behaviour at very low weight. The very high rigidity of a composite panel is achieved under flexural load applied to the panel. Aluminium composite panel (ACP) also known as aluminium composite material, (ACM) is one of the types of flat panel that consists of two thin aluminium sheets bonded to a non-aluminium core, as shown in figure. The inner metal (Core) takes the she are loads and creates a distance between the two aluminium sheets which take the in-plane stresses, upper aluminium skin experiences tension, whereas the lower in compression. Composite structure give high stiffness and strength for lightweight panels and structures. Composite panels with low cost core materials are not only be more lightweight but also less expensive, especially because of the ease of production processes. The use of multiple materials to utilize their desired properties is the basic idea of composites engineering. A composite construction use the fact that the core of a panel that is loaded in bending carry very less in-plane stresses and does not appear on the surface of the composite panel. The core can thus be made by using various, lightweight and/or materials with low cost.

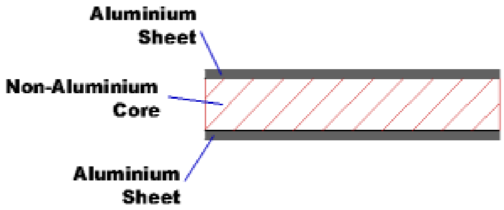


Fig. No.1. Aluminum Metal Sheet(Ref.Paper.1)

In lightweight composite materials the thickness of the core is usually more than that of skin material and has a much lower density as compared to the skins material. The important mechanical requirement for the core layer is to restrict the movement of the skins layers relative to each other (in-plane and out-of-plane). Enough out-of-plane compression properties of the sandwich core are required to support the skins material layers to maintain their distance from the neutral axis, to avoid their buckling and to stop their deformations due to loadings.. Enough good shear properties of the core are also desired to restrict in-plane displacement of the skins relative to each other due to transverse loadings. With high mechanical in-plane properties per weight the skin material usually has to fulfil other requirements like high surface quality, low costs, and good behaviour under loadings.

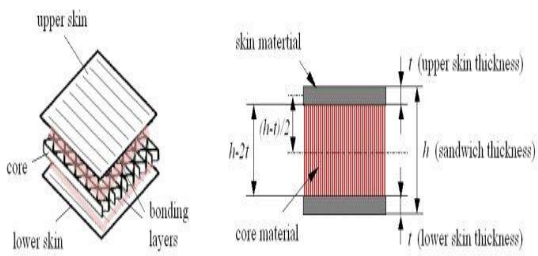


Fig.No.2. Design of Aluminum Composites Panel (Ref.Paper.1)

A. *Problem Definition*

Everywhere using metal sheets is not possible, various applications in industry as well as in society perform actions where weight and easiness of installation is considered, and also sheet metal work in metal form, carbon steels are not accepted everywhere so solution we are trying to replace this sheet metal work with light weighted composite panels.

B. *Aim of the project*

1. To design medium density fiber, aluminium composites panel.

2. To buckling and bending analysis composites panel.

C. *Objective of project*

1. To study and analyse various mechanical properties of Aluminium
2. To study and analyse various mechanical properties of Aluminium multilayer Composite
3. Strength analysis of aluminium and its composite with different boundary conditions
4. Buckling bending behaviour
5. Variants creation and comparing the results Experimentation on standard size panels 12x5 ft

D. *Scope of project*

1. Design of structural panel
2 .Design of test setup of composite panel
3. Multi layer panel with variant
4. Deciding application in domestic and commercial purpose variant wise.
5. CAE validation with multi loading boundary conditions

II. BACKGROUND

Automotive industry is on the verge of development and more comforts are being incorporated in a vehicle. Also the customers have high demand of fuel economy, high performance at low cost. In order to get high fuel economy the manufacturers are intended to minimize the weight. In this paper Author has selected composite material of Aluminium (Aluminium skin, polyethylene core, resin binder material). To optimize of mass of composite material. Tensile test, bending test has been carried out on Universal Testing Machine (UTM).

III. Research Methodology

A. *Design Methodology*

1. Design and CAD implementation

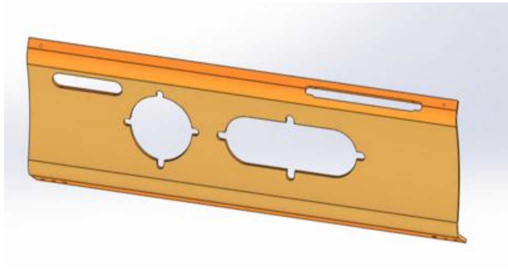


Fig.No.3.Complex Application and shapes function

Preparing different CAD model in sheet metal with applying material properties on every layer, CAD shape to be made complex cuts and bends to prove its stability and mechanical strength limits.

2. Custom Design and Fabrication

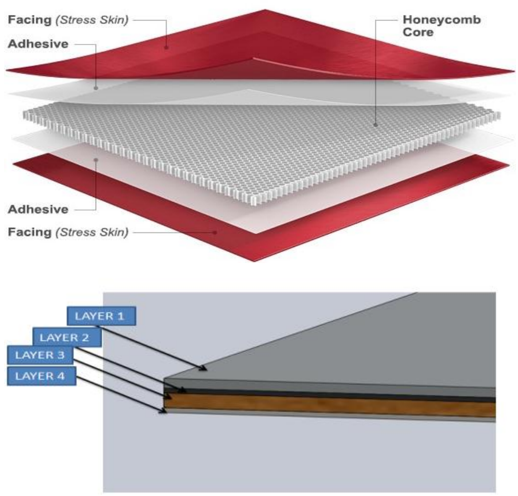


Fig.No.4. Honeycomb with MDF pulp (Ref.Paper.2)

3. Sandwich panel

- Cold and Hot Laminating
- Welding
  - Finished Edges
  - Adhesive Bonding and Assembly
  - Powder Coating if required
  - Forming

IV. Material Selection For sandwich Panel

1. sandwich panel

Sandwich panels are a type of composite materials which have become very significant due to high bending strength and stiffness. Properties viz., Low density of these materials makes them special for use in various applications such as aeronautical, space and marine applications. Geometry of the composite plate is shown in figure

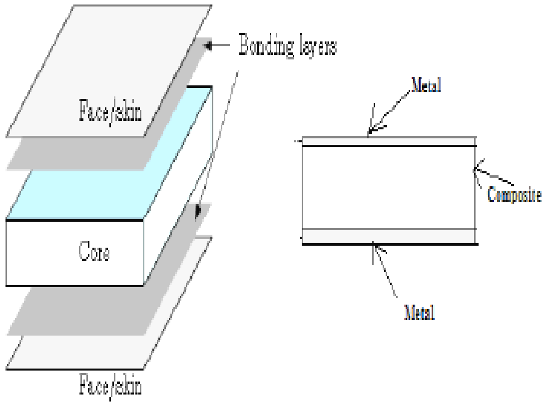


Fig.No.5. Honey Comb Sandwich Panel (Ref.Paper.2)

Properties/ Material	Aluminium	Steel
Stiffness N/m	$22.9*10^3$	$22.65*10^3$
Density Kg/m^3	2700	7800
Weight	Low	High
Young modulus of elasticity N/m^2	$70000*10^6$	$210000*10^6$
Shear modulus N/m^2	$27000*10^6$	$81000*10^6$
Poisson ratio	0.33	0.3
Coefficient of thermal expansion I/K	$23*10^{-3}$	$12*10^{-3}$
Corrosion resistances	High	Low
Ductility	High	Low
Recyclability	Very good	Good
Cost	High	Low

Table No.1. Aluminium composites panel material

IV. Buckling of sandwich Panel

For sandwich panels with material gradients along the thickness, the location of the neutral axis is obtained from Equation.

$$y_0 = \frac{\int_0^{t_1} E_{0f}F\left[T(y),m_f\right]y\,dy + \int_{t_1+c}^{t_1+t_2+c} E_{0f}F\left[T(y),m_f\right]y\,dy + \int_{t_1}^{t_1+c} E_{0c}F\left[T(y),m_c\right]y\,dy}{\int_0^{t_1} E_{0f}F\left[T(y),m_f\right]dy + \int_{t_1+c}^{t_1+t_2+c} E_{0f}F\left[T(y),m_f\right]dy + \int_{t_1}^{t_1+c} E_{0c}F\left[T(y),m_c\right]dy},$$

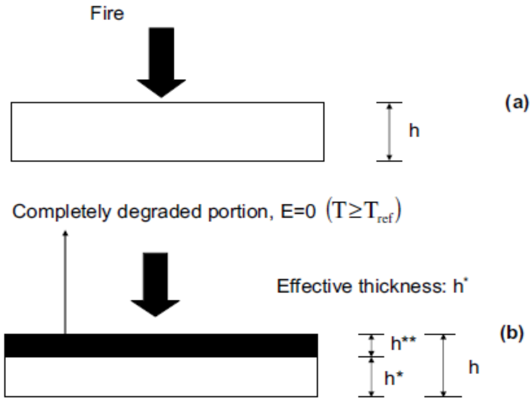


Fig. no.6. Design of analysis Panel

$$P_{cr} = P_E\frac{1 + P_{Ef}/P_c - \left(P_{Ef}/P_c\right)\left(P_{Ef}/P_E\right)}{1 + P_E/P_c - P_{Ef}/P_c},$$

where

$$P_E = \frac{\pi^2 D}{l^2};\quad P_{Ef} = \frac{\pi^2 D_f}{l^2};\quad P_c = AG^*.$$

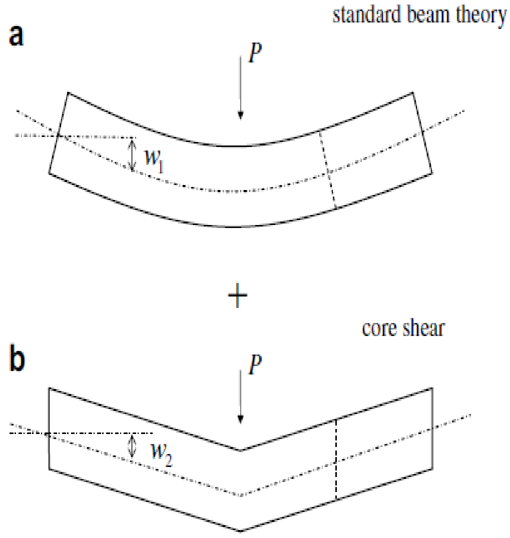


Fig.No.7. Bending deformation in a sandwich panel is composed of two deformation modes.(Ref.Paper.4)

V. Design and Behaviour analysis

The virtual design of a composite sandwich panel requires an efficient multi-scale modelling strategy used in the composites. The virtual design of a composite sandwich panel requires a multi-scale modelling strategy to be able to map the effect of the microstructure onto the macroscopic performance of the panel on composites panel.

1. Analysis on forming standard thickness variants

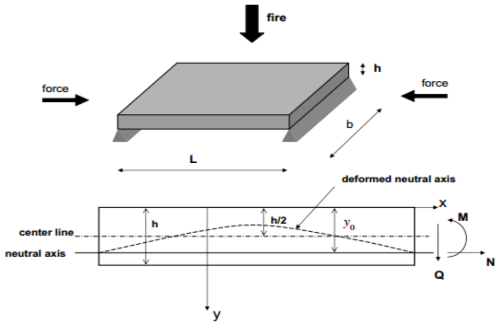


Fig.No.8. Setup to Form

Stresses and Deflection (Analytical Approach) As we are taking layers of four different materials Aluminium, Rubber, Mild Steel and MDF. The Modulus of Elasticity of the composite material is
E = (70 + 0.1 + 200 + 2.5) / 4 = 68.15 GPa
We have taken the plate of composite as shown in fig

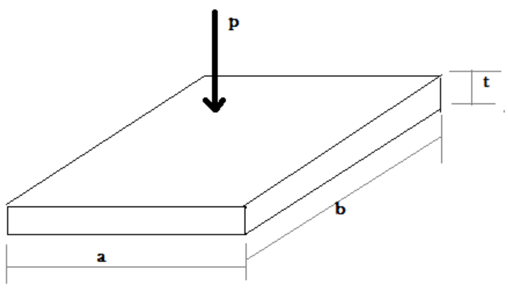


Fig.No.9.rectangular plate with edge simply supported

The plate is considered as Rectangular plate with edges simply supported. We have, a = 400 mm and b = 400 mm
Hence, Maximum bending stress is given by,

$$\sigma_{max} = \frac{\beta q b^2}{t^2}$$

And
Maximum Deflection is given by,

$$y_{max} = \frac{\alpha q b^2}{E t^2}$$

Where,
q = pressure = p/A (N/mm^2)
t = thickness
E = Modulus of Elasticity = 68.15 GPa
Also
For a /b = 1
β = 0.2874 and
α= 0.0444
Hence, Maximum bending stress is given by,

$$\sigma_{max} = \frac{0.2874 q b^2}{t^2}$$

And
Maximum Deflection is given by,

$$y_{max} = \frac{0.0444 q b^2}{E t^2}$$

For load P = 200N
Pressure, q = 0.00125 MPa
Case I
Let Thickness, t = 4 mm
Therefore,
Maximum bending stress is given by,

$$\sigma_{max} = \frac{0.2874 \ x \ 0.00125 \ x \ 400^2}{4^2}$$

$\boldsymbol{\sigma_{max} = 3.59}$ **N/mm^2**
And
Maximum Deflection is given by,

$$y_{max} = \frac{0.0444 \ x \ 0.00125 \ x \ 400^2}{68.15 \ x \ 4^2}$$

$\mathbf{y_{max} = 0.008}$ **mm**

Case II
Let Thickness, t = 8 mm
Therefore, Maximum bending stress is given by,

$$\sigma_{max} = \frac{0.2874 \ x \ 0.00125 \ x \ 400^2}{8^2}$$

$\boldsymbol{\sigma_{max} = 0.89}$ **N/mm^2**
And
Maximum Deflection is given by,

$$y_{max} = \frac{0.0444 \ x \ 0.00125 \ x \ 400^2}{68.15 \ x \ 8^2}$$

$\mathbf{y_{max} = 0.002}$ **mm**
Case III
Let Thickness, t =12 mm
Therefore,
Maximum bending stress is given by,

$$\sigma_{max} = \frac{0.2874 \ x \ 0.00125 \ x \ 400^2}{12^2}$$

$\boldsymbol{\sigma_{max} = 0.4}$ **N/mm^2**
And
Maximum Deflection is given by,

$$y_{max} = \frac{0.0444 \ x \ 0.00125 \ x \ 400^2}{68.15 \ x \ 12^2}$$

$\mathbf{y_{max} = 0.0009}$ **mm**

For load P = 400 N
Pressure, q = 0.0025 MPa
Case I
Let Thickness, t = 4 mm
Therefore,
Maximum bending stress is given by,

$$\sigma_{max} = \frac{0.2874 \ x \ 0.0025 \ x \ 400^2}{4^2}$$

$\boldsymbol{\sigma_{max} = 7.1}$ **N/mm^2**

And
Maximum Deflection is given by,

$$y_{max} = \frac{0.0444\ x\ 0.0025\ x\ 400^2}{68.15\ x\ 4^2}$$

$$\mathbf{y_{max} = 0.016\ mm}$$

Case II
Let Thickness, t = 8 mm
Therefore,
Maximum bending stress is given by,

$$\sigma_{max} = \frac{0.2874\ x\ 0.0025\ x\ 400^2}{8^2}$$

$$\boldsymbol{\sigma_{max} = 1.8\ N/mm^2}$$

And
Maximum Deflection is given by,

$$y_{max} = \frac{0.0444\ x\ 0.0025\ x\ 400^2}{68.15\ x\ 8^2}$$

$$\mathbf{y_{max} = 0.01\ mm}$$

Case III
Let Thickness, t =12 mm
Therefore,
Maximum bending stress is given by,

$$\sigma_{max} = \frac{0.2874\ x\ 0.0025\ x\ 400^2}{12^2}$$

$$\boldsymbol{\sigma_{max} = 0.8 N/mm^2}$$

And
Maximum Deflection is given by,

$$y_{max} = \frac{0.0444\ x\ 0.0025\ x\ 400^2}{68.15\ x\ 12^2}$$

$$\boldsymbol{y_{max} = 0.002\ mm}$$

For load P = 1000 N
Pressure, q = 0.00625 MPa
Case I
Let Thickness, t = 4 mm
Therefore,
Maximum bending stress is given by,

$$\sigma_{max} = \frac{0.2874\ x\ 0.00625\ x\ 400^2}{4^2}$$

$$\boldsymbol{\sigma_{max} = 17.96\ N/mm^2}$$

And
Maximum Deflection is given by,

$$y_{max} = \frac{0.0444\ x\ 0.00625\ x\ 400^2}{68.15\ x\ 4^2}$$

$$\mathbf{y_{max} = 0.041\ mm}$$

Case II
Let Thickness, t = 8 mm
Therefore,
Maximum bending stress is given by,

$$\sigma_{max} = \frac{0.2874\ x\ 0.00625x\ 400^2}{8^2}$$

$$\boldsymbol{\sigma_{max} = 4.5\ N/mm^2}$$

And
Maximum Deflection is given by,

$$y_{max} = \frac{0.0444\ x\ 0.00625\ x\ 400^2}{68.15\ x\ 8^2}$$

$$\mathbf{y_{max} = 0.01\ mm}$$

Case III
Let Thickness, t =12 mm
Therefore,
Maximum bending stress is given by,

$$\sigma_{max} = \frac{0.2874\ x\ 0.00625x\ 400^2}{12^2}$$

$$\boldsymbol{\sigma_{max} = 1.99\ N/mm^2}$$

And
Maximum Deflection is given by,

$$y_{max} = \frac{0.0444\ x\ 0.00625\ x\ 400^2}{68.15\ x\ 12^2}$$

$$\mathbf{y_{max} = 0.005\ mm}$$

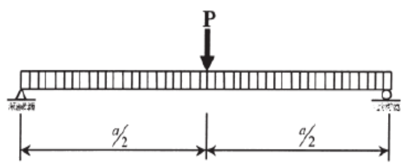


Fig.No.9. A simply supported sandwich panel

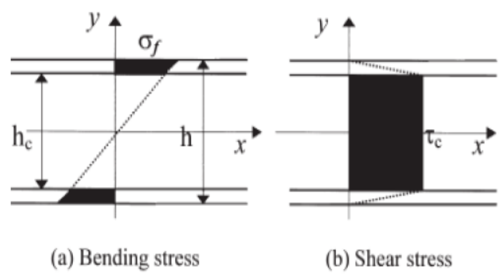
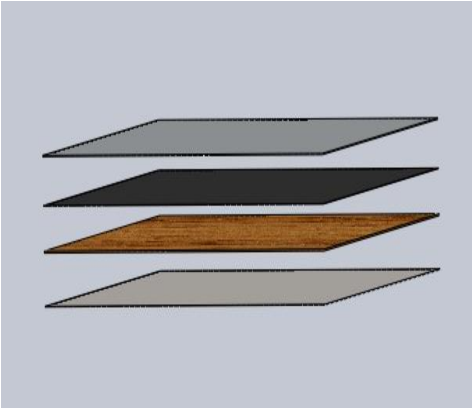


Fig.No.10.Distribution of bending and shear stress in an aluminium composites panel(Ref.Paper.4)

2. CAD Model

Preparing different CAD model in sheet metal with applying material properties on every layer, CAD shape to be made complex cuts and bends to prove its stability and mechanical strength limits.



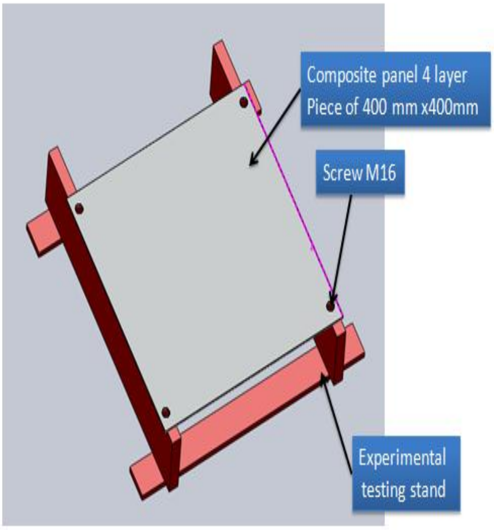


Fig.No.11. CAD model with ANSYS

Property	Value	Units
Elastic Modulus	6.9e+010	N/m^2
Poissons Ratio	0.33	N/A
Shear Modulus	2.7e+010	N/m^2
Density	2700	kg/m^3
Tensile Strength	68935600	N/m^2
Compressive Strength in X		N/m^2
Yield Strength	27574200	N/m^2
Thermal Expansion Coefficient	2.4e-005	/K
Thermal Conductivity	200	W/(m·K)
Specific Heat	900	J/(kg·K)
Material Damping Ratio		N/A

Table No.2.Material -1 Layer - A060 Alloy

Property	Value	Units
Elastic Modulus	6100000	N/m^2
Poissons Ratio	0.49	N/A
Shear Modulus	2900000	N/m^2
Density	1000	kg/m^3
Tensile Strength	13787100	N/m^2
Compressive Strength in X		N/m^2
Yield Strength	9237370	N/m^2
Thermal Expansion Coefficient	0.00067	/K
Thermal Conductivity	0.14	W/(m·K)
Specific Heat		J/(kg·K)
Material Damping Ratio		N/A

Table no.3.Material-2 Layer- Rubber non metal

Property	Value	Units
Elastic Modulus in X		N/m^2
Poisson's Ration in XY		N/A
Shear Modulus in XY		N/m^2
Density	630	kg/m^3
Tensile Strength in X		N/m^2
Compressive Strength in X		N/m^2
Yield Strength		N/m^2
Thermal Expansion Coefficient in X		/K
Thermal Conductivity in X		W/(m·K)
Specific Heat		J/(kg·K)
Material Damping Ratio		N/A

Table no.4.Material -3 Layer –MDF (Medium density fibre)

Property	Value	Units
Elastic Modulus	2.1e+011	N/m^2
Poissons Ratio	0.28	N/A
Shear Modulus	7.9e+010	N/m^2
Density	7800	kg/m^3
Tensile Strength	399826000	N/m^2
Compressive Strength in X		N/m^2
Yield Strength	220594000	N/m^2
Thermal Expansion Coefficient	1.3e-005	/K
Thermal Conductivity	43	W/(m·K)
Specific Heat	440	J/(kg·K)
Material Damping Ratio		N/A

Table No.5.Material-4 Layer- Plain Carbon steel

VI. Experimental Setup For Tensile Test

1. Tensile test of composite material

Figure shows tensile set-up fix the test piece of composite in between jaws of the universal testing machine Tensile stress capacity, all results and graph is generated in UTM.

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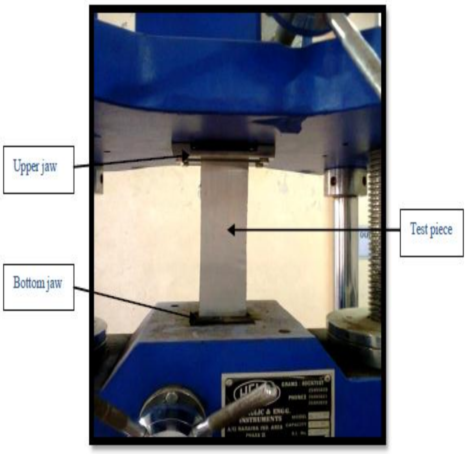

Fig.No.12.Experimental set-up for tensile test

2. Testing

Sandwich panels will be defined here as those consisting of relatively thin face sheets that are strong and stiff in tension and compression compared to the low density core material to which they are adhesively bonded. This definition excludes laminated composite plates, plywood and similar "solid laminates

Validation

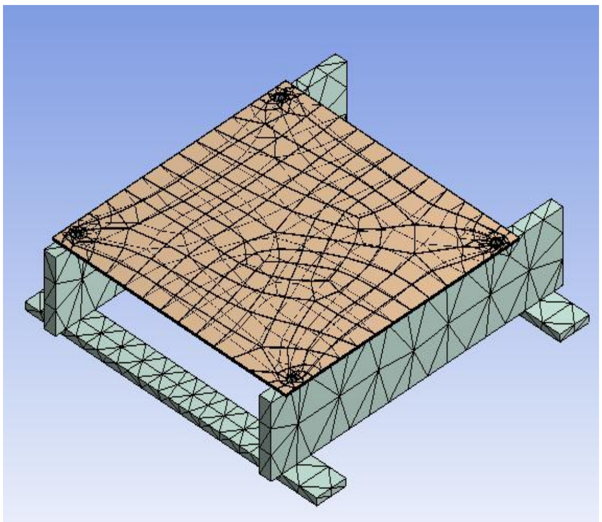

Fig.No.13.Meshed model

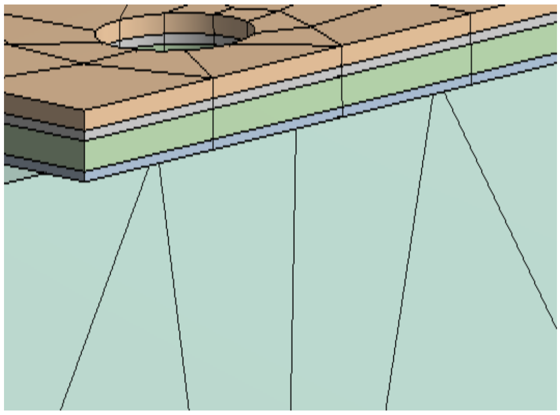

Fig.No.14.Multi layers panel showing .Lets take loading of 200 N

VII. Result

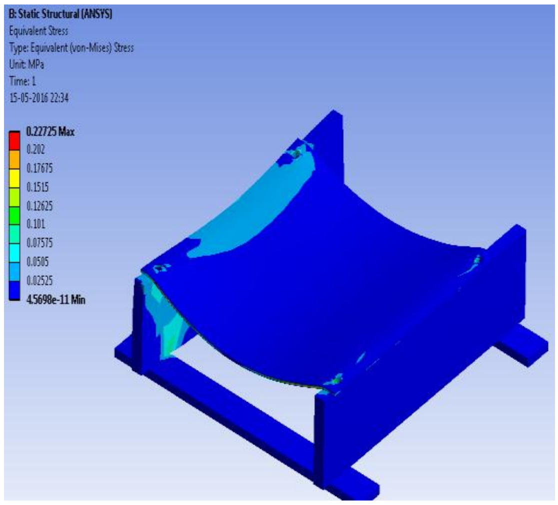

Fig.No.15.Multilayer panel at 0.22 N/mm^2

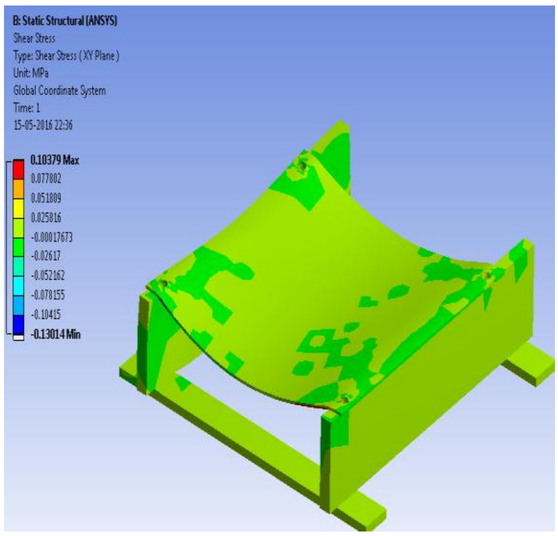

Fig.No.16. stress at 0.11N/mm^2

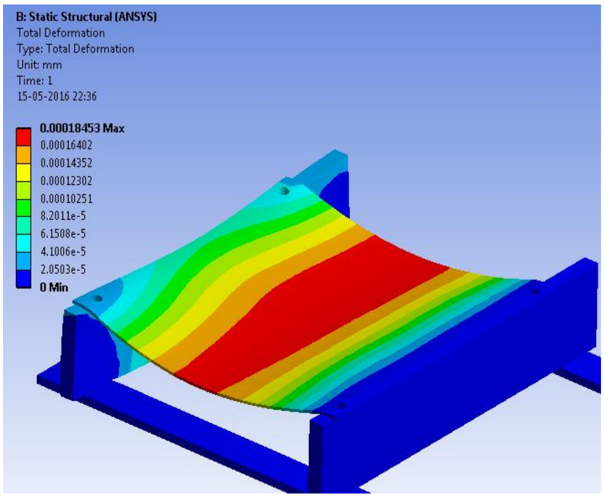

Fig.No.17.Deflection at 0.00018mm

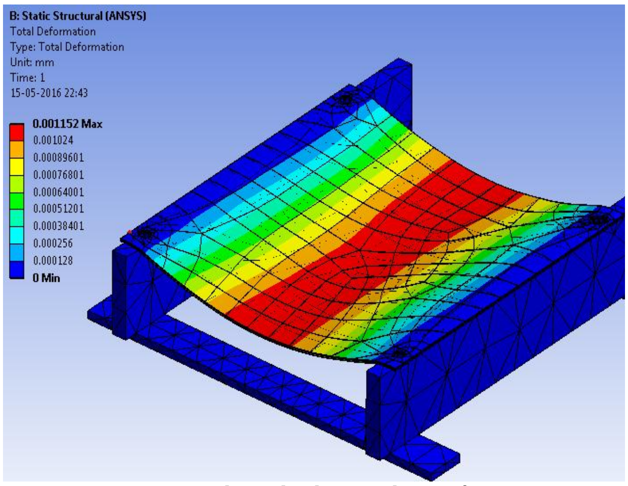

Fig.No.18.Considering loading condition of 400 N

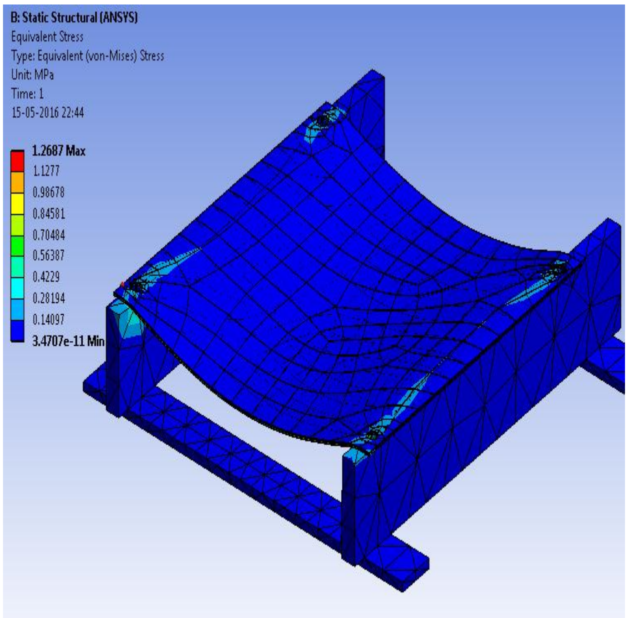

Fig.No.19.composites panel on 0.00011 mm deflection

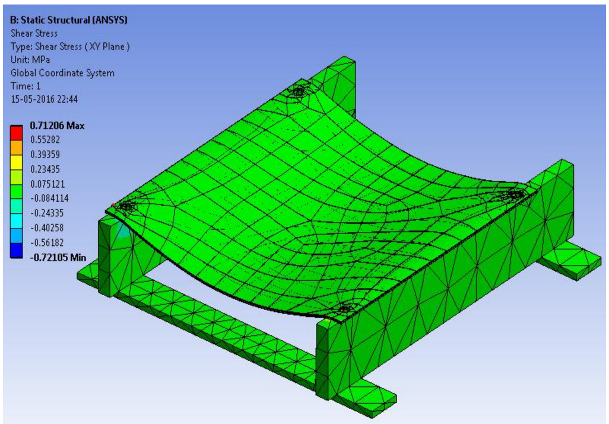

Fig.No.20. 126 N/mm^2 bending stress

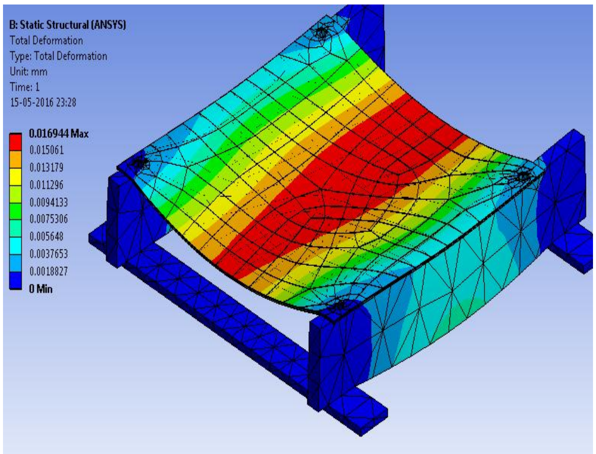

Fig.No.21. Considering 1000 N load

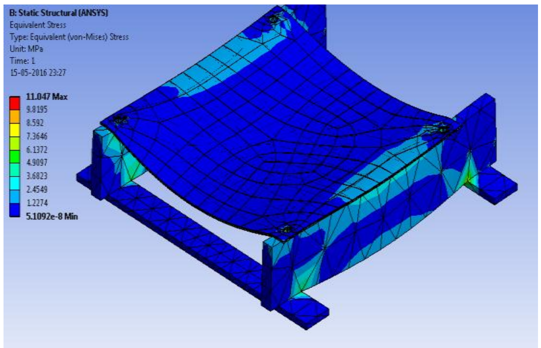

Fig.No.22.0.016 mm deflection

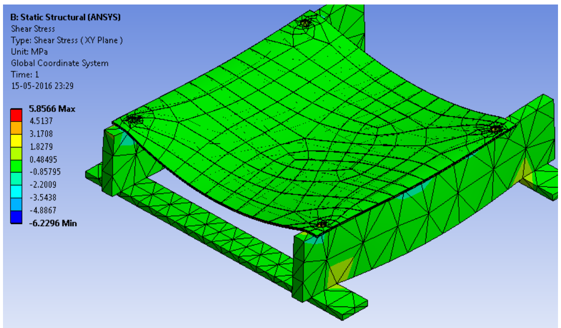

Fig.No.23. 11.04 mpa stress coming under 1000 N load 5.85

mpa shear stress against 1000 N

Parameters out with multiple forces acting vertically

(Results Obtained from ANSYS**)**

Parameters	**Design**	**CAE validation**
200 N load conditions		
Von mises stress		0.22 N/mm^2
Deflection		0.00018 mm
Shear		0.10 N/mm^2
400 N load conditions		
Von mises stress		1.26 N/mm^2
Deflection		0.011 mm
Shear		0.71 N/mm^2
1000 N load conditions		
Von mises stress		11.04 N/mm^2
Deflection		0.016 mm
Shear		5.85 N/mm^2

Table No.6. Result obtained from ANSYS

Stress and Deflection Obtained from analytical calculations are tabulated as below

S. N	**LOAD (N)**	**Quantity**	**Thickness (t)mm**		
			4	**6**	**8**
1	200	**Stress (N/mm^2)**	3.59	0.89	0.4
2		**Deflection (mm)**	0.008	0.002	0.0009
3	400	**Stress (N/mm^2)**	7.1	1.8	0.8
4		**Deflection (mm)**	0.016	0.01	0.002
5	1000	**Stress (N/mm^2)**	17.96	4.5	1.99
6		**Deflection (mm)**	0.041	0.01	0.005

Table no.7. Result obtained from Analytical

VIII. Conclusion

As seen above, different loads are applied on the composite panel and stress and deflections are measured for various thicknesses. From the result and discussion, it can be concluded that the panel with 4 layer multi material under multiple loads is safe till 1000 N load on 1600 mm2 area, if we assembled this sheet on any structure and it goes under 1000 N impact load on its surface, the deflection of the member is very small and Its almost zero value and stress is also very low and under yield strength of aluminium. Hence the composite material can safely be used for the industrial applications viz., in machine cabinets, etc. And for the structure where high strength and low weight of the structure is desired.

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