Design of Honeycomb Sandwich Panel and Its Validation with Flooring Plate of Bus

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Abstract - *In most engineering applications, the weight of the structure must be minimum as possible as for the better performance of the system. Reduction of mass has always presented a challenge to the Design Engineer. A typical example of this is in the Aircraft Industry, where every extra kilogram of structural mass costs the Airline operator thousands of rounds each year. Honeycomb structures are the structures that have the geometry of a honeycomb to allow the minimization of the amount of used material to get the minimal weight and minimal material cost. The honeycomb structure is used to reduce the weight of the overall structure with high strength. In this project work, the honeycomb structure is designed for flooring of the bus and this designed honeycomb sandwich panel is compared with regular aluminum FPB by the numerical and analytical method. The main objective of the project is to design a honeycomb sandwich panel at the same thickness as regular aluminum FPB and shows it has a high stiffness to weight ratio. Also to show honeycomb sandwich panel has low deflection for the same weight as regular aluminum FPB.*

Keywords: Adhesive, Aluminium, Core, Epoxy Resin, Honeycomb, etc.

1. INTRODUCTION

The HSP has low weight and improved mechanical properties compared to metal. Sandwich structures are widely used in production engineering or material engineering prospect due to the very good in the performance of ultra-light, have a higher stiffness than the other material, strength to weight ratios, have excellent energy absorption capability and shock mitigation. Sandwich structure material is also known because of its characteristic to increase the durability and strength of the structure with its outstanding properties such as lightweight construction while the faces of the sandwich structure capable of bearing both tensile stress and compressive stress and the core will be able to bear shear stress.

Basically, honeycomb sandwich structure panel consists of three layers that are face sheets, adhesive bonds, and one core. Face sheets must come from the materials that have high Young's modulus like fiber reinforced plastics or steel and Aluminum composition. The center part of the sandwich structure known as the core can be designed as homogeneous material like foams, paper filling or as textured cores such as a honeycomb. These homogenous cores are used mainly in low cost and low stressed part and on the other hand textural cores such as honeycomb can be found in part with the highest requirements related to mass and stiffness.

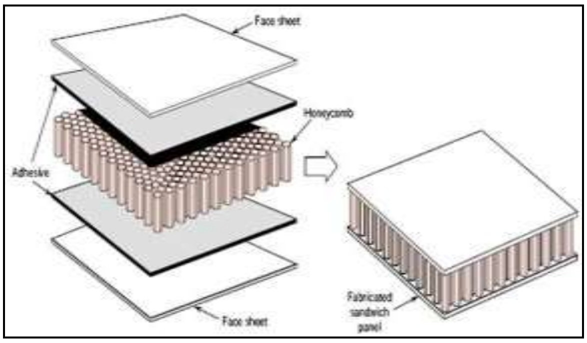


Fig-1: Structure of honeycomb composite

2. LITERATURE REVIEW

2.1 Tom Bitzer's Honeycomb Technology book [1] deals with honeycomb and honeycomb sandwich construction. After reading this book you will have a good understanding of what honeycomb is, how it is manufactured, and how to use it. You also will have the necessary knowledge to design honeycomb sandwich panels and honeycomb energy absorption systems. The honeycomb manufacturing methods, materials, cell configuration, terminology, and uses are all explained. The basic honeycomb sandwich concepts are discussed, failure modes shown and the standard design formulas are given. The standard honeycomb and sandwich test methods are also reviewed.

2.2 Srinivas Athreya, Dr. Y.D.Venkatesh [2] Studied application of the taguchi method for optimization of process parameters in improving the surface roughness of lathe facing operation. Taguchi method is a statistical method developed by Taguchi and Konishi. Taguchi's method of parameter design can be performed with a lesser number of experimentations as compared to that of full factorial analysis and yields similar results. It is found that the parameter design of the Taguchi method provides a simple, systematic, and efficient methodology for optimizing the process parameters.

2.3 Ioannis Barboutis and Vassilios Vassilios [3] studied the strength properties of lightweight paper honeycomb panels for the furniture. The honeycomb panels offer high strength to weight ratio. There are two traditional processes of manufacturing honeycomb panels –conventional expansion process corrugation process. Lightweight honeycomb can be produced economically by the automated in-line process. The main reason to use honeycomb sandwich construction is that it provides high strength to weight and strength to thickness ratios. The bending strength properties of honeycomb panel were low. The impact bending strength of the paper honeycomb is very high.

3. DESIGN OF HSP

3.1 Material Selection:

3.1.1 for Core and Faceplates:

Nowadays, Al 6061 is used as an FPB it is most versatile of the heat-treatable aluminum alloys while keeping most of the good qualities of aluminum. This grade has great mechanical properties and corrosion resistance. It can be made by some commonly used techniques. It is welded by all methods. And because of this reason, it is used in a wide variety of applications and products where good strength and good corrosion resistance are required.

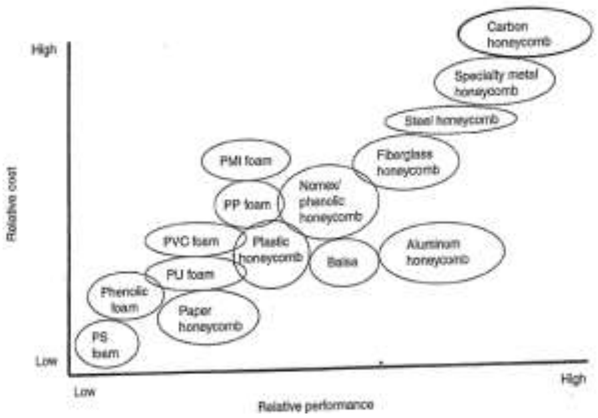
Al6061 Grade- Al-Aluminum, 6 -Magnesium and Silicon, 0-Show modification, Here 0 Modification, 61-content of aluminum is 99.61%.

Properties of AL6061- 1) High Weldability

2) High Corrosion Resistance

3) High Strength.

Now we are going to replace the regular flooring plate by HSP.



Graph-1: Cost vs. performance for different material

From the above graph, aluminum gives the high performance compared to other at that cost.

3.1.2 for Adhesive:

Epoxy Resin is the composition of Epichlorohydrin and Bisphinol-A, is formed by the polymerization reaction. Epoxy cured by adding hardener with equal amount heated to 120 degree Celsius. Resin and hardener mixed in the same proportion for full strength. We used hardener Ethylene Diamine, which is short chain diamine. Epoxy resin is used as the binder in countertops or coatings for floors. It increases the complexity of epoxy polymer chain and potential of a greater degree of control of cross-linking process gives much-improved matrix in terms of strength and ductility.

Molecular Formula –$C_{12}H_{25}CIO_5$

3.2 Design of Edge Length and Cell Wall Thickness:

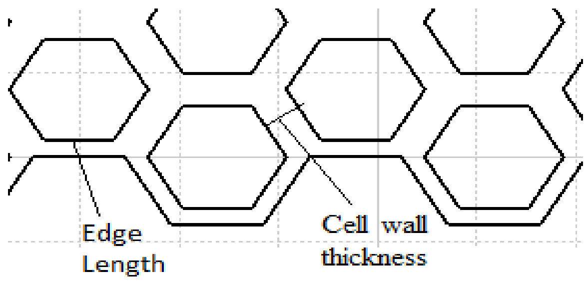


Fig -2: Honeycomb core showing edge length and cell wall thickness

The weight of HSP can be determined by,

Area of the core (A_c) = Area of the rectangle - Area of hexagon*Number of the hexagon,

Again, $V_c = A_c * t_c$

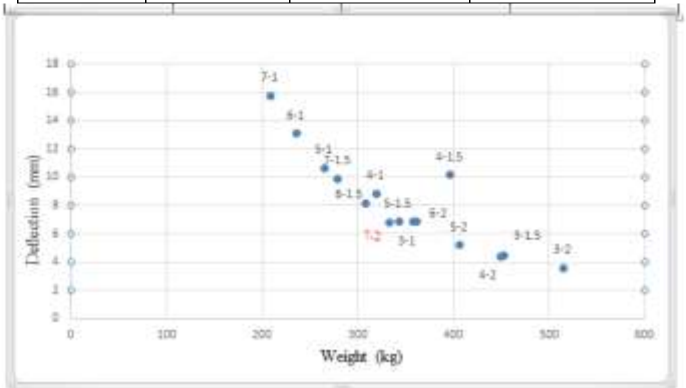
Again, $W_c = V_c * \rho$

The designed HSP is tested on ANSYS by 3 point bending, the results are as follow:

Table-1: Deflection and weight of core for various combinations of edge length and cell wall thicknesses

Edge Length	Cell wall thickness	Weight of core (gm.)	Deflection of core (mm)
3	1	356.895	6.8816
3	1.5	452.193	4.5171
3	2	514.268	3.6141
4	1	318.855	8.8812

4	1.5	395.544	10.21
4	2	448.743	4.4028
5	1	264.297	10.697
5	1.5	342.01	6.88
5	2	405.438	5.2394
6	1	234.925	13.134
6	1.5	307.2	8.1932
6	2	360.837	6.8692
7	1	208.347	15.791
7	1.5	278.2	9.9256
7	2	332.656	6.8397



Graph-2: Deflection vs. Weight for various edge length and cell wall thickness

From this calculation and chart, we get the 7mm edge length and 2mm cell wall thickness which gives optimum deflection -weight relation.

3.3 Design Core Thickness and Face Plate with 7mm Edge Length and 2mm Cell Wall Thickness:

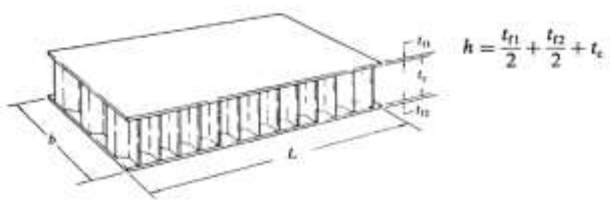


Fig-3: HSP showing thicknesses

3.3.1 Analytical Method:

Rigidity: $U = hG_cb$

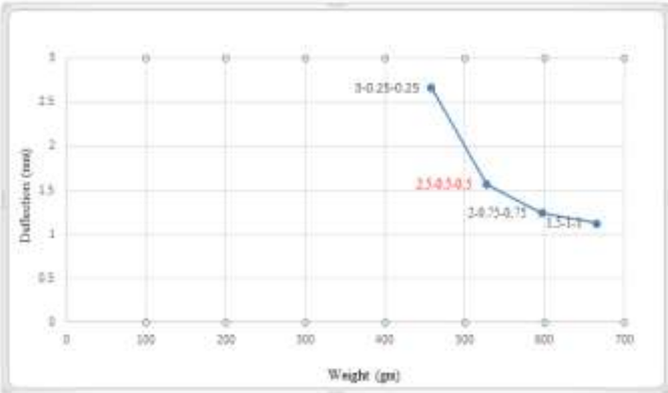
Bending Stiffness:

$D = \frac{Et_f bh^2}{2\lambda}$ .... $\lambda = 1-\mu^2$

Deflection: $\delta = K_b\frac{PL^3}{D} + K_s\frac{PL}{U}$

Table-2: Weight and deflection for various core's and face plate's thicknesses by the analytical method

Core thickness-fp1 thickness-fp2 thickness (mm)	Weight (gm)	Deflection (mm)
3-0.25-0.25	457.306	2.676
2.5-0.5-0.5	526.513	1.571
2-0.75-0.75	595.72	1.247
1.5-1-1	664.928	1.132



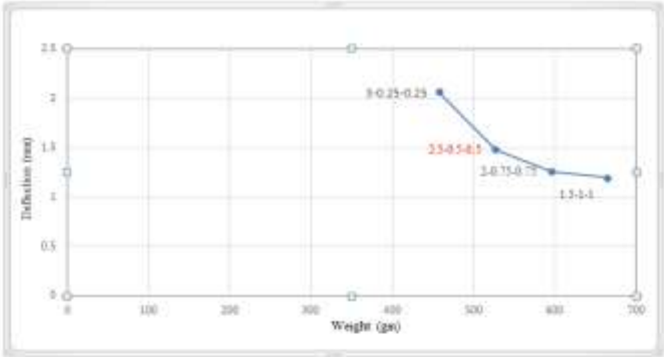
Graph-3: Deflection vs. Weight for different core and face plate thickness by an analytical method

3.3.2 Numerical Method:

The above analytical results are validated by a numerical method using ANSYS,

Table-3: Weight and deflection for various core's and face plate's thicknesses by numerical method

Core thickness-fp1 thickness-fp2 thickness (mm)	Weight (gm)	Deflection (mm)
3-0.25-0.25	457.306	2.0667
2.5-0.5-0.5	526.513	1.4849
2-0.75-0.75	595.72	1.2608
1.5-1-1	664.928	1.1988



Graph-4: Deflection vs. Weight for different core and face plate thickness by a numerical method

From graph 5.2 and graph 5.3, 2.5-0.5-0.5 thicknesses are selected for core thickness-upper face plate thickness-bottom face plate thickness because for this thicknesses there is suddenly decrease in deflection for a small increase in weight.

3.4 Deflection Comparison between Designed HSP and Regular FPB:

The defection of FPB by analytical method,

$$\delta = \frac{1}{EI}\left(\frac{PLx^3}{12} - \frac{Px^4}{24} - \frac{PL^3x}{24}\right)$$

Deflections by numerical method,

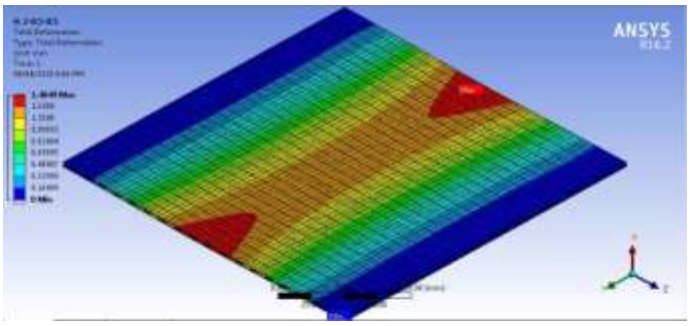


Fig-4: Deformation of designed HSP in ANSYS

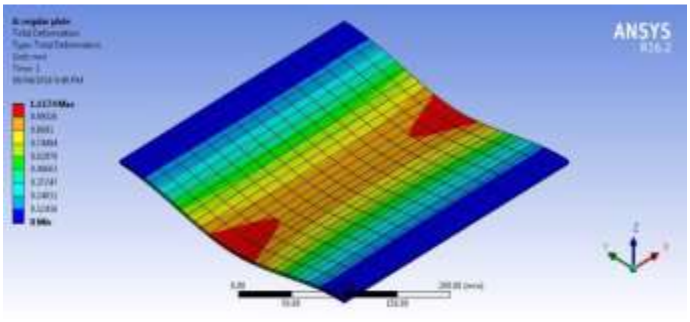


Fig-5: Deformation of the FPB in ANSYS

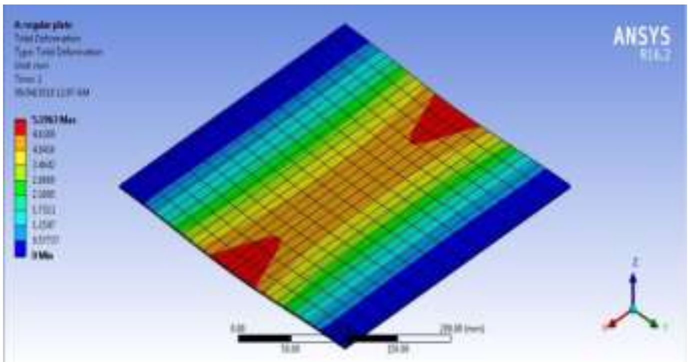


Fig-6: Deformation of FPB of the same weight as honeycomb panel in ANSYS

3.5 Stiffness to Weight Ratio Comparison between Designed HSP and Regular FPB:

Bending Stiffness for HSP:

$$D = \frac{Et_f bh^2}{2\lambda} \quad .... \lambda = 1-\mu^2$$

Bending Stiffness for FPB:

$$D = \frac{Et^3 b}{12\,(1-\mu^2)}$$

4. RESULTS AND DISCUSSION

Comparing the deflections of HSP and FPB by analytical and numerical methods. The results are obtained as follows,

By the analytical method, deflection of HSP and FPB at same thickness of 3.5 mm gives deflection 1.571 mm and 0.851 mm respectively. Now here FPB has less deflection than HSP but FPB has a high weight. When we kept same weight of 526.513 gm for HSP and FPB then FPB shows deflection 2.368 mm more than HSP.

Table-4: Comparison HSP and FPB for same thickness and for the same weight

Method	Deflection for HSP (mm) Thickness= 3.5 mm Weight= 526.513 gm	Deflection for FPB (mm) Thickness=3.5 mm Weight= 872.55 gm	Deflection for FPB (mm) Thickness= 2.1 mm Weight= 526.513 gm
Analytical Method	1.571	0.851	3.939
Numerical Method	1.4849	1.1174	5.1963
% Variation	5.48%	23.84%	24.19%

By the numerical method, deflection of HSP and FPB at same thickness of 3.5 mm gives deflection 1.4849 mm and 1.1174 mm respectively. Now here FPB has less deflection than HSP but FPB has a high weight. When we kept same weight of 526.513 gm for HSP and FPB then FPB shows deflection 3.7114 mm more than HSP.

Table-5: Stiffness to weight ratio comparison

Plate Type	Stiffness to weight ratio
HSP	0.1021
FPB	0.03502
%increase in Stiffness to weight ratio	65.7%

At same weight, HSP and FPB give bending stiffness 53.78 Nm^2 and 18.44 Nm^2 respectively.

5. CONCLUSION

Our designed HSP of total thickness 3.5mm and weight 526.513gm gives deflection 1.571mm and regular FPB of the same thickness and weight 872.55gm gives deflection 0.851mm. Where regular FPB of the same weight as designed HSP (i.e. 526.513gm) and thickness of 2.1mm gives 3.939 mm deflection. Hence, for the same weight, our designed HSP gives deflection 2.5 times less.

For same weights (i.e. 526.513gm), designed HSP and regular FPB give stiffness to weight ratio 0.1021 and 0.03502 respectively. Hence, for the same weight, our designed HSP gives stiffness to weight ratio 2.91 times more.

Above all results are validated by using the numerical method and analytical method and percentage variation between these two is less than 25%.

6. FUTURE SCOPE

1. Further Analysis HSP for different materials for core and face plate and for different thicknesses of the upper faceplate and bottom faceplate.
2. Study on repairing of HSPs.
3. Study of honeycomb material for energy absorption applications.

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BIOGRAPHIES

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