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Design and Analysis of Copper Honeycomb Sandwich Structure

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*Abstract— **The honey comb sandwich construction is one of the most valued structural engineering innovations developed by the composite industry. Used extensively in many industries like aerospace, transportation rails, etc. In this study a stainless steel chosen a face sheet and copper is a core material. Honeycombs are most often an array of hollow hexagonal cells with thin vertical walls Copper Honeycomb is low density permeable material with numerous applications. The defining characteristic of these Honeycombs is a very high porosity; typically 75-95% of the volume consists of void spaces. Static three-point bending tests were carried out in order to investigate load and deflection variations. The theoretical load and defections in copper honey comb sandwich panel values is adapted and compared with experimental and simulation results .Metallic Honeycombs have found a wide variety of applications in heat exchangers, energy absorption, flow diffusion and lightweight optics. Copper honeycomb is used in numerous engineering and scientific applications in industry for both porosity and strength.***

IndexTerms—copper honeycomb sandwich structure, FEA,Three point bending test,

I. INTRODUCTION

1. Introduction:

Sandwich construction is commonly used in structures where strength, stiffness, and weight efficiency are required. Most commonly, Sandwich Panels are used in Aircraft; Space craft, Satellites, Automobiles, Trains, Trucks, Boatsetc.Low-density,[3]hexagonal honeycombs are preferred as the core material on performance basis. The Sandwich Panel" which is composition of a "weak" core material with "strong and stiff" faces bonded on the upper and lower side. The facings provide practically all of the over-all bending and in plane extensional rigidity to the sandwich. . In principle, the basic concept of a sandwich panel is that the faceplates carry the bending stresses whereas the core carries the shear stresses. The core plays a role which is analogous to that of the I beam web while the sandwich facings perform a function very much like that of the I beam flanges. The sandwich is an attractive structural design concept since, by the proper choice of materials and geometry, constructions having high ratios of stiffness-to-weight can be achieved. Since rigidity is required to prevent structural instability, the sandwich is particularly well suited to applications where the loading conditions are conducive to buckling.

Ceramic Honeycomb is often used for thermal insulation, acoustic insulation, adsorption of environmental pollutants, filtration of molten metal alloys, and as substrate for catalysts requiring large internal surface area. The geometric structure of copper honeycomb allows for the minimization of material used thus lowering weight and cost. The honeycomb pattern has a high strength-to-weight ratio. Copper Honeycomb is generally immediately available in most volumes.

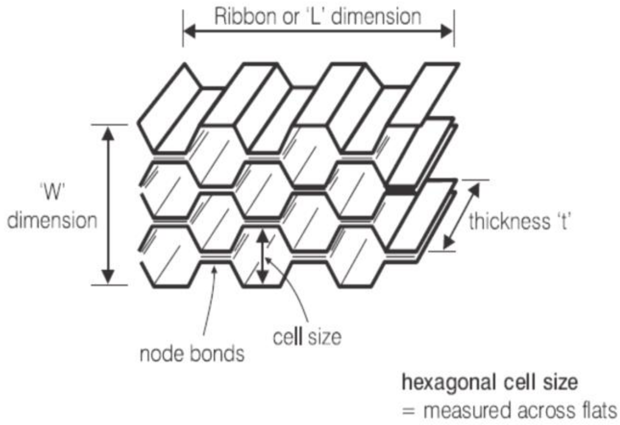

Fig .1 Honey comb structure

Sandwich panels with honeycomb cores have been studied by many researchers. [2]Yang and Qiao (2008) have performed a quasi-static indentation behavior of honeycomb sandwich materials which behavior of honeycomb sandwich materials which will be applied in impact simulations and found that the corresponding global stiffness changes in the load versus displacement curve clearly depict the three loading stages of failure process (i.e., initial core yielding load, global transition load, and ultimate failure load). [3]Crupi and Montaini (2007) performed static and dynamic three-point bending on aluminum foam sandwich to determine the collapse modes of the panels. From their study, different collapse modes (Modes I, IIA and IIB) can be obtained depending on the support span distance and on the own properties of Aluminum Foam Sandwich (AFS) panels.[4] Paik et. al. (1999) have studied the strength characteristics of aluminum honeycomb sandwich panels using a series of strength tests, namely three-point bending tests, buckling/collapse tests and lateral crushing tests. They also carried out a theoretical study to analyze the elastic-plastic bending behavior, buckling/ultimate strength and crushing strength of sandwich panels subject to the corresponding load component. Foo et. al. (2006)

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II. THEORETICAL MODELING OF THE TEST SANDWICH PANELS (BENDING BEHAVIOR)

A simplified method is employed for the analysis of bending behavior for the present sandwich panel specimen. A simply supported honeycomb sandwich beam subjected to a line load at its mid-span is considered as shown in Fig.2

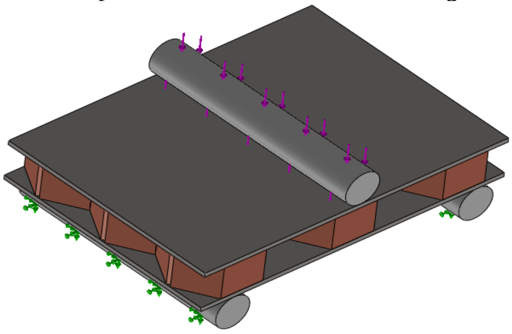

Fig 2 .Sandwich panel loaded at centre

it is assumed that the facing skin carries only bending stresses. However, the variation of bending stress through plate thickness direction may be ignored if the thickness of facing skin t_f is small.

Both honey comb and face sheet thickness (tf=tc)=2mm

A simply supported honeycomb sandwich panel Kelsey *et al*.(1958) provide a formula of the mid-span deflection, δ for the sandwich panel for aluminum honeycomb in the linear elastic regime as follows:

$$\delta = Pa^3/48E_fI_f + Pa/4AcGca \qquad (1)$$

The first term of the right hand side in eq. (1) is due to bending effect alone and the second one account for the shear effect.

In Fig. 4, a comparison of theoretical predictions (i.e., between load and mid-span deflection) using eq. 1 is made against the experimental results for the present test specimen under bending. It is seen that eq. (1) predicts the linear elastic bending response of copper honeycomb sandwich beam well. The critical load P, is obtained when the bending stress of facing skin reaches the yield stress. Therefore, by replacing P by Po, eq. (2) leads us to the following critical load:

$$P = CPt^2f_o/d\ \{1-(tc/t)\} \qquad (2)$$

where C is a constant representing the shear effect due to honeycomb core on the resistive bending moment.

[5]The constant C in the above may be obtained from eq. (1) by assuming that the shear effects of cores for panel strength are likely to be similar to those for panel stiffness.

These results in

$$C = C1/C1+C2 \qquad (3)$$

Where, $C1 = d^3/48E_fI$,

$$C2 = d/4A_cG_{ca} \qquad (4)$$

Deflection of copper honey comb panel under different loads:
Central deflection of honey comb panel is given by:
Sample calculation:

$$w = (Pa^3/48E_fI_f\ ) + (Pa/4AcGca)$$

Right side first part is bending deflection and second part is shear deflection.

[5]If the thickness of the face sheet is very less
Comparing to the length of the panel then we neglect the shear deflection

$I = b(h^3 - hc^3) = 85*(7^3 - 5^3) = 1544.1667\ mm^4$

Deflectionw $= \{(2*10^3*220^3)/(48*2*10^5*1544.1667)\} + \{2*10^3/4*85*2*200*10^5\}$

Total deflection w=1.4365+0.000001245
W=1.4365mm

III.EXPERIMENTAL PROCEDURE

A. Material selection

The mechanical and physical properties of copper and stainless steel are :
Stainless steel (facing material) [7]:
Stainless steel facing material properties:
Mechanical properties

Modulus of elasticity	:	200Gpa
Modulus of rigidity	:	73Mpa
Yield strength	:	520 Mpa
Ultimate tensile strength:		860 Mpa

Physical properties

Density	:	8190 kg/m^3
Melting point	:	1371-1532^{0}C

[7]Copper :(Core material):
Mechanical properties

Modulus of elasticity	:	120Gpa
Modulus of rigidity	:	44130Mpa
Yield strength	:	70Mpa
Ultimate tensile strength	:	220Mpa
Poisons ratio	:	0.3

Physical properties

Density	:	8970kg/m^3
Melting point	:	10820C

B. Specimen preparation

As mentioned earlier, the test specimen consisted copper core with hexagonal cells and stainless steel facing. 2mm thick used for making the sandwich panel faces as well as core. Three core heights, 5mm, 10mm and 15mm are selected for study. The core is spot welded to the face plates. Figures 3 (a) & 3(b) show the spot weld locations (dark spots).Top and bottom face sheets are 133mm X 96mm in dimensions. The cell size of the honeycomb is 28mm. 3-point bending tests are carried out on the specimen. Figure 3 shows the image of the copper honeycomb core fabricated.

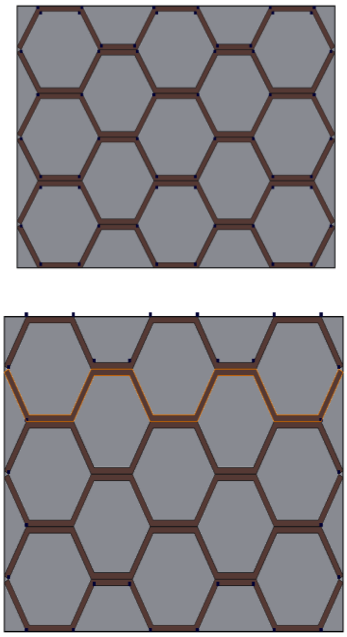

Figure 3: (a) Spot weld location (dark spots) between core and top panel **(b)** Spot weld location (dark spots) between core and bottom panel.

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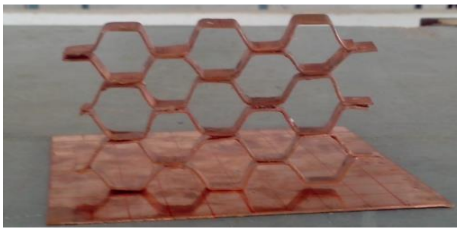

Figure 4: Copper Honeycomb core fabricated

Figure 4 shows the image of the copper honeycomb core fabricated. Figure 5 shows the meshed model used for simulation. s. The bottom two cylindrical models in the model shown are the supports. Each support axis is 15mm from the edge. The top cylinder is the load applying member. All the three cylinders are modeled with high young's modulus material. The face sheets are modeled using shell elements while the core is modeled using solid elements. No penetration contact is simulated between each member. The results of the tests and simulation are presented in the next section.

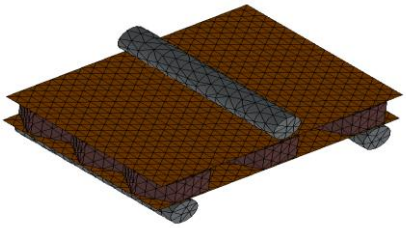

Figure 5: Meshed model

The specimens prepared were subjected to 3 – point bending test on UTM. Figure. 6 shows the test specimen loaded in UTM. A comparison between experimental and numerical simulation results is given in table 1.

Figure 6: Specimen loaded and tested using UTM

IV .RESULTS &DISCUSSION

Static analysis was performed to obtain the response of the hexagonal honeycomb sandwich panel with three different loads, i.e. 2kN, 5kN, 7kN for three different core heights i.e. 5mm, 10mm and 15mm. It is observed during the analysis that the increase in deflection with increase in load is quite high when the core height is 5mm when compared to that of 15mm. Figure 5 show the variation in deflection for various core heights.

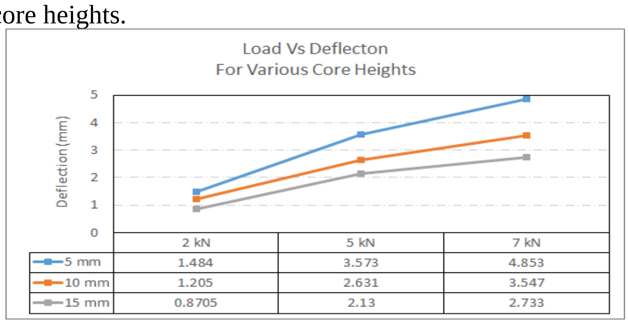

Figure 7: Variation of deflection with core height

Deflection and stress plots all loads for core height of 5mm are only presented in this paper. These plots are shown in figures 7&8 Graph showing the variation of stresses with loading for various core heights is shown in figure 10. From the graph it can be observed that lower stress values are observed for larger core heights.

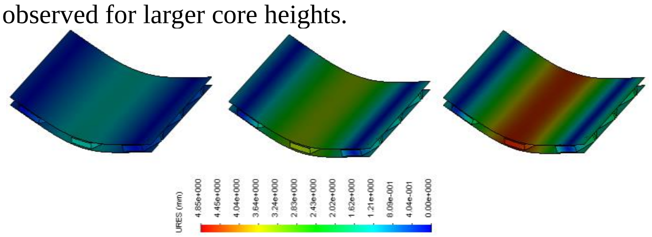

Figure 8: Deflection plots for various loads with core height of 5mm

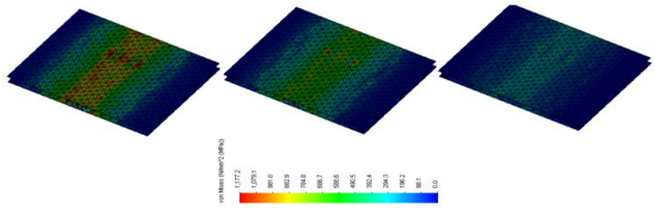

Figure 9: Stress distribution for various loads with core height of 5mm

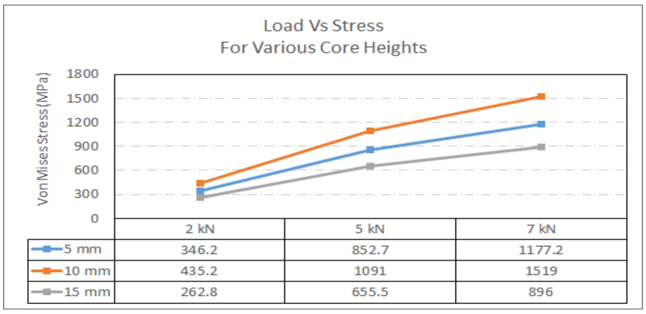

Figure 9: Variation of Von Mises Stress with core height

Table 1.Comparing The Experimental Value With Theoretical And Simulation Values

		Deflections			
Core Heigh t(mm)	Load (KN)	Theoretical (mm)	Experimental (mm)	Simulation (mm)	Vonmises stress
5	2	1.4365	1.9	1.484	519.3
	5	3.591	3.8	3.573	1279
	7	5.0280	5.2	4.853	1765.7
10	2	1.781	1.9	1.205	652.9
	5	2.845	2.9	2.631	1637.6
	7	3.568	3.8	3.547	2278.8
15	2	1.58	1.1	.8705	394.9
	5	2.154	2.6	2.130	963.2
	7	3.12	3.0	2.733	1343.9

V.CONCLUSION

Copper Honeycomb is generally immediately available in most volumes. Copper honeycomb is used in numerous engineering and scientific applications in industry for both porosity and strength. In the current work, bending behavior of copper core honeycomb sandwich panel with stainless steel facing under 3-point bending was studied experimentally for various core heights and loads.

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Numerical simulation was used to predict the deflection. The predicted values and experimental values were compared. Based on the results it is found that the gradient of deflection curve is high for lower core height and stress is low for higher value of core height. These results can be used as input when designing sandwich panels.

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