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Strength Analysis of Sandwich Panels by Considering the Shape Effect of Grid Stiffened Core

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ABSTRACT- ***A sandwich-structured composite is a special case of composite material which consist two stiff and strong skins or faces separated by a thick light weight core. The core is normally having very low strength, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density. This construction is one of the most valued structural engineering innovations developed in the composite industry. It finds its applications in industries like aerospace, transportation rails etc. In the current application static 3-point bending tests were carried out in order to investigate deflection variations in honeycomb sandwich structure by varying the load and also its effect on cell shape of the core. The sandwich structure consisted of Aluminium honeycomb core with stainless steel facing.***

Theoretical calculations and Simulation analysis are carried out by using Catia and Ansys to study the deflections for various loads. The obtained results are compared with experimental values.

Keywords — sandwich composite, Honeycomb Core, Rectangular Core, cell shape of core, 3-Point bending, Catia V5, Ansys R18.1.

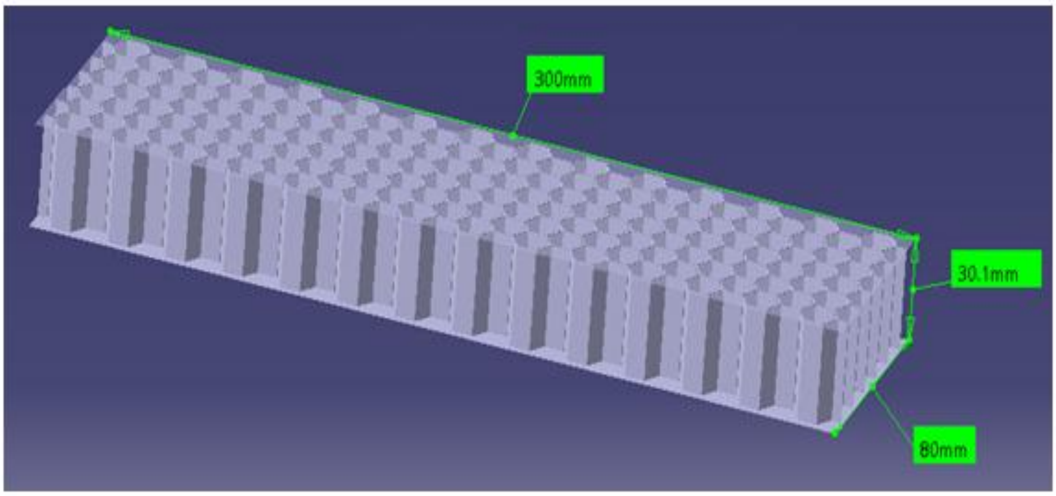
I. INTRODUCTION

The idea of sandwich construction has become tremendously popular among the all possible design concepts in composite structures, because of the development of man-made cellular materials as core materials. Sandwich structures consist of

1) A pair of thin but strong skins

2) A thick, lightweight high stiffened core to separate the skins and to carry loads and

3) An adhesive attachment which is capable of transmitting shear and axial loads (Fig. 1.1).



(Fig. 1)

II. DESIGN GUIDELINES

- ✓ Design loading conditions — Point Loading
- ✓ Define panel type — Simply Supported
- ✓ Define physical/Space Constraints
  - Deflection Limit
  - Thickness Limit
  - Weight Limit
  - Factor of Safety
- ✓ Preliminary Calculations
  - Make assumption about skin material thickness and panel thickness. Ignore the core material at this stage.
  - Calculate stiffness
  - Calculate deflection
  - Calculate facing skin stress
  - Calculate core shear stress
- ✓ Optimize design
- ✓ Detailed calculation
  - Stiffness
  - Deflection

III. PROPERTIES OF MATERIALS

Face plate (stainless steel) Material:

These are containing typically 25% of chromium and nickel, which gives excellent corrosion resistance and also high strength and toughness and do not need to be protected.

Mechanical Properties

Modulus of Elasticity (E_f)	=	193 Gpa
Modulus of Rigidity (G_f)	=	73.66 Mpa
Yield Strength (σ_{yf})	=	520 Mpa
Ultimate Tensile Strength	=	860 Mpa

Physical Properties:

Density (ρ_f)	=	7750 Kg/m^3
Melting Point	=	1371 – 1532 C

Core (Aluminum) Material:

I. High strength to weight ratio.
II. High stiffness to weight ratio.
III. High electrical and thermal conductivity.
IV. Easy to shape.

Mechanical Properties

Modulus of Elasticity (E_s)	=	68GPA
Modulus of Rigidity (G_s)	=	25.56 GPA
Yield Strength (σ_{ys})	=	380 Mpa

Physical Properties:

Density (ρ_s)	=	2800 Kg/m^3
Density of core (honeycomb) (ρ_c^*)	=	277 Kg/m^3
Density of core (rectangle) (ρ_c^*)	=	222 Kg/m^3
Melting Point	=	640 - 650 C
Weight of each Face plate:	=	0.182466 Kg
Weight of Honeycomb core Sandwich Panel W_H	=	0.56 Kg
Weight of Rectangle core Sandwich Panel W_R	=	0.52 Kg
Density of honeycomb core panel	=	**277 Kg/m3**
Density of rectangular core panel	=	**222 Kg/m^3**

$$Honeycomb\ E_c^* = \left(\rho_c^*/\rho_s\right)^2 E_s$$

= **665.506*10^6 N/m^2**

$$Honeycomb\ G_c^* = 0.4\left(\rho_c^*/\rho_s\right)^2 E_s$$

= **266.202*10^6 N/m^2**

$$\text{Rectangle } E_c^* = \left(\rho_c^*/\rho_s\right)^2 E_s$$

= **427.463*10^6 N/m^2**

$$\text{Rectangle } G_c^* = 0.4\left(\rho_c^*/\rho_s\right)^2 E_s$$

= **170.985*10^6 N/m^2**

IV. SANDWICH BEAM STIFFNESS

Taking a beam as being defined as having width (b) less than 1/3rd of span(l).

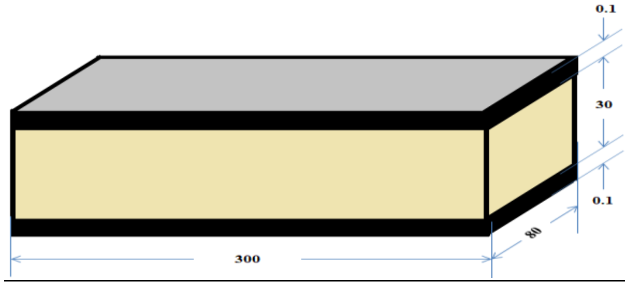


Fig 2

	Density	Young's Modulus	Shear Modulus	Stresses
Face	ρ_f	E_f	-	σ_{yf}
Core	ρ_c^*	E_c^*	G_c^*	σ_{Yc}^*
Solid	ρ_s	E_s	-	σ_{ys}

$\boldsymbol{\delta} = \boldsymbol{\delta}_b + \boldsymbol{\delta}_s$ {Bending deflection + Shear deflection}

↓

(arises from core sheared & $E_c^* <<<< E_f$)

$$\delta_b = \frac{Pl^3}{B_1 (EI)eq}$$

(B_1 = constant depending on loading configuration (3-Point bend, B_1 = 48)

$$\boldsymbol{\delta}_s = \frac{Pl}{B_2 G_c^* A_c}$$

(B2 another constant depend on loading configuration, B2 = 4)

$$\boldsymbol{\delta}_s = \frac{Pl}{B_2 G_c^* bc}$$

$$\delta = \left\{\frac{2Pl^3}{B_1 E_f btc^2}\right\} + \left\{\frac{Pl}{B_2 G_c^* bc}\right\}$$

4.1 <u>Honeycomb:</u>

Honeycomb core panel Deflection ($\boldsymbol{\delta}$) = **0.598 mm**

4.2 <u>Rectangle:</u>

Rectangular core panel Deflection ($\boldsymbol{\delta}$) = **0.657 mm**

V. STRUCTURAL OPTIMISATION

The design of full scale composite materials structures usually requires a building block approach to testing and design. This approach involves increasing the testing complexity and size from coupon tests to full structural tests. In the first stage the chemical and material tests the first stages are generally well denied tests. As we move from the laminate level to sub-element, component and sub-structure level, the test become more application dependent. Neither standard test methods nor databases exist for these larger tests. Thus there is a need to reduce cost and increase the efficiency of structural design and structural failure prediction by a global/local testing and analysis approach. The global/local approach involves supporting the global tests and analyses, used in traditional design approaches, by critical local sub-element tests. These tests are intended to be in between a coupon and sub-structure test. They are cheaper to manufacture and test and most importantly they are fully representative of structural configurations undergoing the same manufacturing processes, and may even be cut from an actual structure.

5.1 Minimum Weight for a given stiffness:

$$\frac{\delta}{P} = \left\{\frac{2l^3}{B_1 E_f btc^2}\right\} + \left\{\frac{l}{B_2 G_c^* bc}\right\} \quad (1)$$

Given face and core materials, beam length, width, loading configurations (B_1B_2), Find,

Core thickness c, face thickness t & core density ρ_c^* to minimize weight.

$$W = \left\{2\rho_f gbtl + \rho_c^* gbcl\right\} \quad (2)$$

If the core density is fixed then optimization is easy.

The single most important structural characteristic of cellular solids is its relative density $\frac{\rho_c^*}{\rho_s}$. Generally speaking, cellular solids have relative densities which are less than about 0.3; most are much less as low as 0.003.

Solve the equation 1 for t,

$$t = \frac{\frac{P}{\delta}\left\{2l^3 B_2 G_c^* bc\right\}}{\left\{B_1 B_2 E_f G_c^* b^2 c^3 - \frac{P}{\delta} B_1 E_f bc^2 l\right\}}$$

Substitute this into objective function i.e., equation 2, which is then minimized with respect to the only the other free variable c, by setting $\frac{\partial W}{\partial C}$ equal to zero; this gives the optimum core thickness (C_{opt}).

$$W = \left\{2\rho_f gbtl + \rho_c^* gbcl\right\}$$

C_{opt} = ?
T_{opt} = ?

VI. CATIA – INTRODUCTION

CATIA which stands for Computer Aided Three Dimensional Interactive Application is CAD software owned and developed by Dassault Systems and marketed worldwide by IBM. It is the world's leading CAD/CAM software for design and manufacturing. CATIA supports multiple stages of product development through conceptualization, design, engineering and manufacturing.

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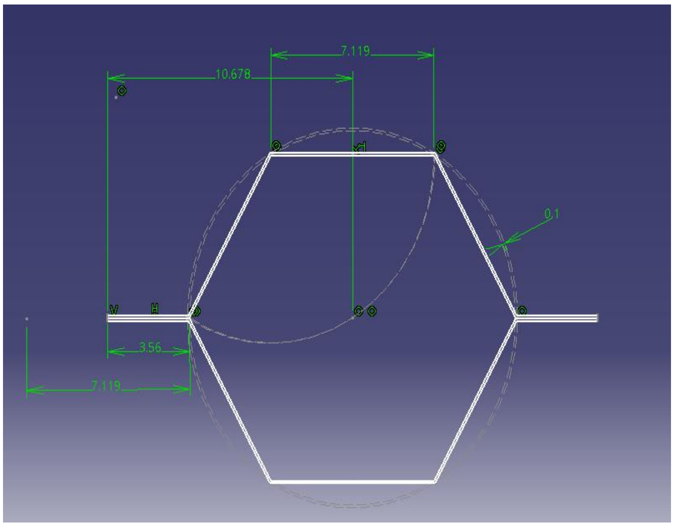
1) A pair of thin but strong skins (faces, facings)

2) A thick, lightweight high stiffened core to separate the skins and carry loads from one skin to the other and

3) An adhesive attachment which is capable of transmitting shear and axial loads to and from the core



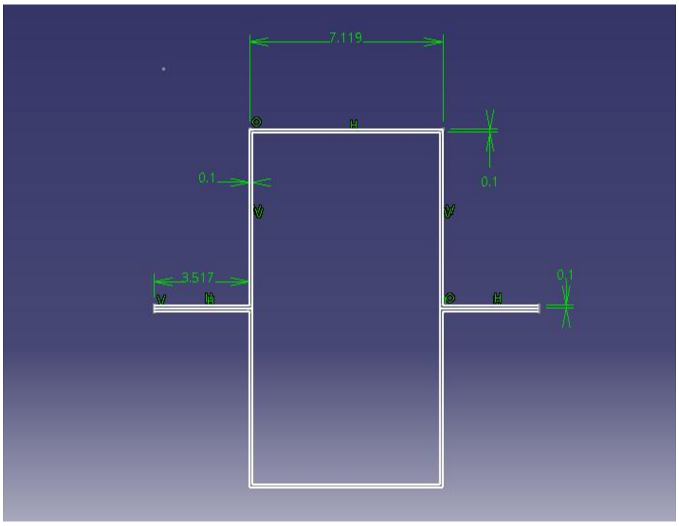
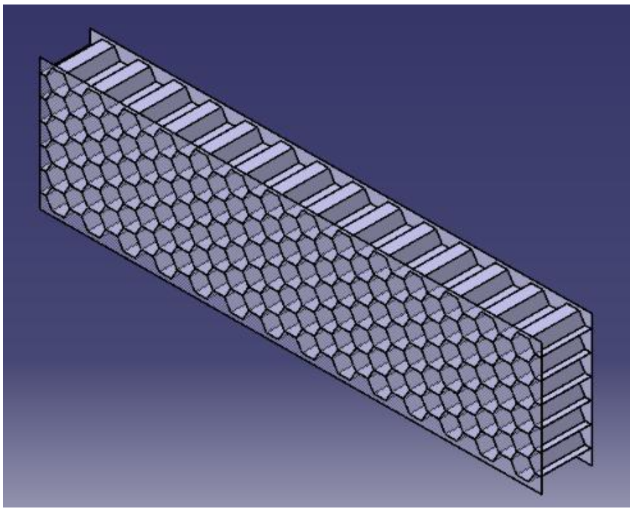


Fig 3 showing dimensions of honeycomb structure in Catia

Fig 4 showing dimensions of rectangular structure in Catia



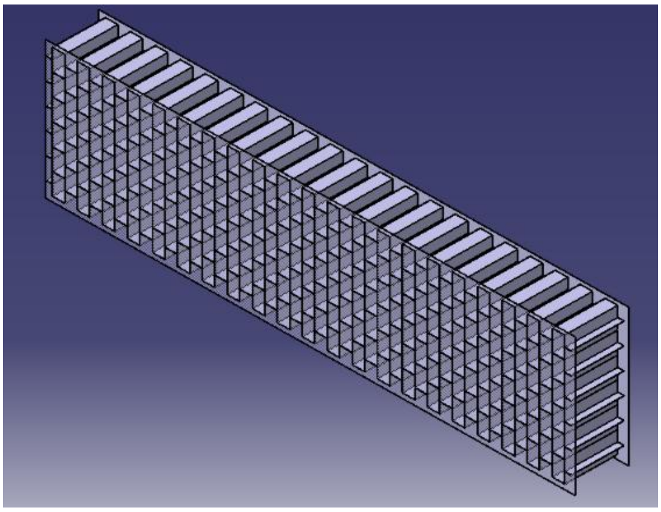
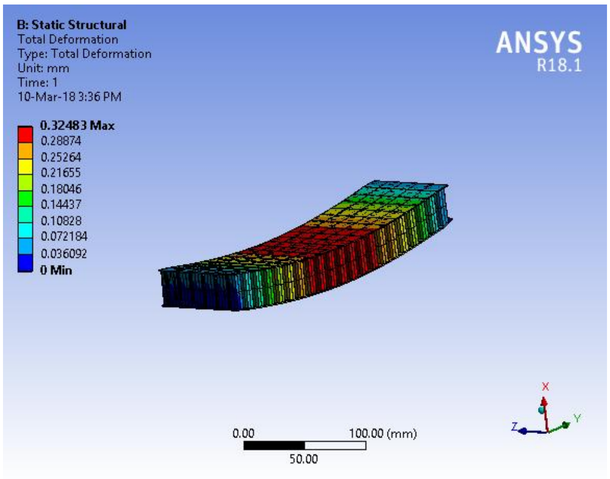


Fig 5 showing design of honeycomb structure in Catia

Fig 6 showing design of honeycomb structure in Catia

VII. ANSYS

ANSYS is general-purpose finite element analysis (FEA) software package. Finite Element Analysis is a numerical method of deconstructing a complex system into very small pieces (of user-designated size) called elements. The software implements equations that govern the behaviour of these elements and solves them all; creating a comprehensive explanation of how the system acts as a whole. These results then can be presented in tabulated or graphical forms. This type of analysis is typically used for the design and optimization of a system far too complex to analyse by hand.



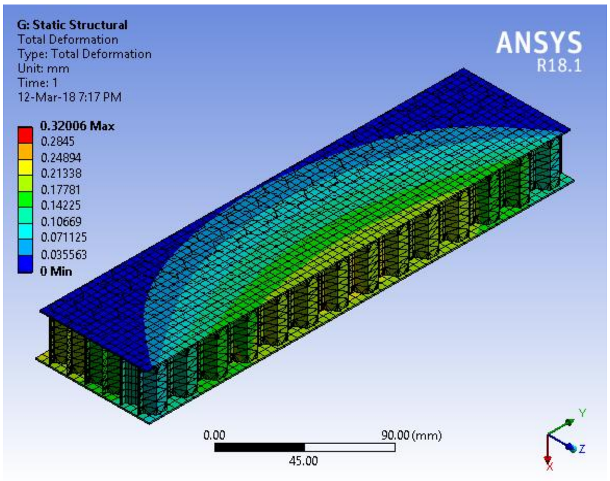


Fig 7 representing total deformation of rectangular cell Structure

Fig 8 representing total deformation of honeycomb cell structure

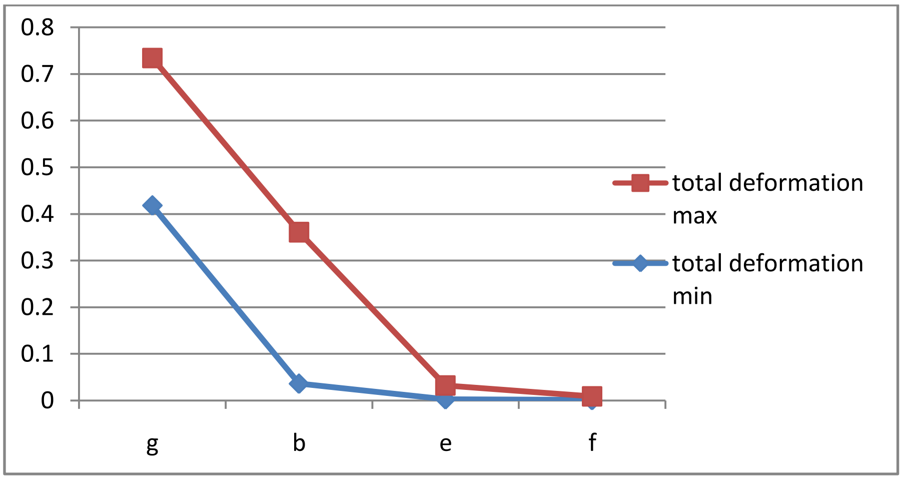


Fig 9 Comparison of total deformation of honeycomb and rectangular cell structure

VIII. FLEXURAL TEST

Flexure tests are generally used to determine the flexural modulus or flexural strength of a material. A flexure test is more affordable than a tensile test and test results are slightly different. The material is laid horizontally over two points of contact (lower support span) and then a force is applied to the top of the material through either one or two points of contact (upper loading span) until the sample fails. The maximum recorded force is the flexural strength of that particular sample.

(a)

(b)

(c)

Fig 10 showing shape structure with aluminium core

Fig 11 Specimens after testing

IX. RESULT COMPARISON

Result Comparison						
Core	Maximum Load (N)	Theoretical deflection (mm)	Theoretical Stresses		Simulation deflection (mm)	Experimental deflection (mm)
			Normal N/mm^2	Shear N/mm^2		
Hexagon	1700	0.598	442.708	0.354	0.32006	1.2
Rectangular	1400	0.657	364.583	0.291	0.32483	1.4

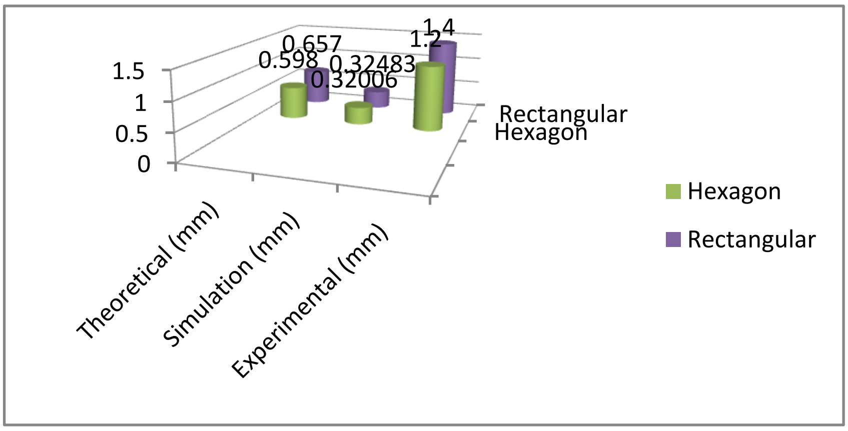


Fig 12 Result comparison by using graph

X. CONCLUSIONS

In present project honey comb structure and rectangular cell structure are compared using three point bending test, for experimentation purpose core made up of aluminium sheets are sandwiched between stainless steel plates, for adhesion industrial grade araldite is used. These specimens are tested using UTM. Experiment results are compared with theoretical calculations and simulations.

Results from experimentation, simulation and theoretical calculations showed similar traits, experimentation results are little high in value due to poor manufacturing quality. The following observations are made from the work

1. During experimentation rectangular cell structure failed at 1400N and honey comb structure failed at 1700N, honey comb have the ability to with stand higher stress and deformations.
2. When compared simulation and theoretical calculations also showed less deformations in honey comb structure.
3. Strength to mass ratio is very high for cellular structures when compared with solid blocks.

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