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STRENGTH ANALYSIS OF A COMPOSITE JOINT USED IN SHIP STRUCTURE

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ABSTRACT

Low weight and high strength panels are always taken into account when designing materials for sandwich panel technology, which offers an efficient solution for different problems. Different types of sandwich panels are currently being used depending on the applications. Honeycomb sandwich panels are a better solution in structural design problem. The work presented in the paper is focused on the study of the behaviour of a composite joint used in ship structure, loaded by transversal force. The components of the joint are sandwich plates, made out of core polypropylene honeycomb and extruded polystyrene and face sheets of the resin polymer. A typical sandwich panel is made of three layers, in which two thin sheets (faces) of a stiff and strong material are separated by a thick core of low-density materials (Allen, 1961). Considering the various uses of these materials in numerous fields, it is essential to know their mechanical properties so as to predict and calculate their behaviour in specific and diverse environments.

KEYWORDS: joint ship, sandwich composite, Ansys FEM, modeling

1. Introduction

The interest in using composites in various building structures has gradually increased. Nowadays, the idea of using sandwich construction has become more and more popular due to the new materials such as cellular materials which can be used as core for the sandwich. The idea of separation of the skins from the core is derived from the beam theory (sectional moment of inertia) [10].

The maritime and aerospace industries have used composite materials in order to reduce the total weight and for low fuel consumption. In the maritime field, the use of composites started in 1950 due to the low costs of GFRP (Glass fiber reinforced plastic) structures. The first applications include lifeboats, pleasure crafts and small yachts [11].

The merits of the sandwich composite structures are the high strength/weight ratio, heat resistance, sound / vibration insulation and easy assembly. In the last decades sandwich structures have been widely used in various fields: aerospace, automotive, ship building and construction industries (Yu and Cleghorn, 2005; Wang and Yang, 2000; Kim and Hwang, 2000). In maritime industry, sandwich composites are ideally suited for special structures [1, 2]. Foam cores meet the critical requirements of strength, buoyancy and low water absorption. Most applications include the construction of bulkheads, hulls, decks, transoms and furniture, but also, which is the most important, the strength structural elements. Considering the multiple uses of these materials in many fields, it is very important to know their mechanical properties in order to predict and calculate the structural behavior in specific and various environments.

One of the most used core materials is honeycomb because it has good properties such as: very high strength to weight ratio, electrically and thermally insulating material, chemically stable, good non-flammable (being self-extinguishing) and non-corrosion properties, shock and fatigue resistant. In nearly all sandwich constructions, certain types of joints have to be used for assembly, but little is known about their failure behavior. This paper deals with the investigation of joints used in shipbuilding and beyond.

2. Literature review

Peter Huson [7] (2012) analysed a joint similar to the combination described in this work but the materials used to sandwich the core were balsa wood and foam (General Plastics FR3707 structural foam core), skins used sheets CRFP (Carbon Fibre

Reinforced Plastic (polymer)) and for the carrier (triangle) balsa wood was used.

FR-3707 foams are chosen for applications in nuclear and hazardous waste extreme transportation. When used as a liner for IMPACT- as fire insulation in transport containers, FR-3707 can be designed to provide the ultimate protection against fire and collision for dangerous, surpassing wood and other polymeric materials. 3707-FR formulation is specifically designed to enable predictable impact-absorption performance under dynamic loading. At the same time, it provides intumescent char layer that insulates and protects hazardous materials, even when exposed to fire conditions. In Peter Huson's work were made more complex experimental tests and simulations using LS-Dyna program. Since impact tests were performed on these composites, quasi-static, dynamic strain and composite delamination were pursued.

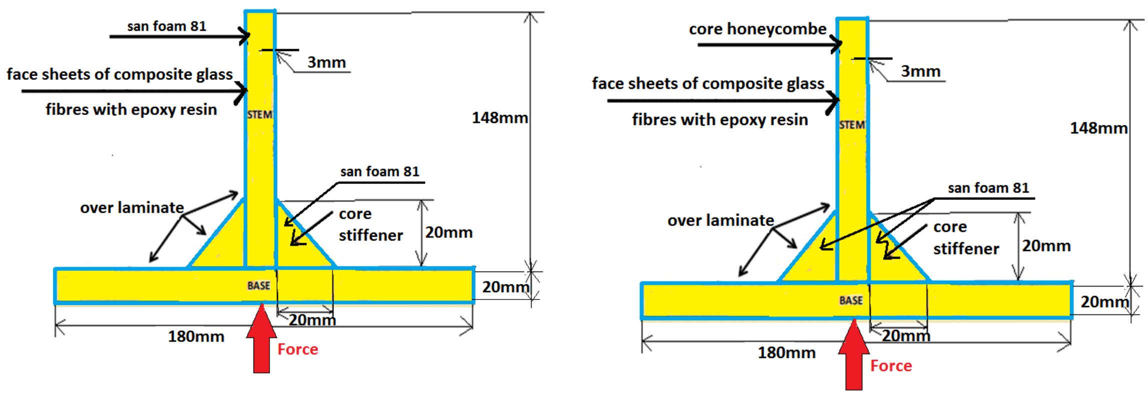
Ch. Naresh [8] compared the response of Square and Hexagonal honeycomb sandwich panels in his paper entitled "Numerical Investigation into Effect of Cell Shape on the Behavior of Honeycomb Sandwich Panel". Numerical simulations using FE techniques are used for simulating the behavior of the sandwich panels under uniformly distributed loads. During simulation, two different combinations of materials (face material – core material) are considered. Based on the response, it is found that, although Al-Al sandwich panel with square honeycomb structure has lower stress values, it showed greater deflection than SS-Cu panel. Modal analysis is also executed to extract the natural frequencies. It is found that the square honeycomb panel has higher natural frequencies than those of the hexagonal honeycomb panel. This paper analyzes the natural frequency and the displacement for these sandwiches.

3. Problem definition

The purpose of this paper is to make a comparison between two materials that were used in the heart core of polypropylene honeycomb sandwich and extruded polystyrene, following the mechanical behaviour of the sandwich. The main steps in this study are:

1. Calculations using classical and finite elements methods for simple constructions with FEM package Ansys [9];
2. Understanding of properties of various face and core materials;
3. This is an analysis of the stiffness during the static test of sandwich panels and their components;
4. Analysis of the joint deflection behaviour;
5. Studying the behaviour of more cases with on joint application of different forces.

The materials used for sandwich are: for two skins Epoxy E Glass-Wet; for the core we used polypropylene honeycomb and extruded polystyrene. The geometry of these structures can be seen below in Figure 1.



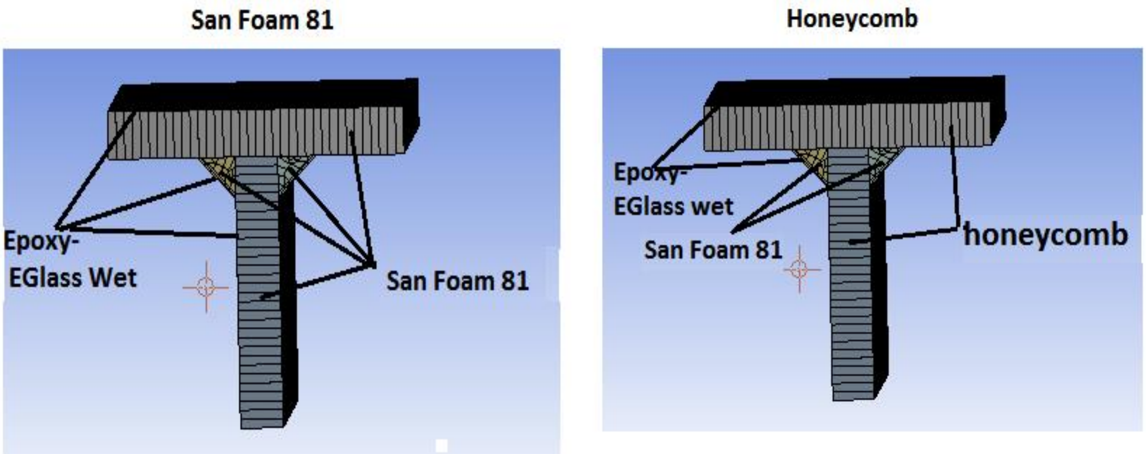
a) Composite joint with polypropylene honeycomb core

b) Joint Composite San Foam core 81

Fig. 1 *Geometry Composite Joints and blunts are considered for review*

4. Meshing and boundary conditions

Geometric nonlinear static analysis has been done for the panels' models using ANSYS Workbench to determine the effect of the previouslymentioned parameters on the deflection as well as on stresses. The skins were modeled using SHELL with orthotropic properties, while SHELL was used for modeling the cores with isotropic properties. This model was able to accommodate both isotropic and orthotropic material properties, but isotropic material properties were initially applied to the model as reported in the present section. The loading and boundary conditions were adapted.



a) Case1, Joint with core Honeycomb   b) Case 2, Joint with San Foam 81

Fig. 2. *Meshed models*

The materials used for the analysis of the two cases are presented in the tables below:

Table 1. *Honeycomb polypropylene* [Source: From ANSYS library]

Honeycomb properties	**Value**	**Unit**
Density	80	Kg/m^3
Orthotropic elasticity		
Young’s Modulus Ex	1	MPa
Young’s Modulus Ey	1	MPa
Young’s Modulus Ez	255	MPa
Poisson’s Ratio υ_{xy}	0.49	
Poisson’s Ratio υ_{yz}	0.001	
Poisson’s Ratio υ_{xz}	0.001	
Shear Modulus Gxy	10^{-6}	MPa
Shear Modulus Gyz	37	MPa
Shear Modulus Gxz	70	MPa

For skin using Mechanical Properties of the Epoxy-E Glass-Wet [Source: From ANSYS library]
Density =1850 Kgm^3
Young’s Modulus x = 3500 Mpa
Young’s Modulus y = 9000 Mpa
Young’s Modulus y = 9000 Mpa
Poisson’s Ratio xy= 0.28
Poisson’s Ratio xy= 0.4
Poisson’s Ratio xz= 0.2

Table 2. *SAN_Foam_81* [Source: From ANSYS library]

SAN_Foam_81kgm^3 Isotropic Elasticity		
Young’s Modulus	60	MPa
Poisson’s Ratio	0.3	
Bulk Modulus	50	MPa
Shear Modulus	22.077	MPa
Density	81	Kg/m^3

5. Results and discussions

As mentioned earlier, for the static analysis with uniformly distributed load from 2 KN – 27 KN, the panels used are executed on models of the two structures.

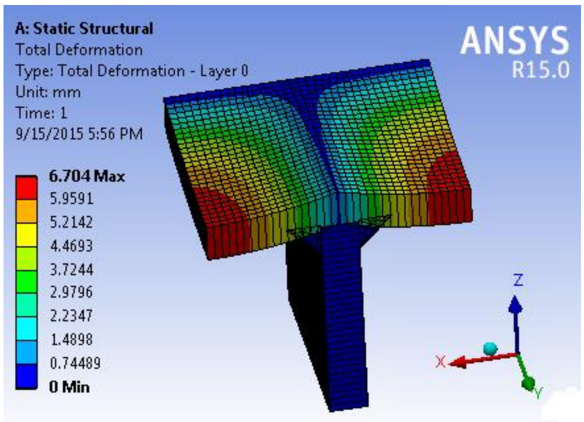


Fig. 3. *Total Deformation of the structure*

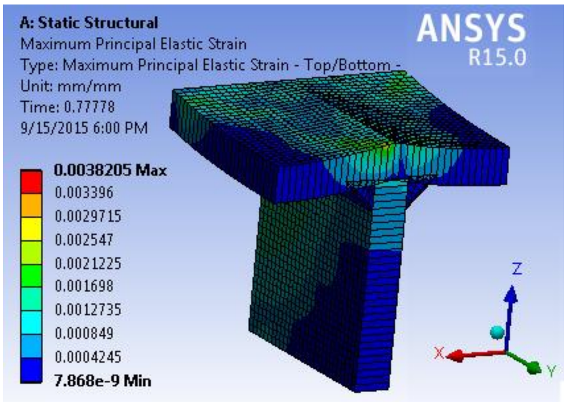


Fig. 4. *Maximum Principal Elastic Strain*

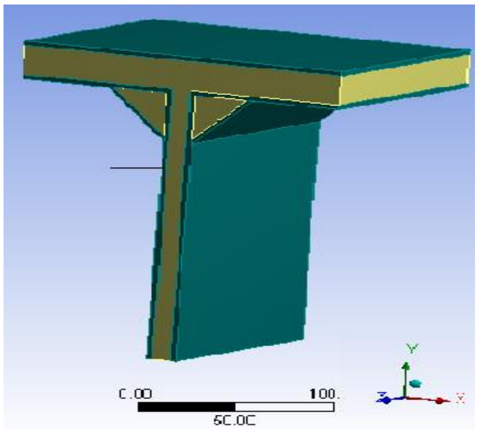


Fig. 5. *The geometry of three layers*

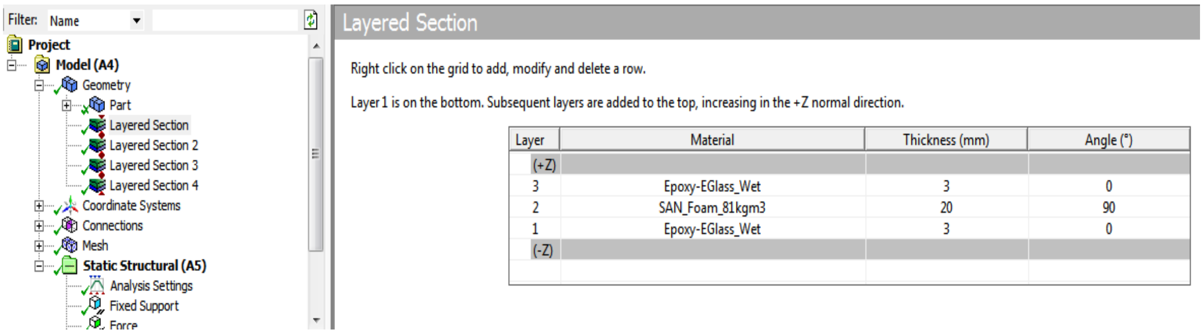


Fig. 6. *The arrangement of layers*

Table 3. *Analysis of several strengths in terms of deflection for honeycomb core*

Honeycomb		
Nr. crt.	**KN**	**Displacement [mm]**
1	2	0.26244
2	4	0.52488
3	6	0.78731
4	8	1.0498
5	10	1.3122
6	12	1.5746
7	14	1.8371
8	15	1.9683
9	16	2.0995
10	17	2.2307
11	18	2.3619
12	19	2.4932
13	20	2.6244
14	21	2.7556
15	22	2.8868
16	23	3.018
17	24	3.1493
18	25	3.2805
19	26	3.4117
20	27	3.5429

Table 4. *Analysis of several strengths of deflection for SANFoam 81*

SanFoam81		
Nr. crt.	**KN**	**Displacement [mm]**
1	2	0.49659
2	4	0.99318
3	6	1.4898
4	8	1.9864
5	10	2.483
6	12	2.9796
7	14	3.4761
8	15	3.7244
9	16	3.9727
10	17	4.221
11	18	4.4693
12	19	4.7176
13	20	4.9659
14	21	5.2142
15	22	5.4625
16	23	5.7108
17	24	5.9591
18	25	6.2074
19	26	6.4557
20	27	6.704

Forty cases were analysed in Ansys Workbench, but these cases were divided for two different cores: honeycomb polypropylene and extruded polystyrene (San Foam 81). Each case has a different force, each starting from 2 kN to 27 kN. The paper dealt with the displacement of the biggest forces application and then a comparison was made between the two cores. In Figures 3 and 4 are shown some images of the forty cases to reveal the total displacement and maximum principal strain. Figure 5 and 6 showed how layers were built to model the structure.

The results of local modelling are presented in more detail, because they can help explain specific phenomena related to the experimental investigation.

In Figure 7 are compared the two cases of important chart displacements to different cores; It should be noticed that the displacement for polypropylene honeycomb was smaller than for San Foam 81.

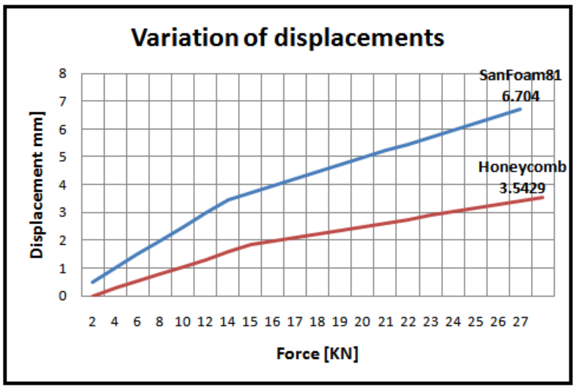


Fig. 7. Comparing the results of two different cores of joints and blunts

6. Conclusions

Static analysis was performed to study the response of honeycomb core and expanded polystyrene sandwich for different strengths. Static analysis was performed with the back edge encased T's. Static analysis was performed to check whether the node can support or not some typical naval forces. Based on the results, it is found that the typical naval node with honeycomb core had a smaller displacement than polystyrene. Core figure (Honeycomb) provides better rigidity than the core of extruded polystyrene (foam breast 81). For better results in typical node naval reinforcement core, it is advisable to use all extruded polystyrene (san foam 81) because honeycomb boards cannot be tight, but there should remain a free space when using the foam that will fill the air gap.

Acknowledgement

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