# Strength Comparison of Fabricated and Modeled Wedge Shaped Composite Honeycomb Sandwich Structure

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***Abstract*—The use of composites in aircraft industry has increased to a great extent in recent years. Among these honeycomb sandwich panels have numerous applications in stealth designing because of their high strength to weight ratio, durability, high strength, high stiffness and ease of processing of complex segments of an aircraft. In this investigation, composite honeycomb sandwich structure is constructed using E-glass face sheets and CNT's coated Nomex honeycomb to improve the electromagnetic (EM) wave absorbing performance. Stealthier flying bodies can be developed by converting the radar cross-section into flat surfaces and sharp edges. For this purpose the honeycomb is sliced into a wedge of $30^0$ and then fabricated into sandwich structure of wedge shape and tested for its strength.**

***Moreover FEM modeling of these wedges is done in ABAQUS in order to visualize their structural strength in different loading conditions. The results obtained from the analytical testing procedures and those obtained from software modeling are compared and the percentage of error has been shown between the results for both methods. Final results conclude that there is difference of 5% in maximum strength obtained from both methods.***

***Keywords*— Electromagnetic wave absorption, Radar cross-section, FEM modeling**

## I. INTRODUCTION

The use of sandwich structures started back in 1845 when a first known man-made sandwich structure of wood egg crate core was used for top compression panel [1]. Later on, the use of honeycomb in the sandwich structures made it possible for the engineers to design and construct lightweight transportation systems such as satellites, aircraft, missiles and high speed trains. The application of sandwich structures can also be seen in wind energy systems and bridge construction [2]. Other advantages offered by sandwich construction are elimination of welding, superior insulating qualities and design versatility. The composition of the sandwich is limited only by the availability of materials and the engineer's ingenuity. In these designs it is assumed that the facings take the bending load (one skin in compression and the other in tension) and the core takes the shear load [3].

Asymmetric sandwich panels are now being utilized in interior and exterior components of aerospace structures [4]. These asymmetric sandwich structures can be of any shapes e.g. wedge shape, Z shape, circular shape, etc. The wedge shaped sandwich panels are used in wing leading edges, side body of helicopters, in beach rest beds, in cargo compartment walls of aircrafts and in many other structures. This research concentrates on the testing of radar absorbing wedge shape honeycomb sandwich structure that may be used as additional structures on existing light weight aircrafts and helicopters to make them stealthier [5]. A comparative study of compressive strength of fabricated and modeled sandwich wedge of $30^o$ has been carried out to show the amount of loads they can carry and the amount of error between the results.

## II. FABRICATION OF WEDGE SHAPE SANDWICH STRUCTURES

Honeycomb sandwich structure have a honeycomb core which is sandwiched by two outer facing skins. In this research sandwich construction consists of fiberglass facing layers separated by a Nomex honeycomb core.

### *A. Dimensions of structure*

The wedge shape sandwich structure has the dimensions *51x 77mm* and has a thickness of *20mm.*

### *B. Face Sheets*

The fiber glass face sheets are prepared by transferring the epoxy from one end to another end using Vacuum Assisted Resin Transfer Molding Technique (VARTM). After that epoxy is cured for 24 hours in vacuum, face sheets are peeled off and placed in laboratory oven for four hours for further curing. Final samples are cut into dimensions using shearing and compression machine. The final sample of fiberglass face sheet is shown in figure.1.

Fig. 1: Fiberglass face sheet Final Sample

### C. *Honeycomb cutting*

The honeycomb is cut into a wedge shape of $30^0$ by clamping the structure and using Hand saw to cut the core.

Fig. 2: Core ready for sandwich construction

### D. *Sandwich Construction*

There are various methods of sandwich construction. For aerospace application sandwiches are fabricated using “heated press method”. In this technique adhesive film is placed between core and face sheets, the sample is bolted between bras plates (pressing) and placed in the oven at 100 degrees for four hours (heating).

The following figure show a wedge shape sandwich structure.

Fig. 3: Sandwich wedge of $30^0$

## III. FINITE ELEMENT MODELING

The wedge shape sandwich structures are modeled in ABAQUS software using shell element feature of deformable type for core and both face sheets. The cell size of 5.5mm is used for core. A single cell is sketched and is replicated using linear pattern. The pattern is then given a depth of 20 mm using extrusion and a flat honeycomb core is created. The flat core is then cut into a wedge shape using extruded cut feature and a line of $30^o$ angle was sketched and the wedge shape honeycomb core was created. The face sheets were also created using rectangular feature and a planer type in shell element and all the parts are assembled using constraints of coincident points as shown in the Fig. 4.

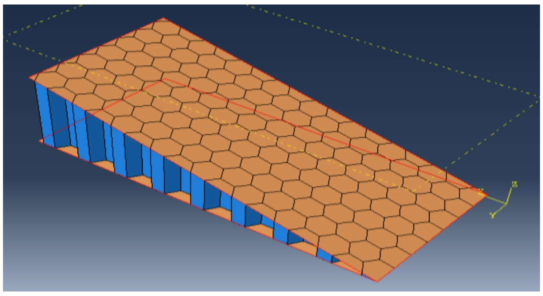

Fig. 4: Modeled Structure

A thickness of 0.62 and 0.3 were given to the face sheets and the core. The material properties were given to each part in the model tree. A set was created for the upper face sheet to apply a force on it. A dynamic, explicit step was created using step module and inputting a time period of 0.2.

Interaction property is created and a general contact was selected from the module.

### A. *Constraint manager*

Create 2 constraints; one between upper face sheet and core and the other between lower face sheet and core. A constraint type of “tie” is used and the master surface was selected from the core using its respective nodes at the upper and lower sides respectively. Both face sheets were selected as slaves separately.

### B. *Boundary condition(BC’s)*

Three BC’s were created. First BC was applied at the lower face sheet to “fix” it. The second BC was applied at the upper face sheet to restrain any “lateral movement”. The third BC was created at the upper face sheet by giving it a velocity to compress in the Z- direction as shown in the Fig. 5.

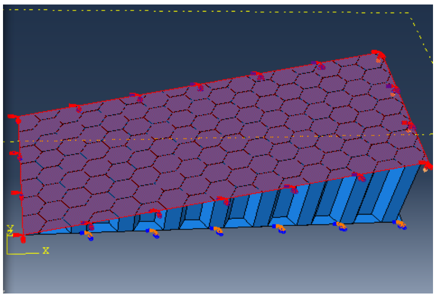

Fig. 5: BC's Applied

### C. *Meshing*

The meshing for three parts was created separately. The approximate global size of 2 was selected for the core and the face sheets so as to avoid the nodes distortion during processing. An independent mesh was selected after seeding so that parts do not depend on the each other during their contact. A quad dominated mesh is created and curvature control module was undertaken to account for the wedge shape meshing during analysis as shown in the fig. 6.

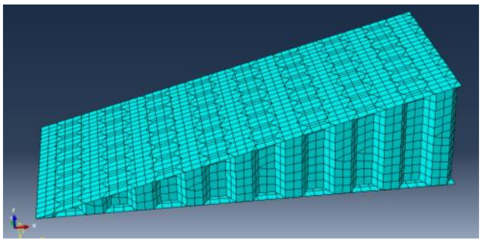

Fig. 6: Meshed Structure

### D. *Creating job*

After all the procedures the job was created for the analysis. Job was monitored and results were checked after completion.

## IV. FINITE ELEMENT ANALYSIS

The finite element analysis of the structure gives data about the "loads" and "displacement" for each node of the honeycomb core. It also shows the deformed shape of structure at different time intervals as shown in Fig. 7.

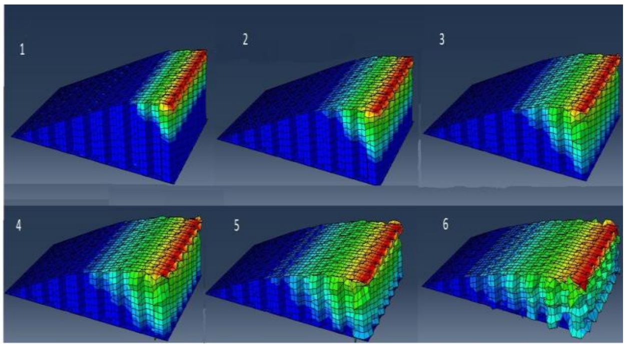


Fig. 7: Deformed Structures (Time lapse)

### A. *Results*

Data points should be created in order to analyze results. It is to be noted that the honeycomb core consists of several nodes and each node has its own values for "Load" and respective "deformation". So to find the overall scenario of deformation upon loading, we need to consider some of the important nodes and interpolating the results to the whole structure. The nodes that are considered are shown "Red" in the Fig.8. They are numbered as 300, 314, 328, 342, 356 and 360.

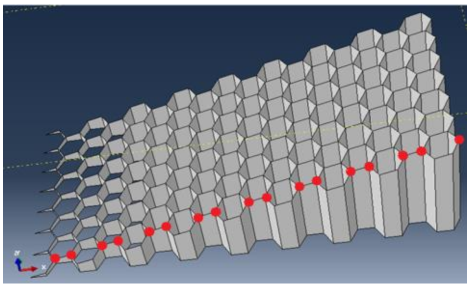

Fig. 8: Considered Nodes

The results for all the nodes are saved and analyzed for the maximum load value. The plots for the nodes undertaken are shown as follows.

- Node 300

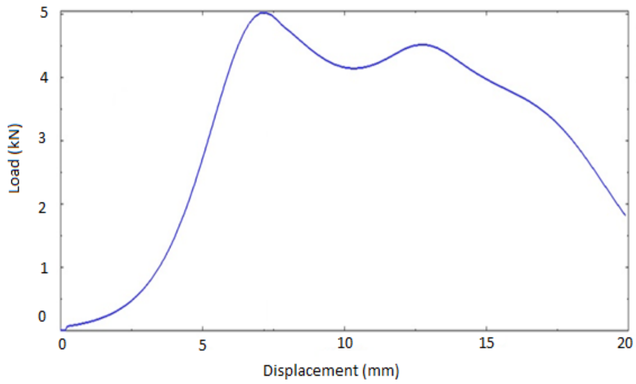


Fig. 9: Load vs. Displacement curve for Node 300

- Node 314

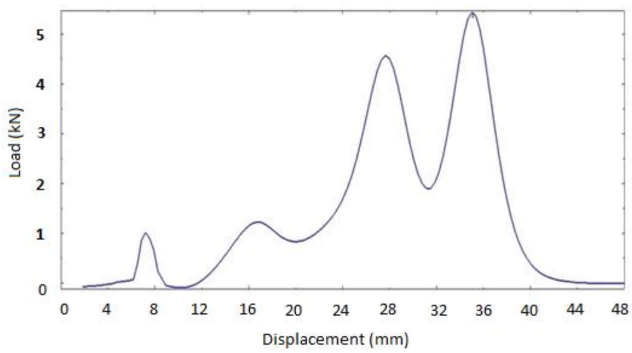


Fig. 10: Load vs. Displacement for Node 314

- Node 328

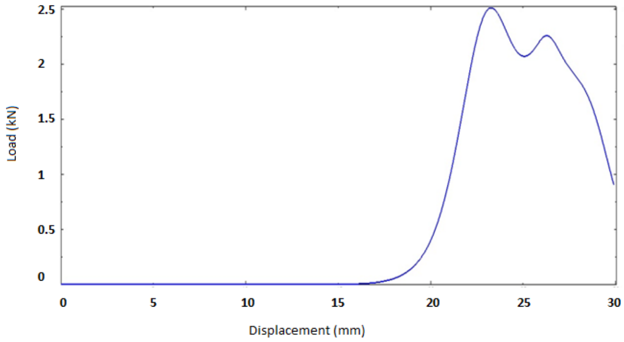


Fig. 11: Load vs. Displacement curve for Node 328

- Node 342

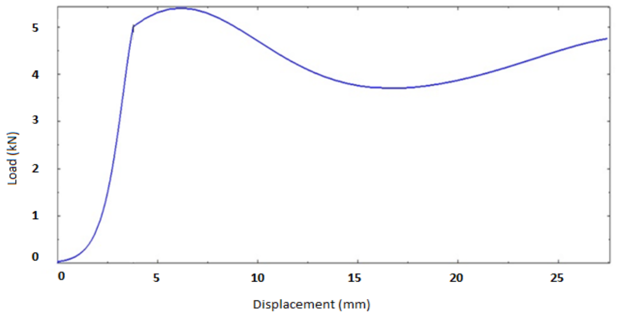


Fig. 12: Load vs. Displacement for Node 342

- Node356

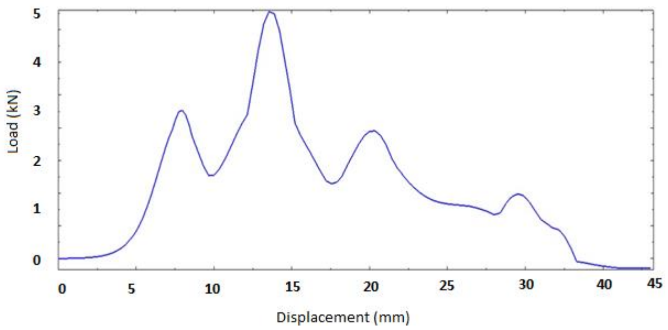


Fig. 13: Load vs. Displacement for Node 356

- Node 360

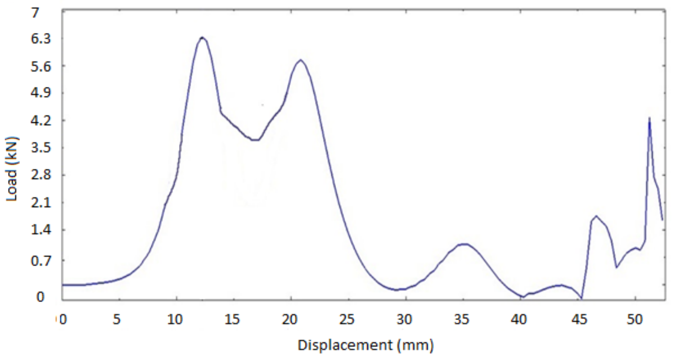


Fig. 14: Load vs. Displacement Node 360

The table below shows the maximum amount of load that is applied on all the considered nodes.

Table 1: Maximum Load Value Each Node

| Nodes | Maximum Load (kN) |
|---|---|
| 300 | 4.5 |
| 314 | 5.4 |
| 328 | 2.5 |
| 342 | 5 |
| 356 | 5.3 |
| 360 | 6.2 |

Taking average of the above mentioned loads, and interpolating it to the rest of the rows we get the maximum amount of load that a $30^0$ degree wedge can carry is equal to “4.81kN”. There is a difference in values of “elastic modulus” for the honeycomb and absence of simulation for the “Adhesive film” in ABAQUS, so we add a tolerance of 0.5kN.

## V. COMPRESSION TEST

The research is carried out on the structure which is supposed to carry only the “Aerodynamic loads” and not the “Structural loads” so it was tested for its strength by using “Compression test”. An ASTM standard *“C-365- Flat wise compression test for honeycomb sandwich structures”* was followed to test the $30^0$ wedge with the help of “Universal Testing Machine (UTM)”.

The sample should be placed exactly at the center point of UTM plate. The compression rate was set to 0.01mm per minute.

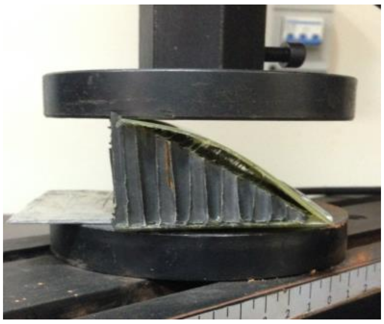

Fig. 15: Compression Test Assembly

The time lapse of compression test is shown with the help of deformed shapes of the structure as shown in the Fig.16.

Fig. 16: Time-lapse of Compression test

*A. Results*

"Load vs. Displacement/deformation" and "Stress vs. Strain" plots after compression test of 30$^o$ wedge are shown below.

*Sample 1*

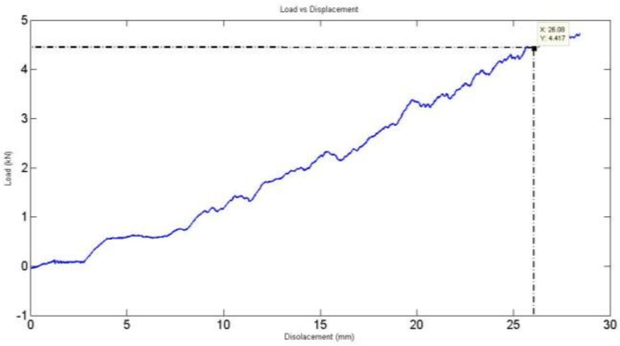


Fig. 17: Load vs Displacement 30$^o$
(SAMPLE 1)

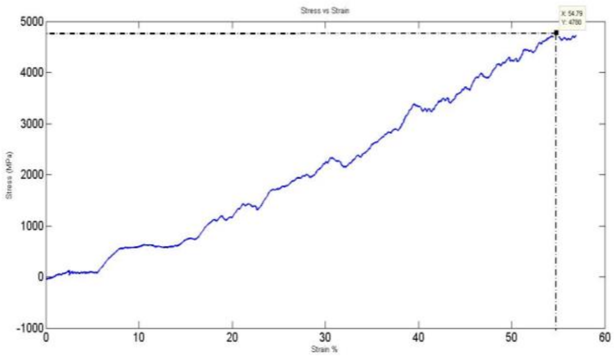


Fig. 18: Stress vs. Strain 30$^o$
(SAMPLE 1)

*Sample 2*

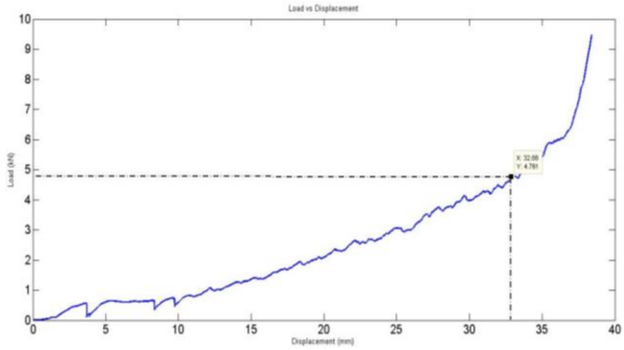


Fig. 19: Load vs Displacement 30$^o$
(SAMPLE 2)

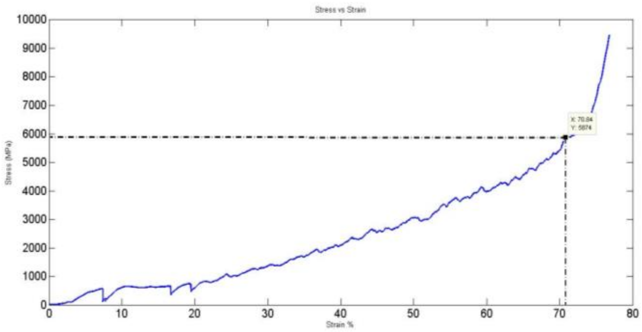


Fig. 20: Stress vs. Strain 30$^o$
(SAMPLE 2)

The average maximum load that a 30 degree wedge honeycomb sandwich structure can withstand is equal to "4.589kN" and the average maximum stress that it can carry is "5327MPa".

Table 2: 30$^o$ Wedge Results

| Sample No. | Maximum Load (kN) | Maximum Stress (MPa) |
|---|---|---|
| 1 | 4.417 | 4780 |
| 2 | 4.761 | 5874 |

## VI. COMPARISON OF RESULTS

The "Compression test" results of 30 degrees wedge honeycomb sandwich structure obtained from the fabrication and those from the FEM modeling are as follows:

- Fabrication results = Max Avg. Load= 4.589 ± 0.5kN
- FEM results =Max Avg. Load = 4.81 ± 0.5kN
- Difference = 0.22kN or 5%

The above discussion indicates that there will be a difference of 5% in the results every time we model a wedge shape structure of same dimensions as that of the fabricated sample.

## VII. CONCLUSION

The wedge shape honeycomb sandwich structures were fabricated and tested for their “Strength”. Moreover, the structure was modeled in the software and finite element analysis was done by inputting the same conditions as that of fabrication.

It has been shown that the results obtained have a satisfactory strength for the wedge shape honeycomb sandwich structures. The comparison with the software simulation showed a considerably less difference between the two results.

## VIII. ACKNOWLEDGMENT

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