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ANALYTICAL STUDY OF METALLIC SANDWICH PANEL UNDER BLAST LOAD

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Abstract: This study has been undertaken to investigate the front layer deflection of metallic sandwich panel under blast loads. This study analytically evaluated the deformation of front layer of honeycomb sandwich panel using different core materials (Steel and Aluminium) and fixed outer layer material (Steel). Results shows Aluminium core with steel outer layer combination shows better performance under blast load. 500 g of Trinitrotoluene (TNT) used as blasting material and the finite-element model simulated using dynamic nonlinear explicit software ANSYS Workbench 16. 1.

***Index Terms* – Honeycomb sandwich panel, TNT, Core topology**

I. INTRODUCTION

The demand for the protection of important government and public buildings has increased in recent days to resist blast loads due to frequent terrorist activities occurring around the world. Sandwich panels are preferred structural elements that can be used to protect the parent structure by mitigating the blast pressure. Recently, major research focus is on passive mitigation systems for improving the resistance of structural elements against blast load. These passive mitigation systems include sacrificial cladding, sacrificial blast walls, impedance mismatching system, and blast wave deflector. One of the solutions considered is using maneuverable blast walls to shield buildings and other structures against blast loads. Maneuverable walls act as a reflective surface for blast waves that reduces the blast effect on the targeted building. During higher severity events, maneuverable walls are erected around structures as a first line of defense, increasing stand-off distance. The two main factors taken into consideration for designing maneuverable walls are the ease of assembly and portability. The most efficient light-weight maneuverable blast resisting walls are usually made of sandwich panels. Sandwich panels are composed of three layers; upper skin, inner core, and lower skin. The inner core can have several forms such as honeycomb cores, corrugated cores, truss cores, Z-cores, C-cores, I-cores or solid foam cores. Sandwich panel dissipates significantly more energy than a solid plate of the same material and mass due to the ability of the core truss structure to deform plastically. The truss and corrugated cores had a significantly lower strength, but acted like a metal foam. On the other hand, honeycomb cores showed a high peak strength, but they exhibited strong softening capabilities. Moreover, comparing the crushable core with the rigid core, it was found that the transmitted impulse was reduced by approximately 25%. However, limited studies have been reported on the behaviour of sandwich panels that are stiffened to mitigate the effect of blast on the structures. Composite honeycomb sandwich structures are used extensively in the aerospace, transportation, marine, and defense industries due to their light weight, high specific strength, high stiffness, and excellent energy absorption. However, composite materials pose some problems when they are subjected to impact loading. Impact loading such as tool drop, debris and bird strike, and hailstone and bullet impact causes severe damage to the composite sandwich structures, which is difficult to repair. The high-velocity impact loading response of the structure is entirely different from that of the low-velocity impact in terms of damage extent, resistance, and tolerance. Furthermore, high-velocity impact causes severe localized damage to the structure. To investigate the response of composite honeycomb sandwich structures under different loading, including low-velocity and high-velocity impact, in terms of failure modes, damage level, and energy absorption characteristics, extensive numerical and experimental studies have been carried out. Characterization of sandwich structures under TNT blast load is entirely different from that under the impact in terms of understanding the failure mechanism. Metal foams are cellular materials consisting of a solid phase and a gaseous phase dispersed therein. As a result of their structure, they exhibit a combination of properties such as low density, favourable stiffness-to-mass ratio and good energy absorption properties. A sandwich design based on dense face sheets can yield compression, tension, torsion or bending properties beyond those of a metal foam alone. Face sheets protect the foam core from surface damage and corrosion, and allow the structure to bear tensile loads, where the bare metal foam performs poorly.

II. OBJECTIVE OF PROJECT

- To find the deflection behaviour of sandwich panel
- Comparison of Steel core and Aluminum core
- To find the thickness behaviour of outer layers of sandwich panels

III. SCOPE OF PROJECT

- To resist explosive loading by minimizing damage
- To ensure its high specific strength
- To ensure light weight and mitigate blast load

IV. METALLIC SANDWICH PANEL

The sandwich structures are light weight structures consists of two stiff, strong outer face layers that are separated by some sort of light weight core. The separating faces of sandwich panels increases moment of inertia, efficient force resisting, bending and buckling like I beam theory. Two faces of sandwich panel act as flanges of I beam and core act as web. The core has several topologies like honeycomb, lattice, folded and woven. This paper studied honeycomb core topology.

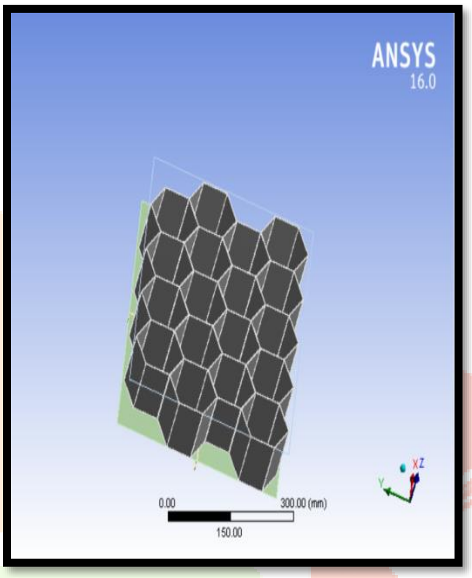

Fig.1. Honeycomb core topology

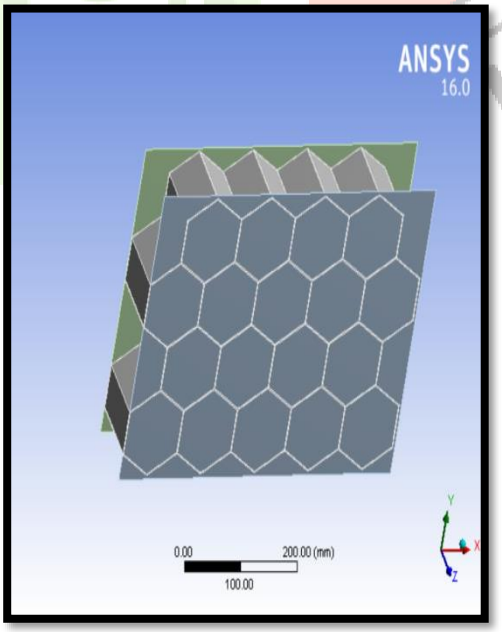

Fig.2. Metallic sandwich panel with honeycomb core topology

V. MATERIAL PROPERTIES

Two face sheets are modelled using Steel material and core topology modelled using Steel Aluminium material respectively.

Table1. Material properties

Material properties	Steel	Aluminium
Young's modulus	$2x10^5$ MPa	71000 Mpa
Density	7900 kg/m^3	2700 kg/m^3
Poisson's ratio	0.3	0.33
Reference temperature	300 K	300 K
Compressive yield strength	250 MPa	280 MPa
Tensile yield strength	250 Mpa	280 MPa
Shear modulus	76923 MPa	26691 MPa

VI. MODELLING AND ANALYSIS

The finite-element model simulated in this study was conducted using dynamic nonlinear explicit software ANSYS Workbench 16. 1. In this study, a three-dimensional explosion was modelled with Steel and Aluminium core topology and Steel face layers.. The panel has outer layers with dimensions of 400 mm x 450 mm and core thickness of 100 mm excluding front and back layer thickness. The thickness of outer layers will varying in this project and core material has fixed thickness of 1 mm. 500 g of TNT explosive material provided at fixed standoff distance of 1000 mm away from centre of front layer of sandwich panel. 500 g of TNT modelled in ANSYS Workbench 16. 1 and TNT have 1630 kg/m^3 density and it is modelled in cubical shape of 67.4 mm edge length. There are 10917 nodes and 7171 elements in mesh model. Goal of the core structure is increases flexural stiffness with very little weight gain. In sandwich structures the light weight core transfers the load between the two face skins which provide the load carrying capability of panel and induce a high second area moment of inertia. In this parametric study steel core topology material replaced by Aluminium alloy.

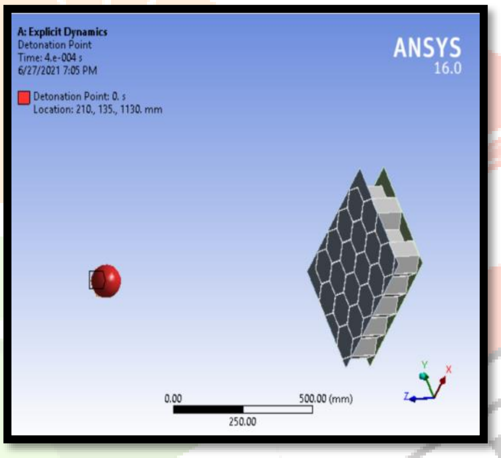

Fig.3. Applications of TNT on sandwich panel

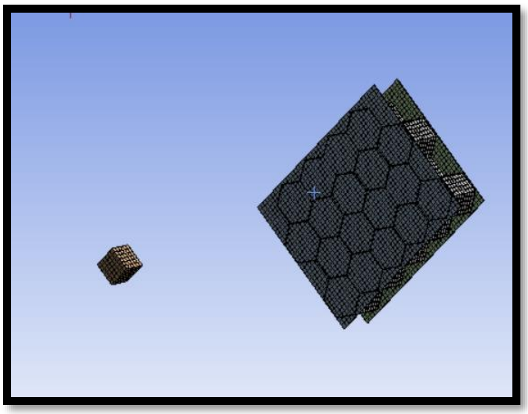

Fig.4. Mesh model

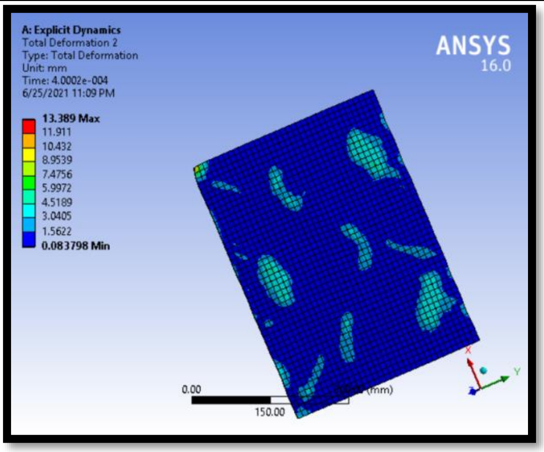

Fig.5. Front layer deflection of honeycomb shape core topology (Aluminium) metallic sandwich panel

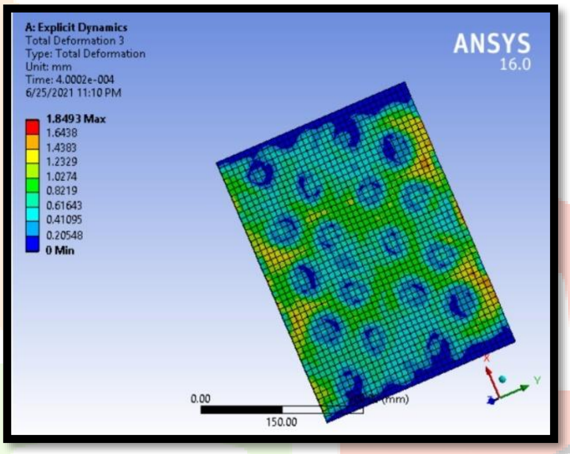

Fig.6. Back layer deflection of honeycomb shape core topology (Aluminium) metallic sandwich panel

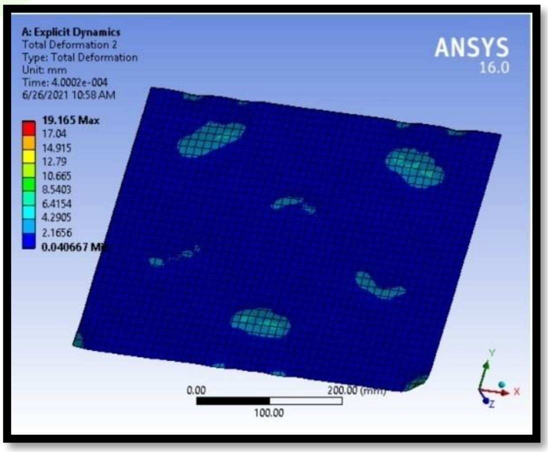

Fig.7. Front layer deflection of honeycomb shape core topology (Steel) metallic sandwich panel

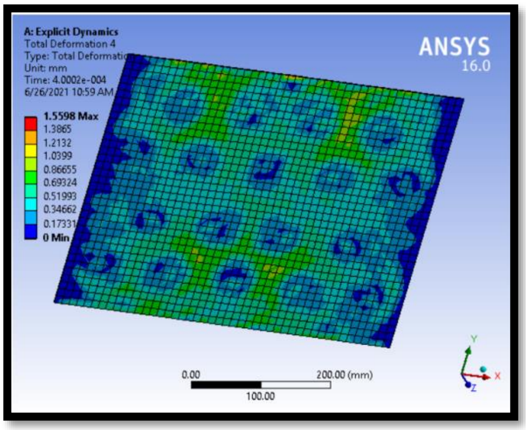

Fig.8. Back layer deflection of honeycomb shape core topology (Steel) metallic sandwich panel

VII. RESULTS AND DISCUSSION

Table 2. Deflection of honeycomb sandwich panel using Aluminium and steel core

Outer layer thickness (mm)	Front layer deflection (mm)		% of difference
	Structural steel core	Aluminium core	
1	22.41	22.931	1
2	19.58	13.38	2
3	10.864	11.396	3
4	6.3816	4.3835	4
5	2.4737	2.2169	5
6	1.9771	1.858	6
7	1.3193	1.306	7

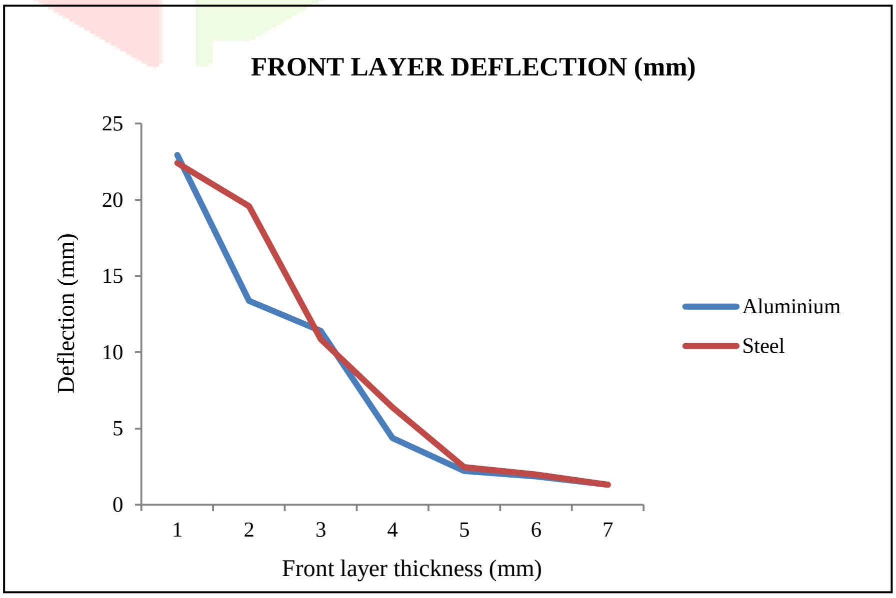

Fig.9. Deflection of hexagonal sandwich panel using Aluminium and steel core

Honeycomb shape core topology sandwich panel modeled in this study. Outer layer thickness of 1, 2, 3, 4, 5 and 6 mm studied with Aluminium core and Steel core material. For 1 mm and 3 mm front layer deflection of Aluminium core increases 2.3% and 4.6% compared with Steel core sandwich panel. For 2, 4, 5 and 6 mm thickness front layer deflection of Aluminium core decreases 31.6%, 31.3%, 10.3%, 6.0% and 1.0% respectively.

VIII. CONCLUSIONS

- By increasing the thicknesses of the outer layers, the panels become stiffer, which results in reducing the front layer deflection.
- Upon applying Aluminium on honeycomb shape core topology less front layer deflection compared to using steel material on core.
- Aluminium composite materials easier to create shape and it weigh one-third less than steel.
- Exterior surface transfer loads caused by bending flexural load and compression load and Core transfers load caused by shearing.

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