WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Experimental Investigation on Influence of various Core Materials and their Cell Geometry on Strength to Stiffness of Honeycomb Sandwich Structure

T J Prasanna Kumar1*, B Rajeev Kumar[2], B Dhanush[3a], Sk Chand Mohiddien[3b], T N Venkata Manikanta[3c], Sk Suhail[3d], Sanapathi parasuram[3e], Sk Afzal Nabi[3f]

1 Assistant professor, Department of Mechanical Engineering, PVPSIT, Vijayawada, India-520007

[2] PG student, Department of Mechanical Engineering, PVPSIT, Vijayawada, India-520007

[3a,b,c,d,e,f] UG student, Department of Mechanical Engineering, PVPSIT, Vijayawada, India-520007

* Email Id: tjpk@pvpsiddhartha.ac.in

DOI: https://doi.org/10.55248/gengpi.5.0224.0571

ABSTRACT

Honeycomb sandwich structures are widely used in aerospace and space structures due to unique characteristics like high strength to weight ratio and High stiffness. Honeycomb sandwich structure consists of honeycomb core made of either metal or thin paper like materials. Core is sandwiched with metallic or composite face sheets. Core gives high compressive strength whereas face sheet gives shear strength. Generally, Honeycomb core is made up of aluminium, fibre glass and advanced composite materials. For nearly same weight honeycomb sandwich structure can give up to 30 times higher stiffness than metallic sheets. Modelling of Honeycomb sandwich structures with actual cell configuration is difficult and time consuming. Hence sandwich structure is generally modelled as equivalent homogeneous structure.

Honeycomb core sandwich structures are especially becoming more prevalent in the field of civil engineering where the need of high structural strength and low weight is necessary. So there is a constant increase in demand for lightweight, high strength and stiffness properties and cost economical materials. These factors are directly or indirectly related to the mechanical properties of honeycomb sandwich structures.

Usually, the optimal geometrical structure at with higher mechanical properties is the main motive in this material research. Often there is a correlation to design and manufacture sandwich panels with much precise geometry and optimal properties. Normally the existing sandwich panels are designed and manufactured with the higher factor of safety in the thickness and mechanical properties required for the particular application. This may be a reasonable solution. But when we consider for complex geometry and larger design, it’s not so comparatively easy, dimensional restrictions, and material consumption and production cost will be the major issues.

The present work is to experimentally analyse the mechanical properties of the sandwich panels and find the optimal geometrical thickness of the sandwich with high strength and stiffness properties.

Keywords: Sandwich, Honeycomb, Aluminium, Balsa, face sheet, strength, stiffness

1. INTRODUCTION

Sandwich Structure with Balsa Core and Aluminium Face Sheets

Sandwich Structures

Sandwich structured composites are a particular class of composite materials which have become very popular due to high specific strength and bending stiffness. The low density of these materials makes them especially suitable for use in aeronautical, space and marine applications. Sandwich panels are composite structural elements, consisting of two thin and stiff face sheets and separated by a thick layer of light weight and a stiff material called core.

The faces and the core material are bonded together with an adhesive to facilitate the load transfer mechanisms between the components. This particular layered composition creates a structural element with both high bending stiffness, bending strength-weight ratios.

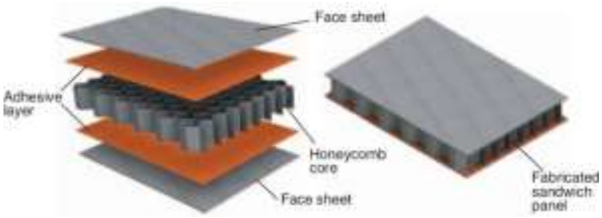


Fig 1.1. Construction of honeycomb core sandwich panel

The construction of honeycomb core sandwich structures is shown in Fig 1.1. The first layer is the face sheet. This layer is the primary layer of the sandwich structure called as skin and the skin is bonded with the honeycomb core by the adhesive layer. The adhesive may be thermoset plastic or thermoplastic.

By splitting a solid laminate down the middle and separating the two halves with a core material the result is a sandwich panel. The new panel weighs little more than the laminate, but its flexural stiffness and strength are much greater by doubling the thickness of the core material the difference is, even more, striking.

Face sheet materials

The primary functions of the face sheets are to provide the required bending and in-plane shear stiffness alongside to carry the axial, bending, and in-plane shear 8 loading. There are various materials that can be used as face sheets. Some examples are given below:

- Aluminium
- Steel/Stainless Steel
- Carbon/Epoxy
- Fiberglass/Epoxy
- Aramid/Epoxy
- Plywood
- Galvanized iron

Fig.1.2. Aluminium sheet

Core materials

The main part of the sandwich structure is core material, in most of the sandwich structure in plain loads and bending loads are carried by the face sheets and the core carries the transverse shear load. The core materials are generally divided into four types solid, honeycomb, web core and truss core.

The inner skin is laminated onto the top of the core material effectively sealing it. Sandwich core laminates of this type are used to stiffen various composite applications such as boat hulls, automobile hoods, moulds, and aircraft panels. By increasing the core thickness, you can increase the stiffness of the sandwich without substantially increasing weight and cost.

The most common types of core materials are Honeycomb, Vinyl Sheet Foam, End Grain Balsa, and Polyurethane Foam

Honeycomb

Honeycomb is a series of cells, nested together to form panels similar in appearance to the cross- sectional slice of a beehive as shown in Fig 1.3. In its expanded form, honeycomb is 90-99 % open space. Honeycomb is fire retardant, flexible, lightweight, and has good impact resistance. It offers the best strength to weight ratio of the core materials. Honeycomb is used primarily for structural applications in the aerospace industry. Parts which require minimum weight often employ Honeycomb sandwich cores.

Fig: 1.3. Honeycomb core Fig 1.4. Vinyl Sheet Foam

Vinyl Sheet Foam

Vinyl sheet foam is shown in Fig 1.4. is one of the most versatile core materials on the market. It is a rigid, closed cell material that resists hydrocarbons, alkalis, dilute acids, methyl alcohol, sea water, gasoline, diesel oil, and it is self-extinguishing. It has been used extensively in aircraft and performance automotive structures, but it can be applied anywhere that high properties and easy handling are needed. Vinyl foam can be thermoformed in an oven or with a heat gun while applying gentle pressure. For ultimate peel strength, use a perforation roller to increase the surface area of the foam. The peel strength will increase an additional 15-20% after perforation.

End Grain Balsa

End-grain balsa is the most widely used core material. It is both a relatively high strength core and less expensive than vinyl or honeycomb. It achieves its high compression strength because on a microscopic level it has a honeycomb type of structure yet is quite dense. It is easy to cut and bevel and is available in 29x49 inch sheets. The individual small blocks of end grain balsa are bonded to a light scrim fabric which makes the sheet quite flexible as shown in Fig 1.5.

Fig1.5. End Grain Balsas Fig 1.6. Polyurethane Foam

Polyurethane Foam

This sheet foam shown in Fig 1.6 is a rigid, closed cell material with excellent thermal insulation and flotation properties. This core has been at the heart of the marine industry for decades and is fairly inexpensive when a lower property cored laminate is needed. It is compatible with both polyester and epoxy resin systems.

ADHESIVES

Adhesives' (or the bounding layer) role in the sandwich structures is to keep the faces and the core co- operating with each other. The adhesive between the faces and the core must be able to transfer the shear forces between the faces and the 9 core. The adhesive must be able to carry shear and tensile stresses. It is hard to specify the demands on the joints; a simple rule is that the adhesive should be able to take up the same shear stress as the core [13]. Some adhesive types, such as phenolic, give out vapor during curing reaction. The vapor can cause several problems if this vapor is trapped; it may cause little or no bond in some areas, the pressure may damage the core material or it may cause the core to move to an undesired position. Common adhesives in current use are:

1. Nitrile Pheonolic
2. Vinyl Pheonolic
3. Epoxy
4. Urethane
5. Polyimide
6. Polyamide

Major Application Areas of Honeycomb Sandwich Structures

1.2.1 Aerospace Applications

In Commercial Aerospace, As Radome: Specialized glass Prepregs. Flexcore honeycomb, For Landing Gear Doors and Leg Fairings: Glass/carbon Prepregs, honeycomb and Redux bonded assembly. Special process honeycomb, For Galley, Wardrobes, Toilets: Fabricated Fibrelam panels, As Partitions: Fibrelam panel materials, For Wing to Body Fairing: Carbon/glass/aramid Prepregs. Honeycombs. Redux adhesive. In Wing Assembly: (Trailing Edge Shroud Box) Carbon/glass Prepregs. Nomex honeycomb. Redux bonded assembly, Flying Control Surfaces - Ailerons, Spoilers, Vanes, and Flaps: Glass/carbon/aramid Prepregs. Honeycomb. Redux adhesive, Passenger Flooring: Fibrelam panels, Engine Nacelles and Thrust Reversers: Carbon/glass Prepregs. Nomex honeycomb. Special process parts, Cargo Flooring: Fibrelam panels

1.2.2. Space & Defense Applications

In Fuselage Panel Sections: Epoxy carbon Prepregs. Non-metallic honeycomb core and Redux adhesives, In Flying Control Surfaces: Epoxy carbon and glass Prepregs. Honeycomb core material and Redux adhesives, In Satellites**,** Solar Panels : Epoxy carbon prepregs, aluminum honeycomb, film adhesive **,** Reflectors Antennae : Epoxy/aramid prepreg, cyanate carbon prepreg, aramid/aluminum honeycomb, Satellite Structures : Carbon prepreg, aluminum honeycomb, film adhesive**, As** Energy Absorbers, Driver Protection: Pre-crushed metallic honeycomb assemblies and carbon prepregs, As Ceiling panels: Molded with prepreg or honeycomb sandwich, As Upper Deck and Lower Flooring: Molded with prepreg or honeycomb sandwich, As Connecting Archway: Molded component with honeycomb and prepreg materials, As External Doors: Bonded honeycomb sandwich construction.

The sandwich structures are used not only directly in automobiles but also indirectly as crash test barriers due to their high shock absorbance capacity such as A-Pillar, Front Side Rail, Other Side Rail, Front Header, B-Pillar, Rear Header, Rearmost Pillar, Upper Roof

2. METHOD OF APPROACH

Experimental Analysis

Tensile test carried out on sandwich honeycomb structure specimen with the following specifications:

Most sandwich constructions are loaded in tension perpendicular to the panel, which is through the thickness direction of the foam. This limits the number of tests standards to be used since the core thickness is typical. Tensile strength is calculated at maximum load, which normally occurs when the specimen breaks. Displacement, or strain, is measured by direct measurement on the specimen with an extensometer. Tensile modulus is calculated from the steepest part of the load-displacement curve in the elastic region.

SPECIMEN SPECIFICATIONS:

Length - 160 mm

Width - 12.5 mm

Thickness - 0.60 mm

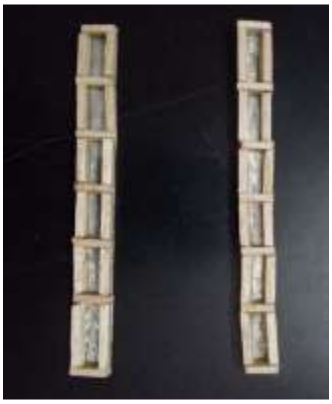


Fig.2.1.Tensile test specimen

Fig.2.2. Specimen in the tensile test machine

Bending test carried out on sandwich honeycomb structure specimen with the following specifications:

Bending-testing sandwich panels, when testing solid laminates the support and loading cylinders usually have relatively small diameters. As discussed above, sandwich specimens are typically supported and loaded as wide flat plates. While the ASTM standards permit to use the steel cylinders, it is noted that there is a greater risk of local specimen crushing because of the more concentrated loading induced by a cylinder.

SPECIMEN SPECIFICATIONS:

Length – 100 mm Width – 25 mm

Thickness - 0.60 mm

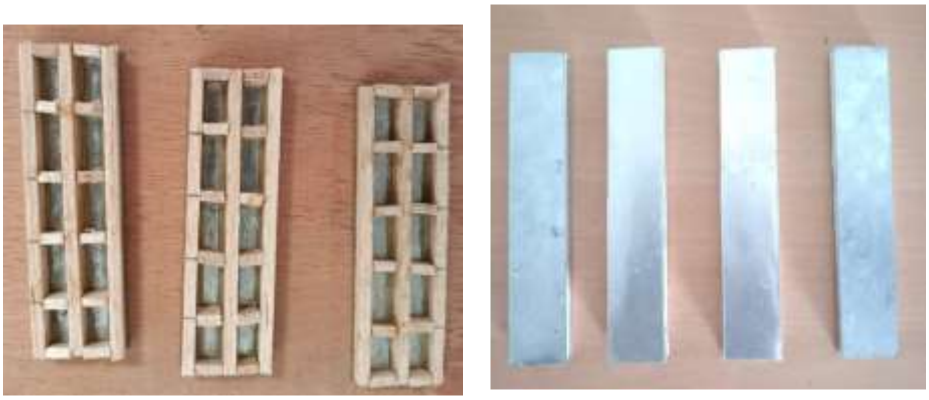


Fig.2.3. Bending test specimens

Fig.2.4. Specimen in bending test machine

Fig.2.5. Specimen after Bending test

2.1.3 Impact test carried out on sandwich honeycomb structure specimen with the following specifications:

Impact energy is described as the amount of energy required to fracture a material subject to a shock loading. Charpy, Izod, and drop weight impact tests are generally used to get impact energy of a material. For a free-falling impactor case, the basic principle is that initial potential energy will be converted to maximum kinetic energy when the impactor collides into a target. This kinetic energy is converted to impact energy when a material is fractured. If there is an initial kinetic energy, impact energy is defined as potential energy and kinetic energy, ignoring friction and sound energies produced by the impact. In the following impact simulations to compare impact energies, the potential

energy of the impactor is ignored due to the very short distance between the impactor and the target structure. Therefore, the impact energy is assumed to be calculated only from the kinetic energy.

SPECIMEN SPECIFICATIONS:

Length - 63.5 mm Width - 12.7 mm

Thickness - 0.60 mm

Fig.2.6 (a). Impact Test Machine, (b). Specimen fixed on testing machine

Fig.2.7. Specimens after impact test

3. Results and Discussions

Experimental Observations from Tensile, Bending and Impact Tests:

Table: 3.1 Tensile test results for G.I sheet

S. NO.	Cell height (mm)	Maximum load (KN)
1	5	3.3
2	6	4.03
3	7	5.5
4	8	5.2

Table: 3.2 Tensile test results for aluminium sheet

S. NO.	Cell height (mm)	Maximum load(KN)
1	5	2.4
2	6	2.9
3	7	2.0
4	8	1.7

Table: 3.3 bending test results for G.I sheet

S. NO.	Cell height(mm)	Maximum load(KN)
1	5	3.3
2	6	5.75
3	7	6.5
4	8	5.0

Table: 3.4 bending test results for aluminium sheet

S. NO.	Cell height (mm)	Maximum load(KN)
1	5	3.3
2	6	2.6
3	7	2.46
4	8	2

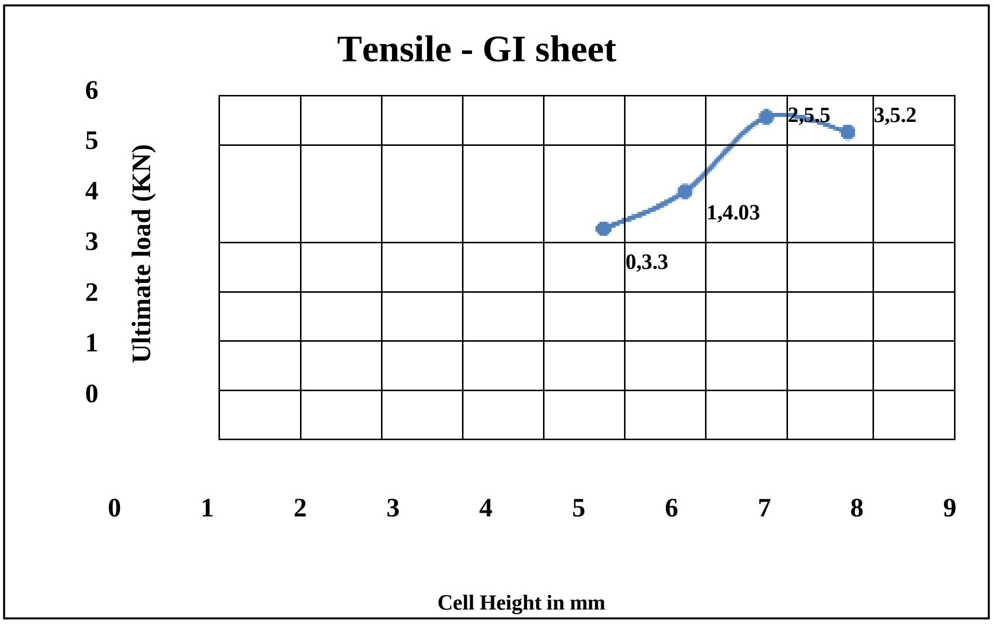
Table: 3.5 Impact test results for G.I sheet

S. NO.	Cell height (mm)	Impact load (Joules)
1	5	6
2	6	6
3	7	6
4	8	6

Table: 3.6 Impact test results for aluminium sheet

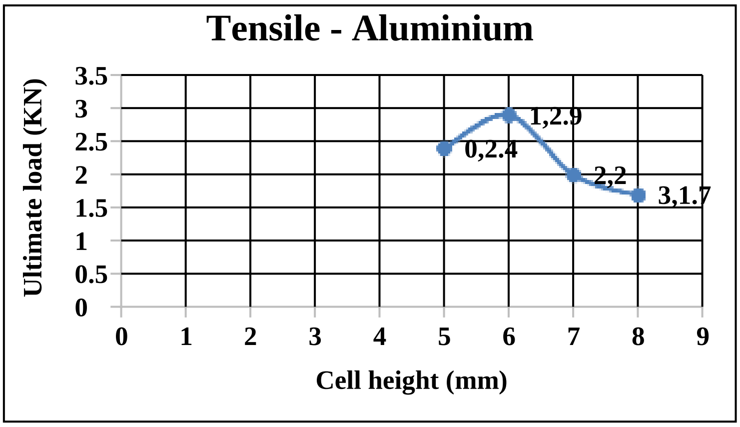
S. NO.	Cell height (mm)	Impact load (Joules)
1	5	4
2	6	4
3	7	6
4	8	6

Plot: 3.1 Variation of Ultimate Load With Respect To Cell Height for GI Sheet



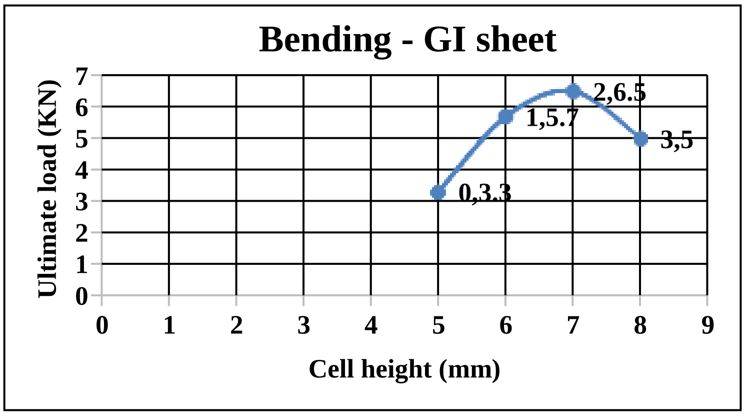
In the graph we observe that the ultimate load goes on increasing upto 7mm height of cell, but the load decreases for 8mm height

Plot: 3.2 Variation of Ultimate Load With Respect to Cell Height for Aluminum Sheet

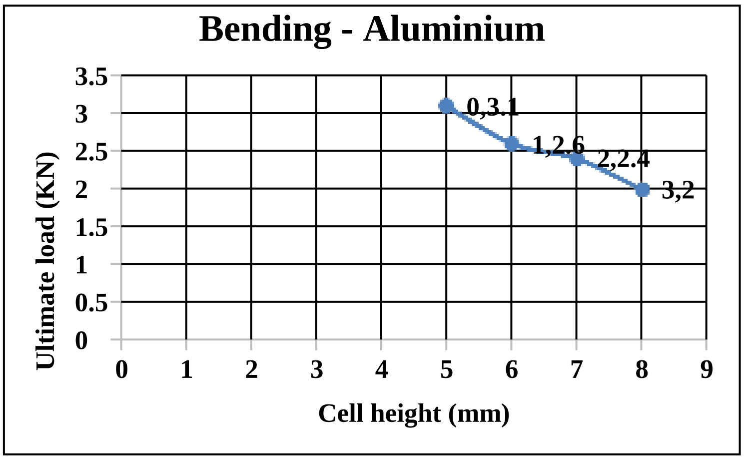


The above graph shows that the load increases up to 6 mm height of the cell but the load decreases for the 7 mm and 8 mm height of the cell.

Plot: 3.3 Variation of Ultimate Load With Respect to Cell Height for GI Sheet

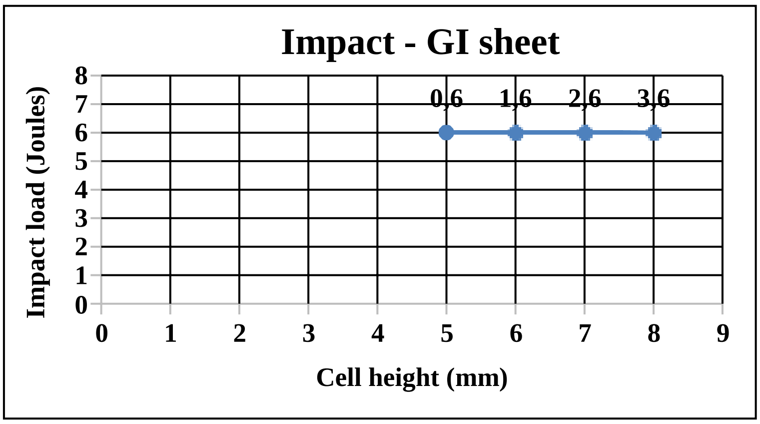


From the graph the ultimate load increases up to 7 mm height of cell but it decreases for 8mm height Plot: 3.4 Variation of Ultimate Load With Respect to Cell Height for Aluminum Sheet

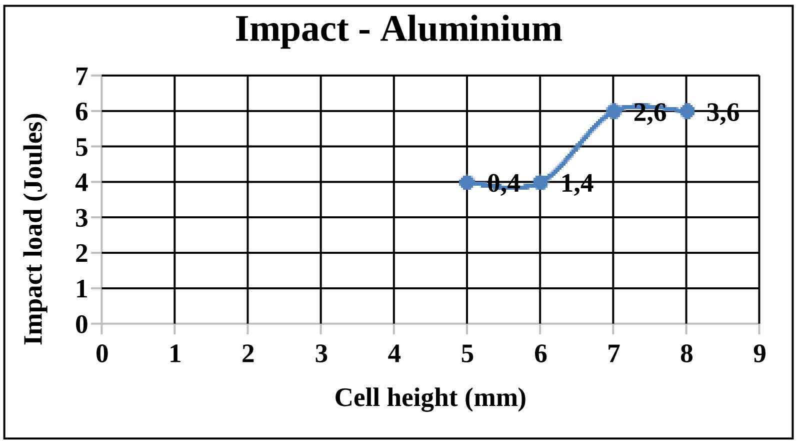


The above graph shows that the load decreases gradually when the height of the cell increases.

Plot: 3.5 Variation of Ultimate Load With Respect to Cell Height for GI Sheet



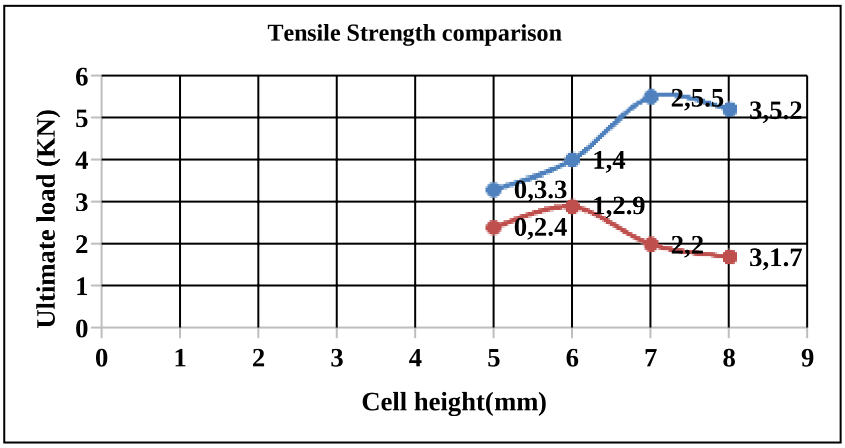
From the above graph it shows that the impact load is constant even when the height of the cell varies. Plot: 3.6 Variation of Ultimate Load With Respect to Cell Height for Aluminium Sheet



It is observe that the Impact load is constant for 5 and 6mm height of cell but the load increases and is constant for 7 and 8mm height of cell.

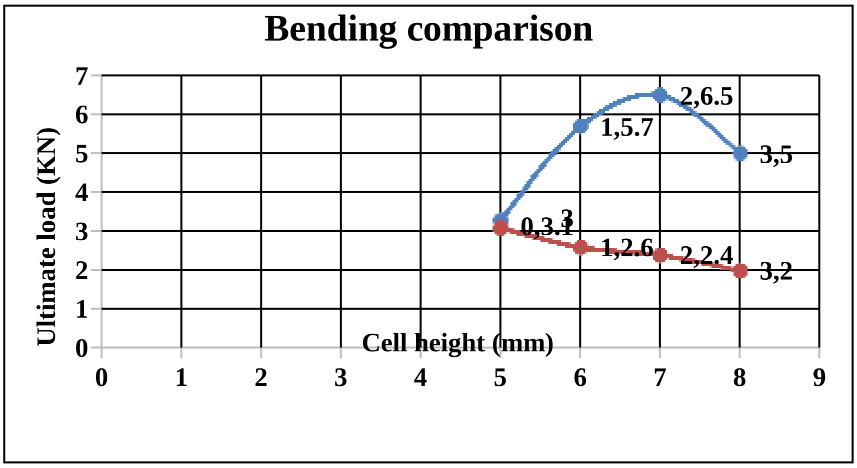
3. **Comparative Plots Between Various Test Carried Out on Specimens Made of Al/Balsa/Al and GI/Balsa/GI Sandwich Honeycomb Structures**

Comparison between Tensile Plots:



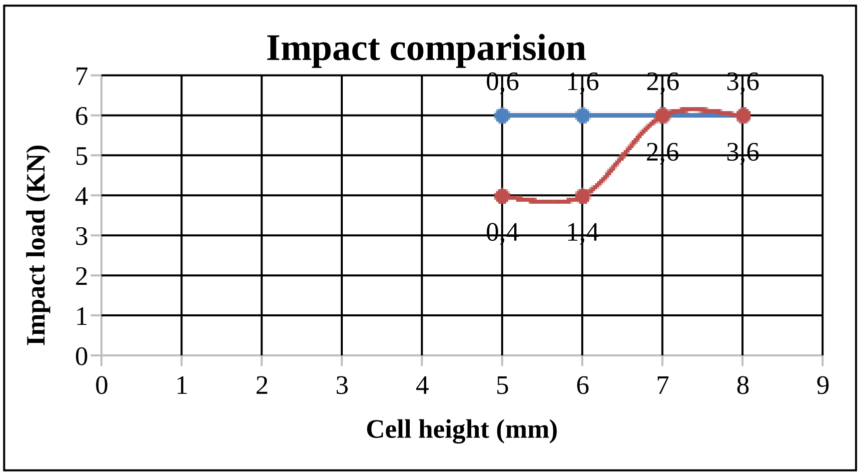
The above graph shows that the variation of Ultimate load in tensile test for different face plate materials.

Comparison between Bending Plots:



It shows that the variation of ultimate load in bending test for different types of face plate materials.

Comparison between Impact test plots:



The above graph shows that the variation of impact loads for GI material and Aluminium material.

4. CONCLUSIONS

From the experimentation analysis carried out on various testing's for specimen modelled using sandwich honeycomb structure with Aluminium/Balsa wood/ Aluminium and Galvanized Iron/ Balsa wood/Galvanized Iron face plates and core structures respectively; the following conclusions have been made:

1. When tensile test carried out on specimen made of GI as faceplates and Balsa wood as core structure the ultimate tensile strength increases as cell height of the core increases from (5/6/7) mm. 7 mm core cell height is observed as optimum, later the strength decreases with increases in height. Maximum load for specimen rupture is noted as 5.5 KN whereas for specimen made of Al as face plates and Balsa wood as core structure, the maximum load for specimen rupture is noted as 2.9 KN. Hence it is observed that GI/Balsa/GI sandwich structure attains more tensile strength than Al/Balsa/Al sandwich structure.

2. When bending test carried out on specimen made of GI as faceplates and Balsa wood as core structure the ultimate bending strength increases as cell height of the core increases from (5/6/7) mm. 7 mm core cell height is observed as optimum, later the strength decreases with increases in height. Maximum load for specimen rupture is noted as 6.5 KN whereas for specimen made of Al as face plates and Balsa wood as core structure, the maximum load for specimen rupture is noted as 3.3 KN. Hence it is observed that GI/Balsa/GI sandwich structure attains more bending strength than Al/Balsa/Al sandwich structure.

3. When impact test carried out on specimen made of GI as faceplates and Balsa wood as core structure the ultimate impact strength is constant as cell height of the core increases from (5/6/7/8) mm. Maximum load for specimen rupture is noted as 6J whereas for specimen made of Al as face plates and Balsa wood as core structure, the maximum load for specimen rupture is noted as 6J for 7 and 8mm cell height, and 4J for 5 and 6mm cell height . Hence it is observed that GI/Balsa/GI sandwich structure attains more impact strength than Al/Balsa/Al sandwich structure.

5. REFERENCES

1. Shubham Upreti, Vishal K. Singh, Susheel K. Kamal, Arpit Jain, Anurag Dixit ; (2019) "Modelling and analysis of honeycomb sandwich structure using finite element method" Materials Today: Proceedings (ELSEVIER)
2. Shanyouming Sun, Dan Liu, Yinglong Sheng , Shangsheng Feng, Hongbin Zhu,Tian Jian Lu (2021) "Out-of-plane compression of a novel hybrid corrugated core sandwich panel" Composite Structures (ELSEVIER)
3. M Kamel, A F Nemnem and M Kassem (2020) "Experimental modal testing of a honeycomb sandwichplate" IOP Conference Series: Materials Science and Engineering(973)
4. Clément Audibert,, Anne-Sophie Andréani, Éric Lainé, Jean-Claude Grandidier(2019) "Discrete modelling of lowvelocity impact on Nomex® honeycomb sandwich structures with CFRP skins" Composite Structures (ELSEVIER)
5. Meifeng He, Wenbin Hu (2008) "A study on composite honeycomb sandwich panel structure" Materials and Design vol .29
6. Qiancheng Zhang, Xiaohu Yang , Peng Li , Guoyou Huang (2015) "Bioinspired engineering of honeycomb structure Using nature to inspire human innovation" Progress in Materials Science vol.74
7. Junhua Zhang, Xiufang Zhu, Xiaodong Yang, Wei Zhang (2019) "Transient Nonlinear Responses of an Auxetic Honeycomb Sandwich Plate under Impact Loads" International Journal of Impact Engineering.
8. Mahammad Muzeeb Baig, Suresh Arjula (2019) " Bending Analysis of Honeycomb Sandwich Panels with Different combinations of Materials for Core and Face Plates" Journal of engineering sciences Vol 10, Issue 12.
9. Recep Gunes, Kemal Arslan, M Kemal Apalak and JN Reddy (2017) "Ballistic performance of honeycomb sandwich structures reinforced by functionally graded faceplates" Journal of Sandwich Structures and Materials.
10. K.Kantha Rao, K. Jayathirtha Rao (2012) "Thermostructural Analysis Of Honeycomb Sandwich Panels" International Journal Ofengineering Science & Advanced Technology Volume-2, Issue-5.
11. Shubham V. Rupani, Shivang S. Jani, G.D.Acharya (2017)" Design, Modelling and Manufacturing aspects of Honeycomb Sandwich Structures: A Review" International Journal of Scientific Development and Research (IJSDR) Vol- 2, Issue 4
12. Ondrej Flasar, Vaclav Triska, and Milan Junas (2017)" Experimental study of impact properties of aluminium honeycomb sandwich structure" MATEC Web of Conferences (133)
13. Zhi-jia Zhang , Bin Han, Qian-cheng Zhang, Feng Jin (2017) "Free vibration analysis of sandwich beams with honeycomb-corrugation hybrid cores" Composite Structures ((ELSEVIER)
14. S P Zaoutsos (2017) "Mechanical behavior of aluminium honeycomb sandwich structures under extreme low temperature conditions" IOP Conf. Series: Materials Science and Engineering.
15. Mohsin Abdullah AL-Shammari & Muhannad AL-Waily (2018) "Analytical Investigation of Buckling Behavior of Honeycombs Sandwich Combined Plate Structure" International Journal of Mechanical and Production Engineering Research and Development (IJMPERD) Vol. 8, Issue 4,
16. Anil Kumar1, Arindam Kumar Chanda, Surjit Angra(2021) "Numerical Modelling of a Composite Sandwich Structure Having Non Metallic Honeycomb Core" EVERGREEN Joint Journal of Novel Carbon Resource Sciences & Green Asia Strategy, Vol. 08, Issue 04, pp759-767,