

Sandwich and Natural fiber composites - A review

G Ramakrishnan *, B. Vijaya Ramnath, C.Vignesh, L.Vignesh, T.Perunddevan and M VidhyaRajan

Department of Mechanical Engineering
Sri Sairam Engineering College, West Tambaram, Chennai-44.

* Corresponding author mail ID: ramakrishnan.mech@sairam.edu.in

Abstract. Sandwich composite is a special form of a laminated composite comprising a combination of different materials that are bonded to each other so as to utilize the properties of each separate component to the structural advantage of the whole assembly. Usually a sandwich structure consists of two relatively thin, stiff and strong faces separated by a relatively thick lightweight core, for instance, honeycomb, balsa or foam cores. The purpose of sandwich structure is to achieve a stiff and simultaneously light component. A natural fiber composite also plays a vital role in automotive and construction field due to their bio degradable behaviour and ease of manufacturing. This paper reviews sandwich structures, various tests performed on it and their properties along with some studies of mechanical behaviour of natural fiber composites. Major applications of the sandwich specimens are also highlighted in this work.

1.0 Introduction

A Composite material is a type of material made from two or more constituent materials, when combined, produces a material with characteristics superior to the individual components. The New Materials are added to improve characteristics such as Specific Strength, Stiffness, Hardness etc. A Sandwich-Structured Composite is a special class of Composite materials that is fabricated by attaching two thin but stiff skins to a lightweight but thick core. The important characteristics of sandwich composites are high stiffness to weight ratio and high bending strength to weight ratio.

2.0 Types of sandwich composites

- 1.FOAM INSULATED CONCRETE SANDWICH COMPOSITE.
- 2.BALSA WOOD SANDWICH COMPOSITE
- 3.ALUMINIUM HONEY COMB SANDWICH COMPOSITE.

2.1 Foam insulated concrete sandwich composite

Fengtao Bai and James S. Davidson. [1] in their paper presents the theoretical development that defines the small displacement behavior of foam insulated concrete sandwich panels. Composite theories presented by other researchers are first thoroughly reviewed and scrutinized in the context of their use for precast concrete beams. A more rigorous Discrete Model that incorporates the complex shear deformation behaviors and independent flexural resistance of the concrete wythes is then derived. Experimental data from full-scale precast sandwich panel tests are used to validate the developed methodology. Finally, it is demonstrated that this study provides a rigorous analysis methodology for foam insulated concrete sandwich structures. The mechanical behaviors of metallic sandwich panels, nailed timber systems, composite bridge beams and ICSPs are similar in some aspects. For example, they all consist of a relatively deformable middle layer that results in large overall shear deformation. However, there are also significant differences. For example, metal faced sandwich structures, due to the slenderness of the face plates, are more susceptible to face buckling and other local failure modes. For nailed timber and composite bridge beams, components are connected tightly through shear



connectors, leaving little room for shear deformation. Actually, those two-layer composite structures could have fairly high composite action that in some circumstances may be considered as fully composite. Whereas metallic sandwich panels and ICSPs have a thick middle insulation bearing considerable amount of shear deformation and therefore are usually Composite material. Granholm [2] published his theory and work in the field of nailed timber structures. Granholm's theory focused on the equilibrium of axial force within individual layer and overall bending moment of the whole cross-section. Zhiqiang Fan et al. [3] conducted blast resistance of metallic sandwich panels subjected to proximity underwater explosion with honey comb structured aluminum-5052 alloy as core and concluded that specimens with thicker face-sheets and denser cores produced smaller deflections. Their sandwich specimens found applications in naval engineering.

2.2 Balsa wood sandwich composite

Grenestedt and Burak Bekisli [4] analyzed a new arrangement of balsa blocks in a sandwich core. This new core, high consisted of an assembly of oddly shaped balsa blocks, allowed the grains in various balsa blocks to be oriented to the normal direction of the core. The effective out-of-plane shear stiffness was isotropic in nature. Numerical analyses predicted superior shear stiffness. The shear stiffness depends on the grain orientation as well as boundary conditions. Experiments proved the new balsa core to be 70% stiffer than end grain balsa. Burak Bekisli and Grenestedt et al. [5] analyzed a new balsa core structure that better utilizes the anisotropy of balsa. Improved shear stiffness was predicted with this new core. Manufacturing methods for this core were developed and more extensive experiments were performed to verify the improvement in shear stiffness as well as to evaluate the shear strength. The increased stiffness and strength were obtained at the cost of complexity in terms of manufacturing and increased scrap. Apart from the CNC milling, the manufacturing methods produced balsa blocks that were not geometrically perfect. This led to gap between the balsa blocks, which filled with resin during the assembly and therefore increased the weight. However, it is believed that the wire saw manufacturing process easily be automated and tuned to produce almost perfect balsa blocks, which would lead to new cores with increased mechanical properties without a prohibitive cost or weight penalty.

Cesim Atas and Cenk Sevim [6] studied the damage process of the sandwich composites and analyzed the cross-examining load-deflection curves, energy profile diagrams and the damaged specimens. The primary damage modes observed are; fiber fractures at upper and lower skins, delaminations between adjacent glass-epoxy layers, core shear fractures, and face/core debonding. Experimental investigation on drop weight impact response of sandwich composite panels with PVC foam core and balsa wood core. Load-deflection curves of the both composites were of a mountain-like shape with two peaks under higher impact energies. It is noted that the second peak value for foam core sandwich samples is higher than first peak value generally while those of the balsa core samples are of the nearly the same values. On the other hand, in two-peaked curves, it is also noted that the first peak load value of foam core samples were smaller than that of balsa core samples as in the one-peaked curves. On the contrary, the second peak load value of foam core samples is found to be higher generally than that of balsa core ones. It is also seen from the Load-Deflection curves that the foam core sandwich is of lower bending stiffness. Balsa core samples are stiffer than PVC ones. It results in higher contact force but smaller deflection of the balsa wood sandwiches for smaller impact energy levels, before failure. This case implies a higher deformation capability of PVC foam samples, resulting in a larger delamination area formed between layers of top face-sheets due to stiffness mismatching. However, for balsa core sandwich, due to poor interface between balsa wood with the glass/epoxy layer compared with PVC foam core; the debonding between core and face-sheets becomes the dominant damage mode along with the fiber bending fractures, as the impact energy increases. As the impact energy is decreased, the Hardness increases for foam core samples compared to balsa wood composites. Vincent Legrand et al. [7] investigated the internal stresses induced by moisture absorption in sandwich composite material. Moisture absorption effect was analyzed for balsa core specimens and sandwich structures composed of E-glass/polyester face sheets bonded to a balsa core. A new experimental technique for measuring hygroscopic expansion has been developed and tested for the balsa core. The obtained results show that the diffusion of water in the balsa core conducts the diffusivity process in the entire sandwich structure. Therefore, the calculated diffusion parameters of the single balsa are higher than those of the balsa embedded in a sandwich structure.

Kepler [8] studied the concept based on utilization of the strongly orthotropic properties of the balsa wood, applying an appropriate transverse layup sequence. Comparing the standard balsa core systems, a substantial increase in the shear stiffness is demonstrated, whereas the transverse stiffness is reduced. The exposure to excess moisture degraded the mechanical properties of the balsa wood. Michael Osei-Antwi et al. [9] studied an experimental to evaluate the effects of parameters such as shear plane, density and adhesive joints on the shear stiffness and strength of balsa wood panels as well as the variation of ductility with respect to the shear planes. The shear planes exerted a significant effect on shear stiffness and strength. The strength of specimens with the shear plane transverse to the flat grain was reduced because of a change in the failure mode. The shear planes exerted a significant effect on shear stiffness and strength. Highest values were obtained for the shear plane (parallel to end grain), intermediate values for the plane (parallel to flat grain) and lowest values for the plane (transverse to flat grain). Shear stiffness and strength increased with increasing density of the balsa. The thin adhesive joints in the balsa panels between the lumber blocks increased the shear stiffness and strength with one exception, the strength of specimens was reduced because of a change in the failure mode. Julia de Castro et al. [10] investigated the fracture in the complex balsa cores of fiber-reinforced polymer (FRP) sandwich beams. The balsa layers were cut from panels which consisted of balsa blocks adhesively bonded together. Failure in the beams was initiated by cracks propagating through the balsa core thickness. The effects of varying block densities and orientations and adhesive bonding between the blocks on the crack propagation and failure mode were investigated. Failure in the beams was initiated by cracks through the balsa core thickness. Cracks initiated and propagated in the low-density blocks due to their low fracture toughness. Cracks were not able to propagate through the transverse adhesive joints between blocks if the bonding was good and thus the fracture toughness was high.

2.3 Aluminium honeycomb sandwich composites

Yahaya et al. [11] studied the resistance of sandwich panels with different aluminum honey comb cores subjected to impact from foam projectiles. They determined that increasing the foil thickness and reducing the cell size led to a decrease in the back-face deflection, but increases in the overall honeycomb sandwich panels' weight. A comparison was also made that the honeycomb sandwich panels out perform both the air sandwich panels and the monolithic plates within an impulse range of $2.25 \text{ kNsm}^2 \sim 4.70 \text{ kNsm}^2$. Crupi et al. [12] analyzed the static and low-velocity impact response of two typologies of aluminum honeycomb sandwich structures with different cell size. The failure mode and damage of the honeycomb panels have been investigated using the 3D Computed Tomography. The experiments concluded that the energy absorption capability of sandwich is strongly influenced by the size of the honeycomb cells. Also they proposed that their specimen would find applications in the transportation industry. Shiqiang Li et al. [13] investigated the response of metallic sandwich panels with stepwise graded aluminum honeycomb cores under blast loading. Their study using LS-DYNA software showed that under the same charge condition, the plastic energy dissipated by the core layers and the contact force attenuation were larger than those of the ungraded ones, especially for the graded panels with relative density descending core arrangement. Foo et al. [14] analyzed the low-velocity impact failure of aluminum honeycomb sandwich panels and inferred that the energy absorbed during impact is independent of the core density. However, a foil with higher density and greater thickness will result in a more damage tolerant core. Smaller cell sizes will also improve the tolerance of the core to impact damage. Xin Li et al. [15] examined the blast-resistance of square sandwich panels with hexagon aluminum honeycomb cores. The major conclusion of the tests is that when the scaled distance decreases, peak pressure loaded on the face sheet enhanced obviously, thus pitting and fragment easily occurred. However, with the increasing of scaled distance, large plastic deformation is prone to occur. Shanshan Shi et al. [16] inspected the flexural strength and energy absorption of carbon-fiber–aluminum-honeycomb composite sandwich reinforced by aluminum grid.

They concluded that the honeycomb filled orthogrid sandwich panels possess higher specific properties which are crucial for aerospace applications.

3.0 Natural fiber composites and their mechanical characteristics

Raman Bharath et al. [17] reviewed the Kenaf fibre reinforced composites. The various properties and the applications of kenaf fibre have been elaborately studied and has concluded that the kenaf composite has many advantages including waste disposal and non-toxic. Vijaya Ramnath et al. [18] studied the mechanical properties of composites with the alternation in their composition that affects the mechanical properties due to the changes in fibre orientation. It has been found that the samples with high abaca content has better properties of tension, flexural and impact loadings. Sathish et al. [19] used the abaca and raffia fibres to fabricate the hybrid composites with epoxy resin and woven glass fibres. The abaca composite has maximum displacement as compared to others while the abaca and raffia hybrid composite has better de-lamination strength. Vijaya Ramnath et al. [20,21] evaluated the mechanical properties of epoxy composites with abaca-jute-glass fibre reinforcement and found that the properties of tensile and shear strength are improved in abaca-jute hybrid composite when compared to abaca fibre alone. But in the case of flexural and impact strength abaca composite turned out to be a better result. This is because the strength increases as interfacial adhesion in case of abaca increases. They also investigated the mechanical properties like double shear and hardness of abaca-raffia hybrid composite. It has been concluded that the composite with GFRP, Abaca and Raffia has more hardness due to the reason that Raffia with abaca makes it harder for the indenter to indent inside the specimen. Hence, this fibre composite can suitably replace the present materials in automobiles.

Yuvaraj et al. [22] studied the flexural and water absorption property of sisal and glass fibre reinforced hybrid composites with different ratios of fibre in random orientation with epoxy composite by hand layup method. It has been found that there is a rise in the flexural property and decrease in the water absorption capacity with the fibre content of the composite being increased. IndaraSoto et al. [23] used sisal fiber reinforced hollow concrete blocks and the mechanical behaviour was studied. Sisal fibre was cut into the required length and then it was mixed in the concrete mixture (cement, sand, coarse aggregates) with respect to concrete volume. Concrete blocks with and without sisal fibres were made. Three types of specimens (blocks, prisms, wallets) were made. The compression and tensile strength on blocks, prisms and wallets were tested. The compression test was done using servo hydraulic controlled device. Tensile strength was carried out in Universal testing machine as per standards. The mechanical properties remain the same in both the cases (with and without sisal) but addition of sisal increased the block ductility.

Partha haldar et al. [24] evaluated two different types of composites were manufactured with combining layup technique and compression moulding. One composite was made with addition of aluminium powder to sisal-epoxy composite and another one was made without the addition of aluminium powder and the testing was done. Micro-hardness test was done using micro hardness tester. Tensile test was done using Instron machine. Impact test was done using impact tester. Moisture absorption test was also conducted. It was found that sisal-epoxy composite with aluminium powder gave more density, high tensile strength, high elastic modulus and high impact strength. The sisal-epoxy composite without aluminium powder showed high moisture absorption and thickness swelling. Kejariwala et al. [25] studied in flammability and moisture absorption behaviour of sisal-polyester composite. Different specimens of different thickness were made for different volume fraction of sisal fibre and the fabrication was done using hot compression moulding and the tests were conducted as per standards. Flammability was tested as per the ASTM standard and the moisture

absorption test was also tested as per ASTM standard. It was found that the rate of burning decreased when the fibre volume fraction and thickness increased. The moisture absorption increased with the increase in fiber volume fraction and thickness

Vijaya Ramnath et al. [26] fabricated and studied the tensile and impact properties of natural fibre composites with abaca and raffia fibres in different compositions. The ultimate tensile strength of the Glass fibre reinforced plastics with abaca and raffia composite is very much higher when compared to the single composite. Also it has been found that the abaca glass fibre has more energy absorbing capacity than the raffia. Srinivasan et al. [27] evaluated the flexural property of Kenaf and Flax hybrid composite along with the mono fibre composite. The effect of hybridization on various aspects has been studied and the crack propagation and shearing styles of the composites are discussed elaborately which are due to the effect of hand layup process. It leads to breakage early when compared to other processes. Sathish et al. [28] conducted the experimental investigation with abaca and raffia hybrid composites on the flexural properties. It has been found that the raffia fibre composite has better strength when compared to abaca composite. The flexural test which has been carried out has better results for raffia composite.

4.0 Conclusion

This paper reviewed on sandwich as well as natural fiber composite and work done by various researchers. It is found that sandwich composites finds its applications in Marines and Aerospace. Moreover they also concluded that natural fiber composites which are biodegradable finds its applications in Domestic and Automotive field.

References

- [1] Fengtao Bai and James S Davidson 2015 *Analysis of partially composite foam insulated concrete sandwich structures*, Engineering Structures 91 pp 197–209
- [2] Granholm H 1949 *On composite beams and columns with particular regard to nailed timber structures*, Transaction of Chalmers University of Technology, No. 88. Gothenburg
- [3] Zhiqiang Fan, Yingbin Liu and Peng Xu. 2016 *Blast resistance of metallic sandwich panels subjected to proximity underwater explosion*. International journal of Impact Engineering 93 pp 128–135.
- [4] Joachim L Grenestedt and Burak Bekisli 2003 *Analyses and preliminary tests of a balsa sandwich core with improved shear properties*, International Journal of Mechanical Sciences 45 pp 1327–46
- [5] Burak Bekisli and Joachim L Grenestedt 2004 *Experimental evaluation of a balsa sandwich core with improved shear properties*, Composites Science and Technology 64 pp 667–674
- [6] Cesim Atas and Cenk Sevim 2010 *On the impact response of sandwich composites with cores of balsa wood and PVC foam*, Composite Structures 93 pp 40–48
- [7] Vincent Legrand, Luan Tran Van, Frédéric Jacquemin and Pascal Casari 2015 *Moisture-uptake induced internal stresses in balsa core sandwich composite plate: Modeling and experimental*, Composite Structures 119 pp 355–364
- [8] J.A. Kepler 2011 *Simple stiffness tailoring of balsa sandwich core material*, Composites Science and Technology 71 pp 46–51

- [9] Michael Osei-Antwi, Julia de Castro, Anastasios P Vassilopoulos and Thomas Keller 2013 *Shear mechanical characterization of balsa wood as core material of composite sandwich panels*, Construction and Building Materials 41 pp 231–238
- [10] Michael Osei-Antwi, Julia de Castro, Anastasios P Vassilopoulos and Thomas Keller 2014 // *Fracture in complex balsa cores of fiber-reinforced polymer sandwich Structures*, Construction and Building Materials 71 pp 194–201
- [11] Yahaya M A , Ruan D, Lu G and Dargusch M S. 2015 *Collapse modes in aluminum honeycomb sandwich panels under bending and impact loading*. International Journal of Impact Engineering 75 .
- [12] V. Crupi, G. Epasto, E. Guglielmino. 2012 *Collapse modes in aluminum honeycomb sandwich panels under bending and impact loading*. International Journal of Impact Engineering 43
- [13] Shiqiang Li, Xin Li, Zhihua Wanga, Guiying Wuc, Guoxing Lu, Longmao Zhao.2016 *Finite element analysis of sandwich panels with stepwise graded aluminum honeycomb cores under blast loading*. Composites: Part A 80 pp 1–12
- [14] C.C. Foo, L.K. Seah, G.B. Chai.2008 *Low-velocity impact failure of aluminum honeycomb sandwich panels*. Composite Structures 85 pp 20–28
- [15] Xin Li, Peiwen Zhang, Zhihua Wang, Guiying Wu and Longmao Zhao.2014 *Dynamic behavior of aluminum honeycomb sandwich panels under air blast: Experiment and numerical analysis*. Composite Structures 108 pp 1001–08
- [16] Shanshan Shi, ZhiSun, XiaozhiHu and HaoranChen. 2016 *Flexural strength and energy absorption of carbon-fiber–aluminum-honeycomb composite sandwich reinforced by aluminum grid*. Thin-Walled Structures 84 pp 416–422
- [17] Raman Bharath V R, Vijaya Ramnath B, Manoharan N. July 2016 *Kenaf Fibre Reinforced Composites: A Review*. ARPN Journal of Engineering and Applied Sciences. Vol.10 NO.13.
- [18] Vijaya Ramnath B, Manickavasagam V M, Elanchezhian C, Vinodh Krishna C, Karthik S and Saravanan K 2014 *Determination of mechanical properties of intra-layer abaca-jute-glass fibre reinforced composite* Materials and Design 60 pp 643-652.
- [19] Sathish P, Kesavan R, Vijaya Ramnath B. July 2015 *Experimental Investigation on delamination behavior of abaca based hybrid composites*. ARPN Journal of Engineering and Applied Sciences. Vol.10.No.13
- [20] Vijaya Ramnath B, Junaid Kokan S, Niranjana Raja R, Sathya Narayanan R, Elanchezhian C, Rajendra Prasad A, Manickavasagam V M. 2013 *Evaluation of mechanical properties of abaca-jute-glass-fibre reinforced epoxy composite* Materials and Design 51 pp 357-366.
- [21] Vijaya Ramnath B, Elanchezhian C, Manickavasagam V M, Gowri Prasad S, Aravind Swamy S and Keshav Raj R. 2016 *Experimental Investigation on shear and hardness of abaca based hybrid composites*. MATECWeb of Conferences 74,

- [22] Yuvaraj G, Vijaya Ramnath B, Hemanth Raagavendiran G, Karthikraja R. 2016 *Investigation of flexural and Water absorption Behaviour of epoxy Hybrid composites*. Advances in Natural and Applied Sciences Special 10(7): pp 34-39.
- [23] .IndaraSotoIzquierdo, OrietaSotoIzquierdo, MarciAntonioRamalho, AlbertoTaliencio, 2017 *Sisal fiber reinforced hollow concrete blocks for structural applications: Testing and modeling*, Construction and Building Materials 151,pp 98-112.
- [24].ParthaHaldar, NipuModak, GoutamSutradhar, 2017 *Comparative Evaluation of Mechanical Properties of Sisal-Epoxy Composites With and Without Addition of Aluminium Powder*, Materials today, 3397-3406.
- [25].Roshan K. Kejariwala, , Keerthi Gowda B S,2017 *Flammability and moisture absorption behavior of sisal-polyester composites*, Materialstoday, 8040-8044.
- [26] Vijaya Ramnath B, Manickavasagam V M, Elanchezhian C, Karthick R, Bharath U, Maruthi Kishore R A and Rahul R. 2015 *Investigation of tensile and impact behavior of abaca-raffia hybrid composites*. APRN Journal of Engineering and Applied Sciences Vol.No.13
- [27] Srinivasan V S, Rajendra Boopathy S, Vijaya Ramnath B 2015 *Investigation of Flexural property of Kenaf –Flax hybrid composite*. ARPJ Journal of Engineering and Applied Sciences. Vol.10. NO.13.
- [28] Sathish P, Kesavan R, Vijaya Ramnath B. 2015 *Experimental investigation on Flexural property of abaca and raffia hybrid composites*. ARPJ Journal of Engineering and Applied Sciences. Vol.10. NO.13.