Sandwich Panel Using Cork Core and Polycarbonate Face Sheets

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Abstract—This research paper provides a literature review on the use of cork and polycarbonate sheets in sandwich panels, examining their potential as sustainable building materials. The review synthesizes findings from various studies on different compositions of sandwich panels, including metal-rubber and FRP-based panels, and focuses on the innovative use of cork as a core material. The analysis reveals that cork-polycarbonate sandwich panels offer superior mechanical properties, particularly in terms of compressive strength and insulation, compared to traditional and other composite panels. The paper highlights the environmental benefits and cost-effectiveness of using cork and suggests future research directions for optimizing the performance of these sustainable sandwich panels.

Index Terms— Cork sheet, Polycarbonate, Sandwich Panel, Sustainable Building Materials

I. INTRODUCTION

The construction industry continually seeks innovative materials that balance performance, cost-effectiveness, and environmental sustainability. Among these innovations, sandwich panels have emerged as a significant solution, known for their lightweight properties and high structural efficiency. Sandwich panels consist of a core material bonded between two face sheets, offering a unique combination of strength and flexibility. This literature review focuses on sandwich panels utilizing cork as the core material and polycarbonate as the face sheets. The aim is to evaluate their potential compared to traditional and other composite sandwich panels. Cork is chosen for its natural, lightweight, and insulating properties, while polycarbonate is recognized for its robustness and durability. By examining various studies, this review seeks to highlight the mechanical performance, environmental benefits, and cost-effectiveness of cork-polycarbonate sandwich panels, providing insights into their applicability in modern construction and identifying future research opportunities for further development.

The methodology employed for this review involved collecting data related to the topic from Elsevier and other digital research paper libraries. Initially, research papers were downloaded, and subsequently, they were read and sorted to identify those directly relevant to the topic. After careful consideration, 22 research papers were shortlisted for inclusion in this review. The selected papers span the last decade, providing a comprehensive overview of recent developments in the field of sandwich panels.

II. REVIEW OF LITERATURE

A. Sandwich panels with Cork as Core

1. Belkacemi C. and Bezzazi B. [1] conducted an experimental investigation to determine the mechanical characteristics in bending, tension, compression, and shear of an innovative sandwich material that is derived from natural materials, specifically jute and cork. The study's outcomes enable the creation of various agglomerated cork white products for low-density sandwich panels intended for application in the building and insulation industries.

2. Mancuso A. [2] described a study that looked at the flexural behavior of a composite sandwich with an agglomerated cork core and skin facings reinforced with flax fibers. He subjected sandwich beams to several span-length tests using three-point bending (TPB). This sandwich is intended to be used as an environmentally friendly option for small sailing boat structural parts.

3. Lakreb N. and Bezzazi B. [3] designed sandwich panels with multilayered patterns made of cork agglomerate as the core and face sheets of Aleppo pine wood veneer for use in buildings. The mechanical characteristics of the panels were examined for shear, three- and four-point bending, longitudinal

compression, perpendicular compression, and tensile strength. The findings indicated that these sandwich panels have the potential to be economically and environmentally friendly building materials for internal partition walls or paneling.

4. Hoto R. and Furundarena G. [4] conducted experimental research into the water absorption and flexural behavior of a new, inexpensive, asymmetric sandwich made of green composite materials. The specimens were created utilizing vacuum-assisted manual layup and an agglomerate cork panel with natural fiber reinforcements, including basalt and flax fiber, in a bio-based epoxy resin matrix. The findings demonstrated that the specimen's posture and core type both affect flexural behavior.

B. Other sandwich Panels

1. Ahmed D. [5] examined the bending performance of the suggested GFRP softwood sandwich beams built utilizing pultruded GFRP and adhesive connection techniques. Experimental evaluations were conducted to determine the ultimate load capacity, load-deflection responses, failure modes, bending stiffness, load-axial-strain behavior, and degree of composite action. The findings demonstrated that the failure mode changed from a brittle to a progressive process when the wood fibers were oriented longitudinally instead of vertically. Further, numerical modeling was developed to assess bending stiffness and composite action, as well as failure loads, deformation, failure modes, and strain responses. With a maximum divergence of 16.1%, the results of the FE modeling technique were in acceptable agreement with the experimental data.

2. Junaedi H. and Khan T. [6] developed sandwich structures with milled glass fiber-reinforced rigid polyurethane foam with a varying glass fiber content for the core and carbon fiber-reinforced polymer for the facing sheets. To evaluate the sandwich construction's mechanical qualities, the author conducted compression and flexural tests. According to the flexural test, when the milled fiber loading increased, the force, face stress, and core shear stress all improved.

3. Zhao J. and Yan Y [7] examined the mechanical properties of sandwich panels made of polyvinyl chloride (PVC) foam and various core types made using the vacuum-assisted resin infusion method (VARI). Three different kinds of PVC sandwich panels were examined for their impact, flexural, and compression characteristics on both the flat and edge sides. The findings show that adding polymer pins can improve the mechanical performance of foam sandwich composites, and that the impact characteristics exhibit modest variations depending on the stage of development.

4. Pramudi G. [8] the flexural strength of each skin, core, and sandwich panel was investigated by the author through research efforts. The sandwich skin composite had a thickness of 2 mm and was composed of unsaturated polyester and recycled carbon fiber (RCF). The results indicated that it is possible to utilize this robust and lightweight sandwich composite as an earthquake-resistant wall panel.

5. Jiang Q. [9] conducted research on the production method and mechanical testing of a sustainable sandwich composite composed of recycled PET foam, polypropylene, flax, and recycled carbon fiber. He compared the flexural characteristics using a three-point bending test. According to the findings, vehicle side panels made of these environmentally friendly sandwich composites would perform effectively in windy and stormy weather.

6. Balaji P. and Dr. Selvan S. [10] investigated the structural behavior of Ferro-cement wall panels with different infills such as m-sand and red soil under an axial compressive load. Based on the findings, Ferro cement wall panels responded satisfactorily to axial compressive stress and wall panels made of red soil and m-sand can be used as infills in the building industry, provided they are optimal and meet the necessary standards.

7. Chen Q. and Linghu T. [11] Using the Vacuum-Assisted Resin Transfer Method (VARTM), the researcher produced a sandwich structure. To enhance the mechanical characteristics of the glass fiber/epoxy resin PVC foam sandwich composites, they employed three distinct types of chopped fibers: glass, carbon, and aramid. It was discovered that the sandwich structure's impact toughness, bending strength, and energy absorption capacity were successfully increased by the addition of chopped fiber mat between the face sheet and core foam.

8. Fang H. and H. Shi [12] introduced a novel type of composite sandwich panel that consists of bonded glass fiber-reinforced polymer (GFRP) pultruded hollow square tubes as the core and steel plates as face sheets. This innovative panel's high bending stiffness,

strength, and excellent ductility were achieved by combining steel and GFRP in the ideal ratio. To examine the distribution of stress, strain, mid-span deflection, and the eventual failure mechanism, they used the Four-Point Bending Test. The values from the FEM simulation, the experimental findings, and the theoretical values were then compared, and they all seemed to be in good agreement.

9. Salleh Z., Md Islam [13] investigated the mechanical characteristics of sandwich composites made of glass fiber sheets for the skin and glass micro balloon/vinyl ester for the syntactic foam core, including the compressive, tensile, and flexural behavior. It is observed that in order to get a suitable combination of the tensile, compressive, and flexural strength qualities, the glass micro balloon combined with vinyl ester should be managed.

10. Karaduman Y. and Onal L. [14] analyzed the flexural behavior of sandwich composites reinforced with nonwoven fabric and composed of jute and polypropylene (PP) fibers. The authors conducted experiments to examine the flexural behavior of the sandwiches. They noticed that when the amount of jute fiber in the sandwiches increased, the flexural qualities got better. Ultimately, they concluded that sandwiches reinforced with jute fiber may be utilized as inexpensive, lightweight, and environmentally friendly constructions for a range of industrial uses.

11. Dai B. and Zhou G. [15] the looped fabric-reinforced foam core sandwich composite (U cor) was tested for flatwise tensile, peeling, and shearing responses. The authors conducted tests to investigate the mechanical behavior of rigid polyurethane foam (RPUF) with varying densities under tension, compression, and shear loading. The study examines U-cor and the standard 2D woven fabric-reinforced foam sandwich composite (2DRFS) made from thick and thin fiber yarns. The author determined that the expected shear strengths and failure mechanisms were consistent with the experimental data.

12. Huo R. and Liu W. [16] investigated a sandwich bridge deck with GFRP face sheets and a foam-web core made using a vacuum-assisted resin infusion technique. The two point bending test was performed. They concluded that, as compared to standard foam-core sandwich decks, an average 657.1% increase in ultimate bending strength may be attained.

13. Kumar V. and Soragaon B. [17] investigated the effects of changing the thickness of fiber reinforced polymer (FRP) face sheets investigated the effects of changing the thickness of fiber reinforced polymer (FRP) face sheets and inserts. They evaluated the data to determine which combination of panels with different thicknesses of face sheets and inserts produced the optimum stiffness values.

14. Raj S. and Kumar V. [18] studied the experimental behavior of a basalt fiber-reinforced composite (BFRC) sandwich panel under flexural loading. The top and bottom skins are made of BFRC mix and pattern sheet flanges while the core is made of profile sheet web. They conducted numerical research to evaluate the integrity of the skin-core connection and its impact on the panel's overall strength and stiffness. The finite element analysis findings were compared to the experimental results of the BFRC sandwich panel and found to be in good agreement.

15. Gopinath S. and Kumar V. [19] created prefabricated sandwich panel made of profiled steel sheet as the core material and textile reinforced concrete (TRC) as the outside shell. They conducted experimental studies to assess the response behavior of sandwich panels under flexural stresses. Two types of TRC sandwich panels were numerically modeled using the finite element software ABAQUS. They discovered that the ultimate loads predicted by numerical models are consistent with experimental data.

16. Satasivam S. and Yu Bai [20] investigated an adhesively bonded modular GFRP sandwich system used in building floor construction and evaluated for four-point bending. They discovered that the span-to-depth ratio had a significant impact on the failure mode, and that adding foam to the sandwich's core increased the load-carrying capacity significantly.

17. Shams A. and Hegger J. [21] presented experimental results on textile reinforced concrete (TRC) sandwich panels at the IMB laboratory. Tests on sandwich panels have demonstrated that achieving a consistent bond quality between conventional cores and concrete facings is challenging. As a result, the authors stated that appropriate connectors must be used to create an inexpensive, stable, and permanent link between the layers.

18. Manalo A. [22] investigated the structural behavior of a prefabricated wall system composed of glass fiber-reinforced rigid polyurethane foam (PUF) and magnesium oxide (MgO) board. He created full-scale wall examples and tested them for transverse bending,

compression, and shear. The findings supported the viability of this composite wall technology in residential modular construction.

III. DISCUSSIONS

The efficiency and effectiveness of sandwich panels in construction call for a thorough investigation into three main areas: optimizing designs, exploring new materials, and evaluating cost-effectiveness. Despite their potential benefits in reducing weight, improving insulation, and enhancing structural integrity, there's still much to explore about the best design parameters, material choices, and economic feasibility compared to traditional building materials. Moreover, we need to understand the environmental advantages and sustainability implications of using sandwich panels in prefabricated structures. So, the main research question centers on how to improve the mechanical performance, environmental friendliness, and cost-effectiveness of sandwich panels using cork and polycarbonate in construction, ultimately leading to innovative and sustainable engineering and building practices.

From the above literature review, it is observed that the numerous research efforts have been undertaken to explore different combinations of face and core materials in sandwich panels, yet there is a noticeable gap in the study of using polycarbonate as a face sheet paired with a cork core. This area remains relatively unexplored and requires further investigation. Additionally, the development of sandwich panels from sustainable materials is limited, presenting an opportunity for innovation. This gap forms the basis of the scope of work for further work, which aims to investigate the potential of combining cork and polycarbonate, eco-friendly materials, in sandwich panels to improve their performance and sustainability in construction applications.

REFERENCES

[1] C. Belkacemi and B. Bezzazi, Sandwich panels from cork and polyester in presence of epoxy resin as interfacial adhesive, International Journal of Physical Sciences, November, 2016

[2] Mancuso A., Giuseppe Pitarresi and Davide Tumino, Mechanical Behaviour of a Green Sandwich Made of Flax Reinforced Polymer Facings and Cork Core, Procedia Engineering, 2015

[3] Nadia Lakreb, Boudjema Bezzazi and Helena Pereira, Mechanical strength properties of innovative sandwich panels with expanded cork agglomerates, European Journal of Wood and Wood Products, 2015

[4] R. Hoto, G. Furundarena, J.P. Torres, E. Muñoz, J. Andrés and J.A. García, Flexural behavior and water absorption of asymmetrical sandwich composites from natural fibers and cork agglomerate core, Materials Letters - Volume 127, 15 July 2014.

[5] Ahmed D. Almutairi, Yu Bai and Wahid Ferdous, Flexural Behaviour of GFRP-Softwood Sandwich Panels for Prefabricated Building Construction, MDPI Polymers, April 2023

[6] Harri Junaedi, Tabrej Khan and Tamer A. Sebaey, Characteristics of Carbon-Fiber-Reinforced Polymer Face Sheet and Glass-Fiber-Reinforced Rigid Polyurethane Foam Sandwich Structures under Flexural and Compression Tests, MDPI Materials, July 2023

[7] Jitao Zhao, Yutong Yan, Lidan Xu, and Hongxia Zhang, Mechanical performances of polyvinyl chloride (PVC) foam sandwich composites with glass cloth face-sheet, ASPBS Materials Express, June 2023

[8] Ganjar Pramudi, Wijang Wisnu Raharjo and Dody Ariawan, Investigation of Flexural strength of Sandwich Panels Recycled Carbon Fibre/Polyester with Cotton Mesh Fabric Reinforcement in Polyurethane Core, Journal of Applied Science and Engineering, Vol. 25, No 5, Page 975-983, December 2021

[9] Qihong Jiang, Guiyong Chen, Abhideep Kumar, Andrew Mills, Krutarth Jani, Vasudevan Rajamohan, Barathan Venugopal, and Sameer Rahatekar, Sustainable Sandwich Composites Manufactured from Recycled Carbon Fibers, Flax Fibers/PP Skins, and Recycled PET Core, MDPI Journal of Composites Science, December 2020

[10] P. Balaji1and Dr. S. Arul Selvan, Performance Evaluation Of Ferro Cement Sandwich Wall Panels With Different Infills, International Research Journal of Engineering and Technology, April 2018

[11] Qihui Chen, Ting Linghu, Yingju Gao, Zhi Wang, Yaqing Liu, Ruikui Du and Guizhe Zhao, Mechanical properties in glass fiber PVC-foam sandwich structures from different chopped fiber interfacial reinforcement through vacuum-assisted resin transfer molding (VARTM) processing, Composites Science and Technology - Volume 144 - 2017 - Pages 202-207, March 2017

[12] Hai Fang, Huiyuan Shi, Yue Wang, Yujun Qi and Weiqing Liu, Experimental and Theoretical Study of Sandwich Panels with Steel Facesheets and GFRP Core, *Advances in Materials Science and Engineering*, September 2016

[13] Zulzamri Salleh, Md Mainul Islam, Jayantha Ananda Epaarachchi and Haibin Su, Mechanical properties of sandwich composite made of syntactic foam core and GFRP skins, AIMS Materials Science, December 2016

[14] Y. Karaduman and L. Onal, Flexural behavior of commingled jute/polypropylene nonwoven fabric reinforced sandwich composites, Composites Part B: Engineering - Volume 93 - 2016 - Pages 12-25, March 2016

[15] Bei Dai, Guangming Zhou, Jin Sun, Mudan Chen and Jiajia Wang, Experimental study on the mechanicalproperties of looped fabric reinforcedfoam core sandwich composite, Journal of Composite Materials, October 2015

[16] Ruili Huo, Weiqing Liu, Li Wan, Yuan Fang, and Lu Wang, Experimental Study on Sandwich Bridge Decks with GFRP FaceSheets and a Foam-Web Core Loaded under Two-Way Bending, Advances in Materials Science and Engineering - Volume 2015, September 2015

[17] Vijay Kumar and Bhimasen Soragaon, Fabrication and Evaluation of Multilayered Polyurethane Foam Core Sandwich Panels for Static Flexural Stiffness, Elsevier Composites Part B: Engineering, March 2016

[18] Smriti Raj, V. Ramesh Kumar, B.H. Bharath Kumar, Smitha Gopinath and Nagesh R. Iyer, Flexural studies on Basalt Fiber Reinforced Composite sandwich panel with profile sheet as core, Construction and Building Materials - Volume 82 – 2015 - Pages 391-400, March 2015

[19] Smitha Gopinath, V. Ramesh Kumar, Harishkumar Sheth, A. Ramachandra Murthy and Nagesh R. Iyer, Pre-fabricated sandwich panels using cold-formed steel and textile reinforced concrete, Construction and Building Materials - Volume 64 - 2014 - Pages 54-59, April 2014

[20] Sindu Satasivam, Yu Bai and Xiao-Ling Zhao, Adhesively bonded modular GFRP web–flange sandwich for building floor construction, Composite Structures - Volume 111 - 2014 - Pages 381-392, January 2014

[21] Ali Shams, Josef Hegger and Michael Horstmann, An analytical model for sandwich panels made of textile-reinforced concrete, Construction and Building Materials - Volume 64 - 2014 - Pages 451-459, May 2014

[22] Allan Manalo, Structural behaviour of a prefabricated composite wall system made from rigid polyurethane foam and Magnesium Oxide board, ELSEVIER Construction and Building Materials, January 2013