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Measurement of Durability in a Structural Sandwich Panel Consists of Rubber and Plastic Waste

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Abstract

The rising accumulation of rubber and plastic waste has become a serious environmental concern, particularly in Malaysia, where disposal issues contribute to pollution and health risks. At the same time, the construction sector seeks affordable, lightweight, and sustainable materials that still offer reliable strength and durability. This study responds to both issues by exploring the development of sandwich panels made from recycled rubber and plastic waste. The objective is to evaluate the durability performance of these panels when used as structural components. The research employs an experimental methodology, where sandwich panels were fabricated using waste rubber and plastic as face sheets bonded to a polyurethane (PU) foam core, followed by mechanical testing including flexural and deflection tests. These tests measured load-bearing capacity, bending strength, and elasticity, with analysis based on load-deflection graphs and failure observations. Results from the flexural test showed the panel sustained a maximum load of 182.26 N with a displacement of 33.86 mm before failure, indicating high flexibility but only moderate strength. The deflection test revealed consistent sagging, increasing to 3.66 mm under a 70kN load, with linear behavior at low loads but reduced stiffness beyond 5 kg. These findings suggest that while the panels may not yet be suitable for high-impact or structural flooring, they perform adequately in low-load areas such as storage rooms, service platforms, or temporary installations. Although mechanical performance remains limited for heavy-duty use, ongoing material optimization could improve their load resistance and expand their application in mainstream construction. Future research may explore hybrid core configurations or fiber reinforcement to enhance strength without compromising sustainability. In conclusion, sandwich panels composed of recycled plastic and rubber exhibit moderate strength and high flexibility, making them appropriate for low-load applications. They hold great promise as environmentally friendly substitutes in the building sector with additional material advancements.

1. Introduction

Rubber and plastic sandwich panels are composite materials designed to offer high performance by combining the strengths of both components. These panels typically consist of a flexible rubber core sandwiched between two rigid plastic layers. The rubber core plays a key role in absorbing shock, reducing noise and vibration, and acting as a thermal insulator, making it especially valuable in situations that demand cushioning and energy absorption [1]. Meanwhile, the outer plastic layers provide structural support and protect the panel from environmental elements such as moisture, chemicals, and UV exposure [2]. This combination results in panels that are both durable and lightweight, making them highly versatile for various applications. The combination of rubber and plastic in sandwich panels results in a structure that is both lightweight and strong, offering a high strength-to-weight ratio. This makes them valuable across many industries. In automotive design, they help reduce vehicle weight while minimizing noise and vibration [3]. In construction, they serve as durable and easy-to-install insulation materials for walls and roofs. The electronics industry uses them for shock absorption and thermal insulation, while the packaging sector benefits from their ability to protect fragile items during transport. Their adaptability allows them to meet the specific needs of each industry effectively.

The manufacturing of rubber and plastic sandwich panels involves several techniques, chosen based on their intended application. Adhesive bonding is commonly used to ensure a strong bond between layers. For shaping the panels precisely, thermoforming allows the plastic to be molded around the rubber core, while co-extrusion combines all layers in one continuous process for consistency [4]. Injection molding is another method, ideal for creating detailed, custom-shaped panels. These advanced techniques not only ensure durability and performance but also support cost-effective large-scale production. In this study, the objectives are to fabricate sandwich panels using waste plastic and rubber, to determine the deflection and flexural strength of the sandwich panel, and to determine the optimum usage of plastic in the design

In summary, rubber and plastic sandwich panels represent a smart material innovation, blending strength, flexibility, and durability in a single solution. Their ability to provide structural support along with thermal and sound insulation makes them valuable across various industries. As manufacturing technologies and material science continue to evolve, these panels are becoming even more efficient and adaptable, meeting the changing needs of modern applications with greater performance and design flexibility [5].

2. Methodology

This section outlines the research methods used to evaluate the durability of sandwich panels made from recycled rubber and plastic waste (Fig. 1). The focus is on evaluating their mechanical strength and the resilience of the sample when subjected to load. These aspects are examined through controlled testing and data analysis, providing a clearer understanding of the panels' structural reliability and real-world potential. The flow chart of this study is as in Fig. 2.

Fig. 1 *Finished sandwich panels*

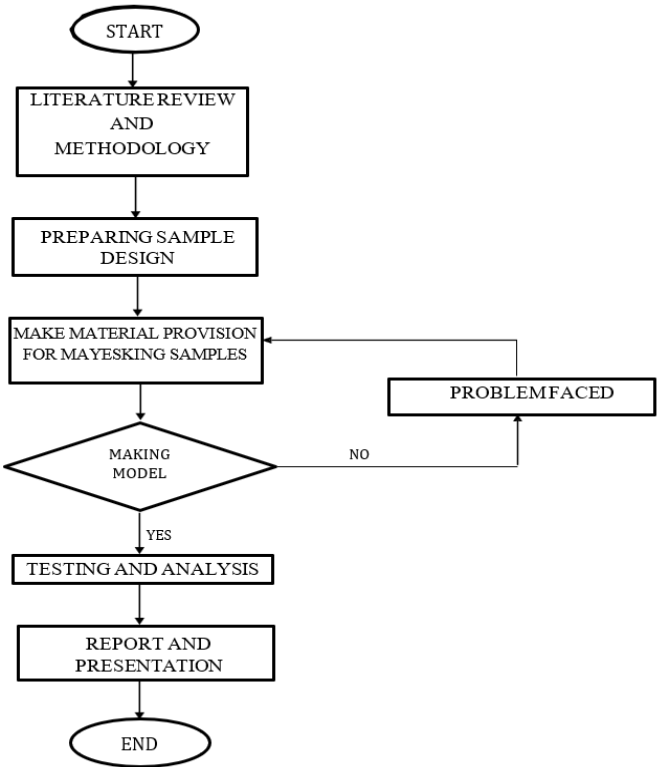


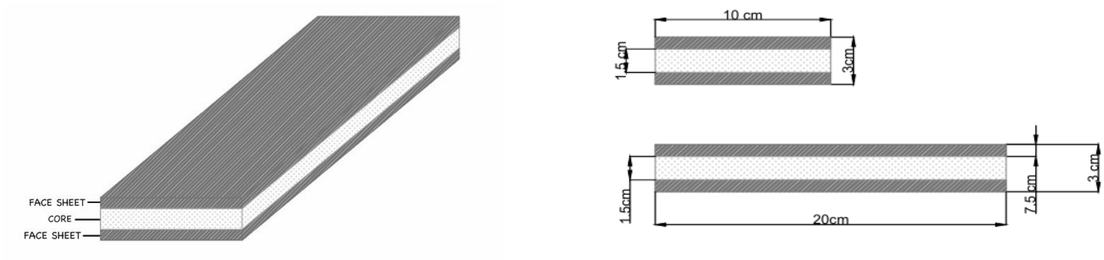
Fig. 2 *Flow Chart*

2.1 Material of the Sandwich panel

The project began with the clear objective of producing sustainable sandwich panels using recycled rubber and plastic waste materials as the outer face sheet, and polyurethane foam (PU) as the core (Fig. 3(a)). This entire process is experimental and aims to simulate real-world construction scenarios, especially floor panel systems [6]. Recycled rubber and plastics are first cleaned, dried, and crushed before being mixed in a certain ratio. These materials are then formed into a face sheet using a heating machine. PU foam, which is known for its lightweight and heat-blocking properties, is molded and cut to fit the panel design before being glued to the face sheet using a strong adhesive glue. The final product is allowed to be cured under pressure to ensure durability and uniformity.

2.2 Size of Sandwich Panel

The drawing details are shown in Fig. 3. The dimensions of the fabricated sandwich panel were approximately 26 cm in length, 13 cm in width, and 3 cm in total thickness. The mixture used for the face sheets consisted of about 230 grams of plastic and 40 grams of rubber, which was found to provide a solid yet flexible outer layer [7]. The core was prepared using a 2:1 ratio of PU foam and water, which expanded during curing but was later trimmed for consistency. The design focused on achieving a compact and bubble-free face surface, essential for structural bonding and mechanical performance [8]. Once assembled, the panels were subjected to tests to evaluate their resistance to flexural and deflection forces, representing typical loads encountered in construction flooring systems [9].



(a) **(b)**

Fig. 3 *Detail drawing (a) Drawing of Design Sandwich Panel; (b)Sandwich Panel Design Drawing Dimensions*

2.3 Testing of Sandwich Panel

To ensure safety and reliability, this study incorporates detailed testing protocols using a Universal Testing Machine [10] for flexural tests (Fig. 4) and dial-gauge setups for deflection measurement (Fig. 5). The tests aim to analyze the maximum load that the panels can bear before bending or cracking, and how much they will bend under gradually applied weight. Safety measures were strictly followed during manufacturing and testing, including the use of heat-resistant gloves, proper machine calibration, and observing load limits. The results of these tests not only demonstrate the flexibility of the panels but also highlight areas where improvements such as reinforcement or material adjustments can enhance structural performance for more demanding applications. [11].

Fig. 4 *Flexural testing is being tested on sandwich panels*

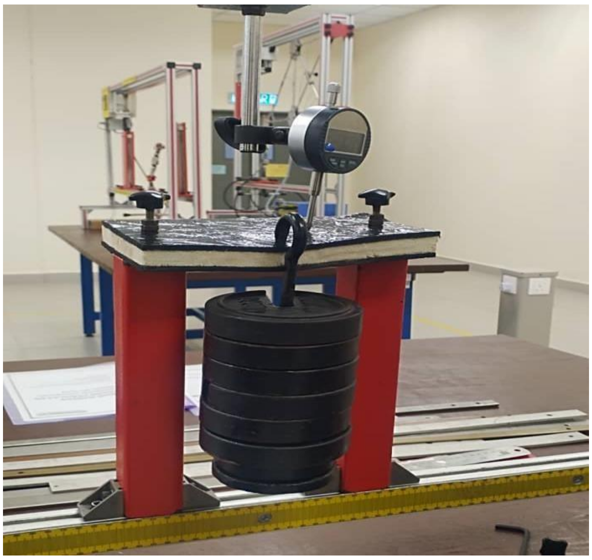


Fig. 5 *Deflection testing is being tested on sandwich panels*

3. Data Collection

The research methods outlined in this section are designed to evaluate the durability of sandwich panels produced from recycled rubber and plastic waste materials. The focus is placed on assessing key performance aspects such as mechanical strength, resistance to environmental conditions, including temperature, humidity, and UV exposure as well as the panels' long-term behavior under these stressors. By conducting controlled laboratory experiments and thorough data analysis, the study aims to produce reliable, evidence-based insights into how these materials perform over time. This approach provides a solid foundation for understanding the structural integrity of the panels and their potential for practical use in various applications, especially in construction and other industries that demand both strength and sustainability [12].

3.1 Deflection Test

Based on the deflection test conducted on the sandwich panel, a consistent pattern of downward bending was observed as static weights ranging from 5kN to 70 kN were applied incrementally at the center of the panel's span [13]. The deflection values recorded in millimeters showed a steady increase with each added load. In the early stages, between 5kN and 40kN, the panel exhibited a near-linear response, suggesting that it was still operating within its elastic range. This means the panel was able to return to its original shape upon unloading, a good indicator of sound structural behavior under moderate pressure.

However, a noticeable shift occurred starting from the 50kN load mark. At this stage, the rate of deflection became more pronounced, as indicated by the steeper slope in the load vs deflection graph. This shift implies that the panel's stiffness began to decline, and the material started showing signs of reduced resistance to bending [14]. The flexibility increased, which may suggest that the panel was nearing or entering its plastic deformation range where it might not fully recover its original form after unloading. This behavior signals a reduction in structural integrity when subjected to higher loading (Fig. 6).

In practical terms, these results highlight a key performance limit for the sandwich panel. While it performs reliably under lower loads, offering both strength and recovery, its ability to maintain form and rigidity decreases significantly once the applied pressure exceeds 50 kN. This threshold is critical for design considerations, especially for applications requiring durability under sustained or heavy loads [12]. Understanding this limit helps guide improvements in panel composition and design, particularly when balancing recycled material use with long-term structural performance [15].

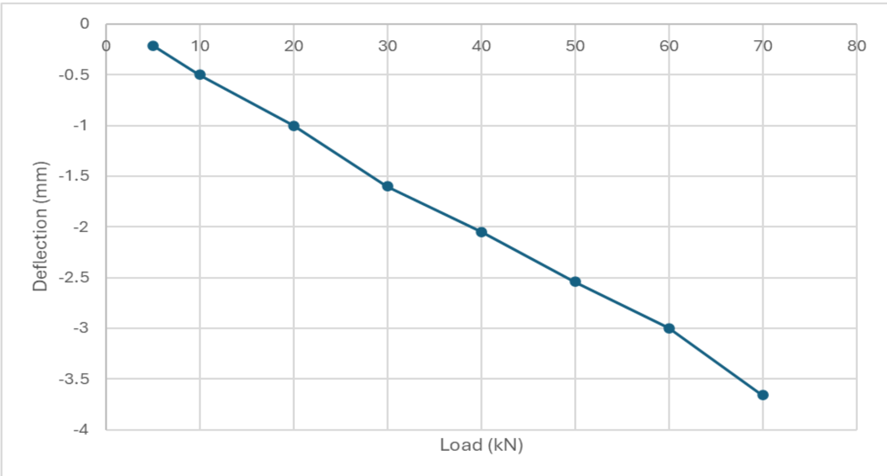


Fig. 6 *Graph load vs deflection for deflection test*

3.2 Flexural Test

Based on the data collected, the flexural test was carried out on a sandwich panel sample identified as S1 B. The sample had a panel width of 90 mm and a thickness of 28 mm, supported over a span of 194 mm. The test was conducted under controlled environmental conditions, with a temperature of 73°F (23°C) and a relative humidity of 50% [16]. A crosshead speed of 2.54 mm/min was used during the test to ensure a consistent rate of loading. These parameters are crucial to ensure the accuracy and repeatability of the test results.

From the test, a load vs. displacement graph (Fig. 7) was generated. The graph displayed a linear trend during the initial loading phase, indicating elastic deformation where the material behaved predictably and reversibly [17]. As the load increased, the graph reached a peak before showing a slight drop, which suggests the onset of material failure. This behavior reflects a typical flexural response where the material begins to crack or deform permanently once it exceeds its elastic limit [18]. The test highlights the structural characteristics and limits of the sandwich panel under flexural stress.

The test results showed that the sample could withstand a maximum load of 0.18226 kN (182.26 N) before failure. The corresponding maximum displacement recorded was 33.86 mm, with an approximate maximum stress of 0.041 MPa. These values provide a useful benchmark for evaluating the panel's strength and performance in real- world applications. Such data is valuable for quality control and further design improvements, ensuring the panels meet the necessary structural requirements for their intended use [19].

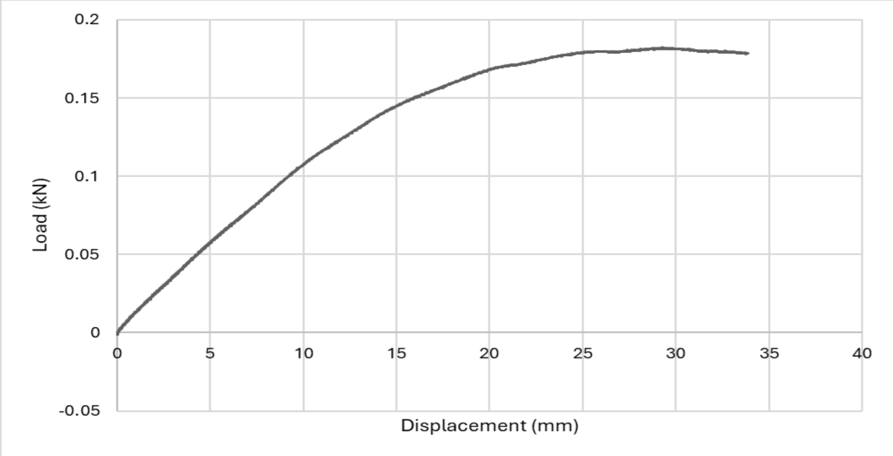


Fig. 7 *Graph load vs displacement for flexural test*

4. Discussion

The development of sandwich panels using recycled rubber and plastic waste demonstrates promising potential as an alternative construction material, particularly in applications that require flexibility and low-weight load-bearing capacity. From the flexural test, the panels exhibited a maximum load capacity of 182.26 N with significant deflection before any visible failure occurred. This suggests that while the panel can absorb mechanical stress without fracturing, its strength remains moderate, making it more suitable for light-use scenarios such as service platforms or storage areas. The ability of the panel to bend without cracking also highlights its energy-absorbing properties, which can be advantageous in certain structural applications that require shock absorption and flexibility under stress [6].

The deflection test further supports the observation that the panel is highly flexible but lacks the stiffness needed to handle heavy or sustained loads. With a deflection of 3.66 mm under just 70kN of load, the panel would likely feel soft or unstable if used as primary flooring in high-traffic or load-intensive areas. Although no critical damage was observed during the test, the progressive increase in deflection indicates a gradual loss in stiffness, especially beyond the 5 kN mark [20]. Despite this limitation, the use of recycled materials in the panel's construction offers significant environmental and economic advantages. It presents a viable step toward more sustainable building practices, particularly in regions like Malaysia where plastic and rubber waste is a growing concern [7].

The experimental results support the idea that, despite their exceptional flexibility, panels composed of rubber and recycled plastics nevertheless have a limited structural capacity when subjected to heavier stresses. While deflection tests demonstrate a notable loss of stiffness beyond 50kN, when the panels start to droop more quickly, flexural testing clearly demonstrates elastic behavior up until a specific point prior to material collapse. These findings are consistent with the panels' potential for lightweight structural applications, especially in situations where energy absorption and low weight are more important than strength. The experimental results support the idea that, despite their exceptional flexibility, panels composed of rubber and recycled plastics nevertheless have a limited structural capacity when subjected to heavier stresses. While deflection tests demonstrate a notable loss of stiffness beyond 50kN, when the panels start to droop more quickly, flexural testing clearly demonstrates elastic behavior up until a specific point prior to material collapse. These findings are consistent with the panels' potential for lightweight structural applications, especially in situations where energy absorption and low weight are more important than strength.

5. Conclusion

The results of the study indicate that sandwich panels composed of waste rubber and plastic can be successfully fabricated using the hot-press method. The panels exhibited a smooth, dense surface and high flexibility. However, results from both the flexural and deflection tests indicate that while the panels can bend significantly without breaking, their mechanical strength is moderate [11]. This makes them more suitable for light-load applications such as walkways, storage platforms, or service areas [6]. Although they effectively absorb stress, the panels are not yet strong enough to serve as primary flooring without additional structural support.

Overall, this study highlights the potential of using recycled materials in the construction industry [7], offering both environmental and economic benefits. Utilizing plastic and rubber waste as core components not only helps reduce landfill waste but also lowers the production cost of construction panels [11]. While there are still limitations in terms of load-bearing capacity, this research provides a solid foundation for future improvements in material composition and design, moving towards more sustainable and efficient building materials [21].

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Maizatul Arafah, Hasya Nadirah, Aidiel Fakhrie, Suhaila Sahat;* ***data collection:*** *Maizatul Arafah, Hasya Nadirah, Aidiel Fakhrie;* ***analysis and interpretation of results:*** *Maizatul Arafah, Hasya Nadirah, Aidiel Fakhrie, Suhaila Sahat;* ***draft manuscript preparation:*** *Maizatul Arafah, Hasya Nadirah, Aidiel Fakhrie, Suhaila Sahat. All authors reviewed the results and approved the final version of the manuscript.*

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