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Development of Biodegradable Cow Dung–Agricultural Waste Composites for Sustainable Construction and Eco-Friendly Applications

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Abstract - The increasing demand for eco-friendly materials has led to a growing interest in biodegradable composites derived from natural and agricultural waste. This research focuses on the development of a low-cost, sustainable composite material made from cow dung and agricultural residues, fabricated using the vacuum compression molding process. Cow dung acts as the organic matrix, while agricultural waste such as straw, husk, and dried leaves serves as reinforcement, with epoxy resin and hardener used as binding agents. Multiple sample compositions were prepared with varying ratios of cow dung to agricultural waste, and their physical and mechanical properties were analyzed through tensile, flexural, hardness, water absorption, density, thermal stability, and biodegradability tests. The results revealed that an optimal composition provides a balanced combination of strength, durability, and environmental compatibility, making it suitable for non-structural applications such as wall panels, insulation boards, and packaging materials. Additionally, the concept of integrating creeping and vine plants with the developed composite panels was explored to enhance microclimate regulation and aesthetic value. The study concludes that this biodegradable composite offers a practical, eco-friendly alternative to conventional synthetic materials, contributing to sustainable construction and circular economy practices.

Key Words: Biodegradable composite, Cow dung, Agricultural waste, Vacuum compression moulding, Sustainable materials, Natural fibres, Eco-friendly construction, Renewable resources, green innovation, Waste valorisation.

1. INTRODUCTION

In recent years, the growing environmental concerns associated with non-biodegradable and petroleum-based synthetic composites have driven researchers toward sustainable alternatives derived from natural and renewable sources. The excessive use of synthetic materials has resulted in serious ecological challenges such as pollution, carbon emissions, and landfill accumulation, emphasizing the need for environmentally responsible solutions. Among the various sustainable materials, biodegradable composites made from agricultural and animal wastes have emerged as promising candidates due to their low cost, easy availability, and reduced environmental footprint.

Cow dung, one of the most abundant organic wastes in rural and agricultural regions, holds immense potential as a matrix material because of its fibrous texture, natural binding characteristics, and biodegradability. Traditionally used as manure or fuel, cow dung remains underutilized in engineered applications despite its favorable composition of cellulose, hemicellulose, and lignin-like materials. On the other hand, agricultural residues such as straw, husk, and dried leaves are produced in large quantities every year, and improper disposal of these wastes—such as open burning—contributes significantly to air pollution and greenhouse gas emissions.

By combining cow dung with agricultural residues, it is possible to develop a composite material that not only reduces waste but also possesses improved mechanical strength, lightweight characteristics, and natural thermal insulation properties. To achieve uniform density and minimise void formation, the vacuum compression moulding process is employed, which provides enhanced structural integrity compared to traditional hand lay-up techniques.

This research aims to design, fabricate, and characterise a biodegradable composite made from cow dung and agricultural waste using the vacuum compression molding process. The study investigates the effects of different composition ratios on the mechanical, physical, and thermal properties of the composite and identifies an optimal mixture suitable for non-structural applications such as wall panels, insulation boards, and eco-friendly packaging materials. Additionally, the paper explores the innovative idea of integrating creeping and vine plants with these biodegradable panels to promote green architecture, natural cooling, and air purification, ultimately contributing to sustainable development and circular economy initiatives.

2. RESEARCH GAP

Although significant progress has been made in the development of natural fiber and biodegradable composites, there remains a noticeable gap in the utilization of animal waste–based materials**,** particularly cow dung, in engineered composite fabrication. Most existing studies focus primarily on plant fibers such as jute, coir, or hemp, while the potential of cow dung — a naturally fibrous, renewable, and biodegradable material — has been largely overlooked. Moreover, while agricultural wastes have been used as reinforcement in bio-composites, the combination of cow dung as a matrix with agricultural residues as reinforcement has not been extensively explored or optimized for mechanical and physical performance.

Another major gap lies in the lack of systematic analysis of mix ratios between cow dung and agricultural waste that balance mechanical strength, biodegradability, and thermal stability. Studies often focus on either mechanical or ecological aspects, but very few attempt to achieve a sustainable trade-off between both. Furthermore, the application of vacuum compression moulding to such bio-waste-based composites is limited, despite its potential to improve compaction, reduce voids, and enhance overall composite integrity.

Additionally, there is insufficient research on integrating plant-based systems such as creeping or vine plants with biodegradable composite materials to create multifunctional applications in sustainable construction. This integration could support environmental cooling, air purification, and aesthetic enhancement — benefits rarely addressed in existing composite studies.

Hence, this study bridges these research gaps by developing a composite material from cow dung and agricultural waste, analyzing its performance across multiple parameters, and proposing innovative applications that extend beyond conventional material usage into eco-functional domains.

3. PROBLEM STATEMENT

Conventional synthetic composites widely used in industries and construction are non-biodegradable and environmentally hazardous. Their production and disposal contribute to pollution, resource depletion, and ecological imbalance. Although natural fiber composites have gained attention as alternatives, many of them still rely on synthetic binders or high-cost raw materials, limiting their overall sustainability and affordability. Cow dung, an abundant organic waste material, possesses natural fibrous content and binding properties but remains largely unexplored for use as a composite matrix. Similarly, agricultural residues such as straw, husk, and leaves are often discarded or burned, leading to severe air pollution and waste management issues. There is a clear need to develop a low-cost, biodegradable, and eco-friendly composite material that effectively utilizes cow dung and agricultural waste while maintaining acceptable mechanical and thermal properties for practical, non-structural applications. This study addresses this problem by designing and fabricating a composite material that not only promotes waste valorization but also supports environmental sustainability through potential plant integration for natural cooling and air purification.

4. OBJECTIVES

The following are the main objectives of this project:

- To develop a biodegradable composite material using cow dung and agricultural waste through the vacuum compression molding process.
- To analyze the mechanical, physical, and thermal properties of the developed composite at different material ratios.
- To identify the optimal composition that offers a balance between strength, durability, and biodegradability.
- To evaluate the feasibility of using the developed composite for non-structural applications such as panels and packaging materials.
- To explore the possibility of integrating creeping and vine plants with the composite panels for enhanced environmental and aesthetic benefits.

5. DESIGN AND METHODOLOGY

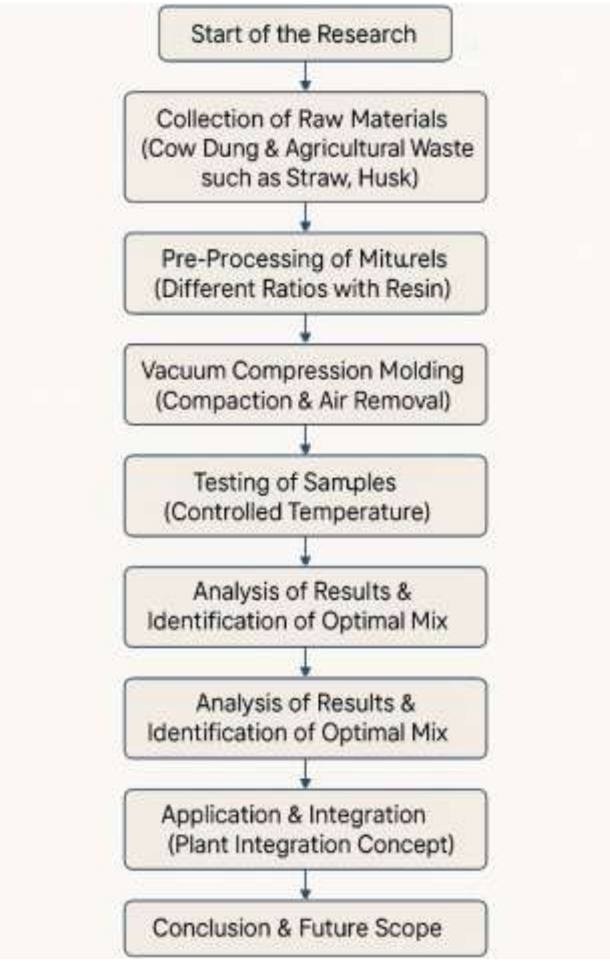

Fig: The Research structure

The study followed a systematic approach beginning with the collection of cow dung from local farms and agricultural wastes such as straw, husk, and dried leaves. The materials were cleaned, dried, and ground to uniform sizes for better mixing. Different weight ratios of cow dung to agricultural waste were prepared, with epoxy resin and hardener used as binding agents.

The mixtures were poured into molds and processed using the vacuum compression molding technique to achieve proper compaction and uniform density. After molding, the samples were cured under controlled temperature and then conditioned at room temperature.

The fabricated specimens were tested for tensile strength, flexural strength, hardness, density, water absorption, thermal stability, and biodegradability. The results were analyzed to identify the optimal composite ratio that provided the best balance of strength, durability, and biodegradability for non-structural applications.

6. WORKING PRINCIPLE

The developed composite works on the principle of combining natural reinforcement and an organic matrix to create a strong yet biodegradable material. Cow dung acts as the primary matrix, providing a natural binding medium due to its fibrous and organic content. Agricultural wastes such as straw, husk, and leaves serve as reinforcement materials, improving the mechanical strength and rigidity of the composite. Epoxy resin and hardener are used as binding agents to ensure strong adhesion between the matrix and reinforcement.

During the vacuum compression molding process, air voids are removed and the mixture is compacted uniformly, resulting in a dense and well-bonded composite structure. The mechanical load applied to the composite is transferred effectively from the cow dung matrix to the reinforcing agricultural fibers, enhancing overall strength and stability. The natural composition of the materials ensures biodegradability after disposal.

In addition, the composite can be designed to support creeping or vine plants on its surface, where the porous texture of cow dung aids in root attachment. This feature not only enhances aesthetics but also promotes environmental cooling and air purification, making the material both functional and eco-friendly.

7. ADVANTAGES

- Utilizes low-cost and easily available raw materials such as cow dung and agricultural waste.
- Promotes waste management and environmental sustainability by converting waste into useful materials.
- Lightweight and suitable for non-structural applications such as panels and packaging.
- Provides good thermal insulation and moderate mechanical strength.
- Biodegradable in nature, ensuring eco-friendly disposal without environmental harm.
- Reduces dependency on petroleum-based synthetic composites.
- Fabricated using the vacuum compression molding process for better compaction and uniformity.
- Can be integrated with creeping and vine plants for natural cooling and aesthetic enhancement.
- Contributes to circular economy practices and sustainable material innovation.

8. APPLICATIONS

- Used in wall panels and partition boards for low-load and temporary structures.
- Suitable for eco-friendly packaging materials and disposable product casings.
- Can serve as thermal and acoustic insulation in buildings and interior setups.
- Applicable in decorative interior elements, furniture inserts, and art installations.
- Can be used as a base material for vertical gardens and living wall systems supporting creeping or vine plants.
- Useful in educational or rural development projects promoting sustainability and green innovation.

9. FUTURE SCOPE

- Use of natural or bio-based binders to make the composite fully biodegradable.
- Improvement in mechanical strength and moisture resistance through fiber treatment.
- Development of hybrid composites using other natural fibers like jute or coir.
- Large-scale production and life-cycle assessment for commercial feasibility.
- Application in sustainable construction and green architectural projects.

10. CONCLUSION

The study successfully demonstrates the development of a biodegradable composite material using cow dung and agricultural waste through the vacuum compression molding process. The composite shows a good balance of strength, light weight, and environmental compatibility, making it suitable for non-structural applications such as panels, insulation boards, and packaging materials. The use of easily available natural wastes reduces both cost and environmental impact while promoting sustainability. Additionally, the concept of integrating creeping and vine plants with the composite enhances its functional and aesthetic value, supporting green building initiatives. Overall, this research presents a promising step toward eco-friendly material innovation and waste utilization for a sustainable future.

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