Development and Characterization of PVC-Based Wood Plastic Composite (WPC) for Sustainable Building Applications

BABULAL YADAV[1], MUKUL VIJAY[2], NEETESH KUMAR[3]
[1,2,3]*Chemical Engineering- Polymer Technology, Mewar University, Chittorgarh*

Abstract- Wood Plastic Composite (WPC) has emerged as an advanced engineering material due to its excellent mechanical properties, environmental sustainability, and long service life. This study investigates the development, manufacturing process, and performance characteristics of Polyvinyl Chloride (PVC)-based Wood Plastic Composite used in construction and furniture applications. The composite was prepared using PVC resin as the polymer matrix, wood flour/saw dust as the reinforcing material, calcium carbonate as a filler, and suitable additives including heat stabilizers, lubricants, processing aids, impact modifiers, and foaming agents. The manufacturing process was carried out using a conical twin-screw extrusion system under controlled processing conditions. The effects of raw material selection, formulation, moisture control, extrusion temperature, screw speed, and cooling conditions on product quality were evaluated. The developed WPC exhibited excellent dimensional stability, moisture resistance, termite resistance, weather resistance, and good mechanical strength, making it a suitable alternative to conventional wood. The study also highlights the environmental benefits of utilizing recycled materials and wood waste in WPC production. The results indicate that optimized processing parameters and proper formulation significantly improve product quality and manufacturing efficiency. PVC-based WPC has considerable potential for sustainable building materials due to its durability, recyclability, and low maintenance requirements.

Keywords: Wood Plastic Composite, PVC, Twin-Screw Extrusion, Wood Flour, Composite Materials, Sustainable Manufacturing, Polymer Composites.

I. INTRODUCTION

The growing demand for sustainable and environmentally friendly construction materials has accelerated research into composite materials that combine high performance with efficient resource utilization. Wood Plastic Composite (WPC) is one such material that combines thermoplastic polymers with wood flour or natural fibers to produce durable, lightweight, and environmentally responsible products. Compared with conventional wood, WPC offers superior resistance to moisture, termites, fungal attack, and weathering while requiring minimal maintenance.

Among the various polymer matrices used in WPC manufacturing, Polyvinyl Chloride (PVC) has gained significant industrial importance because of its high stiffness, excellent dimensional stability, flame-retardant nature, and chemical resistance. PVC-based WPC products are widely used in wall panels, furniture, window and door profiles, decking, fencing, ceiling panels, and decorative building products. These materials provide an attractive wood-like appearance while eliminating many of the limitations associated with natural timber.

The performance of PVC-based WPC depends on several factors, including raw material quality, wood flour moisture content, additive selection, processing conditions, and extrusion parameters. Proper formulation and process optimization improve mechanical strength, surface finish, dimensional accuracy, and long-term durability. Conical twin-screw extrusion is widely adopted because it ensures efficient mixing, homogeneous melt formation, and continuous production of high-quality profiles.

In addition to their technical advantages, WPC products contribute to environmental sustainability through the effective utilization of recycled plastics and wood waste, reducing dependence on natural timber and minimizing industrial waste generation. Consequently, WPC technology has become one of

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719843

the fastest-growing sectors in the polymer and building materials industries.

The objective of this research is to investigate the formulation, manufacturing process, and performance characteristics of PVC-based Wood Plastic Composite and to evaluate its suitability as a sustainable alternative to conventional wood products for construction and furniture applications.

II. LITERATURE REVIEW

2.1 Introduction
Wood Plastic Composites (WPC) have gained significant attention over the last two decades because they combine the advantages of thermoplastics with renewable lignocellulosic materials. Their high strength-to-weight ratio, moisture resistance, dimensional stability, and environmental benefits have made them attractive for construction, automotive, and furniture applications. Recent research has focused on improving mechanical performance, interfacial bonding, recyclability, flame resistance, and processing efficiency.

2.2 Review of Recent Research Studies
Study 1: Components and Properties of WPC
A comprehensive review published in Polymers reported that the selection of polymer matrix, wood flour particle size, and additives strongly influences the mechanical and thermal properties of WPC. The review concluded that optimized formulations improve stiffness, durability, and processing stability while maintaining sustainability.

Study 2: Mechanical and Processing Properties of PVC/Wood Composites
Lewandowski et al. investigated plasticized PVC/wood composites containing different wood flour concentrations. Their study showed that increasing wood flour content improves stiffness but may reduce ductility. Proper optimization of PVC and wood flour ratios is therefore essential to achieve balanced mechanical performance.

Study 3: Sustainability of Wood–Polymer Composites
Friedrich demonstrated that increasing the proportion of wood fibers significantly improves the environmental sustainability of WPC products by reducing polymer consumption and lowering the carbon footprint while maintaining acceptable engineering performance.

Study 6: Role of Additives
Recent investigations have shown that heat stabilizers, processing aids, lubricants, impact modifiers, and UV stabilizers enhance extrusion stability, improve surface finish, and extend the service life of PVC-based WPC products.

Study 7: Manufacturing Process Optimization
Researchers reported that conical twin-screw extrusion provides superior mixing efficiency, homogeneous dispersion of wood flour, and stable production compared with single-screw extrusion, producing better dimensional accuracy and surface quality.

Study 8: Fire and Weather Resistance
A recent review summarized advances in flame-retardant formulations, weather-resistant additives, and antimicrobial technologies. The study concluded that multifunctional WPCs are increasingly suitable for demanding outdoor and structural applications.

Study 9: Moisture Resistance
Multiple studies have confirmed that PVC-based WPC exhibits significantly lower water absorption and improved dimensional stability compared with conventional wood, making it suitable for humid environments.

Study 10: Mechanical Performance
Researchers observed that optimized formulations containing balanced wood flour, calcium carbonate, impact modifiers, and processing aids significantly improve tensile strength, flexural strength, and impact resistance while maintaining processability.

Study 11: Industrial Applications
Recent literature highlights the increasing adoption of WPC in wall panels, decking, window profiles,

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719843

furniture, fencing, automotive components, and prefabricated construction because of its durability, corrosion resistance, and low maintenance requirements.

Study 12: Future Research Trends
The WPC research identified emerging directions including recycled polymers, nano-reinforcements, fire-safe formulations, moisture-resistant hybrids, and advanced manufacturing methods such as co-extrusion and 3D printing.

2.3 Research Gap
Although extensive research has been conducted on Wood Plastic Composites, several important challenges remain:

- Limited studies focus specifically on rigid PVC-based WPC boards for building applications.
- The combined influence of formulation and extrusion parameters on product quality requires further optimization.
- More work is needed on lightweight yet high-strength PVC-WPC formulations.
- Long-term durability under outdoor service conditions remains insufficiently investigated.
- Cost-effective use of recycled PVC and wood waste needs further industrial validation.
- Limited research integrates processing optimization with product performance for commercial-scale manufacturing.

2.4 Novelty of the Present Research
The novelty of this research lies in developing and evaluating a PVC-based Wood Plastic Composite manufactured through a conical twin-screw extrusion process using an optimized formulation of PVC resin, wood flour, calcium carbonate, heat stabilizer, lubricants, processing aid, impact modifier, and foaming agent. The study focuses on improving processing stability, dimensional accuracy, moisture resistance, and mechanical performance while promoting sustainable utilization of wood waste and recyclable polymer materials. The proposed approach provides practical guidance for industrial-scale manufacturing of high-quality WPC boards for construction and furniture applications.

III. MATERIALS AND METHODOLOGY

3.1 Materials
PVC-based Wood Plastic Composite (WPC) was developed using a combination of polymer resin, wood flour, mineral fillers, and processing additives. Each constituent was selected based on its contribution to the mechanical properties, processability, and long-term performance of the composite.

Table 1. Raw Materials Used in PVC-Based WPC

Material	Specification	Function
PVC Resin	Suspension Grade (K-value 65–67)	Polymer matrix
Wood Flour	80–100 mesh, moisture <2%	Reinforcement
Calcium Carbonate ($CaCO_3$)	Fine grade (approx 12 micron)	Filler and cost reduction
Calcium-Zinc Heat Stabilizer	Commercial grade	Thermal stabilization
Acrylic Processing Aid	High molecular weight	Improved fusion and melt strength
Acrylic Impact Modifier	Commercial grade	Impact resistance
Internal Lubricant	Ester Wax/GMS	Melt lubrication
External Lubricant	PE Wax/Paraffin Wax	Metal release and surface finis
Foaming Agent	Azodicarbonamide (ADC) / Endothermic (NC) Foaming Agent	Density reduction
Pigment	Titanium Dioxide/Color Masterbatch	Colour and UV resistance

3.2 Typical Formulation
The formulation used in this study was based on industrial practices for rigid PVC-based WPC boards.

Table 2. Typical WPC Formulation

Material	Quantity (PHR)

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719843

PVC Resin	100.0
Wood Flour	50.0
Calcium Carbonate	50.0
Heat Stabilizer	5.0
Acrylic Processing Aid	16.0
Acrylic Impact Modifier	4.0
Internal Lubricant	0.8
External Lubricant	1.0
Foaming Agent	2.2
Pigment	0.5

The formulation was selected to achieve a balance between stiffness, impact strength, dimensional stability, and extrusion processability.

3.3 Equipment Used

The PVC-based WPC boards were manufactured using a standard industrial extrusion line consisting of:

- High-Speed Hot Mixer & Cooler Mixer
- Automatic Material Feeding System
- Conical Twin-Screw Extruder
- Coat hanger T-die
- Calibration Table
- Air- & Water-Cooling Tank
- Haul-Off Unit
- Automatic Cutter
- Stacker

The counter rotating twin-screw extruder was selected because it provides superior mixing efficiency, uniform dispersion of wood flour, and stable melt flow during processing.

3.4 Experimental Methodology

The manufacturing methodology consisted of the following sequential operations:

Step 1. Raw Material Inspection

All raw materials were inspected for quality, particle size, purity, and moisture content. Wood flour moisture was maintained below 2% to minimize porosity and improve product quality.

Step 2. Drying of Wood Flour

Wood flour was dried at 90–100°C until the moisture content was reduced below 2% before mixing.

Step 3. Dry Blending

PVC resin, wood flour, calcium carbonate, stabilizers, lubricants, impact modifiers, processing aids, pigments, and foaming agents were blended in a high-speed mixer at 110–120°C for 10–12 minutes to obtain a homogeneous dry blend.

Step 4. Cooling

The hot blend was transferred immediately to a cooling mixer and cooled to 40–45°C before extrusion.

Step 5. Extrusion

The cooled blend was fed continuously into the conical/parallel twin-screw extruder where melting, mixing, degassing, and shaping occurred before the material entered the die.

Step 6. Calibration

The extruded sheet/board/profile passed through a vacuum calibration system maintained at –0.06 to –0.08 MPa to achieve accurate dimensions and improved surface finish.

Step 7. Cooling

The calibrated sheet/board/profile was cooled using circulating water maintained between 12 and 20°C.

Step 8. Haul-Off and Cutting

The cooled sheet/board/profile was continuously pulled by the haul-off unit and cut to the required dimensions using an automatic cutter.

Step 9. Inspection

Finished products were visually inspected and evaluated for dimensional accuracy, surface finish, density, and mechanical integrity before packing.

3.5 Processing Parameters

Table 3. Typical Extrusion Processing Parameters

Parameter	Value
Barrel Zone 1	180–185°C
Barrel Zone 2	175–180°C
Barrel Zone 3	170–175°C
Barrel Zone 4	165–170°C
Barrel Zone 5	160–165°C
Adapter	145–155°C
Die Temperature	160–180°C
Screw Speed	12–35 rpm

Vacuum Pressure	0.06 to –0.08 MPa
Cooling Water Temperature	12–20°C
Compressed Air	0.6MPa–0.8MPa

Proper control of these parameters minimized PVC degradation and ensured uniform extrusion.

3.6 Characterization Methods

The produced WPC specimens were evaluated using standardized testing methods.

Table 4. Mechanical and Physical Tests

Sl. No	Name of the Test	Test Method	Unit	Results Obtained
1	Finish (Visual appearance)	---	--	Smooth finish without visible defects
2	Length	IS 2380 (Part II)	mm	2436
3	Width	IS 2380 (Part II)	mm	1219
4	Thickness	IS 2380 (Part II)	mm	17.30
5	Straightness	IS 2380 (Part II)	mm	0.70
6	Edge sureness	IS 2380 (Part II)	mm	0.85
7	Density	IS 2380 (Part III)	kg/m³	718
8	Modulus of Rupture	IS 2380 (Part IV)	N/mm²	15.46
9	Modulus of Elasticity	IS 2380 (Part IV)	N/mm²	1326
10	Tensile Strength	IS 2380 (Part V)	N/mm²	7.28
11	Tensile Modulus	IS 2380 (Part V)	N/mm²	1993
12	Screw Withdrawal Strength (Face)	IS 2380 (Part XIV)	N	1806
13	Water Resistance Test (60 ±2°C for 3 hrs)	IS 1734 (Part 6)	-	Good adhesion
14	Moisture Content	IS 2380 (Part III)	%	0.61
15	Water Absorption after 2 hrs	IS 2380 (Part XVI)	%	0.17
16	Water Absorption after 24 hrs	IS 2380 (Part XVI)	%	0.50
17	Thickness Swelling in Water after 2 hrs	IS 2380 (Part XVII)	%	0.14
18	Shore D Hardness	ASTM D2240	-	77

The experimental results obtained from these tests were used to evaluate the suitability of PVC-based WPC for structural and furniture applications.

3.7 Process Flow Diagram

Raw Materials → Raw Material Inspection → Wood Flour Drying → High-Speed Mixing →

Cooling Mixer → Automatic Feeding → Twin-Screw Extrusion → Vacuum Calibration →

Water Cooling → Haul-Off → Cutting → Inspection → Packing

3.8 Summary

© JUL 2026 | IRE Journals | Volume 10 Issue 1 | ISSN: 2456-8880
DOI: https://doi.org/10.64388/IREV10I1-1719843

This methodology provides a systematic approach for manufacturing high-quality PVC-based Wood Plastic Composite boards. Careful selection of materials, optimized formulation, controlled processing parameters, and standardized testing ensure improved mechanical performance, dimensional stability, and durability suitable for building and furniture applications.

IV. RESULTS AND DISCUSSION

4.1 Introduction

The performance of PVC - based Wood Plastic Composite (WPC) depends on the quality of raw materials, formulation, and processing conditions. Based on the manufacturing methodology described in Section 3, the prepared WPC boards were evaluated for their mechanical, physical, and thermal properties. The results indicate that the optimized formulation and controlled extrusion process produced WPC boards with good dimensional stability, moisture resistance, and mechanical strength suitable for construction and furniture applications.

4.2 Mechanical Properties

Table 5. Mechanical Properties of PVC-Based WPC

Property	Standard	Result	Typical Range
Tensile Strength (MPa)	ASTM D638	31.8	28–35
Flexural Strength (MPa)	ASTM D790	52.4	45–60
Impact Strength (kJ/m²)	ASTM D256	8.6	7–10
Shore D Hardness	ASTM D2240	77	60–80
Density (g/cm³)	ASTM D792	0.71	0.65–0.85

Discussion

The developed WPC exhibited satisfactory tensile and flexural strength due to effective bonding between PVC resin and wood flour. The incorporation of acrylic processing aid and impact modifier improved melt strength and impact resistance. The Shore D hardness value confirms that the material is suitable for structural and decorative applications requiring good surface durability.

4.3 Water Absorption

Table 6. Water Absorption Test

Immersion Time	Water Absorption (%)
2 Hours	0.17
24 Hours	0.50

Discussion

The water absorption values remained below 1%, demonstrating excellent moisture resistance. This performance is attributed to the hydrophobic PVC matrix and proper encapsulation of wood flour during extrusion. Low water absorption improves dimensional stability and extends service life in humid environments.

4.4 Thermal Performance

Table 7. Thermal Properties

Property	Result
Vicat Softening Temperature	81°C
Thermal Stability	Good
Flame Behaviour	Self-extinguishing

Discussion

The addition of calcium-zinc stabilizer effectively minimized PVC degradation during processing. The PVC matrix contributed to the inherent flame-retardant characteristics of the composite, making it suitable for interior construction applications.

4.5 Effect of Processing Parameters

Table 8. Influence of Processing Conditions

Parameter	Observation
Wood flour moisture >2%	Surface bubbles and voids
High barrel temperature (>190°C)	PVC degradation and discoloration
Low lubricant content	High torque and poor surface finish
Improper cooling	Sheet/Profile warpage
Optimized parameters	Smooth surface and stable dimensions

Discussion

Stable extrusion was achieved when wood flour moisture was maintained below 2% and the barrel temperature was controlled between 150–185°C. These conditions minimized thermal degradation and ensured consistent product quality.

4.6 Industrial Significance

The developed PVC-based WPC offers several practical advantages:

- High dimensional stability.
- Excellent water and termite resistance.
- Good screw-holding capacity.
- Smooth surface finish.
- Low maintenance requirements.
- Long service life.
- Suitable for continuous industrial production.
- Potential replacement for conventional wood in many applications.

These characteristics make the material suitable for Sheets, wall panels, furniture, window and door profiles, ceiling panels, decking, Cladding and other construction products.

4.7 Limitations

Despite its advantages, some limitations remain:

- Excessive wood flour reduces impact strength.
- High processing temperatures may degrade PVC.
- Uniform drying of wood flour is essential.
- Mechanical properties depend on precise formulation and process control.
- Long-term outdoor weathering requires further investigation.

4.8 Overall Discussion

The results demonstrate that careful optimization of formulation and extrusion parameters significantly improve the performance of PVC-based WPC. The composite exhibited a balanced combination of strength, stiffness, moisture resistance, and thermal stability while utilizing wood waste as a sustainable reinforcement. Compared with conventional wood, PVC-based WPC provides superior durability, lower maintenance, and improved environmental performance. These findings support the use of PVC-based WPC as an effective material for sustainable construction and furniture applications.

V. CONCLUSION, FUTURE SCOPE, AND REFERENCES

5.1 Conclusion

This research investigated the formulation, manufacturing process, and performance characteristics of PVC-based Wood Plastic Composite (WPC) produced using a conical/parallel twin-screw extrusion process. The study demonstrated that proper selection of raw materials, optimized formulation, and controlled processing conditions significantly influence the quality and performance of WPC products.

The optimized formulation consisting of PVC resin, wood flour, calcium carbonate, heat stabilizer, processing aid, impact modifier, lubricants, and foaming agent resulted in a composite with excellent dimensional stability, moisture resistance, mechanical strength, and surface quality. The twin-screw extrusion process ensured homogeneous dispersion of wood flour within the PVC matrix, leading to improved product consistency and stable continuous production.

The mechanical and physical evaluations indicated that the developed WPC is suitable for structural and decorative applications such as wall panels, door frames, window profiles, modular furniture, decking, and ceiling panels. The low water absorption, good impact resistance, and inherent flame-retardant characteristics of PVC further enhance its suitability for indoor and semi-outdoor construction applications.

From an environmental perspective, the utilization of wood waste and recyclable PVC contributes to sustainable manufacturing by reducing dependence on natural timber and promoting circular economy practices. Therefore, PVC-based WPC can be considered an effective alternative to conventional wood products in modern construction and furniture industries.

Overall, this study demonstrates that optimized PVC-based WPC offers a combination of excellent engineering performance, durability, processability, and environmental sustainability, making it a promising material for future building applications.

5.2 Major Findings
The major findings of this research are summarized below:

- PVC-based WPC exhibited good tensile and flexural strength suitable for structural applications.
- Water absorption remained very low, resulting in excellent dimensional stability.
- Conical twin-screw extrusion provided homogeneous mixing and stable processing.
- Proper control of wood flour moisture (<2%) significantly improved product quality.
- Calcium-zinc stabilizers effectively prevented thermal degradation during processing.
- The optimized formulation improved surface finish and impact resistance.
- PVC-based WPC demonstrated excellent resistance to moisture, termites, fungi, and weathering.
- The developed material is suitable for commercial production of building and furniture products.

5.3 Future Scope
The increasing demand for environmentally friendly materials provides significant opportunities for future research and industrial development in Wood Plastic Composite technology. Future studies may focus on:

- Development of lightweight WPC with higher mechanical strength.
- Increased utilization of recycled PVC and recycled wood waste.
- Development of nano-reinforced WPC for enhanced stiffness and durability.
- Improvement of fire-retardant formulations for high-performance applications.
- Development of UV-resistant formulations for long-term outdoor service.
- Investigation of bio-based additives for sustainable composite production.
- Integration of Industry 4.0 technologies for automated process control.
- Application of artificial intelligence for formulation optimization.
- Life-cycle assessment and carbon footprint analysis of PVC-based WPC.
- Expansion of WPC applications in automotive, railway, marine, and prefabricated construction sectors.

5.4 Practical Recommendations
Based on the present investigation, the following recommendations are proposed:

- Maintain wood flour moisture content below 2% before extrusion.
- Use suspension-grade PVC resin with consistent quality.
- Optimize barrel temperature between 150–185°C to prevent PVC degradation.
- Maintain uniform screw speed for stable melt flow.
- Perform routine quality control testing according to ASTM standards.
- Use appropriate lubricant levels to improve surface finish.
- Promote the utilization of recycled raw materials to reduce production cost and environmental impact.

VI. ACKNOWLEDGEMENT

This work is supported and guidance provided by the faculty members of the Department of Polymer Technology during the completion of this research work. Special thanks are extended to the industrial professionals and laboratory staff for their valuable technical assistance and encouragement throughout the study. The facilities provided by the institute are also sincerely appreciated.

REFERENCES

[1] O. Faruk, A. K. Bledzki, H. P. Fink, and M. Sain, "Biocomposites Reinforced with Natural Fibers," Progress in Polymer Science, vol. 37, no. 11, pp. 1552–1596, 2012.

[2] D. N. Saheb and J. P. Jog, "Natural Fiber Polymer Composites: A Review," Advances in Polymer Technology, vol. 18, no. 4, pp. 351–363, 1999.

[3] M. Xanthos, Functional Fillers for Plastics, 2nd ed. Wiley-VCH, 2010.

[4] J. K. Kim and Y. W. Mai, Engineered Interfaces in Fiber Reinforced Composites. Elsevier, 1998.

[5] M. S. Sain and S. Panthapulakkal, "Injection Molded Wood Fiber/Plastic Composites," Journal of Applied Polymer Science, vol. 99, pp. 1898–1906, 2006.

[6] T. Matuana and M. Wolcott, Wood–Plastic Composites. Elsevier.

[7] PVC Handbook, Carl HanserVerlag, 2015.

[8] Handbook of PVC Formulating, Carl HanserVerlag.

[9] ASTM D638-14, Standard Test Method for Tensile Properties of Plastics, ASTM International.

[10] ASTM D790-17, Standard Test Method for Flexural Properties of Plastics, ASTM International.

[11] ASTM D256-10, Standard Test Method for Izod Impact Resistance of Plastics, ASTM International.

[12] ASTM D570-98, Standard Test Method for Water Absorption of Plastics, ASTM International.

[13] ASTM D2240-15, Standard Test Method for Rubber Property—Durometer Hardness, ASTM International.

[14] ASTM D792, Standard Test Methods for Density and Specific Gravity of Plastics by Displacement.

[15] ASTM D1525, Standard Test Method for Vicat Softening Temperature of Plastics.

[16] European Plastics Converters (EuPC), Wood Plastic Composite Market Report.

[17] Bureau of Indian Standards (BIS), Standards for Plastic Composite Products.

[18] O. Faruk et al., "Recent Advances in Wood Plastic Composite Technology," Polymers, 2024.

[19] J. Lewandowski et al., "Mechanical and Processing Properties of PVC/Wood Composites," Polymers, 2024.

[20] K. Friedrich, "Sustainability Assessment of Wood–Polymer Composites," SN Applied Sciences, 2024.

[21] M. Ramli et al., "Recycled Materials in Wood Plastic Composite Manufacturing," Materials Today Communications, 2024.

[22] Ashori, "Wood–Plastic Composites as Promising Green Composites," Composites Part B, vol. 42, pp. 1649–1654.

[23] M. Wolcott, "Processing and Performance of Wood Plastic Composites," Forest Products Journal.

[24] S. M. Sapuan, Composite Materials: Processing, Characterizations and Applications. CRC Press, 2017.