SUSTAINABLE NATURAL FIBER COMPOSITES

The Synergy of
FLAX *and* SISAL

NATURAL
RENEWABLE

SUSTAINABLE
SOLUTIONS

STRONGER
TOGETHER

NATURE INSPIRED.
PERFORMANCE DRIVEN.
A GREENER FUTURE.

AUTHORS

Arghya Gupta • Akhtarujjaman Sarkar
Soumojit Dasgupta • Sumit Chabri

BIOBASED

ECO-FRIENDLY

HIGH PERFORMANCE

SUSTAINABLE INNOVATION

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Preface

The increasing demand for environmentally sustainable materials has transformed the direction of modern materials science and composite engineering. Conventional synthetic fibre composites, though mechanically strong and widely used, present serious environmental challenges due to their non-biodegradability, high energy consumption during production, and difficulties associated with recycling and disposal. In response to these concerns, natural fibre reinforced composites have emerged as a promising alternative, offering renewable, lightweight, biodegradable, and cost-effective solutions for engineering applications.

Among the numerous natural fibres investigated worldwide, flax and sisal fibres have attracted particular attention because of their unique and complementary properties. Flax fibre, a bast fibre, exhibits excellent stiffness, tensile strength, and low density, making it suitable for lightweight structural applications. Sisal fibre, a leaf fibre, contributes superior toughness, impact resistance, and thermal stability. The hybridisation of these two fibres therefore provides an opportunity to design composite systems that combine stiffness, strength, toughness, and durability within a single sustainable material framework.

This book, *Sustainable Natural Fiber Composites: The Synergy of Flax and Sisal*, has been written to provide a comprehensive understanding of hybrid natural fibre composites reinforced with liquid resole phenolic resin and enhanced through advanced ceramic fillers such as zirconia (ZrO_2) and titanium dioxide (TiO_2). The work explores the scientific foundations, processing methodologies, interfacial engineering, thermal behaviour, mechanical performance, and multifunctional characteristics of these sustainable composite systems.

Special emphasis has been placed on the role of phenolic resins due to their exceptional fire resistance, low smoke generation, thermal stability, and compatibility with natural fibres when processed under controlled curing conditions. Furthermore, the incorporation of zirconia and titania fillers introduces significant improvements in fracture toughness, thermal management, UV protection, moisture resistance, and wear behaviour, enabling the development of high-performance eco-friendly composites suitable for semi-structural and structural applications.

The motivation behind this book arises from the growing need for sustainable engineering materials in automotive, aerospace interiors, railway systems, building materials, marine

structures, sports equipment, and green infrastructure. While considerable research exists on individual natural fibres or conventional polymer matrices, there remains a limited number of detailed resources focusing specifically on hybrid flax–sisal composites combined with phenolic resin systems and ceramic nano/micro-fillers. This book aims to bridge that gap by integrating fundamental science with practical composite fabrication strategies.

Throughout the chapters, I have attempted to present both theoretical concepts and practical considerations in a clear and systematic manner. Topics such as fibre morphology, extraction methods, surface treatments, fibre–matrix adhesion, curing kinetics, thermal degradation, fire behaviour, filler dispersion, and hybrid architecture have been discussed with scientific depth while maintaining accessibility for students, researchers, and practising engineers.

I sincerely hope this book will serve as a valuable reference for researchers working in sustainable materials, polymer science, nanocomposites, and green manufacturing technologies. It is also intended to inspire further innovation toward environmentally responsible composite systems capable of meeting the demanding requirements of modern engineering applications.

Finally, I express my gratitude to the researchers, scientists, and academic communities whose contributions in the fields of natural fibres, polymer composites, ceramic fillers, and sustainable materials have provided the scientific foundation upon which this work has been developed. I also acknowledge the importance of interdisciplinary collaboration in advancing the future of green composite technologies.

I hope this book contributes meaningfully to the advancement of sustainable composite materials and encourages future generations to pursue environmentally conscious engineering solutio

Acknowledgement

I sincerely express my gratitude to Narula Institute of Technology for providing the academic support and research environment necessary for completing this book, Sustainable Natural Fiber Composites: The Synergy of Flax and Sisal.

I am thankful to the faculty members, colleagues, and students for their encouragement and valuable support throughout this work. I also acknowledge the contributions of researchers and authors whose studies in natural fibre composites and sustainable materials greatly inspired this book.

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He serves as an Assistant Professor in the Department of Mechanical Engineering at Narula Institute of Technology, Kolkata. With over 12 years of teaching experience, he holds a B.E. in Mechanical Engineering from Bengal Engineering and Science University and an M.Tech. in Manufacturing Engineering from West Bengal University of Technology. He is currently pursuing his Ph.D. at Indian Institute of Engineering Science and Technology Shibpur. His academic contributions include active participation in numerous national and international conferences, along with publications in reputed journals and conference proceedings. Dedicated to advancing education and research, he is deeply involved in various academic initiatives, fostering innovation, technical excellence, and critical thinking in the field of mechanical engineering. He is also a member of The Institution of Engineers (India).

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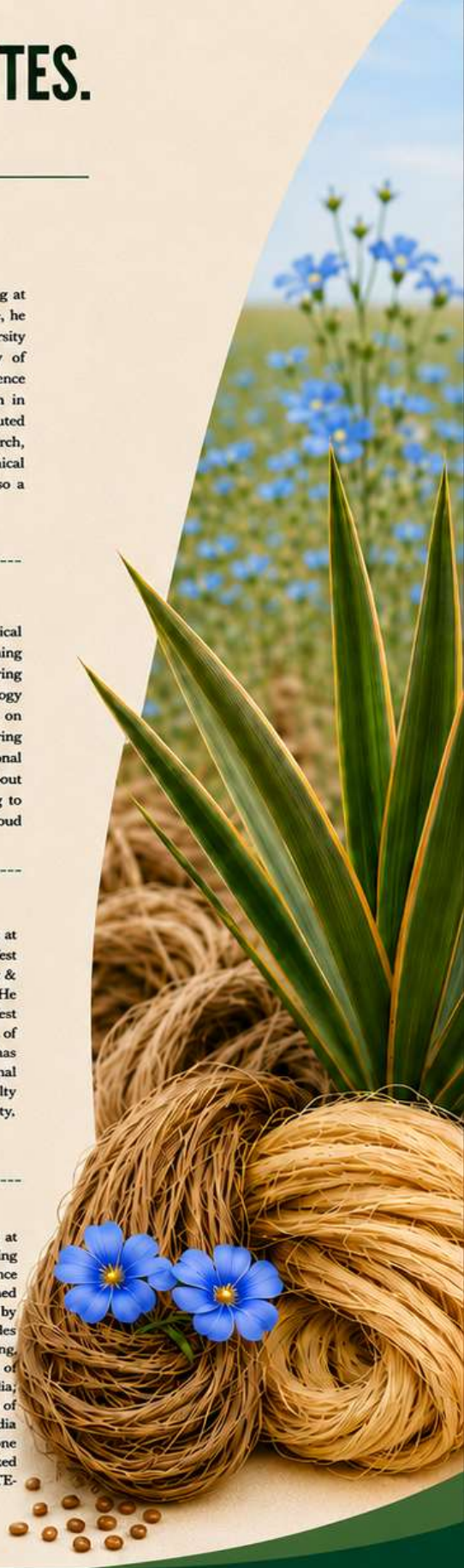

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