National Institute of Forest Science

The Korean Society of Wood Science & Technology
Republic of Korea

SOCIETY OF WOOD SCIENCE & TECHNOLOGY

2026 SWST International Convention

Innovating with Wood: Science and Materials for a Sustainable Future

June 7~12, 2026
Seoul, Korea

Proceedings

as of June 5, 2026

2026 SWST
International Convention

TABLE OF CONTENTS

Welcome Message 02
Organizing Committee 06
Supported & Sponsored By 09
Daily Program 10
Full Agenda 18

June 9_Room A

(08:30) VI-1. Early Stage Researcher (ESR) 3-Minute Talks 69
(10:30) I-1. Fundamentals and Frontiers in Wood Physics and Mechanics 95
(13:30) I-1. Fundamentals and Frontiers in Wood Physics and Mechanics 103
(16:00) I-3. New Insights into Wood Biology 111

June 9_Room B

(08:30) II-2. Designing for Performance and Resilience in Residential Timber Structures 119
(10:30) II-2. Designing for Performance and Resilience in Residential Timber Structures 125
(11:15) IV-2. Ecosystem Services and Biodiversity in Wood Value Chains 129
(13:30) III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials 131
(16:00) III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials 141

June 9_Room C

(08:30) IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts 151
(10:30) IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts 159
(13:30) V-1. Cultural Dimensions and Societal Perceptions of Wood Use 167
(16:00) V-2. New Approaches to Wood Sector Education and Workforce Development 175
(17:00) III-2. Digitalization and Smart Processing Technology 181

June 10_Room A

(08:30) I-4. Traditional Wood Care and Maintenance: Drying, Preservation, Machining, Finishing, etc. 185
(10:30) II-1. Advanced Timber Engineering and Hybrid Structural Systems 193
(13:30) II-1. Advanced Timber Engineering and Hybrid Structural Systems 201
(16:00) IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impact 211

June 10_Room B

(08:30) I-1. Fundamentals and Frontiers in Wood Physics and Mechanics 219
(10:30) I-1. Fundamentals and Frontiers in Wood Physics and Mechanics 227
(13:30) I-2. Fundamentals in Wood Chemistry and Biorefining 231
(16:00) I-2. Fundamentals in Wood Chemistry and Biorefining 241

June 10_Room C

(08:30) VII-1. IUFRO DIV.5. with 2026 SWST in Korea: Wood Properties and Utilization 249
(10:30) VII-1. IUFRO DIV.5. with 2026 SWST in Korea: Wood Properties and Utilization 257
(13:30) III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials 263
(16:00) III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials 271

Poster 279
Poster (Student Competition) 351

WELCOME MESSAGE

Welcome to the 2026 SWST International Convention.

It is a great honor and privilege to welcome distinguished researchers, scientists, and industry professionals from around the world to the Republic of Korea.

This year's convention highlights the importance and role of wood for a sustainable future. In recent years, the international community has increasingly recognized sustainable forest management and wood utilization as key strategies for climate change mitigation and carbon neutrality. Wood is widely recognized as a representative bio-based material that stores carbon and can replace carbon-intensive materials such as steel, concrete, and plastics.

The Korea Forest Service is also advancing policies and institutional frameworks that support greater wood utilization and the transition to a low-carbon economy. Korea established the Act on the Sustainable Use of Wood in 2012, providing the foundation for related policies and initiatives. Korea is also promoting legislation to support timber construction and expand the use of domestic wood products, thereby creating favorable conditions for a low-carbon building culture.

These policies and initiatives are supported by the research and development activities of the National Institute of Forest Science (NIFoS). NIFoS is advancing research on cascading use strategies for wood resources based on regional characteristics and on methodologies for quantifying the carbon substitution effects of wood products. NIFoS is also advancing research in wood-based biomaterials and technologies for tall timber construction. In addition, the Institute contributes to strengthening the competitiveness of the wood industry through the development of energy-efficient wood processing technologies. NIFoS is also expanding its research efforts to integrate emerging technologies, including artificial intelligence (AI), with wood science to drive innovation and advance the bioeconomy.

This convention will provide an important opportunity to share these efforts and scientific achievements, foster international collaboration, and explore the future role of wood science in building a more sustainable society.

Yongkwan KIM

Co-Chair of the Organizing Committee of 2026 SWST International Convention
President of National Institute of Forest Science (NIFoS)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

WELCOME MESSAGE

It is a great honor to welcome you to the 2026 SWST International Convention, to be held in Seoul, Republic of Korea, from June 7 to 12, 2026. This convention brings together wood scientists, industry leaders, educators, and policymakers committed to innovation, sustainability, and collaboration in wood science and technology.

This convention is held with the vision of "Innovating with Wood for Sustainable Future".

The theme reflects the growing role of wood science in addressing the global climate crisis. Once a primarily academic discipline, wood science has become essential to carbon storage and the transition away from fossil-based materials, offering a renewable pathway toward a sustainable future.

A carbon-neutral society requires sustained innovation grounded in rigorous research and advanced engineering. Through continued technological refinement, wood science is enabling safer timber structures, advanced wood-based materials, and a resilient wood culture. Your contributions will be central to advancing these innovations and shaping a sustainable society.

In Korea's modern history, the wood engineering and wood-panel industries played a vital role in post-war reconstruction. Revenues from wood product exports supported national infrastructure and enabled investment in emerging industries, laying the foundation for Korea's rapid economic and cultural growth.

Our host city, Seoul is a city where historic wooden heritage and modern digital culture coexist. From traditional palaces to the global influence of K-culture, the city embodies a unique harmony between tradition and innovation, making it an inspiring host for 2026 SWST.

We hope 2026 SWST will be more than a forum for knowledge, serving as a meaningful platform for connection and inspiration as we move together toward a sustainable future in wood science and technology.

With Sincere Gratitude,

Hwanmyeong YEO

Co-Chair of the Organizing Committee of 2026 SWST International Convention
President of The Korean Society of Wood Science and Technology
Professor of Seoul National University

WELCOME MESSAGE

Welcome to all participants of the 2026 SWST–KSWST International Convention, we're very happy you're here! It is a pleasure to help bring together researchers, students, industry professionals, and partners from around the world. Your presence shows a shared passion for advancing wood science and technology and for building the kind of global connections that help great ideas grow.

This convention is much more than a gathering of experts, it's a space for learning, training, and growing professionally. Students and early-career professionals are right at the center of it all, discovering new ideas, meeting mentors, and finding opportunities that can shape their future paths. At the same time, experienced scientists and practitioners bring their knowledge to the table, helping ensure that progress keeps moving forward in meaningful and lasting ways.

We've put together an ambitious technical program, and there's plenty to explore. You'll find an active exchange of ideas, from fundamental research to practical innovations that support sustainability and the responsible use of forest resources. Through presentations, discussions, and collaborations, you'll see just how much good work is happening around the world and how these diverse perspectives help bridge science, industry, and society.

Just as importantly, this event highlights the role of SWST and KSWST as communities that support people throughout their entire careers. Whether you're just starting out or bringing decades of experience, these societies offer a place to connect, grow, and stay engaged. Many of the conversations you have this week whether over coffee, during sessions, or at networking events can spark collaborations and friendships that last well beyond the convention.

As you take part in the week ahead, I encourage you to connect openly, share ideas freely, and maybe even step outside your usual circle. After all, some of the best opportunities come from unexpected conversations.

We truly thank you for being part of the 2026 SWST–KSWST International Convention and making it a great society. Welcome and enjoy your experience!

Matthew SCHWARZKOPF

Co-Chair of the Organizing Committee of 2026 SWST International Convention
President Elect of Society of Wood Science and Technology
Professor of InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

WELCOME MESSAGE

Dear Distinguished Guests, Researchers, Industry Leaders, and Friends of the Global Wood Science Community,

It is my great pleasure and honor to welcome all of you to the 2026 SWST International Convention in Seoul, Korea. On behalf of the organizing committee and our co-hosting institutions, I would like to extend my sincere gratitude to every participant who has traveled from around the world to join us here today.

Over the past century, humanity has experienced extraordinary progress. Since the beginning of industrialization, the world has changed at a breathtaking pace. Technologies that once existed only in movies and imagination have now become part of our everyday lives. Artificial intelligence communicates with us in real time, vehicles can drive themselves, information travels instantly across the globe, and medical advancements continue to extend and improve human life. Our lives have become more convenient, more connected, and in many ways, more remarkable than ever before.

However, while we celebrate what humanity has achieved, we must also reflect on what we are losing.

The rapid growth and industrial expansion that brought prosperity have also created challenges that previous generations never experienced. Today, climate change is no longer a distant scientific prediction. It is a reality affecting all of us. Around the world, we are witnessing unprecedented wildfires, extreme heat waves, floods, droughts, ecosystem destruction, and disruptions to human lives and industries. These are damages that did not exist at this scale in the past.

In this moment of global uncertainty, the role of wood science and sustainable forest-based industries has become more important than ever.

Wood is not merely a material of the past; it is one of the most promising materials for the future. Sustainable forestry, advanced wood materials, carbon storage technologies, bio-based innovation, and circular resource systems will play critical roles in building a more balanced and sustainable world.

This convention is more than an academic gathering. It is a place where science, industry, policy, and global collaboration come together to seek practical solutions for humanity's future. The discussions we share here may help shape not only the future of our industry, but also the future of our planet.

I hope that you will enjoy meaningful discussions, build new friendships and collaborations, and leave inspired by the passion and expertise gathered here.

Once again, thank you for being part of the 2026 SWST International Convention. I wish all of you a productive, inspiring, and memorable experience in Seoul.

Thank you very much.

Sangjun HAN

Co-Chair of the Organizing Committee of 2026 SWST International Convention
Chairman of Korea Wood Panel Association
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2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

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XYLORIX

DAILY PROGRAM

June 7 (Sun)

Time	Program
18:00 - 20:00	**Welcome Reception & Researcher Activity**

June 8 (Mon)

Time	Program
09:00 - 18:00	**Registration**
10:00 - 12:00	**KSWST Annual Meeting** (Closed meeting)
12:00 - 13:00	**Lunch**
13:00 - 13:30	**Opening Ceremony** MC: Hyo Won KWAK & Min-Ji KIM **Opening Address** • **Hwanmyeong YEO** (President, The Korean Society of Wood Science and Technology) **Welcoming Address** • **Yongkwan KIM** (President, National Institute of Forest Science) • **Matthew SCHWARZKOPF** (President, Society of Wood Science and Technology)
13:30 - 15:30	**Keynote Speech** **Sustainable Wood Utilization Policy in Korea after 50 years of Reforestation** • **Eunsik PARK** (Minister, Korea Forest Service) **Wood as Cultural Heritage: Where Nature Meets Civilization** • **Yoon Soo KIM** (Emeritus Professor, Chonnam National University) **Wood: Nature's Smart Material** • **Tâmara FRANÇA** (Associate Professor, Mississippi State University) **The Age of Wood Has Come: Are We Truly Prepared?** • **Sangjun HAN** (Chairman, Korea Wood Panel Association)
15:30 - 15:50	**IUFRO-SWST Special Seminar**
15:50 - 16:00	**Journal Introduction from KSWST & SWST**
16:00 - 18:00	**Poster Session (Student Competition)**
18:00 - 20:00	**Banquet 1**

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

June 9 (Tue)

Time	Program		
07:30 - 16:30	**Registration**		
08:30 - 10:00	**Oral Presentations**		
	Room A	**Room B**	**Room C**
	VI-1. Early Stage Researcher (ESR) 3-Minute Talks	II-2. Designing for Performance and Resilience in Residential Timber Structures	IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts
10:00 - 10:30	**Break**		
10:30 - 12:00	**Oral Presentations**		
	Room A	**Room B**	**Room C**
	I-1. Fundamentals and Frontiers in Wood Physics and Mechanics	II-2. Designing for Performance and Resilience in Residential Timber Structures IV-2. Ecosystem Services and Biodiversity in Wood Value Chains	IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts
12:00 - 13:30	**Lunch**		
13:30 - 15:30	**Oral Presentations**		
	Room A	**Room B**	**Room C**
	I-1. Fundamentals and Frontiers in Wood Physics and Mechanics	III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials	V-1. Cultural Dimensions and Societal Perceptions of Wood Use
15:30 - 16:00	**Break**		
16:00 - 18:00	**Oral Presentations**		
	Room A	**Room B**	**Room C**
	I-3. New Insights into Wood Biology	III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials	V-2. New Approaches to Wood Sector Education and Workforce Development III-2. Digitalization and Smart Processing Technology

June 10 (Wed)

Time	Program		
07:30 - 16:30	**Registration**		
08:30 - 10:00	**Oral Presentations**		
	Room A	**Room B**	**Room C**
	I-4. Traditional Wood Care and Maintenance: Drying, Preservation, Machining, Finishing, etc.	I-1. Fundamentals and Frontiers in Wood Physics and Mechanics	VII-1. IUFRO DIV.5. with 2026 SWST in Korea: Wood Properties and Utilization
10:00 - 10:30	**Break**		
10:30 - 12:00	**Oral Presentations**		
	Room A	**Room B**	**Room C**
	II-1. Advanced Timber Engineering and Hybrid Structural Systems	I-1. Fundamentals and Frontiers in Wood Physics and Mechanics	VII-1. IUFRO DIV.5. with 2026 SWST in Korea: Wood Properties and Utilization
12:00 - 13:30	**Lunch**		
13:30 - 15:30	**Oral Presentations**		
	Room A	**Room B**	**Room C**
	II-1. Advanced Timber Engineering and Hybrid Structural Systems	I-2. Fundamentals in Wood Chemistry and Biorefining	III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials
15:30 - 16:00	**Break**		
16:00 - 18:00	**Oral Presentations**		
	Room A	**Room B**	**Room C**
	IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts	I-2. Fundamentals in Wood Chemistry and Biorefining	III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

June 11 (Thu) - Field Trip

Time	Program
09:20 - 09:40	**Gathering at Coex** • Please note the bus departs at 09:40 am on time
09:40 - 10:30	**Move to Gyeongbok Palace**
10:30 - 13:00	**Tour at Gyeongbok Palace & National Palace Museum of Korea**
13:00 - 13:10	**Move to Restaurant**
13:10 - 14:10	**Lunch**
14:10 - 15:00	**Move to National Institute of Forest Science**
15:00 - 17:00	**Tour at National Institute of Forest Science** • Hongneung Forest* Tour (The first urban arboretum in Korea) • NIFoS Research Showcase Tour
17:00 - 19:00	**Banquet 2** • Location: Outdoor Dinner at Hongneung at NIFoS
19:00 - 20:00	**Move back to Coex**

*The field trip is ONLY available to those who have pre-registered. On-site registration is NOT available.

June 12 (Fri) - Optional Tour A : Seoul & Incheon

Time	Program
08:50 - 09:00	**Gathering at Coex** • Please note the bus departs at 09:00 am on time • Requirement: Passport (If you do not bring, you cannot enter the Imjingak.)
09:00 - 10:20	**Move to Imjingak**
10:20 - 11:50	**Imjingak Tour** • Please prepare your passport for the entrance
11:50 - 12:15	**Move to Restaurant**
12:15 - 13:00	**Lunch**
13:00 - 14:00	**Move to Dongwha Group**
14:00 - 15:00	**Tour at Dongwha Group (Wood Panel Company)**
15:00 - 16:10	**Move to Seoul National University**
16:10 - 17:00	**Tour at Seoul National University (Haedong Advanced Engineering Building)**
17:00 - 18:00	**Move back to Coex**

*The optional tours are available ONLY to pre-registered attendees who have completed their payment. On-site registration is NOT available.

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

June 12 (Fri) - Optional Tour B : Suwon & Yongin

Time	Program
08:50 - 09:00	**Gathering at Coex** • Please note the bus departs at 09:00 am on time.
09:00 - 10:00	**Move to Forest Bioresources Research Division of NIFoS**
10:00 - 11:30	**Tour at Forest Bioresources Research Division of NIFoS**
11:30 - 11:50	**Move to Restaurant**
11:50 - 12:50	**Lunch**
12:50 - 13:30	**Move to Hyundai Livart**
13:30 - 14:30	**Tour at Hyundai Livart**
14:30 - 15:00	**Move to Korean Folk Village**
15:00 - 16:40	**Tour at Korean Folk Village**
16:40 - 18:00	**Move back to Coex**

*The optional tours are available ONLY to pre-registered attendees who have completed their payment. On-site registration is NOT available.

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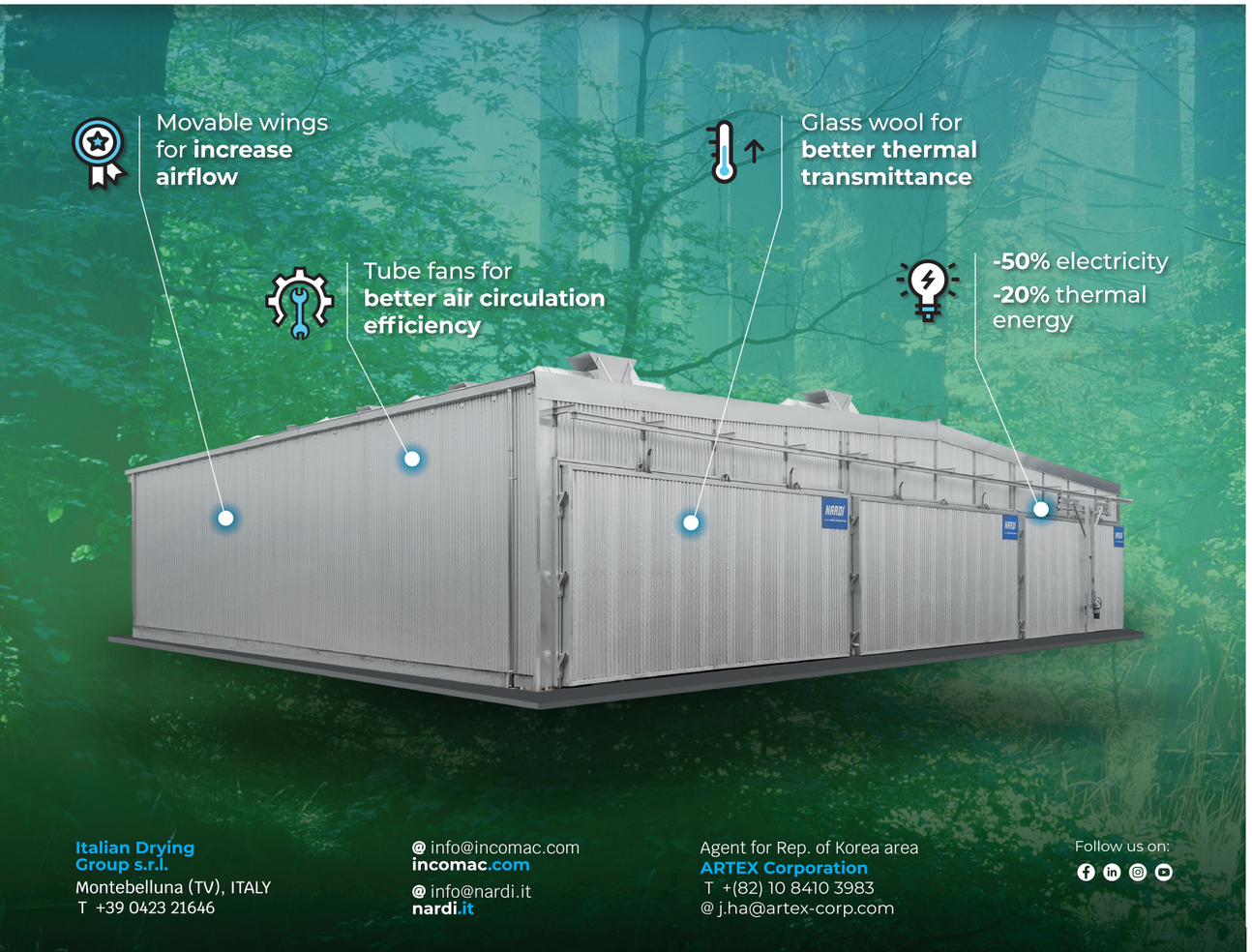

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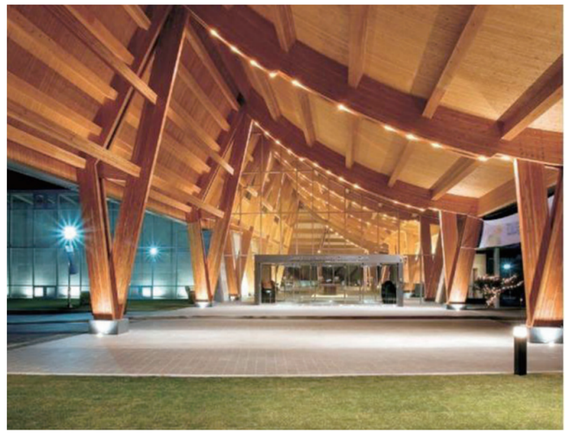
SEOUL NATIONAL UNIVERSITY **CALS**

Program in
Environmental Materials Science

Established in 1970, the Department of Forest Products merged with the Department of Forest Resources into the Department of Forest Sciences in 2004, and was renamed as the Program in Environmental Materials Science. Our program was established in response to growing societal demand for the use of eco-friendly bio-based materials, reinforced by increasing interest in recycling and sustainability.

Environmental materials such as wood, wood-based composites, forest byproducts, pulp, and paper are now recognized as important subjects within environmental materials science. Our mission is to generate and disseminate knowledge in the fields of wood science, paper science and engineering, and forest product utilization through comprehensive academic instruction, laboratory research, and field training.

The program is supported by distinguished faculty and well-equipped modern research facilities.



We are particularly interested in connecting with:
- Prospective students seeking a rewarding academic and professional career
- Graduate students looking for a dynamic and cutting-edge research environment
- Industry professionals with collaborative or research interests

Our graduates are actively employed in industries, academia, and research institutes specializing in wood, paper, and environmental materials. Research funding is sourced from both government and private sectors. The program has been selected for all phases of the Brain Korea 21 (BK21) program, from stage 1 to the current stage 4. We continue to cultivate creative and competent professionals equipped with a pioneering and challenging spirit.

Research Areas

Lab. of Adhesion & Bio-Composites
- Adhesion Science
- Coating Engineering
- Biodegradable Polymers & Biocomposites

Lab. of Green Processing
- Lignocellulosic biosorbent
- Biomass-derived carbon materials
- Biodegradable polymers and its degradation behavior analysis

Lab. of Paper and Cellulose Engineering
- Papermaking & pulping processes and properties of pulp and paper
- Development of eco-friendly cellulose- or paper-based products
- Production and application of cellulose nanomaterials

Lab. of Paper Science
- Colloid and surface chemistry phenomena in paperrmaking process
- Development of functional additives for paper and coating
- Development of specialty papers for electric and electronic applications
- Revitalization and functionalization of recycled fiber resources

Lab. of Timber Engineering
- Engineered Wood Products and Timber Building Components
- Structural and Fire Safety Design for Mid/High-rise Wood Structures
- Building Engineering Physics in Timber Structures

Lab. of Wood Chemistry
- Wood Chemistry
- Biomass based Biochemical and Biorefinery
- Pretreatment and Saccharification of Lignocellulosics for Biofuels

Lab. of Wood Physics
- Wood Physics
- Wood Drying and Machining
- Nondestructive Evaluation on Wood

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FULL AGENDA BY SESSION CATEGORY

* denotes Student.
Italic text denotes non-preregistered presentations.

Poster Presentations (Student Competition)

Date & Time: June 8 (Mon), 16:00~18:00
Location: Lobby of Hall E

I-1. Fundamentals and Frontiers in Wood Physics and Mechanics

1	**Computational Modeling for Predicting Moisture Content Change of Wood During Air Drying** Seong-Hyun LEE* (Department of Agriculture, Forestry and Bioresources, Seoul National University, KR), Bat-Uchral BATJARGAL (Department of Agriculture, Forestry and Bioresources, Seoul National University, MN), Minjee KANG (Department of Agriculture, Forestry and Bioresources, Seoul National University, KR), Hwanmyeong YEO (Department of Agriculture, Forestry and Bioresources, Seoul National University, KR)
2	**Correlation between compression stiffness and strength perpendicular to grain in small clear specimen determined in uniform compression and partial contact (Hertzian) compression** Elijah OLAWUMI (Oregon State University, US), Lech MUSZYNSKI (Oregon State University, US), Michelle JAYAWICKRAMA (Oregon State University, US), Dessie TIBEBU (Oregon State University, US)
3	**Review of the Relationship between Wood Shrinkage Behavior and Anatomical Characteristics** Min Ji KIM* (Chungbuk National University, KR), Min-Soon PARK (Chungbuk National University, KR), Kug Bo SHIM (Chungbuk National University, KR)
4	**The Effects and Mechanism of High Temperature Saturated Steam Heat Treatment on moso bamboo *(Phyllostachys edulis)*** Shumin YANG* (International Centre of Bamboo and Rattan, CN), Ziqiao XUE (International Centre of Bamboo and Rattan, CN), Fushuai SUN (International Centre of Bamboo and Rattan, CN)

I-2. Fundamentals in Wood Chemistry and Biorefining

5	**Multiscale Structural Evolution of Lignin under Long-Term UV Exposure: Mechanism and Stabilization Strategies** Chaeeun KIM* (Seoul National University, KR), Seungoh JUNG (Seoul National University, KR), Jungkyu KIM (Seoul National University, KR), Junsik BANG (Seoul National University, KR), Sangwoo PARK (Seoul National University, KR), Seon-Gyeong KIM (Seoul National University, KR), Dawoon SEO (Seoul National University, KR), Dongho SHIN (Seoul National University, KR), Suhyun OK (Seoul National University, KR), Chaewoo JEONG (Seoul National University, KR), In-Gyu CHOI (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR)
6	***Plant-Derived Biopreservatives for Sustainable Wood Protection: A Biorefinary Based Approach*** *Shivani Bhardwaj*(Dr. Yashwant Singh Parmar University of Horticulture and Forestry), Rajneesh Kumar (Dr. Yashwant Singh Parmar University of Horticulture and Forestry), Yash Pal Sharma (Dr. Yashwant Singh Parmar University of Horticulture and Forestry), Rohit Sharma (Dr. Yashwant Singh Parmar University of Horticulture and Forestry), Bhupesh Kumar (Dr. Yashwant Singh Parmar University of Horticulture and Forestry)*

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

7	**Valorization of Bamboo Tree-Derived Lignin for High-Value Functional Biomaterials: Toward Sustainable Wood-Based Materials** Hyun-Jae SHIN (Chosun University, KR)

I-3. New Insights into Wood Biology

8	**Analysis of anatomical discriminants of major commercial pinaceae species** Wooyoung LEE* (Kangwon National University, KR), Minhyeok HAN (Kangwon National University, KR), Jongho KIM (Kangwon National University, KR)

I-4. Traditional Wood Care and Maintenance: Drying, Preservation, Machining, Finishing, etc.

9	**EVALUATING THE NATURAL DURABILITY PROPERTIES OF Albizia Ferruginea, (Guill. & Perr.) Benth; A LESSER-USED TIMBER SPECIES FROM THE EASTERN PART OF GHANA** SAMUEL AMPADU DWAMENA* (Krobea Asante Technical Institute, GH)
10	**Early Decay Detection in Mass Timber Using Resistance Drilling: Correlation with Mass Loss and Density Changes in CLT and MPP** Opeyemi ODULE* (Oregon State University, US), Gerald PRESLEY (Oregon State University, US), Mariapaola RIGGIO (Oregon State University, US), Laurence SCHIMLECK (Oregon State University, US), Vahid NASIR (Oregon State University, US)
11	**Termite Prevention and Monitoring for the Care and Maintenance of a Traditional Wooden Architecture: The Daeungjeon Hall of Ssanggyesa Temple, Nonsan (National Heritage)** Ju-Eun BAEK* (Korea National University of Heritage, KR), Hae-Ree PARK (Jinsung Cultural Heritage Conservation, KR), Tae-Gyun YEOM (Jinsung Cultural Heritage Conservation, KR), Jung-Hae PARK (Jinsung Cultural Heritage Conservation, KR), Soo-Chul KIM (Korea National University of Heritage, KR)
12	**Effect of Surface Roughness on Moisture Uptake in Coated Exterior Wood Cladding: An X-ray Computed Tomography (CT) Study** Foteini LAGIOU* (NTNU Norwegian University of Science and Technology, NO), Johannes HUBER (Wood KPlus Austria, AT), Lars HANSSON (NTNU Norwegian University of Science and Technology, NO), Alemayehu GEBREMEDHIN (NTNU Norwegian University of Science and Technology, NO), Dick SANDBERG (NTNU Norwegian University of Science and Technology, NO)
13	**Wooden Dowel vs. Epoxy Resin: Comparative Study on Timber Heritage Surface Repair Techniques** Ga-Won LEE* (Chungbuk National University, KR), Kug-Bo SHIM (Chungbuk National University, KR), Hyeong Jun HAN (Chungbuk National University, KR), Gyu-Seong HAN (Chungbuk National University, KR)

II-1. Advanced Timber Engineering and Hybrid Structural Systems

14 **Structural Behaviour of Screw-Laminated Truss Members Assembled from Short-Length Reclaimed Timber**
Donat AGAJ* (Norwegian University of Science and Technology, NO), Dick SANDBERG (Norwegian University of Science and Technology, NO)

15 **Cyclic Performance of a Full-Scale Glued-in Rod Moment Connection**
Min-Jeong KIM* (Seoul National University, KR), Ryul GWANG (Seoul National University, KR), Kyung-Sun AHN (Seoul National University, KR), Hae-Gyu LEE (Seoul National University, KR), Jung-Kwon OH (Seoul National University, KR)

16 **Failure Mode Analysis of Pre-Cambered Glulam Beams Under Dead-Load-Compensating Curvature**
Gwang-Ryul LEE* (Seoul National University, KR), Kyung-Sun AHN (Seoul National University, KR), Min-Jeong KIM (Seoul National University, KR), HaeGyu LEE (Seoul National University, KR), Jung-Kwon OH (Seoul National University, KR)

17 **Anatomy Informed Intelligent 2D Mapping for Evaluating Localized Properties of Large Diameter Timber Members**
Ho-Jeong CHO* (Chonnam National University, KR), Je-Gwan JOUNG (Chonnam National University, KR), Chang-Jin LEE (Jeonbuk National University, KR), Sung-Jun PANG (Chonnam National University, KR)

III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

18 **Construction of Bio-Based Adsorbent Networks: Crosslinking Aminated Lignin with Dialdehyde Xylan for Efficient Pd Capture**
Dawoon SEO* (Seoul National University, KR), Junsik BANG (Seoul National University, KR), Sangwoo PARK (Seoul National University, KR), Jungkyu KIM (Seoul National University, KR), Seunoh JUNG (Seoul National University, KR), Seon-Gyeong KIM (Seoul National University, KR), Chaeeun KIM (Seoul National University, KR), Dongho SHIN (Seoul National University, KR), Suhyun OK (Seoul National University, KR), Chaewoo JEONG (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR)

19 **From Plant Proteins to Durable Wood Adhesives using thermo-mechanical treatments**
Malik RITIKA (BOKU University, AT), Hendrikus W.G van HERWIJNEN (Kompetenzzentrum Holz GmbH (Wood K plus), AT), Johannes KONNERTH (BOKU University, AT), Anita TRAN (BOKU University, AT)

20 **Fabrication of HKUST-1 Nanozyme Supported on Sulfated Cellulose Nanofibril and its Laccase-like Activity**
Dong-Suk JEON (Kangwon National University, KR), Ju-Won JIN (Kangwon National University, KR), Seung-Woo CHO (Kangwon National University, KR), Song-Yi HAN (Kangwon National University, KR), Rajkumar BANDI (Kangwon National University, IN), Ramakrishna DADIGALA (Kangwon National University, IN), Gu-Joong KWON (Kangwon National University, KR), Seung-Hwan LEE (Kangwon National University, KR)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

21 **Chemical Engineering of Oxypropylated Lignin toward Flame-Retardant Rigid Polyurethane Foams**
Dongho SHIN* (Seoul National University, KR), Sangwoo PARK (Seoul National University, KR), Junsik BANG (Seoul National University, KR), Jungkyu KIM (Seoul National University, KR), Seungoh JUNG (Seoul National University, KR), Seon-Gyeong KIM (Seoul National University, KR), Dawoon SEO (Seoul National University, KR), Chaeeun KIM (Seoul National University, KR), Suhyun OK (Seoul National University, KR), Chaewoo JEONG (Seoul National University, KR), Hwanmyeong YEO (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR)

22 **Rapid Hydrothermal Engineering of Alkali Lignin toward Fluorescent Carbon Quantum Dots: Response Surface Optimization**
Suhyun OK* (Seoul National University, KR), Sangwoo PARK (Seoul National University, KR), Junsik BANG (Seoul National University, KR), Jungkyu KIM (Seoul National University, KR), Seungoh JUNG (Seoul National University, KR), Seon-Gyeong KIM (Seoul National University, KR), Chaeeun KIM (Seoul National University, KR), Dawoon SEO (Seoul National University, KR), Dongho SHIN (Seoul National University, KR), Chaewoo JEONG (Seoul National University, KR), In-Gyu CHOI (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR)

23 **Wood-Derived Quaternized Lignin Nanoparticles for Adsorptive Removal of PFAS in Aqueous Systems**
Chaewoo JEONG* (Seoul National University, KR), Sangwoo PARK (Seoul National University, KR), Junsik BANG (Seoul National University, KR), Jungkyu KIM (Seoul National University, KR), Seungoh JUNG (Seoul National University, KR), Seon-Gyeong KIM (Seoul National University, KR), Chaeeun KIM (Seoul National University, KR), Dawoon SEO (Seoul National University, KR), Dongho SHIN (Seoul National University, KR), Su Hyun OK (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR)

24 **Artificial Bark-Inspired Flame-Retardant Wood via Polyelectrolyte Complex Formation of Phosphorylated Nanocellulose**
Heesu YOO* (Kyungpook National University, KR), Bonwook KOO (Kyungpook National University, KR)

25 **Enhanced Flame Retardancy and Antifungal Durability of Wood via Surface Delignification-Assisted Bio-based Modification**
Yejin KIM* (Kyungpook National University, KR), Bonwook KOO (Kyungpook National University, KR)

26 ***Development of lignocellulosic lightweight foams for cavity insulation in beverage coolers using cellulose nanofibrils (CNFs) as a binder***
Quazeem TIAMIYU (School of Forest Resources, University of Maine, Orono, ME, US), Mehdi TAJVIDI (School of Forest Resources, University of Maine, Orono, ME, US)*

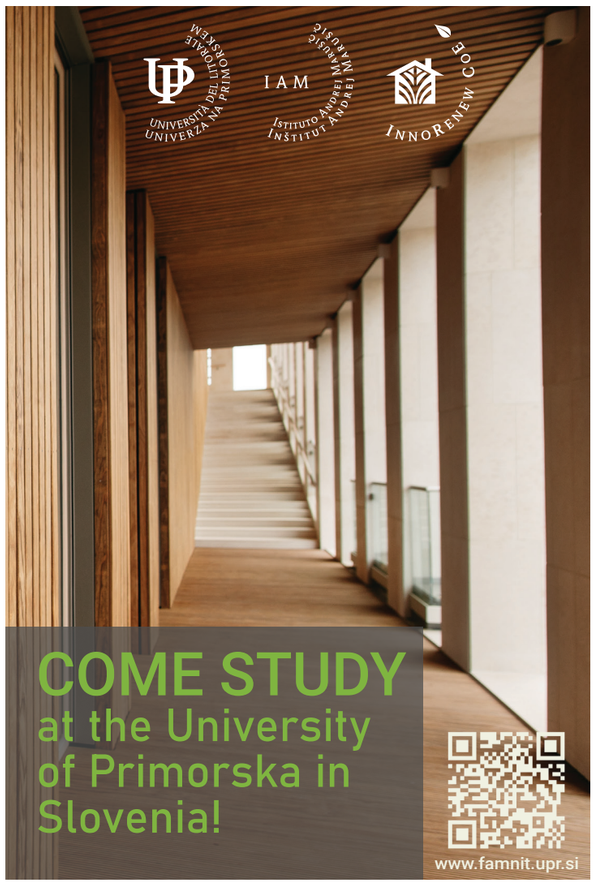
27 ***Phenolated Lignin for Biobased Functional Nanomaterials: Tailoring via Nanoprecipitation and Solvent Exchange***
Azma FAKHAR (Seoul National University, KR), Joon Weon CHOI (Seoul National University, KR)

IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts

28	***Operationalizing Lean Construction for Construction-Phase Decarbonization in Mass Timber Buildings: A Process-Based Life Cycle Assessment Framework*** *Mahboobeh HEMMATI* (University of Arkansas, US), Tahar MESSADI (Universty of Arkansas, US), Moein HEMMATI (University of Arkansas, US), Saghar MOHSENIAN (University of Arkansas, US)*
29	***A Comparative LCA of Mass Timber and Steel Structures*** *Mahboobeh HEMMATI* (University of Arkansas, US), Tahar MESSADI (University of Arkansas, US), Hongmei GU (Forest Products Laboratory, USDA Forest Service, US), Moein HEMMATI (University of Arkansas, US), Jacob SEDDELMEYER (University of Arkansas, US)*

V-2. New Approaches to Wood Sector Education and Workforce Development

30	**Quantitative Analysis of Tree Structural Stability: Sensitivity to Cavity Location, Size, and Wood Material Properties** Je-Gwan JOUNG* (Chonnam National University, KR), Ho-Jeong CHO (Chonnam National University, KR), Ji-Won SON (Korea Heritage Service, KR), Sung-Jung PANG (Chonnam National University, KR)



BSc Wood Innovation for Sustainability

Ready to shape the future of wood? This bachelor's program blends modern know-how, digital skills, and sustainable thinking to prepare you for the evolving wood industry. You'll learn through hands-on projects, real-world case studies, and collaborative teamwork because the best solutions don't happen in alone. With a strong focus on innovation and interdisciplinarity, you'll tackle real industry challenges from day one. Plus, an international mobility window gives you the chance to gain global perspective and direct experience with industry partners abroad.

General information:
Programme coordinator:
Prof. Andreja Kutnar
andreja.kutnar@upr.si

Duration: 3 years
Language of study: English and Slovenian
Location: Koper, Izola

MSc Sustainable Built Environments

Designing buildings that are good for people and the planet? That's the goal here. This master's program brings together engineering, wood science, and architecture to give you a holistic skill set for the built environment. You'll learn how to design, build, and renovate structures that prioritize human health while respecting environmental and social responsibility. If you're passionate about creating smarter, healthier places to live and work, this program gives you the tools to do exactly that.

General information:
Programme coordinator:
Assoc. Prof. Matthew Schwarzkopf
matthew.schwarzkopf@iam.upr.si

Duration: 2 years
Language of study: English and Slovenian
Location: Koper, Izola

PhD Renewable Materials for Healthy Built Environments

For those ready to push boundaries and lead innovation, this doctoral program dives deep into the future of renewable materials and healthy built environments. You'll work at the cutting edge of an emerging field, exploring breakthrough ideas in a highly interdisciplinary and international research setting. Along the way, you'll develop advanced theoretical insight, broad technical expertise, and the independence to generate new knowledge. Graduates leave not just with a PhD but as recognized experts ready to shape the future of sustainable construction.

General information:
Programme coordinator:
Prof. Andreja Kutnar
andreja.kutnar@upr.si

Duration: 3 years
Language of study: English and Slovenian
Location: Koper, Izola

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

* denotes Student.
Italic text denotes non-preregistered presentations.

June 8 (Mon) – Poster Presentations

Date & Time: June 8 (Mon), 16:00~18:00
Location: Lobby of Hall E

I-1. Fundamentals and Frontiers in Wood Physics and Mechanics

1	**Pure and mixed stands wood density and productivity in Lithuania** Benas SILINSKAS (Agriculture Academy, Faculty of Forest Sciences and Ecology, Vytautas Magnus University, LT), Edgaras LINKEVICIUS (Agriculture Academy, Faculty of Forest Sciences and Ecology, Vytautas Magnus University, LT), Lina BENIUSIENE (Institute of Forestry, Lithuanian Research Centre for Agriculture and Forestry, LT)
2	**Investigation of Structural Performance and Lignin Welding Stability of Wooden Nails in Timber-Concrete Composite systems** Kyung-Sun AHN* (Seoul National University, KR), Jun Seo PARK (Seoul National University, KR), Min-Jeong KIM (Seoul National University, KR), Haegyu LEE (Seoul National University, KR), Gwang-Ryul LEE (Seoul National University, KR), Jung-Kwon OH (Seoul National University, KR)
3	**Elm Bark Powder-Modified Soy Protein Adhesive with Enhanced Strength and Mold Resistance for Engineered Wood Panels** Wenbin YUAN (Nanjing Forestry University, CN), An MENG (Nanjing Forestry University, CN), Xiaona LI (Nanjing Forestry University, Yantai University, CN), Li JIANZHANG (Nanjing Forestry University, Beijing Forestry University, CN), Changlei XIA (Nanjing Forestry University, Guangxi University, CN)
4	***Improving the weather resistance of wood by impregnation with active aminated low molecular weight alkali lignin*** *Qiu ZHE (Key Laboratory of Bio-based Material Science and Technology (Ministry of Education), College of Material Science and Engineering, Northeast Forestry University, CN), Yu YANG (Key Laboratory of Bio-based Material Science and Technology (Ministry of Education), College of Material Science and Engineering, Northeast Forestry University, CN), He ZENGCHENG (Key Laboratory of Bio-based Material Science and Technology (Ministry of Education), College of Material Science and Engineering, Northeast Forestry University, CN), Zhang TIANPENG (Key Laboratory of Bio-based Material Science and Technology (Ministry of Education), College of Material Science and Engineering, Northeast Forestry University, CN), Xiao ZEFANG (Key Laboratory of Bio-based Material Science and Technology (Ministry of Education), College of Material Science and Engineering, Northeast Forestry University, CN), Xie YANJUN (Key Laboratory of Bio-based Material Science and Technology (Ministry of Education), College of Material Science and Engineering, Northeast Forestry University, CN)*
5	***Design of wooden multistable metamaterials based on fractal theory and their functionalization*** *Yushan YANG (Southwest Forestry University, CN), Jian QIU (Southwest Forestry University, CN)*

I-2. Fundamentals in Wood Chemistry and Biorefining

6	**Response Surface Optimisation of Peroxide-Assisted Torrefaction for Solid Biofuel Upgrading** Sunyong PARK (National Institute of Forest Science, KR), Jiwook YANG (National Institute of Forest Science, KR), Sungyeol KIM (National Institute of Forest Science, KR), Jaejung LEE (National Institute of Forest Science, KR)
7	**Evaluation of Cellulose Nanofiber Properties According to Manufacturing methods** Kyojung HWANG (National institute of Forest Science, KR), Jaejung LEE (National Institute of Forest Science, KR), Jimin LEE (National Institute of Forest Science, KR), Sang-Jin CHUN (National Institute of Forest Science, KR)
8	**Effect of sulfonation condition on the physicochemical characteristics of biochar-based catalyst** Jonghwa KIM (Korea Research Institute of Chemical Technology, KR), Jaeik LEE (Korea Research Institute of Chemical Technology, KR), Chan-Duck JUNG (Korea Research Institute of Chemical Technology, KR), Hae-min JO (Korea Research Institute of Chemical Technology, KR), June-Ho CHOI (Korea Research Institute of Chemical Technology, KR), Hoyong KIM (Korea Research Institute of Chemical Technology, KR)
9	**Continuous Bioelectrochemical CO2 Conversion using Forest-Derived Formate Dehydrogenase and Macroporous Carbon Electrodes** Sungyeol KIM (National Institute of Forest Science, KR), Jiwook YANG (National Institute of Forest Science, KR), Sunyong PARK (National Institute of Forest Science, KR), Namhee Lee (National Institute of Forest Science, KR), Sun-Hwa RYU (National Institute of Forest Science, KR)
10	**Enhancement and Comparison of Enzymatic Hydrolysis Efficiency of Hydrated-Milled Miscanthus via Binary and Ternary Acetic Acid-Based Deep Eutectic Solvent Pretreatment** Jaeik LEE* (Korea Research Institute of Chemical Technology, Kyungpook National University, KR), Jonghwa KIM (Korea Research Institute of Chemical Technology, KR), Chan-Duck JUNG (Korea Research Institute of Chemical Technology, KR), Hae-Min JO (Korea Research Institute of Chemical Technology, KR), June-Ho CHOI (Korea Research Institute of Chemical Technology, KR), Bonwook KOO (Kyungpook National University, KR), Hoyong KIM (Korea Research Institute of Chemical Technology, KR)
11	**Recombinant Production of Plant-derived Expansin for Biological Pretreatment of Cellulose** Yongtae YU (Kangwon National University, KR), Hyunjun KO (Kangwon National University, KR)
12	**Hydrogen Peroxide-Citric Acid (HPCA) Oxidative System for Delignification of Wood Veneer toward Translucent Wood** Ji-Yeon SIM* (Kangwon National University, KR), Jeongsu BYUN (Kangwon National University, KR), Seungsu PARK (Kangwon National University, KR), Byeongho KIM (Kangwon National University, KR), Se-Yeong PARK (Kangwon National University, KR)
13	**Development of Sustainable Superabsorbent Materials from Cellulose-Based Biomass Incorporating Organic and Inorganic Particles** Sungoo KIM (National Institute of Forest Science, KR), Sang-Jin CHUN (National Institute of Forest Science, KR), Jimin LEE (National Institute of Forest Science, KR), Dokyung LEE (National Institute of Forest Science, KR), Yujin HWANG (National Institute of Forest Science, KR), Youngsu KIM (National Institute of Forest Science, KR)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

14	**Comparative Analysis of Anionic Functionalization of Cellulose: Substitution Mechanisms, Structural Characteristics, and Charge Expression** Jimin LEE (National Institute of Forest Science, KR), Sang-Jin CHUN (National Institute of Forest Science, KR), Sungoo KIM (National Institute of Forest Science, KR), Dokyung LEE (National Institute of Forest Science, KR), Yujin HWANG (National Institute of Forest Science, KR), Youngsu KIM (National Institute of Forest Science, KR)
15	**Improving Lignin Purity in Supercritical Water-Treatment Residues via Selective Removal of Residual Cellulose Using a ZnCl2 Aqueous Non-Derivatizing Process** Tae-in BAN (Forest Industrial Materials Division, National Institute of Forest Science, KR), Soo-Kyeong JANG (Forest Industrial Materials Division, National Institute of Forest Science, KR)
16	**Anti-inflammatory Effects of Alnus hirsuta Extracts on an In Vitro Periodontal Inflammation Model Using Human Gingival Fibroblast Cells** Hyoen Du JANG (Department of Forest Biomaterials Engineering, Kangwon National University, KR), Da Hyeon AN (Department of Forest Biomaterials Engineering, Kangwon National University, KR), Ye Eun KWON (Dr.Oregonin Inc.; Department of AI Biological Parts Materials Engineering, Nambu University, KR), Tae Hee KIM (Dr.Oregonin Inc.; Department of AI Biological Parts Materials Engineering, Nambu University, KR), Hyeon Ji KIM (Department of Pharmacology, School of Dentistry, Kyungpook National University, KR), Do-Yeon KIM (Department of Pharmacology, School of Dentistry, Kyungpook National University, KR), Sun Eun CHOI (Department of Forest Biomaterials Engineering, Kangwon National University; Dr.Oregonin inc, KR)
17	**In Vitro Effects of Catechin Glycoside-Containing Extract from Ulmus macrocarpa on Periodontal Disease** Da Hyeon AN (Kangwon National University, KR), Hyeon Du JANG (Kangwon National University, KR), Tae Hee KIM (Dr. Oregonin Inc.; Nambu University, KR), Ye Eun KWON (Dr.Oregonin Inc.; Nambu University, KR), Hyeon Ji KIM (Kyungpook National University, KR), Do-Yeon KIM (Kyungpook National University, KR), Sun Eun CHOI (Kangwon National University; Dr.Oregonin Inc., KR)
18	**An Eco-Friendly Alternative for the Wood Industry: A Formaldehyde-Free Pea Protein Bio-Adhesive with High Mechanical Strength** Jose Antonio SILVA GUZMAN (Departamento de Madera, Celulosa y Papel, Centro Universitario de Ciencias Exactas e Ingenierias, Universidad de Guadalajara. Guadalajara, Jalisco. Mexico., MX), Jesus Gerardo HERNANDEZ FIGUEROA (Departamento de Madera, Celulosa y Papel, Centro Universitario de Ciencias Exactas e Ingenierias, Universidad de Guadalajara. Guadalajara, Jalisco. Mexico., MX), Jose ANZALDO HERNANDEZ (Departamento de Madera, Celulosa y Papel, Centro Universitario de Ciencias Exactas e Ingenierias, Universidad de Guadalajara. Guadalajara, Jalisco. Mexico., MX), Salvador GARCIA ENRIQUEZ (Departamento de Madera, Celulosa y Papel, Centro Universitario de Ciencias Exactas e Ingenierias, Universidad de Guadalajara. Guadalajara, Jalisco. Mexico., MX), Berenice CLIFTON GARCIA (Departamento de Madera, Celulosa y Papel, Centro Universitario de Ciencias Exactas e Ingenierias, Universidad de Guadalajara. Guadalajara, Jalisco. Mexico., MX), Jessica BADILLO CAMACHO (Departamento de Madera, Celulosa y Papel, Centro Universitario de Ciencias Exactas e Ingenierias, Universidad de Guadalajara. Guadalajara, Jalisco. Mexico., MX)
19	**Explainable Machine Learning Modeling for Bioactive Compound Recovery from Supercritical CO_2 Extraction Residues of *Fraxinus mandshurica*** Hyeon Cheol KIM (Gyeongsang National University, KR), Si Young HA (Gyeongsang National University, KR), Jae-Kyung YANG (Gyeongsang National University, KR)

20	**Tree-Based Machine Learning for Predicting Bioactive Compound Recovery from Ultrasonic-Assisted Extraction of Fraxinus mandshurica Leaves** Hyeon Cheol KIM (Gyeongsang National University, KR), Si Young HA (Gyeongsang National University, KR), Jae-Kyung YANG (Gyeongsang National University, KR)
21	**Integrated co-production biorefinery of *Phyllostachys pubescens* via NaOHHPAC pretreatment for biofuels, platform chemicals, and value-added products** Younho SONG (Bio-energy Research Center, Chonnam National University, KR), Seryung KIM (Bio-energy Research Center, Chonnam National University, KR), Hyeun-jong BAE (Chonnam National University, KR)

I-3. New Insights into Wood Biology

22	**BioWdesign: Design-Driven Research on Biomimetic Mechanisms of Wood and Plants and Their Translation into an Innovative Wellbeing Office Furniture Collection** Zuzana TONCIKOVA (Technical University in Zvolen, SK)
23	**Effects of Basal Shoot Management on Growth characteristics and Bark Yield of *Broussonetia kazinoki Sieb. (Daknamu)*** Sora LEE (National Institute of Forest Science, KR), Eon-ju JIN (National Institute of Forest Science, KR), Bowook MOON (National Institute of Forest Science, KR), Seokju KIM (National Institute of Forest Science, KR), Soonduk KWON (National Institute of Forest Science, KR), Hyung Won LEE (National Institute of Forest Science, KR)
24	**Strain-dependent degradation and basidiocarp formation of *Inonotus obliquus* on sapwood and heartwood of *Alnus incana* and *Betula pendula*** Ville-Oskari KOMU* (University of Eastern Finland, FI), Barbero Lopez, AITOR (University of Eastern FI), Marta CORTINA-ESCRIBANO (Natural Resources Institute Finland, FI), Sari KONTUNEN-SOPPELA (University of Eastern Finland, FI), Yutaka TAMAI (University of Eastern Finland; Natural Resources Institute Finland, FI), Henri VANHANEN (Natural Resources Institute Finland, FI), Antti HAAPALA (University of Eastern Finland, FI), Erkki VERKASALO (Natural Resources Institute Finland, FI)
25	**Contents of Sugars and Inorgaric elements of the sap from Acer *pictum* in Inje in 2025** Bowook MOON (National Institute of Forest Science, KR), Sora LEE (National Institute of Forest Science, KR), Hyung Won LEE (National Institute of Forest Science, KR), Dongsoo KIM (National Institute of Forest Science, KR), Seokju KIM (National Institute of Forest Science, KR)
26	**Biodegradation Potential of Polyethylene Terephthalate by Wood-Decaying Microbes** Sungmin LEE (Kangwon National Universtiy, KR), Hyunjun KO (Kangwon National University, KR)
27	**Growth Trait and Correlation Analysis of 30 Regional individuals of *Broussonetia kazinoki Sieb.* (Daknamu) over Three years** Sora LEE (National Institute of Forest Science, KR), Bowook MOON (National Institute of Forest Science, KR), Seokju KIM (National Institute of Forest Science, KR), Hyung Won LEE (National Institute of Forest Science, KR)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

I-4. Traditional Wood Care and Maintenance: Drying, Preservation, Machining, Finishing, etc.

28	**Preparation of wood bio-composites with low formaldehyde emission by application of modified natural polymers** Jan SEDLIACIK (Technical University in Zvolen, SK), Igor NOVAK (Polymer Institute, Slovak Academy of Sciences, SK), Angela KLEINOVA (Polymer Institute, Slovak Academy of Sciences, Slovakia, SK), Peter JURKOVIC (VIPO, a.s., SK), Jan MATYASOVSKY (VIPO, a.s., SK)
29	**How does RFD plasma treatment affect the chemical properties of steam-modified beech wood?** Peter JURKOVIC (VIPO, a.s., SK), Igor NOVAK (Polymer Institute, Slovak Academy of Sciences, SK), Matej MICUSIK (Polymer Institute, Slovak Academy of Sciences, SK), Jan MATYASOVSKY (VIPO, a.s., SK), Peter DUCHOVIC (VIPO, a.s., SK), Jan SEDLIACIK (Technical University in Zvolen, SK)
30	**Sustainable Particleboard Production Using Waste Sugar Beet Pulp: A Performance Evaluation** Volodymyr HAMANCHUK (Ukrainian National Forestry University in Lviv, UA), Jozef RAHEL (Mendel University in Brno, CZ), Tomas PIPISKA (Mendel University in Brno, CZ), Pavlo BEKHTA (Ukrainian National Forestry University in Lviv, UA), Jan SEDLIACIK (Technical University in Zvolen, SK)
31	**Performance of Particleboards with Reduced MUF Content via Lignosulfonate Substitution** Iryna LYTVYN (Ukrainian National Forestry University in Lviv, UA), Nataliya BEKHTA (Ukrainian National Forestry University in Lviv, UA), Ruslan KOZAK (Ukrainian National Forestry University in Lviv, UA), Iryna KUSNIAK (Ukrainian National Forestry University in Lviv, UA), Jan SEDLIACIK (Technical University in Zvolen, SK), Pavlo BEKHTA (Ukrainian National Forestry University in Lviv, UA)
32	**Evaluation of Moisture and Thermal Diffusion Characteristics of Korean Wood Species for Developing Property-Based Drying Groups** Yonggun PARK (National Institute of Forest Science, KR), Jong-Ik PARK (Daegu University & National Institute of Forest Science, KR), Min LEE (National Institute of Forest Science, KR), Wonho JIN (National Institute of Forest Science, KR), Soo-Hyeok LEE (National Institute of Forest Science, KR)
33	**Kinetics of colour development in European beech during steaming** Anze ZAJC (University of Ljubljana, Biotechnical faculty, SI), Jure ZIGON (University of Ljubljana, Biotechnical faculty, SI), Ales STRAZE (University of Ljubljana, Biotechnical faculty, SI)
34	**Low Steaming Treatment: Impacts on Wood Structure and Properties** Andrea R PROTO (Mediterranean University of Reggio Calabria, IT), Luigi TODARO (University of Basilicata, IT), Antonio ZUMBO (Mediterranean University of Reggio Calabria, IT), Angelo MAMMOLITI (Mediterranean University of Reggio Calabria, IT)

II-1. Advanced Timber Engineering and Hybrid Structural Systems

35 **Fully Recyclable Wall Systems: Material Development and Performance Characterization**
Ana PRSLJA* (BOKU University, AT), Alaudini NURALI (BOKU University, AT), Falk LIEBNER (BOKU University, AT), Rupert WIMMER (Mendel University Brno, CZ), Bernhard REINHOLZ (BOKU University, AT), Sara REICHENBACH (BOKU University, AT), Benjamin KROMOSER (BOKU University, AT)

36 **Moisture control considerations in hybrid CLT walls for multi-story residential buildings**
Yujin KANG (Dankook University, KR), Jihee NAM (Yonsei University, KR), Ji Hun PARK (Yonsei University, KR), Sumin KIM (Yonsei University, KR)

37 **Manufacturing and Performance Evaluation of Novel CLT Structures**
Levente DENES (West Virginia University, US)

II-2. Designing for Performance and Resilience in Residential Timber Structures

38 **Experimental Validation of an Enhanced Fire-Resistance Design Approach for Korean Larch Glulam**
Sang-Hyun YOU (National Institute of Forest Science, KR), In-Hwan LEE (National Institute of Forest Science, KR), Chul-Ki KIM (National Institute of Forest Science, KR), Sang-Jun LEE (National Institute of Forest Science, KR)

39 **A Study on the Improvement of Moisture Absorption and Desorption Performance of Japanese Cedar for Architectural Finishing Materials**
Taejin LEE (Jeonbuk National University, KR), Heejun PARK (Jeonbuk National University, KR)

III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

40 **Effect of Extraction Solvents on the Characteristics of Okara-derived Lipids and Their Potential for Functional Biocomposites**
Hae-min JO (Korea Research Institute of Chemical Technology, KR), Jaeik LEE (Korea Research Institute of Chemical Technology, KR), Chan-Duck JUNG (Korea Research Institute of Chemical Technology, KR), Jonghwa KIM (Korea Research Institute of Chemical Technology, KR), June-Ho CHOI (Korea Research Institute of Chemical Technology, KR), Hoyong KIM (Korea Research Institute of Chemical Technology, KR)

41 **Carbonization Characteristics of Residues from Supercritical Water Hydrolysis of Biomass**
Jiwook YANG (National Institute of Forest Science, KR), Sunyong PARK (National Institute of Forest Science, KR), Sungyeol KIM (National Institute of Forest Science, KR), Ji-eun An (National Institute of Forest Science), Sun-Hwa RYU (National Institute of Forest Science, KR)

42 **Creation of Wood-based Hierarchical Superstructures via In Situ Growth of ZIF-8 for Enhancing Mechanical strength and Electromagnetic Shielding Performance**
Haoran YE (Nanjing Forestry University, CN), Changlei XIA (Nanjing Forestry University, CN)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

43 **Silylated Cellulose Nanofiber-based Thermal Stable Green Insulation Materials**
Jaemin JO (Kyungpook National University, KR), Bonwook KOO (Kyungpook National University, KR)

44 **Reengineering Paper Tubes for the Circular Economy: How Cut Geometry and Cellulose Micro/Nanofibrils Boost Structural Performance**
Gustavo TONOLI (Universidade Federal de Lavras, BR), Mariana NASCIMENTO (Universidade Federal de Lavras, BR), Thiago RAMOS (Universidade Federal de Lavras, BR), Leticia Catta PRETA(RD&I, BarraPapeis Packaging Industry, El i Mendes, MG, BR), Raquel FREITAS (RD&I, BarraPapeis Packaging Industry, El i Mendes, MG, BR), Anand SANADI (University of Copenhagen, DK)

45 **Molded Pulp Packaging Made from Rasau Fibers: Effect of Different Part of Plant as Source of Fibers**
Noviyanti NUGRAHENI (Sebangau National Park, ID), Naura HAZHIYAH S (IPB University, ID), Muhammad THORIQ S (IPB University, ID), Septian AHMAD KH (IPB University, ID), Eko PRASETYO (Borneo Orangutan Survival Foundation, ID), Dede HERMAWAN (IPB University, ID), Lukmanul Hakim ZAINI (IPB University, ID)

46 **Decay resistance of mycelium-bound biocomposites for exterior uses**
Marta CORTINA-ESCRIBANO (Natural Resources Institute Finland, FI), Aitor BARBERO-LOPEZ (Department of Chemistry and Sustainable Technology, University of Eastern Finland, FI), Henri VANHANEN (Natural Resources Institute Finland, Joensuu, FI), Veikko MOTTONEN (Natural Resources Institute Finland, Joensuu, FI), Jenni TIENAHO (Natural Resources Institute Finland, Viikki, FI), Antti HAAPALA (Department of Chemistry and Sustainable Technology, University of Eastern Finland, FI), Erkki VERKASALO (Natural Resources Institute Finland, Joensuu, FI)

47 **Mechanical performance of mycelium-based composites for insulation panel products**
Henri VANHANEN (Natural Resources Institute Finland, LUKE, FI), Miriam KELLOCK (VTT Technical Research Centre of Finland, FI), Jari SIRVIO (VTT Technical Research Centre of Finland, FI), Elisa SPONLA (VTT Technical Research Centre of Finland, FI), Veikko MOTTONEN (Natural Resources Institute Finland, LUKE, FI), Marta CORTINA-ESCRIBANO (Natural Resources Institute Finland, LUKE, FI)

III-2. Digitalization and Smart Processing Technology

48 **Particleboard Property Prediction using X-ray Computed Tomography Images and Machine Learning Techniques**
Shuoye CHEN (Kyoto University / Akita Prefectural University, JP), Hidefumi YAMAUCHI (Akita Prefectural University, JP), Kenji UMEMURA (Kyoto University, JP)

49 **Blockchain for Wood Supply Chain Traceability Ensuring Transparency Security and Sustainability**
Andrea R PROTO (Mediterranean University of Reggio Calabria, IT), Antonio ZUMBO (Mediterranean University of Reggio Calabria, IT), Salvatore F. PAPANDREA (Mediterranean University of Reggio Calabria, IT), Giuseppe ZIMBALATTI (Mediterranean University of Reggio Calabria, IT)

IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts

50 **Soil organic carbon change can reduce the climate mitigation potential of biofuel produced from forest residues**
Kai LAN (North Carolina State University, US), Bingquan ZHANG (Yale University, US), Tessa LEE (Yale University, US), Yuan YAO (Yale University, US)

51 **Enhanced Enzymatic Hydrolysis and Valorization Waste Paper via Mechanical Refining Pretreatment**
Hansol PARK (Chonnam National University, KR), Huynh Thi My Han (Chonnam National University, KR), Eun Jin CHO (Chonnam National University, KR), Hyeun-Jong BAE (Chonnam National University, KR)

52 **Investigating Market Entry Barriers for Family Firms in the Wood-Processing Industry: Empirical Evidence from the Visegrad Group (V4)**
Denis PINKA (Technical University in Zvolen, SK), Mariana SEDLIACIKOVA (Technical University in Zvolen, SK)

53 **Effective Utilization of Forest-Derived Underutilized Resources: Molding and Application of Crushed Dwarf Bamboo Culms**
Rikuho ONO (Hokkaido University, JP), Keiichi KODA (Hokkaido University, JP), Makoto KOBAYASHI (Hokkaido University, JP), Taichi MOTODA (Hokkaido University, JP), Yutaka TAMAI (Hokkaido University, JP), Henri VANHANEN (Luke, FI)

54 **Planting a line on the map: The Elements of Logistics in the Global Mass Timber Panels Industry**
Lech MUSZYNSKI (Oregon State University, US), Matthew Sparr (Oregon State University, US)

55 **Effects of Product Characteristics on Carbon Displacement of Wood Products**
Sae-Min YOON (National Institute of Forest Science, KR), Min-Ji KIM (National Institute of Forest Science, KR), Yong-Seok CHOI (National Institute of Forest Science, KR), SooYeon KWON (National Institute of Forest Science, KR), Sejong KIM (National Institute of Forest Science, KR), Ki Dong KIM (National Institute of Forest Science KR), Myungkil KIM (National Institute of Forest Science, KR)

56 **Development and Validation of an Evaluation Model for Korean Wood Flooring to Reduce Elderly Fatigue and Enhance Walking Safety**
Min-Ji KIM (National Institute of Forest Science, KR), Chang-Deuk EOM (National Institute of Forest Science, KR), Chun Young PARK (Korea Association of Wood Culture, KR)

57 **Enhancing Material Flow Analysis of Wood Resources in Korea through Improvements in Wood Utilization Statistics**
Min-Ji KIM (National Institute of Forest Science, KR), Yong-Seok CHOI (National Institute of Forest Science, KR), Sae-Min YOON (National Institute of Forest Science, KR), Ki Dong KIM (National Institute of Forest Science, KR)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

IV-2. Ecosystem Services and Biodiversity in Wood Value Chains

58 **Empowering small-holder private forest owners in Europe by innovative business opportunities in forest-based bioeconomy value chains: the SMURF Forest Owners project**
Uwe KIES (InnovaWood, BE), Radmila USTYCH (InnovaWood, UA), Claudia ANTONIOTTI (Xylofutur, FR), Abdelwahab BESSAAD (Xylofutur, FR), Adela TRASSIERRA VILLA (CESEFOR, ES), Elena MORENO AMAT (CESEFOR, ES), Alvaro PICARDO (CESEFOR, ES)

59 ***A Data Driven Framework for Environmental Sustainability in the Conservation and Rejuvenation of the River Ganga in the Indian Himalaya***
Vasundhara UNIYAL (National Institute of Advanced Studies (NIAS) Indian Institute of Science (IISc) Campus Bangalore, IN)

V-1. Cultural Dimensions and Societal Perceptions of Wood Use

60 **Renewing the Workspace: Modernizing Office Environments through Sustainable Systems**
Rico RUFFINO (NC State University, US)

61 **The Indiana Wood Utilization Team**
Henry QUESADA (Purdue University, US), Rado GAZO (Purdue University, US), Eva HAVIAROVA (Purdue University, US), Lenny FARLEE (Purdue University, US)

62 **Analysis of Cascading Use and Available Timber Resources Including Forest Disaster-Damaged Wood in Korea**
Chang-Deuk EOM (National Institute of Forest Science, KR), Yiyang QIAO (National Institute of Forest Science, KR), Keon-Ho KIM (National Institute of Forest Science, KR), Myung-Kil KIM (National Institute of Forest Science, KR)

63 **A Quantification Framework for Psychological Evaluation of Wooden Office Environments Integrating Qualitative and Quantitative Approaches**
Takashi SHIMA (The University of Tokyo, JP), Mayu SHIRAKAWA (Seitoku University, JP), Yuko TSUNETSUGU (The University of Tokyo, JP)

V-2. New Approaches to Wood Sector Education and Workforce Development

64 **“Illuminate Circularity” Immersive in Education**
Rico RUFFINO (NC State University, US)

65 **The New European Bauhaus Academy: a novel skills, knowledge and innovation platform to boost sustainable construction within the built environment**
Uwe KIES (InnovaWood, BE), Florence KUIJL (InnovaWood, FR), Andreja KUTNAR (InnoRenew CoE, UP IAM & UP FAMNIT, SI), Mike BURNARD (InnoRenew CoE, UP IAM & UP FAMNIT, SI), Michael SALKA (Institute for Advanced Architecture of Catalonia, ES)

66	**Transforming Underutilized Hardwood into Biophilic Learning Environments** Eva HAVIAROVA (Purdue University, US), Ting-Ho TSAI (Purdue University, US), Jackson WARREN (Purdue University, US)
67	**Collaborative Modular Biophilic Design: An International Student-Built Wall Panel System for Wood Science Education** Eva HAVIAROVA (Purdue University, US), Zuzana TONCIKOVA (Technical University of Zvolen, SK), Lukas STEFANCIN (Technical University of Zvolen, SK), Albert SPALDING (Purdue University, US)
68	**Digital Transformation in Furniture Design: Emerging Trends and Implications for Design Education** Eva HAVIAROVA (Purdue University, US), Tugba Andac GUZEL (Kayseri University, TK)
69	***Advancing Sustainability and Innovation in the Built Environment Through Wood and Bio-based Materials: Degree Programmes at the University of Primorska*** *Amy SIMMONS (University of Primorska, InnoRenew CoE, Andrej Marusic Institute, SI), Matthew SCHWARZKOPF (University of Primorska, InnoRenew CoE, Andrej Marusic Institute, SI), Andreja KUTNAR (University of Primorska, InnoRenew CoE, Andrej Marusic Institute, SI)*

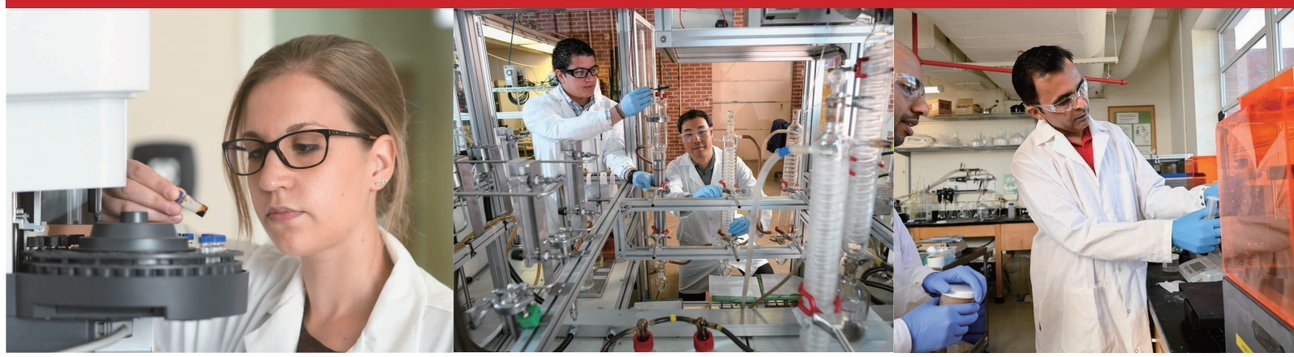
VII-1. IUFRO DIV.5. with 2026 SWST in Korea: Wood Properties and Utilization

70	**Natural Durability of Softwood Species against Wood Decay Fungi** Jae-Hee JUNG (National Institute of Forest Science, KR), Sun Lul KWON (National Institute of Forest Science, KR), Hyun-Mi LEE (National Institute of Forest Science, KR), Jinae SHIN (National Institute of Forest Science, KR), Won-Joung HWANG (National Institute of Forest Science, KR)
71	**Modeling the Relationship Between the Natural Frequency and Elastic Modulus of Table Tennis Blade Based on Laser Resonance** Weiqi LENG (Nanjing Forestry University, CN), Chao CHEN (Nanjing Forestry University, CN)

DEPARTMENT OF FOREST BIOMATERIALS

NC STATE UNIVERSITY College of Natural Resources

Department of Forest Biomaterials



On the Front Line of Emerging Opportunities

The Department of Forest Biomaterials is a research powerhouse with an ecosystem built for achievement and collaboration. Using fundamental science and applied engineering skills, coupled with financial and life cycle analyses, our faculty and students examine the practical uses of forest biomass as renewable resources that could form the basis for many products in the future, including biofuels, bioenergy, bioplastics, chemicals, housing materials, composite components and more.

Our Department is recognized globally for its expertise in:

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- Novel Forest-based biomaterials
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FULL AGENDA BY SESSION CATEGORY

* denotes Student.
Italic text denotes non-preregistered presentations.

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 10:30~12:00
Location: Room A
Moderator(s): Jongho KIM (Kangwon National University)
Matthew SCHWARZKOPF (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

I-1. Fundamentals and Frontiers in Wood Physics and Mechanics

10:30~10:45	1	**Intermittent Release of Wood-Emitted d-Limonene: Effects on Indoor Environmental Perception and Autonomic Regulation** Qifan WANG (Northwest A&F University, CN), Jun SHEN (Northeast Forestry University, CN)
10:45~11:00	2	**Molecular investigation of bamboo during stress relaxation using custom-built mechanical loading platform coupled with Raman spectroscopy** Xinxin MA (International Center for Bamboo and Rattan, CN)
11:00~11:15	3	**Microscopic observation of the G layer of tension wood using a scanning probe microscope** Han WANG (Nagoya University, JP), Tamaki KUGIMIYA (Nagoya University, JP), Hiroyuki YAMAMOTO (Nagoya University, JP), Dan AOKI (Nagoya University, JP), Kazuhiko FUKUSHIMA (Nagoya University, JP), Masato YOSHIDA (Nagoya University, JP)
11:15~11:30	4	**Dimensional stability and mechanical performance of exterior-grade particleboard and MDF after accelerated aging** Tiam MAHMOUDIAN* (Université Laval, CA), Alain CLOUTIER (Université Laval, CA), Rosilei GARCIA (Université Laval, CA), Aziz LAGHDIR (SEREX, CA)
11:30~11:45	5	**Engineering Characteristics of Structural Lumber from Small-Diameter Logs: Small Clear Specimens** Elijah OLAWUMI (Oregon State University, US), Lech MUSZYNSKI (Oregon State University, US), Michelle JAYAWICKRAMA (Oregon State University, US), Dessie TIBEBU (Oregon State University, US)
11:45~12:00	6	**Moisture-activated set-recovery of thermo-hydro-mechanically densified hardwood dowels for high-tolerance timber connections** Lei HAN (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska, SI), Andreja KUTNAR (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska, SI)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 13:30~15:15
Location: Room A
Moderator(s): Jongho KIM (Kangwon National University)
Matthew SCHWARZKOPF (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

I-1. Fundamentals and Frontiers in Wood Physics and Mechanics

13:30~13:45	1	**Physical and mechanical properties of hardboards (HB) made from acetic acid-modified fibers** Szymon JASKIEWICZ (Faculty of Wood Technology, Warsaw University of Life Sciences-SGGW, Warsaw, PL), Eduardo ROBLES (University of Pau and the Adour Region, E2S UPPA, CNRS, IPREM-UMR 5254, Mont de Marsan, FR), Grzegorz KOWALUK (Institute of Wood Sciences and Furniture, Warsaw University of Life Sciences - SGGW, Warsaw, PL)
13:45~14:00	2	**Porosity and liquid water absorption capacity of spruce wood charred with different intensities** Jure ZIGON (University of Ljubljana, Biotechnical Faculty, SI), Anze ZAJC (University of Ljubljana, Biotechnical Faculty, SI), Ales STRAZE (University of Ljubljana, Biotechnical Faculty, SI)
14:00~14:15	3	**Compatibility Assessment between Picture Frame and Compression-Based Methods for Determining the In-Plane Shear Modulus of CLT** Keonho KIM (National Institute of Forest Science, KR), Chul-Ki KIM (National Institute of Forest Science, KR), Chang-Deuk EOM (National Institute of Forest Science, KR)
14:15~14:30	4	**How Variability of FTIR Spectra Influence Machine Learning Based Wood Species Discrimination** Risto NAHKSEPP (Institute of Forestry and Engineering, Estonian University of Life Sciences, EE), Kaido SIIMON (Institute of Forestry and Engineering, Estonian University of Life Sciences, EE), Ahto KANGUR (Institute of Forestry and Engineering, Estonian University of Life Sciences, EE), Oie Renata SIIMON (Institute of Computer Science, University of Tartu, EE)
14:30~14:45	5	**Modification of sorption thermodynamics and hygromechanical coupling in naturally aged structural timber** Ales STRAZE (University of Ljubljana, Biotechnical Faculty, SI), Matjaz DREMELJ (University of Ljubljana, Biotechnical Faculty, SI), Jure ZIGON (University of Ljubljana, Biotechnical Faculty, SI), Anze ZAJC (University of Ljubljana, Biotechnical Faculty, SI)
14:45~15:00	6	**Influence of refining parameters on fiber granulometry, surface quality, and mechanical properties of embossed MDF door panels** Johanna GAITAN-ALVAREZ (Renewable Materials Research Centre (CRMR), Faculty of Forestry, Geography, and Geomatics, Université Laval, CA), Rosilei GARCIA (Renewable Materials Research Centre (CRMR), Faculty of Forestry, Geography, and Geomatics, Université Laval, CA), Alain CLOUTIER (Renewable Materials Research Centre (CRMR), Faculty of Forestry, Geography, and Geomatics, Université Laval, CA), Veronic LANDRY (Renewable Materials Research Centre (CRMR), Faculty of Forestry, Geography, and Geomatics, Université Laval, CA)
15:00~15:15	7	**Evaluating the Technological Properties of Quercus *laurina* and Q. rugosa for Forest Use Diversification in Mexico** Jose Antonio SILVA GUZMAN (Universidad De Guadalajara, MX), Dulce Isamar HERNANDEZ RIVERA (Universidad De Guadalajara, MX), Alma Rosa SALCEDO CORONA (Universidad De Guadalajara, MX), Jose Antonio ANZALDO HERNANDEZ (Universidad De Guadalajara, MX), Berenice CLIFTON GARCIA (Universidad De Guadalajara, MX), Francisco Javier FUENTES TALAVERA (Universidad De Guadalajara, MX), Raul RODRIGUEZ ANDA (Universidad De Guadalajara, MX)

June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 08:30~10:00
Location: Room B
Moderator(s): **Keon-ho KIM** (National Institute of Forest Science)
Matthew SCHWARZKOPF (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

I-1. Fundamentals and Frontiers in Wood Physics and Mechanics

08:30~08:45	1	**Interactive Effects of Temperature, Moisture Content, and Pressure on Birch Veneer Densification** Tolgay AKKURT (Tallinn University of Technology, EE), Anti ROHUMAA (Tallinn University of Technology, EE), Jaan KERS (Tallinn University of Technology, EE)
08:45~09:00	2	**Understanding the effect of thickness variation on adhesive bond formation conditions and bond integrity in cross-laminated timber** Samson Micheal IDOGHOR (Oregon State University, US), Ashley MCCANN (Oregon State University, US), Autumn BATTISTI (Oregon State University, US), Lech MUSZYNSKI (Oregon State University, US), Vahid NASIR (Oregon State University, US), John NAIRN (Oregon State University, US), Fatemeh REZAEI (Mississippi State University, US)
09:00~09:15	3	**The effect of voids on mechanical performances of wood-based products** Wanzhao LI (Nanjing Forestry University, CN), Jiangtao SHI (Nanjing Forestry University, CN)
09:15~09:30	4	**Physical and Mechanical Properties of Bamboo I-Joist Based on Web Diameter, Flange Thickness, and Adhesive Types** Naresworo NUGROHO (IPB University, ID), Wayan DARMAWAN (IPB University, ID), Dede HERMAWAN (IPB University, ID), Lastiur Eva PANGGABEAN (IPB University, ID), Anngun THEVIANNI (IPB University, ID), Khairunnisa Iskandar PUTRI (IPB University, ID)
09:30~09:45	5	**Methods of Cross-linking of Hardwood Kraft Lignin as Bio-Based Wood Adhesives for Wood Bonding** Byung-Dae PARK (Kyungpook National University, KR), Ega Cyntia WATUMLAWAR (Kyungpook National University, KR), Saman GHAHRI (Kyungpook National University, KR), Eko Setio WOBOWO (Research Center for Biomass and Bioproducts, National Research and Innovation, ID)
09:45~10:00	6	**Advancing Wood Identification in the Philippines: Utilizing the Xylorix Platform for Efficient AI Model Development and Deployment for Five Key Species** Rosalie MENDOZA (University of the Philippines Los Banos, PH), Vivian DARACAN (University of the Philippines Los Banos, PH), Arlene ROMANO (University of the Philippines Los Banos, PH), Ronniel MANALO (University of the Philippines Los Banos, PH), Xin Jie TANG (Agritix, MY), Yi Hong WONG (Agritix, MY), Yong Haur TAY (Agritix, MY)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

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June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 10:30~12:00
Location: Room B
Moderator(s): **Keon-ho KIM** (National Institute of Forest Science)
Matthew SCHWARZKOPF (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

I-1. Fundamentals and Frontiers in Wood Physics and Mechanics

10:30~10:45	1	**Study on the Correlation between the Main Chemical Components of Calamus simplicifolius Cell Walls and Micro-Mechanics** Lili SHANG (International Center for Bamboo and Rattan, CN), Long FENG (International Center for Bamboo and Rattan, CN), Jianfeng MA (International Center for Bamboo and Rattan, CN), Zehui JIANG (International Center for Bamboo and Rattan, CN)
10:45~11:00	2	**Wood properties of naturally grown Larix sibirica in degraded forests at seven sites in Mongolia** Sender ALTANGEREL* (Research and Training Institute of Forestry and Wood Industry, Mongolian University of Science and Technology, MN), Murzabyek SARKHAD (Research and Training Institute of Forestry and Wood Industry, Mongolian University of Science and Technology, MN)
11:00~11:15	3	*Author-initiated withdrawal*
11:15~11:30	4	*Author-initiated withdrawal*
11:30~11:45	5	*Structural Reconstruction of Ultrafine Bamboo Fibers for High-Performance Bio-Based Composites* *Susu YANG* (Southwest Forestry University, CN)*
11:45~12:00	6	*Author-initiated withdrawal*

June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 13:30~15:45
Location: Room B
Moderator(s): Soo-Kyeong JANG (National Institute of Forest Science)
Matthew SCHWARZKOPF (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

I-2. Fundamentals in Wood Chemistry and Biorefining

13:30~13:45	1	**Improving moisture resistance of bio-based protein adhesives with different crosslinkers** Anita TRAN (BOKU University, AT), Johannes HOFER (BOKU University, AT), Ritika MALIK (BOKU University, AT), Hendrikus WG VAN HERWIJNEN (Wood K plus-Competence Centre for Wood Composites & Wood Chemistry, Kompetenzzentrum Holz GmbH, AT), Johannes KONNERTH (BOKU University, AT)
13:45~14:00	2	**Distribution of metabolites in Ginkgo biloba seeds** Qinyue GONG (Nagoya University, JP), Yuta ISOMURA (Nagoya University, JP), Nanako OMORI (Nagoya University, JP), Dan AOKI (Nagoya University, JP), Takamitsu UCHIDA (Aichi Center for Industry and Science Technology, JP), Bin LI (Nagoya University, JP), Tetsuya INAGAKI (Nagoya University, JP), Masato YOSHIDA (Nagoya University, JP), Kazuhiko FUKUSHIMA (Nagoya University, JP)
14:00~14:15	3	**Activity-guided isolation and identification of antiviral compounds from tree bark extracts** Aitana ZOCO* (University of Eastern Finland, FI), Miika KARJALAINEN (University of Jyvaskyla, FI), Stefan BOEHMDORFER (BOKU University, AT), Potthast ANTJE (BOKU University, AT), Janne JANIS (University of Eastern Finland, FI), Varpu MARJOMAKI (University of Jyvakyla, FI), Antti HAAPALA (University of Eastern Finland, FI)
14:15~14:30	4	**Using HSQC NMR to elucidate the molecular-level effects of suberin-specific esterases on birch bark** Meera CHRISTOPHER (Chalmers University of Technology, SE), Ahilan MANISEKARAN (Chalmers University of Technology, SE), Giacomo RUZZA (Chalmers University of Technology, SE), Hedieh NOEPARAST (Chalmers University of Technology, SE), Li-Yang LIU (Chalmers University of Technology, SE), Lisbeth OLSSON (Chalmers University of Technology, SE)
14:30~14:45	5	**Integrated Process Optimization and Molecular Characterization of Boreal Bark-Derived Tannins for Sustainable Particleboard Manufacturing** Seyed Saman VAKILI* (Université Laval, CA), Vahideh AKBARI (Université Laval, CA), Papa NIOKHOR DIOUF (Serex, CA), Veronic LANDRY (Université Laval, CA)
14:45~15:00	6	**Steam-Induced Cellular Expansion of *Quercus variabilis* Virgin Cork Granules: Toward Tunable Bio-based Porous Structures** Byeongho KIM* (Kangwon National University, KR), Seungsu PARK (Kangwon National University, KR), Jeongsu BYUN (Kangwon National University, KR), Ji-Yeon SIM (Kangwon National University, KR), Se-Yeong PARK (Kangwon National University, KR)
15:00~15:15	7	**By-product effluents from *Eucalyptus'* sulphite pulping: valorisation of an underutilized source of bioactive compounds** Dmitry D. EVTYUGIN* (CICECO - University of Aveiro, PT), Antonio PRATES (CAIMA-Industria de Celulose S.A, PT), Dmitry V. EVTYUGIN (CICECO - University of Aveiro, PT)
15:15~15:30	8	**Synthesis of a Lignin-Based Binder via Radical Polymerization and its Application for Secondary Batteries** Geun Woo HAN (Seoul National University, KR), Youngmin CHO (Seoul National University, KR), Junho SHIN (Seoul National University, KR), Jonghwan CHOI (Seoul National University, KR), In-Gyu CHOI (Seoul National University, KR)
15:30~15:45	9	**From Bark Waste to High-Value Bio-Based Materials: Cascade Valorization of Tree Bark Post-Extraction Residues** Grzegorz KOWALUK (Warsaw University of Life Sciences - SGGW, PL), Anita WRONKA (Warsaw University of Life Sciences - SGGW, PL), Julia DASIEWICZ (Warsaw University of Life Sciences - SGGW, PL)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

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June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 16:00~18:00
Location: Room B
Moderator(s): **Soo-Kyeong JANG** (National Institute of Forest Science)
Matthew SCHWARZKOPF (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

I-2. Fundamentals in Wood Chemistry and Biorefining

16:00~16:15	1	**Availability and Variability of Post-Extraction Tree Bark Residues as Emerging Raw Materials for Biorefinery Systems** Anita WRONKA (Warsaw University of Life Sciences, PL), Julia DASIEWICZ (Warsaw University of Life Sciences, PL), Grzegorz KOWALUK (Warsaw University of Life Sciences, PL)
16:15~16:30	2	**Chemical Fingerprinting of Bark Post-Extraction Residues Using Integrated Chromatographic Analysis** Julia DASIEWICZ* (Warsaw University of Life Sciences (SGGW), Poland, PL), Anita WRONKA (Warsaw University of Life Sciences, PL), Grzegorz KOWALUK (Warsaw University of Life Sciences, PL)
16:30~16:45	3	**The effect of supercritical CO2 treatment on cell wall composition and cellulose accessibility in spruce wood** Callisto A BEUTHE* (University of Ottawa, CA), M.Reza FORUZANMEHR (University of Ottawa, CA)
16:45~17:00	4	**Lignin-carbohydrate Nanoparticles From Low-purity Lignin: A potential reinforcement for particleboards enhancement** Anass AIT BENHAMOU (Laval University, CA), Vahideh AKBARI (Laval University, CA), Veronic LANDRY (Laval University, CA)
17:00~17:15	5	**Synthesis and Biological Screening of Hydrazones Using Isolated Cholic Acid** Talha MASHHOOD (Government College University Faisalabad, PK), Shehar BANO (Government College University Faisalabad, PK), Muhammad IBRAHIM (Government College University Faisalabad, PK)
17:15~17:30	6	***Author-initiated withdrawal***
17:30~17:45	7	**Evaluation of Lignin Monomer Conversion and Biomass Dissolution Efficiencies in *Pinus rigida P. taeda* via Oxidative Catalytic Fractionation with a Base Catalyst** Soo-Kyeong JANG (National Institute of Forest Science, KR), Tae-In BAN (National Institute of Forest Science, KR)
17:45~18:00	8	***Influence of biomass feedstock on biochar structure, properties, and performance*** *Islam HAFEZ (Oregon State University, US)*

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* denotes Student.
Italic text denotes non-preregistered presentations.

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 16:00~18:00
Location: Room A
Moderator(s): **Jongsik KIM** (Chonnam National University)
Ilona PESZLEN (North Carolina State University)

I-3. New Insights into Wood Biology

16:00~16:15	1	**3D visualization of branched and anastomosed normal resin canals in Pinaceae** Dengcheng FENG* (University of British Columbia, CA), Michael TURNER (The Australian National University, AU), Philip EVANS (University of British Columbia, CA)
16:15~16:30	2	**Genomic Basis of Wood Decay Strategies in Basidiomycetes: Machine Learning Classification and Host Specialization** Natsuki HASEGAWA (Graduate School of Agricultural and Life Sciences, The University of Tokyo, JP), Masashi SUGIYAMA (Center for Advanced Intelligence Project, RIKEN, JP), Kiyohiko IGARASHI (Graduate School of Agricultural and Life Sciences, The University of Tokyo, JP)
16:30~16:45	3	**Bacterial degradation of lignin-modified transgenic poplar** Ilona PESZLEN (North Carolina State University, US), Jack WANG (North Carolina State University, US), Vincent CHIANG (North Carolina State University, US), Robert KELLY (North Carolina State University, US)
16:45~17:00	4	**Section SEM observations of organelle changes during cell death in ray parenchyma cells in Cryptomeria japonica** HyeunKyeung JEONG* (Tokyo University of Agriculture and Technology, KR), Josui KAMIYAMA (Tokyo University of Agriculture and Technology, JP), Ryota MATSUBARA (Tokyo University of Agriculture and Technology, JP), Kenichi YAMANE (Tokyo University of Agriculture and Technology, JP), Izumi ARAKAWA (Akita Prefectural University, JP), Katsushi KURODA (Forestry and Forest Products Research Institute, JP), Tomohiro HATANO (Tokyo University of Agriculture and Technology, JP), Ryo FUNADA (Tokyo University of Agriculture and Technology, JP), Satoshi NAKABA (Tokyo University of Agriculture and Technology, JP)
17:00~17:15	5	**Anatomical and chemical analyses of artificially induced blackened xylem by wounding of branches in Diospyros kaki** Ryotaro SHIGA (Tokyo University of Agriculture and Technology, JP), Hiroki FURUKAWA (Tokyo University of Agriculture and Technology, JP), Nire GI (Tokyo University of Agriculture and Technology, JP), Kana IWAMI (Tokyo University of Agriculture and Technology, JP), Satoshi NOMA (Tokyo University of Agriculture and Technology, JP), Takuya BAN (Tokyo University of Agriculture and Technology, JP), Yasuyuki MATSUSHITA (Tokyo University of Agriculture and Technology, JP), Ryo FUNADA (Tokyo University of Agriculture and Technology, JP), Satoshi NAKABA (Tokyo University of Agriculture and Technology, JP)
17:15~17:30	6	***Stem wood growth of stomata-sensitive conifers may profit more from the mobile carbon storage accumulated during the post-growing season*** *Fang WANG (Hebei Normal University, CN), Xiaohua Gou (Lanzhou University, CN), Patrick Fonti (Swiss Federal Institute for Forest, Snow and Landscape Research WSL, CH)*
17:30~17:45	7	**Discovering the anatomical and chemical composition of the corky bark of Eucalyptus suberea** Jorge GOMINHO (Instituto Superior de Agronomia, PT), Ana LOURENO (Instituto Superior de Agronomia, PT), Antonio VELEZ (Instituto Superior de Engenharia de Lisboa, PT)
17:45~18:00	8	***Author-initiated withdrawal***

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

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June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 08:30~10:00
Location: Room A
Moderator(s): **Jong Bum RA** (Gyeongsang National University)
Young-Seok CHOI (National Institute of Forest Science)

I-4. Traditional Wood Care and Maintenance: Drying, Preservation, Machining, Finishing, etc.

08:30~08:45	1	**Study on the Processing of Large Timber Components in Sabi-Period Wooden Architecture (3rd5th Century)** Haeree PARK (Korea National University of Heritage, KR), Heesoo SONG (Korea National University of Heritage, KR), Soochul KIM (Korea National University of Heritage, KR)
08:45~09:00	2	**Development of Pretreatment Techniques and Optimal Kiln-Drying Schedules to Reduce Drying Defects in Large-Cross-Section Round Timber from Red Pine** Bat-Uchral BATJARGAL* (Seoul National University, KR), Minjee KANG (Seoul National University, KR), Seonghyun LEE (Seoul National University, KR), Chang-Jin LEE (Jeonbuk National University, KR), Hwanmyeong YEO (Seoul National University, KR)
09:00~09:15	3	**Comprehensive Fire Performance of Softwood-Based Engineered Wood Products Treated with a High-Concentration Boron-Phenolic Hybrid Fire-Retardant System** Halim PARK (Chungnam National University, KR), Suhwan YEO (Chungnam National University, KR), Duy Vuong NGUYEN (Chungnam National University, VN), Taek Yong JEONG (The Korean Woodism-city Project Research Center, KR), Seoggoo KANG (Chungnam National University, KR)
09:15~09:30	4	**Acetylation of European Ash *(Fraxinus excelsior)* wood as an alternative to the traditional thermal modification method** Stepan BERANEK* (Mendel University, CZ), Jakub DOMENY (Mendel University, CZ), Jan BAAR (Mendel University, CZ)
09:30~09:45	5	**Hygrothermal performance of timber rainscreen façade systems** Seong Taek KANG* (Yonsei University, KR), Yujin KANG (Dankook University, KR), Ji Hun PARK (Yonsei University, KR), Sumin KIM (Yonsei University, KR)
09:45~10:00	6	***Comparative Analysis of Traditional Wood Preservation and Maintenance Practices: A Case Study of Gwagwalada, Nigeria*** *Michael OKE (Michael Adedotun Oke Foundation/ Federal Capital Territory Agricultural Development Programe, NG)*

June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 10:30~12:00
Location: Room A
Moderator(s): Jung-Kwon OH (Seoul National University)
Mohammad DERIKVAND (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

II-1. Advanced Timber Engineering and Hybrid Structural Systems

10:30~10:45	1	**Assessment of heritage timber beams for dowel-laminated timber production: material recovery rate and structural performance** Mohammad DERIKVAND (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska, SI)
10:45~11:00	2	**Innovations in wood product value chains for construction markets: a European overview** Uwe KIES (InnovaWood, BE), Vanesa BANO (InnovaWood, ES), Peter ROMIH (InnovaWood, InnoRenew CoE, SI), Oliver JANCKE (InnovaWood, FR), Andreja KUTNAR (InnoRenew CoE, UP IAM & UP FAMNIT, SI), Mike BURNARD (InnoRenew CoE, UP IAM & UP FAMNIT, SI), Stergios ADAMOPOULOS (Swedish University of Agricultural Sciences, SE)
11:00~11:15	3	**Expanding the Structural Role of Wood in Hybrid Systems: Configuration-Oriented Synthesis from the Finnish Carbon-Regulated Context** Huseyin Emre ILGIN (Tampere University, FI), Markku KARJALAINEN (Tampere University, FI), Jami JARVINEN (Tampere University, FI)
11:15~11:30	4	**Feasibility on a novel GLT-Steel composite beam system with on-site self-installation for 3D modular building units** Hae-Seon HWANG (Seoul National University, KR), Min-Jeong KIM (Seoul National University, KR), Kyung-Sun AHN (Seoul National University, KR), Gwang-Ryul LEE (Seoul National University, KR), Hae-Gyu LEE (Seoul National University, KR), Chul-Ki KIM (National Institute of Forest Science, KR), Jung-Kwon OH (Seoul National University, KR)
11:30~11:45	5	**Lateral Load Resistance and Connection Behavior of a Prefabrication Timber Wall System** Hyung Woo LEE (National Institute of Forest Science, KR), Chul-Ki KIM (National Institute of Forest Science, KR), Nayoung YOON (National Institute of Forest Science, KR)
11:45~12:00	6	**Novel Test-Method to evaluate Thermal Bond Line Stability** Oliver VAY (Wood K plus - Competence Centre for Wood Composites & Wood Chemistry, Kompetenzzentrum Holz GmbH, AT), Hermann KIRCHMAYR (Stora Enso Wood Products GmbH, AT), Markus HIRMKE (Stora Enso Wood Products GmbH, AT), Robert STINGL (BOKU University, Institute of Wood Technology and Renewable Materials, Department of Natural Sciences and Sustainable Resources, Austria, AT), Florian LAUBERGER (Wood K plus - Competence Centre for Wood Composites & Wood Chemistry, Kompetenzzentrum Holz GmbH, AT), Christian HANSMANN (Wood K plus - Competence Centre for Wood Composites & Wood Chemistry, Kompetenzzentrum Holz GmbH, AT)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

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June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 13:30~15:30
Location: Room A
Moderator(s): Jung-Kwon OH (Seoul National University)
Mohammad DERIKVAND (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

II-1. Advanced Timber Engineering and Hybrid Structural Systems

13:30~13:45	1	**Performance of PVA-Modified MUF Adhesives for Cold-Press Manufacturing of Structural Engineered Wood** Min LEE (National Insititute of Forest Science, KR), Sang-Min LEE (National Insititute of Forest Science, KR), Yonggun PARK (National Insititute of Forest Science, KR), Soo-Hyeok LEE (National Insititute of Forest Science, KR)
13:45~14:00	2	**Experimental Investigation of Monotonic Behavior of Moment Resisting Connections for GLT** Min-Soon PARK* (Chungbuk National University, KR), Min-Ji KIM (Chungbuk National University, KR), Kug-Bo SHIM (Chungbuk National University, KR)
14:00~14:15	3	**INFLUENCE OF PLYWOOD CORE ORIENTATION AND ADHESIVE TYPE ON THE STRUCTURAL PERFORMANCE OF CLT PANELS** Duy Vuong NGUYEN (Chungnam National University, VN), Taek-Yong JEONG (The Korean Woodism-city Project Research Center, KR), Seon-Mee Yoon (The Korean Woodism-city Project Research Center, KR), Ha-Lim PARK (Chungnam National University, KR), Seog-goo KANG (Chungnam National University, KR)
14:15~14:30	4	**Mill Scale Manufacturing and Cost Modeling of Structural Grade Hardwood Lumber from Yellow Poplar Cants for Mass Timber Applications** Sailesh ADHIKARI (National Hardwood Lumber Association, US), Brian BOND (Virgina Tech, US)
14:30~14:45	5	**Innovative Rotary Peeling of Thick Timber Panels from Underutilized European Aspen: Process Parameters and Surface Integrity** Heikko KALLAKAS (Tallinn University of Technology, EE), Aleksandr SEREBRENNIKOV (Tallinn University of Technology, EE), Catherine KILUMETS (Tallinn University of Technology, EE), Ignatius Kristia ADIKURNIA (Tallinn University of Technology, EE)
14:45~15:00	6	**Evaluation of Expected Structural Performance of Larch-Pine Hybrid Glulam for Efficient Utilization of Domestic Timber Resources** Taek Yong JEONG (The Korean Woodism-city Project Research Center, KR), Do Yoon HWANG (Korea Woodism-city Project Research Center, KR), Seog-Goo KANG (Chungnam National University, KR)
15:00~15:15	7	**Analytical and numerical investigation of the stiffness of single wooden dowel timber-to-timber connections** Inayat Ullah KHAN (Deakin University, AU), Mahbube SUBHANI (Chalmers University of Technology, SE), Kazem GHABRAIE (Deakin University, AU), Mahmud ASHRAF (Deakin University, AU)
15:15~15:30	8	***The Bonding Performance of CCA treated Radiata Pine Mass Plywood Panel*** *Lili JIA (University of Canterbury, School of Forestry, NZ), Hyungsuk LIM (University of Canterbury, School of Forestry, NZ), Xinyu WU (Nanjing Forestry University, CN)*

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 08:30~10:00
Location: Room B
Moderator(s): **Sang-Joon LEE** (National Institute of Forest Science)
Mohammad DERIKVAND (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

II-2. Designing for Performance and Resilience in Residential Timber Structures

08:30~08:45	1	**Development of Weather-Resistant Structural Plywood for Temporary Waterproofing During Construction of Mass Timber Buildings: Specification Selection Based on Weathering Tests** Yoshida KYOHEI (Center for Sustainable Building Engineering, Shibaura Institute of Technology, JP), Yamashiro SATORU (Shibaura Institute of Technology, JP), Kuramoto YASUHIRO (NISSHIN CO., LTD., JP), Aratani AIKO (NISSHIN CO., LTD., JP)
08:45~09:00	2	**Current Status of R&D on Impact Sound Insulation for Vitalizing Multi-Residential Timber Buildings in Korea** Sang-Joon LEE (National Institute of Forest Science, KR), Hyung Woo LEE (National Institute of Forest Science, KR), Beom-Yeol YUN (National Institute of Forest Science, KR), In-Hwan LEE (National Institute of Forest Science, KR), Chul-Ki KIM (National Institute of Forest Science, KR), Sung-Joon PANG (Chonnam National University, KR), Yeon-Su HA (Korea Institute of Civil Engineering and Building Technology, KR), Hyo-Jin LEE (Fire Insurers Laboratories of Korea, KR)
09:00~09:15	3	**Lateral Resistance Properties of SIP wall Sheathed with Structural PB** Chul-Ki KIM (National Institute of Forest Science, KR), Hyung Woo LEE (National Institute of Forest Science, KR), Nayoung YOON (National Institute of Forest Science, KR)
09:15~09:30	4	**Derivation of a New Structural Element for Revising the Fire-Resistant Structural Standard for Light-Frame Wood Structures** In-Hwan LEE (National Institute of Forest Science, KR), Sang-Joon LEE (National Institute of Forest Science, KR), Chul-Ki KIM (National Institute of Forest Science, KR), Beom Yeol YUN (National Institute of Forest Science, KR), Hyung Woo LEE (National Institute of Forest Science, KR), Tae-Ik HWANG (National Institute of Forest Science, KR)
09:30~09:45	5	*Author-initiated withdrawal*
09:45~10:00	6	**Evaluating Flexible Bondlines and Thermal Enhancement in Wood Composites** Matthew SCHWARZKOPF (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska, SI), Rok PRISLAN (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska, SI), Jaka Gasper PECNIK (Slovenian National Building and Civil Engineering Institute, SI), Argyrios ANAGNOSTOPOULOS (Institute of Chemistry, University of Silesia in Katowice, PL)

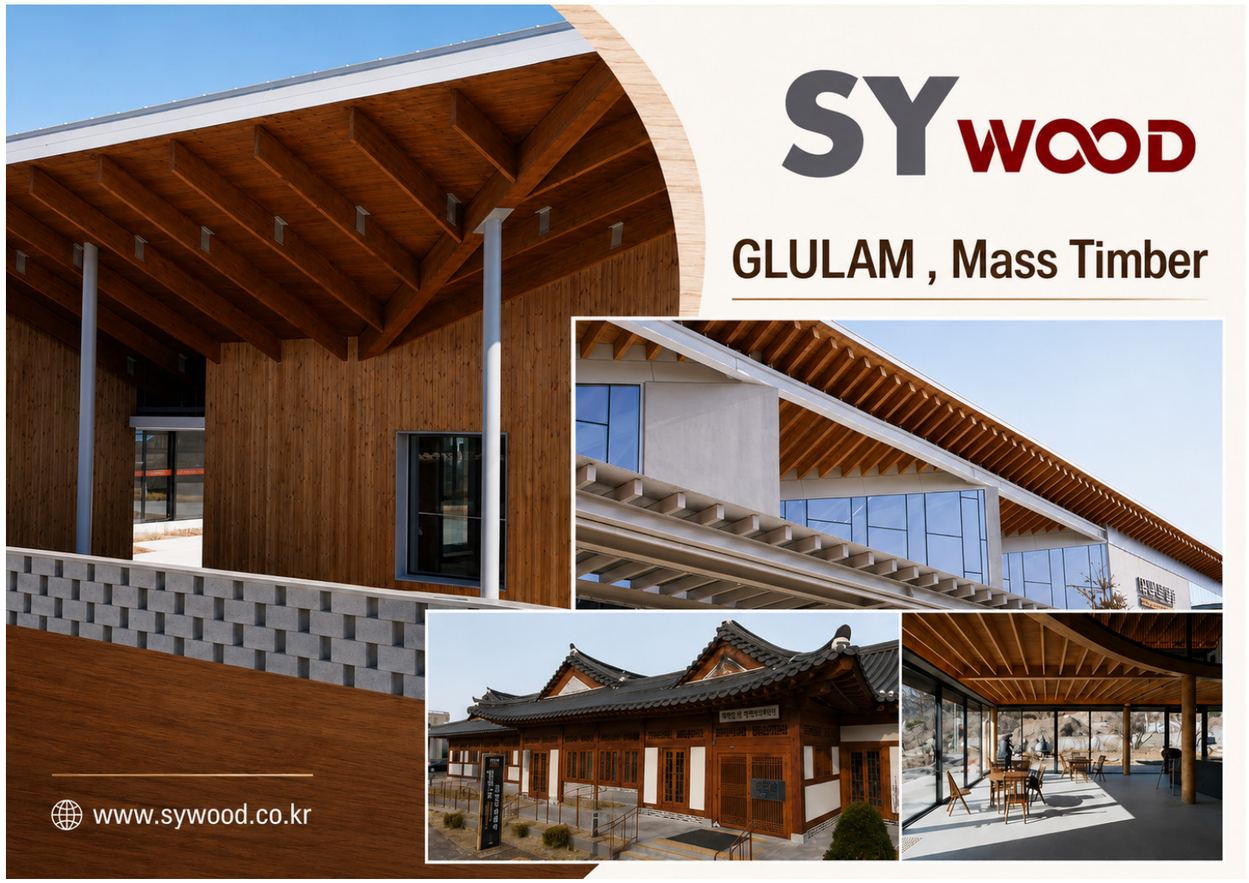
2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 10:30~11:15
Location: Room B
Moderator(s): **Kug-Bo SHIM** (Chungbuk National University)
Mohammad DERIKVAND (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

II-2. Designing for Performance and Resilience in Residential Timber Structures

10:30~10:45	1	**Design of an Energy Self-Sufficient Disaster Shelter Using Fire-Damaged Timber** Jin-U JEON* (Chungnam National University, KR), Jeonghun LEE (Chungnam National University, KR)
10:45~11:00	2	**Energy retrofit for aging building using CLT panels with thermal bridges** Ji Hun PARK* (Yonsei University, KR), Seong Taek KANG (Yonsei University, KR), Jihee NAM (Yonsei University, KR), Sumin KIM (Yonsei University, KR)
11:00~11:15	3	**Optimization of PCM-Integrated Timber Structures for Cold Climate Applications** Hyun Bae KIM (Chungnam National University, KR), Minji KWON (Chungnam National University, KR), Takuyuki YOSHIOKA (The University of Tokyo, JP)



June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 13:30~15:30
Location: Room B
Moderator(s): Hoyong KIM (Korea Research Institute of Chemical Technology)
Milan ŠERNEK (University of Ljubljana)

III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

13:30~13:45	1	**Toward a Renewable Supply of Graphite: Catalytic Biographite Production and Techno-Economic Evaluation for Energy Storage Applications** Sunkyu PARK (North Carolina State University, US)
13:45~14:00	2	**Cellulose Acetate Sulfate Hydrogels as 3D Printing Bio-Inks** Seong-Min CHO (North Carolina State University, US), Seonghyun PARK (North Carolina State University, US), Tavila SHARMIN (North Carolina State University, US), Rohan SHIRWAIKER (North Carolina State University, US), Sunkyu PARK (North Carolina State University, US)
14:00~14:15	3	**Processing and Characterization of Cellulose Reinforced Polyamide Composites** Brooke MCKENZIE (North Carolina State University, US), Muhammad Khusairy Bin BAKRI (Washington State University, US), Hui LI (North Carolina State University, US)
14:15~14:30	4	**From Biomass Valorization to Circular Remediation: Fully Biodegradable Hydrogels for Nanoplastic Capture** Seungoh JUNG* (Seoul National University, KR), Sangwoo PARK (Seoul National University, KR), Junsik BANG (Seoul National University, KR), Jungkyu KIM (Seoul National University, KR), Seon-Gyeong KIM (Seoul National University, KR), Dawoon SEO (Seoul National University, KR), Chaeeun KIM (Seoul National University, KR), Dongho SHIN (Seoul National University, KR), Suhyun OK (Seoul National University, KR), Chaewoo JEONG (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR)
14:30~14:45	5	**Towards Sustainable and Recyclable Lignin Fibers: Melt-Spun Lignin Esters with Iron Oxide Nanoparticles** Unnimaya THALAKKALE VEETTIL (Stockholm University, SE), Adrian MORENO (University Rovira I Virgili, Tarragona, ES), Alberto J. HUERTAS-ALONSO (Stockholm University, SE), Mohammad MORSALI (Stockholm University, SE), Ievgen V. PYLYPCHUK (Stockholm University, SE), Li-Yang LIU (Chalmers University of Technology, SE), Mika. H SIPPONEN (Stockholm University, SE)
14:45~15:00	6	**Spray-coating self-assembled Cellulose Nanocrystals on wood: how to create structural colorful and bio-based wood coatings** Celia LOINTIER (BOKU University, AT), Stefan VEIGEL (BOKU University, AT), Johannes KONNERTH (BOKU University, AT), Claudia GUSENBAUER (BOKU University, AT)
15:00~15:15	7	**Bonding Performance of Wood with Renewable Bio-Based Shellac Adhesive** Milan ŠERNEK (University of Ljubljana, Biotechnical Faculty, SI), Maks BRUS (University of Ljubljana, Biotechnical Faculty, SI)
15:15~15:30	8	**Smooth, self-standing cellulose nanopaper composite and its applications** Yuyo YEH* (National Taiwan University, TW), Pei-Yu WANG (National Taiwan University, TW), Wei-Ssu LIAO (National Taiwan University, TW), Feng-Cheng CHANG (National Taiwan University, TW)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 16:00~18:00
Location: Room B
Moderator(s): Hoyong KIM (Korea Research Institute of Chemical Technology)
Milan ŠERNEK (University of Ljubljana)

III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

16:00~16:15	1	**Metal-Ion-Induced Microfibril Engineering of Cellulose and Its Applications** Zhang XUEFENG (University of Maine, US)
16:15~16:30	2	**Silica-supported carboxymethylated kraft lignin for the sequestration of transition metals in wastewater** Micaela SANTOS (University of Aveiro, PT), Carlota NELSON (University of Aveiro, PT), Sofia REBOLA (CELBI, S. A., PT), Alisa RUDNITSKAYA (University of Aveiro, PT), Dmitry EVTUGUIN (University of Aveiro, PT)
16:30~16:45	3	**Accelerated Thermal Stabilization for Lignin-based Carbon Nanofibers via In-situ UVC Irradiation during Electrospinning** Jungkyu KIM (Seoul National University, KR), Sangwoo PARK (Seoul National University, KR), Junsik BANG (Seoul National University, KR), Seungoh JUNG (Seoul National University, KR), Seon-Gyeong KIM (Seoul National University, KR), Chaeeun KIM (Seoul National University, KR), Dawoon SEO (Seoul National University, KR), Dongho SHIN (Seoul National University, KR), Su Hyun OK (Seoul National University, KR), Chaewoo JEONG (Seoul National University, KR), In-Gyu CHOI (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR)
16:45~17:00	4	**Bio-Based Crosslinking of PVA/Chitosan Composite Films Using Water Soluble Dialdehyde Cellulose for Moisture-Resistant Active Packaging** Ju-Won JIN* (Kangwon National University, KR), Seung-Woo CHO (Kangwon National University, KR), Dong-Suk JEON (Kangwon National University, KR), Song-Yi HAN (Kangwon National University, KR), Rajkumar BANDI (Kangwon National University, IN), Ramakrishna DADIGALA (Kangwon National University, IN), Gu-Joong KWON (Kangwon National University, KR), Seung-Hwan LEE (Kangwon National University, KR)
17:00~17:15	5	**Nanocellulose Reinforced PRF Resin in Extrudable Wood Composites for Potential Additive Manufacturing Applications** Armando MCDONALD (University of Idaho, US), Japneet KUKAL (University of Idaho, US), Maria Soledad PERESIN (Clemson University, US)
17:15~17:30	6	**Enabling Highly Reversible Zinc Metal Batteries by Wood-based Cellulose Nanomaterials** Chaozheng LIU (Nanjing Forestry University, CN), Changtong MEI (Nanjing Forestry University, CN)
17:30~17:45	7	**Green Construction of High-Performance Biochar/Wood-Based Functional Composites Driven by Hydroplasticization** Suiyi LI (Nanjing Forestry University, CN), Haoran YE (Nanjing Forestry University, CN), Changlei XIA (Nanjing Forestry University, CN)
17:45~18:00	8	**Investigation of Fungal Resistance of Wood-Fiber Insulation Boards** Volha MIALESHKA* (University of Sopron, HU), Zoltan PASZTORY (University of Sopron, HU), Inha HENIUSH (Belarusian State Technological University, BY), Ihar BAZHELKA (Belarusian State Technological University, BY)

June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 13:30~15:30
Location: Room C
Moderator(s): **June-Ho Choi** (Korea Research Institute of Chemical Technology)
Milan ŠERNEK (University of Ljubljana)

III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

13:30~13:45	1	**Enhancing Biochar for Supercapacitors through Fungal Pretreatment of Woody Biomass** Gloria S. OPORTO* (West Virginia University, US), Balazs BENCSIK (West Virginia University, US), Matt KASSON (West Virginia University, US), Edward SABOLSKY (West Virginia University, US)
13:45~14:00	2	**Turning Banana Waste into Functional Biofoams: A Simple Liquefaction Approach toward Sustainable Materials** Yi-Chun CHEN (National Chung Hsing University, TW), Hao-Yue DONG (National Chung Hsing University, TW)
14:00~14:15	3	**Nanocellulose-based functional emulsions and foams** Shuaib MUBARAK (Mississippi State University, US), Dikshya POKHREL (Mississippi State University, US), Bikal GHIMIRE (Mississippi State University, US), Yunsang KIM (Mississippi State University, US)
14:15~14:30	4	**Multi-Functional Chemically Modified Cellulose Nanocomposites for Advanced Energy Storage** Hyeyun KIM (Korea Institute of Science and Technology, KR), Seonmyeong YU (Korea Institute of Science and Technology, KR), Dahae OH (Korea Institute of Science and Technology, KR), Geon-young PARK (Korea Institute of Science and Technology, KR), Kahyun HUR (Korea Institute of Science and Technology, KR)
14:30~14:45	5	**The Potential of Rasau Fibers as a Sustainable Feedstock for Molded Pulp Packaging** Lukmanul Hakim ZAINI (IPB University, ID), Verastra Pradiva Maurensia GUNAWAN (IPB University, ID), Noviyanti NUGRAHENI (Sebangau National Park, ID), Eko PRASETYO (Borneo Orangutan Survival Foundation, ID), Wolfgang GINDL-ALTMUTTER (BOKU University, ID)
14:45~15:00	6	**Development strategies of cellulose based opacifiers, as sustainable alternative whitening agent to Titanium di oxide (TiO2)** Muhammad MUJTABA (VTT Technical Research Center of Finland, FI)
15:00~15:15	7	*Author-initiated withdrawal*
15:15~15:30	8	**Analysis of Upcycled Lint Fiber for Composite Applications** Lee Miller SMITH (Northeastern State University, US), Xuan WANG (University of North Texas, US)

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Innovating with Wood: Science and Materials for a Sustainable Future

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June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 16:00~17:45
Location: Room C
Moderator(s): **June-Ho Choi** (Korea Research Institute of Chemical Technology)
Milan ŠERNEK (University of Ljubljana)

III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

16:00~16:15	1	**Computationally Accelerated Design, Discovery, and Development of Chemically Recyclable Polyolefin-like Multiblock Polymers** Seonah KIM (Colorado State University, US)
16:15~16:30	2	***Enhancing the Mechanical Properties of Flax Fiber- Reinforced Epoxy Composites through Cellulose Nanofiber Incorporation*** *Ruiwen YU (Beihua University, CN), Mingli LIU (Beihua University, CN), Jung-IL SONG (Changwon National University, KR)*
16:30~16:45	3	***Microstructural and thermochemical evolution of marine algae-nanocellulose hybrid formulation for fire-safe wood insulation composites*** *Stephen AMIANDAMHEN (Norwegian Institute of Bioeconomy Research, NO), Ralf RAUTENBERGER (Norwegian Institute of Bioeconomy Research, NO)*
16:45~17:00	4	***Lightweight Cellulose-Based Composite Aerogels for Integrated Flame Retardancy and Thermal Insulation*** *Fengwu ZHANG (Southwest Forestry University, CN), Yushan YANG (Southwest Forestry University, CN), Jian QIU (Southwest Forestry University, CN)*
17:00~17:15	5	***Evaluation of Hardwood Bark-Derived Tannins for Bio-Adhesive Formulation and Sustainable Wood-Based Biocomposites Production*** *Md. ASHADUZZAMAN (Khulna University, BD), Sandhi Mahamud SHAKIL (Khulna University, BD), Sagar BISHNU (Khulna University, BD), Md. Rakibur Rahman SHOVON (Khulna University, BD), Shahadat HOSSAIN (Khulna University, BD), Sazzad HOSSEN (Khulna University, BD), Nowreen Akther REME (Khulna University, BD)*
17:15~17:30	6	***Determination of Physical, Mechanical and Fire Retardancy Properties of Innovative Particleboard Made from Corn Stalk (Zea mays L.) Particles*** *Lilik ASTARI (National Research and Innovation Agency of Republic of Indonesia (BRIN), ID)*
17:30~17:45	7	***Developing Lightweight Silanized Cellulose Ultramaterials as the Strongest Engineered Aerogel*** *Kangkang ZHANG (Southwest Forestry University, CN), Yushan YANG (Southwest Forestry University, CN), Jian QIU (Southwest Forestry University, CN)*

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 17:00~18:00
Location: Room C
Moderator(s): **Min LEE** (National Institute of Forest Science)
Frederico FRANÇA (Mississippi State University)

III-2. Digitalization and Smart Processing Technology

17:00~17:15	1	**Digital modelling of the internal structure of composites made from wood-based by-products - optimization of the manufacturing process** Mikolaj KUC* (The Faculty of Wood Technology of the Warsaw University of Life Sciences, Warsaw, PL), Grzegorz KOWALUK (Institute of Wood Sciences and Furniture, Warsaw University of Life Sciences - SGGW, Warsaw, PL)
17:15~17:30	2	**Sophisticated Approach of NIR Spectroscopy to Forest Products** Satoru TSUCHIKAWA (Nagoya University, JP), Te MA (Nagoya University, JP), Tetsuya INAGAKI (Nagoya University, JP)
17:30~17:45	3	**Toward Digital Predictive Maintenance of Wood Coatings: Mid-Infrared Spectroscopy Coupled with Machine Learning** Teramoto YOSHIKUNI (Graduate School of Agr, Kyoto University, JP)
17:45~18:00	4	*Author-initiated withdrawal*

The Korea Wood Construction Association(KWCA) envisions a sustainable future for architecture!

The KWCA engages in the following activities:

Research Institutions
· Industry-Academia Joint Research
· Establishment and Operation of Affiliated Institutes
· Experimental Research
· University Research Institutes
· Korea Institute of Civil Engineering and Building Technology
· National Institute of Forest Science

Government
· Proposals for Legal and Institutional Improvements to Promote Wood Construction
· Standardization including Group Standards
· Korea Forest Service
· Ministry of Land, Infrastructure and Transport
· Ministry of Trade, Industry and Energy
· Seoul Metropolitan City
· Local Governments

Public Institutions
· Entrusted Projects for Public Institutions
· Professional Training
· MOU Signing Ceremony
· Korea Forestry Promotion Institute
· National Forestry Cooperative Federation
· National Recreation Forest Management

Academic Societies / Associations
· Organizer of the Korea Wood Design Awards
· Exchange of Energy Reduction Technologies
· Technical Exchange on Insulation Standards
· Korea Institute of Registered Architects
· Korean Institute of Architects
· Korea Architect Institue
· Korea Zero Energy Building Association
· Passive House Institute Korea
· Korea Institute of Building Construction
· Korea Association of Wood Culture
· Korean Society of Wood Science & Technology
· Architectural Institute of Korea
· Architectural Policy Association of Korea
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2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 08:30~10:00
Location: Room C
Moderator(s): **Min-Ji KIM** (National Institute of Forest Science)
Michael BURNARD (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts

08:30~08:45	1	**Global Land and Carbon Consequences of Mass Timber Products** Kai LAN (North Carolina State University, US), Alice FAVERO (RTI International, US), Yuan YAO (Center for Industrial Ecology, Yale University, US), Robert MENDELSOHN (Yale University, US), Hannah Szu-Han WANG (Yale University, US)
08:45~09:00	2	**Second Life Structures: From CLT Waste to Circular Furniture** Rico RUFFINO (NC State University, US)
09:00~09:15	3	**Has Anything Changed? An Overview of Perceptions, Use, and Understanding of Cross-laminated Timber in the U.S. South: 2018 & 2025 from the Perspective of Architects, Non-Residential Builders, and Engineers** Richard VLOSKY (Louisiana State University Agricultural Center/Louisiana Forest Products Development Center, US)
09:15~09:30	4	**Use of agricultural residues in the production of lignocellulosic composites with a reduced carbon footprint** Julia KOZERSKA* (Faculty of Wood Technology, Warsaw University of Life Sciences - SGGW, PL), Nidal DEL VALLE RAYDAN (University of Pau and the Adour Region, FR), Grzegorz KOWALUK (Institute of Wood Sciences and Furniture, Warsaw University of Life Sciences - SGGW, PL)
09:30~09:45	5	**End-of-Life Management of CCA-Treated Vineyard Posts in Australia: Circular Economy Opportunities, Constraints and Policy Pathways** Martin STRANDGARD (University of the Sunshine Coast, AU), Penelope MITCHELL (University of the Sunshine Coast, AU), Tripti SINGH (University of the Sunshine Coast, AU)
09:45~10:00	6	**Integrating Design for Disassembly and Adaptability (DfD/A) in timber buildings A qualitative study on the design process** Sol VILLANUSTRE COPPOLA (Aalto University, FI), Mark HUGHES (Aalto University, FI), Anne TOPPINEN (University of Helsinki, FI)

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 10:30~12:00
Location: Room C
Moderator(s): **Min-Ji KIM** (National Institute of Forest Science)
Michael BURNARD (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts

10:30~10:45	1	**Hydrothermal recycling of copper from wooden utility poles and railway sleepers** Aitor BARBERO-LOPEZ (University of Eastern Finland, FI), Jaka LEVANIC (Biotechnical Faculty, University of Ljubljana, SI), Aitana ZOCO (University of Eastern Finland, FI), Eemeli ERONEN (University of Eastern Finland, FI), Janis JANNE (University of Eastern Finland, FI), Miha HUMAR (Biotechnical Faculty, University of Ljubljana, SI), Antti HAAPALA (University of Eastern Finland, FI)
10:45~11:00	2	**Towards Sustainable upcycling of particleboards and MDF - development directions and technological barriers** Aleksandra KOWALCZUK* (Warsaw University of Life Sciences - SGGW, PL), Grzegorz KOWALUK (Institute of Wood Sciences and Furniture, Warsaw University of Life Sciences - SGGW, Warsaw, Poland)
11:00~11:15	3	**Mycelium Composites as Partial Substitutes for Timber in CLT to Reduce Pressure on Timber Resources** Shaghayegh ELAHI (Faculty of Built Environment, Tampere University, FI), Kimiya TAJIK (Department of Bioproducts and Biosystems, Aalto University, FI), Harvey SHAW (Department of Bioproducts and Biosystems, Aalto University, FI), Matti ISAKOV (Faculty of Engineering and Natural Sciences, Tampere University, FI), Sami PAJUNEN (Faculty of Built Environment, Tampere University, FI), Lauri RAUTKARI (Department of Bioproducts and Biosystems, Aalto University, FI)
11:15~11:30	4	**Development of a Catalogue of Innovative Bio-Based and Sustainable Wood Composites for Design Applications** Natalia PADEREWSKA* (The Faculty of Wood Technology of the Warsaw University of Life Sciences, PL)
11:30~11:45	5	**Development of an Optimization Model for Green Supply Chain Management of Domestic Wood to Maximize Greenhouse Gas Reduction Effects** Dayoung KIM (Seoul National University), Hee HAN (Seoul National University, KR)
11:45~12:00	6	**Analysis of Domestic Unused Forest Biomass Supply Trends and Sustainable Potential in South Korea** Jaejung LEE (National Institute of Forest Science, KR)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 16:00~18:00
Location: Room A
Moderator(s): **Hee HAN** (Seoul National University)
Michael BURNARD (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts

16:00~16:15	1	**Symbiotic Waste Valorisation: A Case Study of the Estonian Wood and Furniture Industry** Jaan KERS (Tallinn University of Technology, EE), Jaana MERISAAR (Tallinn University of Technology, EE), Margit KULL (Tallinn University of Technology, EE), Tarmo TUISK (Tallinn University of Technology, EE), Jelena HARTENKO (Tallinn University of Technology, EE), Merle KUTTIM (Tallinn University of Technology, EE), Wolfgang D. GERSTLBERGER (Tallinn University of Technology, EE), Heikko KALLAKAS (Tallinn University of Technology, EE)
16:15~16:30	2	**Why Does Locally Harvested Timber Leak Out of Small-Scale Wood-Producing Regions? Structural Bottlenecks in Local Wood Circulation in Yasugi City, Japan** Shohei KAWANAKA (National Institute of Technology(KOSEN), Yonago College, JP)
16:30~16:45	3	**Influence of timber application to building envelopes on urban microclimate under seasonal conditions** Jihee NAM* (Yonsei University, KR), Jinyoung PARK (Yonsei University, KR), Seong Jin CHANG (Gyeongsang National University, KR), Sumin KIM (Yonsei University, KR)
16:45~17:00	4	**Material Matters: Wooden Corporate Buildings as Signals of Sustainability and Lower Perceived Greenwashing** Erlend NYBAKK (Kristiania University of Applied Sciences, NO), Jakob UTEGRD (Kristiania University of Applied Sciences, NO), Eric HANSEN (Oregon State University, US)
17:00~17:15	5	**Woody Biochar from Forestry Residues for enhancing the resilience of agroecosystems** Ling LI (The University of Maine, US), Swikar KARKI (The University of Maine, US), Lino REYES (The University of Maine, US), Jianheng ZHAO (The University of Maine, US), Adam DAIGNEAULT (The University of Maine, US), Libin LOUIS (The University of Maine at Fort Kent, US)
17:15~17:30	6	*Author-initiated withdrawal*
17:30~17:45	7	**Forest-to-Forest: A truly circular ecology for timber architecture: from the forest to built form, and back** Paul MAYENCOURT (University of California Berkeley, US), Liz GALVEZ (University of California Berkeley, US)
17:45~18:00	8	**Global Supply Chain Shocks and Wood Import Resilience: A VECM and Gravity Model Approach for Korea** Raeyeong KIM* (Seoul National University, KR), Yohan LEE (Seoul National University, KR)

* denotes Student.
Italic text denotes non-preregistered presentations.

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 11:15~11:45
Location: Room B
Moderator(s): **Kug-Bo SHIM** (Chungbuk National University)
Erlend NYBAKK (Kristiania University of Applied Sciences)

IV-2. Ecosystem Services and Biodiversity in Wood Value Chains

11:15~11:30	1	*Author-initiated withdrawal*
11:30~11:45	2	***Sustainable development from ecosystem services to legality and regulation in forests and forest products*** *Annika HYYTI (University of Helsinki, FI)*

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 13:30~15:15
Location: Room C
Moderator(s): **Suyeon LEE** (National Institute of Forest Science)
Richard VLOSKY (Louisiana State University)

V-1. Cultural Dimensions and Societal Perceptions of Wood Use

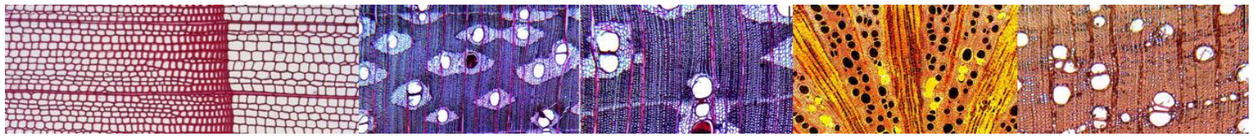
13:30~13:45	1	**From Bus Shelter to Floating Grove: Bringing the First CLT Building to NC State** Frederik LALEICKE (NC State University, US), Rico RUFFINO (NC State University, US)
13:45~14:00	2	**Wood Culture in the fabrication of handicrafts for tourism in Costa Rica** Moya ROGER (Instituto Tecnologico de Costa Rica, CR), Carolina TENORIO (Instituto Tecnologico de Costa Rica, CR), Marta SAENZ-MUNOZ (Instituto Tecnologico de Costa Rica, CR)
14:00~14:15	3	**Identifying Bottlenecks to Mass Timber Adoption in Rural Japan: A Comparative National Questionnaire Survey** Kanata YANO* (National Institute of Technology, Yonago College, JP), Shohei KAWANAKA (National Institute of Technology, Yonago College, JP)
14:15~14:30	4	**Development of a Play-Based Wood Education Program Integrating Environmental Values for Early Childhood** Jiyoon YANG (National Institute of Forest Science, KR), Bo Hyun KIM (Anyang University, KR), Suyeon LEE (National Institute of Forest Science, KR), Joo-Saeng PARK (National Institute of Forest Science, KR)
14:30~14:45	5	**A study on demand forecasting analysis through a survey of the operational status of wood culture experience centers** Suyeon LEE (National Institute of Forest Science, KR), Jiyoon YANG (National Institute of Forest Science, KR)
14:45~15:00	6	**Interactions in sensory experiences of wood** Michael BURNARD (InnoRenew CoE, UP IAM and UP FAMNIT, University of Primorska, SI), Spela VRTOVEC (InnoRenew CoE, UP IAM and UP FAMNIT, University of Primorska, SI), Rok PRISLAN (InnoRenew CoE, UP IAM and UP FAMNIT, University of Primorska, SI), Andreja KUTNAR (InnoRenew CoE, UP IAM and UP FAMNIT, University of Primorska, SI)
15:00~15:15	7	*Author-initiated withdrawal*

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 16:00~17:00
Location: Room C
Moderator(s): Jiyoon YANG (National Institute of Forest Science)
Michael BURNARD (InnoRenew CoE, UP IAM & UP FAMNIT, University of Primorska)

V-2. New Approaches to Wood Sector Education and Workforce Development

16:00~16:15	1	**Pursuing Excellence Through Experiential Learning: Undergraduate Leadership in Quality Control and Industry Engagement at the Forest Biomaterials Service Center** Daniel SALONI (North Carolina State University, US), JT CHAPPELL (NC State University)
16:15~16:30	2	**Sustainability and Innovation in Wood Sector Education: BOKU University Program Transformation** Lena Maria LEITER (BOKU University, AT), Johannes KONNERTH (BOKU University, AT)
16:30~16:45	3	**Professional Identity and Work Readiness in a Large-Scale Sustainability Infrastructure Project** Vera Junita SITANGGANG* (Oregon State University, US), Pipiet LARASATIE (Virginia Tech, US), Eric HANSEN (Oregon State University, US)
16:45~17:00	4	**The Vulnerability of Wood Science Programs in an AI-Driven Academic Landscape** Levente DENES (West Virginia University, US)



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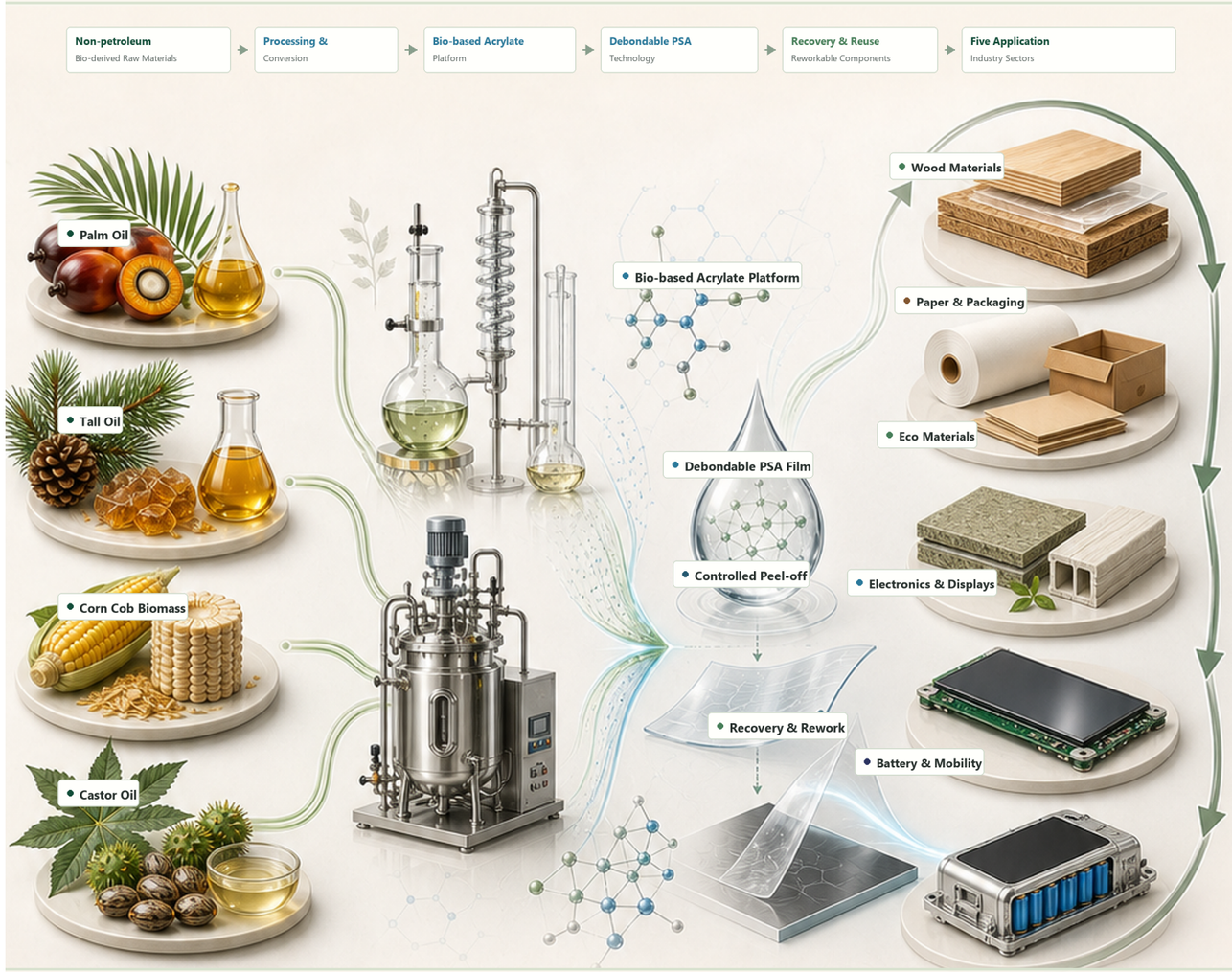
Bio-origin Debondable Adhesive Technology for Green & Advanced Industries

From Biomass-derived Acrylates to Reusable High-value Components



JB Lab develops bio-based acrylate adhesive platforms from non-petroleum, biomass-derived raw materials such as Palm Oil, Tall Oil, Corn Cob Biomass, and Castor Oil. By converting bio-origin feedstocks into advanced debondable pressure-sensitive adhesives, JB Lab enables controlled peel-off, reworkability, component recovery, and reuse across wood materials, paper and packaging, eco-materials, electronics, displays, battery, and mobility applications.

From Bio-Origin to Advanced Reuse

Green Chemistry Expanding into Sustainable and High-value Industrial Technologies

Bio-based Acrylate Platform
Adhesive materials developed from non-petroleum, biomass-derived feedstocks.

Debondable PSA Technology
Controlled peel-off and reworkable bonding for industrial manufacturing.

Recovery & Reuse
Supporting reuse across sustainable materials and high-value components.

June 9 (Tue) – Oral Presentations

Date & Time: June 9 (Tue), 08:30~10:00
Location: Room A
Moderator(s): **Se-Yeong PARK** (Kangwon National University)
Lena LEITER (BOKU University)

VI-1. Early Stage Researcher (ESR) 3-Minute Talks

08:30~08:33	1	**Design of Lignin-Based Hydrogels with Tunable Polyamine Structures for Efficient Pd Recovery and Catalytic Upcycling** Seon-Gyeong KIM* (Seoul National University, KR), Seungoh JUNG (Seoul National University, KR), Jungkyu KIM (Seoul National University, KR), Junsik BANG (Seoul National University, KR), Sangwoo PARK (Seoul National University, KR), Chaeeun KIM (Seoul National University, KR), Dawoon SEO (Seoul National University, KR), Dongho SHIN (Seoul National University, KR), Suhyun OK (Seoul National University, KR), Chaewoo JEONG (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR)
08:33~08:36	2	**Influence of Lignin Type and Nano-Microparticles Preparation Method on Properties of PLA Films** Ye-Jin JEONG* (Department of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University, KR), Jae-Won LEE (Department of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University, KR)
08:36~08:39	3	**Interfacial Optimization in Fully Biodegradable Biomass Composites: Comparative Analysis of PLA, PBS, and PHA Matrices** Sangwoo PARK* (Seoul National University, KR), Dongho SHIN (Seoul National University, KR), Junsik BANG (Seoul National University, KR), Jungkyu KIM (Seoul National University, KR), Seungoh JUNG (Seoul National University, KR), In-gyu CHOI (Seoul National University, KR), Hwanmyeong YEO (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR)
08:39~08:42	4	**Tailoring Lignin Properties via Rational Binary Solvent Design Based on Hansen Solubility Parameter Clustering** Junsik BANG* (Seoul National University, KR), Sangwoo PARK (Seoul National University, KR), Jungkyu KIM (Department of Agriculture, Forestry and Bioresources, College of Agriculture & Life Sciences, Seoul National University, KR), Seungoh JUNG (Seoul National University, KR), Seon-Gyeong KIM (Seoul National University, KR), Dawoon SEO (Seoul National University, KR), Chaeeun KIM (Seoul National University, KR), Dongho SHIN (Seoul National University, KR), Su Hyun OK (Seoul National University, KR), Chaewoo JEONG (Seoul National University, KR), In-Gyu CHOI (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR)
08:42~08:45	5	**Tailoring Lignin Nanoparticles (LNPs) by Molecular Drilling and its Characterization** Yoonjung SHIN* (Department of Wood Science and Landscape Architecture, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University, KR), Jae-Won LEE (Department of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University, KR)
08:45~08:48	6	**Control of Aggregation Behavior of Lignin Nanoparticles** Eunsun JOO* (Department of Wood Science and Engineering, Chonnam National University, Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University, KR), Jae-Won LEE (Department of Wood Science and Engineering, Chonnam National University, Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University, KR)
08:48~08:51	7	**Adsorption and Photocatalytic Degradation of Polyethylene Microplastics and Diazinon by KOH-Activated Pine Bark/TiO2 Composites** Jiwon YANG* (Department of Wood Science and Engineering, Chonnam National University, KR), Yoonjung SHIN (Department of Wood Science and Landscape Architecture, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University, KR), Yoon PARK (Department of Wood Science and Engineering, Chonnam National University, KR), Jae-Won LEE (Department of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University, KR)
08:51~08:54	8	**Development of Enzyme-Immobilized Magnetic Biochar/Alginate Beads as an Industrial Enzyme Cocktails** Eun-Ju LEE* (Department of Wood Science and Landscape Architecture, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University, KR), Jae-Won LEE (Department of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University, KR)
08:54~08:57	9	**Plasma-assisted enhancement of adhesion strength between alder veneer and thermoplastic LDPE film in veneer-based composites** Jozef RÁHEĽ (Mendel University in Brno, CZ), Tomáš PIPÍŠKA (Mendel University in Brno, CZ), Pavlo BEKHTA (Mendel University in Brno, CZ), Barbora MAYER (Mendel University in Brno, CZ), Marek NOCIAR* (Mendel University in Brno, CZ), Michal ŠULÁK (Mendel University in Brno, CZ), Richard SLÁVIK (Mendel University in Brno, CZ), Dimitrios TSALAGKAS (Mendel University in Brno, CZ), Jaroslav PANDA (Mendel University in Brno, CZ), Pavel KRÁL (Mendel University in Brno, CZ)
08:57~09:00	10	**Evaluation of Internal Defects in Pine Wood Using the Indirect Elastic-Wave Method** Kyoung-Hyun RYU* (Chungbuk National University, KR), Hyeong-Jun HAN (Chungbuk National University, KR), Kug-Bo SHIM (Chungbuk National University, KR)
09:00~09:03	11	**A Three-Stage Machine Learning Framework for Physically Consistent Biomass Property Prediction** Sunyong PARK (National Institute of Forest Science, KR), Jiwook YANG (National Institute of Forest Science, KR), Sungyeol KIM (National Institute of Forest Science, KR), Kyojung HWANG (National Institute of Forest Science, KR)
09:03~09:06	12	**Durability Performance of Modified Wood under Various Environmental Conditions** Sun Lul KWON (National Institute of Forest Science, Republic of Korea, KR), Jae-Hee JUNG (National Institute of Forest Science, KR), Hyun-Mi LEE (National Institute of Forest Science, KR), Yong-Seok CHOI (National Institute of Forest Science, KR), Won-Joung HWANG (National Institute of Forest Science, KR)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

09:06~09:09	13	**Plasticizer for Poly (vinyl Chloride) (PVC) derived from α-phellandrene** Youngmin CHO* (Seoul National University, KR), Junho SHIN (Seoul National University, KR), Geun Woo HAN (Seoul National University, KR), Jonghwan CHOI (Seoul National University, KR), Hyo Won KWAK (Seoul National University, KR), In-Gyu CHOI (Seoul National University, KR)
09:09~09:12	14	**Lignin-g-PEG Reactive Plasticizers for Cellulose Acetate Films: Role of PEG Molecular Weight in Mechanical, Thermal, and UV-Shielding Properties** Jonghwan CHOI* (Seoul National University, KR), Youngmin CHO (Seoul National University, KR), Junho SHIN (Seoul National University, KR), Geunwoo HAN (Seoul National University, KR), In-Gyu CHOI (Seoul National University, KR)
09:12~09:15	15	**Analysis of Building Energy and Hygrothermal Performance of Mass Timber Buildings: A Case Study of the Han-Green CLT Building** Beom Yeol YUN (National Institute of Forest Science, KR), Hyung Woo LEE (National Institute of Forest Science, KR), Chul-Ki KIM (National Institute of Forest Science, KR), Sang-Joon LEE (National Institute of Forest Science, KR)
09:15~09:18	16	**Quantifying the Economic Impacts of Local Timber Value Chains: A Regional Input-Output Analysis of Chuncheon, South Korea** Eunjeong AHN* (Seoul National University, KR), Yoonseong CHANG (National Institute of Forest Science), Hyunkyu WON (National Institute of Forest Science), Dayoung KIM (Seoul National University, National Institute of Forest Science), Hee HAN (Seoul National University, KR)
09:18~09:21	17	**Regional Economic Impacts of Wood Utilization: The Case of Korea** Yiyang QIAO (National Institute of Forest Science, KR), Chang-Deuk EOM (National Institute of Forest Science, KR), Keon-Ho KIM (National Institute of Forest Science, KR), Dajung KIM (National Institute of Forest Science, KR)
09:21~09:24	18	**Durability and Dimensional Stability of Densified Wood as an Engineered Wood Material** Nayun KIM (Gyeongsang National University, KR), Haedeun PARK (Gyeongsang National University, KR), Hyeonwoo JEONG (Gyeongsang National University, KR), Jiyeong BYEON (Gyeongsang National University, KR), Seong Jin CHANG (Gyeongsang National University, KR)
09:24~09:27	19	**Life cycle assessment of carbon reduction in mid-rise timber buildings incorporating domestic timber supply and reforestation** Hyeonwoo JEONG (Gyeongsang National University, KR), Haedeun PARK (Gyeongsang National University, KR), Jiyeong BYEON (Gyeongsang National University, KR), Nayun KIM (Gyeongsang National University, KR), Seong Jin CHANG (Gyeongsang National University, KR)
09:27~09:30	20	**Effect of Distillation Time on the Yield and Chemical Composition of Leaf Essential Oil from *Abies koreana*** Chanjoo PARK (National Institute of Forest Science, KR), Nahyun KIM (National Institute of Forest Science, KR), Soo-Kyeong JANG (National Institute of Forest Science, KR), Da-Yun SEO (National Institute of Forest Science, KR), Mi-Jin PARK (National Institute of Forest Science, KR)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

09:30~09:33	21	**Carbonized Wood as a Thick Monolithic Electrode for Supercapacitors** Minjee Kang* (Dept of Agriculture, Forestry and Bioresources, Seoul National University), Bat-Uchral Batjargal (Dept of Agriculture, Forestry and Bioresources, Seoul National University), Seonghyun Lee (Dept of Agriculture, Forestry and Bioresources, Seoul National University), Hwanmyeong Yeo (Dept of Agriculture, Forestry and Bioresources, Seoul National University)
09:33~09:36	22	**Sustainable Gel Polymer Electrolytes from Carboxymethyl Cellulose and Xylan-Based Crosslinkers** Junho SHIN* (Seoul National University, KR), Youngmin CHO (Seoul National University, KR), Geunwoo HAN (Seoul National University, KR), Jonghwan CHOI (Seoul National University, KR), Seungoh JUNG (Seoul National University, KR), In-Gyu CHOI (Seoul National University, KR)
09:36~09:39	23	**Comparative Evaluation of Machine Learning Models for Predicting Tree-ring Growth of Quercus mongolica under Climate Change** Yo-Seop LEE* (Chungbuk National University, KR), Jeong-Wook SEO (Chungbuk National University, KR)
09:39~09:42	24	**Glued-in perforated plate (GiP) connection for large-scale timber structures** Zhengyao LI (Chalmers University of Technology, SE), Mahbube SUBHANI (Chalmers University of Technology, SE), Robert JOCKWER (TU Dresden, DE), Mohammad AL-EMRANI (Chalmers University of Technology, SE)

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Guide to the Verification on Timber Legality (VTL)

Korea Forest Service / Korea Forestry Promotion Institute

Korea revised「the Act on the Sustainable Use of Timbers」 and related regulations, and has been fully implementing the Verification on Timber Legality (VTL) system. Importers are required to submit documentation proving that the timber was legally harvested.

1. Background & Purpose

Illegal logging is a major global problem that contributes to forest loss and climate crisis.
The theft, laundering and trade of illegal timber, occurs across the world. Hence, global efforts are essential to halt illegal logging and prevent negative impacts on forestry ecosystems and economies.
Since 2018, Korea has had laws to combat illegal logging and associated trade, and promote the trade of legal timber products. These laws are set out in the Act on the Sustainable Use of Timbers and related regulations.
When you import timber and products including pulp into Korea, you have legal responsibilities and need to check your obligations.

• Products Subject to Import Declaration (12 categories)

Logs
HS 4403

Sawn Wood
HS 4407

Preservative Wood
HS 4407

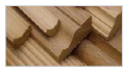
Retardant Wood
HS 4407

Laminated Wood
HS 4407

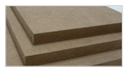
Plywood
HS 4412

Wood Pellets
HS 440131

Wood Sheet
HS 4408


Shaped Wood
HS 4409

Particleboard
HS 4410


Fibreboard
HS 4411

Wood Pulp
HS4701~4705

2. Types of Legality Proof Documents

Pursuant to Article 19-3(2) of the Act on the Sustainable Use of Timber and Article 3 of the Detailed Criteria for Determining Legal Harvesting of Imported Timber:

1. A permit for felling issued pursuant to the statutes of the country of origin
2. Documents internationally recognized to certify legally harvested timber and products
   - Forest Management or Chain of Custody certificates issued by FSC/PEFC
   - certificates issued in accordance with mutual recognition between countries and PEFC
   - certificates issued in accordance with the international verification system for sustainable use of biomass (including a third-party certificates under ISO 17065)
3. Documents mutually recognized through bilateral consultation between the Republic of Korea and the country of origin
4. Any other documents that assure the relevant timber and products have been legally harvested and traded

• Recognized Certificate Types

FSC

PEFC

V-Legal

Annex No.1

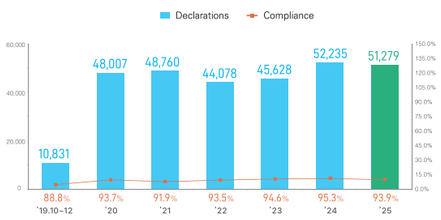
3. Import Inspection Operation

Import Declaration Customs Clearance System (Korea Customs Service)	→ **Transmission** KCS → KFS	→ **Documentation Inspection** The inspection Agency (the KFS system: FOTRA)	→ **Transmission** KFS→ KCS
Customs Declaration (the KCS system: UNI-PASS)	→ **Check of Import Requirements** KCS	→ **Customs Clearance**	→ **Microscopic Analysis** The inspection Agency

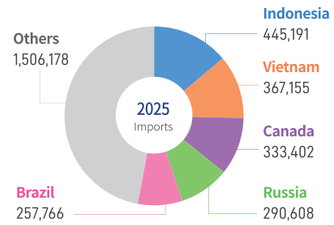
* KCS : Korea Customs Service / KFS : Korea Forest Service

4. Legal Timber Import Status

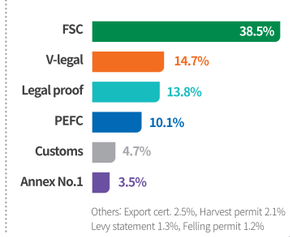
• Annual Import Declarations & Compliance Rates (cases /%)



• Major Importing Countries ('25, thousand USD)



• Major Document Type ('25, top 10)



Forest Products Trade System
https://trade.forest.go.kr

Korea Forestry Promotion Institute
Timber Import Declaration Inquiry Center **1600-2954**

June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 08:30~10:00
Location: Room C
Moderator(s): **Hyo Won KWAK** (Seoul National University)
Guo JUAN (Research Institute of Wood Industry, Chinese Academy of Forestry)

VII-1. IUFRO DIV.5. with 2026 SWST in Korea: Wood Properties and Utilization

08:30~08:45	1	**Tunable-performance sustainable bamboo composites via thinning and bioinspired layered reassembly** Xianke WANG (International Centre for Bamboo and Rattan, CN), Yichen YANG (International Centre for Bamboo and Rattan, CN), Changhua FANG (International Centre for Bamboo and Rattan, CN)
08:45~09:00	2	**A Fully Bio-Based UV-Curable Flame-Retardant Coating Derived from Palm Oil and Phytic Acid for Wood Protection** Wendi LIU (Fujian Agriculture and Forestry University, CN), Zelong CAI (Fujian Agriculture and Forestry University, CN), Yizhen CHEN (Fujian Agriculture and Forestry University, CN), Renhui QIU (Fujian Agriculture and Forestry University, CN)
09:00~09:15	3	**Development of a Palm Oil-Based Bio-Adhesive for Formaldehyde-Free Bamboo Particleboards: Interface Enhancement and Process Optimization** Renhui QIU (Fujian Agriculture and Forestry University, CN), Shiwen HE (Fujian Agriculture and Forestry University, CN), Yizhen CHEN (Fujian Agriculture and Forestry University, CN), Wendi LIU (Fujian Agriculture and Forestry University, CN)
09:15~09:30	4	**A Study on the Preparation of High-Performance Formaldehyde-Free Plywood via In-Situ Polymerization of a Polymerizable Deep Eutectic Solvent** Chenghua WANG* (Southwest Forestry University, CN), Xinyi CHEN (Southwest Forestry University, CN), Xiaojian ZHOU (Southwest Forestry University, CN)
09:30~09:45	5	**Lignin-rich tyloses regulate competitive water-ethanol co-diffusion and suppress hyperswelling in oak wood** Tao SHI (Nanjing Forestry University, CN), Jianxiong LYU (Nanjing Forestry University, CN), Tianyi ZHAN (Nanjing Forestry University, CN)
09:45~10:00	6	**Multi-Scale Oriented Reconstruction and Functional Enhancement of Bio-based Composite Materials** Yue QI (Research Institute of Wood Industry, Chinese Academy of Forestry, CN), Namhun KIM (College of Forest and Environmental Sciences, Kangwon National University, KR), Wenji YU (Research Institute of Wood Industry, Chinese Academy of Forestry, CN), Yahui ZHANG (Research Institute of Wood Industry, Chinese Academy of Forestry, CN)

2026 SWST International Convention
Innovating with Wood: Science and Materials for a Sustainable Future

June 10 (Wed) – Oral Presentations

Date & Time: June 10 (Wed), 10:30~11:45
Location: Room C
Moderator(s): **Hyo Won KWAK** (Seoul National University)
Guo JUAN (Research Institute of Wood Industry, Chinese Academy of Forestry)

VII-1. IUFRO DIV.5. with 2026 SWST in Korea: Wood Properties and Utilization

10:30~10:45	1	*Author-initiated withdrawal*
10:45~11:00	2	**In-Situ Construction of Thermoresponsive Shape Memory Polymer Network to Improve Bamboo's Processability and Mold Resistance** Fangli SUN (Zhejiang A&F University, CN), Ohnmar-Kyaw NAN (Zhejiang A&F University, CN), Xinxing WU (Zhejiang A&F University, CN), Ren XIN (Zhejiang A&F University, CN), Yan ZHANG (Zhejiang A&F University, CN), Hui WANG (Zhejiang A&F University, CN), Shuaibo HAN (Zhejiang A&F University, CN)
11:00~11:15	3	**Wood Structure and Properties for Wooden Cultural Relics Conservation** Guo JUAN (Research Institute of Wood Industry, Chinese Academy of Forestry, CN)
11:15~11:30	4	**Evaluation of tree growth and wood quality for young Paulownia trees planted in Japan** Ikumi NEZU (Utsunomiya University, JP), Umi Latifah Dyah DHARMAWATI (Utsunomiya University, ID), Hikari YOKOYAMA (Utsunomiya University, JP), Jyunichi OHSHIMA (Utsunomiya University, JP), Shinso YOKOTA (Utsunomiya University, JP), Futoshi ISHIGURI (Utsunomiya University, JP), Masashi NIHEI (KKBC, JP), Shigeru KATO (KKBC, JP), Naoki OTANI (Tochigi Pref. For. Res. Cen., JP)
11:30~11:45	5	**Developmental Changes in Cell Wall Structure and Chemical Composition in the Xylem of Pinus massoniana** Jiangtao SHI (Nanjing Forestry University, CN), Shaofei XING (Nanjing Forestry University, CN), Wanzhao LI (Nanjing Forestry University, CN), Weiqi LENG (Nanjing Forestry University, CN)

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Innovating with Wood:
Science and Materials for a Sustainable Future

June 9 (Tue) 08:30~10:00

VI-1. Early Stage Researcher (ESR) 3-Minute Talks

Design of Lignin-Based Hydrogels with Tunable Polyamine Structures for Efficient Pd Recovery and Catalytic Upcycling

Seon-Gyeong Kim* (Seoul National University), **Seungoh Jung** (Seoul National University), **Jungkyu Kim** (Seoul National University), **Junsik Bang** (Seoul National University), **Sangwoo Park** (Seoul National University), **Chaeeun Kim** (Seoul National University), **Dawoon Seo** (Seoul National University), **Dongho Shin** (Seoul National University), **Suhyun Ok** (Seoul National University), **Chaewoo Jeong** (Seoul National University), **Hyo Won Kwak** (Seoul National University)

Corresponding author: bk0502@snu.ac.kr

Abstract

An amine-functionalized lignin-based hydrogel was developed as a multifunctional material for palladium (Pd) adsorption and catalytic reuse. Kraft lignin was chemically modified with ethylenediamine (EDA), diethylenetriamine (DETA), and triethylenetetramine (TETA) to introduce protonatable amine groups and systematically investigate the influence of polyamine structure on Pd adsorption performance. The aminated lignin were subsequently crosslinked with poly(ethylene glycol) diglycidyl ether (PEGDGE), forming three-dimensional hydrogels with porous structures and enhanced structural stability in aqueous environments.

Structural analyses confirmed successful amination and covalent network formation. The physicochemical, morphological, and mechanical properties of the hydrogels varied depending on polyamine type, influencing swelling behavior and active site accessibility. Pd adsorption behavior was evaluated through isothermal and kinetic analyses, revealing that amine density and molecular configuration played a decisive role in adsorption capacity and rate. The adsorption mechanism was attributed to electrostatic attraction and coordination interactions between protonated amine groups and anionic Pd chloro-complexes within the hydrogel matrix.

Following adsorption, the immobilized Pd species were retained inside the hydrogel network and directly converted into catalytically active sites without additional separation processes. The Pd-loaded hydrogels functioned as efficient heterogeneous catalysts for the reduction of hexavalent chromium (Cr(VI)) to trivalent chromium (Cr(III)), demonstrating effective redox activity and structural stability during catalytic operation. The hydrogel matrix provided uniform dispersion and stabilization of Pd species, facilitating electron transfer while maintaining mechanical integrity.

This study demonstrates a sustainable closed-loop strategy that integrates Pd capture and catalytic reutilization within a single lignin-based hydrogel platform. The results highlight the potential of polyamine-functionalized lignin hydrogels as bio-based materials for noble metal recovery and environmental remediation.

Key words

Aminated lignin; Lignin-based hydrogel; Palladium adsorption; Catalytic reuse

Proceedings of the International Convention of
Society of Wood Science and Technology

Influence of Lignin Type and Nano-Microparticles Preparation Method on Properties of PLA Films

Ye-Jin Jeong* (Department of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University), **Jae-Won Lee** (Department of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University)

Corresponding author: ljw43376@jnu.ac.kr

Abstract

In this study, lignin obtained from kraft, organosolv, and deep eutectic solvent (DES) processes was converted into nano-micro particles and then blended with poly lactic acid(PLA) to produce composite films. The film properties were comparatively analyzed as a function of lignin type and nano-micro particles preparation method. Lignin nano-micro particles were prepared to the solvent-antisolvent method, solvent-exchange method, and acid precipitation method, and the composite films were produced by solution casting. The optical properties, thermal stability, surface hydrophobicity, and UV-blocking performance of the resulting films were evaluated. As a result, the particle sizes varied widely depending on the preparation method, ranging from 467 to 2586 nm, and kraft lignin-based particles exhibited the smallest size. This was attributed to the lower molecular weight (949 g/mol) and higher hydroxyl group content (4.51 mmol/g) of kraft lignin compared with the other lignins. The water contact angle increased from 62.38° for neat PLA to 74.03° for the organosolv lignin nano-micro particles composite film, indicating improved hydrophobicity compared with the simple lignin/PLA composite film (70.41°).

Key words

lignin; lignin nanoparticle; biodegradable film

Interfacial Optimization in Fully Biodegradable Biomass Composites: Comparative Analysis of PLA, PBS, and PHA Matrices

Sangwoo Park* (Seoul National University), **Dongho Shin** (Seoul National University), **Junsik Bang** (Seoul National University), **Jungkyu Kim** (Seoul National University), **Seungoh Jung** (Seoul National University), **In-gyu Choi** (Seoul National University), **Hwanmyeong Yeo** (Seoul National University), **Hyo Won Kwak** (Seoul National University)

Program in Environmental Materials Science, Department of Agriculture, Forestry, and Bioresources Seoul National University

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Abstract

The development of fully biodegradable structural composites is essential for advancing carbon-neutral material systems in automotive and industrial applications. Rice straw, an abundant agricultural residue, represents a sustainable reinforcement source however, its intrinsic hydrophilicity and weak interfacial compatibility with hydrophobic polymer matrices limit its structural performance. In this study, Rice straw-derived biomass (RB) and Torrefied Rice straw-derived biomass (TRB, 230 °C under N_2) were systematically compared as reinforcing preforms for three biodegradable matrices: polylactic acid (PLA), polybutylene succinate (PBS), and polyhydroxyalkanoate (PHA). Torrefaction significantly reduced hygroscopicity and enhanced dimensional stability but induced fiber embrittlement. To address this limitation, a nano-structured binder system composed of cellulose nanofiber (CNF), graphene oxide (GO), and lignin-PVA was introduced to fabricate mechanically stable wet-laid preforms, improving fiber integrity and interfacial cohesion. Unlike conventional melt compounding, a solution impregnation technique was employed to maximize matrix infiltration and minimize void formation. The impregnated preforms were subsequently consolidated via hot compression molding. TRS-based composites exhibited improved water resistance and dimensional stability compared to RB systems. Although torrefaction slightly reduced tensile strength, the incorporation of CNF and GO compensated for this loss by reinforcing interfacial load transfer. Among the matrices, PLA composites demonstrated the highest tensile modulus, PBS composites showed superior impact resistance and ductility, and PHA systems provided a balanced mechanical profile with enhanced biodegradability. These findings demonstrate that the combined strategy of torrefaction, nano-binder interfacial engineering, and solution impregnation provides an effective route to upgrade agricultural residues into high-performance fully biodegradable composites.

Key words

Torrefaction; Rice straw preform; Solution impregnation; Biodegradable polymers (PLA/PBS/PHA); Interfacial adhesion; Biobased composites

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Tailoring Lignin Properties via Rational Binary Solvent Design Based on Hansen Solubility Parameter Clustering

Junsik Bang* (Seoul National University), **Sangwoo Park** (Seoul National University), **Jungkyu Kim** (Seoul National University), **Seungoh Jung** (Seoul National University), **Seon-Gyeong Kim** (Seoul National University), **Dawoon Seo** (Seoul National University), **Chaeeun Kim** (Seoul National University), **Dongho Shin** (Seoul National University), **Su Hyun Ok** (Seoul National University), **Chaewoo Jeong** (Seoul National University), **In-Gyu Choi** (Seoul National University), **Hyo Won Kwak** (Seoul National University)

Corresponding author: bk0502@snu.ac.kr

Abstract

Lignin, one of the most abundant biopolymers on Earth, holds significant promise for high-value applications; yet its inherent structural heterogeneity remains a critical bottleneck for valorization. Conventional solvent fractionation methods have largely relied on empirical trial-and-error approaches, which limit reproducibility and scalability. In this study, we present a systematic solvent design strategy that combines k-means clustering of Hansen Solubility Parameters (HSP) with Globally Harmonized System (GHS)-based toxicity screening to rationally identify eco-friendly solvent candidates. This framework enabled us to select ethyl acetate and ethyl lactate as a binary solvent pair, chosen for their structural similarity—sharing an ester backbone that ensures miscibility—and functional complementarity in hydrogen bonding capacity. Using this binary system, a three-step sequential fractionation protocol was established, achieving a total lignin recovery of 88.74% with highly uniform yield distribution across fractions. The fractionated products demonstrated substantially narrowed molecular weight ranges (1,080-4,010 Da) and reduced polydispersity index values (1.76-2.20), with distinct hydroxyl group profiles tailored for downstream applications. Benchmarking against eight published fractionation studies confirmed the superiority of the proposed method in both process efficiency and fractionation resolution. This work demonstrates that HSP-guided rational design can shift lignin fractionation from empirical practice toward a transferable engineering framework applicable to diverse lignin feedstocks.

Key words

Lignin valorization; Solvent fractionation; Hansen Solubility Parameters; Binary solvent system; Eco-friendly process

Tailoring Lignin Nanoparticles (LNPs) by Molecular Drilling and its Characterization

Yoon-Jung Shin* (Department of Wood Science and Landscape Architecture, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University), **Jae-Won LEE** (Department of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University)

Corresponding author: ljw43376@jnu.ac.kr

Abstract

Lignin, which constitutes 15-35% of lignocellulosic biomass, is a promising renewable aromatic polymer containing various functional groups for advanced material applications. However, the low solubility, poor compatibility of lignin with other polymers, and structurally complex heterogeneity limit its direct utilization. Therefore, various methods for lignin modification are introduced. Among these, the fabrication of lignin nanoparticles (LNPs) has attracted considerable attention as an effective approach to enhance processability. In this study, a novel surface engineering method, termed perforin-mimicking molecular drilling, is proposed to control the surface pore structure and reactivity of LNPs. Surface structural control can improve interfacial adhesion with polymer matrices, increase surface hydrophobicity, and enhance barrier properties against moisture and oxygen. LNPs were prepared using lignin extracted form eucalyptus and its structure were analyzed by FTIR, DLS, SEM. Subsequently, molecular drilling was applied for surface modification, and the resulting surface structural changes were analyzed using zeta potential and SEM.

Key words

Lignin; Lignin nanoparticles; molecular drilling

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Control of Aggregation Behavior of Lignin Nanoparticles

EunSun Joo* (Dept. of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University), **Jae-Won Lee** (Dept. of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University)

Corresponding author: ljw43376@chonnam.ac.kr

Abstract

Lignin is an aromatic biopolymer with antioxidant activity, ultraviolet absorption capability, excellent thermal stability, and biodegradability, making it an attractive sustainable functional material. However, low solubility, limited bioavailability, and strong intermolecular self-aggregation of lignin restrict its applications. Lignin nanoparticles provide high specific surface area and typical surface properties, thereby enhancing antioxidant and antimicrobial performance. The preparation of lignin nanoparticles is influenced by π-π interactions between aromatic rings and hydrogen bonding. In particular, the phenolic hydroxyl group plays a critical role in determining particle size and morphology. Nevertheless, lignin nanoparticles dissolve or aggregate under acidic and alkaline pH conditions or in organic solvents, which cause problems in the application of lignin nanoparticles. In this study, organosolv lignin extracted from larch and eucalyptus was chemically modified to regulate the phenolic hydroxyl groups. Lignin nanoparticles were subsequently prepared using a solvent exchange method. In addition, a catalyst was used to prevent lignin aggregation, and changes in particle size over time were systematically analyzed to evaluate colloidal stability and aggregation behavior.

Key words

Lignin nanoparticles; Solvent exchange; Phenolic hydroxyl group; Aggregation behavior; Dispersion stability

Adsorption and Photocatalytic Degradation of Polyethylene Microplastics and Diazinon by KOH-Activated Pine Bark/TiO2 Composites

Ji-Won Yang* (Department of Wood Science and Engineering, Chonnam National University), **Yoon-Jung Shin** (Department of Wood Science and Landscape Architecture, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University), **Yoon Park** (Department of Wood Science and Engineering, Chonnam National University), **Jae-Won Lee** (Department of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University)

Corresponding author: ljw43376@jnu.ac.kr

Abstract

Plastics are extensively used in modern society, leading to significant environmental concerns. Plastic is exposed to the environment and does not decompose easily. It also remains in ecosystems as microplastics (< 5 mm), causing serious impacts on both the environment and human health. Low-density polyethylene (LDPE), commonly used in plastic bags and zipper bags, undergoes photooxidation and biodegradation, leading to surface abrasion and fragmentation. Subsequently, LDPE acts as a carrier by adsorbing and transporting organic pollutants. Diazinon, one of the organic contaminants, is a widely used organophosphate insecticide in agriculture. It can adsorb onto agricultural mulching films and, as these films degrade into microplastics, be transported to other environments, acting as a carrier that poses adverse effects on both humans and ecosystem. In this study, a KOH-activated biochar obtained from pine bark was combined with TiO2 to investigate a coupled adsorption-photocatalysis. KOH activation was performed to maximize the specific surface area of the biochar and introduce oxygen containing functional groups, thereby enhancing the adsorption efficiency for microplastics and diazinon. Furthermore, photocatalytic treatment was carried out to increase cleavage of polymer chains in microplastics, facilitating their conversion into lower molecular weight compounds. The physicochemical properties of the KOH-activated biochar/TiO2 composites were characterized using XRD, FTIR, and BET. The adsorption and photocatalytic degradation efficiency for polyethylene microplastics and diazinon were evaluated.

Key words

Activated biochar; Microplastics; Diazinon; Adsorption; Photocatalytic degradation

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Development of Enzyme-Immobilized Magnetic Biochar/Alginate Beads as an Industrial Enzyme Cocktails

Eun-Ju Lee* (Department of Wood Science and Landscape Architecture, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University), **Jae-Won Lee** (Department of Wood Science and Engineering, Chonnam National University; Interdisciplinary Program in IT-Bio Convergence System, Chonnam National University)

Corresponding author: ljw43376@chonnam.ac.kr

Abstract

Enzymes are biocatalysts widely utilized in biochemical and physiological processes, including wastewater treatment, pulp and paper industries, and biofuel production. However, enzymes exhibit limited stability under environmental conditions such as high temperature and pH, resulting in reduced activity. In addition, the difficulty of enzyme recovery and reuse significantly increases the operational costs of enzyme-based processes. Enzyme immobilization is an effective to retain activity and enhancing thermal and chemical stability, with improved recovery and reusability. Nevertheless, when biochar/immobilized enzymes are applied in enzymatic hydrolysis, separation of enzyme is difficult due to mixing of biochar with biomass substrates. Alginate is a biocompatible material with gelation properties and serves as a suitable matrix for enzyme immobilization. In this study, a single enzyme was immobilized onto magnetic biochar (larch: L-BC/M), followed by encapsulation into alginate beads. The physicochemical properties and catalytic performance of the immobilized enzyme were evaluated through enzymatic hydrolysis. The specific surface area of L-BC was 419.83 m^2/g, whereas that of L-BC/M decreased to 342.02 m^2/g after iron oxide coating, indicating partial pore coverage by the magnetic layer. In the XRD and FTIR analyses, the presence of iron oxide-related characteristic peaks on the surface of L-BC/M were observed. Magnetic property analysis revealed a saturation magnetization value of 33.41 emu/g, demonstrating superparamagnetic behavior. These results confirm the successful coating of iron oxide onto the biochar surface and the formation of magnetic biochar suitable for efficient recovery.

Key words

Magnetic Biochar; Enzyme; Immobilization; Alginate bead

Plasma-assisted enhancement of adhesion strength between alder veneer and thermoplastic LDPE film in veneer-based composites

Jozef Ráheľ (Department of Wood Science and Technology, Faculty of Forestry and Wood Technology, Mendel University in Brno), **Tomáš Pipíška** (Department of Wood Science and Technology, Faculty of Forestry and Wood Technology, Mendel University in Brno), **Pavlo Bekhta** (Department of Wood Science and Technology, Faculty of Forestry and Wood Technology, Mendel University in Brno), **Barbora Mayer** (Department of Wood Science and Technology, Faculty of Forestry and Wood Technology, Mendel University in Brno; Department of Plasma Physics and Technology, Faculty of Science, Masaryk University in Brno), **Marek Nociar*** (Department of Wood Science and Technology, Faculty of Forestry and Wood Technology, Mendel University in Brno), **Michal Šulák** (Department of Wood Science and Technology, Faculty of Forestry and Wood Technology, Mendel University in Brno), **Richard Slávik** (Department of Wood Science and Technology, Faculty of Forestry and Wood Technology, Mendel University in Brno), **Dimitrios Tsalagkas** (Department of Wood Science and Technology, Faculty of Forestry and Wood Technology, Mendel University in Brno), **Jaroslav Panda** (Department of Wood Science and Technology, Faculty of Forestry and Wood Technology, Mendel University in Brno), **Pavel Král** (Department of Wood Science and Technology, Faculty of Forestry and Wood Technology, Mendel University in Brno)

Abstract

Achieving reliable adhesion between hydrophilic wood and thermoplastics is challenging because polyolefins are inherently hydrophobic and chemically inert. Here, alder (Alnus glutinosa) veneer plywood bonded with low-density polyethylene (LDPE) film was enhanced using atmospheric-pressure air plasma generated by a dielectric barrier discharge operated in a corona-like configuration. Four plywood variants were produced to isolate the contribution of surface activation: (I) untreated veneer + untreated LDPE (reference), (II) plasma-treated LDPE with untreated veneer, (III) plasma-treated veneer with untreated LDPE, and (IV) plasma-treated veneer combined with plasma-treated LDPE. Panels were hot-pressed at 130 °C and 150 °C under 0.5, 1.0, 1.5 and 2.0 MPa.

Plasma activation led to marked improvements in mechanical performance. The strongest effect was observed at 1.5 MPa and 130 °C, where the modulus of rupture and modulus of elasticity increased by 16% and 19%, respectively, relative to the reference panels. Wet shear strength testing showed that all LDPE-bonded plywood configurations complied with EN 314-2:1993 requirements. Microstructural evaluation supported these results: optical microscopy and SEM observations revealed a more coherent wood-polymer bondline after plasma treatment, with only limited delamination following water soaking in the plasma-activated samples. Overall, the highest performance was obtained when both the LDPE film and alder veneer were plasma-treated, while single-surface activation of LDPE provided greater improvements than treating the veneer alone.

Key words

alder veneer; low-density polyethylene; plasma; plywood; physical and mechanical properties

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Evaluation of Internal Defects in Pine Wood Using the Indirect Elastic-Wave Method

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Abstract

Wooden architectural cultural heritage can develop internal cracks, decay, and insect-related deterioration as preservation conditions change over time. Because many heritage timber members have experienced long-term environmental exposure and aging, internal defects are often difficult to identify through visual inspection alone. In practice, condition assessment and repair decisions have frequently relied on the experiential judgment of master carpenters, and replacement or reinforcement of members has sometimes been performed without objective and quantitative indicators of material quality. To improve the reliability and transparency of conservation decisions, non-destructive testing (NDT) methods have increasingly been introduced for timber diagnosis. Although direct-transmission wave-based NDT techniques have been widely investigated and applied, their practical use in wooden architectural heritage is often limited because access to opposite surfaces of structural members is restricted by architectural constraints and conservation requirements.

This study evaluates the applicability of indirect ultrasonic and stress-wave NDT methods, in which the transmitter and receiver are positioned on the same surface, for detecting internal defects in timber members. Standard structural lumber of Korean red pine (Pinus densiflora) was first tested to examine defect detectability under controlled conditions using indirect wave transmission. Measurements were conducted with the transmitter–receiver spacing set to 30 cm along the longitudinal direction of the timber, which was determined as the optimal condition through preliminary experiments. The same indirect testing configuration was subsequently applied to aged timber in order to assess practical applicability to wooden architectural cultural heritage. To validate the interpretation of wave-based measurements, resistance drilling tests were performed along selected measurement paths to confirm the presence or absence of internal defects and to provide comparative reference data.

The indirect ultrasonic and stress-wave measurements identified zones suspected of internal deterioration, and the resistance drilling results qualitatively supported the defect locations indicated by the NDT measurements. These findings demonstrate that indirect wave-based NDT methods can provide meaningful diagnostic information even when direct transmission measurements are not feasible. The proposed approach offers a practical and minimally invasive strategy for field-oriented deterioration assessment and has potential to support more objective conservation planning, maintenance prioritization, and decision-making processes for wooden architectural cultural heritage.

Key words

nondestructive testing; indirect ultrasonic testing; stress-wave timing;

A Three-Stage Machine Learning Framework for Physically Consistent Biomass Property Prediction

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Abstract

This study presents a physically consistent three-stage machine learning framework for predicting post-treatment biomass properties during torrefaction and mild pyrolysis. Unlike conventional single-stage multi-output models that treat mass yield, composition, and fuel properties as independent targets, the proposed framework reflects the causal hierarchy of thermochemical conversion by decomposing the prediction task into sequential stages. Stage 1 predicts mass yield using a logit-transformed target to ensure numerical stability within bounded physical limits. Stage 2 models' elemental composition (C, H, O) and higher heating value in a logarithmic enhancement-factor space, enabling mass-normalized learning of compositional enrichment and oxygen removal. Stage 3 predicts proximate analysis variables (volatile matter and fixed carbon) under an explicit closure constraint, with ash determined deterministically to enforce mass balance. Model training and validation were performed using a paired dataset of untreated and thermally treated biomass samples collected from diverse literature sources. Out-of-fold evaluation demonstrated that, although a single-stage baseline achieved high global R2 values (0.90-0.94), it frequently produced physically inconsistent predictions, including violations of proximate closure and implausible heating-value trends. In contrast, the proposed hierarchical framework preserved mass balance and compositional consistency by construction while maintaining competitive predictive accuracy across all targets. External validation using independent literature datasets confirmed robust generalization for composition-driven variables, particularly carbon and oxygen contents, and physically realistic directional trends for HHV. Deviations in MY and proximate variables were primarily attributed to heterogeneous experimental conditions not explicitly encoded as inputs, rather than architectural deficiencies. The final model was implemented in a graphical user interface to enable physically consistent deployment for rapid scenario analysis. Overall, this study demonstrates that structural enforcement of physical principles, rather than algorithmic complexity alone, is critical for reliable machine learning prediction in thermochemical biomass systems.

Acknowledgement

This work was supported by the National Institute of Forest Science (grant number: FP0700-2022-01-2026)

Key words

Biomass torrefaction; Physical constraints; Mass balance; Machine learning; Fuel property prediction;

Proceedings of the International Convention of
Society of Wood Science and Technology

Durability Performance of Modified Wood under Various Environmental Conditions

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Abstract

Wood has served as important biological resource in various industries for centuries. However, its applications are constrained by susceptibility to biotic and abiotic degradation and dimensional instability. To overcome these challenges, modification technologies such as furfurylation and silicification have been developed to improve durability and dimensional stability. The effectiveness of these treatments, however, varies among wood species and origins, underscoring the necessity for systematic evaluation to optimize modification strategies and enhance material performance. The objective of this study was to evaluate the effectiveness and field applicability of furfurylation and silicification treatments applied to Korean domestic wood species, with particular emphasis on assessing their suitability under diverse environmental exposure conditions. Performance was assessed using weight percent gain, equilibrium moisture content, water absorption, anti-swelling efficiency, and resistance to fungal decay. Chemical and structural changes resulting from the treatments were characterized by ATR-FTIR and SEM. Five Korean domestic wood species—Hybrid poplar, Japanese larch, Korean red pine, Radiata pine, and sawtooth oak—were selected to examine the applicability of these modification methods. Field-scale tests were conducted to assess the durability under practical service environments, including above-ground, ground-contact, and marine environments. Furfurylation resulted in higher WPG and demonstrated superior water resistance, dimensional stability, and fungal decay resistance across all tested species. Silicification also enhanced dimensional stability and fungal resistance, although its effectiveness in improving water resistance varied by wood species and treatment type. In above-ground exposure tests, treated specimens retained water repellency, as indicated by water and moisture absorption measurements. In ground-contact environments, all treated samples achieved a durability rating of grade 9 at two test sites after one year, except for specimens treated with 10% silicification. Under marine exposure conditions, specimens treated with furfuryl alcohol at concentrations ≥30% showed no evidence of damage by marine borers. These results confirm the potential of furfurylation and silicification to enhance the durability and performance of Korean domestic wood species, supporting their sustainable use in diverse industrial applications.

Key words

Furfurylation; Silicification; Korean domestic wood species; Durability; Field exposure

Plasticizer for Poly (vinyl Chloride) (PVC) derived from α-phellandrene

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Abstract

Since the first synthesis of polymer, numerous types of polymers have been manufactured and utilized in daily life. The development and advancement of polymers have brought great convenience to humanity, and along with the progress of polymer chemistry, the field of polymer plasticizers—used to improve or reinforce polymer properties—has also evolved. Plasticizers for polymer are additives introduced into a polymer matrix to weaken the intermolecular interactions between polymer chains, lower the melting temperature, and enhance processability. Currently, most plasticizers used in polymers are petroleum-derived phthalate-based compounds. However, these substances can leach out and act as endocrine-disrupting chemicals, posing potential health risks to humans. In this study, we designed wood extractive-derived plasticizer for poly (vinyl chloride) (PVC) by chemically modifying monoterpene to mimic the aromatic ring and ester structure of conventional phthalates-type plasticizers. Specifically, α-phellandrene was reacted with maleic anhydride via a Diels-Alder reaction to obtain a cyclic compound. The resulting product was then reacted with methanol to form a diester structure, and the chemical structure of the final compound was elucidated by NMR analysis. To evaluate its plasticizing performance, the synthesized compound was blended with PVC in the form of films. For comparison, PVC films containing dimethyl phthalate (DMP), which is a conventional plasticizer, were also fabricated. The optical properties of each film were obtained using UV-Vis spectrophotometer. The interactions between each plasticizer and the PVC chains were evaluated by FT-IR analysis, while tensile strength and elongation at break were measured using a universal testing machine (UTM). Thermal properties were further analyzed by thermogravimetric analysis (TGA) and differential scanning calorimetry (DSC).

Key words

Extractives; Poly (vinyl chloride) (PVC); plasticizer

Proceedings of the International Convention of
Society of Wood Science and Technology

Lignin-g-PEG Reactive Plasticizers for Cellulose Acetate Films: Role of PEG Molecular Weight in Mechanical, Thermal, and UV-Shielding Properties

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Abstract

Cellulose acetate (CA) is a promising bio-based polymer, but its brittleness and low chain mobility limit its use in flexible films. Common external plasticizers such as polyethylene glycol (PEG) can improve flexibility, yet they may migrate over time and reduce long-term stability. In this study, we develop lignin-grafted PEG (lignin-g-PEG) as a multifunctional plasticizer for CA films. Technical lignin was grafted with PEG of different molecular weights to adjust polarity, compatibility, and plasticizing efficiency. Lignin-g-PEG was mixed with CA in tetrahydrofuran (THF) and cast into free-standing films.

We investigate how PEG molecular weight influences dispersion and film performance, focusing on tensile properties, glass transition temperature (Tg), thermal stability, and UV-visible transmittance. Film morphology and phase behavior are also examined using SEM and DSC/TGA. Compared with neat PEG, attaching PEG to lignin is expected to lower plasticizer migration and help maintain film properties. By combining plasticization with lignin's aromatic structure, this approach aims to improve flexibility and UV shielding while keeping good thermal stability. Overall, lignin-g-PEG provides a sustainable route to high-performance CA composite films for bio-based packaging and coating applications.

Key words

Lignin-g-PEG; Cellulose acetate; Plasticizer; UV shielding; Mechanical properties

Analysis of Building Energy and Hygrothermal Performance of Mass Timber Buildings: A Case Study of the Han-Green CLT Building

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Abstract

This study evaluates the building energy consumption and hygrothermal performance of the 'Han-Green CLT Building,' the tallest mass timber structure in South Korea, to provide a technical foundation for high-rise wooden construction. To achieve a comprehensive performance analysis, a dual-track simulation approach was employed. First, DesignBuilder was utilized to model the building's thermal environment and quantify the annual heating and cooling loads, specifically focusing on the thermal mass effects of mass timber compared to conventional materials. Second, the hygrothermal behavior of the exterior wall assemblies was analyzed using the WUFI (Wärme Und Feuchte Instationär) program. This dynamic simulation assessed the risks of interstitial condensation and moisture accumulation within the structural layers under South Korea's distinct climatic conditions. The results demonstrate that the integrated design of the Han-Green CLT Building effectively reduces energy demand while maintaining the wood moisture content within a safe range to prevent structural decay and mold growth. By verifying the synergy between energy efficiency and moisture safety, this case study offers practical guidelines for the design and construction of sustainable, high-rise timber buildings.

Key words

Mass Timber Building; Han-Green Building; Building Energy Performance; Hygrothermal Analysis; Wood Moisture Content

Proceedings of the International Convention of
Society of Wood Science and Technology

Quantifying the Economic Impacts of Local Timber Value Chains: A Regional Input-Output Analysis of Chuncheon, South Korea

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Abstract

Establishing a robust local timber value chain is essential for revitalizing regional economies and promoting sustainable forest management. This study quantitatively analyzes the economic ripple effects of developing a regional timber value chain, focusing on Chuncheon, South Korea, where a comprehensive wood industry framework, comprising leading forest management zones and wood industrial complexes, is being implemented. To assess these impacts, we reclassified the 2020 National Input-Output Table to focus on 13 wood-related industry sectors and estimated regional economic indicators using the Location Quotient (LQ) method. Our analysis evaluated the effects on production, value-added, and employment resulting from the wood utilization plans in Chuncheon. The results demonstrate that the establishment of a local value chain significantly stimulates the regional economy. The total economic impact, including indirect effects, was estimated at approximately 45 billion KRW in production inducement and 1,289 jobs in employment inducement. Notably, the processing and distribution stages showed the highest value-added multipliers, highlighting the importance of integrated industrial facilities. These findings suggest that localized timber supply chains can serve as a key driver for regional development, providing a strategic model for wood-friendly cities and sustainable forest-based economies.

Key words

Regional Timber Value Chain; Economic Impact Analysis; Input-Output Model; Wood Industry; Regional Development

Regional Economic Impacts of Wood Utilization: The Case of Korea

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Abstract

Regional variations in forest endowments and wood-based industrial structures shape distinct patterns of wood production and consumption across regions in Korea, leading to heterogeneous economic impacts of wood-related sectors. Expanding domestic wood utilization has therefore emerged as a strategy to promote sustainable resource management and environmental sustainability, while also serving as a potential driver of region-specific economic development. In response to persistent regional imbalance, the Korean government announced the '5-pole, 3-special' regional balanced development strategy in September 2025, designating five regional hubs and three special self-governing provinces to promote balanced growth and a transition toward a multi-polar economic structure. In this context, this study evaluates the regional economic impacts of increased domestic wood utilization across the '5-pole, 3-special' regions. Using the 2020 regional input-output table published by the Bank of Korea, we reconstruct the interregional input-output structure to align with the updated regional classification and estimate output, value-added, and employment effects. Specifically, we design multiple region-specific scenarios, including increases in final demand associated with wood-friendly city initiatives and other wood-based development projects. Scenario simulations are conducted to examine how economic ripple effects vary across regions depending on their industrial composition and linkage structures. The analysis is expected to demonstrate the potential of expanded wood utilization to generate regional economic benefits through output growth, value-added creation, and employment expansion. The findings may serve as a basis for policy initiatives aimed at promoting region-specific wood utilization strategies as a viable instrument for balanced regional development and sustainable industrial growth in Korea.

Key words

Domestic wood utilization; input-output analysis; wood-based industries; economic ripple effects; regional economic development

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Society of Wood Science and Technology

Durability and Dimensional Stability of Densified Wood as an Engineered Wood Material

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Abstract

Densified wood has emerged as a promising engineered wood material due to its substantially enhanced mechanical properties achieved through structural consolidation of the cellular framework. While increased density improves stiffness and strength, long-term durability and dimensional stability remain critical performance factors, particularly because wood is inherently hygroscopic and sensitive to environmental moisture fluctuations. A comprehensive understanding of how densification influences moisture-related behavior and structural integrity at multiple hierarchical levels is therefore essential. This study investigates densified wood from a wood material science perspective, focusing on the interrelationships among densification parameters, microstructural modification, mechanical reliability, and moisture-induced dimensional response. Mechanical performance was evaluated through measurements of stiffness and load-bearing capacity, while dimensional stability was assessed using swelling-shrinkage analysis, set-recovery behavior, and performance retention under cyclic moisture exposure. Particular attention was given to structural transformations within the cellular architecture, including lumen collapse, cell wall densification, porosity reduction, and enhanced intercellular contact. Microstructural consolidation resulting from densification was found to significantly reduce internal void volume and restrict moisture transport pathways. This modification altered hygroscopic response patterns and mitigated moisture-driven dimensional variation. Compared with untreated wood, densified specimens exhibited improved resistance to deformation under fluctuating humidity conditions and demonstrated enhanced structural continuity. The densification-induced reorganization of cell wall components contributed to greater resistance against environmentally induced degradation mechanisms, thereby supporting long-term performance stability. Furthermore, the study clarifies how processing intensity influences the balance between mechanical enhancement and dimensional restraint, highlighting the importance of optimizing densification conditions to minimize set recovery while preserving structural integrity. The findings demonstrate that densified wood can achieve a synergistic improvement in strength, stiffness, and environmental resistance when microstructural modification is appropriately controlled. By elucidating the material-level mechanisms governing durability and dimensional stability, this research provides a scientific basis for performance optimization of densified wood as a high-performance engineered wood material. The results advance fundamental understanding of structure-property relationships in densified wood and contribute to the development of more stable, reliable, and structurally efficient wood-based materials for advanced engineering applications.

Key words

Densified wood; Dimensional stability; Durability; Microstructural modification; Moisture-induced deformation

Life cycle assessment of carbon reduction in mid-rise timber buildings incorporating domestic timber supply and reforestation

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Abstract

Carbon neutrality goals have increased interest in mid-rise timber buildings in Korea as a low-carbon alternative to conventional reinforced concrete construction. However, the large-scale adoption of timber structures requires not only low-carbon structural systems but also a sustainable domestic supply of structural timber. In this context, this study assesses the life-cycle greenhouse gas (GHG) emissions of mid-rise timber buildings by integrating domestic engineered timber, off-site construction (OSC), and reforestation-based material supply strategies to identify carbon mitigation approaches at the structural system level. A comprehensive life-cycle assessment was conducted covering material production, transportation, construction, operation, maintenance, replacement, and end-of-life stages. The structural analysis focuses on engineered timber systems based on Korean larch, applied in cross-laminated timber (CLT) and glued laminated timber (GLT) configurations. The results indicate that Korean larch-based timber structures, particularly when combined with OSC, exhibit lower life-cycle GHG emissions than conventional reinforced concrete structural systems. The application of OSC significantly reduced A5-stage GHG emissions reduced by approximately 30% through shortened construction durations, reduced on-site equipment use, and improved process efficiency. Across the operational, maintenance, replacement, and end-of-life stages, timber-based systems generally showed lower cumulative emission profiles than reinforced concrete systems. In addition to structural system performance, reforestation scenarios were examined to evaluate carbon mitigation potential and resource sustainability of domestic timber supply. Scenario suggests that transitioning forest composition toward timber-suitable, high carbon-sequestering species can enhance carbon uptake, increase biogenic carbon storage, and improve structural timber yield, thereby supporting carbon mitigation and a stable domestic supply of construction-grade timber.

Key words

Mid-rise timber buildings; Life cycle assessment; Domestic engineered timber; Off-site Construction; Reforestation

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Society of Wood Science and Technology

Effect of Distillation Time on the Yield and Chemical Composition of Leaf Essential Oil from *Abies koreana*

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Abstract

Distillation time is a key parameter influencing yield, chemical composition, and fragrance characteristics, and its optimisation is crucial for production. This study is the first to investigate the effect of distillation time on leaf oils from *Abies koreana*, aiming to maximise oil yield and targeted bioactive components for cosmetic applications. Essential oils were obtained by hydrodistillation at 14 different distillation times (1, 3, 5, 10, 20, 40, 80, 120, 160, 200, 240, 280, 360, and 480min), and their yields, chemical profiles, and fragrance characteristics were comparatively analysed. The control (exhaustive hydrodistillation: 20h) yielded 2.82% and was dominated by *D*-limonene, bornyl acetate, camphene, and β-eudesmol. The contents of bioactive compounds associated with whitening and anti-wrinkle properties (α-pinene, *D*-limonene, borneol, and bornyl acetate) varied markedly depending on distillation times. The highest oil yield was obtained at 80min (0.34 ± 0.01%), while targeted components were achieved at 80-160min. Heatmap-based multivariate analysis revealed distinct compositional differences between oils distilled at 80min and 160min, with distillation times shifting fragrance profiles from fresh, monoterpene-rich notes (linalyl acetate, camphor, and fenchol) to longer-lasting, sesquiterpene-dominated aromas (bisabolol and β-eudesmol). Therefore, distillation time significantly influenced *A. koreana* oil, with shorter distillation (80min) maximising yield and longer distillation (80-160min) enriching bioactive components for cosmetic applications.

Acknowledgement

This study was conducted with the support of R&D Program for Forest Science Technology (RS-2024-00403260). The essential oils used in this study was obtained from the Essential oils Bank at National Institute of Forest Science (Seoul, South Korea).

Key words

Abies koreana; essential oils; hydrodistillation; distillation time; oil yield; bioactive components

Carbonized Wood as a Thick Monolithic Electrode for Supercapacitors

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Abstract

Supercapacitors, unlike traditional dielectric capacitors, store energy through the formation of an electrical double layer (EDLC) at the electrode-electrolyte interface. While they exhibit lower energy density compared to batteries, their exceptionally high power density facilitates ultrafast charging and discharging, meeting the growing demand for high-power energy storage systems. To develop greener and more sustainable electrochemical devices, woody biomass has emerged as an abundant and renewable resource. Its natural structural features-specifically, low tortuosity and hierarchical porosity-are highly advantageous for maximizing supercapacitor performance.

In this study, we utilize carbonized wood as a freestanding, thick monolithic electrode to achieve high areal mass loading. We propose a physical investigation into its unique “ordered-disordered hybrid” architecture. Macroscopically, the highly ordered, anisotropic vertical channels of wood provide a low-tortuosity pathway for rapid electrolyte infiltration across the thick bulk. Microscopically, the thermal carbonization process transforms the lignocellulosic cell walls into disordered hard carbon, creating abundant nanoscopic defects and micropores that are thermodynamically favorable for dense ion packing. By controlling the carbonization temperature, we systemically modulate this multiscale porosity. Electrochemical measurements including cyclic voltammetry, galvanostatic charge-discharge were conducted to evaluate areal capacitance and ion diffusion behavior. Through this approach, we aim to establish a direct physical correlation between the multiscale structural traits and the capacitive performance.

Key words

Wood-derived thick electrode; Supercapacitor; Hierarchical Porous Structure; Ordered-Disordered Hybrid

Proceedings of the International Convention of
Society of Wood Science and Technology

Sustainable Gel Polymer Electrolytes from Carboxymethyl Cellulose and Xylan-Based Crosslinkers

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Abstract

Carboxymethyl cellulose (CMC) is a promising bio-derived matrix for gel polymer electrolytes (GPEs) owing to its film-forming ability and abundant functional groups that facilitate network formation. A sustainable polysaccharide-based GPE platform is described in which CMC provides the structural backbone, while xylan-based derivatives serve as tunable crosslinkers to modulate gel architecture and compatibility with liquid electrolytes.

Crosslinked CMC gel polymers are prepared using a series of chemically modified xylan derivatives, enabling systematic variation of crosslinking chemistry and intermolecular interactions. Xylan-based crosslinkers are obtained through representative functionalization routes, including carboxymethylation, amination, oxidation to dialdehyde xylan, and methacrylation. These modifications introduce diverse interaction motifs, such as hydrogen bonding, ionic interactions, and covalent or radical-assisted network formation, thereby offering a modular approach to tailoring network integrity and polarity.

Following membrane formation, liquid electrolyte is incorporated by impregnation to yield GPE membranes. The resulting materials are characterized to establish structure-property relationships, with emphasis on mechanical integrity, thermal stability, and electrochemical properties relevant to electrolyte operation. Comparative assessment across xylan crosslinker chemistries under consistent processing conditions is expected to clarify how crosslinker functionality influences network stability, electrolyte uptake, and ion transport in renewable polymer systems.

Overall, combining a CMC backbone with xylan-derived crosslinkers provides a practical route toward environmentally benign GPE materials and a flexible design framework for bio-based electrolyte membranes.

Key words

Carboxymethyl cellulose; GPEs; Bio-based material; Crosslinker

Comparative Evaluation of Machine Learning Models for Predicting Tree-ring Growth of *Quercus mongolica* under Climate Change

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Abstract

This study aimed to evaluate machine learning models for predicting the radial growth of *Quercus mongolica* at Mt. Gariwang, South Korea, and to analyze how climate change influences this growth. Initially, historical climatic and topographic variables were selected as independent variables. The dependent variable, Ring-Width Index (RWI), was derived from a residual chronology constructed from 38 core samples extracted from 19 trees. The models employed for prediction included Multiple Linear Regression, Spline Regression, Random Forest, and Light Gradient Boosting Machine (LightGBM).

Model accuracy was assessed using R^2, while prediction error was evaluated using root mean squared error (RMSE). Growth trends and pattern consistency between actual and predicted chronologies were validated through leave-one-tree-out cross-validation. Among the tested models, LightGBM demonstrated the highest predictive performance, with an R^2 of 0.442 and an RMSE of 0.082. Cross-dating results further validated the model's accuracy, showing a high time-series agreement (r = 0.979, GLK = 94.4%). SHAP analysis revealed that current-year January and July precipitation exerted the strongest influence on the growth index, displaying varying directional effects dependent on the trees' physiological stages.

Finally, to project future growth changes, four Shared Socioeconomic Pathways (SSP) scenarios (SSP1-2.6 to SSP5-8.5) were applied. Projections indicated overall growth suppression across all scenarios, with the most severe suppression (70.4% of years) occurring under the intermediate scenario (SSP2-4.5) rather than the extreme emission scenario. Because traditional linear models struggle to account for such non-proportional outcomes, these results demonstrate the efficacy of non-linear machine learning. The findings of this study have practical implications for assessing carbon sink vulnerabilities and establishing future forest carbon management strategies.

Key words

Dendrochronology; Quercus mongolica; Machine Learning; LightGBM; Climate Change

Proceedings of the International Convention of
Society of Wood Science and Technology

Glued-in perforated plate (GiP) connection for large-scale timber structures

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Abstract

Glued-in perforated plate (GiP) timber connections are increasingly applied in large-scale timber structures, such as wind turbine towers and high-rise lateral load-resisting systems. These composite connections rely on adhesive penetrating perforated steel plates to form mechanical interlocks known as adhesive dowels. This study investigates the structural behaviour and failure mechanisms of GiP connections through local-scale tests on single- and multi-dowel specimens, examining the relationship between dowel-level response and global connection performance. Results show that well-designed GiP connections achieve high stiffness, strong load-carrying capacity, and adequate ductility, with clear group effects indicating the importance of appropriate dowel spacing. Complementary numerical analyses using linear-elastic and perfectly plastic constitutive models demonstrate that reliable predictions can be achieved without complex nonlinear or damage-based calibration. The findings provide fundamental insight into GiP mechanics and support their use as high-performance alternatives to conventional timber fasteners in demanding structural applications.

Key words

Glued-in perforated plate; adhesive dowels; failure mechanism; stiffness; numerical model.

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Innovating with Wood:
Science and Materials for a Sustainable Future

June 9 (Tue) 10:30~12:00

I-1. Fundamentals and Frontiers in Wood Physics and Mechanics

Intermittent Release of Wood-Emitted d-Limonene: Effects on Indoor Environmental Perception and Autonomic Regulation

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Abstract

Wood is not only a structural material; the volatile organic compounds it releases, such as d-limonene, also serve as key components of indoor olfactory environments. To scientifically evaluate the impact of wood volatiles on indoor human health, this study focuses on the typical wood volatile d-limonene, investigating the regulatory effects of its intermittent release mode in simulated indoor environments on the autonomic nervous system, cognitive performance, and air quality. A randomized controlled experiment (n=36) was conducted under strictly controlled background conditions of temperature, humidity, O_3, and TVOCs, while simultaneously monitoring subjects' heart rate variability (HRV), heart rate (HR), emotional state (POMS), and cognitive task performance.

The results show that compared to continuous release, intermittent release of d-limonene significantly reduces the cumulative level of indoor TVOCs while maintaining stable olfactory perception intensity. This mode effectively increases SDNN heart rate variability, lowers resting heart rate, and the regulatory effect persists even after the olfactory intervention ends. Subjects' emotional state improved significantly, with total mood disturbance (TMD) reduced by 0.53. The study indicates that the release timing of d-limonene is a key factor influencing its environmental efficacy: intermittent release is more suitable for promoting relaxation during rest periods, while it has limited effects on enhancing cognition during continuous work periods.

Starting from the environmental behavior of wood volatiles, this study reveals the relationship between their release dynamics and human physiological responses, providing new scientific evidence for understanding the "non-structural functions" of wood in indoor environments. The findings not only expand the research frontiers of wood physics but also offer theoretical and methodological support for health-oriented indoor environmental design based on the intrinsic properties of materials.

Key words

d-Limonene; Intermittent Release; Heart Rate Variability (HRV);Healthy Built Environment

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Society of Wood Science and Technology

Molecular investigation of bamboo during stress relaxation using custom-built mechanical loading platform coupled with Raman spectroscopy

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Abstract

Spring-in behaviour of bending bamboo products is relevant to the stress relaxation. In this study, a custom-built mechanical loading platform coupled with Raman spectroscopy were acquired in situ during stress relaxation of bamboo under different humidity. Bamboo node has a positive effect on the stress relaxation. The stress relaxation of bamboo decreases from bamboo outer to inner part, and also gradually decreases with the increase in humidity. As the stress increased and then relaxed, the Raman spectral at 1097 cm-1, which indicate the elongation of the cellulose chain bands, shows a decreasing trend followed by an increasing trend, opposite to the change in stress. The Raman spectral band shifts at ambient temperature are larger than those at 90% RH. This corresponds to the results of the simulated cellulose molecular stretching under different moisture contents, which show a larger stress response at lower moisture content. The maximum stress of two cellulose molecular with moisture content of 3.3% and 7.8% are 0.85 GPa and 0.79 GPa, and their corresponding strains at maximum stress are 0.116 and 0.18. The absolute value of the adsorption energy between cellulose molecules and water molecules is twice as large at 7.8% moisture content than at 3.3% moisture content. Furthermore, the stress relaxation under different temperature are also investigated. During relaxation at 60℃ or 80 ℃, the Raman band at 1097 cm-1 first decreased and then increased, or showed a continuous decreasing trend. When bamboo ruptured at 80 ℃, the Raman bands at 1097 cm-1 and 378 cm-1 did not fully recover to their original states. Moreover, a larger spectral shift was observed at higher temperatures, indicating that the stress response of bamboo fiber increases with rising temperature.

Key words

Bamboo; Raman; Stress relaxation

Microscopic observation of the G layer of tension wood using a scanning probe microscope

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Abstract

Tension wood in hardwood species is characterized by the presence of a gelatinous layer (G-layer) in the fiber cell wall. The G-layer is rich in highly crystalline cellulose with a microfibril angle close to zero, providing wood with a high tensile modulus and strong growth stress. During drying, wood containing G-layers often exhibits unusual physical behavior, such as increased longitudinal shrinkage and structural deformation. However, the detailed microscopic morphology of the G-layer after air-drying remains incompletely understood.

In this study, the microscopic surface morphology of the G-layer in tension wood was investigated using a scanning probe microscope (SPM) with high spatial resolution. Samples were obtained from 36-year-old Zelkova serrata trees grown in the Experimental Forest of Nagoya University. Frozen-embedded tension wood specimens were prepared and surface-smoothed using a cryo-microtome. To ensure reproducibility, samples were collected from three different positions within the tension wood. After air-drying at room temperature for 48 hours, surface topography and phase images were acquired using SPM in dynamic force microscopy (DFM) mode. Additionally, laser scanning confocal microscopy (LSCM) was employed to validate the SPM observations over a wider field of view.

SPM observations revealed that the cell wall surface was not uniformly planar. Contrary to previous reports describing collapse of the G-layer after drying, the G-layer regions in this study were found to be either at a similar height to the surrounding S1 layer or locally protruding by approximately 30-100 nm. Height profiles showed alternating protruding and level regions, indicating intrinsic morphological features rather than measurement artifacts. Laser microscopy observations supported these findings at the microscale, clearly distinguishing the G-layer from the S1 layer by their height distribution.

These results suggest that the G-layer may retain a relatively intact morphology in air-dried conditions, possibly due to slower moisture loss associated with its low permeability. Further quantitative evaluation of cell-level moisture content will be necessary to clarify the underlying mechanism.

Key words

Hardwood; Tension wood; G-layer; SPM

Proceedings of the International Convention of
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Dimensional stability and mechanical performance of exterior-grade particleboard and MDF after accelerated aging

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Abstract

Wood-based composite panels are increasingly used in exterior and semi-exposed applications; however, their long-term durability remains insufficiently documented under standardized accelerated aging conditions. This study evaluates the aging performance of industrial exterior-grade panels including a three-layer phenol-formaldehyde bonded particleboard (PB1), a single-layer phenol-formaldehyde bonded particleboard (PB2), and a polymeric methylene diphenyl diisocyanate bonded medium-density fiberboard (MDF). Specimens were subjected to six cycles of the ASTM D1037 accelerated aging protocol involving water soaking, steaming, freezing, oven drying, and reconditioning. Physical and mechanical properties were evaluated in both non-aged and aged conditions, including moisture content, residual thickness swelling (TS), modulus of rupture, modulus of elasticity, in both parallel and perpendicular directions, and internal bond (IB) strength. Vertical density profiles were analyzed to better understand the differences in performance. The results showed significant differences among panel structures. PB2 exhibited the highest dimensional stability with substantially lower residual TS compared to PB1 and MDF. PB1 demonstrated moderate stability suitable for protected outdoor use, whereas MDF experienced the highest degradation in mechanical properties, particularly IB strength, which fell below exterior performance requirements after aging. The specimen orientation had a negligible effect on dimensional stability but affected the retention of bending properties. Vertical density profile analysis indicated that higher surface densification and reduced core permeability improved resistance to moisture-induced damage. Overall, panel structure and adhesive type strongly influence aging resistance. PB2 is suitable for demanding exterior applications, PB1 for semi-protected conditions, and MDF requires protective treatments for outdoor use.

Key words

exterior-grade panels; accelerated aging; thickness swelling; mechanical retention; density profile

Engineering Characteristics of Structural Lumber from Small-Diameter Logs: Small Clear Specimens

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Abstract

Restorative forest thinning is an effective procedure for mitigating risk of outbreaks of diseases, insects and catastrophic wildfires. These procedures generate substantial volumes of small-diameter logs considered low value because of higher processing costs, lower yields and lumber of lower quality than lumber from commercial harvests. Utilization of this material in structural applications is expected to add market value. However, there is limited evidence that lumber from small logs does not meet benchmark modulus values for its visual grade published in National Design Specification (NDS), presumably due to high content of juvenile wood, casting doubts on its suitability for construction and applicability of current grading procedures for that material.

This study is a part of a larger project whose goal is to verify that earlier findings on material better representing the growing region and on broader set of engineering characteristics. If confirmed, the second goal is to revise assumptions and correlations between visual grade markers and strength when applied to lumber from small logs. Like earlier studies, instead of targeting all species removed in forest restoration thinnings in Western forests, this project is focused on Ponderosa pine considered the weakest of Western Wood species.

The specific objective of this study is to compare mechanical characteristics determined on small clear specimens (SCS) of ponderosa pine from small logs with engineering characteristics measured earlier on dimension lumber from the same material, and with published data of characteristics established for commercial harvests. Design values derived from ponderosa SCS are compared to those currently published in the NDS for Western Woods.

Standard methods for determination of strength and elastic modulus in compression parallel and perpendicular to grain and shear parallel to grain on SCS are followed. Design values are derived following ASTM D2555 and D245 standard.

The outcome of this study will be used to verify correlations between properties determined for structural-size lumber and small clear specimens of the same material in comparison with lumber from commercial harvests.

Key words

Restorative forest thinning; Small-diameter logs; Juvenile wood; Design values; mechanical characteristics

Proceedings of the International Convention of
Society of Wood Science and Technology

Moisture-activated set-recovery of thermo-hydro-mechanically densified hardwood dowels for high-tolerance timber connections

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Abstract

Press-fit assembly of dowel-laminated timber (DLT) requires high insertion forces and tight machining tolerances. Thermo-hydro-mechanical (THM) densification provides a moisture-activated shape-memory effect (set-recovery) that can enable high-tolerance installation followed by post-installation tightening, but the attainable expansion pressure and its dependence on material and processing parameters are not yet well quantified. European beech (Fagus sylvatica L.) and black poplar (Populus nigra L.) were THM densified (170 °C, up to 10 MPa) at compression ratios of 27-35% (beech; radial and tangential) and 35-55% (poplar; radial). Moisture-induced free expansion was tracked during cold (20 °C) and hot (100 °C) water uptake; restrained expansion was quantified as swelling pressure; and four-point bending (EN 408) was used to evaluate stiffness and strength. Prototype beech dowels were further analysed by X-ray computed tomography (CT) during end-grain capillary uptake to map the propagation of the expansion front and cross-sectional shape changes. All densified groups exhibited substantially greater total expansion (swelling plus set-recovery) than non-densified controls. Radially densified beech at 35% compression ratio delivered the most favourable balance between mechanical performance and tightening capacity, reaching swelling pressures of 5.7 MPa and approximately 6 MPa total expansion pressure while maintaining a modulus of rupture of about 268 MPa. In contrast, densified poplar showed large free expansion but generated low pressure under restraint (about 1.0-1.2 MPa), indicating that high set-recovery potential alone is insufficient without adequate intrinsic stiffness. CT measurements confirmed anisotropic transverse recovery in densified beech dowels, leading to an elliptical cross-section that concentrates contact pressure and mitigates dowel rotation. These results demonstrate that THM-densified beech dowels can function as moisture-activated, self-tightening connectors, supporting low-force assembly and robust adhesive- and metal-free timber joints.

Key words

THM densification; set-recovery; swelling pressure; dowel-laminated timber; X-ray computed tomography

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June 9 (Tue) 13:30~15:30

I-1. Fundamentals and Frontiers in Wood Physics and Mechanics

Physical and mechanical properties of hardboards (HB) made from acetic acid-modified fibers

Szymon Jaśkiewicz* (Faculty of Wood Technology, Warsaw University of Life Sciences-SGGW), **Eduardo Robles** (University of Pau and the Adour Region), **Grzegorz Kowaluk** (Institute of Wood Sciences and Furniture, Warsaw University of Life Sciences - SGGW)

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Abstract

The modern European wood-based materials industry is facing increasing environmental pressure, forcing reductions in free formaldehyde emissions and a decrease in the share of synthetic binders. There is also a search for materials that are easily degradable in the environment, reducing the problem of waste management. Research focuses on organic materials and on manufacturing wood composites without synthetic resins.

The aim of this study was to modify the wood fibers and to investigate the mechanical and physical properties of the resulting fiberboard.

Wood fibers were modified by treatment with acetic acid. Various concentrations and modification times were applied; the samples were modified at concentrations of 0.25%, 0.5%, 1%, and 2% for 1, 2, and 24 hours. After the specified modification time, the fibrous mass was washed, and then a mat was formed from the obtained material using the wet method. The mats were subjected to preliminary pressing to remove excess water, and the dewatered mats were then pressed in a hot press to produce binderless hardboards.

Samples were conditioned at 65% relative humidity and 20 °C. Basic mechanical and physical tests were performed, including modulus of elasticity, modulus of rupture, internal bond, and screw withdrawal resistance. Tests of physical properties, such as surface water absorption and density profile, were also conducted. The chemical characterization of the material was performed using FTIR analysis, and cellulose was extracted. In addition, microscopic images of the sample surface were taken, and the color of the manufactured samples was examined using a spectrophotometer.

Preliminary data analysis showed a positive effect of fibre modification on the modulus of rupture and modulus of elasticity, depending on time and solution concentration, compared with a reference board produced by the same method using non-treated fibres. Correlations between acid concentration and time effects on the remaining mechanical tests were detected. An effect on the surface water absorption test was also observed, with samples subjected to stronger modification exhibiting higher values. Differences in the color of the samples were also observed. Colorimetric analysis revealed differences in lightness between the samples.

Key words

HB; hardboard; modification; mechanical properties; physical properties

Proceedings of the International Convention of
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Porosity and liquid water absorption capacity of spruce wood charred with different intensities

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Abstract

We studied the effects of surface charring on the porosity and liquid water absorption capacity of Norway spruce (Picea abies) wood, which are important properties for easier assessment of the durability and usability of wood after exposure to fire, which is especially important in construction and restoration work. Pieces of wood of 30 mm thickness were charred in a cone calorimeter according to the ISO 5660-1:2015 standard, with a heat flux of 50 kW/m2. Samples with the dimensions 15 × 15 × 30 mm were sawn from the charred pieces, with which we gradually removed the charred material in layers to study the properties according to the degree of charring of the wood. Five types of spruce wood surfaces were obtained: control uncharred wood (1), minimally charred wood (2), charred wood (3), the base of the charred layer (4), and the charred layer (5). The studies with Fourier transform infrared spectroscopy and X-ray photoelectron spectroscopy revealed the differences in chemical properties of the wood surfaces and the dynamics of liquid water absorption was related to these observations. The average water uptake was highest in samples with a completely charred layer (5; 287.6 g/m2) and lowest in the charred wood layer (3; 125.6 g/m2). We measured the density and indirectly calculated the porosity of the material removed during sample preparation. The density decreased with increasing thermal degradation. The control spruce had a density of 423.82 kg/m3, while the charred layer had a density of 123.08 kg/m3. In contrast, the porosity increased with the degree of charring, amounting to 91.8% for the charred layer and 71.7% for the control wood. The degree of porosity thus increased with the degree of charring, but the water uptake varied depending on the degree of charring of the wood.

Key words

wood; pyrolysis; charred surface; water absorption; porosity

Compatibility Assessment between Picture Frame and Compression-Based Methods for Determining the In-Plane Shear Modulus of CLT

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Abstract

With the rapid growth of mid- and high-rise timber construction, the in-plane shear modulus of Cross-Laminated Timber (CLT) has become a critical mechanical parameter for structural analysis and performance-based design. In Korea, a picture frame test method has been standardized (KS F 2082) to evaluate the in-plane shear modulus of CLT. However, in Europe, an alternative approach based on a 45° rotated compression configuration, as suggested in EN-related procedures, is also employed. As discussions toward the development of an international standard for CLT in-plane shear testing are expected within ISO/TC 165, establishing technical consistency between different test methodologies has become increasingly important. The present study aims to comparatively examine the picture frame method and the compression-based shear modulus evaluation method using CLT panels manufactured from major Korean softwood species, including larch (Larix kaempferi), Korean red pine (Pinus densiflora), and Korean pine (Pinus koraiensis). The primary objective is to assess the compatibility, correlation, and methodological differences between the two approaches in determining the in-plane shear modulus of CLT. Particular attention will be given to differences in load transfer mechanisms, deformation measurement concepts, and shear stress distribution assumptions inherent in each method. By systematically comparing the two test principles, this research seeks to provide a technical basis for evaluating their equivalency or complementary applicability. The findings are expected to contribute foundational data to support international standardization efforts and to facilitate consensus-building during ISO standard development processes. Furthermore, the study aims to enhance the reliability of shear modulus evaluation frameworks used in structural design and numerical modeling of CLT systems.

Key words

Cross-Laminated Timber (CLT); In-Plane Shear Modulus; Picture Frame Test; Compression-Based Shear Test; Test Method Compatibility

Proceedings of the International Convention of
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How Variability of FTIR Spectra Influence Machine Learning Based Wood Species Discrimination

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Abstract

Evolving regulatory frameworks, increasing global demand for timber, and economic pressures have contributed to complex challenges within contemporary timber supply chains. In some cases, timber and derived products enter the market through illegal or unethical channels, labeled with misleading certifications, adulterated species specification, or insufficient documentation of origin. As a result, reliable provenance verification has become a necessity. Various analytical techniques and combinations thereof have been proposed to determine wood species and geographic origin. To ensure practical utilization in real-world contexts, there is a growing need for the development of rapid, cost-effective, and field-deployable identification methods.

Our work combined ATR-FTIR (Attenuated Total Reflectance Fourier Transform Infrared) spectroscopy and machine learning. The results indicate the superiority of linear classifiers for wood species classification with prediction accuracies ranging from 97.2% to 99.6% for best performing classifiers across all samples. Although, spectral variability is a key issue that needs to be accounted for. Across more than 5000 spectra and 20 species intraspecies variability strongly exceeds interspecies variability. In other words, spectra vary more within a single tree than between averaged spectra of many trees of the same species. We identified the origin of this variability to be the varying chemical composition of growth rings. Based on several experiments we found that good prediction accuracy necessitates comprehensive reference spectra, where all anatomical parts (such as pith, heartwood, sapwood, earlywood, and latewood) are included in the analysis.

Further research is needed to assess the applicability of this approach under real-world conditions. The impact of expanding the reference spectral database to include a greater number of species and broader geographic representation on prediction accuracy remains to be determined. Nevertheless, the findings suggest strong potential that the reduced spectral resolution of handheld ATR-FTIR instruments may still provide sufficient discriminatory power for reliable classification.

Key words

Analytical techniques; Infrared spectroscopy; Taxonomy classification

Modification of sorption thermodynamics and hygromechanical coupling in naturally aged structural timber

Aleš Straže* (University of Ljubljana, Biotechnical faculty), **Matjaž Dremelj** (University of Ljubljana, Biotechnical faculty), **Jure Žigon** (University of Ljubljana, Biotechnical faculty), **Anže Zajc** (University of Ljubljana, Biotechnical faculty)

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Abstract

Long-term natural ageing leads to gradual reorganisation within the lignocellulosic cell wall, yet its impact on moisture thermodynamics and mechanical coupling remains insufficiently understood. This study investigates spruce (Picea abies) and fir (Abies alba) structural timber aged 95-391 years, focusing on sorption thermodynamics and the resulting hygro-mechanical behaviour.

Equilibrium moisture content (EMC) was measured at 20 °C under controlled adsorption and desorption conditions. Aged wood consistently exhibited reduced hygroscopicity. At 65 % RH, EMC decreased from 10.7% in recent wood to 9.7-9.8% in aged material (approximately 9% reduction), and at 88% RH from 17.5% to 15.4% (approximately 12% reduction). Application of the Dent sorption model revealed a significant reduction in the saturation of primary sorption sites (u_0) and a decrease in the Gibbs free energy of primary bound water (ΔG_1), indicating reduced availability and an altered energetic state of hydroxyl sorption sites associated with amorphous cellulose and hemicelluloses.

Mechanical testing showed directional changes consistent with this thermodynamic shift. Longitudinal tensile strength ($\sigma t_{\parallel 0}$) increased with age, reaching 80-90 N/mm^2. Specific bending stiffness averaged 21.1 N/mm^2 and did not decrease with age. Dynamic mechanical measurements confirmed higher sound and ultrasonic velocities and increased specific dynamic stiffness in aged wood. In contrast, specific shear stiffness and shear strength in the transverse plane decreased significantly with age. Additionally, viscoelastic and mechanosorptive creep deformability were reduced in aged samples.

The combined thermodynamic and mechanical evidence supports progressive hornification of the lignin-carbohydrate complex, characterised by reduced hydroxyl accessibility, enhanced supramolecular ordering, and restricted polymer mobility. These structural changes weaken moisture-compliance coupling while maintaining or increasing longitudinal stiffness.

Key words

wood; natural ageing; Dent sorption model; Hygro-mechanical coupling; Cell wall hornification

Proceedings of the International Convention of
Society of Wood Science and Technology

Influence of refining parameters on fiber granulometry, surface quality, and mechanical properties of embossed MDF door panels

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Abstract

Medium-density fiberboard (MDF) is widely used in the production of embossed door panels, where refining parameters strongly influence surface quality and mechanical performance. Optimizing refining conditions is therefore essential to obtain high-quality embossed panels with uniform surfaces suitable for priming, painting, or lamination. This study investigated the effects of the refining process on fiber size distribution and MDF panel performance. Three refining parameters were evaluated: digester steam pressure (0.8 and 0.9 MPa), refiner specific energy (70 and 80 kWh/t), and refiner differential pressure (24, 35, and 50 kPa). The panels were evaluated based on their vertical density profile, surface roughness, bending properties, and cleavage strength using polyvinyl acetate (PVAc) and hot-melt adhesives. The results show that digester steam pressure and refiner specific energy are the primary refining parameters governing fiber granulometry, while refiner differential pressure plays a secondary but reinforcing role through interaction effects. Regarding the mechanical performance, the bending modulus of rupture (MOR) and modulus of elasticity (MOE) were significantly influenced by the combination of the three refining parameters. The peak MOR was achieved at low-to-medium steam pressure and specific energy, where fiber length and structural integrity were preserved, avoiding the mechanical degradation associated with excessive pressure and energy. In contrast, the MOE increased with higher steam pressure and specific energy, driven by enhanced fiber plasticization and panel consolidation. The adhesion revealed adhesive-dependent sensitivities: PVAc adhesion was primarily driven by the interaction between steam pressure and specific energy, which enhanced surface-layer development and density gradients. Hot-melt adhesion was influenced by interactions among the three refining parameters, requiring a balance among them to achieve optimal surface wetting and fiber granulometry for effective bonding. Surface roughness remained largely unchanged within the range of refining parameters tested. Overall, the results confirm that balanced refining parameters to optimize fiber size are key to producing MDF panels with well-balanced properties. Specifically, lower-intensity steam pressure and specific energy (0.8 MPa and 70 kWh/t) optimize bending strength, while higher steam pressure, combined with balanced energy and a medium differential pressure (0.9 MPa, 70-80 kWh/t, and 35kPa, respectively), enhances bending stiffness without compromising surface adhesion.

Key words

medium-density fiberboard; digester steam pressure; refiner specific energy; refiner differential pressure; vertical density profile.

Evaluating the Technological Properties of *Quercus laurina* and Q. rugosa for Forest Use Diversification in Mexico

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Abstract

This study evaluates the technological properties of two oak species (*Quercus laurina* and *Q. rugosa*) from San Jerónimo Zacapexco, State of Mexico, to propose diversified, high-value industrial applications and reduce their traditional use as firewood and charcoal. Comprehensive anatomical, physical, and mechanical characterizations demonstrate that these species possess attributes for demanding industrial applications. Anatomical analysis revealed robust cellular structures with thick-walled fibers and the presence of tyloses, particularly in Q. rugosa. Physically, both classify as heavy woods with a basic density between 0.58 and 0.65 g/cm³. This translates into exceptional mechanical strength that outperforms commercial coniferous woods: static bending Modulus of Rupture (MOR) reaches 70-112 MPa, Modulus of Elasticity (MOE) exceeds 11,000 MPa, and Janka hardness tops 450 kgf (approx. 69 N/mm²). However, this high density also correlates with significant volumetric shrinkage (over 15%), requiring strictly controlled drying processes to prevent structural defects like warping or cracking. The findings confirm that the wood from these Quercus species possesses excellent technological aptitude for high-value applications, including heavy construction, flooring, and fine furniture. Locally, transitioning from rustic charcoal production to engineered wood manufacturing offers a crucial opportunity to boost economic development, generate better-paying jobs, and improve living standards in ejidal communities. Nationally, validating the viability of native oak enables import substitution of hardwoods, diversifies the domestic timber market, and promotes sustainable silviculture by granting native forests tangible economic value.

Key words

Quercus spp; anatomical characteristics; physical properties; mechanical properties; wood uses.

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June 9 (Tue) 16:00~18:00

I-3. New Insights into Wood Biology

3D visualization of branched and anastomosed normal resin canals in Pinaceae

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Abstract

This study investigates the anatomy of longitudinal resin canals and fusiform rays in selected Pinaceae species. By employing helical X-ray micro-CT alongside AI-powered segmentation, we were able to visualize 3D features of resin canals which are difficult to derive from 2D sectional images. In particular we observed branched resin canals including: (1) ray-separated short branches in all selected species and; (2) extended Y-shaped branches in white pine (Pinus strobus L.) and southern pine (Pinus spp.). Anastomosis of longitudinal and radial resin canals often occurred at canal margins. Moreover, we observed various types of anastomoses in Pinus, inside or at the ends of axial resin canals. Extended branches of axial resin canals bridged radial canals and ray parenchyma tangentially. We conclude that branching is a ubiquitous feature in selected taxa, and it integrates radial and longitudinal resin canals and their associated parenchyma cells into 3D networks. Furthermore, combining AI with X-ray micro-CT provides a powerful framework for studying complex 3D structures in softwoods and potentially in hardwoods. Virtual reality is a promising tool for presenting such 3D information on the microstructure of wood.

Key words

Wood anatomy; resin canals; X-ray microcomputed tomography; neural network segmentation; virtual reality

Proceedings of the International Convention of
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Genomic Basis of Wood Decay Strategies in Basidiomycetes: Machine Learning Classification and Host Specialization

Natsuki Hasegawa (Graduate School of Agricultural and Life Sciences, The University of Tokyo), **Masashi Sugiyama** (Center for Advanced Intelligence Project, RIKEN), **Kiyohiko Igarashi*** (Graduate School of Agricultural and Life Sciences, The University of Tokyo)

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Abstract

Wood-decaying basidiomycetes are the primary agents of lignocellulose decomposition in forest ecosystems, classified into two functional guilds: white-rot fungi (WRF), which degrade cellulose, hemicellulose, and lignin, and brown-rot fungi (BRF), which selectively attack polysaccharides while leaving a chemically modified lignin residue. Understanding the genomic basis of these contrasting decay strategies is central to both forest ecology and biomass conversion research.

In our first study (Hasegawa et al., Applied and Environmental Microbiology, 2024), we applied linear discriminant analysis and a Random Forest (RF) machine learning algorithm to a dataset of 232 basidiomycetes (183 WRF, 49 BRF), using the gene copy numbers of all CAZyme families as explanatory variables. The RF model achieved over 98% classification accuracy. Feature importance analysis identified AA9 lytic polysaccharide monooxygenases as the most discriminative family, followed by GH7 cellobiohydrolases and AA2 class II peroxidases, enzymes indispensable for crystalline cellulose degradation and ligninolysis in WRF. All CAZyme families of high importance were more abundant in WRF, suggesting that BRF may rely on non-CAZyme-based mechanisms for wood decomposition.

In a complementary study (Hasegawa et al., Journal of Wood Science, 2024, JWRS Best Paper Award), we extended this RF framework to predict host tree specialization, whether a given species preferentially colonizes angiosperms (hardwood), gymnosperms (softwood), or both as a generalist. Training on a dataset of 182 genome samples yielded approximately 80% classification accuracy. CE1 (acetylxylan esterase) emerged as the most important predictor by a wide margin, reflecting the critical role of O-acetyl-glucuronoxylan degradation capacity in determining hardwood accessibility. WRF showed significant CE1 gene number differences between gymnosperm specialists and other groups, while BRF showed no significant CAZyme-based differentiation among host specialization groups, suggesting that alternative mechanisms drive host range in BRF.

Together, these studies demonstrate that RF-based comparative genomics provides a powerful, bias-free framework for dissecting the ecological and genetic diversity of wood-decay basidiomycetes. Ongoing work in our laboratory integrates these genomic insights with biochemical and structural analyses of key CAZymes, toward a mechanistic understanding of fungal lignocellulose deconstruction.

Key words

wood-decay basidiomycetes; CAZymes; machine learning; random forest; host specialization

Bacterial degradation of lignin-modified transgenic poplar

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Abstract

Biotechnology offers a rapid pathway for optimizing wood properties, enabling the development of engineered trees with modified lignin profiles to enhance pulping and biofuel efficiency. A primary challenge in biomass conversion is the recalcitrance of the plant cell wall, where lignin acts as a physical barrier to microbial solubilization. This study investigates the susceptibility of genetically modified Populus trichocarpa with reduced lignin content to degradation by Caldicellulosiruptor bescii, a thermophilic anaerobic bacterium capable of fermenting cellulose and hemicellulose.

Six-month-old stems from two transgenic lines and a wild-type (WT) control were evaluated. Line #54 was generated via down-regulation of the coumarate 3-hydroxylase 3 (PtrC3H3) gene, resulting in a lignin content of 10% and an S/G ratio of 9.9. Line #80 targeted the down-regulation of cinnamyl alcohol dehydrogenases (PtrCAD1, PtrCAD2), resulting in 13.8% lignin content and an S/G ratio of 3.0. In comparison, the Wild-Type control contained 22% lignin with an S/G ratio of 2.1.

Stem segments were incubated for seven days across three conditions: a 25°C control, a 65°C abiotic control, and a 65°C treatment with C. bescii. Cell wall degradation was characterized using a FEI Verios 460L field-emission scanning electron microscope (FESEM) on 1 mm disks and 3 mm longitudinal sections. The results of this investigation will be discussed in this presentation.

Key words

Populus trichocarpa; genetic modification; transgenic tree; thermophilic anaerobic bacteria; field-emission scanning electron microscopy (FESEM).

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Section SEM observations of organelle changes during cell death in ray parenchyma cells in *Cryptomeria japonica*

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Abstract

A detailed understanding of the mechanism of heartwood formation is important for controlling properties of heartwood. The death of ray parenchyma cells is involved in heartwood formation, the analysis of changes in cellular contents during the cell death is an important research topic. Studies on the death of ray parenchyma cells have been conducted based on transmission electron microscopy (TEM) and light microscopy. While light microscopy allows for observation over a wide area, it cannot observe ultra structural details. On the other hand, TEM allows high resolution observation, but it has a limitation of a narrow field of view. Therefore, we applied section SEM to overcome these limitations. The objective of this study was to elucidate the characteristics of the cell death process in ray parenchyma cells in Cryptomeria japonica.

Samples were taken from two individual trees of C. japonica growing in the Chiyoda nursery of FFPRI (Ibaraki, Japan) in December 2021 and July 2024. Samples were fixed by a 2.5% glutaraldehyde solution, followed by post-fixation in an 1% osmium tetroxide solution. These samples were embedded in epoxy resin. Radial sections of 0.2-0.35 μm thickness were prepared using an ultramicrotome. The sections were observed by field emission scanning electron microscopy (FE-SEM, S-4800, Hitachi High-Tech). Images were obtained by a YAG backscattered electron detector under an accelerate voltage of 5 kV.

In both July and December, the following common changes of organelles were observed. The number of vesicles near the endoplasmic reticulum decreased significantly from inner sapwood. Furthermore, a greater change was observed in inner most part of sapwood (intermediate wood). In this region, vacuolization of ray parenchyma cells was observed. Chromatin condensation of nuclei was started from the inner intermediate wood. No organelles were observed in heartwood. On the other hand, enlarged vacuoles were observed more frequently in intermediate wood in July. While significant decrease of proteins in vacuoles occurred from outer sapwood in December, it occurred from inner sapwood in July. Our observations revealed that while common changes occur in both July and December, the timing and frequency of some changes are different.

Key words

Cell death; Cryptomeria japonica; Heartwood formation; Ray parenchyma cell; Section SEM

Anatomical and chemical analyses of artificially induced blackened xylem by wounding of branches in *Diospyros kaki*

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Abstract

Diospyros kaki rarely forms wood with black patterning that is called “kurogaki” in Japan and is highly valued. Understanding the mechanism of blackening of xylem in D. kaki provide useful information for production of highly valued wood. However, there is still limited information about the mechanism of blackening of xylem because kurogaki rarely occurs. Therefore, artificially inducible blackening of xylem would be an effective model for elucidating the mechanisms of kurogaki formation. The objective of this study was to evaluate the usefulness of a model experimental system for kurogaki formation by induction of blackening through wounding of blanches.

We used blanches of *D. kaki* trees growing in the orchard of Tokyo University of Agriculture and Technology (Fuchu, Tokyo, Japan). We collected samples that had been wounded to induce blackening of xylem (induced samples, three individual trees) in July 2021, and samples that had naturally blackened (kurogaki samples, one individual tree), and samples with no accumulation of colored substances (control samples, one individual tree) in March 2020. For microscopic observations, 20-μm-thick transverse sections were cut and observed without staining under a light microscope. For chemical analysis, after extraction of each sample with methanol and ethyl acetate, the extracts were analyzed by gas chromatography-mass spectrometry (GC-MS). We also analyzed 4,8-dihydroxy-5-methoxy-2-naphthaldehyde which is the major extractive of kurogaki (Matsushita et al. 2010).

Coloration of cell walls in secondary xylem cells were observed in wound induced blackened xylem. In addition, accumulations of colored substances in pits, cell lumens and intercellular spaces were detected. Similar accumulation pattern of colored substances was observed in kurogaki. Therefore, diffusion pathway and accumulation of colored substances might be common between wound induced blackened xylem and kurogaki. GC-MS analysis showed that four common peaks were detected between wound induced blackened xylem and kurogaki. Furthermore, one of these peaks was identified as 4,8-dihydroxy-5-methoxy-2-naphthaldehyde based on its retention time and mass spectrum. These results indicate that common chemical components are synthesized both wound induced blackened xylem and kurogaki. Taken together, wound induced blackening of xylem is an useful model for understanding the mechanism of kurogaki formation.

Key words

Blackened xylem; Colored substance; Diospyros kaki; Extractive; Wounding

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Stem wood growth of stomata-sensitive conifers may profit more from the mobile carbon storage accumulated during the post-growing season

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Abstract

Species-specific differences in stomatal behavior under drought conditions may influence seasonal patterns of carbon assimilation and storage, leading to divergent stem wood growth strategies. To test this, we monitored leaf gas exchange, intra- and inter-annual stem wood growth, non-structural carbohydrates (NSC), leaf stoichiometry, and microclimatic variables over three growing seasons in three conifer species with contrasting stomatal regulation in the cold, arid northeastern Tibetan Plateau. The species included Picea wilsonii and Pinus tabuliformis (isohydric, with tight stomatal regulation) and Juniperus przewalskii (anisohydric, with loose stomatal regulation). Our findings indicate that photosynthesis was highest in autumn for all three conifers, with a corresponding accumulation of NSC beginning in the late growing season. This peak was closely associated with increased stomatal conductance following the alleviation of drought stress, rather than with changes in leaf nitrogen concentrations. Notably, the increase in photosynthesis from summer to autumn was significantly greater in the two isohydric Pinaceae species than in J. przewalskii. This pattern aligned with the observed stem wood growth-climate relationships, whereby autumn drought in the preceding year had a stronger negative impact on the stem wood growth of the isohydric conifers than on the anisohydric species. We therefore propose that, in the cold and arid Tibetan Plateau, the stem wood growth of stomata-sensitive species is more dependent on photosynthates accumulated during the preceding post-growing season.

Key words

photosynthesis; stomatal behavior; radial growth; non-structural carbohydrates; Tibetan Plateau

Discovering the anatomical and chemical composition of the corky bark of *Eucalyptus suberea*

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Abstract

Eucalyptus suberea, also known as cork mallee, is an endemic species of Western Australia. This species belongs to the genus *Eucalyptus* and the family Myrtaceae, but unlike other eucalypts, it has thick, grey-yellow, corky bark that may be flaky and yellowish. Visually, as well as after touching, the sensation is similar to virgin cork (*Quercus suber*), meaning that a reasonable amount of suberous tissue is expected in this bark. This was the driving force for the development of this work: i) characterize this bark (which was never made before), ii) to verify the presence of suberin and compare it with the characteristics of cork suberin from cork oak. The chemical analysis revealed a suberin content of 18.5%, which was quite high compared to E. globulus (>1%) [1] but somehow low compared to Q. suber (42.8%) [2]. Despite this, the suberin chemical composition was similar to that of cork oak, in which glycerol (13%), ω-hydroxyacids (48%), and α,ω-diacids (23.5%) were the main components. Besides these, suberin also contained low amounts of vic-diols and epoxides, in agreement with its biosynthetic pathway as mentioned by Serra and Geldner [3]. The second most abundant polymer in the cell wall was lignin, whose content of 22.1% was similar to that of cork oak (22.0%). The monomeric composition revealed a GS-type of lignin, being rich in guaiacyl units, but the presence of syringyl units was also expressive, as proved by an S/G ratio of 0.65, much higher than 0.10 reported in cork from *Q. suber* [4]. Overall, the bark of E. subarea exhibits interesting chemical features for various applications (e.g., compound extraction), but further research is needed to fully exploit the potential of the entire species.

Acknowledgments

FCT funding to CEF (UID/00239/2025).

Key words

Biorefineries; biomass valorization; cork; suberin; lignin.

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2026 SWST
International Convention

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June 9 (Tue) 08:30~10:00

II-2. Designing for Performance and Resilience in Residential Timber Structures

Development of Weather-Resistant Structural Plywood for Temporary Waterproofing During Construction of Mass Timber Buildings: Specification Selection Based on Weathering Tests

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Abstract

As mass timber buildings become more common, reliable temporary waterproofing during construction is increasingly urgent. This is especially critical for fire-resistive assemblies, where leakage through structural plywood subfloors can damage gypsum boards below and create major quality and schedule risks. This study seeks to improve temporary waterproofing by quantitatively evaluating the weather resistance of structural plywood using different surface treatments and panel-joint taping specifications under jobsite-like conditions.

Four-week outdoor ponding exposure tests were performed using 24 mm Japanese structural plywood. Four panels were installed on a mock-up floor frame and nailed to replicate actual floor construction. Six specifications combined: edge treatment (tongue-and-groove machining, urethane coating, or none), surface treatment (urethane coating, film application, water-repellent coating, or none), and joint waterproof tape width (50 or 100 mm). After exposure, the panels were removed and photographed on both faces. Water staining was analyzed as stained area ratios for edges and panel surfaces.

The best performance was achieved by the “urethane-coated surface + 100 mm joint tape” configuration, which markedly suppressed water ingress, particularly from central edges. In contrast, water-repellent coating and untreated panels showed widespread top-surface staining, indicating lower waterproofing effectiveness. Overall, 100 mm tape outperformed 50 mm tape in both workability and water resistance.

The results indicate that while surface treatments reduce face penetration, overall performance also depends on tape adhesion, local defects (e.g., dead knots), and edge treatment, which strongly influences moisture migration to the underside. Urethane coating was consistently effective; however, film-applied panels showed underside staining linked to tape lifting. These findings emphasize integrated waterproofing design that coordinates surface treatment, edge sealing, and installation quality. The proposed specification may support construction rationalization and quality improvement for multi-story timber housing and mid-rise offices, helping stabilize schedules under variable weather. Future work should assess long-term weathering durability, aging-related tape adhesion degradation, and field validation for standardization.

Key words

Mass timber buildings; Structural plywood; Weather resistance; Surface treatment; Edge treatment; Waterproofing performance

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Current Status of R&D on Impact Sound Insulation for Vitalizing Multi-Residential Timber Buildings in Korea

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Abstract

In South Korea, impact sound control in multi-residential buildings is governed by a dual regulatory framework consisting of a pre-certification system and a post-construction verification system. The pre-certification system evaluates the performance of floor structures at the design stage through accredited institutions, while the post-construction verification system verifies compliance through on-site measurements conducted on completed buildings prior to occupancy approval. Under the current framework, a performance criterion of 49 dB or less is applied to both lightweight and heavyweight impact sound, representing one of the most stringent standards worldwide.

The National Institute of Forest Science conducts research to address impact sound regulations for timber-based multi-residential buildings. For the pre-certification system, CLT hybrid floor configurations using various wood species, joint types, and resilient materials are being developed. In July 2024, these research outcomes led to an amendment of the Enforcement Decree of the Housing Act, which had previously permitted only reinforced concrete floor systems. In addition, through collaboration with pre-certification institutions, a standard sound insulation test building for certification is being constructed. For the post-construction verification system, studies using a mock-up test building focus on floor-wall connections, resilient layers, and ceiling structures beneath the floor.

Key words

Multi-Residential Timber Building; Impact Sound Insulation; CLT Hybrid Floor, Mock-up Test

Lateral Resistance Properties of SIP wall Sheathed with Structural PB

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Abstract

The National Institute of Forest Science have been conducted research to make domestic produced structural board for replacing Oriented Strand Board (OSB), which is totally imported material and used in the majority of wooden houses in Korea. Considering the domestic plywood and board manufacturing industry condition, the Particle Board (PB) production process was revised to develop and produce structural PB. In this study, lateral resistance properties were obtained on Structural Insulated Panel (SIP) walls using structural PB as sheeting material. SIP wall system is widely used in North America for their high energy performance, but the system is not adapted in Korea Design Code (KDS). 2×6 lumber (cross-section size: 38×140 mm2) was used as the studs, top and bottom joists, and two sheets of 12 mm thick structural PB were used as the structural sheeting. To investigate the factors affecting the lateral resistance performance of SIP walls using structural PB, SIP walls were manufactured with lengths of 1.2 and 2.4 m, and two types of joints (lumber spline, block spline) were used for preparing the 2.4 m long SIP wall. For the test, the ISO 16670 protocol with 100% displacement of 83.3 mm in accordant with ASTM E2126. As a result, the shear strength and shear stiffness of the 1.2 m long wall were 14.9 kN/m and 3.2 kN/mm. For the 2.4 m long SIP wall, the shear strength and shear stiffness of the SIP wall using lumber spline were 13.9 kN/m and 3.7 kN/mm, and the shear strength and shear stiffness of the SIP wall using block spline were 14.3 kN/m and 3.5 kN/mm. When compared to the horizontal shear performance of SIP walls using OSB as structural paneling previously studied, the 1.2 m long wall showed 85% higher performance in shear strength, and the 2.4 m long wall showed an average of 14% higher performance. In shear stiffness, the performances were 16% and 52% higher, respectively. These results suggest that structural PB can be used instead of OSB in the structural walls of wooden houses, and thus, it is expected to contribute to achieving carbon neutrality.

Key words

Structural PB; Sheathing Material; SIP wall; Wooden House; Lateral Resistance Property

Proceedings of the International Convention of
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Derivation of a New Structural Element for Revising the Fire-Resistant Structural Standard for Light-Frame Wood Structures

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Abstract

Driven by national policies targeting carbon neutrality by 2050, the application of light-frame timber structures in Korea has expanded from single-family housing to multi-family and mid-rise to large-scale timber buildings. As these systems are increasingly used as infill walls and floor assemblies, performance-based evaluation has become essential. Fire resistance, in particular, is a critical requirement for the safe and widespread adoption of timber construction, necessitating systematic technical validation and standardization. Although fire-resistance requirements for light-frame timber structures are specified in the Korean Industrial Standards (KS), limited updates have resulted in outdated structural configurations and material specifications that no longer reflect current construction practices or market conditions. To address these limitations, this study proposes new fire-resistive light-frame timber assemblies to support revisions of the relevant KS standards. A collaborative working group comprising accredited fire resistance testing institutions, timber construction associations, and major manufacturers of light-frame timber components was established. The group evaluated target fire resistance ratings, contemporary construction methods, and the availability of KS-compliant materials, including insulation and gypsum boards. Based on this process, five new structural assemblies were identified: three load-bearing wall systems, one floor system, and one flat roof system. In addition, obsolete terminology in the existing KS standards was reviewed and updated through comparison with current KS documents. Future work will involve full-scale fire resistance testing of the proposed assemblies to enable formal revisions of the KS standards. The proposed approach is expected to reduce testing costs and approval lead times, thereby facilitating broader adoption of timber construction while supporting national carbon neutrality goals.

Key words

Light-frame timber structure; Fire resistance; Korean Industrial Standards (KS); Carbon neutrality

Evaluating Flexible Bondlines and Thermal Enhancement in Wood Composites

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Abstract

Advancing sustainable construction requires high-performance bio-based materials capable of meeting structural, thermal, and long-term durability demands. This presentation merges two complementary research efforts: the DIAMONDS project and the Eco-Friendly Wood Insulation Phase Change Solutions (EWIPCS) project. These projects both address challenges in engineered wood systems through materials science and multi-scale characterization.

The DIAMONDS project focuses on understanding the performance and ageing behavior of flexible polyurethane (PUR) adhesive bonds in engineered wood products subjected to complex hygro-thermo-mechanical loading. Environmental stressors including UV radiation, precipitation, temperature fluctuations, and moisture cycling degrade both wood and adhesive bondlines. This can impact structural reliability in mass-timber elements such as CLT and glulam. Ongoing work in this project combines accelerated and natural weathering, tensile and fracture testing, FTIR analysis, and dynamic-response evaluation using laser vibrometry. Findings show that flexible PURs maintain stiffness but exhibit reduced elongation and moderate strength loss over time, while spectroscopic analysis reveals characteristic oxidation and hydrogen-bond degradation, especially under accelerated weathering.

Complementing these structural investigations, the T4EU-funded EWIPCS project develops thermally enhanced, environmentally benign wood-based materials incorporating nanoparticle-doped phase-change materials (PCMs). Through thermal modification, wood porosity and hydrophobicity are altered to improve PCM uptake and retention. Nanoparticle-enhanced PCMs further increase thermal conductivity, stability, and energy density. Comprehensive testing assesses thermal performance, leakage resistance, dimensional stability, and durability under natural and accelerated weathering.

Together, these projects illustrate a multi-disciplinary approach to sustainable building solutions: enhancing the mechanical resilience of adhesive bondlines in structural elements while simultaneously advancing thermally adaptive, bio-based materials.

Key words

Adhesives; phase-change materials; mechanical testing; wood composites; wood modification

2026 SWST
International Convention

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June 9 (Tue) 10:30~12:00

II-2. Designing for Performance and Resilience in Residential Timber Structures

Design of an Energy Self-Sufficient Disaster Shelter Using Fire-Damaged Timber

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Abstract

The increasing frequency and severity of wildfire events driven by climate change have led to a growing number of displaced populations, thereby intensifying the demand for emergency shelters that can operate sustainably under limited external infrastructure. However, conventional temporary shelters often exhibit insufficient thermal insulation and energy performance, resulting in high energy consumption and operational costs during heating and cooling. At the same time, large quantities of fire-damaged timber generated after wildfires pose significant environmental and economic challenges if not properly managed.

In this context, the present study proposes a disaster-relief shelter system that integrates the resource utilization of fire-damaged timber with a net-zero energy design approach. A 40 ft high-cube (HC) container-based shelter was assumed for a single household, and its annual heating and cooling energy demand was evaluated using dynamic energy simulation. The results indicate that the annual cooling and heating energy demands are 780.86 kWh and 184.19 kWh, respectively, yielding a total annual energy consumption of 965.05 kWh.

To assess the feasibility of energy self-sufficiency, a photovoltaic (PV) system was designed under standard test conditions (STC), assuming a module efficiency of 20%. By incorporating the average solar irradiation conditions in Korea, the required PV installation area was estimated to be approximately 3.10 m^2 to offset the annual energy demand. These results suggest that, for small-scale disaster-relief shelters, the integration of recycled timber resources with renewable energy systems can potentially enable energy self-sufficient operation with minimal reliance on external power supply.

Furthermore, the proposed approach contributes not only to carbon reduction and the mitigation of post-disaster waste through timber resource utilization, but also to improving the quality of temporary housing, strengthening the residential safety net for displaced populations, and reducing long-term operational and national disaster recovery costs.

Key words

Disaster shelter; Fire-damaged timber; Net-zero energy; PV; Simulation

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Energy retrofit for aging building using CLT panels with thermal bridges

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Abstract

Decarbonizing existing building stock increasingly depends on retrofit strategies that pair low-carbon materials with rigorous, defensible performance assessment. In this context, ply-lam cross-laminated timber (CLT) panels are being explored as a sustainable solution for aging public buildings. However, retrofit benefits are frequently overstated when junction-level thermal bridges are simplified, generalized, or omitted. This paper presents an integrated workflow that links detailed three-dimensional junction modeling with whole-building energy simulation to quantify their actual influence quantitatively in practice. Thermal bridge calculations were performed in Physibel TRISCO following ISO 10211, and building-scale impacts were evaluated using calibrated DesignBuilder simulations. Particular attention was given to critical junctions—such as wall-floor and wall-roof connections—where localized heat transfer can compromise both energy efficiency and hygrothermal durability. Results indicate that targeted detailing measures, including selective insulation reinforcement and internal thermal breaks, reduce these vulnerabilities and directly support compliance with established performance and hygiene requirements. Beyond reporting junction-specific effects, the study demonstrates that careful modeling improves the credibility of predicted energy savings, lowers condensation risk, and enhances long-term envelope safety. Overall, the proposed approach emphasizes that material substitution alone is insufficient, and argues for retrofit methodologies that combine material innovation with robust thermal detailing. The findings offer practical implications for policy and design communities developing national retrofit standards aligned with carbon-neutrality goals.

Key words

Cross-laminated timber; Retrofit strategy; Thermal bridge; Energy performance

Optimization of PCM-Integrated Timber Structures for Cold Climate Applications

Hyun Bae Kim* (Chungnam National University), **Minji Kwon** (Chungnam National University), **Takuyuki Yoshioka** (The University of Tokyo)

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Abstract

Light-frame timber structures are recognized for their sustainability and seismic resilience; however, their inherent low thermal mass often leads to significant indoor temperature fluctuations and high heating demands during winter. To mitigate this, integrating Phase Change Materials (PCMs) into the building envelope has been proposed to enhance thermal storage capacity. This study aims to identify the optimal PCM melting temperature for minimizing the annual heating load of a standard timber house in Nagano, Japan (Climate Zone 4). Using EnergyPlus, numerical simulations were conducted on a two-story timber model, employing the Conduction Finite Difference (CondFD) algorithm to analyze transient heat transfer. We evaluated “BioPCM” models with varying melting points ranging from 17°C to 31°C, maintaining a heating setpoint of 20°C. The results demonstrated that PCM integration effectively stabilizes indoor temperatures by delaying the cooling process through latent heat storage. Notably, the PCM with a melting point of 19°C achieved the lowest annual sensible heating load of approximately 2.1 GJ, a substantial reduction from the 3.9 GJ observed in the case without PCM. The benefit diminished as the melting temperature increased beyond 21°C. This suggests that a melting point of 19°C, being closest to the heating setpoint, allows for the most frequent and effective phase transitions within Nagano’s typical winter temperature range. In conclusion, precise selection of PCM melting temperatures, tailored to local climatic conditions and heating setpoints, is crucial for maximizing energy efficiency in timber-frame constructions.

Key words

Phase-change material(PCM); EnergyPlus; Thermal performance; Annual heating load; Melting temperature optimization

June 9 (Tue) 10:30~12:00

IV-2. Ecosystem Services and Biodiversity in Wood Value Chains

Sustainable development from ecosystem services to legality and regulation in forests and forest products

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Abstract

Natural resources of forests with certification are actively discussed in the policy area worldwide and competitiveness is a topical theme. With legality of trade in timber and timber products by policies, EU trade policy has an opportunity in promoting sustainable forestry and deforestation-free value chains. Green Deal aims at resource-efficient and competitive economy. Also, Green Deal strives for economic growth disconnected from resource use. The EU Timber Regulation (EUTR) (Regulation (EU) No 995/2010) will be repealed with the Regulaiton on deforestation-free products entering into application on 30 December 2026. The Regulation (EU) 2023/115 on deforestation-free products (EUDR) aims to diminish greenhouse gas emissions and biodiversity loss.

2026 SWST
International Convention

Innovating with Wood:
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June 9 (Tue) 13:30~15:30

III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

Toward a Renewable Supply of Graphite: Catalytic Biographite Production and Techno-Economic Evaluation for Energy Storage Applications

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Abstract

The escalating global demand for graphite, a primary anode material for lithium-ion batteries, has exposed vulnerabilities in the current supply chain, which is heavily reliant on non-renewable and geographically concentrated resources. This research presents a comprehensive approach to producing biographite, a reliable, renewable, and sustainable alternative to fossil-based graphite. This next-generation graphitic carbon material is synthesized from biomass pyrolysis products, including biochar and fast pyrolysis bio-oil, under moderate conditions, which contrasts with conventional high-energy non-catalytic graphitization practice. This innovative process addresses both technical and economic barriers in the production of high-quality anode active materials (AAM). Catalytic graphitization of biomass-derived precursors enables the sustainable fabrication of AAM with electrochemical performance comparable to that of market-available graphite under moderate conditions. The resulting biographite products demonstrate excellent electrochemical properties, delivering a reversible capacity of ~350 mAh g^{-1} along with remarkable initial Coulombic efficiency and cycling stability over 100 cycles. A conceptual process design of a reaction-separation-recovering sequence was also simulated to understand the technical performance at scale. Cost modeling and risk analysis were introduced to predict the prospective market performance of biographite. Integrating AAM production with liquid biofuels demonstrates the most favorable economic metrics, achieving a minimum selling price of $3.3 per kilogram of uncoated AAM with a preliminary profitability margin of 27%. By utilizing integrated biorefineries, biographite can be competitive with commercial graphite at scales higher than 1500 tonnes per day. This study showcases a promising pathway to secure a domestic supply of critical materials for sustainable energy storage.

Key words

Biographite; Anode materials; energy storage; techno-economic analysis

Proceedings of the International Convention of
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Cellulose Acetate Sulfate Hydrogels as 3D Printing Bio-Inks

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Abstract

Cellulose has attracted attention as a promising alternative to petroleum-based polymers because it is biodegradable and derived from renewable resources such as wood, agricultural residues, and cellulosic waste. However, its strong intra- and intermolecular hydrogen bonding between hydroxyl groups gives cellulose exceptional stability, which also makes it difficult to process into hydrogels. To address this limitation, various strategies have been developed to control or disrupt hydrogen bonding. For example, dissolving cellulose in DMAc/LiCl breaks hydrogen bonds and enables cellulose processing as a solution. Similarly, cellulose nanofibers (CNFs) and cellulose nanocrystals (CNCs), produced via mechanical shear and acid hydrolysis, exhibit enhanced interactions with water due to their disrupted hydrogen bonding structures. Chemical modification of hydroxyl groups is another effective approach, producing derivatives that interact more readily with solvents.

In this study, functional cellulose acetate sulfates were developed through cation exchange of ammonium cellulose acetate sulfate (NH4-CAS) synthesized from cellulose acetate (DSacetyl 1.8) using sulfamic acid. The degree of sulfonyl substitution was tunable from 0.4 to 1 by adjusting sulfamic acid dosage. Conversion to sodium cellulose acetate sulfate (Na-CAS) was achieved through treatment with ethanolic sodium acetate solution, resulting in a water-soluble derivative. After solvent exchange to water and heating at 60 °C, Na-CAS fully dissolved in water and formed hydrogels with tunable rheological properties, including shear-thinning, yield stress, and thixotropy. A 4 wt% Na-CAS hydrogel (DSacetyl 1.8 and DSsulfonyl 0.7) showed optimal performance as a bio-ink for 3D printing. However, due to its water solubility, Na-CAS hydrogels lack structural stability in excess water. This issue was addressed by soaking the hydrogel in calcium chloride solution, enabling further exchange to form calcium cellulose acetate sulfate (Ca-CAS) with ionic cross-linking.

Alternatively, using ethanolic silver acetate solution during NH4-CAS work-up yielded silver cellulose acetate sulfate (Ag-CAS). Notably, Ag-CAS underwent spontaneous reduction during storage, forming silver nanoparticle-incorporated CAS (AgNP-CAS) without external reducing agents, heat, or light. The resulting AgNP-CAS exhibited antibacterial activity against Escherichia coli and Aspergillus niger, highlighting its potential for functional applications.

Key words

cellulose acetate sulfate; hydrogel rheology; 3D-printing bio-ink; in-situ silver nanoparticles

Processing and Characterization of Cellulose-Reinforced Polyamide Composites

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Abstract

This study investigates high-temperature melt-processed polyamide 6 (PA6) composites reinforced with alpha cellulose (AC) and microcrystalline cellulose (MCC) as renewable alternatives to conventional glass and carbon fiber fillers.

Cellulose reinforcements were first characterized by thermogravimetric analysis and X-ray diffraction to evaluate the thermal stability and crystallinity against processing conditions for PA6. Composites containing 5-30wt% cellulose (AC, MCC-1, and MCC-2) were then produced by twin-screw extrusion and subsequent injection molding, and their performance was evaluated using tensile, flexural, impact, and thermal testing. Both MCC samples showed higher onset degradation temperature and crystallinity than AC, which translates to better ability to withstand necessary processing conditions for PA6. At 30 wt% cellulose, Young's modulus and flexural modulus increased substantially when compared to neat PA6, while impact strength decreased with increasing filler loading.

Overall, the results demonstrate that AC and MCC-reinforced PA6 can be processed at conventional temperatures while delivering improved mechanical properties and thermal stability, highlighting their potential for moderately demanding engineering applications.

Key words

Cellulose; Composites; Polyamide; Thermal Stability

Proceedings of the International Convention of
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From Biomass Valorization to Circular Remediation: Fully Biodegradable Hydrogels for Nanoplastic Capture

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Abstract

The rapid accumulation of nanoplastics in aquatic environments demands remediation strategies that combine high removal efficiency with intrinsic environmental sustainability. In this study, we report a hierarchically structured hydrogel derived from renewable lignocellulosic resources for efficient and circular removal of polystyrene nanoplastics (PSNPs). Quaternized wood fibers (QWF) were integrated with chitin nanofibrils (ChNFs) to construct a micro-nano interconnected hydrogel network through physical entanglement and hydrogen bonding, without the use of chemical crosslinkers.

The QWF/ChNFs hydrogel exhibited an open-cell porous architecture and high swelling capacity (>55 g g-1), enabling rapid diffusion of PSNPs throughout the internal structure. The maximum adsorption capacity reached 1,940 mg g-1, with adsorption equilibrium achieved within 2.5 hours. Kinetic and thermodynamic analyses indicated that adsorption was dominated by electrostatic interactions between negatively charged PSNPs and cationic surface groups of the hydrogel, complemented by π-π interactions. Even under real-water conditions (tap water, groundwater, wastewater), the hydrogel maintained adsorption capacities exceeding 750 mg g-1.

Notably, the hydrogel could be regenerated by simple mechanical compression under mild acidic conditions, retaining over 98% of its initial removal efficiency after 30 adsorption-desorption cycles. Following use, the material achieved complete biodegradation within 23 days under ISO 17556 soil conditions.

This work demonstrates that hierarchical design at the micro-nanofiber scale enables simultaneous achievement of high performance, structural resilience, and full life-cycle degradability. The QWF/ChNFs hydrogel establishes a sustainable pathway from biomass valorization to circular water remediation.

Key words

Lignocellulose; Chitin; Hydrogel; Nanoplastic; Adsorption; Sustainability

Towards Sustainable and Recyclable Lignin Fibers: Melt-Spun Lignin Esters with Iron Oxide Nanoparticles

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Abstract

The sustainable valorization of lignin, a major byproduct of the pulping and biorefinery industries, is critical for developing circular, bio-based materials and reducing reliance on fossil-derived polymers. In this work, we present the design, fabrication, and mechanical recycling of melt-spun fibers derived from esterified lignin incorporating iron oxide nanoparticles, demonstrating a scalable strategy toward circular lignin-based fiber materials.

Technical lignin was chemically modified via esterification to tune its thermoplastic properties, enabling solvent-free melt spinning into continuous fibers. The introduction of iron oxide nanoparticles provided additional functional attributes, including magnetic responsiveness, without compromising the melt processability or fiber morphology. Comprehensive characterization confirmed uniform fiber formation, good mechanical performance, and homogeneous nanoparticle distribution throughout the lignin matrix.

To evaluate circularity, the fibers were subjected to multiple melt reprocessing cycles. Mechanical testing and thermal analysis revealed that the fibers retained structural integrity, spinnability, and mechanical strength after repeated processing, highlighting their potential for closed-loop recycling. Notably, the presence of iron oxide nanoparticles did not hinder recyclability, underscoring the compatibility of functional fillers with sustainable lignin-based matrices.

These findings illustrate that lignin, traditionally considered a low-value byproduct, can be transformed into high-performance, reprocessable fibers suitable for advanced applications. The combination of chemical modification, nanoparticle incorporation, and melt processing provides a versatile platform for creating circular lignin materials with tailored functionality. This approach aligns with broader efforts to promote bio-based, sustainable polymers and contributes to closing material life cycles through mechanical recycling.

Overall, this study demonstrates a promising pathway for the production of functional, mechanically recyclable lignin fibers, bridging the gap between lignin valorization and sustainable materials engineering. The strategy has significant implications for bio-based fiber technologies, circular economy initiatives, and the development of multifunctional wood-derived materials, reinforcing the role of lignin as a renewable, high-value polymer for future sustainable applications.

Key words

Wood-derived materials; Lignin; melt-spinning; water purification; circular materials

Proceedings of the International Convention of
Society of Wood Science and Technology

Spray-coating self-assembled Cellulose Nanocrystals on wood: how to create structural colorful and bio-based wood coatings.

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Abstract

Coatings are essential to enhance the durability and aesthetics of wood by protecting it from moisture, UV exposure, and mechanical wear. However, coatings often contain poorly biodegradable or toxic components, which may compromise wood recycling due to the presence of contaminants. In line with recent European guidelines, there is a growing need for reversible, sustainable and fully bio-based wood treatments.

A promising approach to achieve fully bio-based wood coatings lies in mimicking nature's vibrant hues. The fruit Pollia condensata displays an intense blue coloration arising from the reflection of light on hierarchically organized cellulose microstructures within its cell wall, a phenomenon known as structural colouration.

We exploited the unique self-assembly properties of Cellulose Nanocrystals (CNCs), which above a critical concentration formed left-handed chiral nematic phases. The chiral pitch, defined as the transverse distance at which the CNCs undergo a full 360° twist, shrinks upon drying in the order of the wavelength of visible light, resulting in vivid photonic coatings.

A key challenge in the development of CNCs-based coatings on wood lies in the application technique. In this work, we demonstrate for the first time the use of spray-coating to deposit CNCs onto wood substrates. Structurally coated oak assembled-boards were produced. Compared to drop-casting, spray application enhanced color intensity, reduced the coffee-ring effect and promoted a continuous coating layer with fewer defects.

Among the three tested concentrations, the most intense coloration was obtained with 8% wt. anisotropic CNCs. On the contrary, 3% wt. CNCs resulted in the formation of a transparent layer due to the isotropic nature of the deposited CNCs. Thermal treatment at 60°C showed a decupled color intensity with concentrations as low as 6,75% wt. CNCs and a higher water contact angle. Nanoscale self-assembly and pitch organization structures within the spray-coated CNCs layer were observed using Atomic Force Microscopy and compared with drop-casted coatings. Ongoing work investigates multilayer coating strategies combining transparent isotropic and coloured CNC layers.

This study provides fundamental insights into CNC-based wood coatings and highlights spray-coating as a scalable route toward sustainable, structurally coloured wood coatings compatible with future recycling strategies.

Key words

Cellulose Nanocrystals; Wood coatings; Structural colour; Spray-coating

Bonding Performance of Wood with Renewable Bio-Based Shellac Adhesive

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Abstract

Shellac, traditionally used in wood coatings, also represents an underexplored renewable and biodegradable alternative for wood bonding. This study systematically assessed the adhesive performance of six different shellac types under both cold- and hot-pressing conditions, bonding European beech lamellas (EN 205:2016). Cold-pressed dry bond strengths ranged from 1.4 to 9.5 MPa, with shellac type SH2 performing best; this type was then further evaluated under hot-pressing conditions. Results confirmed that thermal treatment induced polycondensation, forming a crosslinked polyester network that enhanced thermal stability, increasing the glass transition temperature from approximately 40 °C in native shellac to 90 °C after curing at 200 °C. The highest dry bond strength was achieved with hot-pressing at 175 °C, with a shear strength of 9.8 MPa, but this was not significantly different from the shear strength of cold-pressed samples. Increasing the temperature to 200 °C resulted in a statistically significant decrease in bond strength to 8.2 MPa, due to thermal degradation of wood tissue, which was not significantly different from the shear strength of 8.5 MPa achieved at 150 °C. None of the pressing parameters satisfied the D1 requirements for dry strength, which is at least 10 MPa. To improve bonding performance, shellac SH2 was modified with citric and phosphoric acids to enhance crosslinking and mechanical integrity. Results from the Automated Bonding Evaluation System (ABES) showed that increasing the addition of citric acid from 2.5% to 20% increased the lap shear bond strength between two beech veneers. Adding 1.7% phosphoric acid in addition to citric acid further increased the shear strength. Press temperature significantly affected the development of adhesive bond strength over pressing time. The results for bond strength development were modelled using the Hill and Logistic models. The best results were achieved at 175 °C, which were then used to specify pressing time for standardized shear tests and to evaluate whether the best shellac adhesive mixture could be classified into D1 and D2 durability classes.

Key words

Bio-based material processing; renewable adhesive; shear strength; shellac; wood bonding

Proceedings of the International Convention of
Society of Wood Science and Technology

Smooth, self-standing cellulose nanopaper composite and its applications

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Abstract

This study developed cellulose nanopaper (CNP) fabricated from cellulose nanofibrils (CNF) and cellulose nanocrystals (CNC), crosslinked with citric acid (CA). To fabricate the CNP, a CNF suspension was cast on sapphire, and the dried film was either immersed in a CA solution for esterification or directly peeled off from the substrate and hot-pressed. Various tests were conducted to investigate the chemical composition, crystallinity, morphology, tensile strength, and other fundamental properties of CNP. The CNP exhibited a smooth and dense surface morphology, replicating the sapphire substrate surface. The addition of CNC altered the optical transmittance and improved the Young's modulus of CNP. Successful esterification was confirmed by signals in the Fourier-transform infrared spectrum, reduced water uptake, and increased decomposition temperature. With these enhanced properties, CNP has demonstrated promising performance in printing technology and oil-water separation applications. In printing technology, the smooth CNP substrate enabled precise pattern transfer with clear microscale features observed under an optical microscope. In oil-water separation tests, the esterified CNP allowed water flux while blocking most of the oil. These results indicate that CNC reinforcement and CA crosslinking strategies effectively tailor the properties of CNP and broaden its applicability across different functional fields.

Key words

Cellulose nanomaterials; cellulose nanopaper; esterification; nanocomposite, printing

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Innovating with Wood:
Science and Materials for a Sustainable Future

June 9 (Tue) 16:00~18:00

III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

Metal-Ion-Induced Microfibril Engineering of Cellulose and Its Applications

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Abstract

Cellulose is an abundant biopolymer that provides structural integrity to plant cell walls through a hierarchical microfibril network. While naturally hydrophilic, cellulose can be engineered at the molecular level to achieve advanced functionalities by manipulating its crystalline and amorphous regions. This work explores metal-ion-modification (MIM) as a transformative strategy for the microfibril engineering of cellulose. By coordinating multivalent metal cations (e.g., Fe3+, Zr4+) with lignocellulose microfibrils, a robust crosslinking network is induced that facilitates a transition from hydrophilic to hydrophobic behavior.

This molecular-level design enables the creation of high-performance hybrid materials, such as hydrophobic membranes for efficient oil-water separation (>99.5%) and PFAS-free coatings for molded fiber packaging. Unlike traditional synthetic treatments, this metal-ion-ligand network effectively closes the porous fiber network, enhancing water and grease resistance while maintaining the biodegradability of the final product.

Overall, metal-ion-induced microfibril engineering serves as a scalable, top-down approach for converting renewable biomass into value-added products. This design principle provides a sustainable pathway for the next generation of functional materials, ranging from environmental remediation tools to advanced packaging, while eliminating reliance on persistent synthetic chemicals.

Key words

Multivalent metal cations; crosslinking; microfibril engineering; hydrophobization; packaging

Proceedings of the International Convention of
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Silica-supported carboxymethylated kraft lignin for the sequestration of transition metals in wastewater

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Abstract

The sequestration of heavy metals in wastewater using economically viable and environmentally friendly renewable sources is a constant trend for sustainable adsorbent materials. In this study, lignin isolated from the residual liquor of the kraft cooking process of Eucalyptus wood was carboxymethylated (DS of 0.41) in a pilot-scale trial and immobilized on mesoporous silica (0.5 mm particles) using a vacuum impregnation process to obtain a lignin-silica hybrid composite. Approximately 4.3% (w/w) of carboxymethylated kraft lignin (CMKL) was incorporated into the silica, causing a reduction of only 8.8% in the specific surface area of the silica and about 10% in the pore volume. The lignin deposition mode on silica was studied using SEM-EDS and AFM. It has been suggested that lignin extensively coats both the outer surface and the inner pores of silica, in the form of unevenly distributed round-shape particles with sizes between approximately 40 and 200 nm. It was proposed that lignin interacts strongly with silica both by hydrogen bonding and by dispersion forces thus explaining its minimal leaching in water at pH <7. The study on the sequestration of Cu(II), Cd(II), and Pb(II) by lignin-modified silica in aqueous solutions (10-5 mol L-1, pH 6) was carried out using conventional batch method. The metals concentrations were monitored using respective ion-selective potentiometric chemical sensors with chalcogenide glass membranes or the activated screen-printed carbon electrodes. The efficiency of CMKL in scavenging Cu(II) and Cd(II) decreased by almost half when supported on silica, but remained the same with respect to Pb(II) adsorption. The adsorption of metals was better described by pseudo-second-order kinetics than by first-order kinetics. Analysis of the Elovich kinetic model allowed to conclude that, during the initial stages of adsorption, the mechanisms are dominated by chemisorption for all metals. However, the presence of heterogeneous surfaces with non-uniform binding sorption energies, suggesting multilayer or structurally irregular adsorption sites, has also been suggested as being particularly important for Cd(II) adsorption. These results provide design guidelines for future lignin-based hybrid adsorbents that operate at realistic trace metal concentrations.

Key words

kraft lignin; Eucalyptus; carboxymethylation; lignin-silica hybrid; transition metals; ion-exchange composite material; adsorption kinetics

Accelerated Thermal Stabilization for Lignin-based Carbon Nanofibers via In-situ UVC Irradiation during Electrospinning

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Abstract

Lignin is a promising precursor for sustainable carbon nanofibers (LCNFs) due to its high carbon content and renewability. However, the prolonged thermal stabilization process required to prevent fiber fusion during high-temperature carbonization remains a critical bottleneck in the commercialization of LCNFs. This study proposes a novel and efficient approach to significantly accelerate the stabilization of lignin nanofibers (LNFs) by integrating UVC irradiation directly into the electrospinning process.

In this work, UVC lamps were positioned to irradiate the polymer jet during the Taylor cone formation and flight phase of electrospinning. The primary objective was to induce immediate radical formation within the lignin molecular structure. These photo-induced radicals initiate cross-linking reactions prematurely, reducing dependence on the slow, diffusion-controlled oxidative stabilization typically required during subsequent thermal treatments.

Electron spin resonance was utilized to quantify the radical density generated in the LNFs by UVC irradiation. Furthermore, chemical and structural transitions during the stabilization process were observed, validating that these changes serve as a key mechanism for shortening the overall thermal stabilization time. Experimental results confirmed that UVC-treated LNFs maintain their fibrous morphology even at a heating rate of 3 °C/min, a 10-fold increase compared to the 0.3 °C/min required for non-irradiated LNFs. This drastic improvement demonstrates the potential to substantially reduce total processing time.

Furthermore, the impact of this photo-induced stabilization on the final carbon microstructure after high-temperature carbonization was investigated using X-ray diffraction and Raman spectroscopy. This study demonstrates that in-situ UVC irradiation is a transformative strategy to overcome the kinetic limitations of lignin processing, offering a faster and more energy-efficient pathway for the production of high-performance green carbon materials.

Key words

Lignin-based carbon nanofiber; Electrospinning; UVC irradiation; Radical formation; Accelerated thermal stabilization

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Bio-Based Crosslinking of PVA/Chitosan Composite Films Using Water Soluble Dialdehyde Cellulose for Moisture-Resistant Active Packaging

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Abstract

Poly(vinyl alcohol) (PVA)/chitosan (Ch) composite films are promising biodegradable materials for sustainable packaging due to their excellent film-forming ability and inherent antibacterial activity. However, their practical application is limited by poor water stability resulting from the hydrophilic nature of both polymers. In this study, water-soluble dialdehyde cellulose (sDAC) was introduced as a bio-based crosslinker to improve the moisture resistance of PVA/Ch composite films. Chemically crosslinked films containing 1-10 phr sDAC were prepared and evaluated for water stability, moisture barrier properties, antioxidant and antibacterial activities, and food preservation performance. Crosslinking occurred mainly through Schiff base reactions between aldehyde groups of sDAC and amino groups of chitosan, along with hemiacetal linkages involving hydroxyl groups. Only the sDAC-crosslinked films retained structural integrity after water immersion, confirming effective network formation. Water vapor permeability decreased with increasing sDAC content, indicating the development of a denser crosslinked structure. The antioxidant and antibacterial properties of the films were preserved after crosslinking. In strawberry storage tests, sDAC-crosslinked films delayed fungal growth and reduced surface deterioration compared with non-crosslinked films. These results demonstrate that sDAC is an effective bio-based crosslinker for producing moisture-resistant PVA/Ch films suitable for sustainable packaging applications.

Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education(No. RS-2018-NR031068).

Key words

Poly(vinyl alcohol); Chitosan; Dialdehyde cellulose; Crosslinker; Packaging

Nanocellulose Reinforced PRF Resin in Extrudable Wood Composites for Potential Additive Manufacturing Applications

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Abstract

This study investigated the effect of nanocellulose (NC) addition (1 and 3%) and phenol resorcinol formaldehyde (PRF) resin age on the properties and performance of extrudable wood composites. Three types of NC sources were evaluated, (i) crystalline nanocellulose (CNC), bleached cellulose nanofibers (BCNF) and unbleached cellulose nanofibers (UBCNF). The NC samples were characterized by X-ray diffraction (XRD), Fourier transform Infrared spectroscopy (FTIR) and microscopy for chemical and structural properties. The curing behavior of the PRF was determined by differential scanning calorimetry (DSC), where an increase of its exothermic peak temperature was correlated with the presence of nanocellulose. Dynamic rheometry was employed to investigate the flow characteristics of the PRF and the onset of gelation and vitrification with temperature of the NC-PRFs. The addition of NC increased the flexural properties of PRF and the fresh PRF outperformed the aged PRF. Wood (50%) was blended with NC-PRF (50%) preparations and extruded into composite rods. The Wood-NC-PRF composites were evaluated for their rheological (flow) behavior. The cured composites were evaluated for their flexural, water absorption, and thermal properties and will be discussed. The extruded composites showed promise for use in applications such as additive manufacturing of building materials.

Key words

Nanocellulose; Extrudable composites; Thermoset resin

Proceedings of the International Convention of
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Enabling Highly Reversible Zinc Metal Batteries by Wood-based Cellulose Nanomaterials

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Abstract

Aqueous zinc metal batteries have been a promising alternative for lithium metal batteries due to their high theoretical capacities and excellent safety, however, the poor stability of zinc anode still present a serious challenge. Thus, wood-based cellulose nanomaterials are utilized to enable highly reversible zinc anodes. Firstly, a protective solid-electrolyte interfacial layer consisting of lignocellulose nanofibers (LCNF) and MXene was developed to stabilize the zinc anode. The LCNF serves as a desolvation layer to suppress the water-induced parasitic side reactions on the zinc anode. Secondly, the pristine LCNF membrane was fabricated to be as a water-gating and zinc-sieving separator for dendrite-free zinc anode. Such this bifunctional separator demonstrates good mechanical properties and superior ion transport properties, accompanied by the complete degradation within 14 days in the natural soil. Moreover, a Janus membrane with asymmetrical proton transport for cross communications harmony in Zn-V batteries was exhibited for an energy-dense practical zinc metal battery. The LCNF-rich side enables proton-selective transport and captures dissolved vanadium, while the MXene-rich side inhibits the formation of zinc dendrites. Furthermore, a dual-network LCNF-based hydrogel electrolyte was prepared to confine the water activity for high-energy and dendrite-free zinc metal batteries. This hydrogel electrolyte widens the electrochemical voltage window and suppresses the zinc dendrite growth of zinc metal batteries. In addition, the cationic cellulose nanofiber was employed to enlarge the iodine loadings and improve the stability of the cathodes even at high temperatures. These studies provide valuable strategies for the development of high-performance, sustainable zinc metal batteries.

Key words

Zinc metal batteries; Stable zinc anode; Wood-based cellulose nanomaterials; Dendrite suppression

Green Construction of High-Performance Biochar/Wood-Based Functional Composites Driven by Hydroplasticization

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Abstract

This work presents a green strategy for constructing high-performance functional composites by integrating biochar with wood using a hydroplasticization-driven approach. Hydroplasticization enables room-temperature shaping and self-densification of wood, achieving ultra-high flexural strength (483 MPa) without energy-intensive hot-pressing. Biochar particles derived from bamboo are incorporated into the wood matrix to form a conductive core-shell structure, delivering exceptional electromagnetic interference shielding effectiveness (72.4 dB) with absorption-dominated performance. The resulting composites exhibit excellent mechanical strength, thermal stability, and a significantly reduced carbon footprint compared to metals and plastics. This study demonstrates that hydroplasticization serves as an effective platform for transforming renewable biomass into sustainable, high-performance functional materials for applications in electronics packaging, construction, and beyond.

Key words

Hydroplasticization; Biochar; Functional composites; Wood-based materials; Sustainability

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Proceedings of the International Convention of
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Investigation of Fungal Resistance of Wood-Fiber Insulation Boards

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Abstract

Fungal degradation of bio-based construction materials compromises structural integrity, thermal performance, and indoor air quality. This study evaluates the fungal resistance of innovative thermal insulation materials produced via hydromechanical wood fiber processing without synthetic binders. For the testing, eleven wood-staining fungal strains including Aspergillus spp., Trichoderma spp., and Penicillium spp. were isolated from local sawmill environments. The results showed significant differences in mycelial growth, with coverage reaching up to 80% depending on the fungal consortia group. In almost all cases, contamination of the samples resulted in different surface pigmentation (brown, green, and black). Evaluation of the impact of the major wood-destroying basidiomycete, Coniophora puteana, showed significant mass losses ranging from 30% to 50%, depending on the technical parameters used in pulp formation during the material production. Samples treated with a water-soluble preservative demonstrated high bio-efficacy against wood-destroying and wood-staining fungi, showing no surface contamination or mass loss. The study results highlight the urgent need for protective solutions for biomaterials that ensure their durability without compromising their environmental performance.

Key words

Bio-based insulation; Wood fiber processing; Fungal resistance; Wood-destroying fungi; Material durability

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June 9 (Tue) 08:30~10:00

IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts

Global Land and Carbon Consequences of Mass Timber Products

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Abstract

Mass timber products can reduce greenhouse gas emissions by replacing steel and cement. However, the increase in wood demand raises wood prices, and the environmental consequences of these market changes are unclear. Here we investigate the global carbon and land use impacts of adopting mass timber products, focusing on cross-laminated timber (CLT) as a case study. We develop an interdisciplinary modeling framework that integrates economics, ecology, and LCA to quantify the interactions among demand, supply, forest management, and land use at both regional and global levels. This framework integrates the Global Timber Model, GTM, with process-based LCA models to quantify the direct and indirect land and carbon implications of emerging wood product demand from 2020 to 2100. This framework is applied specifically to CLT, a common mass timber product. The LCA quantifies the life-cycle GHG emissions associated with CLT, traditional wood products, and substituted products (e.g., concrete, steel, electricity). This study compares a baseline scenario without future CLT demand with three alternative CLT demand scenarios to examine the effects of CLT demand on the timber market. Our results show that higher wood prices reduce the production of traditional wood products but expand productive forestland by 30.7-36.5 million hectares from 2020 to 2100 and lead to more intensive forest management. If the cumulative global cross-laminated timber production reaches 3.6 to 9.6 billion m3 by 2100, long-term carbon storage can increase by 20.3-25.2 GtCO2e, primarily in forests (16.1-17.7 GtCO2e) and in cross-laminated timber panels (4.1-8.1 GtCO2e). Including emission reductions from steel, cement, and traditional wood products, the net reduction of life-cycle greenhouse gas emissions will be 25.6-39.0 GtCO2e. The results suggest that it would be reasonable to subsidize the demand for CLT as a GHG mitigation strategy. By increasing the market value of timber, the subsidy would provide an additional market incentive to maintain the world's existing forest. Given the difficulties of regulating global land use, this subsidy would be a practical tool to increase carbon storage in forests. This study has been published in 2025 (Lan et al., Nature Comm., 2025).

Key words

Mass timber products; cross-laminated timber; greenhouse gas emissions; global timber model; life cycle assessment; carbon stock; forest land

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Second Life Structures: From CLT Waste to Circular Furniture

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Abstract

The journey of creating circular furniture from Cross-Laminated Timber (CLT) for the Floating Grove pavilion illustrates the concept of circularity. This presentation will explore the diverse forms of circularity involving textiles, individuals, and organizations, focusing on three main areas: material waste, collaboration among individuals, and institutional involvement.

For the Floating Grove pavilion, we sourced lumber from Jordan Lumber in North Carolina and Cross-Laminated Timber from Evergreen. During the pavilion's production, a significant amount of waste was generated. Addressing this material waste is a key focus of our initiative. After completing the project, the committee continued to meet and recognized that the pavilion was incomplete without furniture to enhance the space and overall aesthetic. To avoid random picnic tables or unattached items cluttering the area, we decided to design custom furniture specifically for the Floating Grove. Once the project was finished, the leftover materials were donated to the Sustainable Materials and Technology program, which led to the idea of recycling them into furniture for the pavilion.

Previously, we contacted Laura Olson at Trashy, a company that specializes in outdoor furniture made from a lightweight concrete mixed with densified recycled Styrofoam. Collaborating with Trashy allowed us to design furniture under the committee's guidance. Once the team finalized the design, we decided that a group of students, led by me, would oversee the development process. The design incorporates Trashy's material for the tabletops and seat tops, while the legs and bases are made from recycled CLT waste. A unique aspect of our furniture is that we use recycled Styrofoam sourced from NC State University, effectively repurposing our own waste in the production process.

The final element of circularity involves the institutions involved. Not only did we engage students from NC State's College of Natural Resources, but we also collaborated with those from the College of Design. Our industry partners, Laura Olson and her associate, Liz Tracy from Trashy, are both graduates of NC State University. This project truly exemplifies the principles of circularity across materials, people, and institutions.

Key words

Circular Economy; Cross-Laminated Timber (CLT); Cross-Institutional Collaboration; Waste Repurposingy

Has Anything Changed? An Overview of Perceptions, Use, and Understanding of Cross-laminated Timber in the U.S. South: 2018 & 2025 from the Perspective of Architects, Non-Residential Builders, and Engineers

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Abstract

Cross-laminated Timber (CLT) was first manufactured and used in building construction in Europe in the early 1990s, although product development goes back to 1980s with the first patent from France. CLT was later introduced into North American building markets in the early 2000s. The first CLT manufacturer in North America started production in 2010 in Canada, followed by the U.S. in 2012. North American (CLT) production and use in building has grown significantly in the Pacific Northwest and eastern Canada, while CLT manufacturing and construction in the U.S. South using southern yellow pine (SYP) has been on a slower trajectory. The literature is sparse regarding drivers, perceptions, awareness, and potential involvement in the CLT supply chain in the region. Given this, in 2018, a study was conducted at the Louisiana Forest Products Development Center, Louisiana State University Agricultural Center, to better understand the dynamics of CLT market knowledge, perceptions, and adoption targeting influencers - architects, engineers (architectural, civil, and structural), non-residential builders. This study was replicated in 2025. Results examine changes that have occurred between these years. The most salient results show that the most important characteristics in specifying structural construction materials for both periods were: Structural Performance, Durability Over Time, and Economic Performance. Structural materials specified/used: Plywood & OSB also remained the same (78% of respondents) while CLT increased from 7% to 20% and Mass Plywood Panels increased 3% to 6%. A general understanding of CLT increased from 52% of respondents to 57%. Reasons for specifying/using CLT relative to steel or concrete (ranked): Cost-Cheaper material costs; Speed of construction; Aesthetics look of wood; Sustainability-Net Carbon Impact For companies not currently using CLT, 37% said they would do so in the future, and 8.8% increase. Main Concerns with specifying/using CLT: (ranked): Compatibility with Building Codes; CLT Availability; General knowledge of CLT In general, in 2025, 72% of respondents thought CLT use in the South would increase, an increase of 20% from 2018.

Key words

Cross-laminated Timber; Adoption; Perceptions; U.S. South; Architects; Engineers; Non-Residential Builders; Temporal Study: 2018 and 2025.

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Use of agricultural residues in the production of lignocellulosic composites with a reduced carbon footprint

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Abstract

The decarbonization of wood-based panel production requires systemic strategies that simultaneously address fossil-derived resin dependency, raw material sourcing, and waste valorization. Conventional particleboards rely heavily on formaldehyde-based synthetic adhesives and timber feedstocks, both of which contribute to greenhouse gas emissions and pressure on resources. This study proposes an integrated circular approach that combines two underutilized agricultural by-products - Jerusalem artichoke stems and feather-derived keratin - into a lower-carbon particleboard system.

Jerusalem artichoke (Helianthus tuberosus L.) is a fast-growing perennial crop cultivated primarily for its tubers, while its lignocellulosic stems remain largely unexploited. Previous research has demonstrated that boards produced from these stems using commercial UF and pMDI resins can meet EN 312 P2 requirements, confirming their technical feasibility as a wood substitute. However, the environmental impact associated with synthetic adhesives remains unresolved.

In parallel, poultry feathers represent a significant protein-rich waste stream with limited high-value applications. Keratin extraction enables valorization of this by-product, yet adhesive performance strongly depends on the extraction process. While alkaline hydrolysis has been widely studied, enzymatic extraction offers a potentially less chemically intensive pathway with improved sustainability performance.

This study investigates the feasibility of producing three-layer particleboards using enzymatically extracted keratin from duck feathers as the primary adhesive component in panels manufactured from (1) industrial wood particles and (2) Jerusalem artichoke stem particles. Mechanical and physical properties are evaluated in accordance with EN 312 to assess structural applicability.

The central hypothesis assumes that enzymatically extracted keratin can enable substitution of synthetic formaldehyde-based resins while maintaining functional board performance. By integrating two agricultural waste streams into a single composite system, the proposed approach aims to reduce fossil carbon inputs, reduce reliance on formaldehyde, and enhance resource efficiency in particleboard manufacturing. The study contributes to the development of circular material strategies that support climate mitigation and sustainable value-chain transformation in the wood-based panel sector.

Key words

keratin; Jerusalem artichoke; particleboard; eco-binder; agricultural residues;

End-of-Life Management of CCA-Treated Vineyard Posts in Australia: Circular Economy Opportunities, Constraints and Policy Pathways

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Abstract

The circular economy (CE) aims to retain materials at their highest value for as long as possible through reuse, recycling, and recovery pathways. Despite its growing prominence in policy and industry discourse, implementation remains limited for chemically treated timber, particularly chromated copper arsenate (CCA)-treated products. In Australia, CCA-treated vineyard posts constitute a significant and expanding end-of-life (EOL) waste stream. It is estimated that more than 1.5 million posts, equating to over 15,000 tonnes of material, are removed annually, with the majority currently disposed of in landfill. This practice represents a substantial loss of embedded material value and raises environmental concerns associated with long-term contaminant management.

This presentation critically evaluates a range of non-landfill alternatives for managing EOL CCA-treated vineyard posts within a CE framework. The options assessed include repair and reuse, reprocessing into particleboard, incorporation into wood-cement and wood-plastic composites, thermochemical conversion via pyrolysis, and energy recovery through controlled combustion processes such as cement kiln co-firing. Each pathway is examined in terms of technical feasibility, environmental performance, economic viability, and regulatory compliance within the Australian context.

The analysis indicates that while several alternatives are technically feasible, their large-scale adoption is constrained by a combination of systemic barriers. These include inconsistent regulatory frameworks across jurisdictions, high costs associated with collection, transport, and processing, concerns regarding contamination and worker safety, and negative market perceptions of treated timber reuse. Among the options considered, repair and direct reuse—particularly as secondary fence posts—offer the highest circular value and lowest energy input, yet remain significantly underutilised due to logistical and perception challenges.

Thermochemical pathways, such as pyrolysis, and industrial applications like cement kiln co-firing, demonstrate strong potential for higher-volume diversion from landfill, especially where effective immobilisation or capture of heavy metals can be ensured. The research concludes that enabling circularity for CCA-treated timber in Australia will require harmonised national regulations, the development of product stewardship schemes, targeted investment in processing infrastructure, and the integration of carbon accounting mechanisms to appropriately value material recovery pathways.

Key words

Product Stewardship; Timber Circularity; Treated timber; Waste hierarchy

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Integrating Design for Disassembly and Adaptability (DfD/A) in timber buildings - A qualitative study on the design process

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Abstract

A paradigm shift from linear construction models toward more circular approaches is imperative to mitigate climate change. Wood represents a crucial opportunity in the built environment due to its environmental properties, making it particularly suitable for construction practices, following circular economy (CE) principles. Although renewable, wood is a finite resource, which makes it essential to keep it in circulation as long as possible.

Design for Disassembly and Adaptability (DfD/A) emerges as a powerful architectural strategy by enabling buildings and components to be deconstructed, recovered and repurposed over time, thus extending material lifecycle, enhancing resource efficiency, and aligning closely with CE and climate-mitigation objectives. This technique can also respond to social needs, strengthen resilience by allowing reconfiguration, extension or relocation as household needs, demographic or urban conditions evolve.

However, despite growing interest in both DfD/A and CE, relatively little is known about how these principles are interpreted and implemented in architectural practice, especially in the context of timber architecture. This study addresses that gap by exploring architects' experiences with DfD/A in timber projects through qualitative methods, conducting semi-structured interviews. The analysis focused on motivations, key design features, and barriers encountered in real design processes.

The study concludes with practice-oriented recommendations for integrating DfD/A in timber architecture, highlighting its potential to reduce waste, extend the service life of residential timber structures, and contribute to circular, low-carbon, and socially responsive built environments.

Key words

Design for disassembly and adaptability; timber architecture; circular economy; resource efficiency; resilience.

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June 9 (Tue) 10:30~12:00

IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts

Hydrothermal recycling of copper from wooden utility poles and railway sleepers

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Abstract

Copper-treated wood represents a significant environmental challenge at the end of its service life due to the presence of copper that hinder safe disposal and recycling. Large volumes of decommissioned railway sleepers and utility poles are generated each year worldwide, and conventional disposal routes, including landfilling or incineration, pose environmental risks such as leaching of toxic metals and contamination of soil and water. These challenges underscore the urgent need for sustainable management and valorization strategies that can mitigate environmental impact while recovering useful components.

Hydrothermal liquefaction (HTL), a thermochemical conversion process that transforms wet biomass into hydrochar, light- and heavy-oil under subcritical water conditions, offers a promising pathway to valorize copper-containing wood waste. Depending on the process conditions, the hydrochar and oils will have different properties, and copper may either remain in the solid phase or be partially transferred into the oil. In this study, railway sleeper wood chips (oil-based copper preservative-treated Fagus sylvatica wood) and utility pole wood chips (copper ethanolamine-treated Pinus sylvestris wood) were processed separately. Each material was individually mixed with water at a 1:6 (w/w) ratio and subjected to hydrothermal liquefaction at 330 °C for 2 hours. The resulting light oil fraction was collected after each run. This procedure was repeated twice for both the railway sleeper and utility pole samples. Untreated Fagus sylvatica and Pinus sylvestris wood chips were processed separately under the same hydrothermal liquefaction conditions and used as control samples. The light oil fraction obtained from HTL of copper-treated railway sleepers and utility poles will be chemically characterized to determine the copper content. Its antifungal activity will be evaluated at different concentrations against the brown-rot fungus Coniophora puteana to assess its potential for wood protection applications.

This study will provide a first step toward exploring potential cascade uses of copper-treated wood after the end of its service life, transforming a hazardous residue into valuable products. By demonstrating the chemical properties and bioactivity of HTL-derived light oil, it will contribute to developing sustainable strategies that convert treated timber waste into functional materials, thereby creating new value streams and reducing environmental hazards.

Key words

Circular economy; copper-treated wood; hazardous waste; hydrothermal technologies; valorization

Proceedings of the International Convention of
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Circular economy, copper-treated wood, hazardous waste, hydrothermal technologies, valorization

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Abstract

The increasing production and consumption of wood-based panels, such as particleboard and medium-density fiberboard (MDF), generate substantial amounts of post-industrial and post-consumer waste. At the same time, the availability of virgin lignocellulosic raw materials is becoming increasingly limited and costly in many regions. Circular economy strategies therefore promote the recovery and reuse of wood-based materials in order to extend resource utilization and reduce the environmental burden associated with panel production. Although recycled wood particles are already used industrially, the combined utilization of particles derived specifically from recycled MDF and particleboard remains insufficiently characterized, particularly with respect to their influence on bonding quality and dimensional stability.

The objective of this study was to evaluate the feasibility of manufacturing three-layer particleboards using particles obtained by mechanical grinding and sorting of post-consumer and post-industrial MDF and particleboard. Experimental boards with a thickness of 16 mm and a target density of 700 kg/m^3 were produced. Recycled MDF particles were incorporated into both face and core layers at levels of 0%, 5%, 10%, 25%, 50%, 75%, 90%, 95%, and 100%, replacing particles derived from recycled particleboard.

Mechanical performance was evaluated by determining bending strength (MOR) and modulus of elasticity (MOE) according to EN 310, internal bond strength (IB) according to EN 319, and screw withdrawal resistance (SWR) according to EN 320. Physical performance was assessed by thickness swelling (TS) according to EN 317, water absorption, and density profile measurements. Microscopic observations and FTIR spectroscopy were used to characterize particle morphology and chemical features of the recycled materials.

The results demonstrated that particle type strongly influenced bonding performance. Boards containing higher proportions of recycled particleboard particles exhibited higher internal bond strength and fulfilled standard requirements, whereas increasing MDF particle content resulted in reduced IB values. Screw withdrawal resistance showed limited sensitivity to particle composition. All board variants exhibited favorable dimensional stability, with thickness swelling values meeting standard requirements. The results indicate that mechanically recycled MDF and particleboard can be effectively utilized in particleboard production, although maintaining a sufficient proportion of particleboard particles is essential to ensure adequate internal bond strength.

Key words

recycled wood composites; particleboard; MDF recycling; internal bond strength; circular utilization

Mycelium Composites as Partial Substitutes for Timber in CLT to Reduce Pressure on Timber Resources

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Abstract

Timber can be a sustainable material when forests are managed sustainably, which means that harvest rates do not exceed growth, rotation periods allow biomass and soil to recover, and adequate land is available to meet demand. Given rising global consumption and the many conditions required for truly sustainable production, complementary materials that can partially substitute timber are of growing interest. Mycelium-based composites have recently attracted attention as potentially low-impact materials: fungal mycelium can bind agricultural and wood-industry by-products into lightweight bio composites, often with modest inputs and short growth cycles. Here, we evaluate mycelium composites for load-bearing applications with the long-term goal of replacing one lamella in cross-laminated timber (CLT). Composites were produced by inoculating a ligninolytic fungus, Trametes versicolor, onto hardwood sawdust and allowing it to colonize the substrate. After growth, the material was shaped in molds for compression, tensile, and shear testing, then inactivated by thermal treatment; a subset of specimens was hot-pressed to 75% of their original thickness to increase density and stiffness. Preliminary results indicate promising compressive and tensile responses relative to density, whereas shear performance remains a limiting factor for use in CLT, where rolling shear capacity is critical. Further improvements in interfacial bonding, fiber reinforcement, and hybrid layups are needed before structural integration and code compliance can be considered.

Key words

Bio-based composites; Climate Mitigation; CLT; Mycelium composites; Structural performance

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Development of a Catalogue of Innovative Bio-Based and Sustainable Wood Composites for Design Applications

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Abstract

In an era of growing environmental awareness and the urgent need for sustainable design, quick access to systematized knowledge about modern raw materials is becoming crucial. The aim of this project is to develop a comprehensive, periodically updated compendium that serves as a practical tool for designers seeking alternatives in bio- and eco-friendly wood composites.

The study divides the gathered material database into two main categories: commercialized materials ready for implementation in large-scale production, and experimental materials currently in the research and development (R&D) phase. The catalogue compiles their key physical and functional properties. Furthermore, the work analyzes selected wood composites in terms of their practical applications in design and Life Cycle Assessment (LCA), facilitating the conscious selection of raw materials for specific applications.

An innovative and distinguishing element of the project is the inclusion of medical aspects related to the use of catalogbio- and eco-friendly wood composites in the catalogue. As part of the work, an original system of allergological pictograms was proposed. Based on an analysis of available scientific literature, this system enables rapid identification of the allergenic potential of a given raw material.

The project represents a fundamental step toward creating a reliable database for the design industry (with the prospect of being expanded to include detailed studies of surface and strength properties). It supports creators in making decisions and choosing solutions that are both helpful in design and environmentally friendly, and safe for end-user health. By integrating material performance data with LCA indicators and user health considerations, the proposed catalogue creates a decision-support framework aligned with circular bioeconomy principles. The tool has the potential to reduce environmental impacts at the material selection stage, where a significant part of a product's life-cycle footprint is determined. In this way, the project contributes to climate mitigation strategies by enabling informed substitution of high-impact materials with sustainable wood-based alternatives.

Key words

ecological materials; biomaterial; sustainable design; wood composite innovation; design compendium.

Development of an Optimization Model for Green Supply Chain Management of Domestic Wood to Maximize Greenhouse Gas Reduction Effects

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Abstract

Forests and harvested wood products (HWPs) play a critical role in mitigating climate change by sequestering atmospheric CO2 and substituting carbon-intensive materials. To enhance the forest sector's contribution to National Determined Contributions (NDC), this study developed a Green Supply Chain Management (GSCM) optimization model specifically tailored for domestic wood utilization in South Korea. We conceptualized the domestic wood supply chain as an integrated system encompassing silviculture, harvesting, manufacturing, utilization, and disposal. Using a Life Cycle Assessment (LCA) approach, we quantified greenhouse gas (GHG) mitigation and emission factors across all stages. The optimization model functions as a decision-support tool, evaluating carbon flows under various policy scenarios and ecological constraints to derive optimal reduction pathways. The analysis revealed that while harvesting causes a temporary decline in cumulative GHG reductions, the synergistic effect of reforestation and the carbon storage/substitution provided by HWPs leads to a recovery of cumulative reductions within approximately 31 years. Notably, expanding the proportion of long-lived wood products by 20% increased cumulative reductions by 5.42% and shortened the carbon recovery period by three years. These findings provide a robust scientific basis for formulating sustainable domestic wood utilization strategies and establishing effective national GHG reduction pathways in the forest sector.

Key words

Green Supply Chain Management (GSCM); Greenhouse Gas Reduction; Life Cycle Assessment (LCA); Harvested Wood Products (HWP); Optimization Model; Climate Change Mitigation

Proceedings of the International Convention of
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Analysis of Domestic Unused Forest Biomass Supply Trends and Sustainable Potential in South Korea

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Abstract

As South Korea pursues its 2050 Carbon Neutrality goals, unused forest biomass—residues like branches and tops from timber harvesting—is becoming a vital renewable energy source. This study analyzes supply trends and resource potential to suggest a sustainable utilization model. National statistics from 2019 to 2024 show that the supply of unused forest biomass grew rapidly, peaking at 1.51 million tons in 2023. This growth was driven by the Renewable Portfolio Standard (RPS) policy. The main sources are timber harvesting (34%), land-use changes (18.5%), and wildfire-damaged wood recovery (16.3%). Using GIS-based modeling, the theoretical potential is estimated at 276.5 million tons, but technically accessible potential is 106.4 million tons. Considering the annual forest growth rate, the sustainable annual supply is calculated at 4.58 million tons. Currently, Korea utilizes only about 33% of this sustainable potential. A significant issue is that utilization is heavily concentrated in specific regions near large-scale wood fuel manufacturing facilities, such as wood pellet plants. This geographical imbalance means many forest-rich areas remain under-utilized. The study concludes that South Korea must transition to a strategic supply system based on regional resource potential. This approach is essential to maximize resource efficiency by reducing logistics costs and to support balanced regional development by creating jobs in forest-dependent rural communities. Policy efforts should focus on expanding regional collection centers and developing technologies suited to local topographic characteristics.

Acknowledgment

This study was supported by the National Institute of Forest Science (Project no.: FP0900-2022-01-2026).

Key words

Unused Forest Biomass; Resource Efficiency; Regional Development; Wood Fuel Manufacturing; South Korea

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June 9 (Tue) 13:30~15:30

V-1. Cultural Dimensions and Societal Perceptions of Wood Use

From Bus Shelter to Floating Grove: Bringing the First CLT Building to NC State

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Abstract

The path to sustainable innovation on a university campus is rarely a straight line. This presentation chronicles a multi-year effort to introduce mass timber to NC State, culminating in the completion of The Floating Grove, the campus's first cross-laminated timber (CLT) structure.

Our journey didn't start with a landmark pavilion. It started with a bus shelter. While that initial design never left the drawing board, the failure was a crucial experience. It allowed us to spend time navigating the university's administrative landscape, identifying key advocates in facilities, and building the soft infrastructure of trust required for such a project.

The momentum finally shifted when the vision evolved into a permanent outdoor gathering space. Through a partnership with the School of Architecture's Design + Build Studio, a dedicated group of students took the lead for their summer project. They designed and constructed the pavilion between Biltmore and Jordan Halls, utilizing locally sourced CLT panels and lumber to create a living case study for sustainable design.

In this talk, we share the lessons learned from those early setbacks. We will discuss the importance of persistence, the power of campus-wide networking, and how a failed transit stop eventually paved the way for a high-profile demonstration of biomaterials in the heart of campus.

Key words

Mass Timber; Cross-Laminated Timber; Design-Build; Campus; Sustainability

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Wood Culture in the fabrication of handicrafts for tourism in Costa Rica

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Abstract

Handicraft plays an important role is social context that reflects traditional and cultural heritage, and Costa Rica is nor exception. Besides, Biodiversity and infrastructure of this country have spurred tourism development, generating economic benefits for the handicraft sector. Handicrafts embody the symbolic values of culture, showcase artisans' manual skills, and utilize various raw materials, including wood. This study characterizes the wood handicraft industry in Costa Rica by examining the wood species used, their characteristics, origins, workability Properties, the products created, and the marketing channels employed. A qualitative, descriptive-complementary methodology was utilized, involving in situ data collection through structured interviews, supplemented by insights identified as important for development by evaluators. A total of 29 different species were identified, with the most common being Cedrela odorata, Bombacopsis quinata, and Dalbergia retusa. Among them, sixty-five per cent of the woods are catalogued as decorative, 52% have a high density, 79% of the species are extracted from natural forests, and 15% come from forest plantations or agroforestry systems. 89.66% of all the woods exhibit well-defined heartwood-sapwood demarcation, and growth rings were observed in 86% of them. Wood colour is the primary characteristic to determine its usage in handicraft fabrication. Multivariate analysis of the colour as a parameter determined four different colour groups: light woods (G1), brown woods (G3), and dark woods (G4), with a fourth group (G2) situated between G1 and G3. Woods from G3 and G4 present problems of sawlog supply. Besides, the results showed that most workshops are small, employing fewer than five people, and primarily use small-dimension sawlogs, lumber, and end-boards as raw materials. The predominant products manufactured are functional items, followed by decorative and playful products. These items often feature motifs that reflect the region's rich biodiversity, religious themes, and cultural heritage, appealing to tourists. Some workshops distribute their handicrafts to local tourist shops, while others sell directly to these establishments or operate their own retail outlets. Four main marketing channels are employed: dealers, websites, social media, and direct sales.

Key words

handicrafts; recreation; tradition; wood market; wood culture; tourist; souvenir; woodcraft; inheritances.

Identifying Bottlenecks to Mass Timber Adoption in Rural Japan: A Comparative National Questionnaire Survey

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Abstract

While mid-to-large-scale mass timber buildings are increasingly realized in Japan's urban areas due to technological innovation, their adoption in rural regions remains severely stagnant. For example, Tottori Prefecture currently has only one three-story wooden office building. With declining housing demand caused by population loss, harvest-ready local timber is losing its market, making non-residential wood utilization an urgent priority. Although governments have increased subsidies for non-residential wooden construction, this has not translated into actual projects. This indicates that rural stagnation involves challenges beyond mere financial shortages. Therefore, investigating this reality and elucidating the fundamental bottlenecks hindering practical adoption is critical.

This research aims to identify rural-specific bottlenecks hindering the widespread adoption of mid-to-large-scale wooden buildings in Japan. By surveying architectural professionals and conducting comparative analyses, we highlight critical perception gaps to provide foundational data for optimizing mass timber diffusion in rural markets.

An online survey, based on a Forestry Agency study, was conducted among Japanese architectural professionals. This paper quantitatively compares responses from Tottori Prefecture (n=40) and national (n=116) groups, evaluating their perceptions and actual proposal experiences regarding mass timber applications in non-residential and mid-to-high-rise residential buildings of four or more stories.

Rural professionals highly value the environmental benefits of wood, specifically forest resource utilization (75.0%) and contributions to SDGs (62.5%). However, severe practical barriers exist in design realities: high construction costs (62.5%) and a shortage of skilled builders (60.0%). Crucially, mass timber is frequently excluded from initial design phases; proposal consideration rates are roughly half the national average. Furthermore, client-driven demand is completely absent. Zero percent cited "user needs" as a motivation, while awareness of well-being benefits remains strikingly low (17.5%).

Rural mass timber adoption is hindered by a clear "Attitude-Behavior Gap." Professionals desire sustainability but perceive economic and technical barriers. However, mass timber is rarely considered in early design phases. The primary bottleneck is a preconception of high costs formed without actual consideration, stemming from a critical lack of knowledge and experience. To break this, educational initiatives—such as seminars and public pilot projects—are essential to correct perceptions and build practical expertise.

Key words

Mass timber buildings; Adoption barriers; Attitude-behavior gap; Regional disparity; Questionnaire survey

Proceedings of the International Convention of
Society of Wood Science and Technology

Development of a Play-Based Wood Education Program Integrating Environmental Values for Early Childhood

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Abstract

Carbon neutrality education has become an essential component of sustainability strategies in response to climate change. Wood, as a renewable material with inherent carbon storage capacity, plays a critical role in sustainable resource cycles and climate mitigation. Despite its environmental significance, systematic educational frameworks that introduce the environmental values of wood at the early childhood level remain limited. This study aimed to develop a structured, play-based wood education program integrating environmental values for early childhood education. The program was aligned with the Korean Nuri curriculum and designed to reflect the environmental, economic, and cultural dimensions of wood utilization. A needs assessment survey of early childhood teachers and expert consultations were conducted to establish educational objectives, content structure, and pedagogical principles. Based on these findings, the program was organized into three domains: Wood and Emotion, Wood and Daily Life, and Wood and Environment. The instructional design emphasized child-centered, inquiry-based, and experiential learning approaches. To examine practical applicability, a five-week pilot implementation was conducted in kindergarten classes for three- and five-year-old children in Yongin, South Korea. Children's perceptions and attitudes toward wood were evaluated through structured classroom observations and teacher assessments. Results indicated increased voluntary selection of wood-based play materials, improved recognition of wood as an environmentally valuable resource—including its role in carbon storage—and expansion of pro-environmental behaviors in daily contexts. Teachers reported strengthened material familiarity, positive emotional engagement with wood, and high curricular appropriateness across evaluation criteria. The findings demonstrate that a structured, play-based wood education program can effectively foster environmental awareness and material sensitivity in early childhood. This study provides a practical educational framework that connects wood science concepts with sustainability education, supporting the broader integration of wood-based environmental values into early childhood curricula.

Acknowledgment

This research was supported by the Research Project (FP0000-2023-01-2026) through the National Institute of Forest Science (NIFoS), Korea.

Key words

Childhood Wood Education; Wood Education; Wood Culture

Childhood Wood Education, Wood Education, Wood Culture

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Abstract

This study aims to analyze the operational status of wood culture experience centers across Korea and estimate their demand potential, thereby providing policy implications for their sustainable development. A nationwide census survey was conducted on 49 wood culture experience centers to collect comprehensive data on facility characteristics, operational structures, program composition, and utilization. Based on these findings, this study applies a demand estimation framework derived from previous research on forest welfare facilities. Specifically, a gravity-model-based approach combined with Poisson Pseudo Maximum Likelihood (PPML) estimation is used to analyze visitor demand. The model incorporates key determinants such as operational duration, connectivity with recreational forests, and travel distance. The estimation results indicate that both operational duration and linkage to recreational forests have statistically significant positive effects on visitor numbers. Centers with longer operational histories and those connected to recreational forests tend to attract more visitors. In contrast, the distance variable does not show statistical significance, contrary to theoretical expectations. This result is attributed to the dataset's limitation, which is based on total visitor counts at the facility level rather than on origin-destination flow data. Overall, wood culture experience centers, as components of forest welfare services that provide experiential and educational functions, exhibit significant potential for future demand growth. To increase their utilization, it is essential to diversify programs, enhance professional capacity, improve accessibility, and implement data-driven management systems. This study contributes by combining operational analysis with demand estimation, providing a quantitative basis for policy development and strategic planning.

Key words

wood culture experience center; demand estimation; operational status survey; gravity model

Proceedings of the International Convention of
Society of Wood Science and Technology

Interactions in sensory experiences of wood

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Abstract

Wood use indoors provides benefits for occupant comfort by moderating the hygrothermal environment, addressing aesthetic preferences, and triggering restorative effects. Although the hygrothermal contributions to the environment are well understood, the links between the aesthetic preferences, restorative effects, and occupant comfort remain underexplored. Our sensory experiences are important factors in these links, but past investigating them has largely focused on a single sense at a time. Recent research has begun to expand our understanding by investigating multiple senses simultaneously. For example, a recent promising study investigated thermal sensation and visual environment finding that the wood we see can influence our perception of thermal comfort. Importantly, our sensory experiences of the environment are filtered through personal health and cultural factors, indicating that findings in any one region must be validated in other cultural contexts. A strong and replicable methodology is needed to understand these culture and context dependent phenomena. This highlights the importance of robust investigations that deliberately seek to understand how multisensory experiences of wood change occupant perceptions so that evidence can inform design decisions and lead to better occupant outcomes in buildings.

To explore these multisensory experiences a series of pilot studies were conducted at the InnoRenew CoE Health lab in Slovenia. The studies investigated the interaction between multiple sensory stimuli including visual, haptic, olfactory, and aural on occupant perceptions with the intent of developing a robust methodology for future investigations. In addition to investigating sensory stimuli, instruments for capturing occupant responses were also tested allowing for the selection of questionnaires, cognitive assessment tools, and physiological indicators that provide robust information without overwhelming study participants. These results provide useful input for designing and implementing future studies in controlled settings that allow researchers to explore the effect of sensory experiences on occupants in varied cultural contexts.

Acknowledgment

The Authors acknowledge funding support from ARIS projects BuildWell N2-0386, Model O2-386, and Horizon Europe project WoodStock #101181021.

1 Guo et al., 2025. Investigating the impact of indoor wood element combinations on human subjective thermal perception in cold region using virtual reality technology. J Wood Sci 71, 41 (2025). https://doi.org/10.1186/s10086-025-02213-0

Key words

Indoor comfort; multisensory; restoration; interior design; wellbeing

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Innovating with Wood:
Science and Materials for a Sustainable Future

June 9 (Tue) 16:00~18:00

V-2. New Approaches to Wood Sector Education and Workforce Development

Pursuing Excellence Through Experiential Learning: Undergraduate Leadership in Quality Control and Industry Engagement at the Forest Biomaterials Service Center

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Abstract

Excellence in undergraduate education is best achieved when theory is integrated with meaningful, real-world application. This paper highlights the transformative experience of undergraduate students working at the Forest Biomaterials Service Center, where academic knowledge is reinforced through hands-on engagement in quality control, industry collaboration, and applied laboratory operations. Within this professional setting, students develop technical expertise in material characterization, standardized testing methods, data analysis, and quality assurance systems aligned with industry expectations.

By participating in client-driven projects, students move beyond traditional laboratory exercises to contribute to a performance-focused, service-oriented environment. They prepare technical reports, interpret results against industry standards, communicate findings to industrial partners, and support continuous improvement initiatives. These responsibilities cultivate precision, accountability, and a commitment to operational excellence. Direct interaction with industry professionals further strengthens students' communication skills, professional confidence, and understanding of customer needs, timelines, and performance specifications.

Balancing service center responsibilities with rigorous coursework, research involvement, and extracurricular activities demands advanced time management and prioritization skills. Students learn to navigate competing deadlines, uphold academic performance, and maintain high-quality laboratory output. This dynamic environment fosters resilience, leadership, and adaptability—qualities essential for success in forest biomaterials and allied industries.

The Forest Biomaterials Service Center exemplifies a high-impact educational model that promotes excellence through experiential learning. By integrating quality control practice, industry engagement, and academic development, the program equips undergraduates with both technical competence and professional maturity. This experience demonstrates how structured, industry-connected service centers can serve as powerful platforms for cultivating workforce readiness, leadership capacity, and a sustained commitment to excellence in forest biomaterials education.

Key words

Undergraduate education excellence; Industry-academy integration; Workforce readiness; Leadership development

Proceedings of the International Convention of
Society of Wood Science and Technology

Sustainability and Innovation in Wood Sector Education: BOKU University Program Transformation

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Abstract

The wood and bio-based materials sector is undergoing a profound transformation, driven by climate-related challenges, digitalization, and the evolving demand for sustainable construction. Universities play a pivotal role in equipping future professionals with the interdisciplinary and international competencies required to address these issues. At BOKU University, several educational innovations are underway to strengthen the link between science and engineering in response to this shift.

Currently, the Master's Program in Wood Technology and Management is being redesigned and transitioned into an English-language program. Building on a long-standing combination of engineering and management education, this transformation further strengthens graduates' ability to drive circular economy strategies and innovation management in wood-based and other bio-based sectors. The renewed curriculum emphasizes advanced wood material engineering and processing, industrial production and logistics, innovation and entrepreneurship, and socio-economic and policy dimensions, consistently integrating natural, social, and economic science perspectives.

The Green Building Engineering Master's program deepens students' expertise in green building construction, covering topics such as structural design, building physics, resource-efficient material selection, and life-cycle assessment of buildings. Graduates learn to design and evaluate new green buildings and transform existing structures based on circular economy principles, renewable energy concepts, and constructive greenery, such as green roofs and facades. The program integrates digital design tools with basic knowledge of spatial planning, law, economics, innovation management, and the social sciences. This forms a well-rounded engineering profile at the intersection of the natural, social, and economic sciences.

At the doctoral level, Build Like Nature: Resilient Buildings, Materials, and Society (Build.Nature) provides early-career scientists with internationally oriented, research-based training. Build.Nature establishes an interdisciplinary research environment that connects disciplines ranging from architecture and civil engineering to materials science and the social sciences under the overarching themes of bio-inspired design, resilience, and sustainability. Doctoral candidates acquire a systematic understanding of their research field and learn to communicate and critically discuss their findings with expert and non-expert audiences.

These initiatives illustrate how BOKU University fosters a new educational culture that combines interdisciplinary content, project based learning, and international cooperation.

Key words

wood science education; circular economy; sustainable construction; wood innovation management; interdisciplinary bioeconomy

Professional Identity and Work Readiness in a Large-Scale Sustainability Infrastructure Project

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Abstract

Equipping future engineers and researchers to tackle sustainability and resilience challenges requires more than classroom-based learning; it calls for immersive experiences that closely resemble professional practice. This study examines how participation in a large-scale mass timber experimental project shaped graduate students' professional identity formation and perceived workforce readiness within the context of sustainability transitions. As mass timber advances globally as a low-carbon alternative to steel and concrete, workforce development has become critical to scaling adoption. Yet, little research has explored how immersive research infrastructures influence the human capital needed to support the forest bioeconomy.

Using a qualitative exploratory design, six graduate students involved in a full-scale mass timber shake-table test under the NHERI Converging Design Project were interviewed. Semi-structured interviews (30-45 minutes) were analyzed using thematic analysis supported by NVivo 15. The study examined how authentic participation, interdisciplinary collaboration, and high-consequence decision-making shaped identity development and preparedness for professional practice.

Four interrelated developmental mechanisms emerged. First, biographical anchoring connected personal experiences (e.g., earthquake exposure, national timber transitions) with professional commitments to resilience and sustainability. Second, legitimate participation under real experimental constraints strengthened identity salience as students moved from peripheral roles to consequential actors. Third, boundary spanning across engineers, wood scientists, contractors, and laboratory personnel expanded identity content toward sociotechnical fluency. Fourth, adaptive readiness developed through decision-making under uncertainty, time pressure, and material consequence.

Findings indicate that large-scale experimental infrastructures function as identity accelerators by compressing professional socialization through accountability, visibility, and interdisciplinary engagement. Work readiness and professional identity co-developed rather than emerging sequentially. Importantly, mass timber itself operated as an identity frame within broader bioeconomy and sustainability narratives, transforming students from learners of engineered wood systems into empirically grounded advocates.

This study contributes to forest products and wood science education by demonstrating that experiential engagement in full-scale mass timber building projects strengthens both technical competence and professional agency. Large-scale sustainability infrastructures may therefore serve as strategic platforms for developing the next generation of mass timber leaders.

Key words

professional identity; workforce readiness; experiential learning; mass timber; sustainability

Proceedings of the International Convention of
Society of Wood Science and Technology

The Vulnerability of Wood Science Programs in an AI-Driven Academic Landscape

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Abstract

Artificial intelligence (AI) is rapidly transforming the higher education systems including the wood science and technology programs also. Despite the increasing reliance on data-driven decision-making, advanced manufacturing, and digital quality controls the adaptation and integration of AI tools into forest products domain both at industrial and educational levels is slow. However, the radical changes the AI generates are inevitable. This study critically examines the dual role of AI in shaping both the perceived attractiveness and the academic quality of wood science education. On one hand, the increasing reliance on generative AI and automated problem-solving tools may reduce student engagement with fundamental material science concepts, experimental reasoning, and hands-on laboratory skills that are essential to the discipline. There is a growing risk that overdependence on AI-assisted outputs could dilute technical rigor, homogenize learning outcomes, and weaken the identity of wood science programs in competition with more digitally oriented engineering fields. On the other hand, when strategically integrated, AI technologies present substantial opportunities to enhance educational quality and relevance. AI-driven tools can improve curriculum delivery through adaptive learning systems, real-time data interpretation, and advanced visualization of complex wood-material behaviors. Applications such as computer vision for anatomical analysis, machine learning for property prediction, and digital twins of manufacturing processes enable students to engage with modern, industry-relevant methodologies. Furthermore, concerns related to academic integrity, superficial learning, and reduced motivation for deep domain expertise may negatively impact program credibility and long-term enrollment trends. The study highlights the potential of AI to bridge the gap between traditional wood science education and emerging smart manufacturing paradigms. Challenges related to data quality, model interpretability, and curriculum adaptation are also discussed. The findings support the adoption of AI-driven pedagogical strategies to prepare a future workforce capable of advancing sustainable biomaterials and engineered wood technologies in a digitally integrated industry.

Key words

Artificial Intelligence; Wood Science and Technology; Higher Education; Risks and Benefits of AI; AI-assisted Learning

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June 9 (Tue) 16:00~18:00

III-2. Digitalization and Smart Processing Technology

Digital modelling of the internal structure of composites made from wood-based by-products - optimization of the manufacturing process

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Abstract

The increasing demand for sustainable wood-based materials has intensified the use of heterogeneous wood by-products in composite manufacturing, creating new challenges in process control and structural quality. Conventional trial-and-error approaches to panel development are inefficient when complex raw material mixtures are involved. This study presents a physics-based digital modelling framework for predicting internal structure development in composites manufactured from wood by-products, enabling virtual process optimization prior to physical production.

A three-dimensional microstructural model was developed to represent the spatial distribution and interaction of particles derived from wood-based by-products. The model integrates stochastic structure generation with coupled thermo-mechanical simulations of the hot-pressing process. The simulations account for pressure transfer, temperature gradients, and moisture-dependent material behavior, providing a realistic representation of densification processes within the board thickness.

The modelling framework enables prediction of density profiles, local structural heterogeneity, and defect-prone regions associated with insufficient consolidation and particle bridging. Unlike conventional empirical approaches, the proposed method allows direct analysis of the micromechanical mechanisms governing internal structure formation during pressing.

Simulation results for laboratory-scale panels demonstrated the model's ability to reproduce characteristic density distributions and structural variability typical of wood-based particleboards containing by-products. Parametric studies showed strong sensitivity of internal structure development to pressing conditions and material composition, highlighting the importance of coupled thermo-mechanical effects.

The proposed approach establishes a digital framework for predictive design of wood-based composites and supports the transition from empirical process development toward physics-based virtual prototyping. The results demonstrate the potential of digital modelling as a key component of smart processing technologies for next-generation wood-based panels.

Key words

digital modelling; wood-based panel; hot-pressing simulation; thermo-mechanical modelling; wood by-products

Proceedings of the International Convention of
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Sophisticated Approach of NIR Spectroscopy to Forest Products

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Abstract

Depending on the uniformity of the quality attribute within forest products, there is often a need to develop non-destructive and efficient evaluation methods to assure their qualities. Near-infrared spectroscopy (NIRS), in terms of reflected or transmitted absorbance of electromagnetic energy in the range 800-2500 nm, has been studied for the non-destructive measurement of organic materials such as foods, agricultural products, and forest products. The NIR absorption is attributed mainly to overtones and combinations of vibrational bands involving C-H, O-H, and N-H in the infrared (IR) region.

This presentation introduces scientific and technical reports using the NIRS to evaluate forest products. Overall, basic spectroscopic research is continuously progressing; indeed, in combination with big-data information technology and spectral imaging techniques, material analysis is improving to maximize performance. Portable and low-cost devices have also been designed and produced, enabling remote analysis. Future advancements are expected to result in its applications in even more fields for online or at-line quality monitoring.

Key words

NIR; Non-destructive measurement; GX

Toward Digital Predictive Maintenance of Wood Coatings: Mid-Infrared Spectroscopy Coupled with Machine Learning

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Abstract

This presentation summarizes our recent progress toward digital predictive maintenance of wood coatings by integrating mid-infrared spectroscopy with machine learning. Wood coatings are widely used to protect wood materials in outdoor environments and to extend their service life. However, coating deterioration often begins with subtle chemical changes that are difficult to detect before visible defects such as discoloration, cracking, or peeling appear. This makes it challenging to determine the optimal timing for maintenance and may result in either premature recoating or delayed intervention.

In our studies, accelerated weathering tests were conducted using various commercial wood coatings, especially waterborne systems, applied to wood substrates. Surface chemical changes during degradation were monitored by ATR-FTIR spectroscopy. The resulting spectral data were analyzed using multivariate approaches, including partial least squares (PLS) regression and genetic-algorithm-based wavenumber selection, to construct predictive models for coating deterioration. This whole-spectrum approach is particularly useful for latent deterioration, where diagnostically relevant changes may be distributed across the spectrum rather than concentrated in a single prominent band.

The results demonstrated that degradation-related chemical changes can be detected from infrared spectra before clear macroscopic damage becomes visible. The machine learning models enabled quantitative prediction of deterioration and also helped identify important spectral regions associated with degradation behavior. These findings highlight the value of combining spectroscopy and data-driven analysis not only for prediction accuracy but also for improving the interpretability of degradation processes. From a maintenance perspective, reproducible correlations themselves can be practically meaningful even before the full causal mechanism is completely understood.

Overall, this work suggests that mid-infrared spectroscopy coupled with machine learning can serve as a practical basis for digital predictive maintenance of wood coatings, contributing to longer service life, reduced maintenance uncertainty, and more sustainable use of wood materials in the built environment.

Key words

Wood coatings; Mid-infrared spectroscopy; Machine learning; Predictive maintenance; Digital wood science

June 10 (Wed) 08:30~10:00

I-4. Traditional Wood Care and Maintenance: Drying, Preservation, Machining, Finishing, etc.

Study on the Processing of Large Timber Components in Sabi-Period Wooden Architecture (3rd-5th Century)

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Abstract

This study reconstructs the timber-working process of a 3rd-5th century Sabi-period wooden storage facility and validates it by comparing experimentally produced tool traces with those on excavated members, addressing the limited research on processing methods for large ancient architectural timbers. Fresh oak was felled and processed to reproduce tool marks on mokgwakgo components, and the results were evaluated against traces observed on excavated artifacts. Trace morphology—length, continuity, and surface texture—was recorded with a handheld 3D scanner, and minute features were confirmed by stereomicroscopy. The reproduction work also supported estimation of construction time and labor.

Experiments replicated the manufacturing sequence using an adze, chisel, and saw, which are identifiable on excavated members. Adze marks fell into two types: fine, straight blade-edge lines from grooving or trimming, and plucked (tear-out) traces from forceful chopping that pulled out fibers. Chisel marks varied with mallet use. Using only a chisel produced broad, continuous blade marks, whereas striking the chisel head with a wooden mallet yielded regularly repeated straight blade-edge lines. Plucking increased when the striking angle was improper or when the tool acted nearly perpendicular to the surface. Saw marks appeared as multiple layers of fine, straight striations, and lower operator proficiency tended to leave clearer, more pronounced traces.

For the Geumsan Baengnyeongseong mokgwakgo, a skilled worker required about 10 minutes to process a 15×20 cm area using a 70 cm-wide adze. Scaled by surface area, total production time was estimated at approximately 4,278 hours, equivalent to about 535 days for one person at 8 hours/day, or roughly two months with ten skilled workers.

Overall, the reproduced traces showed high correspondence with the tool marks preserved on excavated members. These findings provide baseline evidence for interpreting timber-shaping techniques and tool use in large ancient wooden architecture, and the 3D scan-based record of tool traces offers reference criteria for future comparative studies and newly excavated wooden cultural heritage.

Key words

Tool traces; Woodworking techniques; Ancient architecture; 3D scanning

Proceedings of the International Convention of
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Development of Pretreatment Techniques and Optimal Kiln-Drying Schedules to Reduce Drying Defects in Large-Cross-Section Round Timber from Red Pine

Bat-Uchral Batjargal* (Seoul National University), **Minjee Kang** (Seoul National University), **Seonghyun Lee** (Seoul National University), **Chang-Jin Lee** (Jeonbuk National University), **Hwanmyeong Yeo** (Seoul National University)

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Abstract

Large-cross-section (LCS) pine timber is essential for cultural heritage restoration and large-scale wooden architecture. However, during the kiln-drying process, rapid moisture differences between the inner and outer layers create severe moisture gradients, inevitably leading to critical drying defects such as surface checking. Historically, field practices have relied on empirical drying methods, which have shown limitations in effectively controlling these defects. Therefore, this study aimed to scientifically develop an optimal kiln-drying schedule by analyzing pretreatment techniques designed to control moisture movement pathways and minimize drying defects in LCS timber.

Experiments were conducted on Korean red pine (Pinus densiflora) logs with a top diameter of 45 cm. Various pretreatments were applied, including a control and end sealing. To monitor the internal moisture gradient during drying, miniature temperature and humidity sensors were inserted into the timber at a depth of 80 mm. Furthermore, moisture content measurement method estimating the oven-dry weight using end-grain specific gravity specimens and timber volume was utilized to prevent damage to the full-scale timber. Although there were inherent technical limitations in directly monitoring real-time moisture evaporation, internal water movement, and internal stress generation during the process, this study successfully evaluated the effects of various pretreatments and analyzed internal heat and moisture transfer trends.

The results demonstrated that cross-sectional sealing is highly effective in reducing rapid longitudinal moisture movement. Furthermore, the surface case-hardening pretreatment mitigated the moisture gradient between the shell and the core, significantly delaying and reducing the occurrence of surface checks. The developed optimal schedule incorporated high-temperature (95℃) steam conditioning prior to drying and extended the surface case-hardening treatment until the internal moisture content reached 50%. Consequently, the total area of surface checking a chronic issue in drying LCS timber was dramatically reduced by 97% compared to conventional methods.

This study represents a critical advancement in developing reliable drying process technologies for large-diameter timber. More importantly, the experimental data obtained will serve as a significant milestone and foundational basis for future numerical analysis of internal coupled heat and moisture transfer in LCS timber, paving the way for further optimization of advanced drying schedules.

Key words

NIR hyperspectral imaging, fire classification, CPLS-LDA, fire-retardant leaching, wood properties digitalisation

Comprehensive Fire Performance of Softwood-Based Engineered Wood Products Treated with a High-Concentration Boron-Phenolic Hybrid Fire-Retardant System

Halim Park* (Chungnam National University), **Suhwan Yeo** (Chungnam National University), **Nguyen Duy Vuong** (Chungnam National University), **Taekyong Jeong** (The Korean Woodism-city Project Research Center), **Seoggoo Kang** (Chungnam National University)

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Abstract

As the demand for sustainable mass timber construction continues to grow, improving the fire resistance and durability of engineered wood products (EWPs) has become increasingly important. Although boron-based fire retardants are highly effective, their susceptibility to leaching limits long-term performance. This study proposes a high-concentration boron-phenolic hybrid fire-retardant system aimed at enhancing fixation stability and fire performance by integrating inorganic boron into a water-soluble phenolic resin matrix. This system establishes a dual-layered protection mechanism that improves boron retention within the wood matrix, excludes oxygen through glass-coating formation, and promotes stable carbonaceous char.

For the experimental design, EWPs including plywood, particleboard (PB), lamina, and 3-layer laminated timber were manufactured using softwoods such as Korean larch and pine. The hybrid system was applied via vacuum-pressure impregnation, surface coating, or resin-mixing, each tailored to the specific characteristics of the product group. Fire performance was evaluated through flame-retardancy tests, cone calorimetry (ISO 5660-1) for impregnated lamina, and high-temperature resistance tests at 600°C for 3-layer laminated timber. Furthermore, microstructural analysis (SEM/EDS) was conducted to investigate char morphology and elemental distribution.

The results demonstrated exceptional fire suppression across all scales. For treated pine plywood, the system achieved a charred area of 5.1 cm^2 and delayed ignition by 196 seconds, with a THR reduction from 29.1 to 7.9 MJ/m^2. The treated PB also showed significant retardancy with a charred area of 12.5 cm^2. In structural-scale evaluations, treated Radiata Pine lamina exhibited remarkably low THR values of 4.5-6.1 MJ/m^2. During a 10-minute exposure at 600 °C for the 3-layer laminated timber, the cross-sectional charring rate of Pine decreased from 34% to 23%, and Radiata Pine from 44% to 14%. Notably, the treated Radiata Pine glulam showed no ignition throughout the exposure, with mass loss significantly reduced from 25.6% to 7.1%. These results indicate that the proposed system improves both fire resistance and retention stability, providing a practical framework for durable fire-retardant treatments in future structural applications.

Key words

Boron-Phenolic Fire Retardant; Fire performance; Engineered wood products; Cone Calorimetry; Charring Behavior

Proceedings of the International Convention of
Society of Wood Science and Technology

Acetylation of European Ash (*Fraxinus excelsior*) wood as an alternative to the traditional thermal modification method

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Abstract

Wood modification techniques like thermal modification and acetylation have grown significantly over the past three decades due to environmental concerns and the need for high-quality, durable wood products without toxic preservatives. These processes alter wood's chemical structure to improve properties like dimensional stability and durability. Thermal modification involves heating wood at temperatures between 160 and 240°C in an oxygen-controlled environment. Acetylation represents a chemical modification approach where wood is treated with acetic anhydride, resulting in the replacement of accessible hydroxyl groups in the cell wall with acetyl groups and producing acetic acid as a byproduct. Due to the poor permeability of ash wood, acetylation of ash wood is not widely used as thermally modified ash wood. This study compares water-related properties between thermally modified, traditionally acetylated in liquid phase, newly designed acetylated in gas phase and reference European ash (*Fraxinus excelsior*) wood.

During the acetylation processes, a decrease in the efficiency of the traditional liquid phase process was confirmed for poorly permeable ash wood. Compared to the liquid phase, the results of the acetylation reaction in the gas phase exceeded almost double the values of the weight percentage gain (WPG). Linear dependences of WPG on the values of bulk coefficient (BC) and retention (R) were observed for acetylated ash samples of both heartwood and sapwood.

The reduced equilibrium moisture content (EMCR) of all acetylated ash samples was reduced depending on the increasing WPG value at different relative humidity (RH) values. However, when comparing EMCR results with thermally modified ash samples at 65% RH (3.7%) and 90% RH (6.64%), only acetylated white ash samples in the gas phase at 65% (3.77%) and 90% RH (6.75%) were comparable. However, acetylated and thermally modified samples significantly reduced moisture uptake compared to the reference samples. Both modification methods cause a decrease in the number of hydroxyl groups in the main wood components to which water molecules bind.

Key words

Bulking coefficient; reduced equilibrium moisture content; retention; moisture exclusion efficiency; weight percentage gain.

Hygrothermal performance of timber rainscreen façade systems

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Abstract

Timber-based rainscreen façade systems are increasingly adopted in low-carbon buildings due to their renewable characteristics and carbon storage capacity; however, their long-term durability remains strongly constrained by moisture accumulation within ventilated cavity environments. In particular, the backside surface of timber cladding, which is exposed to fluctuating temperature and humidity conditions, frequently becomes a critical condensation interface, leading to biological degradation and performance deterioration. Despite the importance of this hidden interface, functional strategies for controlling hygrothermal behavior at the rear surface of timber siding remain insufficiently explored.

This study investigates the hygrothermal performance of aerogel-based functional coatings applied to the backside of cedar wood siding within a ventilated rainscreen system. Three coating systems were comparatively evaluated: a conventional acrylic reference paint (RP), an organic aerogel-based coating (OA), and an inorganic aerogel-based coating (IA). The coatings were applied under controlled conditions and characterized through microstructural analysis, thermal conductivity measurements, water vapor diffusion resistance testing (ISO 12572), surface wettability evaluation, and accelerated weathering exposure. The results demonstrate that coating microstructure significantly governs coupled heat and moisture transport behavior. The organic aerogel coating exhibited the lowest thermal conductivity while maintaining vapor permeability comparable to uncoated timber, indicating an effective balance between insulation enhancement and drying potential. In contrast, the inorganic aerogel coating formed a dense silicate network that improved thermal and chemical durability but resulted in relatively higher thermal conductivity due to continuous solid-phase heat transfer. Accelerated weathering tests further confirmed that aerogel incorporation enhances hydrophobic stability and surface durability under prolonged UV and thermal exposure. Overall, the findings reveal that polymer-based aerogel coatings provide the most favorable hygrothermal regulation for timber rainscreen assemblies by simultaneously reducing heat transfer and preventing moisture accumulation without inhibiting vapor diffusion. This study highlights the critical role of backside surface modification in timber façade design and demonstrates the potential of aerogel-enabled coatings as an effective strategy for improving moisture resilience and long-term energy performance in ventilated timber building envelopes.

Key words

Rainscreen; Timber cladding; Aerogel coatings; Deterioration; Hygrothermal performance

Proceedings of the International Convention of
Society of Wood Science and Technology

Comparative Analysis of Traditional Wood Preservation and Maintenance Practices: A Case Study of Gwagwalada, Nigeria

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Abstract

Rationale

In Nigeria's burgeoning informal timber sector, Gwagwalada serves as a critical junction for wood processing and trade. However, traditional maintenance protocols—ranging from open-air drying to the use of indigenous plant extracts—often lack scientific standardization. This study evaluates the efficacy of these time-honored methods against international durability benchmarks to optimize local wood utilization.

Methods

A multi-faceted research approach was employed in the Gwagwalada timber market. Literature reviews were synthesized with field data from twenty local sawmills and carpentry workshops. Primary data included:

1. Moisture Content (MC) Analysis: Using handheld digital meters on Milicia excelsa (Iroko) and Khaya ivorensis (Mahogany).
2. Preservation Assessment: Comparing traditional "cold-soaking" in spent engine oil and Euphorbia balsamifera (Aguwa) extracts against synthetic chemical treatments.
3. Machining Efficiency: Measuring lumber recovery rates and surface finish quality using locally maintained circular saws and manual planning tools.

Results

Data revealed that traditional air-drying in Gwagwalada's semi-arid climate achieved an Equilibrium Moisture Content (EMC) of 12-14% over 45 days, significantly higher than the 8% required for export-grade furniture. Literature suggests indigenous extracts like Aguwa provide a 65% resistance rate against subterranean termites, comparable to low-concentration synthetic pesticides. However, machining waste remains high; recovery efficiency averaged only 54% due to manual calibration errors and blade vibration. Newspaper reports from The Guardian Nigeria (2025) corroborate that rising costs of imported chemicals are forcing a 40% increase in the adoption of these traditional, albeit unrefined, preservation techniques.

Conclusions

While Gwagwalada's traditional wood care methods are cost-effective and culturally integrated, they require scientific refinement in kiln-drying and extract concentration to meet global standards. Integrating solar-kiln technology with indigenous preservation knowledge offers a sustainable pathway for Nigeria's wood industry to reduce waste and increase the service life of timber products.

Key words

Indigenous; Preservation; Gwagwalada; Moisture Content; Wood Machining; Sustainability

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Innovating with Wood:
Science and Materials for a Sustainable Future

June 10 (Wed) 10:30~12:00

II-1. Advanced Timber Engineering and Hybrid Structural Systems

Assessment of heritage timber beams for dowel-laminated timber production: material recovery rate and structural performance

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Abstract

Structural timber sourced from heritage buildings constitutes a valuable resource due to both its material quality and cultural importance. When subjected to appropriate processing and structural evaluation, this timber may have the potential to be reused in load-bearing applications. This study examines the technical feasibility of converting large, reclaimed softwood beams from a heritage building site in Slovenia into dowel-laminated timber (DLT) elements. The research focuses on three interconnected aspects: (i) the recovery rate of usable boards following a full processing of reclaimed beams into sawn and planed boards, (ii) the mechanical properties of the recovered boards, and (iii) the structural performance of DLT elements and their connections fabricated from the reclaimed boards.

The recovered boards underwent both visual and mechanical assessments, including non-destructive evaluation of dynamic modulus of elasticity and static bending tests. DLT elements produced from the reclaimed boards were then tested at both the connection and panel levels. Double-shear DLT connections were experimentally investigated and compared with reference connections made from virgin spruce timber, as well as with predictions derived from the latest Eurocode 5 design formulations. Additionally, the bending performance of DLT panels made from the reclaimed boards was evaluated and benchmarked against equivalent panels made from virgin spruce boards.

The results of this study provide new insight into the recovery potential of heritage timber and its suitability for structural reuse in high-value engineered timber systems. This directly contributes to ongoing efforts in the development of circular construction strategies and reducing environmental impact of the building and construction sector.

Key words

Reclaimed timber; reuse; DLT; timber connections; Eurocode 5

Proceedings of the International Convention of
Society of Wood Science and Technology

Innovations in wood product value chains for construction markets: a European overview

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Abstract

European companies are global leaders in engineered wood products (EWP) and related building systems. The European Bioeconomy Strategy supports EWPs as a priority lead market for 'Bio-based construction products'. The European Commission is also pursuing standardisation of construction products, resource efficiency and circularity, and certification of long-lasting biogenic carbon storage in buildings aiming to simulate market growth and innovation. 'Underutilised wood' includes hardwood, damaged and low-quality wood, and recovered post-consumer wood. These have currently no or low market value, but are gaining attention by companies and researchers as novel resource for EWP.

This study analyses European innovations in EWP technologies along five paths: i) products certified by harmonized European standards (hEN); ii) fast-tracked innovative products certified with European Technical Assessment (ETA); iii) products with other national certificates; iv) non-standardised product prototypes, v) innovative EWP processing technologies, and vi) new building design rules. An increase of innovative EWP is apparent, including hardwoods and hybrid softwood-hardwood products, but also enhanced wood-based panels, wall and ceiling finishes, insulation materials, and a multitude of new connector systems. New processing technologies include sorting, grading, and fiber recycling from post-consumer wood, resource-efficient panel design, and novel high-performance materials. The findings portray high innovation activity in various branches of the European wood sector with ongoing diversification. The range of innovations credit the ingenuity and constant technological push of European manufacturers. However, EWP are still a niche in the construction market and face a long path to compete at scale.

The enabling research and innovation ecosystem in Europe comprises industries, universities, research centers, testing and verification labs, clusters and networks, regulatory and governmental bodies rooted in their specific regional and national contexts. Although the growing policy support is encouraging, regional and national fragmentation and redundancies demonstrate strong need for wood policy coordination, collaborative R&I infrastructures and aligned funding programs. Initiatives like the European Wood Policy Platform and the New European Bauhaus Academy are already setting the foundation for greater alignment and investment in EWPs and their wider adoption in construction. However, further research to increase our systemic understanding of the entire innovation landscape is needed.

Acknowledgment

Co-funded by Horizon Europe projects EcoReFibre, WoodStock, Eufore

Key words

research and development; innovative construction products; underused wood; innovation ecosystem; research policy

Expanding the Structural Role of Wood in Hybrid Systems: Configuration-Oriented Synthesis from the Finnish Carbon-Regulated Context

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Abstract

The introduction of mandatory embodied carbon limit values in Finland (effective 9 January 2026) is reshaping structural decision-making in the construction industry across all stages, including design and permitting phases. As lifecycle carbon calculations become embedded in approval processes, structural configuration is evaluated not only through strength, serviceability, and fire compliance, but also through carbon intensity per gross floor area. Rather than prompting simple material substitution, this shift is accelerating hybrid structural systems in which engineered timber products increasingly serve as a primary load-bearing component within integrated assemblies. These systems must reconcile fire safety, acoustic performance, air permeance, stiffness and vibration control, prefabrication constraints, connection detailing, and lifecycle carbon accounting within a coherent structural configuration.

This paper presents a configuration-oriented synthesis of Finnish hybrid timber applications organized through a hierarchy-based analytical framework distinguishing: (i) element-level hybridization, where localized reinforcement (e.g., post-tensioned or stiffness-enhanced timber members) modifies sectional behavior without altering global load paths; (ii) structural assembly-level hybridization, including timber-concrete composite (TCC) floors and wall systems where performance emerges from inter-component interaction and controlled composite action; and (iii) building-level structural integration, where timber is positioned within a broader load-resisting hierarchy involving reinforced concrete cores, composite diaphragms, and distributed stiffness strategies.

Drawing on documented Finnish case projects, regulatory guidance, and performance-based studies, the synthesis identifies recurring configuration logics influencing structural and carbon performance. Across the reviewed evidence, hybrid effectiveness depends less on material pairing itself than on timber's position within the structural hierarchy, specifically its role in governing primary load paths, stiffness distribution, and subsystem coupling. While component-level hybridization delivers localized mechanical improvements, system-level timber integration is more consistently associated with improved material utilization efficiency, rationalized prefabrication, enhanced adaptability, and reduced embodied carbon intensity per gross floor area.

The Finnish experience indicates that embodied carbon regulation is acting as a catalyst for configuration-driven structural reconsideration rather than isolated material optimization. The proposed scale-based classification offers a transferable analytical lens for interpreting emerging timber hybrid systems and identifying system-level strategies capable of achieving regulation-compliant, low-carbon multi-story construction in comparable regulatory contexts.

Key words

Timber Hybrid Systems; Structural Configuration; System-Level Integration; Embodied Carbon Regulation; Finland

Proceedings of the International Convention of
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Feasibility on a novel GLT-Steel composite beam system with on-site self-installation for 3D modular building units

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Abstract

This study proposes a gravity-driven, self-installing timber rivet shear-connector system for glued-laminated timber (GLT)-steel composite beams in 3D modular construction. In conventional modular systems, the floor beam of the upper module and the ceiling beam of the lower module are duplicated, leading to increased member depth, excessive material use, and reduced story height. To address this structural inefficiency, a welded-head timber rivet connector is introduced, enabling automatic penetration and installation solely by the self-weight of the upper module during stacking. The experimental study showed that the proposed timber rivets can be stably installed by the self-weight of the upper module without buckling. Single-rivet shear tests showed that both the stiffness and strength of the connection increase with increasing penetration depth, and that a penetration depth of 25 mm represents an optimal condition satisfying both structural performance and construction stability. The results of the multi-rivet shear tests indicated that, as the number of rivets increases, the non-uniformity of load sharing within the connection becomes more pronounced, resulting in a reduction in both stiffness and strength compared to the single-rivet connection. However, when the rivet spacing is 50 mm or greater, the influence of the group effect on the connection performance becomes practically negligible. The composite beam tests show that the effective flexural stiffness increases by approximately 1.49 times compared to the non-composite case. Under the design condition of typical modular unit (dead load of 2 kN/m^2 and live load of 5 kN/m^2), achieving a target composite efficiency of $\gamma \geq 0.3$ allows the beam depth to be reduced by approximately 16%. In addition, the difference between the composite flexural stiffness (EI) predicted by the γ-method and that obtained from the experimental results was within approximately 4%, confirming the applicability of the proposed system to structural design. Overall, the proposed GLT-steel composite beam system effectively improves structural efficiency in modular construction by eliminating beam duplication while ensuring reliable composite action and practical constructability.

Key words

Timber modular construction; GLT-steel composite beam; Timber rivet; Self-installing shear connector;

Lateral Load Resistance and Connection Behavior of a Prefabrication Timber Wall System

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Abstract

In Korea, the number of educational facilities older than 30 years is steadily increasing. These buildings require structural rehabilitation and spatial reconfiguration to meet current safety and educational standards. Because school buildings cannot be closed for long periods, remodeling methods that minimize construction time and on-site work are required. Prefabricated timber structural systems have emerged as an effective alternative. They provide environmental benefits, reduced structural weight, and rapid installation. This study evaluates the lateral load resistance performance of a prefabricated timber wall system and investigates the moment resistance performance of its connections for application in school remodeling.

The proposed system consists of a glulam post-beam frame with a light-frame timber shear wall used as an infill wall. The post and beams were fabricated using 10S-30B grade glulam. The cross-sections were 330 × 330 mm^2 for post and 330 × 760mm^2 for beam. Post-beam and post-foundation connections were designed as pinned joints. The infill wall was composed of 2×6 lumber (cross-section size: 38×140 mm^2) and 12 mm thick structural particle board (SPB). It was connected to the frame using 12d nails.

Quasi-static cyclic loading tests were conducted in accordance with KS F 2154 and ASTM E2126. The specimen size was 3,000 × 3,000 mm2. The maximum displacement was set to 168.41 mm based on static test results and inter-story drift limits.

The maximum load was 159.94 kN. The shear capacity was 54.68 kN/m. This value is approximately 5.6 times higher than that of a conventional SPB light-frame shear wall (9.6 kN/m). The shear stiffness was 4.6 kN/mm, which is about 1.5~2 times higher than that of conventional walls. However, the stiffness was relatively low compared to the shear capacity. Joint deformation analysis showed lower stiffness at the post-foundation connection. This indicates that improving foundation joint stiffness is necessary to enhance overall system rigidity.

Key words

Prefabrication Timber System; Post-Beam Structure; Lateral Load Resistance; Moment Resistance

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Novel Test-Method to evaluate Thermal Bond Line Stability

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Abstract

The thermal stability of adhesives is a key factor for the reliability of bonded, load-bearing timber components under fire conditions. In engineered wood products such as glued laminated timber (GLT) and cross-laminated timber (CLT), insufficient high-temperature resistance of bond lines may lead to layer delamination (“char layer fall-off”), increased charring rates, and premature structural failure. Existing test methods are based, among other things, on comparing the mechanical strength of glued samples with that of solid wood references after prior conditioning to defined test temperatures. Although the compression shear tests according to the standard provide relevant classification parameters, the critical point at which a bonded joint in a loaded component suddenly loses its load-bearing capacity as the temperature rises is only indirectly detected. Against this background, this contribution presents a novel experimental approach designed to directly determine the thermal stability limit of adhesive bond lines under defined mechanical load during heating - interpreting the temperature at which abrupt bond line failure occurs as the thermal stability limit.

Specimens were prepared from Norway spruce (Picea abies). Two structural adhesive systems were investigated. To enable cross-method comparison, compression-shear tests in accordance with EN 18070 were conducted on matching material batches. Initial results demonstrate clear differences between the investigated adhesive systems with respect to failure temperature under sustained tensile loading. The ranking obtained from the proposed method is consistent with trends observed in standard compression-shear testing. The presented methodology enables a failure-based characterization of high-temperature adhesive performance and may contribute to the further development of adhesive systems regarding their fire performance with comparatively little effort.

Key words

Wood Adhesives; Bond-Line Failure; Thermostability; High-Temperature Performance

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June 10 (Wed) 13:30~15:30

II-1. Advanced Timber Engineering and Hybrid Structural Systems

Performance of PVA-Modified MUF Adhesives for Cold-Press Manufacturing of Structural Engineered Wood

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Abstract

This study developed and evaluated room-temperature-curing melamine-urea-formaldehyde (MUF) adhesives intended for structural engineered wood products, including glued laminated timber (GLT) and cross-laminated timber (CLT). MUF resins were synthesized at a constant formaldehyde-to-(melamine + urea) molar ratio of 1.5, while the melamine proportion was varied from 20 to 30% to examine its influence on resin and bonding performance.

To enhance the storage stability of the liquid adhesive, alcohol-based additives—polyvinyl alcohol (PVA), ethanol, methanol, and propanol—were screened. Fully hydrolyzed PVA (2-8 wt%) was identified as the most suitable stabilizer because it improved stability without compromising the fundamental resin properties. In particular, the formulation containing 25% melamine and 2% PVA maintained acceptable viscosity and curing behavior for more than 10 weeks at room temperature.

For bonding trials, the MUF adhesive was mixed with a 20% ammonium chloride solution at a mass ratio of 10:4 and applied at 250 g/m^2. Two-ply domestic pine veneers (2.6 mm) and two-ply pine lamellas (6.5 mm), conditioned to moisture contents below 6%, were assembled and cold-pressed at room temperature under 10 kgf/cm^2 for 828 min. Bond performance was assessed under dry, semi water-resistant, and water-resistant conditions. All specimens satisfied the KS minimum requirement of 0.7 MPa, demonstrating that structural-level bonding can be achieved under room-temperature pressing.

Comparative testing against imported reference adhesives (a European powdered melamine resin and a U.S. isocyanate resin) indicated that the developed MUF systems delivered comparable or superior bond strength. Overall, the results suggest that room-temperature-curing MUF adhesives offer a practical domestic alternative for structural engineered wood products, providing both adequate storage stability and mechanical performance for field application.

Key words

Wood Adhesive; Bonding quality; Melamine-urea-formaldehyde; Storage life

Proceedings of the International Convention of
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Experimental Investigation of Monotonic Behavior of Moment Resisting Connections for GLT

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Abstract

The increasing application of mid-rise timber buildings has intensified the demand for reliable beam-column moment-resisting connections. Conventional bolted joints suffer from initial slip and stiffness degradation due to hole clearance, as well as fire resistance issues caused by exposed steel components, while glued-in rod connections present constructability limitations and risks of brittle failure.

Accurate prediction of the strength and rotational stiffness of dowel-type timber moment connections is essential for the design of semi-rigid timber frames. This study experimentally investigates beam-column joints fabricated from Japanese larch glulam produced in Korea and reinforced with double steel plates and steel dowels, and compares the results with analytical models based on Eurocode 5.

Monotonic loading tests were conducted on connections incorporating 12 mm and 8 mm diameter steel dowels penetrating two internal steel plates, forming four shear planes per fastener. The beam and column cross-sections were 140×240 mm and 280×420 mm, respectively. The 12 mm configuration consisted of 47 dowels, whereas the 8 mm configuration employed 59 dowels, resulting in different load redistribution characteristics within the fastener group. A vertical load was applied at the beam end to induce combined bending and shear in the joint.

The 8 mm dowel connection achieved a higher maximum load of 141.0 kN than the 12 mm joint (129.2 kN), despite its lower individual fastener capacity, due to more uniform load distribution. In contrast, rotational stiffness was greater for the 12 mm joint (13,666.7 kNm/rad) compared to the 8 mm joint (7,205.9 kNm/rad). The beam flexural stiffness was 1,610 kNm/rad, corresponding to stiffness ratios of 8.49 and 4.48, classifying both connections as semi-rigid.

Eurocode 5 analytical predictions incorporating multi-shear-plane effects and unfavorable service conditions estimated ultimate capacities of approximately 150 kN for both configurations, in close agreement with the experimental results. Experimental to predicted ratios of 0.86 for the 12 mm joint and 0.93 for the 8 mm joint confirm that Eurocode 5 provides conservative yet reasonable strength estimates, while significantly underestimating rotational stiffness.

Key words

Dowel-type timber connection; Moment-resisting joint; Semi-rigid timber structures; Eurocode 5

INFLUENCE OF PLYWOOD CORE ORIENTATION AND ADHESIVE TYPE ON THE STRUCTURAL PERFORMANCE OF CLT PANELS

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Abstract

Cross-laminated timber (CLT) has emerged as a promising engineered wood product for sustainable construction. In this study, three-layer CLT panels were fabricated with a cold-pressed plywood core bonded using two adhesive types: melamine polyurethane (MPU) and phenol-resorcinol formaldehyde (PRF). The plywood core orientation was varied in two configurations: (i) face plies of the plywood parallel to the CLT face layers, and (ii) face plies of the plywood perpendicular to the CLT face layers. The objective was to evaluate the influence of core orientation and adhesive type on the structural performance of CLT panels.

A series of mechanical tests were conducted. Tensile tests (both wet and dry conditions) were performed on 120 specimens to assess bond durability. Bending tests were carried out on 24 mm thick, 11-ply plywood samples (600(L) × 50(W) × 24(T) mm) to compare adhesive performance. Planar shear tests were conducted on CLT specimens (198(L) × 50(W) × 72(T) mm) with different core orientations, and block shear tests were performed to further investigate adhesive bond strength.

Preliminary results indicate that adhesive type and plywood core orientation significantly affect the mechanical performance of CLT panels. PRF-bonded specimens generally exhibited higher shear strength and better water resistance, while MPU-bonded panels showed competitive performance under dry conditions. Core orientation was found to influence load transfer efficiency, with parallel orientation enhancing bending stiffness and perpendicular orientation improving shear resistance. These findings provide insights into optimizing CLT manufacturing with hybrid plywood cores for enhanced structural reliability.

Acknowledgments

This study was supported by the R&D Program for Forest Science Technology (Project Nos. FTIS-2400000135, RS-2024-00404631) funded by the Korea Forest Service (Korea Forestry Promotion Institute).

Key words

cross-laminated timber; plywood core orientation; MPU adhesive; PRF adhesive; structural performance

Proceedings of the International Convention of
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Mill-Scale Manufacturing and Cost Modeling of Structural-Grade Hardwood Lumber from Yellow-Poplar Cants for Mass Timber Applications

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Abstract

Yellow-poplar (Liriodendron tulipifera) is abundant in the eastern United States and possesses favorable mechanical properties, yet it remains underutilized for structural markets due to the hardwood industry's dependence on appearance-based grading. This study demonstrates a mill-scale pathway for producing structural-grade hardwood lumber (SGHL) from yellow-poplar cants and quantifies production economics using a transparent, replicable cost model. Eighty-eight yellow-poplar cants were processed under commercial conditions to maximize 2×6 and 2×8 output suitable for cross-laminated timber (CLT) lamina. All boards were dual graded using National Hardwood Lumber Association (NHLA) rules and SGHL structural rules; defects were recorded to quantify downgrading mechanisms. Conversion matrices linking NHLA grades to SGHL grades were developed, including an enhanced SGHL-2 scenario representing achievable recovery if avoidable manufacturing defects are minimized. A mixed grading strategy—retaining higher NHLA appearance grades while structurally grading lower NHLA grades—provided the highest revenue in this dataset. Using observed grade yields as inputs, an adapted activity-based costing (ABC) framework estimated manufacturing cost per MBF and identified dominant station-level cost drivers. Results indicate that yellow-poplar cants can reliably yield SGHL for mass-timber supply chains, and that process control improvements (edging, surfacing, sawing alignment) and drying/resaw efficiency offer the largest near-term opportunities to improve structural recovery and cost competitiveness.

Key words

yellow-poplar; structural-grade hardwood lumber; SGHL; NHLA-to-SGHL conversion; manufacturing defects; activity-based costing; station-level costs; cross-laminated timber

Innovative Rotary Peeling of Thick Timber Panels from Underutilized European Aspen: Process Parameters and Surface Integrity

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Abstract

European aspen (Populus tremula L.) remains an underutilized hardwood resource in Northern and Eastern Europe despite its wide availability and favorable cost structure. Expanding its use beyond pulpwood requires the development of new processing approaches. One promising direction is the production of thick rotary-cut veneer (>3.5 mm), which can be regarded as a timber panel and offers potential for improved material efficiency and new applications in engineered wood products such as cross-laminated timber (CLT). However, the feasibility of producing thick veneer with sufficient surface quality and structural integrity remains insufficiently explored. This study investigates the technological feasibility of producing thick timber panels from fast-growing aspen through rotary peeling, targeting thicknesses up to 10 mm. Experimental trials were conducted using an industrial-scale peeling lathe, with key parameters including log conditioning temperature, peeling speed, and compression ratio systematically varied. Veneer thicknesses of 3, 6, and 9 mm were produced, alongside exploratory trials to determine the maximum achievable thickness. Particular emphasis was placed on surface-related properties critical for downstream processing, including surface roughness, wettability (contact angle), and lathe check formation. Surface integrity was evaluated using standardized profilometry and contact angle measurements, while lathe checks were assessed through scanner-based imaging combined with image analysis, with additional validation methods under development.

Preliminary results confirm the feasibility of producing 6 mm aspen veneer with stable quality, while 9 mm veneer remains challenging but achievable under specific process conditions. Lower conditioning temperatures (<10 °C) were found to be more favorable for thicker veneer production compared to higher or subzero conditions. Surface properties were strongly influenced by conditioning temperature, whereas compression ratio and peeling speed showed comparatively smaller effects. Increasing veneer thickness led to a pronounced increase in lathe check depth and spacing. Overall, the results demonstrate that thick aspen timber panels produced by rotary peeling represent a viable pathway for higher-value utilization of this resource. At the same time, key technological challenges related to drying and surface quality control remain. This study extends current knowledge beyond conventional veneer thickness ranges and supports the development of thick timber panels as a novel material for future industrial applications.

Key words

veneer; rotary peeling; aspen; lathe check; surface

Proceedings of the International Convention of
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Evaluation of Expected Structural Performance of Larch-Pine Hybrid Glulam for Efficient Utilization of Domestic Timber Resources

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Abstract

While Larix kaempferi (Japanese larch) is currently the only domestic species widely utilized for structural glued laminated timber (glulam) in South Korea, its increasing demand has led to significant concerns regarding potential resource depletion. To address this, there is a pressing need to incorporate Pinus densiflora (Korean red pine), which is relatively abundant and possesses favorable mechanical properties. This study aims to develop and evaluate a hybrid glulam configuration that strategically integrates these two species to ensure a stable supply of high-quality engineered wood.

A five-layer hybrid glulam will be fabricated with Larix kaempferi laminations positioned at the outermost tension and compression zones to handle maximum bending stresses, while Pinus densiflora will occupy the three intermediate core layers. The primary objective is to satisfy the 10S-30B grade requirements according to KS F 3021 (Structural Glued Laminated Timber). The evaluation will focus on verifying whether the allowable bending stresses for both the X-X and Y-Y axes, as well as the allowable shear stress (based on pine standards), meet the established structural criteria.

It is anticipated that the hybrid configuration will leverage the high stiffness of larch in critical zones while utilizing the cost-effectiveness and availability of pine in the core. The success of this performance evaluation would demonstrate that larch-pine hybrid glulam represents a technically viable and resource-efficient alternative. This approach is expected to reduce dependence on imported timber and provide a clear pathway for the value-added utilization of Korea's abundant domestic pine forests, ultimately contributing to a more sustainable timber industry.

Key words

Hybrid Glulam; Bending Performance; Domestic Timber; Shear Performance; Allowable Stress

Analytical and numerical investigation of the stiffness of single wooden dowel timber-to-timber connections

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Abstract

Engineered wood products joined using wooden dowels, commonly referred to as dowel-laminated timber (DLT), are receiving increasing attention due to their recyclability, ease of modification, absence of toxic adhesives, aesthetic appeal, rapid assembly, and high design flexibility. The structural efficiency of DLT panels and beams is governed primarily by the stiffness of the dowel connections. Unlike metal dowel connections, where no embedment occurs in the dowel itself, wooden dowels undergo combined bending and shear deformation, together with embedment deformation at the timber-dowel interface. These interacting deformation mechanisms significantly complicate the determination of the stiffness of wooden dowel timber-to-timber connections (WDTCs). Consequently, the stiffness expressions provided in Eurocode 5 are not directly applicable, as the complex failure and deformation modes associated with wooden dowels are not explicitly considered in current design standards.

Joint stiffness is defined within the linear elastic stage of the force-deformation response of WDTCs and requires the simultaneous consideration of timber embedment deformation, dowel embedment deformation, and wooden dowel bending and shear deformation. Accurately capturing these coupled mechanisms remains challenging. To date, no comprehensive study has systematically evaluated existing theoretical models or developed alternative mechanics-based approaches for reliably predicting the stiffness of WDTCs.

This study aims to develop and validate a mechanics-based design framework for predicting the stiffness of WDTCs. Three modelling approaches, namely beam-on-elastic-foundation theory, spring-in-series models, and embedment-stiffness-based formulations, are employed to derive analytical expressions for joint stiffness. The proposed models are validated against a broad range of experimental data to assess their predictive accuracy. Furthermore, experimentally validated WDTC models are used to conduct a parametric study using LS-DYNA, employing material model MAT-143. The influence of key parameters, including member thickness, dowel diameter, loading direction, and end and edge distances, on the mechanical performance of WDTCs is systematically investigated. The outcomes of this study provide a comprehensive and practical design framework for wooden dowel connections, offering valuable guidance for engineers, manufacturers, and researchers in the development of sustainable, adhesive-free timber connection systems.

Key words

Dowel laminated timber; stiffness; dowel connection; analytical model; numerical model.

Proceedings of the International Convention of
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The Bonding Performance of CCA treated Radiata Pine Mass Plywood Panel

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Abstract

This study evaluates the moisture durability of Resorcinol Formaldehyde (RF)-bonded Chromated Copper Arsenate (CCA)-treated radiata pine Mass Plywood Panels (MPP) under cyclic moisture exposure. Bondline integrity was assessed through delamination testing in accordance with EN16351 standard, under adjusted drying temperatures, conditioning environments, and exposure cycles. No delamination was observed at any bondline after single wet-dry cycle. However, repeated wet-dry cycles and intensified wetting procedures resulted in progressive delamination within the phenolic-based primary bondlines. Importantly, no delamination was observed in the RF secondary bondline. The results demonstrate that cumulative moisture exposure significantly influences long-term bond performance, and that single-cycle testing may overestimate the durability of MPP products. The findings further suggest that conventional radiata pine plywood may not be suitable as the substrate for MPP intended for moisture exposure environments.

Key words

Bonding performance; MPP; delamination; timber bridge

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Innovating with Wood:
Science and Materials for a Sustainable Future

June 10 (Wed) 16:00~18:00

IV-1. Circular Economy, Climate Mitigation, and Socio-Economic Impacts

Symbiotic Waste Valorisation: A Case Study of the Estonian Wood and Furniture Industry

Jaan Kers* (Tallinn University of Technology), **Margit Kull** (Tallinn University of Technology), **Jaana Merisaar** (Tallinn University of Technology), **Tarmo Tuisk** (Tallinn University of Technology), **Jelena Hartšenko** (Tallinn University of Technology), **Merle Küttim** (Tallinn University of Technology), **Heikko Kallakas** (Tallinn University of Technology), **Wolfgang D. Gerstlberger** (Tallinn University of Technology)

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Abstract

Based on the European Union's Green Deal, the Estonian Green Reform Action Plan and Waste Act, the strategic direction of industries is to make their business models more circular and to find ways for efficient waste usage. The concept of industrial symbiosis (IS) is based on the sharing of resources between industries. The scientific literature has highlighted the enablers and barriers associated with the creation of symbiosis networks. Several problems arise in the Estonian context which would need attention to support IS, such as successful functioning of symbiotic waste valorization - the inadequacy of the database of waste generated in industries, limited possibilities of use, lack of cooperation between different parties.

The aim of current research is to find out the possibilities and value chains of waste valorization and symbiotic networks that would support the valorization of waste, using the Estonian wood and furniture industry sector (WFI) for case study. The target groups involved are the WFI, industries that valorize wood waste, representatives of research institutions and the public sector. The mixed method study uses PESTLE analysis and Delphi method to model functional and potential symbiotic wood waste value chains. In case study the bleached chemo-mechanical pulp is produced from low grade aspen logs. Logs are debarked before chipping. Most of bark waste has been sold to boiler houses. Some bark waste is mixed with the bio mud and composted on-site to be sold as fertilizer for farmers. Then logs are chipped and wood chips are washed. Company has Europe's largest anaerobic reactor producing biogas from their biowaste (bio mud) produced in wastewater treatment. Biogas is sold to bus transport company. The remaining sludge will be processed into high-quality fertilizer for farmers. Part of the production scrap like sawdust and fibers are sold, to producers of mycelium-based boards. Heat collected from the production process can be used to supply greenhouses to grow plants and seedlings.

Based on the collected data and analysis of research results the enablers and barriers associated with symbiotic network are identified, suggestions and policy recommendations will be made to all stakeholders.

Key words

industrial symbiosis; wood and furniture industry; symbiotic wood waste value chains

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Why Does Locally Harvested Timber Leak Out of Small-Scale Wood-Producing Regions? Structural Bottlenecks in Local Wood Circulation in Yasugi City, Japan

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Abstract

Local wood utilization has gained policy attention as a means of activating regional forest resources. However, even in timber-rich municipalities, circular use of locally harvested logs often fails to materialize. This study examines why logs harvested in Yasugi City, Shimane Prefecture, Japan, consistently flow outside the local market rather than being processed and consumed within the region.

Primary data spanning three fiscal years (FY2022-2024) were collected through semi-structured interviews with the local forest cooperative, two adjacent log markets, four local sawmills, and a precut factory. The study identifies institutional and capacity constraints governing routing decisions across the supply chain and diagnoses the structural bottlenecks preventing local wood circulation.

Housing-related timber demand declined from an estimated 6,109 m^3 in 2000 to 2,624 m^3 in 2023, reflecting a drop in housing starts from 149 to 64 units. The forest cooperative produced 4,728-5,281 m^3 annually in FY2022-2023, of which 62.8-68.6% was shipped outside Shimane Prefecture. Combined log purchases by the four local sawmills totaled only 13-15% of cooperative output. Applying a recovery rate of approximately 50%, the lumber yield from cooperative output roughly matches local housing demand, suggesting supply and demand are potentially balanced if sufficient local processing capacity existed. The sawmills maintained stable operations, confirming the mismatch is structural rather than a result of temporary disruption.

The primary driver of log outflow is therefore not a quantitative imbalance, but a critical shortfall in local processing capacity compounded by the complete absence of a log market within the city. Without local aggregation and price formation, logs flow structurally toward the neighboring Yonago market and other extra-regional destinations.

Effective policy responses should extend beyond demand promotion to include strengthening log-yard functions, expanding local sawmill capacity, and introducing practicable lot-level or prefectural-scale traceability. If housing starts continue to decline, a circulation model dependent solely on housing demand will become increasingly unsustainable. From a circular economy perspective, developing new intra-regional end-use strategies beyond housing emerges as a critical long-term challenge. The Yasugi case offers an empirically grounded diagnosis of structural log outflow in market-infrastructure-deficient municipalities and a basis for redesigning circular forestry policy.

Key words

local wood circulation; timber supply chain; log market infrastructure; circular economy; regional forest policy

Influence of timber application to building envelopes on urban microclimate under seasonal conditions

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Abstract

Urban heat island (UHI) refers to the phenomenon in which urban areas experience significantly higher temperatures than their surrounding regions due to human activities and the built environment. Timber materials, characterized by lower thermal mass and higher reflectivity than concrete, have the potential to serve as an effective material strategy for mitigating UHI effects. This study aims to evaluate the influence of timber application to building envelopes on urban microclimate under seasonal conditions. Using ENVI-met simulations in combination with field data, key thermal environmental indicators, including air temperature, surface temperature, mean radiant temperature, and outdoor thermal comfort, were assessed. The results indicate that the microclimatic effects of timber application vary by season. In summer, the timber-applied scenario showed changes in surface thermal behavior and outdoor thermal conditions, suggesting that the replacement of conventional envelope materials with timber may contribute to local UHI mitigation. In contrast, different thermal effects were observed in winter, implying that the conversion of building envelopes to timber should be interpreted from a balanced seasonal perspective rather than based solely on summer performance. These findings demonstrate that building envelope materials are not merely architectural components, but also important variables affecting urban microclimate. This study provides foundational evidence for evaluating the potential of timber application as a climate-responsive urban design strategy and offers methodological implications for integrating material-based approaches into urban thermal environment assessment.

Key words

Timber based envelope; Urban heat island; Urban microclimate; Thermal environment; Outdoor thermal comfort

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Material Matters: Wooden Corporate Buildings as Signals of Sustainability and Lower Perceived Greenwashing

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Abstract

Corporate buildings are major contributors to environmental impact through material use and embodied emissions, but they also function as visible and credible signals of corporate values. In the context of growing interest in wood-based construction, this study examines how the materiality of corporate headquarters influences stakeholder perceptions, with a particular focus on greenwashing, ecological customer engagement, and future patronage intention.

We employ between-subjects experiment (N = 1174) with respondents from the United States and the UK. Participants are randomly exposed to a press release describing a fictitious company's new headquarters constructed either in wood or in concrete/steel. This manipulation isolates building material as a sustainability signal. Perceived greenwashing is measured using established multi-item scales, alongside customer engagement and future patronage intentions. Environmental worldviews are captured using the New Ecological Paradigm scale.

The study contributes to wood science and market adoption research in two ways. First, we estimate the causal effect of wood (vs. concrete) as a building material on perceived greenwashing and downstream behavioural outcomes. Second, using structural equation modelling (SEM), we examine the latent relationships between greenwashing perceptions, customer engagement, and future patronage intentions.

The results show that wooden corporate buildings significantly reduce perceived greenwashing compared to conventional materials. Ecological attitudes moderate this relationship, such that the effect of wood as a sustainability signal is stronger among respondents with more pro-environmental worldviews. Lower perceived greenwashing, in turn, increases customer engagement and future patronage intentions, indicating a mediated pathway from material choice to behavioural outcomes.

The findings demonstrate that wood-based construction can function as a sustainability signal in corporate contexts. Beyond technical and environmental performance, material choice influences stakeholder trust and market responses. The study provides novel insights into how wood corporate headquarters contribute to value creation through perception-based mechanisms, offering implications for architects, developers, and firms seeking to leverage wood in sustainable construction and branding strategies.

Key words

Wooden buildings; Corporate headquarters; Perceived greenwashing; Consumer behaviour; Experimental design

Woody Biochar from Forestry Residues for enhancing the resilience of agroecosystems

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Abstract

Woody biochar from forest residues upcycles byproducts into soil amendments that can improve soil health by increasing water retention, enhancing nutrient absorption, and fostering a beneficial microbial community. In addition, biochar can absorb toxic chemical compounds, such as heavy metals and PFAS, reducing their uptake by crops. Biochar shows a promising solution to enhance the resilience of agroecosystems. This presentation will introduce our research studies conducted in the past several years on woody biochar's manufacturing, modification, characterization, and the performance assessment of being used as a soil amendment 1) to sustain water retention in coarse-textured, acidic soils for wild blueberries; and 2) to immobilize PFAS movement in the soil-water-crop system to reduce the bioaccumulations of PFAS in lettuce leaves and tomato fruits. The socio-economic impacts of biochar derived from forestry residues will also be discussed.

Key words

Agroecosystems; Biochar; Forestry residues; Resilisense; Socio-economic impacts

Proceedings of the International Convention of
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Forest-to-Forest: A truly circular ecology for timber architecture: from the forest to built form, and back

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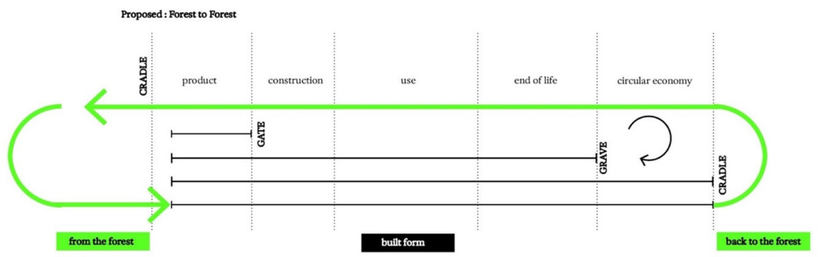
Abstract

The concept of 'material circularity' has recently reemerged in the disciplines of engineering and architecture as an important methodology with which to extend the carbon stored in the built environment. The reuse of building components or materials across multiple buildings allows embodied carbon to be distributed over multiple life cycles. The existing research on circularity has predominantly focused on the reuse of components or materials within the building and rebuilding cycles. However, this research leaves the end-of-life scenario— what happens to the materials after their use in buildings— undefined. In the case of wood and other biogenic materials, the worst case options for their end-of-life scenario can significantly nullify their carbon benefits.

This research proposal looks beyond conventional frameworks such as 'Design for Deconstruction' and 'Design for Reuse' by considering the full material ecology of timber construction: from the forest to built form, and back. By addressing the uncertainties surrounding material pathways, this study will address what happens to wood building materials after their use and reuse in the built environment, specifically focusing on the California context.

We aim to develop a more comprehensive understanding of the carbon life cycle for timber materials used in construction. Here we expand life cycle considerations to include information about wood sourcing (from the forest), to its life as a construction material (to built form) and to its end-of-life with a holistic ecological principle focusing on the cyclical principles of materials in nature. What if we could source timber from a local forest, process the timber into building components to be used over many building life cycles, and ultimately return its nutrients to the forest to support the growth of future building materials.



Key words

Circular construction; carbon cycle; forest; nutrient cycle; wood construction

Global Supply Chain Shocks and Wood Import Resilience: A VECM and Gravity Model Approach for Korea

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Abstract

The COVID-19 pandemic and the Russia-Ukraine conflict have exposed critical vulnerabilities in global supply chains, yet how these disruptions transmit through wood product markets remains poorly understood. Understanding trade resilience is essential for securing stable raw material supply for wood-based manufacturing and construction industries worldwide. South Korea, which imports over 83% of its industrial wood demand with high supplier concentration (HHI > 2,500), provides a compelling case for examining supply chain resilience across different product types. This study presents an integrated two-stage framework combining a Poisson Pseudo-Maximum Likelihood gravity model with triple fixed effects (PPML-FE) and a Vector Error Correction Model (VECM) to analyze both the structural determinants and dynamic shock responses of Korea's wood imports. Five major product categories—logs (HS 4403), sawn wood (HS 4407), plywood (HS 4412), wood pellets (HS 440131), and pulp wood chips (HS 440122)—were examined using annual bilateral trade data (2002-2023) for eight trading partners and monthly time-series data (2004-2023). The VECM results reveal a four-type resilience classification with markedly different recovery speeds: (i) market-driven products (logs, pulp chips) with rapid error correction (half-life < 1 month), (ii) an exchange-rate-sensitive product (sawn wood) with slow recovery (half-life = 3.54 months) and unique vulnerability to the Russia-Ukraine conflict, (iii) a demand-driven product (plywood) linked to domestic construction cycles (half-life = 0.95 months), and (iv) a policy-dependent product (wood pellets) where market-based adjustment mechanisms do not function (ECT = 0.003, p = 0.766). The gravity model further shows that free trade agreements and illegal logging regulations produce strikingly different effects across product categories, with environmental regulations acting as dual-edged mechanisms that facilitate trade for raw inputs while restricting processed products. Structural change analysis confirms that COVID-19 most severely disrupted plywood imports, while the Russia-Ukraine conflict uniquely affected sawn wood. These findings challenge the assumption that uniform risk management strategies can address supply chain vulnerabilities across the wood sector and provide an empirical basis for designing product-specific resilience policies.

Key words

supply chain resilience; wood products trade; gravity model; VECM; Korea

Interactive Effects of Temperature, Moisture Content, and Pressure on Birch Veneer Densification

Tolgay Akkurt* (Tallinn University of Technology), **Anti Rohumaa*** (Tallinn University of Technology), **Jaan Kers*** (Tallinn University of Technology)

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Abstract

Increasing environmental concerns and the limited availability of high-quality hardwood resources have intensified the need to enhance the performance of wood-based materials, particularly veneer-based products. Densification has emerged as an effective and sustainable approach to improve mechanical strength, surface quality, and dimensional stability. However, most previous studies have focused on individual processing parameters, resulting in a limited understanding of their combined effects. This study addresses this gap by systematically investigating the interactive influence of temperature, equilibrium moisture content (EMC), and pressure on the densification behavior of birch (Betula spp.) veneer.

A comprehensive experimental design was implemented, where veneers were densified in the radial direction under four temperature levels (90, 130, 170, and 210 °C), three pressure levels (1.8, 3.6, and 5.4 MPa), and three initial EMC levels (5%, 12%, and 20%). A constant pressing time of 8 minutes was applied across all treatments, resulting in 36 unique parameter combinations. This approach enabled a detailed evaluation of parameter interactions rather than isolated effects.

The results demonstrate that both higher pressing pressure and higher initial EMC consistently enhance the degree of densification. Notably, two distinct parameter regions yielded optimal performance: (1) low temperature (90 °C) combined with high EMC and high pressure, and (2) high temperature (210 °C) with similarly high EMC and pressure. In contrast, intermediate temperature ranges (130-170 °C) were less effective, indicating that densification efficiency does not increase linearly with temperature. Temperatures exceeding 200 °C were particularly influential, likely due to lignin softening above its glass transition temperature, which facilitates structural modification and compression of the wood matrix.

These findings highlight the importance of considering the combined effects of processing parameters when optimizing densification processes. The study provides practical insights for industrial applications aimed at upgrading low-quality veneers into high-performance engineered wood products. By improving process efficiency and material performance, this work supports more sustainable utilization of wood resources and contributes to the advancement of veneer-based product technologies.

Key words

Densification; Birch; EMC; Temperature; Pressure

Proceedings of the International Convention of
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Understanding the effect of thickness variation on adhesive bond formation conditions and bond integrity in cross-laminated timber

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Abstract

The integrity of the adhesive bond is an imperative criterion for qualifying layered engineered wood-based composites (EWP) for structural applications, such as cross-laminated timber (CLT). Given relatively easy control of spread rates and pressing parameters, adhesive bond failures in CLT are often attributed to adhesive-wood incompatibility, while neglecting other possible factors like thickness variability in lamstock. In CLT, even moderate variations in lamination thickness within the same layer can significantly affect the distribution of clamping pressure within layups, potentially affecting liquid resin distribution and cured bond integrity in finished panels. While the North American product performance standard ANSI/APA PRG320 specifies very tight thickness tolerance targets for CLT laminations, they seem not to be supported by theoretical rationale or experimental evidence.

The aim of the project is to determine the effect of thickness variation in adjacent laminations on the redistribution of clamping pressure transfer between layers on adhesive bond formation in pressing operations and on the integrity of adhesive bonds in finished CLT products. This presentation is focused on determination of the effect of controlled thickness variations in adjacent laminations on clamping pressure redistribution and resulting bond integrity in cross-laminated layups.

Measurements were conducted on scaled-down models of 3-ply and 5-ply layup sections covering three intersections of laminations with planted thicknesses variation in the middle layer. The test layups were subjected to simulated pressing conditions with and without adhesive. The pressure transfer between layers and redistribution of pressure between laminations in the core layer with thickness variation were evaluated from displacement and strain patterns on cross-section faces of the model layups captured with an optical measurement system based on the digital image correlation principle, and bond integrity was assessed using both standard destructive and experimental non-destructive methods.

The outputs support the refinement of analytical and numerical models predicting clamping pressure redistributions in structural size layups in response of known or assumed lamstock thickness tolerances. The models will be used to determine critical thickness tolerance thresholds to ensure consistent bond integrity in CLT products.

Key words

CLT; bond integrity; lamstock thickness tolerance; optical measurement; ultrasound transmission

The effect of voids on mechanical performances of wood-based products

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Abstract

Oriented strand board (OSB) is composed of cross-oriented layers consisting of thin and rectangular wood strands bonded together with adhesive under heat and pressure. OSB has become increasingly accepted in the construction market and is widely applied as a structural or non-structural panel, since it presents excellent physical and mechanical properties as well as competitive pricing. The various voids affect the mechanical properties of OSB. The influence of voids of the side face on the internal bond strength (IB) and bending strength is studied through image visual identification and digital image correlation (DIC). For IB test, the voidage within strain accumulation regions is significantly higher than total voidage ($p=0.003$), indicating that strain preferentially localizes in void aggregation regions. The initiation of cracks is prone to occur in the location with a cluster of large voids, and the cracks transversely propagate along the vicinity voids. Five structural factors are used to predict the IB. Three density-related factors (i.e. density, minimum density, and the density range along thickness direction) are considered, the R^2 are approximately 0.74 and 0.62. By incorporating voidage, void aggregation, and minimum density, the IB can be accurately predicted (R^2 are approximately 0.99 and 0.96). For bending test, in both major and minor axes, voidage and structural changes in core layer is much larger and smaller than those in face layer respectively. The size of voids hardly changes when the loading force is lower than 0.7 times of the maximum loading force. Structural changes in voids and nearby voids were much larger than those in other regions, which is obvious in core layer. Emergence of fractures is prone to occur in face layers due to certain voids, and in core layer due to regional large voidage. Characteristics of fractures play a crucial on modulus of elasticity (MOE) and modulus of rupture (MOR) of the specimens. Continuous and large fractures could contribute to energy dissipation and absorption, resulting in high MOE and MOR of the specimens. These findings provide practical guidance for IB, MOE and MOR evaluation when density range of the specimens is narrow.

Key words

Oriented strand board; Voidage; IB; MOE; MOR

Proceedings of the International Convention of
Society of Wood Science and Technology

Physical and Mechanical Properties of Bamboo I-Joist Based on Web Diameter, Flange Thickness, and Adhesive Types

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Abstract

This study evaluates the influence of geometric configuration and adhesive parameters on the physical and mechanical performance of bamboo-based I-joists manufactured from Siam bamboo (Thyrsostachys siamensis) as the web and Akasia wood (Acacia mangium) as the flange. The research integrates two experimental approaches: (1) variation in web diameter (3 cm and 4 cm) and flange thickness (2.0, 2.5, and 3.0 cm), and (2) variation in adhesive type (epoxy and polyurethane) and penetration depth (½, ¾, and full flange thickness). All materials were conditioned to a moisture content of 12-14% prior to fabrication to ensure consistency. Physical properties, including moisture content and density, were assessed alongside mechanical performance through bending tests - modulus of elasticity (MOE) and modulus of rupture (MOR) - as well as tensile withdrawal strength and failure mode characterization. The results demonstrate that increasing flange thickness significantly enhances density and bending performance, while optimal results were obtained at a web diameter of 3 cm combined with a 3 cm flange thickness. In contrast, larger web diameters tended to reduce structural efficiency due to increased susceptibility to instability and bonding limitations. Adhesive performance showed that epoxy resin outperformed polyurethane, particularly at a penetration depth of ¾ flange thickness, yielding the highest bonding quality and structural stiffness. Maximum values reached 22,361 kgf/cm^2 for MOE and 132 kgf/cm^2 for MOR. Failure analysis revealed that flange cracking and web-flange delamination were the predominant modes, especially in specimens with insufficient adhesive penetration and larger web diameters. Overall, the findings confirm that both geometric optimization and adhesive selection play critical roles in enhancing the structural integrity of bamboo I-joists. This study highlights the potential of engineered bamboo composites as sustainable and high-performance alternatives for structural applications in eco-friendly construction.

Key words

Engineered bamboo composites; bamboo I-joists; adhesive bonding performance; flexural properties; sustainable construction materials

Methods of Cross-linking of Hardwood Kraft Lignin as Bio-Based Wood Adhesives for Wood Bonding

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Abstract

This presentation aims to provide an overview about recent advances in ways of cross-linking hardwood kraft lignin (HKL) for bio-based adhesives of wood bonding. Prior to its cross-linking, HKL extracted from black liquor of pulp mill is acetone-fractionated to obtain acetone-soluble HKL (AS-HKL) and acetone-insoluble HKL (AI-HKL) to improve their low reactivity and high heterogeneity. And their molecular weight, chemical structure and thermal behavior were characterized. And various ways of cross-linking of HKL and technical lignin, using epichlorohydrin (ECH), demethylation, glyoxalation, amination, or organic acids to build thermosetting polymer for lignin-based wood adhesives. The crosslinking of syringaldehyde lignin via cross-coupling reaction is also included for lignin-based wood adhesives. These fractions were glyoxalated to improve their reactivity, and to build network structure via their self-crosslinking. FTIR, XPS and 13C CP/MAS NMR spectra showed that the cross-linking was successfully done between lignin molecules by forming new peaks for the formation of ether bonds in the glyoxalated lignin. The adhesive strength of lignin-based adhesives was determined by measuring tensile shear strength of plywood. The lignin-phenol-formaldehyde (PF) resins with 20% demethylated softwood KL showed good adhesion of plywood. The self-crosslinked AI-HKL showed the best adhesion performance. And the crosslinking of model syringaldehyde by cross-coupling reaction also showed exothermic reaction for a successful cross-linking of syringaldehyde. Two organic acids (citric acid and maleic acid) promote cross-linking HKL with greater adhesion strength. These results indicate that ways of cross-linking of HKL show a good potential of building thermosetting polymers for wood bonding.

Key words

Hardwood kraft lignin; cross-linking; cross-coupling; demethylation; glyoxalation

Proceedings of the International Convention of
Society of Wood Science and Technology

Advancing Wood Identification in the Philippines: Utilizing the Xylorix Platform for Efficient AI Model Development and Deployment for Five Key Species

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Abstract

This study investigates the use of artificial intelligence to improve wood identification in the Philippines through the Xylorix platform. Accurate wood identification is essential in the Philippines for conservation efforts and combating illegal logging, given the archipelago's rich biodiversity and the persistent challenges posed by the illicit timber trade. However, traditional identification methods remain limited by their dependence on specialized equipment and expertise, time-intensive procedures, and some that are susceptible to human error. This study presents a streamlined approach to developing and deploying artificial intelligence (AI) models for macroscopic wood identification using the Xylorix Platform: an integrated system of mobile applications, web-based tools, and cloud infrastructure designed to make AI model development accessible to wood scientists without requiring computational expertise. Focusing on five key Philippine wood species: Rain tree (Samanea saman), Banuyo (Wallaceodendron celebicum), Ipil (Intsia bijuga), Tindalo (Afzelia rhomboidea), and Mangium (Acacia mangium), chosen based on their availability and the presence of shared macroscopic characteristics that frequently present significant challenges to accurate identification. A structured workflow was implemented, encompassing standardized image capture, dataset curation, model training, and validation within the platform environment. The system enables systematic organization of image datasets, traceable annotation processes, and iterative model evaluation, supporting consistent and reproducible analysis. This work shows that an AI Platform such as Xylorix enables wood scientists to build reliable wood identification AI models with minimal technical overhead, and offers a practical, portable, and scalable solution for species identification and verification for the end users in forests, ports, sawmills, and other settings.

Key words

artificial intelligence; Philippine wood species; wood identification; Xylorix

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Innovating with Wood:
Science and Materials for a Sustainable Future

June 10 (Wed) 10:30~12:00

I-1. Fundamentals and Frontiers in Wood Physics and Mechanics

Study on the Correlation between the Main Chemical Components of Calamus simplicifolius Cell Walls and Micro-Mechanics

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Abstract

Rattan cane stems exhibit exceptional elasticity and toughness, making them a traditional natural raw material for household and craft products. This study focused on Calamus simplicifolius, innovating a combined characterization technique integrating plant cell wall micromechanics and regional chemistry. Confocal Raman imaging was employed to perform co-regional imaging on resin-embedded nanoindentation specimens of Calamus simplicifolius fiber cells. These specimens were derived from lignin-depleted, hemicellulose-depleted, as well as various cellulose crystalline forms. This approach elucidates how the cellulose crystalline structure, lignin, and hemicellulose influence the indentation modulus and hardness of rattan fiber cell walls at the cellular scale. The modulus and hardness of rattan fiber cells are 10.85 GPa and 487.62 MPa, respectively. The hardness of rattan cell walls decreased with reduced lignin content, while the modulus increased with decreased hemicellulose content. Cellulose crystallinity shifts from Type I to Type II, involving cellulose chain rearrangement, with crystal planes transitioning from (200) to (020), and increased grain size, leading to higher cell wall modulus and reduced hardness. Higher relative hemicellulose content enhanced transient elastic recovery deformation, whereas an increased proportion of cellulose type II diminished it. Changes in lignin and hemicellulose content, as well as cellulose crystalline transformation, were positively correlated with a decrease in creep rate. This study explains the variation in mechanical properties of rattan from a molecular structural perspective, providing theoretical guidance for the processing and utilization of rattan materials.

Key words

Words: Rattan; Main chemical components; Micromechanics

Proceedings of the International Convention of
Society of Wood Science and Technology

Wood properties of naturally grown Larix sibirica in degraded forests at seven sites in Mongolia

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Abstract

In Mongolia, Larix sibirica is the main tree species, covering about 62% of forest area. Between 2011 and 2020, around 729,000 m^3 of wood were harvested annually, mostly from forest cleaning and sanitation, with only 19% used for industrial purposes and the rest primarily as fuelwood. About 13% of forests (1.8 million ha) are degraded, and over 64 million m^3 of deadwood have accumulated due to aging stands, fires, logging, and pests. While the growth and wood properties of living L. sibirica trees have been extensively studied in Mongolia, there is virtually no research on deadwood, which remains largely unutilized.

This study assessed growth characteristics (stem diameter, tree height, and annual ring width), stress-wave velocity of standing trees, physical (basic density), and mechanical (modulus of elasticity [MOE], modulus of rupture [MOR], and compressive strength parallel to grain [CS]) properties of living, fire-affected, and standing dead L. sibirica trees across different snag stages in natural forests of Ulaanbaatar, Khuvsgul, Zavkhan, Bulgan, Dornod, and Khentii provinces. To evaluate differences among snag stages and decay classes for each measured property, an intercept-only linear mixed-effects model with a random effect of stages was developed.

The results indicate that standing and fallen L. sibirica retain sufficient wood quality for potential industrial use. Utilization of deadwood could reduce wildfire risk and support sustainable forest management, though further research on chemical properties is needed.

Key words

Forest fire; dead wood; snag stages; stress-wave velocity; physical and mechanical properties

Structural Reconstruction of Ultrafine Bamboo Fibers for High-Performance Bio-Based Composites

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Abstract

Developing bamboo-based structural materials that simultaneously exhibit high strength, dimensional stability, fire resistance, and moisture resistance remains challenging due to the intrinsic porosity of natural bamboo and inefficient interfacial load transfer. Herein, a densified bamboo fiber composite (BFC) is fabricated from ultrafine bamboo fibers (200 μm) through ordered fiber assembly combined with deep phenolic resin impregnation and high-pressure hot-press densification. The two-step strategy enables uniform resin infiltration into fiber lumens and inter-fiber gaps, collapsing the native hollow structure and reconstructing a continuous, densely aligned load-bearing network with a stable fiber-resin interface.

As a result, the composite exhibits excellent mechanical performance, with a flexural strength of 121.11 MPa, compressive strengths of 51.23 MPa (parallel) and 100.84 MPa (perpendicular) to the fiber direction, and a Brinell hardness of 19.23 HBW. The BFC also demonstrates improved moisture resistance, with contact angles of 108.16° (lateral surface) and 85.6° (cross-section), a water absorption rate of 7.8%, and a volumetric swelling ratio of 1.77% after 24 h immersion. In addition, the composite maintains structural integrity during 120 s flame exposure and exhibits effective thermal insulation. This work provides a scalable strategy for converting natural bamboo fibers into lightweight, fire-resistant, and water-resistant structural composites for sustainable construction applications.

Key words

bamboo fibers; mechanical performance; water-resistant; fire-resistant

Improving moisture resistance of bio-based protein adhesives with different crosslinkers

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Abstract

Protein-based adhesives have been used in wood bonding for centuries, but were eventually replaced by fossil-based alternatives due to economic and technical reasons. With increasing demand for sustainable materials, there is a renewed focus on enhancing protein adhesives to meet modern standards, such as low viscosity at high solid content, efficient processing times and most importantly, adequate water resistance of the end product.

Building on prior findings that mechanical treatment improves solubility and viscosity, high pressure homogenization (HPH) was found to improve viscosity, increase solid content and both dry and wet tensile shear strength (Malik, 2026, in press). In this study, we explore the potential of subsequent incorporation of crosslinkers to further enhance network formation and reinforce moisture resistance. Therefore, pea and maize proteins, available in Europe, were subjected to HPH treatment and crosslinkers such as glyoxal, polyethylenimine (PEI) and magnesium oxide were added. Distinct formulation-property trade-offs were observed with ABES and laboratory scale plywood; certain crosslinkers and crosslinker ratios increased viscosity and supported higher strength, whereas others lowered viscosity and improved application while maintaining comparable strength. Overall, combining HPH with tailored crosslinking strategies effectively improved moisture resistance and mechanical performance of European plant protein adhesives contributing to the development of environmentally friendly and sustainable wood adhesives.

Key words

bio-based adhesives; protein adhesives; high-pressure homogenization; crosslinking agents; moisture resistance; wet strength

Proceedings of the International Convention of
Society of Wood Science and Technology

Distribution of metabolites in *Ginkgo biloba* seeds

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Abstract

Ginkgo biloba seeds (GBS) are traditionally consumed in East Asia because of their high starch and protein content. In addition to their nutritional value, GBS contain polysaccharides and phenolic compounds with reported bioactivity. However, excessive consumption of GBS can cause acute poisoning due to ginkgotoxin (4′-O-methylpyridoxine), a neurotoxic analog of vitamin B6. Rational detoxification strategies are therefore required, yet the spatial localization of ginkgotoxin within seed tissues remains poorly understood.

In this study, the distribution of ginkgotoxin on cut surfaces of freeze-fixed GBS was analyzed by cryo-secondary ion mass spectrometry (cryo-SIMS). Combined with microscopic observation, cryo-SIMS results suggested that ginkgotoxin is spatially associated with widely distributed starch granules.

To further investigate its three-dimensional (3D) localization, volumetric datasets were acquired by gas cluster ion beam-assisted cryo-SIMS (cryo-GCIB-SIMS). Datasets were acquired in both polarities and segmented into hydrophilic and hydrophobic regions of interest (ROIs) using the water dimer ion ([(H2O)2±H]±) as an indicator of local water abundance. In negative mode, candidate ions reported as starch-derived fragments were significantly enriched in the hydrophobic ROI relative to the hydrophilic ROI (paired t-test, $P = 0.013$). PCA was performed for each ROI after excluding dominant contributions from H^-, OH^-, and water-cluster ions. The ginkgotoxin-derived ion (m/z 182), reconstructed independently, was found to be predominantly co-localized with the hydrophobic, particle-like domain model and was rarely detected in the hydrophilic ROI, indicating intragranular localization of ginkgotoxin in starch granules.

The workflow developed in this study enables volumetric assessment of specialized metabolite localization in storage tissues and offers a methodological basis for investigating chemical distribution patterns in woody-plant organs.

Key words

Ginkgo biloba; Ginkgo biloba seeds; cryo-TOF-SIMS; cryo-GCIB-SIMS; mass spectrometry imaging; ginkgotoxin; metabolites

Activity-guided isolation and identification of antiviral compounds from tree bark extracts

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Abstract

Tree bark is known as a rich source of extractives with diverse chemical structures and bioactivities. It is still considered as a low-value by-product of the forest industry and hence underutilized in terms of its biorefining potential. Promoting its valorization could contribute significantly to sustainable resource utilization and the development of bio-based alternatives to fossil derived products. In this work, ethanol:water (1:1) bark extracts from several boreal tree species were evaluated for antiviral activity against enveloped (coronavirus OC43) and non-enveloped (enteroviruses CVA9 and EV71) viruses. Ultrahigh-resolution mass spectrometry (FT ICR MS) revealed highly distinct chemical fingerprints across species. Bark extracts from European rowan (Sorbus aucuparia), Scots pine (Pinus sylvestris) and silver birch (Betula pendula) completely inhibited viral infections. Notably, antiviral efficiency showed no direct correlation with total phenolic content, indicating that antiviral activity is governed by specific metabolites and/or synergistic interactions rather than the high level of phenolics alone. Among the screened species, European rowan bark extract exhibited the highest antiviral activity against all viral strains tested, achieving complete inhibition at concentrations between 500 and 1000 μg/mL. Based on this pronounced bioactivity, rowan extract was selected for further investigation. The crude extract was fractionated using normal phase flash chromatography to obtain chemically simplified fractions, which were subsequently evaluated for antiviral activity. Active fractions were chemically characterized, enabling the identification of specific antiviral molecules present in European rowan bark extract. By combining broad screening of crude bark extracts with activity-guided fractionation, this study links bark chemical composition to antiviral function at the molecular level.

Key words

wood extractives; antivirality; activity-guided fractionation; phenolics; waste valorization

Proceedings of the International Convention of
Society of Wood Science and Technology

Using HSQC NMR to elucidate the molecular-level effects of suberin-specific esterases on birch bark

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Abstract

The transition towards a sustainable economy requires efficient use of biomass to replace fossil-based products. In forestry and timber-processing industries, large volumes of bark (approximately 300 Mt/year) are generated as byproducts, which are typically combusted for low-value energy recovery, despite bark being rich in biopolymers. Particularly, Birch (Betula pendula) bark is rich in suberin (~ 50% w/w), a highly heterogeneous plant polyester that can be used as a macromonomer for the synthesis of bio-based materials and specialty chemicals.

Suberin consists predominantly of long-chain fatty acids (LCFAs) interconnected through 1o, 2o and acylglycerol ester bonds and epoxides. Suberin is also covalently linked with lignocellulosics through ester and ether bonds. This structural complexity and heterogeneity limit its detailed characterization and utilization. The common practice to extract suberin uses chemical depolymerization, which requires harsh processing conditions. Enzymatic extraction can be milder and more selective approach; however, the bottleneck is that esterases capable of efficiently acting on suberin have not yet been reported.

In this study, filamentous fungi growing on lignocellulose were investigated as a source of esterases targeting suberin. Secreted enzymes were assayed for their specificity towards LCFAs and were then tested on birch bark. The impact of these enzymes on suberin's ester bond cleavage was assessed using semi-quantitative Heteronuclear Single Quantum Coherence (HSQC) NMR spectroscopy.

Two Talaromyces species were identified that secrete esterases with marked specificity for LCFA model substrates. Enzymatic treatment of birch bark resulted in significant reduction of multiple ester and ether bonds, particularly β-aryl ethers (-56%), 1,3-diacylglycerols (-64%), and epoxides (-41%), demonstrating selective modification of recalcitrant bark polymers. Consequently, a remarkable increase of free fatty acids (+106%), monoacyl glycerols (+47%), and primary alcohols (+43%) was also observed. which indicates the successful hydrolysis of suberin esters. Therefore, beyond enabling bark valorization, these results highlight the use of esterases as molecular probes, in conjugation with HSQC NMR, for investigating intermolecular ester linkages in bark, thereby contributing to advancing our understanding of the chemical structure of wood-derived materials.

Key words

2D NMR; LCFA; fungal; HSQC; lignin; ester bond

Integrated Process Optimization and Molecular Characterization of Boreal Bark-Derived Tannins for Sustainable Particleboard Manufacturing

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Abstract

Replacing petrochemical adhesives with bio-based alternatives requires reactive and reliable tannin sources from forest residues. Boreal softwood bark is an abundant resource, yet extraction efficiency and chemical variability between species remain important challenges. In this study, tannins from jack pine, black spruce, and white spruce bark were extracted and evaluated to assess their suitability for adhesive applications, specifically for the production of sustainable particleboards.

Aqueous, ethanolic, and alkaline extraction systems were compared to identify conditions that maximize tannin yield and reactivity. Extraction yield, total phenolics, and tannin reactivity were quantified. The molecular profile was further characterized through spectroscopic and chromatographic techniques to determine the chemical composition and purity of the extracts. Alkaline extraction produced the highest yields, reaching approximately 30% in spruce species. Stiasny values above 70% indicated a high proportion of reactive condensed tannins. Molecular characterization showed that procyanidin-type structures were dominant, although clear compositional differences were observed between species. While black spruce and white spruce barks showed similar behavior, jack pine bark exhibited lower extraction yield and a distinct phenolic distribution, suggesting the need for adjusted extraction conditions.

Overall, the results highlight the importance of integrating process optimization with molecular analysis to better understand tannin performance. Spruce bark tannins demonstrated strong potential as bio-based adhesive precursors for particleboard manufacturing, while species-specific strategies may improve the utilization of pine bark resources.

Key words

Boreal softwoods; Bio-based adhesives; Tannin extraction; Stiasny index; Picea; Pinus

Proceedings of the International Convention of
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Steam-Induced Cellular Expansion of *Quercus variabilis* Virgin Cork Granules: Toward Tunable Bio-based Porous Structures

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Abstract

Cork is widely recognized as an eco-friendly and sustainable material and has recently attracted increasing attention in aerospace, automotive, and construction applications. Commercial cork products predominantly rely on reproduction cork derived from cork oak (*Quercus suber*), which is obtained from subsequent harvest cycles. In contrast, virgin cork—defined as the bark obtained from the first harvest—particularly from *Quercus variabilis*, which is widely distributed in South Korea, remains underutilized. First-harvest virgin cork typically exhibits a denser and more heterogeneous cellular structure, which can limit its processing into uniform porous granules. Moreover, due to cork's intrinsic thermal insulation properties, dry heating can generate steep internal temperature gradients, resulting in non-uniform modification and surface charring. Despite the importance of processing control, the cellular response of *Q. variabilis* virgin cork to steam-based treatments has been less extensively documented than that of *Q. suber*. This study evaluates saturated-steam treatment in an autoclave system as a controlled approach to induce cellular expansion in Korean *Q. variabilis* virgin cork granules.

Virgin cork was granulated and sieved to a 2-4 mm fraction. Granules were treated in a laboratory autoclave under saturated-steam conditions at selected temperatures, followed by natural cooling to minimize depressurization damage and freeze-drying prior to characterization. Microstructural changes were screened using optical microscopy and further examined by SEM. Cell expansion was assessed from SEM cross-sectional images by approximating lumens as ellipses, measuring major and minor axes, and summarizing lumen size as an equivalent circular diameter (ECD); 25 lumens were analyzed per condition.

To capture composition-property coupling beyond morphology, chemical properties will be assessed by FT-IR and TGA, while surface and bulk behaviors will be evaluated by contact angle (wettability), bulk density, and elastic recovery. The combined dataset will be integrated using multivariate analysis (e.g., PCA) to map the process window and to clarify how steam-driven softening and moisture phase change translate into tunable porous structures and functional performance. The results will be presented as a framework for valorizing domestically sourced *Q. variabilis* virgin cork as a bio-based porous feedstock.

Key words

Quercus variabilis cork; steam treatment; cell expansion; lightweight materials; PCA analysis

By-product effluents from Eucalyptus' sulphite pulping: valorization of an underutilized source of bioactive compounds

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Abstract

Worldwide emerging trends towards sustainable approaches and the market's ever-glowing interest in safe natural products have prompted the manufacturers to search for alternative sources of raw materials and investing in natural compound recovery from wastes and by-products. In this context, both major by-products of acidic sulphite pulping process, sulphite spent liquor (SSL) and alkaline extract (AE) from alkali extraction purification stage, can be considered an underutilized natural resource since they are well known to contain ellagic acid (EA), beta-sitosterol (BS) and their derivatives. Valorisation and chemical characterisation of such molecules, with paradigmatic biological properties, can meet the demand for high-value natural compound recovery within sustainability and circular economy concepts. Hence, the development of a large-scale production of EA and sterol-based products from industrial streams of acid sulphite pulping of Eucalyptus can represent an important profit for pulp companies and contribute to the development of natural alternatives for synthetic additives in e.g., functional food and cosmeceutical industries.

A new method for the isolation of BS from alkaline extract (AE) of unbleached sulphite pulp purification was developed. BS was recovered by two-step acidification of AE up to pH 3 under pre-selected conditions, followed by fractionation of the formed precipitate with water-miscible organic solvents, having obtained best results with methanol (>90% purity), followed by BS crystallization induced via addition of water (ca. 10% vol.). The method is adaptable for large-scale industrial production of BS and may represent an important source of high-purity BS-based products.

In addition, a new solvent-free eco-friendly method for the recovery of EA from SSL and AE of unbleached sulphite pulp was proposed. EA was isolated from sulphite pulping streams via crystallization from acidified solutions under preselected conditions (80 °C, 24 h, glass crystallizer and high surface-to-volume ratio) followed by washings with acidified water to reduce concomitants, reaching ca. 85-95% (w/w) purity.

The developments related to industrial exploration of proposed products, as well as the new insights in characterization of their main fractions, contribute greatly to availability of high-quality natural products on the market and prompt further advances in the exploration of natural bioactive additives.

Key words

sulphite pulping; Eucalyptus; ellagic acid; phytosterols; sustainability; biorefinery

Proceedings of the International Convention of
Society of Wood Science and Technology

Synthesis of a Lignin-Based Binder via Radical Polymerization and its Application for Secondary Batteries

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Abstract

This study aims to synthesize a bio-based composite polymer film by combining biomass-derived lignin and water-soluble poly (vinyl alcohol) (PVA) through reversible Schiff base chemistry between aldehyde (-CHO) and amine (-NH2) functionalities. The research was designed as a stepwise workflow comprising precursor synthesis, composite blending and film casting, and verification of network formation and performance. First, lignin was functionalized with amine groups to provide reactive sites (Lig_Am), while PVA was modified to introduce complementary aldehyde-bearing functionalities (PVA-Ald). The resulting precursors were subjected to post-treatment such as precipitation/washing and drying to reduce residual low-molecular species and solvent effects. FT-IR and $^{1}H/^{13}C$ NMR were then used to qualitatively confirm precursor modification while ensuring that the lignin and PVA backbone structures were retained, thereby establishing the chemical building blocks for subsequent composite polymer formation. In the next stage, Lig_Am was solubilized and blended with PVA-Ald solvent, followed by solution casting. During drying, condensation between -CHO and -NH2 is expected to generate imine (C=N) linkages, yielding a dynamic covalent crosslinked network within the film. Key processing variables including blend ratio, solids content, and drying conditions (temperature, humidity) was systematically tuned to achieve uniform films and controlled network density. Network formation was evaluated by spectroscopic signatures associated with imine formation (changes in the corresponding IR bands). Finally, the contribution of dynamic linkages to autonomous repair behavior and mechanical integrity was assessed via cut-and-rejoin self-healing tests and tensile measurements. The proposed platform is anticipated to enable sustainable packaging films, coatings/membrane materials, and functional films leveraging lignin-derived attributes (UV shielding and antimicrobial activity), with further extension to conductive composites through incorporation of conductive fillers.

Key words

Biobased; polymer; lignin; self-healing

From Bark Waste to High-Value Bio-Based Materials: Cascade Valorization of Tree Bark Post-Extraction Residues

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Abstract

Wood bark is one of the largest underutilized resources generated by the forest-based industry. Although bark is increasingly processed in emerging biorefineries to obtain valuable compounds such as tannins, lignin, and suberin-derived products, the resulting post-extraction residues are still predominantly treated as low-value fuel. This practice limits the resource efficiency of bark processing and contradicts the principles of circular bioeconomy.

This research introduces a novel concept of bark biorefinery in which post-extraction residues are treated as valuable raw materials rather than waste streams. The project aims to comprehensively characterize residues generated during bark extraction processes and evaluate their potential as renewable feedstocks for bio-based materials and wood-based composites.

The study focuses on bark from major European tree species (Betula, Pinus, and Picea) and includes residues obtained after organosolv lignin extraction, alkaline extraction of tannins and extractives, and depolymerization of suberin into suberinic acids. The residues contain significant amounts of lignin, polysaccharides, and hydrophobic compounds that may provide functional properties such as adhesion, barrier performance, and biological resistance.

Advanced chemical characterization will be combined with material-oriented testing to identify promising pathways for residue upcycling. Particular attention will be given to the development of bio-based materials, including binder components and composite additives, enabling higher-value utilization of bark-derived biomass.

The expected outcome is a scientifically validated cascade processing model that integrates primary extraction products and residual fractions into a coherent valorization strategy. By demonstrating the material potential of bark extraction residues, the project aims to improve resource efficiency in bark biorefineries and support the transition toward sustainable forest-based industries.

The proposed approach provides a new perspective on bark utilization by shifting the focus from waste management toward value creation. The results are expected to contribute to the development of next-generation bio-based materials and to strengthen the role of tree bark as a strategic raw material for the circular bioeconomy.

Key words

tree bark valorization; bark biorefinery; bio-based material; cascade processing; extraction residues

Availability and Variability of Post-Extraction Tree Bark Residues as Emerging Raw Materials for Biorefinery Systems

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Abstract

Tree bark represents a major underutilized lignocellulosic resource generated in large quantities by the forest-based industry. While significant progress has been achieved in the extraction of high-value bark components such as polyphenols, lignin and suberin-derived compounds, the resulting post-extraction residues remain largely uncharacterized and are rarely considered as secondary raw materials. A systematic understanding of the availability and variability of these residues is essential for their reliable utilization within emerging bark-based biorefinery systems.

This study investigates post-extraction bark residues originating from both industrial extraction processes and laboratory-scale fractionation pathways. Residues associated with phenolic extraction, organosolv processing, and alcohol- and alkaline-based suberin recovery were collected from multiple sources representing different biomass origins and processing conditions. For each residue stream, material origin, processing history and key technological parameters were documented in order to enable direct comparison between different fractionation routes.

The analysis revealed pronounced heterogeneity among post-extraction bark residues. Variations were observed in physical structure, particle size distribution and residual extractives content, reflecting differences in extraction severity, solvent systems and raw material characteristics. The results indicate that extraction pathway and biomass origin represent the dominant factors governing residue variability and strongly influence the comparability of bark-derived materials obtained from different suppliers and processing routes.

The study provides the first structured overview of currently available post-extraction bark residue streams relevant to bark-based biorefinery concepts. Identification of the main sources of variability establishes a basis for standardized characterization and supports the development of cascade utilization strategies for tree bark biomass.

Improved understanding of post-extraction bark residues will facilitate their integration into circular bioeconomy concepts and enable more efficient utilization of forest-based resources.

Key words

tree bark; post-extraction residues; bark biorefinery; lignocellulosic biomass; cascade utilization

Proceedings of the International Convention of
Society of Wood Science and Technology

Chemical Fingerprinting of Bark Post-Extraction Residues Using Integrated Chromatographic Analysis

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Abstract

The development of bark-based biorefinery concepts requires detailed knowledge not only of extracted compounds but also of the chemical composition of the remaining post-extraction residues. These materials contain complex mixtures of carbohydrates, lignin-derived structures, polyphenolic compounds and lipophilic fractions whose composition strongly depends on the applied extraction pathway. Despite increasing interest in bark valorization, systematic analytical approaches enabling comparison between different post-extraction residue streams remain limited.

This study investigates the chemical composition of bark post-extraction residues obtained from representative European tree species using an integrated chromatographic approach. Residues originating from different fractionation pathways were analyzed using complementary techniques including liquid chromatography, size exclusion chromatography and gas chromatography coupled with mass spectrometry (GC-MS). The analytical workflow was designed to provide reproducible chemical fingerprints suitable for direct comparison between residues produced by different technological treatments.

Chromatographic profiles revealed clear compositional differences between residues originating from different extraction pathways. Variations were observed in the distribution of low-molecular-weight compounds, oligomeric fractions and lipophilic components, indicating distinct degrees of extraction severity and structural modification of the bark matrix. Size exclusion chromatography showed systematic differences in molecular-weight distribution, while GC-MS analysis identified characteristic groups of phenolic and aliphatic compounds associated with specific processing routes.

The combined analytical approach enables reliable differentiation of bark post-extraction residues and provides a basis for classification of bark-derived secondary raw materials. The results demonstrate that integrated chromatographic fingerprinting represents an effective tool for assessing the chemical heterogeneity of bark processing streams.

Establishing reproducible chemical fingerprints supports the development of cascade utilization strategies and facilitates the integration of bark residues into emerging biorefinery systems and circular bioeconomy concepts.

Key words

Bark biorefinery; Post-extraction residues; Chromatographic fingerprinting; Chemical composition; Circular bioeconomy

The effect of supercritical CO_2 treatment on cell wall composition and cellulose accessibility in spruce wood

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Abstract

Creep deformation occurs in the cellulosic portion of wood cell walls due to the unstructured nature of the amorphous region of cellulose and the unbonded hydroxyl groups found in this portion. Traditional surface coatings and innovative techniques such as nanoparticle impregnation are commonly used to increase the creep resistance of wood by reinforcing the wood macro- and microstructure. However, the cellulosic portion of wood is known to be difficult to access and modify, resulting in an inability to address the direct cause of this behaviour. This study examines the potential for supercritical carbon dioxide (sCO2) treatment to facilitate direct modification of the amorphous region of wood cellulose. sCO2 treatment is commonly used to aid in the hydration and dehydration of wood and to act as a solvent for wood modification. Furthermore, this treatment method has been demonstrated to unclog bordered pits in wood tracheids and promote the formation of an interconnected pore network that enhances the permeability of wood. This study aims to address a research gap concerning the effect of sCO_2 treatment on the distribution and concentration of cellulose, hemicellulose, and lignin within wood cell walls. Samples taken from the earlywood portion of Engelmann spruce (Picea engelmannii) were subjected to sCO2 treatment at varied temperatures and pressures. Raman microscopy was used to visualize morphological and nanoscale changes in the cell walls. The samples were further characterized using differential scanning calorimetry, powder X-ray diffraction, and coupled Fourier-transform infrared spectroscopy/thermogravimetric analysis. This research is currently in progress and characterization results will be compared to those obtained from a set of non-treated samples to determine the optimal method for increasing the accessibility of cellulose while avoiding excessive damage to the cell wall structure.

Key words

Supercritical carbon dioxide; spruce wood; amorphous cellulose; wood cell wall; Raman microscopy

Proceedings of the International Convention of
Society of Wood Science and Technology

Lignin-carbohydrate Nanoparticles From Low-purity Lignin: A potential reinforcement for particleboards enhancement

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Abstract

Low-purity lignin cake generated from the thermomechanical pulping (TMP) process represents an abundant yet underutilized byproduct within the pulp and paper industry. Its high content of non-lignin components, mainly carbohydrates (27%), often limits its direct application in wood adhesive systems due to its high molecular weight and structural heterogeneity. In this study, lignin-carbohydrate nanoparticles (nano-lignin) were successfully produced from lignin cake using an antisolvent process to obtain nanoscale particles with high colloidal stability. Comprehensive structural characterization using FTIR, ^{31}P NMR, HSQC-NMR, AFM, DLS, and TGA confirmed the successful formation of lignin-carbohydrate nanoparticles, although with a relatively low yield (~10%).

The prepared nanoparticles were incorporated at 0-2 wt% into UF resin systems to evaluate their influence on adhesive reactivity, curing behavior, and particleboard performance. Gel time and DSC analyses revealed moderate reductions in curing reactivity, mainly due to the increased water content introduced by nano-lignin, while maintaining acceptable processing windows. Particleboards manufactured with nano-lignin-modified UF adhesives exhibited internal bond strength values exceeding the ANSI A208.1 (2022) requirements for Grade M-2 panels, with 1 wt% nano-lignin providing the most favorable balance between mechanical performance and processability. Additionally, free-formaldehyde measurements showed a measurable reduction in formaldehyde emissions, confirming the scavenging effect of lignin-derived nanoparticles.

Overall, this study demonstrates, for the first time, a viable pathway to valorize TMP lignin cake through nanoscale conversion and highlights the potential of lignin-carbohydrate nanoparticles as functional additives in UF adhesive formulations. Their incorporation supports both improved performance and reduced environmental impact in wood-based composite production, contributing to the broader transition toward sustainable bio-based materials.

Key words

Lignin-Carbohydrate; Nanoparticles; Urea-formaldehyde adhesives; particleboard; TMP process

Synthesis and Biological Screening of Hydrazones Using Isolated Cholic Acid

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Abstract

Natural product modification is one of the key areas of synthetic organic chemistry for the accomplishment of valuable chemical building blocks that have prized medicinal significance. Hydrazones possess an azomethine (-NHN=CH-) group and are considered derivatives of aldehydes and ketones in which the oxygen atom has been replaced by the (R-NHN=C) functional group. These are widely studied molecules owing to their ease of preparation and diverse medicine, agriculture and pharmacology potential. Herein, cholic acid based hydrazones were synthesized and characterized using spectroscopic techniques. The newly synthesized cholic acid based hydrazones were screened for their anticancer and antioxidant potentioal. Antioxidants showed their activity by inhibiting the oxidative chain reactions that produce reactive oxygen species. The antioxidant activity showed that 4-NBCH exhibited the maximum DPPH inhibitory activity when compared with other synthesized compounds. The compound purified by thin-layer chromatography and column chromatography. Characterized by Ultra-Violet Visible Spectroscopy, Infra-red, Mass Spectrometry and Nuclear Magnetic Resonance Spectroscopy. Finally, the synthesized compound tested for its biological activities like anti-microbial, anti-oxidant and anti-cancer.

Key words

Cholic acid; Anti-microbia; Anti-oxidant; DFT Study; Spectroscopic Analysis

Proceedings of the International Convention of
Society of Wood Science and Technology

Evaluation of Lignin Monomer Conversion and Biomass Dissolution Efficiencies in *Pinus rigida* × *P. taeda* via Oxidative Catalytic Fractionation with a Base Catalyst

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Abstract

Lignin is the second most abundant chemical constituent in lignocellulosic biomass after cellulose, forming a complex polymer network of monolignol units within the cell wall. As these phenylpropane-based monolignols possess aromatic ring structures, they are highly regarded as promising raw materials for reducing carbon emissions by replacing fossil-derived aromatics. However, the diverse linkages among the three types of monolignols—p-coumaryl, coniferyl, and sinapyl alcohols—present challenges in ensuring the structural uniformity required for industrial applications. To overcome this limitation, research on lignin depolymerization is being actively pursued.

Among various depolymerization strategies, oxidative catalytic fractionation (OCF) offers the advantage of producing lignin monomers under relatively mild reaction conditions with high selectivity toward vanillin-based compounds, such as vanillin and vanillic acid. In this study, OCF was performed on powders of *Pinus rigida* × *P. taeda*—a hybrid known for its rapid growth and adaptability to harsh environments—at various temperatures (120-200 °C) using a base catalyst and an oxidizer. Biomass dissolution efficiency was calculated based on the weight ratio of the wood powder dissolved into the aqueous solution (the solubilized biomass fraction), achieving a maximum efficiency of approximately 96%. Furthermore, the content of vanillin-based compounds in the fraction was quantified via high-performance liquid chromatography, confirming that approximately 12.5% and 3.7% of the initial lignin content were converted into vanillin and vanillic acid, respectively. Subsequently, the extraction efficiency of these compounds from the solubilized biomass fraction was evaluated using organic solvents, such as methyl isobutyl ketone, under various conditions to optimize recovery.

Acknowledgement

This work was supported by the General Research Project of the National Institute of Forest Science (FP0701-2025-01-2026)

Key words

Lignin depolymerization; Oxidative catalytic fractionation; Lignocellulosic biomass; Vanillin-based compounds; Lignin monomer extraction

Influence of biomass feedstock on biochar structure, properties, and performance

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Abstract

Biochar derived from lignocellulosic biomass exhibits a wide range of physicochemical properties that depend strongly on the nature of the original feedstock composition and thermochemical conversion conditions. This study examined biochar produced from multiple biomass feedstock to establish direct links between fundamental composition, resulting carbon structure, and application-relevant performance. The results showed that variations in the chemical composition led to different degrees of carbon ordering, porosity, and surface functionality following thermochemical conversion. Additionally, selected biochar from various feedstocks were evaluated in representative applications, including soil durability, modified biochar-based insulating panels to impart fire resistance, and biochar-filled composite materials. Differences in performance were interpreted in relation to feedstock composition and its influence on the resulting material properties. Overall, this work provides insights into biochar structure-processing-property relationships and supports the development and selection of biochar as a multifunctional material across diverse engineering and environmental applications.

Key words

Biochar; biomass feedstock; structure-processing-property; functional materials

2026 SWST
International Convention

Innovating with Wood:
Science and Materials for a Sustainable Future

June 10 (Wed) 08:30~10:00

VII-1. IUFRO DIV.5.
with 2026 SWST in Korea:
Wood Properties and
Utilization

Tunable-performance sustainable bamboo composites via thinning and bioinspired layered reassembly

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Abstract

Bamboo, a rapidly renewable and eco-friendly resource offers significant potential to replace conventional materials in sustainable applications. However, bamboo composites often face challenges such as structural inhomogeneity, poor dimensional stability, and energy-intensive processing. Here, we propose a novel strategy integrating bamboo flattening and thinning technology with bioinspired structural design to engineer the performance of thin bamboo veneer composites. By tangentially splitting flattened bamboo into three gradient layers (outer, middle, and inner) and reassembling them into symmetric "hard-soft-hard" multilayered architectures, we achieved tunable density (0.63-0.92 g/cm3), porosity (26.3 %-45.5 %), mechanical properties, and enhanced stability. The outer-layer-dominant composites exhibited superior bending strength (243 MPa) and modulus (18.4 GPa). While the composites with inner-layer-enhanced structures demonstrated improved flexibility. Symmetric designs effectively eliminate asymmetric bending and reduce warping by more than 90 % compared to gradient-structured flattened bamboo. Moreover, these composites showed high specific strength (216 N m/kg), outperforming conventional flattened bamboo and delignified bamboo materials. Demonstrating applications in biodegradable cutlery, load-bearing furniture, sports equipment and sustainable construction, our approach provides a scalable pathway to advance bamboo-based sustainable materials, reducing reliance on plastics and promoting circular forestry economies.

Key words

Bamboo; Bamboo-based composites; Bamboo flattening

Proceedings of the International Convention of
Society of Wood Science and Technology

A Fully Bio-Based UV-Curable Flame-Retardant Coating Derived from Palm Oil and Phytic Acid for Wood Protection

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Abstract

The inherent flammability of wood limits its application in fire-safety scenarios, necessitating the development of efficient and environmentally friendly flame-retardant treatments. This study presents a fully bio-based UV-curable flame-retardant coating synthesized from renewable palm oil and phytic acid. First, palm oil-based methacrylate (MPOEA) was prepared via amidation and esterification, introducing reactive double bonds. Phytic acid was modified with glycidyl methacrylate through ring-opening reaction to obtain GPA, enhancing its compatibility with the hydrophobic resin matrix. The chemical structures were confirmed by FTIR and NMR. A series of coatings were formulated by blending MPOEA and GPA at various ratios. The formulation with a GPA/MPOEA mass ratio of 8:2 (GP8M2) exhibited optimal comprehensive performance, achieving a limiting oxygen index of 33.27% and a UL-94 V-0 rating for the cured film. The flame-retardant mechanism involved catalytic char formation in the condensed phase, producing a dense intumescent layer, complemented by gas-phase radical quenching. This optimal formulation was applied to wood via a delignification and impregnation process. SEM confirmed successful filling of the flame-retardant resin within the wood cell lumens. Treated wood showed significantly enhanced thermal stability and flame retardancy, with the LOI index increasing from 23.68% to 29.75% and achieving a UL-94 V-0 rating. Cone calorimetry results demonstrated that the coating delayed the time to peak heat release rate from 30 s to 90 s and reduced total heat release by 16%, effectively mitigating fire hazards. Notably, the coating eliminated secondary heat release and smoke production peaks, reducing the risk of flashover. Raman spectroscopy of the residual char revealed a highly graphitized structure, confirming the formation of a robust protective barrier. This work provides a green and sustainable strategy for developing high-performance bio-based flame-retardant coatings, offering significant potential for applications in construction and interior decoration.

Key words

Bio-based coating; Phytic acid; Palm oil; UV-curable; Wood flame retardancy

Development of a Palm Oil-Based Bio-Adhesive for Formaldehyde-Free Bamboo Particleboards: Interface Enhancement and Process Optimization

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Abstract

To address the environmental and health concerns associated with conventional aldehyde-based adhesives, this study explores the utilization of a palm oil-based adhesive derived from industrial by-products for the fabrication of formaldehyde-free bamboo particleboards. The adhesive was synthesized via esterification and characterized by FTIR and NMR, confirming the presence of hydroxyl groups and carbon-carbon double bonds, which facilitate substrate wetting and radical cross-linking. Rheological analysis revealed low viscosity, ensuring uniform dispersion on bamboo particles. Curing kinetics (Kissinger-Ozawa model) indicated a controlled curing process with low activation energy, compatible with industrial hot-pressing technique. Although boards bonded with the unmodified adhesive met requirements for modulus of elasticity (MOE, 2300 MPa) and internal bond strength (IB, 0.69 MPa), they fell short in modulus of rupture (MOR, 11.5 MPa) and exhibited high thickness swelling (TS, 14.3%). To overcome these limitations, four modifiers, i.e., maleic rosin, unsaturated polyester (UPE), maleic anhydride (MA), and polymeric methylene diphenyl diisocyanate (pMDI), were evaluated. Among these, MA (30%) demonstrated superior performance by forming ester linkages with bamboo components, creating a robust interfacial transition layer. This modification shifted the failure mode from interfacial debonding to fiber fracture, significantly improving mechanical properties and water resistance. Subsequently, response surface methodology was employed to optimize hot-pressing parameters. The optimal conditions (11% adhesive content, 156.2 °C, 300 s, 14.55 MPa) yielded boards with MOR of 19.93 MPa, MOE of 2834.56 MPa, IB of 1.06 MPa, and 24h TS of 12.94%, meeting the requirements for load-bearing applications. This research provides a sustainable pathway for utilizing oil palm industrial by-products to produce high-performance, eco-friendly bamboo composites

Key words

Palm oil-based adhesive; Bamboo particleboard; Formaldehyde-free; Interface modification; Response surface methodology

Proceedings of the International Convention of
Society of Wood Science and Technology

A Study on the Preparation of High-Performance Formaldehyde-Free Plywood via In-Situ Polymerization of a Polymerizable Deep Eutectic Solvent

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Abstract

To replace traditional wood-based panels relying on formaldehyde-emitting petroleum-based adhesives, and address the bottlenecks of conventional wood surface activation (multiple washing, time-consuming, low product strength) and inherent defects of common adhesives (premature curing of urea-formaldehyde adhesives, easy deterioration of soy protein adhesives), this study proposes an innovative “in-situ crosslinking of wood components” strategy.Using polymerizable deep eutectic solvent (PDES) to efficiently activate and reorganize wood’s inherent components, high-performance adhesive-free wood panels were successfully prepared. The DES system consists of glucose, oxalic acid, water, and p-toluenesulfonic acid. Wood veneers pretreated under mild 80℃ condition achieved direct cleavage of lignin-cellulose structure without multiple washing, rapidly exposing abundant active sites including phenolic hydroxyl and carbonyl groups. During subsequent hot-pressing, in-situ condensation and esterification between active groups and residual DES components were triggered, constructing a robust covalent crosslinking network with synergistic “dense aromatic skeleton-aliphatic bridge” structure.The prepared adhesive-free plywood showed dry and wet strength far exceeding the Type II board requirement of GB/T 17657-2013, with bonding strength of 1.41 MPa after 63℃ warm water immersion and 1.16 MPa after 93℃ boiling water immersion. Both activated veneers and final products can be stably stored for 6 months. This highly versatile strategy can efficiently fabricate adhesive-free particleboard (internal bonding strength 1.37 MPa), bamboo-based composites and pine lap joints, completely eliminating dependence on petroleum-based adhesives. It provides a technical path with both academic value and industrial potential for developing next-generation formaldehyde-free, process-simplified, high-performance and sustainable wood-based composites.

Key words

Polymerizable deep eutectic solvent (PDES); In-situ polymerization; Formaldehyde-free adhesive; Wood adhesion; Water resistance

Lignin-rich tyloses regulate competitive water-ethanol co-diffusion and suppress hyperswelling in oak wood

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Abstract

Owing to the presence of lignin-rich tyloses, white oak is favored over red oak for barrel cooperage of alcoholic beverage. To reveal how tyloses regulate diffusion processes and dimensional stability in oak wood, this study investigated the absorption and swelling characteristics of white oak and red oak immersed in ethanol solutions (0 - 100%). Co-diffusion revealed competitive interactions: water expedited ethanol motion while ethanol hindered water diffusion by disrupting its cooperative hydrogen-bond network and limiting cell wall polysaccharide reorganization. Water was the principal solvent penetrating the polysaccharides, whereas ethanol preferentially associated with lignin. In white oak latewood, radial swelling decreased monotonically from 8.8% in pure water to 4.9% in pure ethanol. In red oak latewood, radial swelling was 6.9% and 5.0%, respectively in pure water and pure ethanol, but a distinct "hyperswelling" effect occurred at 40% ethanol (8.3%). The plasticization of amorphous cellulose and hemicellulose was reduced with increasing ethanol concentrations, while lignin softened most at 40% ethanol. Lignin-rich tyloses in white oak obstructed vessels, restricted solvent co-diffusion, and constrained plasticization of cell wall, thereby suppressing the amplification of molecular softening into macroscopic hyperswelling. These findings elucidate the co-diffusion behavior of water and ethanol in wood and clarify the role of tyloses in regulating co-diffusion pathways and macroscopic swelling responses, which is essential for establishing a mechanistic understanding of multicomponent diffusion and swelling regulation in hierarchically structured porous biomaterials.

Key words

oak; tyloses; lignin; ethanol - water interaction; hyperswelling

Proceedings of the International Convention of
Society of Wood Science and Technology

Multi-Scale Oriented Reconstruction and Functional Enhancement of Bio-based Composite Materials

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Abstract

Oriented reconstruction across multiple scales represents a critical pathway for overcoming performance development in high-value bio-based materials. This study established a comprehensive scientific framework interconnecting three stages, including elementary unit design, multi-component reconstruction, and interfacial functionalization, thereby bridging structural design with performance regulation mechanisms. For elementary unit, the oriented alignment behaviors of wood-based units (particles, strands and veneers) across multi-scale interfaces were investigated. Quantitative correlation model of structure and property was established through unit orientation, hierarchical proportion, and macroscopic mechanical properties. This enabled the development of fine oriented strand boards (FOSB) with optimized structural stability and surface aesthetics. For multi-component reconstruction, studies on the size effects and morphological characteristics of bamboo and wood units revealed the correlations among unit features, interfacial structures, and macroscopic properties. Bamboo-wood oriented strand boards were manufactured, achieving structural synergy and performance complementarity between multi-source biomass resources. For interfacial functionalization, a layered adhesive strategy was investigated by employing soy-based protein adhesives in surface layers for environmental sustainability, while utilizing traditional resins (such as isocyanate and phenolic) in the core layer for enhanced structural stability, achieving gradient performance regulation across the material thickness. Concurrently, a lignin-based micro-nano paraffin waterproofing agent was developed via microencapsulation method, establishing in-situ hydrophobic barriers at interfaces. The micro-nano structural mechanism impeding water transport was elucidated, yielding ≥60% performance improvement over conventional water-proofing agents. Additionally, an alumina flame-retardant system was introduced, and utilizing ferric chloride coordination complexation to reinforce chemical bonding at multi-scale interfaces, which revealed synergistic enhancement mechanisms for interfacial strength and dimensional stability. This research constructs a scientific framework spanning intrinsic structural regulation to interfacial functional construction, providing theoretical foundations and technical pathways for high-performance manufacturing and engineering applications of bio-based composites.

Key words

oriented reconstruction; multi-component structure; Multi-scale; Interfacial Functionalization

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Innovating with Wood:
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June 10 (Wed) 10:30~12:00

VII-1. IUFRO DIV.5. with 2026 SWST in Korea: Wood Properties and Utilization

In-Situ Construction of Thermoresponsive Shape Memory Polymer Network to Improve Bamboo's Processability and Mold Resistance

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Abstract

Bamboo has been used extensively in a wide range of fields, including building, furniture, packaging, and high-end industrial applications such as automotive interiors and electronic products. However, its inherent limitations—including poor melt fluidity, remarkable dimensional instability under alternating dry-humid conditions, and high susceptibility to mold fungi—have severely restricted its using field especially for precision-molding and long-service components. Shape memory polymers (SMPs) offer a novel strategy to mitigate these challenges. In this study, a thermoresponsive SMP network was in-situ constructed via free radical polymerization using dimethylaminoethyl methacrylate (DMAEMA) and hydroxyethyl methacrylate (HEMA) as monomers. Disodium octaborate tetrahydrate (DOT) was further incorporated as an antimicrobial agent to fabricate a drug-loaded shape memory bamboo composite (DLSMP-B). The optimal DMAEMA:HEMA ratio (5:1) resulted in the PDH polymer with a gel fraction of 60.1%, tensile strength of 14.8 MPa, flexural strength of 31.0 MPa, 100% shape recovery at 130℃. DOT participated in crosslinking through hydrogen bonds and borate ester bonds, enhancing the gel fraction of PDHD polymer to 64.8% and improving its mechanical strength, along with pH/temperature dual-responsive drug release behavior.

Vacuum-pressure impregnation of PDHD reaction agents into NaOH pretreated bamboo yielded shape memery bamboo (DLSMP-B), which achieved complete shape recovery within 2 min at 100℃under 12 damage-free cycles, a 44% reduction in DOT leaching, and excellent long-term mold resistance. This work provides a novel technical route for improving bamboo's processability and mold resistance, thereby supporting the "bamboo-for-plastic" substitution strategy.

Key words

Bamboo; shape Memory Polymer; drug-Loaded polymer; mold resistance

Proceedings of the International Convention of
Society of Wood Science and Technology

Wood Structure and Properties for Wooden Cultural Relics Conservation

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Abstract

Wooden cultural relics are important parts of global cultural heritage. Wood structure and properties play a critical role in supporting the conservation of cultural relics. Wooden cultural relics generally undergo severe deterioration. Our stuides reveal that wood deterioration involves the partial cleavages of polysaccharide backbones and cellulose hydrogen-bonding networks, almost complete loss of acetyl side chains in hemicelluloses, the partial cleavage of β-O-4 interlinks, as well as oxidation, demethylation and demethoxylation of lignin. These changes further caused the disoriented arrangement of crystalline cellulose, and the decrease in both cellulose crystallite dimensions and crystallinity. In consequence, mesopores and macropores formed, and the number of moisture-adsorbed sites and their accessibility increased. Such structural variations lead to substantial losses in mechanical properties and dimensional stability, as well as changed hygroscopicity and discoloration, posing greater challenges to culturial relics conservation. Evaluating the preservation status of wooden cultural relics is the necessary for conservation. Polysaccharide oligomers, lignin structural units, and their dimers and trimers can therefore serve as key molecular markers. We further analyzed variations in moisture-adsorption sites, microfibril aggregation, and pore structure during moisture migration in archaeological wood. Results demonstrated that pre-freezing treatment effectively reduces dimensional deformation in slightly to moderately degraded waterlogged wood. For severely degraded waterlogged wood, consolidants infiltration into pore structures and regulation of consolidant-cell wall interactions are essential for wood properties improvement. Using statistical approaches including structural equation modeling and multiple linear regression, we also explored the relationships between cell wall components, metal ion complexation, and discoloration of wooden cultural relics. Accordingly, a non-invasive bleaching strategy was developed to achieve controllable surface decolorization of archaeological wood. These findings provide robust scientific and technological support for the improvement of wood properties and the innovative conservation of wooden cultural relics.

Key words

wood; cell wall components; dimension stabilization; discoloration; cultural relics

Evaluation of tree growth and wood quality for young *Paulownia* trees planted in Japan

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Abstract

Maximizing the yield of wood with desirable properties for end-use products is one of the major challenges in forestry management. These challenges are important, especially for fast-growing plantation forestry. Trees in the genus *Paulownia* have been widely planted in many regions, including East Asia, the United States, and Europe, due to their rapid growth. In Tochigi, Japan, *Paulownia* plantations have been established on abandoned farmlands since 2020. These *Paulownia* plantations are expected to contribute to the production of solid wood and fuelwood within a short rotation period. To propose an optimal management plan for these *Paulownia* plantations, information on tree growth and wood quality is essential.

In this presentation, results on standing-tree characteristics and wood properties related to solid-wood and fuelwood qualities of plantation *Paulownia* trees will be introduced. As the standing tree characteristics, stem diameter, tree height, and stress-wave velocity of stems were measured for *Paulownia* trees at the ages from one to five in eight plantations. Modeling of radial and height growth was conducted to estimate wood yield from *Paulownia* plantations and to determine the optimal harvesting age. The following wood properties were measured using small-clear specimens from four-year-old *Paulownia* trees: anatomical characteristics (vessel and wood fiber morphologies), physical properties (moisture content and basic density), and mechanical properties (modulus of elasticity, modulus of rupture, and compressive strength). Age-related changes in these wood properties were modeled. Stem volume and fuel characteristics (chemical component, calorific value, and elemental analysis) were investigated at the age of four. Visual grading and bending tests were conducted on lumber (38 × 89 × 1820 mm, with or without a pith cavity) obtained from four- and five-year-old *Paulownia* trees. Finally, a management plan for *Paulownia* plantations established in abandoned farmlands is proposed to maximize both yield and quality by integrating solid-wood and fuelwood production.

Key words

Fast-growing tree; short-rotation forestry; tree growth model; wood quality model

Proceedings of the International Convention of
Society of Wood Science and Technology

Developmental Changes in Cell Wall Structure and Chemical Composition in the Xylem of *Pinus massoniana*

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Abstract

Xylem development is a dynamic and continuous process, involving cell expansion, secondary wall deposition, and final maturation. During this process, wood cell walls are gradually constructed, accompanied by continuous changes in both structure and chemical composition. However, how these changes proceed during xylem development remains unclear. In this study, we investigated the developmental changes in cell wall structure and chemical composition in the xylem of *Pinus massoniana* using anatomical observation and Raman imaging.

The results showed a clear developmental sequence in tracheids. As xylem development proceeded, cell wall thickness increased continuously, while lumen diameter generally decreased, reflecting the gradual formation and consolidation of the secondary wall. At the same time, bordered pits and cross-field pits became clearer and more complete, indicating progressive structural differentiation during cell maturation.

Raman imaging revealed clear spatiotemporal changes in cell wall chemical composition. Lignin was mainly distributed in the cell corners and compound middle lamella, whereas cellulose was mainly concentrated in the secondary wall, especially in the S2 layer. With development, the Raman signals of both lignin and cellulose increased and became more localized, suggesting the gradual establishment of a dense and ordered cell wall architecture.

Overall, these results show that xylem development in *Pinus massoniana* is accompanied by coordinated changes in cell wall structure and chemical composition. This study helps clarify the developmental pattern of wood cell wall formation and provides new insight into wood formation at the cellular level.

Key words

xylem development; cell wall structure; chemical composition; Raman imaging; Pinus massoniana

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Innovating with Wood:
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June 10 (Wed) 13:30~15:30

III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

Enhancing Biochar for Supercapacitors through Fungal Pretreatment of Woody Biomass

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Abstract

Yellow poplar (*Liriodendron tulipifera*), red oak (*Quercus rubra*) and soft maple (Acer rubrum) were pretreated with selected white-rot fungi to modify the lignocellulosic structure, selectively degrading hemicellulose and cellulose while enriching lignin content. This biological pretreatment aims to improve carbon yield, porosity, and surface chemistry during pyrolysis. Following fungal treatment, the wood was pyrolyzed under control conditions to produce biochar, which was then characterized for surface area, pore distribution, electrical conductivity, and electrochemical performance. Results indicate that fungal pretreatment significantly enhances the development of hierarchical porosity and increases the density of electroactive sites, leading to superior capacitance and charge-discharge stability in supercapacitor testing. This approach demonstrates a sustainable pathway to convert lignocellulosic residues into high-performance energy storage materials, leveraging the synergistic effects of biological pretreatment and controlled pyrolysis to optimize biochar functionality for electrochemical applications.

Key words

Supercapacitors; biochar; fungal pretreatment; lignocellulosic biomass; hierarchical porosity

Proceedings of the International Convention of
Society of Wood Science and Technology

Turning Banana Waste into Functional Biofoams: A Simple Liquefaction Approach toward Sustainable Materials

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Abstract

Banana pseudostem is an abundant lignocellulosic residue generated after fruit harvest and is often underutilized despite its high potential as a renewable material resource. In this study, banana pseudostem fiber was directly liquefied in a PEG400/glycerol solvent system and utilized without post-liquefaction separation to prepare biomass-based polyurethane foams. This integrated processing route differs from previous approaches that rely on purification or phase separation, and enables the simultaneous incorporation of liquefied polyol components, lignocellulosic residues, and inorganic ash into the final material. The liquefaction process reached a stable state within 45 min, providing a shorter processing time than many previously reported banana biomass liquefaction routes. The resulting biofoams exhibited lower density and lower thermal conductivity than petroleum-based reference foams, indicating promising potential for thermal insulation and lightweight cushioning applications. Thermogravimetric analysis further showed that the biofoams had higher weight retention and char yield, suggesting improved condensed-phase stability during thermal decomposition. These effects are associated with the coexistence of bio-aromatic structures and plant-derived inorganic components retained from the non-separated liquefied banana fiber system. In addition, a screening cradle-to-gate assessment indicated that the biomass-based formulations reduced the estimated carbon footprint by about 8.2-9.8% relative to conventional polyurethane systems. This study demonstrates a practical route for converting banana agricultural residues into functional bio-based foams with insulation potential, reduced fossil resource dependence, and material-based carbon retention value. The study highlights how non-wood agricultural fibers can be reimagined as sustainable material feedstocks and aligns with broader efforts in circular bioeconomy and low-carbon material innovation.

Key words

banana pseudostem; biomass, liquefication; polyurethane; polyol; thermal degradation

Nanocellulose-based functional emulsions and foams

Shuaib Mubarak (Mississippi State University), **Dikshya Pokhrel** (Mississippi State University), **Bikal Ghimire** (Mississippi State University), **Yunsang Kim*** (Mississippi State University)

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Abstract

Nanocellulose has recently emerged as a promising bio-based stabilizer for emulsions because of its high surface area, amphiphilic character, and exceptional mechanical properties. In this talk, cellulose nanofibril (CNF)-stabilized oil-in-water (O/W) Pickering emulsions are introduced as a model system for encapsulating oil-borne active ingredients. These systems can achieve internal oil phase fractions exceeding 74%, making them high internal phase emulsions (HIPEs). Resulting O/W and inverse water-in-oil (W/O) emulsions show strong potential for applications such as thermal energy storage, coatings, and bioinks for 3D printing. The talk also explores the use of CNF-stabilized O/W emulsions as templates for constructing nanostructured materials. Emulsion-templated aerogels and foams will replicate the microstructure of the parent emulsion, allowing precise control over pore structures. This structural tunability opens opportunities in applications such as adsorbents and lightweight porous materials.

Key words

Nanocellulose; Pickering emulsion; cellulose foam

Proceedings of the International Convention of
Society of Wood Science and Technology

Multi-Functional Chemically Modified Cellulose Nanocomposites for Advanced Energy Storage

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Abstract

The transition toward sustainable energy storage requires materials that simultaneously deliver high performance and low environmental impact, driving growing interest in bio-based nanocomposites and multi-functional hybrid materials. In this context, cellulose has emerged as a versatile and scalable platform due to its abundance, biodegradability, and tunable surface chemistry.

Cellulose enables the design of advanced nanocomposites through synergistic integration with polymers and inorganic components, functioning both as a porous structure and an effective binding matrix. Its intrinsic characteristics, including high aspect ratio, interconnected porous networks, and abundant hydroxyl functionalities, make it particularly suitable as a template for porous membranes. When applied as a separator, nanocellulose forms a highly porous and uniform architecture that facilitates electrolyte uptake, enhances ionic conductivity, and improves thermal and mechanical stability. Through chemical modification and controlled processing, robust separator structures with tailored pore morphology can be fabricated, contributing to enhanced safety and electrochemical performance in lithium-ion batteries.

Beyond separator applications, chemical modification of cellulose enables the development of in situ processable gel-polymer electrolytes by controlling its solubility in organic solvents. This approach allows energy-efficient fabrication while improving interfacial contact and effectively suppressing lithium dendrite growth. Furthermore, this strategy can be extended to multi-functional hybrid binder systems that establish strong interfacial interactions with active materials, particularly high-nickel cathodes. Unlike conventional aqueous binders, which may induce undesirable surface reactions, a non-aqueous cellulose-based binder system ensures interfacial stability under high-voltage conditions. Functional groups on cellulose promote strong adhesion and facilitate ion transport along the electrode surface, mitigating parasitic side reactions and enhancing cycling stability. These interfacial advantages are especially critical in solid-polymer electrolyte systems, where conventional binders often fail to provide sufficient compatibility.

Overall, cellulose-derived nanocomposites represent a strategically important materials that integrates structural templating and interfacial functionality. As a PFAS-free, biodegradable, and mass-producible material, cellulose offers a promising pathway toward next-generation, sustainable, and high-performance energy storage systems.

Key words

Nanocellulose; lithium-ion batteries; separators; gel-polymer electrolyte; binder

The Potential of Rasau Fibers as a Sustainable Feedstock for Molded Pulp Packaging

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Abstract

Pandanus helicopus is an abundant, underutilized non-wood biomass with strong potential as a biodegradable packaging feedstock. Its fibers offer an alternative for raw-material diversification in response to resource constraints and environmental concerns associated with wood-based fibers and the declining supply of high-quality recycled fibers. This study evaluates pulp production from rasau using Neutral Sulfite Semi-Chemical (NSSC) and Subcritical Water Extraction (SCWE). NSSC is effective in reducing lignin content, whereas SCWE primarily removes hemicellulose. Fiber morphology, yield, and chemical composition were characterized, and lab-scale molded-pulp trays were fabricated to assess bonding performance. Results show that SCWE largely preserves lignin relative to raw material, while NSSC significantly reduces it. Accordingly, SCWE-derived products exhibited a darker appearance but better water resistance, whereas NSSC-derived products showed lower water resistance. At comparable freeness, molded pulp from NSSC-treated rasau fibers achieved a higher tensile index, while SCWE-treated fibers yielded lower tensile strength. Overall, these findings illustrate the technical feasibility of converting rasau fibers into molded-pulp packaging and highlight a sustainable pathway for valorizing non-wood biomass, particularly in wetland and conservation-area contexts.

Key words

Fibers; molded pulp packaging; NSSC; Pandanus helicopus; SCWE;

Proceedings of the International Convention of
Society of Wood Science and Technology

Toward TiO-Free Whitening Technologies: Development of Cellulose-Based Sustainable Opacifiers

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Abstract

Titanium dioxide (TiO_2) has long been used as a whitening and opacifying agent in paints, coatings, and cosmetics due to its high refractive index and efficient light-scattering properties. However, growing environmental and health concerns—such as its classification as a category II carcinogen and the ecological damage caused by open-pit mining—have intensified the search for sustainable alternatives. Among emerging candidates, cellulose has garnered significant attention as a bio-based, biodegradable, and abundant material that can be engineered to mimic the optical performance of TiO_2. The key to achieving high opacity lies in maximizing diffuse light scattering, which TiO_2 accomplishes through its optimal particle size (~200-300 nm) and high refractive index. While cellulose has a lower intrinsic refractive index, its morphology can be tuned to enhance scattering. Recent advances have demonstrated that creating ultra-porous cellulose structures with controlled pore sizes and high air-solid interfaces can significantly boost light scattering in the visible range. Strategies such as hard templating, alkali-induced swelling, and physical alterations to fiber network, have been employed to fabricate such structures. These approaches enable the formation of hierarchical porosity and sub-micron features that promote multiple scattering events, thereby enhancing opacity without relying on inorganic additives. This work presents a comparative overview of various processing techniques to tailor cellulose morphology for optical applications. Emphasis is placed on the relationship between processing conditions, resulting microstructure, and optical performance. The findings highlight the potential of cellulose-based materials to serve as environmentally benign opacifiers, paving the way for their integration into sustainable formulations across paint, coatings, packaging, and personal care products.

Key words

Opacifiers; cellulose; light scattering; paint; Titanium di oxide

Analysis of Upcycled Lint Fiber for Composite Applications

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Abstract

Lint fibers are waste fibers that are created due to fiber breakage that occurs as clothing is laundered, and when a dryer is used, they are collected in a lint trap so as to prevent fiber buildup in the dryer that can result in a fire hazard. These fibers are made up of a mix of natural and synthetic short fibers. Lint fiber shows potential as a possible source of fiber for composites due to the formability of the fiber. This study aims to validate if lint fiber is suitable as a fiber source for composite applications. HPLC was performed on multiple sources of lint fiber gathered from residential, laundromat, and hotel sources to see the consistency of cellulose content in lint fiber from different sources. Lint fiber/epoxy composites were characterized to determine the mechanical properties of the material to see how if it is comparable to other fiber sources. One of the most common applications of lint fiber is to turn it into a fire starter and due to this the flammability of the lint fiber was tested and a fire-retardant treatment was performed to see if it can reduce this property. Acoustic properties were studied using an impedance tube to better understand the sound absorption and uniformity of the material. Lint fiber shows great potential and by creating upcycling it into value added composites it can reduce waste and promote sustainability.

Key words

Natural Fiber Composite; Waste Material; Lint Fiber

2026 SWST
International Convention

Innovating with Wood:
Science and Materials for a Sustainable Future

June 10 (Wed) 16:00~18:00

III-1. Innovations and Opportunities in Bio-based Nano Composites and Multi-Functional Hybrid Materials

Computationally Accelerated Design, Discovery, and Development of Chemically Recyclable Polyolefin-like Multiblock Polymers

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Abstract

A significant challenge to a sustainable plastics economy is that the needs of plastics are diverse and have been met by over 100 years of advances in polymer chemistry and engineering. We synthesized chemically recyclable multiblock polymers (polyBLOCKs) through a step-growth condensation polymerization of telechelic (di-end functionalized) hard or soft oligomers (BLOCKs) possessing identical chain-end groups. These fundamental hard and soft BLOCKs for separation and repolymerization to realize a closed-loop lifecyle which solves plastic recycling issues.

Structure-property relationships and design principles of this new class of macromolecules are required to accelerate their evolution toward commercially viable, chemically recyclable plastics as replacements for polyolefins. Driven by our development of machine learning (ML) models for quantitative structure-property relationships, we will demonstrate how we can accelerate the efficient design and realization of this class of chemically recyclable plastics.

Key words

Polyolefin; computation; Machine Learning; AI; block copolymer

Proceedings of the International Convention of
Society of Wood Science and Technology

Enhancing the Mechanical Properties of Flax Fiber - Reinforced Epoxy Composites through Cellulose Nanofiber Incorporation

Ruiwen Yu (Beihua University), **Jung-Il Song** (Changwon National University), **Mingli Liu*** (Beihua University)

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Abstract

For economic success and environmental persistence, the “Bioeconomy” model of the 21st century promotes the utilization of renewable resources instead of the mere use of nonrenewables. Cellulose is the most important source of renewable resources. In the annual production in nature, a significant source of people is 7.5×1010 tons, the most abundant natural composite material on earth. The mechanical properties of cellulose nanofibers (CNFs)-reinforced natural fiber composites have been the focus of researchers in recent years. Due to its high elastic modulus, low density, high aspect ratio, bio compatibility and biodegradability, it is widely used in the reinforcement of polymer materials. Therefore, it is necessary to develop CNFs-reinforced natural fiber green composites, but few researchers focus on impregnating cellulose on the surface of natural fibers. However, they are limitations using CNFs in green composites. Such as, high cost, extraction process is complete. Property of CNFs is deference with different extraction process and source. Further the mixing homogeneously of CNFs with thermoplastic/thermoset polymer is also challenge task.

Presently, natural fiber composite materials exist Problems such as sustainable application and poor mechanical properties, in our experiments, we extracted cellulose nanofibers (ECNFs) from a natural grass (Imperata), used flax fabrics to impregnate them in a nanosolution, and fully exploited the adhesion mechanism to prepare ECNFs/tFF fibers and adding Epoxy Resin (ER), and preparing ECNFs-tFF/ER composite by vacuum-assisted resin transfer molding (VARTM).

Key words

Cellulose Nanofibers; Reinforcement; Green composites; Treatment

Microstructural and thermochemical evolution of marine algae-nanocellulose hybrid formulation for fire-safe wood insulation composites

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Abstract

The development of fire-resistant bio-based insulation materials remains a critical challenge in sustainable construction. Recent observations have shown that mixtures of marine algae processing residues and wood-based materials exhibit enhanced fire resistance, however, the underlying mechanisms remain poorly understood. In this study, hybrid films were prepared by forming aqueous slurries of marine algae residue and cellulose nanofibrils (CNF), followed by controlled drying. The objective was to investigate the microstructural, chemical, and thermochemical evolution of the hybrid system and identify mechanisms contributing to improved thermal stability in the composite material. Chemical interactions were analysed using ATR-FTIR and elemental analysis (ICP-OES), while structural changes were examined by XRD. Morphology and mineral distribution were evaluated using SEM-EDS. STA was performed to assess degradation pathways and char formation. Results indicate interaction between CNF and algae-derived components, evidenced by shifts in hydroxyl and carboxylate bands, suggesting hydrogen bonding and ionic coordination. SEM imaging revealed densified fibrillar networks with embedded mineral-rich domains, while EDS mapping confirmed the redistribution of inorganic species within the hybrid structure. STA showed modified degradation behaviour and increased char yield compared to neat CNF, indicating mineral-assisted carbonization and barrier formation. The findings provide mechanistic insight into chemical structuring during formulation and demonstrate how marine biomass residues can enhance the properties of nanocellulose systems. This work supports the current development of circular, fire-safe bio-based insulation materials and establishes a scientific basis for further board-scale optimization.

Key words

Alginate; fire reaction; microscopy; thermal analysis; wood product

Proceedings of the International Convention of
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Lightweight Cellulose-Based Composite Aerogels for Integrated Flame Retardancy and Thermal Insulation

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Abstract

Lightweight aerogels that simultaneously combine flame retardancy, thermal insulation, and mechanical robustness are highly desirable for applications in thermal safety protection, building insulation, and advanced lightweight structures. In this work, a cellulose-based composite aerogel was constructed using cellulose nanofibrils (CNF) and poly(vinyl alcohol) (PVA) as a continuous porous framework, together with SiO_2 and $Al(OH)_3$ as inorganic functional components. The composite aerogels were prepared through a facile sol-gel, freeze-casting, and freeze-drying route, resulting in a three-dimensional interconnected porous structure with ultralow density and good structural integrity. Structural characterization indicates that SiO_2 and $Al(OH)_3$ are uniformly distributed within the CNF/PVA network and form strong interfacial interactions with the organic framework, which contributes to the stability of the hybrid architecture. Mechanical analysis shows that the aerogel maintains stable viscoelastic behavior over a broad temperature range and can effectively dissipate stress under compression through pore-wall bending and particle-bridging effects. In addition, the incorporation of SiO_2 and $Al(OH)_3$ significantly improves the flame-retardant performance of the aerogel. Microscale combustion calorimetry and thermogravimetric analysis reveal reduced heat release intensity, suppressed intrinsic flammability, and increased residual stability, demonstrating a clear synergistic flame-retardant effect. During combustion, $Al(OH)_3$ undergoes endothermic decomposition and releases water vapor, while the resulting Al_2O_3 together with SiO_2 forms a protective inorganic barrier that inhibits heat transfer and combustible gas diffusion. Meanwhile, the highly tortuous heat-transfer pathways and enhanced interfacial thermal resistance within the hybrid porous network endow the aerogel with low thermal conductivity and excellent thermal insulation performance. These results demonstrate that the developed cellulose-based composite aerogel is a promising sustainable material for integrated flame-retardant and thermal-insulating applications.

Key words

Cellulose nanofibrils; Composite aerogels; Flame retardancy; Thermal insulation; Mechanical stability

Evaluation of Hardwood Bark-Derived Tannins for Bio-Adhesive Formulation and Sustainable Wood-Based Biocomposites Production

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Abstract

The widespread use of synthetic adhesives in wood-based composite industries has raised significant environmental and health concerns due to formaldehyde emissions, toxicity, and reliance on non-renewable resources. In response, this study explores the development and application of tannin-based bio-adhesives derived from the bark of different hardwood species e.g. Ceriops decandra, Acacia catechu, Acacia nilotica, and Cassia fistula. Tannin extraction was carried out using hot-water methods, followed by filtration and concentration. Chemical characterization of extracts included determination of total tannin content (TTC) using the Folin-Ciocalteu assay and evaluation of condensed tannins via the Stiasny index were done. All species showing significant condensed tannin content (>65%) and exhibited higher TTC, indicating superior adhesive potential.

Bio-adhesives were formulated by incorporating hexamine as a hardener at varying concentrations (0-12%). The physicochemical properties of adhesives, including viscosity, pH, solid content, and gel time, were analyzed, revealing that 8% hexamine provided optimal performance, with reduced gel time and improved bonding characteristics. Fourier Transform Infrared (FTIR) analysis confirmed the presence of characteristic functional groups, validating the reactivity and suitability of tannin extracts for adhesive applications.

The developed adhesives were applied in the fabrication of plywood and particleboard. Composite panels were produced under controlled pressing conditions and evaluated according to ASTM and ANSI standards. Physical properties such as density, moisture content, water absorption, thickness swelling, and linear expansion were measured alongside mechanical properties including modulus of elasticity (MOE), modulus of rupture (MOR), and internal bonding strength (IB). Results indicated that panels bonded with Ceriops decandra-based adhesives consistently exhibited superior performance, with density values up to 0.78 g/cm^3, lower moisture content (~6.78%), and improved dimensional stability. Mechanical properties were also enhanced, with maximum MOE (3252 N/mm^2), MOR (up to 32.4 N/mm^2), and IB (up to 0.93 MPa) observed at the optimized 8% hexamine formulation.

Overall, the study demonstrates that tannin-based bio-adhesives from hardwood barks are effective, eco-friendly, and technically viable substitutes for conventional synthetic adhesives. Their successful application in plywood and particleboard production highlights their potential for advancing sustainable and low-emission wood composite technologies.

Key words

Hardwood Bark, Tannin, Folin-Ciocalteu Assay, Biocomposites, Bio-adhesive

Proceedings of the International Convention of
Society of Wood Science and Technology

Determination of Physical, Mechanical and Fire Retardancy Properties of Innovative Particleboard Made from Corn Stalk (Zea mays L.) Particles

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Abstract

The demand for particleboard is increasing along with economic and population growth. However, two major barriers to the manufacture of particleboard are a shortage of raw materials (woodchips) and the emission of for maldehyde from conventional adhesives. Agricultural by-products such as corn stalks contain an abundance of renewable lignocellulosic fiber. This study evaluates the effect of citric acid as a natural adhesive and fire retardant addition on the physical, mechanical, and fire retardancy properties of particleboards fabricated from corn stalks. A cost-effective and inorganic salt, calcium carbonate, was tested to enhance the fire retardancy. Ammonium dihydrogen phosphate was also considered as a comparative control. Particleboards with the addition of calcium carbonate were pretreated with sodium chloride. The particleboards were pressed for 10 min at 200°C. Japanese Industrial Standard JIS A 5908:2022 was used as the benchmark for the physical and mechanical tests. Fire retardancy was dynamically tested by simulating a Bushfire Attack Level of 19 kW/m2. The particleboard with 25 wt% citric acid had superior mechanical properties and complied with the JIS A 5908 standard for Type 13 base particleboard. Particleboard with the addition of calcium carbonate (5% and 10%) showed significantly delayed pyrolysis time.

Key words

Particleboard; corn stalk; fire retardancy; citric acid; mechanical properties

Developing Lightweight Silanized Cellulose Ultramaterials as the Strongest Engineered Aerogel

Kangkang Zhang* (Southwest Forestry University), **Jian Qiu** (Southwest Forestry University), **Yushan Yang** (Southwest Forestry University)

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Abstract

Silica aerogel materials exhibit exceptional properties, including unique light, heat, fluid, and ion characteristics with vast potential. Despite similarities incomposition to glass, silica aerogel lacks ductility and is prone to breakage upon impact. Therefore, the development of advanced engineering aerogel ultra materials that combine the mechanical strength of engineered materials with the ultralight superinsulation of aerogels remains a significant challenge. Herein, a multidimensional and multiscale gradient-pore strategy is proposed for the scalable production of nanostructured silanized cellulose (SiCell) nanofibrous frameworks through colloidal self-assembly using an active earth-abundant biopolymer from the wood as a functional component. The configuration of the SiCell/polymer-crosslinked silica-aerogel-powder(SiAP)-locked structure creates a regional framework that forms SiCell/polymer-crosslinked SiAP-locked aerogels (SiCSiPA) with a 3Dnanoporous architecture. With an ultralow thermal conductivity of 15.9 mWm 1 K 1, the lightweight super insulating SiCSiPA emerges as a prime candidate for thermal insulation, offering exceptional strength for practical applications. Moreover, SiCSiPA exhibits superior strength, stiffness, and toughness, making it the best insulating material. Owing to its outstanding strength-to-weight ratio and robust thermomechanical stability, SiCSiPA introduces a new technology for lightweight construction applications requiring superior thermal insulation.

Key words

cellulose nanofibrils; mechanical/thermomechanical multistability; silanized cellulose ultramaterials; strongest engineered aerogels; thermal insulation

2026 SWST
International Convention

Innovating with Wood:
Science and Materials for a Sustainable Future

June 9 (Tue) 08:30~10:00

Poster

Pure and mixed stands wood density and productivity in Lithuania

Benas Šilinskas* (Agriculture Academy, Faculty of Forest Sciences and Ecology, Vytautas Magnus University; Institute of Forestry, Lithuanian Research Centre for Agriculture and Forestry), **Edgaras Linkevičius** (Agriculture Academy, Faculty of Forest Sciences and Ecology, Vytautas Magnus University; Institute of Forestry, Lithuanian Research Centre for Agriculture and Forestry), **Lina Beniušienė** (Agriculture Academy, Faculty of Forest Sciences and Ecology, Vytautas Magnus University; Institute of Forestry, Lithuanian Research Centre for Agriculture and Forestry)

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Abstract

Mixed-species forests are increasingly promoted in Europe due to their potential to enhance productivity, resilience, and ecosystem functioning compared with pure stands. This study evaluated the productivity and wood density of pure and mixed stands of three dominant tree species in Lithuania—Scots pine (Pinus sylvestris L.), Norway spruce (Picea abies (L.) H. Karst.), and Silver birch (Betula pendula Roth). Nine study plots representing pure and 70:30 mixed-species stands were selected from forest inventory data on infertile light soils (Nbl), with stand age ranging from 45 to 50 years. Within each plot, tree diameter at breast height (DBH), tree height (H), crown width (CW), competition index (CI) and wood density (WD) were measured for 809 trees. Wood density was measured using an IML Resi PD500 resistance drilling device. All trees were measured with a 500 mm drill at a drilling speed of 200 cm min^{-1} and a rotation speed of 2500 rpm. Resistance drilling was performed in the north-south (N-S) direction at breast height. Statistical differences among stands were assessed using ANOVA followed by Duncan's multiple range test. Pearson correlations were used to determine relationship between wood density and other tree characteristics.

Results showed that mixed stands generally improved tree growth and stand productivity compared with pure stands. The highest mean diameter and height values were observed in pine-spruce mixtures, where Scots pine exhibited up to 36% greater DBH and 16% greater tree height than in pure pine stands. Birch growth also benefited from mixtures, particularly in pine-birch stands, where DBH increased by up to 32% compared with pure birch stands. Stand volume was consistently higher in mixed stands across all species combinations. The most pronounced effect was observed in pine-spruce mixtures, where stand volume exceeded that of pure pine stands by 85%. Admixtures of spruce or pine increased stand volume in birch-dominated stands by 28-30%, while admixture of pine in spruce stands increased volume by 29%. The wood density correlates with DBH. The highest correlations were between DBH with H and CW.

Key words

Resistance drilling; wood density; stand productivity; pure-mixed stand characteristics; Scots pine; Norway spruce; Silver birch.

Proceedings of the International Convention of
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Investigation of Structural Performance and Lignin Welding Stability of Wooden Nails in Timber-Concrete Composite systems

Kyung-Sun Ahn* (Seoul National University), **Jun Seo Park** (Seoul National University), **Min-Jeong Kim** (Seoul National University), **Gwang-Ryul Lee** (Seoul National University), **Haegyu Lee** (Seoul National University), **Jung-Kwon Oh** (Seoul National University)

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Abstract

An amine-functionalized lignin-based hydrogel was developed as a multifunctional material for palladium (Pd) adsorption and catalytic reuse. Kraft lignin was chemically modified with ethylenediamine (EDA), diethylenetriamine (DETA), and triethylenetetramine (TETA) to introduce protonatable amine groups and systematically investigate the influence of polyamine structure on Pd adsorption performance. The aminated lignin were subsequently crosslinked with poly(ethylene glycol) diglycidyl ether (PEGDGE), forming three-dimensional hydrogels with porous structures and enhanced structural stability in aqueous environments.

Structural analyses confirmed successful amination and covalent network formation. The physicochemical, morphological, and mechanical properties of the hydrogels varied depending on polyamine type, influencing swelling behavior and active site accessibility. Pd adsorption behavior was evaluated through isothermal and kinetic analyses, revealing that amine density and molecular configuration played a decisive role in adsorption capacity and rate. The adsorption mechanism was attributed to electrostatic attraction and coordination interactions between protonated amine groups and anionic Pd chloro-complexes within the hydrogel matrix.

Following adsorption, the immobilized Pd species were retained inside the hydrogel network and directly converted into catalytically active sites without additional separation processes. The Pd-loaded hydrogels functioned as efficient heterogeneous catalysts for the reduction of hexavalent chromium (Cr(VI)) to trivalent chromium (Cr(III)), demonstrating effective redox activity and structural stability during catalytic operation. The hydrogel matrix provided uniform dispersion and stabilization of Pd species, facilitating electron transfer while maintaining mechanical integrity.

This study demonstrates a sustainable closed-loop strategy that integrates Pd capture and catalytic reutilization within a single lignin-based hydrogel platform. The results highlight the potential of polyamine-functionalized lignin hydrogels as bio-based materials for noble metal recovery and environmental remediation.

Key words

Aminated lignin; Lignin-based hydrogel; Palladium adsorption; Catalytic reuse

Elm Bark Powder-Modified Soy Protein Adhesive with Enhanced Strength and Mold Resistance for Engineered Wood Panels

Wenbin Yuan (Nanjing Forestry University), **Meng An** (Nanjing Forestry University), **Xiaona Li** (Nanjing Forestry University, Yantai University), **Jianzhang Li** (Nanjing Forestry University, Beijing Forestry University), **Changlei Xia*** (Nanjing Forestry University, Guangxi University)

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Abstract

Traditional adhesives used in engineered wood panels, such as urea-formaldehyde, phenol-formaldehyde, and melamine-formaldehyde resins, have raised environmental concerns due to formaldehyde emissions. In response, the wood industry has increasingly focused on developing eco-friendly, renewable adhesives derived from biomass. Among these, formaldehyde-free soy-based adhesives have attracted considerable attention and have already been scaled for industrial use in plywood and other veneer-based products. Soy protein, the primary component of soybean meal, offers key advantages including abundance, low cost, and renewability, positioning soy-based adhesives as promising candidates for sustainable wood bonding. However, despite these benefits, their market share remains limited, accounting for only about 0.1% of total wood adhesive production, due to performance constraints such as poor water resistance and insufficient bonding strength, as well as economic limitations.

To address these challenges, our research team introduced an innovative modification approach using elm bark powder, a material historically documented in texts such as Tian Gong Kai Wu and Xiang Cheng for its adhesive properties in incense binding. By incorporating raw elm bark powder into soy adhesive formulations, we achieved significantly improved performance, with a wet shear strength of 1.27 MPa. Further enhancement was obtained by adding sodium borate as an inorganic crosslinking agent, which not only increased adhesive strength (wet shear strength: 1.37 MPa) but also imparted outstanding anti-mold properties (LOI index: 27.54%; mold resistance duration under 100% relative humidity: ≥90 days).

The resulting adhesive system enables efficient chemical crosslinking among proteins, polysaccharides, saponins, and their derivatives via Maillard reactions, Michael additions, and condensation reactions. Entirely biomass-derived, this formulation offers a cost-effective strategy for enhancing the performance of soy-based adhesives, thereby supporting their broader industrial application.

Key words

Soy-based adhesive; Elm bark powder; Biomass modification; Water resistance; Mold resistance

Proceedings of the International Convention of
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Response Surface Optimisation of Peroxide-Assisted Torrefaction for Solid Biofuel Upgrading

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Abstract

Low-concentration hydrogen peroxide (H2O2) pretreatment offers a controllable oxidative pathway for modulating biomass carbonisation without the operational risks associated with concentrated oxidants. This study systematically investigated the combined effects of H2O2 (0-6.04 wt%) and torrefaction temperature (210-290 °C) on the physicochemical evolution and fuel properties of Quercus variabilis. A central composite design within a response surface methodology (RSM) framework was applied to quantify linear, interaction, and quadratic effects. Temperature was identified as the dominant factor governing mass yield (MY), elemental composition, devolatilisation behaviour, and carbonisation severity. Increasing temperature enhanced carbon enrichment while reducing H/C and O/C ratios, shifting the solid product toward coal-like characteristics. In contrast, H2O2 concentration exerted secondary yet temperature-dependent effects. At ≤210 °C, mild oxidation promoted selective dehydration and partial delignification, slightly decreasing MY and HHV. Around 250 °C, oxidative and pyrolytic pathways approached kinetic balance, resulting in relatively stable compositional and energetic behaviour. At ≥290 °C, intensified peroxide decomposition likely increased radical-driven decarboxylation and deoxygenation. Energy analysis revealed intrinsic trade-offs between mass retention and carbon densification. Although higher temperatures increased higher heating value (HHV), energy yield (EY) declined due to mass loss. Quadratic RSM models showed strong predictive performance, and multi-response optimisation identified 288.5 °C and 6.04 wt% H2O2 as the optimal condition, representing a practical compromise between yield preservation, oxygen removal, and calorific enhancement.

Overall, low-concentration H2O2 selectively modulates oxidative-thermal reaction pathways without overriding intrinsic thermochemical behaviour, providing a safer and controllable strategy for solid biofuel upgrading.

Acknowledgement

This work was supported by the National Institute of Forest Science (grant number: FP0700-2022-01-2026)

Key words

Hydrogen peroxide pretreatment; Torrefaction; Oxidative carbonization; Biomass upgrading; Response surface methodology

Evaluation of Cellulose Nanofiber Properties According to Manufacturing methods

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Abstract

Cellulose is the most abundant natural polymer on Earth, with an estimated annual production of approximately 1.5 trillion tons. Owing to its hydrophilicity, biodegradability, and biocompatibility, cellulose has been widely utilized in food, cosmetic, pharmaceutical, and rheological applications. Recently, cellulose nanofibers (CNFs) have attracted significant attention due to their nanoscale width, high aspect ratio, large specific surface area, optical transparency, and superior mechanical properties, enabling their use in advanced materials and functional composites.

In this study, the properties of CNFs were evaluated according to the preparation method. Commercially available domestic hardwood pulp (mixed bleached kraft pulp composed of oak, acacia, and other species) was used as the raw material. Two different fabrication routes were employed: (i) alkali pretreatment with 20 wt% NaOH followed by mechanical grinding, and (ii) TEMPO-mediated oxidation pretreatment followed by Microfluidizer processing. The resulting CNFs were comparatively analyzed to elucidate the effects of chemical pretreatment and mechanical fibrillation on their structural and physicochemical characteristics. These findings provide insight into the relationship between processing methods and CNF properties, contributing to the optimization of nanofiber production for industrial applications.

Alkali-treated cellulose exhibited a transformation in crystalline structure from cellulose I to cellulose II, whereas no significant change in crystalline structure was observed in the TEMPO-treated samples. The particle size of the prepared cellulose nanofibers was larger in the alkali-treated samples than in those produced via the TEMPO-mediated oxidation method. This difference is attributed to fiber swelling induced by alkaline pretreatment.

This study was supported by the National Institute of Forest Science General Research Project (FP0701-2021-02).

Key words

Cellulose nanofiber (CNFs), Alkali pretreatment, TEMPO oxidation, Ultrafine grinder, Microfluidizer

Proceedings of the International Convention of
Society of Wood Science and Technology

Effect of sulfonation condition on the physicochemical characteristics of bio-char-based catalyst

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Abstract

Biochar is a carbonaceous material which can be produced from pyrolysis of lignocellulosic biomass. It has been widely applied in various industrial fields such as energy storage, pollutant mitigation, and catalysis. Among these applications, the use of biochar as a heterogeneous catalyst has advantages because its high surface area, diverse functional group and thermal stability. Moreover, catalytic activity of biochar can be enhanced through modification of functional group such as sulfonic or amine groups. Especially, sulfonic group functionalized biochar acts as strong acidic catalyst for esterification or dehydration reactions.

However, sulfonation efficiency is strongly affected by sulfonation condition and surface characteristics of biochar. Therefore, optimizing sulfonation condition and analyzing effect of surface functional group of biochar to sulfonation reaction is crucial for the preparation of highly efficient sulfonated biochar. In this study, sulfonation of lignin-derived biochar was conducted in various reaction conditions. The effect of sulfonation condition on surface characteristics and ion exchange capacity (IEC) were analyzed. In addition, oxidized biochar was further subjected to sulfonation reaction to evaluate the influence of initial functional groups of biochar on sulfonation efficiency.

Key words

Lignocellulosic biomass; Biochar; Sulfonation; Optimization; Oxidation

Continuous Bioelectrochemical CO2 Conversion using Forest-Derived Formate Dehydrogenase and Macroporous Carbon Electrodes

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Abstract

Bioelectrochemical CO2 conversion using enzymes is an effective Carbon Capture, Utilization, and Storage (CCUS) strategy for producing organic acids. We investigated the reduction of CO2 to formate using a recombinant formate dehydrogenase (PsFDH) from the white-rot fungus Phanerochaete sordida. To maintain the continuous reaction, this enzymatic process was coupled with an electrochemical system for the in situ regeneration of NADH.

However, long-term continuous operation resulted in a plateau in formate production. Our recent experiments revealed that this limitation is due to the time-dependent activity loss of free enzymes and the structural instability of NADH. Specifically, continuous CO2 purging lowers the buffer pH, which accelerates NADH degradation.

To address this, we focused on increasing the NADH regeneration rate. Initial material screening showed that glassy carbon was the most effective for NADH regeneration. However, standard disk-type electrodes lack the active surface area required for scale-up. Therefore, we are implementing a three-dimensional, macroporous reticulated vitreous carbon (RVC) electrode to maximize the electrochemically active surface area and enhance the NADH regeneration rate. This approach aims to secure the long-term operational stability of the PsFDH-based continuous bioelectrochemical reactor for sustained formate production.

Acknowledgement

This work was supported by the National Institute of Forest Science (grant number: FP0700-2022-01-2026)

Key words

CCUS, Formate dehydrogenase, Bioelectrochemical CO2 conversion, NADH regeneration, Reticulated vitreous carbon

Proceedings of the International Convention of
Society of Wood Science and Technology

Enhancement and Comparison of Enzymatic Hydrolysis Efficiency of Hydrated-Milled Miscanthus via Binary and Ternary Acetic Acid-Based Deep Eutectic Solvent Pretreatment

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Abstract

Deep eutectic solvents (DES) have attracted considerable attention as green and sustainable solvents for lignocellulosic biomass pretreatment. In this study, hydrated-milled Miscanthus was pretreated using acetic acid-based binary (choline chloride/acetic acid) and ternary (choline chloride/acetic acid/ethylene glycol) DES systems to enhance enzymatic hydrolysis efficiency. Pretreatments were conducted at various conditions, and xylan removal, lignin removal, and glucan preservation were systematically evaluated. The compositional changes of the pretreated residues were analyzed, followed by enzymatic hydrolysis to determine glucan conversion. The results showed that increasing pretreatment temperature significantly improved lignin and xylan removal in both DES systems. In the binary DES system, treatment at 160 °C resulted in xylan and lignin removal rates of 82.3% and 80.8%, respectively, with a glucan preservation rate of 80.2%. In contrast, the ternary DES system achieved xylan and lignin removal rates of 72.3% and 78.5%, respectively, while exhibiting a higher glucan preservation rate of 89.1%. These results suggest that, although the binary DES promotes slightly greater hemicellulose and lignin removal, the ternary DES more effectively preserves glucan. Although the binary DES removed slightly more lignin, the ternary DES exhibited superior saccharification performance, achieving a glucan conversion of 96.4%, compared to 94.1% for the binary system.

Key words

Lignocellulosic biomass; Deep Eutectic Solvent; Enzymatic hydrolysis; Delignification

Recombinant Production of Plant-derived Expansin for Biological Pretreatment of Cellulose

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Abstract

Lignocellulose is a promising bioresource for addressing environmental challenges and reducing dependence on fossil resources. Among its components, cellulose, the most abundant carbohydrate, has been widely utilized across various industrial sectors due to its renewability and biodegradability. However, its highly crystalline structure and dense hydrogen-bonding network confer structural rigidity that limits the penetration of solvents, catalysts, or enzymes, thereby restricting overall reactivity.

Expansins are non-catalytic proteins that loosen interactions between cellulose microfibrils without cleaving cellulose backbones. Owing to this unique mechanism, they have attracted as auxiliary agents for biomass pretreatment and as synergistic partners of cellulases. However, previous studies have focused on microbial expansins, largely because recombinant production of plant-derived expansins from higher eukaryotes remains challenging.

To address these limitations, this study aimed to establish Escherichia coli-based microbial cell factories for the efficient production of a β-expansin (AtEXPB) from Arabidopsis thaliana. To achieve enhanced soluble expression, a fusion tag strategy was employed, and the production yields were optimized. The purified recombinant AtEXPB was subsequently characterized for its cellulose-binding capacity and its impact on cellulose structural properties. Structural changes induced by AtEXPB treatment were investigated using X-ray diffraction (XRD), scanning electron microscopy (SEM), and Brunauer-Emmett-Teller (BET) analysis.

These findings demonstrate the feasibility of recombinant production of higher eukaryotes-derived expansins in a microbial cell factory and highlight their potential as an auxiliary proteins for reducing cellulose recalcitrance and enhancing biomass valorization.

Key words

Cellulose; Pretreatment; Expansin; E. coli

Proceedings of the International Convention of
Society of Wood Science and Technology

Hydrogen Peroxide-Citric Acid (HPCA) Oxidative System for Delignification of Wood Veneer toward Translucent Wood

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Abstract

Recent advancements in wood valorization have expanded its application into optically functional materials such as touch panels, displays, and lighting systems. However, the intrinsic opacity, natural coloration, and grain structure of wood limit its use in applications requiring optical transparency. To overcome these limitations, delignification—removal of lignin and extractives from the wood cell wall— is essential prior to polymer impregnation for translucent wood fabrication. Conventional delignification agents, including sodium chlorite, sodium hypochlorite, and peracetic acid, pose environmental and safety concerns due to toxic gas generation, odor, and explosion risks, and complete delignification remains impractical.

In this study, an eco-friendly delignification system was developed using citric acid (CA, 99.5%), a naturally occurring and biodegradable organic acid, combined with hydrogen peroxide (HP, 30%) to form a Hydrogen Peroxide-Citric Acid (HPCA) solution. Concentration-dependent CA were mixed with HP at a 1:1 (v/v) ratio. Wood (European Ash) veneers were immersed in the HPCA solution and treated at 70 °C for 4 h.

Colorimetric analysis revealed increased L* values with higher CA concentrations, indicating improved brightness, whereas a* and b* values were elevated relative to untreated samples. FT-IR spectra showed diminished lignin-related functional groups, and quantitative analysis confirmed reduced lignin content after treatment, evidencing effective partial delignification by HPCA. Partially delignified wood was impregnated with commercial epoxy resin to fabricate translucent wood. UV-Vis spectroscopy showed significantly improved visible-light transmittance while maintaining natural wood texture and color. Near-zero transmittance in the UV region suggests UV-blocking capability. Haze values remained relatively stable.

These findings demonstrate that HPCA provides an environmentally sustainable alternative for delignification and enables the development of translucent wood with promising optical functionality.

Key words

Oxidative delignification; Hydrogen peroxide; Citric acid; Translucent wood; Sustainable processing

Development of Sustainable Superabsorbent Materials from Cellulose-Based Biomass Incorporating Organic and Inorganic Particles

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Abstract

Sustainable superabsorbent materials derived from cellulose-based biomass are being actively explored as environmentally friendly alternatives to petroleum-derived polymers. In this study, starch/carboxymethyl cellulose (CMC) superabsorbent films were prepared and reinforced with inorganic and organic fillers, including silica, zeolite, and cellulose (5-15 wt%), to improve mechanical stability and absorption performance in both distilled water and saline solutions. The addition of fillers significantly altered polymer-filler interactions and swelling characteristics, leading to improved dimensional stability during swelling. Among the investigated compositions, the film containing 5 wt% filler exhibited the best overall performance, showing the highest absorbency, water retention, and absorbency under load, which reflects a well-balanced structure between reinforcement and swelling ability. Rheological analysis revealed increases in viscosity and storage modulus with filler incorporation, indicating enhanced resistance to deformation and improved structural integrity in the swollen state. Zeolite and silica were particularly effective in saline environments due to their hydrophilic nature and microporous features, which facilitate water uptake and help stabilize the gel matrix. Thermal analysis of the drying process demonstrated that drying temperature plays a decisive role in determining final properties: while elevated temperatures accelerated water removal, excessive drying (≥100 °C) caused structural densification and diminished absorbency. A moderate drying range of 60-80 °C was identified as optimal for maintaining material functionality. Overall, this study highlights the importance of tailoring both filler content and processing conditions to develop high-performance, eco-friendly superabsorbent materials for practical applications.

Acknowledgment

This study was supported by the National Institute of Forest Science (grant number: FP0701-2025-02-2026) and the Korea Forest Service (grant number: 2023486C10-2425-AA01).

Key words

Superabsorbent materials; Carboxymethyl cellulose; Starch; Organic and inorganic particles; Cellulose-based biomass; Swelling behaviour; Water retention capacity

Proceedings of the International Convention of
Society of Wood Science and Technology

Comparative Analysis of Anionic Functionalization of Cellulose: Substitution Mechanisms, Structural Characteristics, and Charge Expression

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Abstract

Cellulose contains abundant hydroxyl groups; however, its dense hydrogen-bonded network limits intrinsic surface charge expression and water dispersibility. To enhance dispersibility and interfacial interactions, anionic functionalization is widely employed. Because substitution chemistry influences both structural stability and charge expression, systematic comparison among functional groups is required.

In this study, phosphorylation, TEMPO oxidation, and carboxymethylation were comparatively investigated. Phosphorylation introduces phosphate ester groups(-PO3Hx), TEMPO oxidation selectively converts C6 hydroxyl groups to carboxylates(-COO-), and carboxymethylation introduces ether-linked carboxymethyl groups(-CH2COO-). Functional group contents were quantified by conductometric titration to calculate the degree of substitution (DS), and effective surface charge density was evaluated by zeta potential measurements. Structural and chemical changes were analyzed using FTIR, XRD, and ICP.

XRD results showed minimal crystallinity change in TEMPO-oxidized cellulose, while phosphorylation and carboxymethylation caused a noticeable decrease in crystallinity due to disruption of hydrogen-bonds. TGA revealed enhanced char yield and thermal stability in phosphorylated cellulose. Morphologically, phosphorylated and TEMPO-oxidized celluloses maintained fibrous structures in aqueous suspension with increased zeta potential and reduced sedimentation rates. In contrast, increasing DS in carboxymethylated cellulose induces a suspension-to-solution transition.

Overall, even at comparable DS levels, the chemical nature and structural role of introduced functional groups governed charge expression and functional performance. These findings provide guidance for selecting appropriate anionic modification strategies tailored to target application domains.

Acknowledgment

This study was supported by the National Institute of Forest Science (grant number: FP0701-2025-02-2026)

Key words

Anionic Cellulose; Phosphorylation; TEMPO oxidation; Carboxymethylation; Charge density; Hydrogen bond; Functionalization

Improving Lignin Purity in Supercritical Water-Treatment Residues via Selective Removal of Residual Cellulose Using a ZnCl2 Aqueous Non-Derivatizing Process

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Abstract

Supercritical water treatment is widely recognized as a process for recovering sugars and soluble components from biomass. In this treatment, a lignin-rich residue known as supercritical water-treated biomass residues (SWBR) is produced, which is a valuable biomass resource for applications in polymeric materials, biofuels, and chemical feedstocks. Despite this potential, SWBR generated under most supercritical water treatment conditions contains a significant amount of residual cellulose; therefore, it is essential to remove this cellulose fraction to ensure high lignin purity and enhance its utilization value.

However, studies focusing on the selective removal of cellulose while maintaining lignin integrity remain limited. In this study, a ZnCl2 aqueous solution-based non-derivatizing process was applied to SWBR to improve lignin purity through the selective removal of residual cellulose. The ZnCl2 aqueous solution-based non-derivatizing process is a system capable of directly dissolving cellulose without chemical derivatization, and it may contribute to selective cellulose removal by disrupting the hydrogen-bonding network of cellulose. The major variables in this process were ZnCl2 loading, the addition of formic acid, holding time (overnight or not), ZnCl2 supplier, and molar ratios between water and ZnCl2. After treatment, changes in lignin content and glucan reduction were determined under various conditions to evaluate the lignin purity. Under the condition of 10 g ZnCl2 loading, the lignin content was maintained at the initial level ($\Delta \leq 0.3$ percentage points), while the glucan content decreased by 17.88% relative to its initial content. These results suggest that a ZnCl2 aqueous non-derivatizing process may contribute to selective component separation in SWBR.

Acknowledgement

This work was supported by the General Research Project of the National Institute of Forest Science (FP0701-2025-01-2026) and the Korea Forest Service R&D Project (RS-2024-004003384-2026).

Key words

Supercritical water-treated biomass residues; Lignin; Purity improvement; ZnCl2; Non-derivatizing process; Cellulose; Selective removal

Proceedings of the International Convention of
Society of Wood Science and Technology

Anti-inflammatory Effects of *Alnus hirsuta* Extracts on an In Vitro Periodontal Inflammation Model Using Human Gingival Fibroblast Cells

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Abstract

This study was conducted to evaluate the anti-inflammatory effects of *Alnus hirsuta* extracts in an in vitro periodontal inflammation model using human gingival fibroblasts. Periodontal disease is a chronic inflammatory disorder affecting periodontium tissue and can lead to tissue destruction and tooth loss. In Korea, the number of patients with periodontal disease has reached approximately 20 million as of 2024 due to population aging, highlighting the increasing need for related research. Alnus hirsuta contains bioactive compounds such as oregonin, hirsutanonol, and hirsutenone and was selected as the source material for this study.

Alnus hirsuta was extracted by immersion in 60% edible ethanol to obtain the extract (AH60E). AHRF1 was prepared by ethyl acetate fractionation, while AHRF2 was produced through enzymatic hydrolysis followed by solvent fractionation. The treatment concentrations of the three extracts were determined using a CCK assay as 25 μg/ml for AH60E and AHRF1 and 10 μg/ml for AHRF2. Inflammatory responses were induced using TNF-α and Porphyromonas gingivalis LPS, and the mRNA expression levels of inflammatory cytokines (TNF-α, IL-6, and IL-1β) were analyzed using RT-PCR.

Under TNF-α stimulation, all extracts significantly suppressed TNF-α and IL-1β expression. Under LPS stimulation, TNF-α, IL-6, and IL-1β expression levels were reduced by more than 80% compared with the LPS-treated control group. In contrast, the positive control corn extract showed maximum inhibitory effects of approximately 20% under TNF-α stimulation and 45% under LPS stimulation. In comparison, Alnus hirsuta extracts exhibited strong inhibitory activity with suppression levels reaching approximately 90%.

These findings suggest that Alnus hirsuta extracts have high potential as natural functional materials for the development of health functional foods, quasi-drugs, and natural medicines. Further validation will be conducted through additional in vitro and in vivo studies.

Acknowledgement

This study was conducted with the support of the R&D program for Forest Science Technology (project no. RS-2026-25501499) provided by Korea Forest Service (Korea Forestry Promotion Institute). This research was supported by the Regional Innovation System & Education(RISE) program through the Gangwon RISE Center, funded by the Ministry of Education(MOE) and the Gangwon State(G.S.), Republic of Korea. (2026-RISE-10-002).

Keywords

Alnus hirsuta; Diarylheptanoid; Human Gingival fibroblasts; Periodontal inflammation; Natural Product Medicine

In Vitro Effects of Catechin Glycoside-Containing Extract from *Ulmus* macrocarpa on Periodontal Disease

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Abstract

Periodontal disease is a chronic inflammatory disorder involving periodontal tissue destruction due to excessive inflammatory responses, with increasing public health importance. Thus, regulating inflammatory responses is a key strategy, highlighting the need for natural product-based anti-inflammatory materials with minimal side effects.

Ulmus spp. contains bioactive compounds, including flavan-3-ols and catechin glycosides, and exhibits anti-inflammatory, antioxidant, and anticancer activities. In the traditional Korean medical text *Donguibogam*, the bark (Yu-baek-pi) and root (Yu-geun-pi) of *Ulmus* spp. are described as medicinal materials for alleviating inflammation and improving skin disorders, among others. Therefore, this study aimed to evaluate the effects of 50% edible-ethanol extract of *Ulmus* macrocarpa bark (Dr-UE50) and catechin glycoside-enriched fraction of *Ulmus* macrocarpa (UMRF3) on cell viability and the inhibition of TNF-α and LPS-induced inflammatory responses in human gingival fibroblasts (HGFs) in vitro.

Based on cytotoxicity evaluation in HGFs, the optimal treatment concentration of Dr-UE50 and UMRF3 was set at 25 μg/mL for subsequent experiments. In the TNF-α-induced endogenous inflammation model, TNF-α, IL-6, and IL-1β were increased, whereas Dr-UE50 and UMRF3 significantly decreased these levels (up to approximately 85%). In the *P. gingivalis* LPS-induced exogenous inflammation model, these cytokines were significantly increased, while Dr-UE50 significantly reduced TNF-α and IL-1β expression and UMRF3 reduced TNF-α expression. To confirm these inhibitory effects, comparative analysis was conducted using corn extract, a major component of adjunctive therapeutics for periodontal disease, as a positive control. Dr-UE50 exhibited superior anti-inflammatory activity, showing up to 91.65% greater inhibition than corn extract under TNF-α treatment, while demonstrating comparable activity under LPS treatment.

These results suggest that *Ulmus*-derived extracts attenuate periodontal inflammation by suppressing inflammatory cytokines. Based on these findings, further in-depth in vitro mechanistic and in vivo studies using marker compounds of *Ulmus* species, and a standardized GMP pilot-scale extract are planned.

Acknowledgement

This study was conducted with the support of the R&D program for Forest Science Technology (project no. RS-2026-25501499) provided by Korea Forest Service(Korea Forestry Promotion Institute). This research was supported by the Regional Innovation System & Education(RISE) program through the Gangwon RISE Center, funded by the Ministry of Education(MOE) and the Gangwon State(G.S.), Republic of Korea.(2026-RISE-10-002).

Key words

Ulmus macrocarpa; Polyphenols; Periodontal disease; Human gingival fibroblasts; Natural medicine

Proceedings of the International Convention of
Society of Wood Science and Technology

An Eco-Friendly Alternative for the Wood Industry: A Formaldehyde-Free Pea Protein Bio-Adhesive with High Mechanical Strength

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Abstract

Currently, the timber industry heavily utilizes formaldehyde-based adhesives, which are derived from petroleum, are non-renewable, and pose severe health risks such as respiratory tract irritation. Therefore, there is a crucial need to generate knowledge and develop formaldehyde-free, environmentally friendly adhesives. The main objective of this study is to evaluate a sustainable adhesive based on pea protein and citric acid applied to medium-density wood, in order to understand its performance and viability for the manufacturing of plywood panels. The bio-adhesive was formulated using isolated pea protein (Pisum sativum), citric acid, and poly(ethylene glycol) diglycidyl ether (DEPEG). Physical characterization of the formulated adhesive (CHAD-2) revealed a favorable viscosity of 708 cP, significantly lower than the 1500 cP of the commercial control. Chemical analysis via Fourier-transform infrared spectroscopy (FT-IR) confirmed successful cross-linking, indicated by key absorption bands such as the ester carbonyl peak at 1720 cm^{-1}. Additionally, Nuclear Magnetic Resonance (NMR) showed specific chemical shifts between 41 and 53 ppm, verifying the opening of the epoxy rings and the interaction between the components. Plywood test specimens were elaborated to conduct mechanical testing, utilizing a pressing temperature of 170 °C. Under dry conditions, the bio-adhesive demonstrated a tensile strength of 3.6 MPa and an outstanding wood failure of 94%. After cyclic accelerated aging, the tensile strength was maintained at 3.5 MPa, successfully meeting standard requirements without significant differences compared to the conventional urea-formaldehyde adhesive. Furthermore, Scanning Electron Microscopy (SEM) of the glue line corroborated a solid, continuous bonding interface without micro-cracks. The findings suggest that the developed bio-adhesive based on pea protein and citric acid presents a sustainable, formaldehyde-free alternative with highly competitive physical and mechanical properties for its application in the plywood industry.

Key words

Bio-adhesive; Pisum sativum; citric acid; plywood; formaldehyde-free; mechanical properties

Explainable Machine Learning Modeling for Bioactive Compound Recovery from Supercritical CO_2 Extraction Residues of *Fraxinus mandshurica*

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Abstract

The utilization of forest biomass processing residues in a circular fashion has gained considerable momentum within the context of forest biorefinery frameworks. Nevertheless, the recovery of residual phytochemicals from supercritical extraction by-products remains a largely untapped opportunity. *Fraxinus mandshurica*, a commercially harvested hardwood species across Northeast Asia, has been found to accumulate polyphenolic and flavonoid metabolites. These substances have been found to persist in substantial quantities following industrial supercritical CO2 processing. To bridge this resource gap, it is necessary to employ predictive modeling approaches that overcome the limitations of classical statistical methodologies in capturing highly nonlinear interactions. To this end, a structured solvent extraction dataset was assembled by independently varying the concentrations of ethanol, the extraction temperature, and the extraction duration against dual bioactive response variables: total polyphenol content (TPC) and total flavonoid content (TFC). Machine learning, following randomized cross-validation tuning, delivered high-fidelity predictions with R^2 = 0.950 and 0.968 for TPC and TFC, demonstrating that the predictions of the machine learning model are reliable. In order to move beyond black-box prediction, SHapley Additive exPlanations (SHAP) were applied to dissect the relative contribution of each process variable. The analysis revealed a mechanistic bifurcation between the two classes of compounds: polyphenol solubilization was principally regulated by solvent polarity and thermal energy input, whereas flavonoid mobilization depended predominantly on cumulative contact duration. This compound-specific sensitivity divergence has direct implications for the design of selective, multi-target extraction protocols in the context of woody biomass valorization. It is acknowledged that there is a competing nature between TPC and TFC maximization. To delineate Pareto-optimal extraction scenarios, Non-dominated Sorting Genetic Algorithm II was applied. The optimum result was found to be 69.99 °C, 3.01% ethanol, 15.00 h, which achieved concurrent yields of 94.65 mg GAE/g and 4.90 mg QE/g. Python-based decision-support interface was developed to operate the trained model for real-time process guidance. This explainable AI pipeline, when considered as a whole, provides a replicable framework that can be replicated to achieve systematic phytochemical recovery from lignocellulosic processing residues. This, in turn, contributes to the extension of the value chain in the forest biomass industry.ea.(2026-RISE-10-002)

Key words

Forest biomass valorization; Explainable artificial intelligence; Multi-output neural network; Phytochemical optimization; Forest biorefinery

Proceedings of the International Convention of
Society of Wood Science and Technology

Tree-Based Machine Learning for Predicting Bioactive Compound Recovery from Ultrasonic-Assisted Extraction of *Fraxinus mandshurica Leaves*

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Abstract

Fraxinus mandshurica (Manchurian ash) leaves are rich in polyphenols and flavonoids with demonstrated antioxidant, antimicrobial, and neuroprotective activities, attracting considerable interest in the pharmaceutical and functional food industries. Ultrasonic-assisted extraction (UAE) has emerged as an environmentally friendly and energy-efficient alternative to conventional solvent extraction, enhancing mass transfer through acoustic cavitation while minimizing solvent consumption and processing time. However, systematic studies on UAE for bioactive compound recovery from F. mandshurica leaves remain scarce. In extraction processes, multiple variables such as extraction time, solvent ratio, and solvent concentration interact in complex, nonlinear manners, making it difficult to predict extraction outcomes and design optimal process conditions based on experimental data alone. Machine learning (ML) algorithms address this challenge by constructing data-driven predictive models capable of learning these complex relationships directly from experimental observations, enabling reliable prediction of bioactive compound contents under varying process conditions. A Box-Behnken design was employed to investigate the effects of extraction time (15-25 min), solvent-to-material ratio (40-60 g/mL), and ethanol concentration (55-95%, v/v) on polyphenol and flavonoid contents. Following outlier removal, second-order polynomial feature engineering expanded the input space to nine variables. Four ensemble algorithms—Random Forest (RF), Extra Trees (ET), Gradient Boosting (GB), and XGBoost—were optimized via randomized hyperparameter search with 5-fold cross-validation. RF and ET achieved the highest mean cross-validation R^2 (0.646), and RF was selected as the best model. On an 80/20 train-test split, RF attained R^2 = 0.778 and 0.829 for polyphenol and flavonoid contents, respectively. SHAP analysis revealed that ethanol concentration was the dominant variable governing both polyphenol and flavonoid recovery, with its quadratic term and interaction with extraction time further highlighting the nonlinear sensitivity of bioactive compound solubility to solvent polarity. These results demonstrate that tree-based ML coupled with polynomial feature engineering provides an interpretable and accurate framework for predicting and optimizing UAE of bioactive compounds from F. mandshurica leaves.

Key words

Box-Behnken design; polynomial feature engineering; Random Forest; hyperparameter optimization; SHAP analysis

BioWdesign: Design-Driven Research on Biomimetic Mechanisms of Wood and Plants and Their Translation into an Innovative Wellbeing Office Furniture Collection

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Abstract

The bioWdesign project is a design-driven research initiative rooted in the field of design and art and operating within a highly interdisciplinary framework. The project integrates expertise from wood science and biology, with wood scientists and biologists participating as active members of the research team during the analytical phase. The conceptual development and biomimetic translation were guided by a research-through-design approach. The study focused on the investigation of selected biological mechanisms characteristic of wood and plant tissues: phi-thickenings in plant roots functioning as reinforcement structures, T-joint configurations between trunk and branches enabling balanced load distribution and flexibility, and cystolith formations in Ficus leaves responsible for light diffusion. These phenomena were analysed at morphological and functional levels and subsequently abstracted into biomimetic models. Based on this analysis, structural and geometric principles were formulated and translated into modular design systems. Additive manufacturing strategies supported layered construction logic inspired by fibre organization in wood, enabling the transformation of biological structural patterns into physical prototypes. The research resulted in the development of the bioWellbeing collection, consisting of three interconnected elements: bioWroot (low seating derived from phi-reinforcement logic), bioWglow (diffusive lighting inspired by cystolith structures), and bioWdivider (a modular partition system based on branching and T-joint principles). Together, these elements form an innovative office furniture collection aimed at enhancing adaptability, structural logic, and user wellbeing in contemporary work environments. The project demonstrates how biomimicry methodology and biomimetic mechanisms derived from wood and plant biology can be systematically translated into furniture design through interdisciplinary collaboration and design-led research.

Acknowledgement

This research was supported by the Slovak Research and Development Agency under project No. APVV-21-0015.

Keywords

biomimicry; wood biology; research through design; additive manufacturing; office furniture

Proceedings of the International Convention of
Society of Wood Science and Technology

Effects of Basal Shoot Management on Growth characteristics and Bark Yield of *Broussonetia × kazinoki Sieb.* (Daknamu)

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Abstract

Broussonetia × kazinoki Siebold (daknamu), a shrub in the Moraceae family, is widely distributed in East Asia and has long been cultivated as the primary raw material for traditional Korean handmade paper, Hanji. Hanji is renowned for its exceptional durability and preservation properties and has gained international recognition through its use in the restoration of important cultural heritage. Typically, one-year-old shoots of B. × kazinoki are used for Hanji production. The harvested shoots are steamed in a process known as dakmuji to facilitate bark removal and then dried. The black bark is subsequently soaked in water to remove the outer layer, producing white bark used for Hanji manufacturing. The bast fibers of B. × kazinoki, characterized by their long fiber length, contribute significantly to paper strength and long-term durability. Despite the recognized excellence of Hanji, the cultivation of B. × kazinoki has recently declined due to rural depopulation, an aging workforce, rising labor costs, and increased reliance on imported raw materials. Therefore, establishing efficient cultivation and management practices is essential to ensure a stable supply of high-quality raw materials. This study aimed to improve black bark production from one-year-old shoots by regulating basal shoot density. We hypothesized that basal shoot number influences shoot growth and bast fiber yield. In June 2024, basal shoot numbers were adjusted to control (no cutting), 10, 7, and 4 per plant. Shoot length and diameter were measured at 30-day intervals until October, and shoots were harvested in February 2025 to determine biomass and bark dry weight. Shoot length increased by 25.6% in the 7-shoot treatment compared with the control. Shoot diameter significantly increased by 40.0% and 29.1% in the 4- and 7-shoot treatments, respectively. Bark dry weight per shoot increased by 69.5% and 60.1% in the 4- and 7-shoot treatments, respectively. Overall, reducing basal shoot density enhanced biomass accumulation and bark yield containing bast fibers, although increased branching may affect processing efficiency. These findings indicate that optimized basal shoot management can improve bast fiber production efficiency in B. × kazinoki cultivation, while further research is needed to balance yield improvement with quality.

Key words

Broussonetia × kazinoki; bast fiber yield; black bark production; shoot biomass; cultivation management

Strain-dependent degradation and basidiocarp formation of *Inonotus obliquus* on sapwood and heartwood of *Alnus incana* and Betula pendula

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Abstract

The cultivation of specialty fungi has gained increasing attention among forest owners in Finland over the past decade. Among these, *Inonotus obliquus* is valued for its use in functional beverages and dietary supplements. Despite commercial interest, scientific knowledge of optimal cultivation practices, particularly strain and substrate selection, remains limited. Assessing lignocellulose degradation by different strains is crucial for improving biomass utilization and sustainable forest product development.

This study compares the decay potential of geographically distinct strains of I. obliquus on leeched and non-leeched heartwood and sapwood of birch (Betula pendula) and alder (Alnus incana). A modified version of the European standard EN 113 was employed. Sapwood samples were collected from the outer wood layer immediately beneath the bark, while heartwood samples were obtained from the visually distinct inner heartwood zone. All samples were carefully separated to avoid cross-contamination between wood types. The samples were placed on fungal plates once full mycelial coverage was achieved. The wood pieces were maintained on a mesh above the fungal culture for 16 weeks. Decay efficiency was quantified by determining the weight loss of the wood after drying at 103 ˚C.

Significant differences in degradation were observed among the fungal strains. In Alnus incana, no substantial difference in mass loss was detected between sapwood and heartwood samples. In contrast, Betula pendula exhibited marked variation, with heartwood samples losing considerably more mass than sapwood. These findings indicate that both wood species and fungal strain identity influence lignocellulose degradation efficiency, with *B. pendula* heartwood being particularly susceptible to mass loss.

The results highlight the variability in decay potential among I. obliquus strains and between wood types. While A. incana showed consistent degradation regardless of wood part, B. pendula heartwood was more susceptible to fungal breakdown.

Keywords

Inonotus obliquus; Pakuri; Lignocellulose degradation; Betula pendula.

Proceedings of the International Convention of
Society of Wood Science and Technology

Contents of Sugars and Inorgaric elements of the sap from *Acer pictum* in Inje in 2025

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Abstract

The sap of Acer pictum serves as a vital source of short-term forest income for mountain village farms during the spring season. Historical records in Journal of Korean Pharmaceutical Sciences indicate its long-standing use, and recent consumer trends favoring natural health foods over synthetic additives have further increased its commercial value. This study investigates the extraction yield and chemical composition specifically sugar and inorganic elements of Acer pictum sap collected in Inje during the 2025 season to evaluate its potential as a high-value natural resource.

Collection of the sap of Acer pictum was conducted over a 21-day period from March 3 to March 23. Sap extraction yields were measured based on tree diameter, revealing average yields of 2.9 liters for small-diameter trees, 9.4 liters for medium-diameter trees, and 12.7 liters for large-diameter trees. A significant temporal trend was observed approximately 10 days after the initial tapping on March 3, the sap discharge began to decrease steadily after. These findings suggest that harvesting efficiency is highly dependent on both the physiological maturity of the tree and the timing of the extraction.

Sucrose is the primary component of the sap. At the beginning of the harvest, sucrose content reached a peak of 3.0%, which is notably higher than the 2.0% average found in common maple tree sap, thereby confirming its superior quantity for production. Furthermore, inorganic element analysis using inductively coupled plasma mass spectrometry (ICP-MS) revealed high concentrations of minerals. In the Inje Acer pictum sap, calcium (Ca) was measured at 74 mg/L and magnesium (Mg) at 6 mg/L, while trace amounts of potassium (K) was detected.

In conclusion, the high sucrose content and rich mineral profile of Acer pictum sap validate its status as a premium natural health beverage. The data provided in this study regarding yield patterns by tree diameter and harvest timing offer a scientific foundation for optimizing sap collection, which may enhance forest-based income for rural communities.

Key words

Acer pictum subsp. mono(Maxim.), Forest income, Sucorose content, Minerals

Biodegradation Potential of Polyethylene Terephthalate by Wood-Decaying Microbes

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Abstract

Polyethylene terephthalate (PET) is one of the most widely used synthetic polymers worldwide, yet it is well known for its environmental persistence and resistance to biodegradation. Although PET was long considered recalcitrant to microbial attack, the discovery of *Ideonella sakaiensis* capable of degrading PET has opened new avenues for biological plastic degradation and stimulated extensive exploration of PET-degrading microorganisms in diverse environments. Wood-decaying microorganisms possess enzymatic systems specialized for the depolymerization of lignocellulosic biomass, particularly lignin, which contains aromatic rings and ester linkages structurally analogous to those found in PET. Based on this structural similarity, we hypothesized that lignin-degrading enzymatic machinery may exhibit adaptable or promiscuous activity toward PET.

In this study, PET films were incubated for six months in soil amended with mushroom cultivation residue, after which the films were recovered for microbial community analysis. PET-degrading strains were isolated using a selective medium in which PET served as the primary carbon source. The selected isolates were further cultivated with PET films to evaluate growth and monitor potential degradation intermediates in the culture medium. Biodegradation of both soil-exposed and strain-treated PET films was assessed through water contact angle measurements to determine surface hydrophilicity, Fourier-transform infrared spectroscopy (FTIR) to analyze chemical structural changes, and scanning electron microscopy coupled with energy-dispersive X-ray spectroscopy (SEM-EDS) to examine surface morphological and elemental alterations.

Collectively, these findings suggest that wood-decaying microbial communities associated with mushroom cultivation residue represent a promising biological resource for PET biodegradation and provide a foundation for future enzyme optimization and recombinant production strategies aimed at mitigating plastic pollution.

Keywords

Polyethylene terephthalate; Biodegradation; Wood-decaying microorganism

Proceedings of the International Convention of
Society of Wood Science and Technology

Growth Trait and Correlation Analysis of 30 Regional individuals of *Broussonetia × kazinoki Sieb.* (Daknamu) over Three years

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Abstract

Broussonetia × kazinoki, commonly known as daknamu, is a species belonging to the family Moraceae and has long been used as the primary raw material for Hanji, the traditional Korean handmade paper. Hanji has a history of more than 1,500 years and is well known for its excellent durability and preservation properties. It is mainly produced from the bast fibers of B. × kazinoki, whose long-fiber characteristics play an important role in determining the strength, durability, and preservation quality of Hanji. After harvesting, one-year-old shoots are steamed in a process known as dakmuji to facilitate bark feeling and then dried. The peeled bark is called black bark. The black bark is subsequently soaked in water to remove the outer layer, producing white bark used for Hanji manufacturing. Although *B. × kazinoki* is known to exhibit substantial genetic variation among regional populations, comparative information on growth characteristics, bark yield, and raw material quality remains limited.

In this study, 30 individuals originating from different regions of Korea were collected and evaluated for shoot length, shoot diameter, number of branches, and black bark dry weight from 2023 to 2025 to analyze variation in growth traits among regional individuals.

In 2023, the bark ratio ranged from 13.3% to 34.3%, while the number of branches ranged from 0.71 to 9.50. In 2024, the bark ratio ranged from 28.3% to 82.0%, with an average of 39.7%. In 2025, bark ratio ranged from 28.9% to 96.8%, with an average of 46.8%. Correlation analysis revealed that shoot length and shoot diameter were positively correlated ($r = 0.823$, $p < 0.01$). Bark ratio showed negative correlations with shoot length ($r = 0.587$, $p < 0.01$) and shoot diameter ($r = 0.539$, $p < 0.01$), whereas the main shoot dry weight showed strong positive correlations with both traits. These findings provide fundamental data for selecting individuals suitable for Hanji production and may support future breeding programs using regional genetic resources.

Key words

bast fiber; *Broussonetia × kazinoki*; regional variation; shoot growth; Hanji raw material

Preparation of wood bio-composites with low formaldehyde emission by application of modified natural polymers

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Abstract

In recent years, sustainable building and/or furniture materials have become a key factor from an environmental point of view. The performance of an adhesive mixture is generally dependent on their composition. The aim of this study was to reduce the release of formaldehyde emissions from wood based panels by developing and testing new, more effective modifiers that bind formaldehyde during the hardening process of urea-formaldehyde (UF) adhesives. For this study, research was focused on the biopolymer collagen and keratin after its modifications with alkaline silicate and sulfur additive at 125 °C for 2 hours. Formaldehyde emission from 5-layer beech (*Fagus sylvatica L.*) plywood was evaluated by the desiccator method according to EN ISO 12460-4 and bonding quality according to EN 314-1 and EN 314-2.

XPS and FTIR-ATR spectroscopy confirmed that the parameters of the biopolymers depend on the modification. The total amount of sulfur increases to about 6.0%, which is caused by the modification of the biopolymers with a sulfur additive at a temperature of 125 °C and also the amount of sulfur in the reduced form expressed as sulfide increases from 44.4% to 58.4%. The silicon oxide content in the samples was determined to be 8% and the antioxidant stability was studied by (DSC) calorimetry. The most significant decrease in formaldehyde emissions compared to the reference by up to 38% determined after 7 days was achieved with a 1% application of a samples of modified collagen or keratin to the UF adhesive mixture.

Measured values of tested samples confirmed the decrease of formaldehyde emissions for each concentration of modified collagen and keratin in comparison with the reference sample. Tested plywood fulfils the strength requirements of the standard. This work was supported by the Slovak Research and Development Agency under contracts No. APVV-18-0378, APVV-21-0051, APVV-22-0238, APVV-23-0224 and VEGA 1/0077/24.

Keywords

beech veneer; keratin; collagen; bio-polymer; formaldehyde; plywood

Proceedings of the International Convention of
Society of Wood Science and Technology

How does RFD plasma treatment affect the chemical properties of steam-modified beech wood?

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Abstract

The color difference of false heartwood from the sapwood and mature beech wood (Fagus sylvatica L.) is the reason for the removal of sawmill assortments from the production of furniture, construction, and carpentry products. Modification of beech heartwood with thermal treatment with saturated water steam leads to the unification of the colors of beech sapwood and of heartwood and false heartwood. This research investigates surface, adhesive, and chemical changes in mature and heartwood after thermal treatment with saturated steam at a temperature of 135 ± 2 °C during 9 hours. The aim of this contribution is to determine the differences in the chemical properties of wood with false heartwood compared with mature wood and sapwood after treatment by radio-frequency discharge (RFD) plasma. The RFD plasma in air markedly increases the hydrophilicity of wood because various polar groups are formed, and the wood macromolecules are also cross-linked, which leads to an increase in scratch resistance and an improvement in the barrier properties of the wood material. Hydrophilicity of steam-treated beech heartwood before/after plasma treatment was evaluated by the determination of contact angle with glycerol as the testing liquid. The FTIR-ATR spectrum of wood was recorded in the mid-infrared region (4000-650 cm-1). X-ray photoelectron spectroscopy (XPS) data were recorded using a Thermo Scientific K-Alpha XPS system. Adhesion measurements were carried out with determination of the tensile strength of thermoplastic adhesive lap joints for native and steam-modified beech heartwood before/after plasma treatment according to EN 204 durability class D4. The plasma-treated samples reached significantly lower contact angle values in comparison with plasma-unmodified samples. After plasma treatment an increase was observed in the intensity of peaks corresponding to carbon-oxygen groups, especially those assigned to C=O and COOH groups. Better hydrophilicity was confirmed by the higher strength of lap adhesive joints after different conditioning sequences.

Acknowledgement

This work was supported by the Slovak Research and Development Agency under the contracts APVV-17-0456, APVV-21-0051, APVV-23-0224, and VEGA 1/0450/25.

Key words

beech wood; false heartwood; steam treatment; plasma; surface chemistry; adhesion

Sustainable Particleboard Production Using Waste Sugar Beet Pulp: A Performance Evaluation

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Abstract

The growing demand for environmentally sustainable materials has driven interest in substituting traditional wood components in particleboard production with agricultural waste. Agricultural waste constitutes a significant yet underexploited source of biomass. One such agricultural waste is sugar beet pulp (SBP), a by-product of sugar production from sugar beet. This study explores the feasibility of using SBP as a partial or complete replacement for wood particles in particleboard production. Particleboards were manufactured with SBP contents ranging from 0% to 100%, using pMDI as the adhesive. The investigation focused on evaluating the morphological, chemical, and mechanical implications of SBP integration, with particular attention to particle structure, wettability, board microstructure, and chemical bonding via FTIR spectroscopy. The results confirm SBP's potential as a viable raw material for particleboard manufacturing. Boards containing SBP exhibited strong internal bond (IB) strength, attributed to effective chemical interactions between SBP hydroxyl groups and the isocyanate groups of pMDI, resulting in urethane bond formation. Notably, even 100% SBP boards achieved high IB strength, which improved by 25% when the target density increased from 600 to 750 kg/m^3. All boards with 25% to 100% SBP content met the EN 312 standard for IB strength. However, increasing SBP content led to a decline in bending strength, likely due to its irregular, lumpy morphology and rough surface texture. UV fluorescence analysis revealed that SBP particles failed to fill gaps between wood particles effectively, instead introducing voids that reduced structural compactness. This structural inefficiency may be addressed by refining the SBP particle size or optimizing the board density. To balance mechanical performance with material sustainability, the study recommends using SBP at 25-50% content in the core layer of three-layer particleboards, with wood particles in the surface layers. This configuration maintains bending strength while leveraging SBP's excellent bonding capacity. Prepared panels are formaldehyde-free, as an environmentally friendly product. In conclusion, incorporating SBP into particleboard production offers a promising path to reduce reliance on virgin wood, lower waste, and enhance sustainability in wood composites manufacturing. Future work should focus on optimizing particle morphology and pressing parameters to maximize the performance of SBP-based composites.

Keywords

sugar beet pulp; particleboards; wood particles; polymeric methylene di-isocyanate resin; physical and mechanical properties

Proceedings of the International Convention of
Society of Wood Science and Technology

Performance of Particleboards with Reduced MUF Content via Lignosulfonate Substitution

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Abstract

Resin represents one of the most significant cost factors in particleboard manufacturing, accounting for approximately 30% to 50% of total material expenses, even though it constitutes only 2% to 14% of the final product's dry weight. Despite its relatively low concentration, resin remains a primary cost driver due to its high unit price. As a result, even small reductions in resin consumption or price can lead to substantial savings in overall production costs, making resin optimization a key focus in efforts to improve manufacturing efficiency and profitability. This study investigates the feasibility of partially replacing melamine-urea-formaldehyde (MUF) resin with lignosulfonates (sodium (NaLS) and magnesium (MgLS) lignosulfonate), to reduce costs while maintaining board performance. Particleboards were produced with MUF resin partially substituted by 10%, 20%, and 30% NaLS or MgLS by weight, alongside control boards using 100% MUF for comparison. The findings reveal that both the type and amount of lignosulfonate significantly influence the boards' physical and mechanical properties, particularly internal bond (IB) strength, bending strength (MOR), and thickness swelling (TS). While the lignosulfonate type notably affected IB strength, it had less impact on MOR and TS. Boards incorporating 10% NaLS showed performance similar to the control, and overall, NaLS outperformed MgLS, although not to a statistically significant extent. Substitution of MUF resin with lignosulfonates up to 30% produced boards with acceptable performance, but higher substitution levels were associated with a decline in IB strength and reduced hydrophobicity, as indicated by increased thickness swelling. However, particleboards containing 10-20% NaLS or MgLS met the EN 312 standard for type P2 boards, suitable for indoor use in dry environments such as furniture. Internal bond strength values at all substitution levels also fulfilled the stricter requirements for type P3 boards. In conclusion, partial replacement of MUF resin with lignosulfonates, especially NaLS, presents a viable strategy for reducing production costs without compromising essential performance of boards. Substitution levels of 10-20% NaLS are particularly recommended, offering a sustainable and cost-effective adhesive solution that closely matches the mechanical and physical performance of conventional MUF-bonded boards.

Acknowledgement

This work was supported by APVV-18-0378, APVV-22-0238.

Key words

wood adhesive; particleboards; magnesium lignosulfonate; sodium lignosulfonate; melamine-urea formaldehyde resin; physical and mechanical properties

Evaluation of Moisture and Thermal Diffusion Characteristics of Korean Wood Species for Developing Property-Based Drying Groups

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Abstract

Efficient kiln drying requires species-specific drying schedules to minimize defects such as checking, cracking, or deformation. In Korea, however, a wide variety of domestic wood species are produced in relatively small volumes, making it difficult to fully utilize kiln capacity when species must be dried separately. This constraint reduces operational efficiency and increases energy consumption. To address this limitation, the development of property-based drying groups consisting of species with similar drying behavior is necessary to enable controlled mixed-species kiln drying.

As a preliminary step toward developing such drying groups, this study evaluated the fundamental transport properties governing heat and moisture movement during drying. Six softwood species and six hardwood species commonly used in Korea were investigated. The moisture diffusion coefficient and thermal diffusivity were experimentally determined under controlled laboratory conditions to quantify interspecies differences in mass and heat transfer behavior.

The results demonstrated clear variations among species in both moisture and thermal diffusion properties, reflecting differences in anatomical structure, density, and porosity. Softwoods generally exhibited relatively consistent diffusion tendencies, whereas hardwoods showed greater variability, likely due to vessel distribution and heterogeneous microstructures. These findings indicate that transport-property-based analysis provides a rational foundation for establishing drying groups with comparable drying responses.

Although drying groups were not established at this stage, the dataset provides essential baseline information for subsequent statistical grouping analysis. Future research will expand the database by incorporating two to three additional softwood species and approximately ten hardwood species. Based on the expanded dataset, statistical methods will be applied to develop property-based drying groups, and optimized drying schedules will be proposed for each group. Ultimately, this research aims to enable mixed-species kiln drying while maintaining drying quality and improving kiln utilization efficiency and energy performance in the domestic wood processing industry.

Keywords

Kiln drying; Moisture diffusion coefficient; Thermal diffusivity; Property-based drying groups; Mixed-species drying

Proceedings of the International Convention of
Society of Wood Science and Technology

Kinetics of colour development in European beech during steaming

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Abstract

Hydrothermal treatment of green hardwood is widely used to relieve growth stresses, sterilise wood, plasticise tissue and modify wood colour. In European beech (Fagus sylvatica), colour development during steaming depends on anatomical category, moisture content, and temperature, yet quantitative kinetic data remain limited.

This study quantified time-dependent colour changes in green beech during steaming and evaluated the influence of temperature and wood category. Samples of sapwood, transition wood, and red heartwood were steamed at 70 °C and 85 °C. Initial moisture content ranged from 82 % to 95 % in sapwood and transition wood, and from 62 % to 71 % in red heartwood. Colour and moisture content were monitored after 1, 4, 7, 11, 24, and 30 hours.

Colour was evaluated from flatbed scanner images (HP Scanjet G4010) acquired under fixed settings as 24-bit TIFF files without automatic corrections. RGB values (0-255) were converted to CIELab, assuming the sRGB colour space (D65 illuminant, 2° observer). Mean values and standard deviations were calculated from ten measurement points, and the total colour difference (ΔE) relative to 0 h was determined.

Steaming caused a marked decrease in lightness (L*) across all wood categories, indicating progressive darkening, while changes in a* and b* were smaller. After 30 hours at 70 °C, ΔE reached 18.8 ± 2.0 in sapwood, 12.1 ± 1.4 in transition wood, and 7.2 ± 0.9 in red heartwood; at 85 °C, the values increased to 23.5 ± 2.3, 15.6 ± 1.8, and 10.4 ± 1.1, respectively.

The time dependence of ΔE showed rapid initial development followed by a decelerating phase, and was well described by a first-order kinetic model,

$$\Delta E(t) = \Delta E_{\infty}\left(1 - e^{-kt}\right)$$

with apparent rate constants increasing from 0.10 h^{-1} at 70 °C to 0.16 - 0.33 h^{-1} at 85 °C, this confirms a strong temperature dependence of chromophore formation. The model described red heartwood particularly well (R^2 up to 0.86), whereas sapwood did not reach clear saturation within 30 h, suggesting continued colour development beyond the investigated period.

These results provide statistically supported kinetic insight into colour evolution in steamed beech and contribute to improved control of industrial hydrothermal treatment processes.

Key words

European beech; hydrothermal treatment; colour kinetics; CIELab; first-order model

Low Steaming Treatment: Impacts on Wood Structure and Properties

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Abstract

Wood modification refers to a set of chemicals, thermal, and physical treatments aimed at improving wood performance and selected physical characteristics. Among these approaches, wood steaming is attracting increasing attention, particularly for species traditionally regarded as difficult to process. Hygrothermal treatments, including steaming, can effectively modify key physical properties such as dimensional stability, hygroscopic behaviour, resistance to fungal decay, and colour. However, despite potential gains in durability, steaming may also negatively affect mechanical performance. This study assessed the influence of steaming on selected physical and mechanical properties of olive wood, with the aim of evaluating how different treatment durations at a constant temperature affect wood behaviour. Olive wood boards were divided into four groups: three subjected to distinct steaming cycles and one control group naturally seasoned. Bending tests showed that the shortest steaming cycle (12 h) increased the modulus of elasticity (MOE) by 13.45% compared with the control. Overall, low-temperature steaming induced controlled changes in the structural integrity and in the physicochemical properties of lignin and cellulose. These modifications improved workability, dimensional stability, and aesthetic quality while preserving the traditional character of olive wood. The results indicate that steaming can significantly enhance the value of olive wood, supporting its suitability for indoor product applications.

Keywords

Wood properties; modification; colour changes; steaming; stability

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Fully Recyclable Wall Systems: Material Development and Performance Characterization

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Abstract

A range of strategies can improve resource efficiency in building constructions, including the selection of appropriate materials, optimization of structural design, and more efficient production processes. The construction sector is widely recognized for its high demand for raw materials and its substantial generation of solid waste, making better material efficiency and recycling practices a pressing challenge. One promising route is the use of bio-based, carbon-storing materials such as wood. Yet limited wood availability and inefficient processing often result into poor overall utilization of renewable feedstocks.

The „3DP Biowalls“ project responds to these challenges by applying additive manufacturing (3D printing) with renewable raw materials to produce fully recyclable wall systems. The project targets four key issues: (1) global raw material scarcity, (2) the widespread reliance on inorganic construction materials such as concrete and steel, (3) inefficient use and recycling of renewable resources, and (4) the historically low productivity of the construction industry.

This research focuses on developing material formulations for large-scale 3D printing that are fully bio-based and, where possible, derived from industrial by-products. Materials we focused on was dried thick spent sulfite liquor (DTSSL) (25%) in a combination with one of the three additives casein, pea protein, bentonite (25%) and wood particles (50%). Experimental results confirm DTSSL combined with protein-based additives—especially casein—shows strong potential as an adhesive system for additively manufactured wood composites. Its ability to deliver competitive stiffness and strength without the need for additional heat makes it well suited to the technical and economic requirements of robotic additive manufacturing. These approach aims to significantly improve raw wood utilization in construction products, targeting utilization rates above 90%, compared with conventional levels of 40-60%.

Overall, the project is expected to deliver innovative solutions that strengthen both the scientific basis and practical deployment of circular-economy concepts in construction, helping to set new benchmarks for sustainable building practices.

Key words

Sustainable construction; Bio-based materials; Additive manufacturing; 3D printing in construction; Circular economy

Moisture control considerations in hybrid CLT walls for multi-story residential buildings

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Abstract

Cross-laminated timber (CLT) is increasingly adopted in hybrid construction as a low-carbon alternative to conventional materials; however, its hygrothermal performance in high-rise residential buildings remains insufficiently understood, particularly under humid indoor conditions. This study investigated the indoor moisture risk and hygrothermal behavior of hybrid CLT wall systems in mid- and high-rise apartment buildings under the Korean climate. Building models ranging from 10 to 30 stories were analyzed using WUFI Plus simulations, comparing reinforced concrete (RC) walls with CLT wall assemblies incorporating different insulation materials. The simulations considered coupled heat and moisture transfer, indoor environmental conditions based on ASHRAE standards, and typical occupancy schedules. The results show the CLT wall systems effectively reduce outdoor moisture penetration due to the use of exterior insulation, resulting in stable thermal profiles within the wall. However, increased moisture accumulation was observed within the CLT layer under high indoor humidity conditions, indicating greater sensitivity to interior moisture loads compared to RC walls. Although moisture levels remained below critical thresholds, the findings highlight potential moisture risks in wood-based assemblies. Energy performance differences between CLT and RC walls were minimal, reflecting the high baseline thermal performance of modern concrete buildings. In contrast, hybrid CLT systems demonstrated substantial carbon reduction potential over the building life cycle. These findings emphasize that indoor moisture conditions are a key factor governing the hygrothermal performance of CLT walls and underline the importance of appropriate vapor control and interior finishing strategies for moisture-safe design in high-rise residential applications.

Keywords

Cross-laminated timber (CLT); Hygrothermal performance; Moisture control; Hybrid wall system; Residential buildings

Proceedings of the International Convention of
Society of Wood Science and Technology

Manufacturing and Performance Evaluation of Novel CLT Structures

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Abstract

Cross-laminated timber (CLT) has emerged as a key engineered wood product enabling the transition toward low-carbon construction systems. While commercial CLT manufacturing has traditionally relied on softwood species due to their favorable processability and established supply chains, the growing availability of underutilized hardwood resources—particularly in regions such as the Appalachian forest ecosystem—creates an opportunity to expand the raw material base for mass timber construction. The development of hardwood-based CLT panels offers the potential to enhance mechanical performance, increase resource efficiency, and improve the economic value of lower-grade hardwood species. This study investigates the feasibility of manufacturing structural CLT panels from selected hardwood species, with emphasis on material characterization, adhesive bonding performance, and structural behavior. The research evaluates the influence of hardwood anatomical characteristics, density variability, and moisture-dependent dimensional stability on panel integrity and long-term performance. Particular attention is given to bonding interface performance, rolling shear resistance, and stiffness optimization through lamination layup configuration. Experimental results are complemented by analytical modeling approaches aimed at predicting mechanical performance and optimizing panel design. Results indicate that hardwood-based CLT panels can achieve superior stiffness and strength properties compared with conventional softwood systems, enabling reduced panel thickness and improved structural efficiency. Challenges associated with increased density, adhesive penetration, and potential residual stresses are addressed through process optimization strategies including surface preparation, adhesive selection, and pressing parameter adjustment.

The findings demonstrate that hardwood CLT systems represent a viable pathway toward diversification of the mass timber market while supporting sustainable forest management and improved utilization of regional wood resources. The integration of hardwood species into CLT manufacturing contributes to enhanced value chains, reduced carbon footprint of construction materials, and increased resilience of the forest-based bioeconomy.

Key words

cross-laminated timber; hardwood species; mass timber; structural performance; innovative CLT structures

Experimental Validation of an Enhanced Korean Fire-Resistance Design Approach for Korean Larch Glulam

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Abstract

Current Korean fire-resistance design method for Korean larch glulam, simply adds a stipulated charring depth to the ambient-temperature design cross-section without any upward strength adjustment of residual section. In contrast, the National Design Specification (NDS) applies a strength adjustment factor of 2.85 under fire conditions, while Eurocode (EN 1995-1-2) employs a factor of 1.15 to adjust the characteristic strength from 5th to 20th percentile for glulam. This absence of strength adjustment mechanisms in Korea standards leads to structural inefficiency compared to international standards. This study proposes a refined residual cross-section calculation method and a design strength procedure for fire conditions, and experimentally verification applicability to Korean larch glulam. The residual cross-section is determined by subtracting the effective charring depth — comprising the charring depth and a zero-strength layer — from the original cross-section. Fire design strength is then determined by applying a 2.85 upward modification factor to the allowable bending stress of the residual cross-section. Specimens fabricated from Korean larch with cross-section 150 mm × 200 mm, length 4,700 mm, allowable bending stress of 9 MPa, and PRF adhesive were tested. Fire resistance tests were conducted at KICT under the ISO 834 standard temperature-time curve with three-sided exposure for 60 minutes, sustaining a constant load in four-point bending. All three specimens maintained structural integrity throughout the 60-minute fire exposure without failure. Specimens 1 and 2 experienced unintended four-sided charring due to flame penetration through ceramic wool on the top surface, producing additional charring depths of 6.8 mm and 3.7 mm respectively; neither reached failure, indicating a sufficient structural safety margin. These results confirm that the proposed residual cross-section and fire design strength methods provide adequate structural safety, establishing a sound technical basis for their incorporation into domestic fire resistance design provisions for structural glulam.

Keywords

Fire-resistance design; Residual cross-section method; Charring; Homogeneous glulam

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A Study on the Improvement of Moisture Absorption and Desorption Performance of Japanese Cedar for Architectural Finishing Materials

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Abstract

With increasing emphasis on carbon neutrality and energy reduction in the building sector, the importance of indoor humidity control using building materials is increasing. In particular, as indoor occupancy time increases, the importance of indoor humidity control using building materials is further increasing. This study evaluated the moisture adsorption and desorption performance by treating cedar wall finishing materials with functional materials made of calcium chloride and activated carbon in order to improve the moisture adsorption and desorption performance of wood for interior finishing materials.

In order to increase the surface area of the finishing materials, surface perforations with opening ratios of 1%, 3%, and 5% were applied to the cedar wall finishing materials. In addition, functional materials with different mixing ratios of calcium chloride and activated carbon were prepared, impregnated into sponges, and then attached to the backside of the finishing materials. The moisture adsorption and desorption performance were evaluated in accordance with KS F 2611.

As a result of the experiment, when only perforation was applied, the humidity control performance was partially improved, but it did not reach the standard of 65 g/m^2. On the other hand, in the finishing materials to which functional materials were applied, the moisture adsorption and desorption performance were improved, and the imbalance between adsorption and desorption was reduced, resulting in an overall improvement in humidity control performance. As a result, it is expected that the standard of moisture adsorption and desorption amount presented in the legal standard can be satisfied.

These results show that the combined treatment of surface perforation and functional materials is an effective method to improve the humidity control performance of wood finishing materials. This application is expected to improve indoor humidity control and occupant comfort without increasing energy consumption, and ultimately contribute to carbon-neutral building design.

Key words

Absorption and Desorption; Functional building materials; Calcium chloride; Activated carbon; Standards for Construction of Health-Friendly Housing

Effect of Extraction Solvents on the Characteristics of Okara-derived Lipids and Their Potential for Functional Biocomposites

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Abstract

Okara, an abundant agricultural byproduct of the soybean industry, represents a highly sustainable resource for the development of functional biomaterials. In this study, lipids were recovered from okara using various solvent systems to systematically evaluate their extraction efficiency and physicochemical characteristics. The extracted okara lipids were characterized to determine their chemical structural profiles and thermal stability utilizing Fourier-transform infrared spectroscopy (FT-IR), thermogravimetric analysis (TGA), and differential scanning calorimetry (DSC). Subsequently, to explore their applicability in sustainable packaging, the recovered lipids were incorporated into cellulosic matrices to formulate functional biocomposites. The developed biocomposite matrices, designed to be applicable as either films or surface coatings, were comprehensively evaluated for their physical and barrier performances. Key assessments included the measurement of mechanical strength, surface hydrophobicity, and oil resistance. The findings indicated that the selection of extraction solvent significantly dictated the compositional profile and thermal behavior of the recovered lipids. These inherent variations profoundly influenced the lipid dispersion and interfacial compatibility within the hydrophilic cellulosic network. Consequently, this governed the final mechanical integrity and barrier efficacy of the biocomposites. This study demonstrates that tailoring the extraction process of okara-derived lipids is a critical parameter in optimizing the functional properties of cellulose-based biocomposites, highlighting their immense potential as eco-friendly alternatives for advanced food packaging applications.

Keywords

Okara; Lipid extraction; Solvent effect; Biomaterials; Sustainable packaging

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Society of Wood Science and Technology

Carbonization Characteristics of Residues from Supercritical Water Hydrolysis of Biomass

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Abstract

The demand for porous carbon materials for applications such as adsorbents and energy storage devices is constantly increasing. However, conventional petroleum-based precursors require energy-intensive processes, including high-temperature stabilization, carbonization, and graphitization, which consequently result in substantial environmental burdens. Accordingly, biomass conversion technologies utilizing renewable resources have attracted considerable attention as sustainable alternatives.

Supercritical water hydrolysis (SWH) is a rapid and efficient method for decomposing biomass by exploiting the unique physicochemical properties of water under supercritical conditions, eliminating the need for external catalysts or enzymes. However, the process generates a substantial amount of solid residues enriched with lignin and incompletely decomposed components. These residues typically exhibit limited direct utilization due to their low specific surface area and structural non-uniformity. Nevertheless, the high lignin content of the residues suggests their potential as high value-added carbon precursors.

In this study, the physicochemical properties and carbonization behavior of SWH residues were investigated as a function of temperature. Comparative analyses with untreated biomass were conducted to evaluate the influence of the supercritical pretreatment on the subsequent carbonization process. Structural transformations were characterized using yield analysis, FT-IR, BET, and XRD. Based on these characterizations, the possibility of utilizing SWH residues as carbon material precursors was assessed.

Acknowledgement

This work was supported by the National Institute of Forest Science (grant number: FP0700-2022-01-2026)

Key words

Supercritical water saccharification; Biomass-derived carbon; Lignin-rich residues; Porous carbon materials; Carbonization

Creation of Wood-based Hierarchical Superstructures via In Situ Growth of ZIF-8 for Enhancing Mechaical strength and Electromagnetic Shielding Performance

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Abstract

Given the escalating prevalence of electromagnetic pollution, there is an urgent need for the development of high-performance electromagnetic interference (EMI) shielding materials. Herein, wood-based electromagnetic shielding materials have gained significant popularity due to their exceptional performance as building materials. In this study, a novel wood-based composite with electromagnetic shielding properties is developed. Through the in situ growth of zeolitic imidazolate framework-8 (ZIF-8) crystals on wood fibers, coupled with uniform integration of carbon nanotubes (CNTs), a multifunctional composite named ZIF-8/Poplar-CNT composite is synthesized via a one-step thermoforming process (Figure 1). The incorporation of CNTs endows the composites with excellent EMI shielding effectiveness (EMI SE). Among these elements, despite ZIF-8 crystals not possessing intrinsic electromagnetic shielding functionality, their distinctive dodecahedral structure proves adept at scattering and reflecting electromagnetic waves within the composites, further improving the electromagnetic shielding effect. Hence, the ZIF-8/Poplar-CNT composite (56.95 dB) has about 10 dB higher EMI SE compared to that of the composites without ZIF-8 crystals. Meanwhile, ZIF-8 crystals endow the materials with excellent tensile strength (54.84 MPa, enhanced by 4 times). Moreover, the introduction of Zn2+ provides superior antibacterial properties. The potential applications of ZIF-8/Poplar-CNT composites extend to diverse areas such as building decoration, electronic products, and medical equipment.

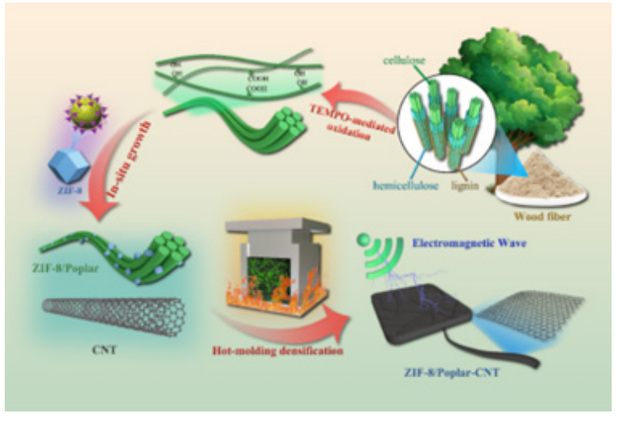

Figure 1. Schematic diagram of the fabrication process of ZIF-8/Poplar-CNT composite with efficient EMI SE.

Keywords

Self-bonding; Metal organic framework; Electromagnetic shielding; Antimicrobial properties; High strength

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Silylated Cellulose Nanofiber-based Thermal Stable Green Insulation Materials

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Abstract

Thermal insulation materials are essential components for efficient energy management in buildings. The demand for high-performance insulation materials is increasing significantly as carbon neutrality policies advance. Conventional insulation materials have traditionally included petroleum-based organic insulators and inorganic insulators derived from minerals. While organic insulation materials possess low thermal conductivity and excellent processability, they suffer from several drawbacks, such as flammability, the emission of toxic gases from petroleum-based components, and a lack of self-extinguishing properties. In contrast, inorganic insulation materials offer superior fire resistance but generally exhibit relatively lower thermal performance.

In this study, we developed an organic-inorganic hybrid aerogel insulation material based on silica and cellulose. The chemical interactions between the components were analyzed using Fourier-transform infrared spectroscopy and X-ray photoelectron spectroscopy, confirming the successful incorporation of silica particles onto cellulose nanofibers' surface. The dispersion of silica particles and the morphology of cellulose fibers were observed using scanning electron microscopy and energy-dispersive X-ray spectroscopy, and the results showed that a nanostructure had formed without agglomeration. The Brunauer-Emmett-Teller method and density functional theory were used to analyze the specific surface area and pore size distribution. The specific surface area increased 11-fold compared to a cellulose aerogel, and microporous structures also formed. The enhanced pore characteristics positively impacted thermal insulation performance, resulting in a two-fold decrease in thermal conductivity. Furthermore, microscale combustion calorimetry test revealed that the heat release rate decreased by six-fold, confirming the excellent flame retardancy of the developed organic-inorganic hybrid aerogel.

Key words

Cellulose nanofibers; Silylation; Thermal insulation; Flame-retardant; Aerogel

Reengineering Paper Tubes for the Circular Economy: How Cut Geometry and Cellulose Micro/Nanofibrils Boost Structural Performance

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Abstract

The use of cellulose micro/nanofibrils (CMNF) in the development of new materials has gained increasing attention due to their ability to enhance the performance of paper-based products. However, the properties of CMNF vary significantly depending on the raw material source, pretreatments, and production processes, which directly affect their industrial applicability. In this study, CMNF obtained through mechanical shearing of the partner company's own industrial residues was incorporated into the sodium silicate adhesive used in the production of multilayer paper tubes. The company's manufacturing process traditionally involves winding successive layers of adhesive-impregnated paper, and this work explored two reinforcement strategies intended to improve mechanical strength: (i) longitudinal cuts of 20 mm spaced 20 mm apart on all sides of the paper sheets, and (ii) the addition of 1% CMNF to the adhesive formulation. Multilayer composites were produced using 190 g/m² kraft paper impregnated with the modified adhesive, applied with a bar-coating device to simulate industrial conditions. The composites—with and without cuts, and with or without CMNF—were evaluated for physical and mechanical properties, with emphasis on bending performance. Composites produced from cut papers showed increases of 39% in tensile strength and 9% in elastic modulus. When 1% CMNF was incorporated, these improvements rose to 44% and 9%, respectively, compared with the control (uncut paper). Composites reinforced only with CMNF, without any paper cuts, demonstrated even greater improvements: a 60% increase in modulus of rupture and a 16% increase in elastic modulus. Overall, the results highlight the effectiveness of combining structural modifications and CMNF reinforcement to enhance the mechanical performance of paper composites. This study contributes valuable insights into the practical application of CMNF and provides a data-driven basis for future research aimed at scaling up CMNF production from industrial residues and expanding their use in advanced paper-based materials.

Keywords

Lignocellulosic; paper composites; multilayer composites; kraft paper; micro fibrillated cellulose

Proceedings of the International Convention of
Society of Wood Science and Technology

Molded Pulp Packaging Made from Rasau Fibers: Effect of Different Part of Plant as Source of Fibers

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Abstract

Rasau (Pandanus helicopus) fibers are an interesting source of materials for molded pulp packaging due to their behavior as a natural component of swamp and riparian ecosystems. However, it is a dominant native species, and it can be problematic by hindering access or land use due to dense root systems while clearing is costly. On the other hand, its fibers have potential as source of fibers for molded pulp packaging either from its stem or leaf. By assessing stem and leaf of rasau fibers characteristics, this study evaluated the ratio of its combination to find the optimal condition. Fiber morphology, yield, and chemical composition were characterized, and lab-scale molded-pulp trays were fabricated with different parts of rasau. Combination of stem and leaf fibers was used to assess strength performance of resulting molded fibers. Stem fibers perform the highest strength due to their longer fibers compared to leaf resulting in better intact among the molded fibers. Molded pulp from combination of leaf and stem exhibits similar performance with different ratio; However, the 1:1 ratio (stem : leaf) resulting in similar density and strength of molded fibers compared to 2:1. This finding opens the opportunity of whole part of rasau as feedstock for molded pulp packaging. Thus, using whole part of rasau plant by increasing its added value can be an alternative pathway to both cost of clearing rasau and opening access or land use, particularly in a wetland area.

Key words

Fibers; molded pulp packaging; stem; Pandanus helicopus; leaf

Particleboard Property Prediction using X-ray Computed Tomography Images and Machine Learning Techniques

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Abstract

Particleboard is widely used in flooring, furniture, and construction, and reliable quality control is essential to ensure mechanical performance. In our previous studies, a multi-input convolutional neural network (CNN) was developed to predict mechanical properties from surface and cross-sectional images. Although acceptable prediction accuracy was achieved, surface-based imaging cannot fully capture the internal structure of particleboard. To address this limitation, this study using X-ray computed tomography (CT) combined with a three-dimensional residual neural network (3D-ResNet) to predict the mechanical properties of particleboard.

Fifty-four particleboards manufactured from Japanese cedar (Cryptomeria japonica) under 27 different conditions were used. Five specimens (200 × 30 × 9 mm) were prepared from each board, and three-point bending tests were conducted to determine their modulus of elasticity (MOE). Small specimens (30 × 10 × 9 mm) cut from the bending specimens were scanned using an X-ray CT scanner to have 3D image data with a resolution of 71 μm/pixel and a final size of 500 × 140 × 150 voxels.

Then a lightweight 3D-ResNet model was constructed based on the ResNet-18 framework. The model consisted of four residual blocks followed by global average pooling to directly predict the MOE values. Training was performed using TensorFlow with the Adam optimizer and a learning rate of 0.001.

To validate the reliability of CT imaging, density profiles reconstructed from the 3D CT data exhibited the characteristic U-shaped distribution typical of particleboard, confirming that essential internal structural information was captured. The 3D-ResNet achieved an average coefficient of determination (R^2) of 0.88 and a root mean squared error (RMSE) of 0.20 GPa. This performance is comparable to our previously developed density-informed multi-input CNN (R^2 = 0.90, RMSE = 0.19 GPa) and substantially outperforms the image-only CNN model (R^2 = 0.73, RMSE = 0.31 GPa).

Keywords

Particleboard; Property Prediction; X-ray CT; Density Profile; Machine Learning

Proceedings of the International Convention of
Society of Wood Science and Technology

Blockchain for Wood Supply Chain Traceability Ensuring Transparency Security and Sustainability

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Abstract

This research is part of the National project titled Tech4You - Technologies for climate change adaptation and quality of life improvement funded by National Recovery and Resilience Plan. In a global context where illegal timber procurement and limited information on the logistics of wood movement and marketing are increasingly being addressed, this study investigates an electronic traceability system based on blockchain technology to enhance process and product transparency and safety along the production and processing chain. The proposed approach relies on a decentralized and distributed ledger, accessible through a secure digital platform to all stakeholders, which enables the recording, consultation, and sharing of verified data on timber provenance and on each transformation step—from tree felling to sawmill processing. By ensuring the immutability and transparency of transactions, blockchain strengthens trust among actors (including producers, processors, and end users) and reduces the risk of fraud such as document tampering or material substitution. In addition, the system supports sustainability by enabling accurate monitoring of forest resources and facilitating verification that timber originates from responsibly managed sources. Overall, the study highlights how digital technologies and traceability frameworks can improve transparency, accountability, and sustainability in the wood sector, while also reducing the time and costs associated with manual controls and conventional certification procedures.

Key words

Forest Operations; Digital Technologies; Certification; Wood quality

Soil organic carbon change can reduce the climate mitigation potential of biofuel produced from forest residues

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Abstract

Producing biofuel from renewable biomass has great potential to enhance energy security and reduce the environmental impacts of the transportation sector. Among various biomass feedstocks, forest residues have been identified as critical contributors to bioenergy sector in future climate change mitigation scenarios. Many previous studies have highlighted the climate benefits of forest residues in producing biofuel to substitute fossil fuels, and avoiding land-use change and relevant carbon emissions. However, changes in soil carbon stock are often ignored for forest residues in previous life cycle assessment (LCA) and low carbon fuel policies. Previous studies show that intensive forest residue removal may lead to long-term soil organic carbon (SOC) loss, affecting the carbon intensity of biofuels. This ignorance of SOC changes may result in exaggerating the climate benefits of biofuels from forest residues. Understanding such impacts and driving factors of SOC changes associated with forest residue is essential to the simultaneous development of sustainable forest management and low-carbon biofuels, along with corresponding policies. Here, we established a dynamic life cycle modeling framework to investigate the impacts of SOC changes due to forest residue removal on the life-cycle carbon footprint of biofuels derived from forest residues. The framework was applied to a cradle-to-grave biofuel system utilizing fast pyrolysis to convert pine residues from the Southern U.S. into biofuels. We show that the average GHG emissions by SOC changes over 100 years are 8.8-14.9 gCO2e MJ-1, accounting for 20.3%-65.9% of life-cycle GHG emissions of biofuel. These SOC-associated GHG emissions vary by timeframe, site conditions, and forest management strategies. For land management, converting forest residues to biofuel is more climate-beneficial than on-land decay or pile burning, depending on fossil fuel substitution and site conditions. Our results highlight the need to include soil carbon assessment in biofuel LCAs, policymaking, and forest management even when forest residues are used and no land-use change is involved. This study has been published in 2024 (Lan et al., Joule., 2024).

Keywords

biofuel; greenhouse gas emissions; soil organic carbon; forest residues; life cycle assessment; fast pyrolysis

Proceedings of the International Convention of
Society of Wood Science and Technology

Enhanced Enzymatic Hydrolysis and Valorization Waste Paper via Mechanical Refining Pretretment

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Abstract

With the rapid growth of the global population, approximately 2.01 billion tonnes of municipal solid waste (MSW) are generated annually, of which paper constitutes the second-largest fraction (~17%). Waste paper, primarily derived from wood species such as pine, fir, and eucalyptus through chemical and mechanical pulping processes, contains a high proportion of cellulose due to extensive lignin removal. This cellulose-rich composition, coupled with elevated glucose content relative to other lignocellulosic feedstocks, makes waste paper an attractive substrate for biorefinery applications. However, its compact fiber network and strong inter-fiber hydrogen bonding limit enzyme accessibility and saccharification efficiency, necessitating additional pretreatment strategies that avoid harsh chemical inputs.

In this study, mechanical refining was employed as an environmentally benign pretreatment for office paper and newspaper to enhance enzymatic digestibility by increasing fibrillation, surface area, and porosity. Enzymatic hydrolysis conducted at 2% (w/v) substrate loading significantly improved glucose production, increasing concentrations from 0.54 to 17.76 mg/mL for office paper and from 6.60 to 12.09 mg/mL for newspaper. The resulting glucose was subsequently converted to the rare sugar allulose via a two-step enzymatic cascade involving xylose isomerase and D-allulose 3-epimerase, achieving an allulose yield of approximately 40%. Residual sugars were further fermented to bioethanol using yeast, reaching an ethanol yield of ~80%.

Overall, this integrated valorization strategy demonstrates an efficient carbon-utilization pathway that converts low-cost waste paper into high-value rare sugar and biofuel products, offering a sustainable and zero-waste biorefinery model for circular resource management.

Key words

-Waste paper; Lignocellulosic biomass; Allulose; Bioethanol; Zero-waste biorefinery

Investigating Market Entry Barriers for Family Firms in the Wood-Processing Industry: Empirical Evidence from the Visegrad Group (V4)

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Abstract

Family businesses play a pivotal role in the EU economy by underpinning the stability and renewal of traditional industries, including the wood-processing sector. Within the Visegrad Group (V4), family businesses in wood processing constitute a distinctive entrepreneurial segment. As a traditional industry grounded in long-standing craft and industrial know-how, wood processing given the region's environmental and resource endowment can represent a cornerstone of national and regional economies in Czechia, Hungary, Poland, and Slovakia. Supporting the formation and early development of family enterprises in this field is therefore not merely an entrepreneurial concern, but a strategic economic priority. This paper investigates the market entry barriers encountered when establishing family businesses in the wood-processing industry across the V4, focusing on their prevalence, perceived severity, and cross-country differences. To reflect the realities of entry and early growth in this sector, barriers are conceptualized as two broad categories: internal barriers and external barriers. The analysis draws on primary data collected through a structured questionnaire administered to nascent and recently established family businesses. Descriptive and inferential statistical procedures are used to test research hypotheses and to identify robust patterns within and between V4 countries. The findings indicate that start-up and early-stage family businesses most acutely experience financial barriers, followed by wider economic constraints and political-legal impediments. The paper contributes in two ways. First, it provides a concise comparative account of which barriers are common across the V4 and which appear more strongly conditioned by national institutional settings. Second, it proposes actionable measures to improve the current situation, including policy and ecosystem interventions to reduce administrative frictions, expand access to tailored finance, and strengthen capacity-building support that enables families to professionalize governance from inception. Collectively, these recommendations outline pathways to enhance the creation, resilience, and long-term competitiveness of family businesses in this traditional V4 industry.

Keywords

family business; wood-processing industry; Visegrad Group (V4); start-up barriers

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Effective Utilization of Forest-Derived Underutilized Resources: Molding and Application of Crushed Dwarf Bamboo Culms

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Abstract

Sasa bamboo species are widely distributed in the forest understory of Hokkaido, with an estimated biomass of approximately 150 million tons. Despite this abundance, their practical utilization has remained limited. This study re-evaluates the feasibility of producing molded boards from Sasa kurilensis, inspired by earlier attempts in the 1950s-60s. Fresh Sasa materials collected from the Uryu Experimental Forest were separated into culms and leaves, pulverized with a 5-mm screen, and further classified into 10-mesh and 20-mesh fractions. Each fraction was adjusted to 10% moisture content and mixed with 8% urea resin adhesive based on oven-dry weight. Hot-pressing was carried out at 160°C for 15 minutes under pressures ranging from 5 to 15 MPa. Physical and mechanical properties of the resulting boards were evaluated following JIS A 5908:2015 particleboard standards.

Boards were successfully fabricated under all conditions, displaying a light khaki color with minimal thermal discoloration. Densities ranged from 0.75 to 1.11 g/cm^3, and both bending strength and modulus of elasticity increased with density. Boards with densities of 1.04 and 1.11 g/cm^3 achieved bending strengths of 24.2 and 25.8 N/mm^2, respectively, exceeding the JIS Type 18 requirement of 18 N/mm^2. Furthermore, boards produced using particles finer than 20 mesh demonstrated the highest performance, reaching a density of 1.16 g/cm^3 and a bending strength of 33.2 N/mm^2. These results confirm that Sasa kurilensis powder is suitable for producing molded boards with mechanical properties comparable to conventional wood-based particleboards. The findings highlight the potential for effective utilization of underused Sasa resources and contribute to the development of novel materials derived from abundant forest understory biomass.

Key words

Sasa kurilensis; Particleboard; Hot pressing; Bamboo resources; Mechanical properties

Planting a line on the map: The Elements of Logistics in the Global Mass Timber Panels Industry

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Abstract

In 2026, the mass timber panel (MTP) industry, exemplified by Cross-Laminated Timber (CLT), does not feel all that new anymore. And yet the industry must still be recognized as a radically new concept challenging both commodity-oriented forest products, industry models, and the linear models of construction project development. It is much smaller and more diverse than the volume of information and noise around it would suggest. Organic development of the global mass timber industry since the first commercial applications in the late 1990s has produced substantial diversity in manufacturing processes, levels of automation, scales of operation, and products and services options, as well as in market strategies and modes of interaction with its extensive supply chain. The principal distinction of the MTP industry compared to the rest of engineered wood products sectors, is high level of integration of the elements of architectural and engineering design process, manufacturing technologies, and construction. The project, not the panel, is the product. Fabrication of panels is just a step in this larger process.

One of the less discussed aspects of the MTP industry is its peculiar logistic calculus that may need to be approached somewhat differently than with common commodity operations. While mass timber projects are being routinely shipped on intercontinental routes, planting a manufacturing line on a map requires careful triangulation with complicated supply and value chain elements. We believe that a thing or two on that topic may be inferred from the analysis of the existing global mass timber operations, which taken together, make a living laboratory that can be used for better understanding of both the current state of the industry and its future development. The presentation will highlight recent updates on the location of MTP manufacturing operations between the material supply sources and potential client base.

Keywords

mass timber panels; logistics; supply chain

Proceedings of the International Convention of
Society of Wood Science and Technology

Effects of Product Characteristics on Carbon Displacement of Wood Products

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Abstract

As global efforts to address climate change and achieve carbon neutrality intensify, initiatives to reduce carbon emissions across various sectors are expanding. In this context, wood has gained attention as a promising alternative to carbon-intensive materials such as steel and concrete due to its renewability and carbon storage capacity.

Accordingly, numerous studies have been conducted to quantify the carbon displacement effects of wood products, with displacement factors (DFs) widely used as a primary approach. However, to establish practical substitution criteria, it is necessary to better understand how carbon displacement varies depending on product characteristics.

This study analyzes the influence of product characteristics on carbon displacement based on existing DF-based approaches. Carbon emissions were estimated using material-specific emission factors for representative products in the furniture and building sectors, and the effects of material composition and structural design were comparatively evaluated.

The results show that carbon displacement varies with material composition and structural characteristics, with greater effects observed when high-emission materials are substituted. These findings suggest that carbon reduction depends not only on the use of wood, but also on how it is applied within product systems

Key words

Carbon displacement; Material substitution; Wood-based products

Development and Validation of an Evaluation Model for Korean Wood Flooring to Reduce Elderly Fatigue and Enhance Walking Safety

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Abstract

This study aimed to develop and validate an evaluation and selection model for Korean wood flooring systems designed to reduce fatigue and enhance walking safety among older adults. The research was conducted as a multi-year collaborative project incorporating field surveys, material performance analysis, wearable sensor-based gait assessment, and test-bed validation. An analysis of national statistics on wood flooring production and public-sector use showed that indoor wood flooring accounts for a substantial share of total production (192,440 m^3 out of 322,268 m^3), while public-sector utilization remains limited to 9.7%. These findings highlight the need to expand public applications and promote the use of domestic timber. Based on a literature review and user-centered criteria, evaluation factors focusing on physical and emotional stability were derived. A test-bed with various flooring types arranged under controlled conditions was established, and surveys were conducted with elderly users and the general public. Two evaluation frameworks were applied: (1) a user-centered assessment encompassing emotional and physical stability, and (2) a comprehensive project evaluation including economic feasibility and environmental contribution. The results indicated that a 10 mm plywood-based engineered wood flooring system achieved the highest overall satisfaction (29.6%), demonstrating strong emotional (34.4%) and physical (25.0%) performance. Notably, a significant perceptual difference in “cold-warm” sensation between wood and non-wood materials was observed, underscoring the perceived thermal comfort advantages of wood flooring. This study provides scientific evidence supporting the advantages of domestic wood flooring for broader application in public facilities. Future research should focus on developing functional products—such as anti-slip and high-elastic cushion-layer systems—and establishing standardized flooring design guidelines to further promote the utilization of Korean wood flooring.

Acknowledgment

This study was carried out with the support of ‘R&D Program for Forest Science Technology (Project No. RS-2023-KF002500)’ provided by Korea Forest Service (Korea Forestry Promotion Ins titute).

Keywords

Circular economy; Material flow analysis; Wood product; Wood resource statistics

Proceedings of the International Convention of
Society of Wood Science and Technology

Empowering small-holder private forest owners in Europe by innovative business opportunities in forest-based bioeconomy value chains: the SMURF Forest Owners project

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Abstract

Europe’s forests are owned by an estimated 20 million landowners, of which about half are privately owned and 65% are smaller than 100 ha. A large share are small-scale properties where management is inefficient or neglected because it is no longer economically viable. The rural exodus exacerbates declining land use and even land abandonment: a new generation of landowners with more urban lifestyles loses interest in forest and the knowledge to manage it. This leads to higher disturbance risks, a declining provision of ecosystem services, and lower resilience against climate change. On the other hand, the emerging bioeconomy creates new opportunities for value chains based on biomaterials and ecosystem services, which could translate into a source of income for landowners.

The SMURF Forest Owners project studies these opportunities by addressing the entire range of timber products, non-wood forest products (NWFP), ecosystem services, and cultural uses. The objectives are i) to develop a comprehensive conceptual framework for innovative forest uses and value chains, ii) to map a collection of good practice examples across the framework from European regions, and iii) to assess their potential for delivering higher value added to forest owners from a holistic sustainability point of view. By means of literature review and expert interviews, both traditional and innovative uses are studied. Abandoned traditional uses are of interest if they might be revived by enhancing their profitability, e.g. by improved technology. Innovative forest uses address novel products, services, markets, and business models, ranging from low tech to high tech solutions, e.g. with digital tools. The initial results highlight various interesting innovation fields such as biochar, engineered wood products, NWFP markets, carbon certificates, biodiversity conservation and nature credits, and recreation. A series of 25 local demonstration projects was launched together with forest owner associations from different countries to further test and evaluate the solutions, which include as well cooperative models and progressive forest management approaches to overcome structural barriers. The results will inform the foundation of a European network of smallholder forest owner initiatives which aims to revitalize rural forest regions through knowledge exchange and joint policy advocacy.

Acknowledgment

Funded by the European Union under the Horizon Europe “SMURF” project no. 101135516.

Key words

sustainable forest management; private forest ownership; innovative forest products; forest-based industry; rural development; forest policy

Renewing the Workspace: Modernizing Office Environments through Sustainable Systems

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Abstract

This project focuses on the sustainable design of an office lobby and a specific copy room. It involved collaboration among students from the College of Natural Resources and the College of Design, as well as industry partners from Columbia Forest Products. They provided their market-leading, formaldehyde-free, pure Bond plywood, along with new materials currently under development, including recycled cork and recycled-elastomer substrates. The project demonstrates collaboration and design that prioritize materials and minimize environmental impact.

As a sustainable designer, often approached by individuals seeking healthier ways to produce products that have a positive impact on our environment. Dr. Jingxin Wang sought such improvements for his spaces within the forest, in conjunction with the Materials Department. We held several meetings with various stakeholders to understand their specific needs, using a design thinking process that began with the empathy phase. After establishing the requirements and values for the spaces, we developed a point-of-view statement to guide the ideation phase, focusing on the project's overall look, materials, aesthetics, and processes.

The result is a stunning modernist aesthetic with a touch of 1950s retro. We used various materials, including plywood, to minimize the number of production and manufacturing components while integrating joinery to reduce the need for hardware during assembly. Both spaces now offer a unique, brighter atmosphere that enhances functionality and systems management. Each aspect of the design serves a specific purpose, ranging from seating and comfort to document processing and collection systems. The material itself is a communication piece that we used as an aesthetic, a talking point, and to showcase other sustainable materials. The materials were used creatively, exposing certain layers of the Columbia Forest Products substrate alongside different layers of recycled cork and recycled elastomer. This culminated in a beautiful, customized interior design with an industrial aesthetic, featuring functional furniture pieces.

Keywords

Sustainable Interior Design; Formaldehyde-Free Substrates; Interdisciplinary Collaboration; Design Thinking

Proceedings of the International Convention of
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The Indiana Wood Utilization Team

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Abstract

The Indiana Wood Utilization Team (IWUT) has been formed to increase forest health and resilience, competitiveness of the wood products industry, and economic development in rural areas in Indiana. The forestry and the wood products industry in Indiana face many issues and challenges, such as workforce shortages, spread of invasive species, poor forestry management, negative public perception, loss of competitiveness, limited access to financial resources, and late technology adoption. However, at the same time, there are opportunities that the industry could take advantage of, such as the mass timber market, value adding to the low-value hardwood species, and the increased push for environmentally friendly solutions. The IWUT will create and implement a strategic plan using input from an industry advisory board and a series of roundtable discussions across the state. After the advisory board is formed and a plan is implemented, the team will continue to meet once a year, even after the project is completed. Specific outputs of this project include guidelines for the utilization of low-value hardwood species, guidelines to support the penetration of yellow poplar lumber in the mass timber market, and the design, development, and implementation of a statewide promotional and educational campaign for the general public to increase awareness and utilization of wood products. The IWUT will continue to revise strategic plan and specific actions every five years.

Key words

wood markets; wood innovations; wood supply chain

Analysis of Cascading Use and Available Timber Resources Including Forest Disaster-Damaged Wood in the Korea

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Abstract

The Republic of Korea possesses substantial forest resources accumulated through decades of reforestation and sustainable forest management. Despite continuous forest growth and increasing standing volume, domestic wood utilization remains constrained by a structural dependence on imports and limited high value-added processing capacity. At the same time, changing climate conditions, evolving industrial demand, and carbon neutrality commitments are reshaping the role of forests from a traditional timber supply base to a strategic bio-resource platform.

This study aims to comprehensively assess the availability of forest-based timber resources in Korea—including commercial harvests, thinning materials, and wood derived from forest disturbances—and to propose integrated utilization strategies that enhance industrial value and resource efficiency. The research analyzes forest stock characteristics, harvest potential, material quality distribution, and industrial demand structures to identify feasible pathways for expanding domestic wood use.

By broadening the perspective from disaster-damaged wood to the entire forest resource base, this research highlights the strategic importance of forests in supporting carbon-neutral development, rural revitalization, and the transformation of the domestic wood industry. The results provide foundational evidence for establishing a long-term, sustainable forest-based bioeconomy in Korea.

Keywords

Forest disaster-damaged wood; timber resource availability; cascading use

Proceedings of the International Convention of
Society of Wood Science and Technology

A Quantification Framework for Psychological Evaluation of Wooden Office Environments Integrating Qualitative and Quantitative Approaches

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Abstract

Wooden office environments have recently attracted attention in the context of sustainability and well-being. However, most previous studies have relied on case-based observations, and the evaluation structures linking physical design elements to psychological responses have not been sufficiently modeled quantitatively. This study aims to develop a quantitative framework for modeling psychological evaluation structures of wooden office environments by integrated qualitative and quantitative approach.

First, qualitative interviews were conducted using the Evaluation Grid Method (EGM) to systematically elicit users' evaluation structures. Through laddering procedures, a hierarchical evaluation structure was constructed, comprising three layers: physical environmental attributes (e.g., wood ratio and greenery), spatial impressions (e.g., openness and casualness), and psychological self-state responses (e.g., feelings of relaxation and concentration). The extracted evaluation structure provided the basis for selecting evaluation items and specifying latent variables in subsequent quantitative modeling.

Next, a large-scale web-based survey was conducted using computer-generated office images with systematically varied spatial conditions. Structural equation modeling (SEM) was applied to quantify relationships among physical parameters, spatial impression factors, and psychological evaluations related to self-state. The model demonstrated acceptable goodness-of-fit. The results showed an inverted U-shaped relationship between visible wood ratio and evaluation scores, indicating that moderate wood visibility maximizes psychological evaluations. The optimal wood ratio varied depending on evaluation items and individual attributes such as gender, age, personality traits, and work activities.

To examine whether the quantitative model developed from the web-based survey can be applied to user evaluations under more realistic, immersive spatial conditions, VR experiments were conducted. The comparison revealed that the overall evaluation structure was largely consistent across methods, supporting the structural validity of the model. However, differences in absolute evaluation scores were observed, particularly under high wood-ratio conditions, where web-based evaluations tended to underestimate responses compared to VR. These findings indicate the necessity of calibration when applying web-based models to real or immersive environments.

These results demonstrate that psychological evaluations of wooden office environments can be quantitatively modeled by integrating user perceptions and physical parameters, providing a basis for evidence-based and user-centered design.

Key words

Wooden office environment, Psychological evaluation, Evaluation Grid Method, Structural equation modeling , Virtual reality

"Illuminate Circularity" Immersive in Education

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Abstract

The Illuminate Circularity project provides a valuable opportunity to engage students through storytelling in education. It focuses on the furniture life cycle, starting with clear classroom instructions. In the SMT 307 Product Visualization course, students learn about sustainable design and how to represent these ideas in digital formats, including light prototyping. The goal of the Illuminate Circularity project is to bring more immersive virtual reality experiences into the classroom, helping students better understand design and sustainability.

We will create an immersive storytelling experience using 360-degree video and allowing students to explore the entire life cycle of furniture. The journey begins in the forest, where wood originates. We will scan and film forests to create a 3D virtual reality experience. Next, we will show the processes of cutting and drying the wood, then move to the design phase, followed by manufacturing. We will demonstrate how furniture is used in homes and discuss what happens to it when it ends up in a landfill. This comprehensive storytelling approach will benefit students and the environment.

Helping students understand the life cycle of trees, including their use in products, from tree growth in ecosystems to their use over time. We will investigate how trees are turned into usable lumber through sustainable logging practices. Students will learn how this lumber becomes functional and attractive furniture, focusing on the details of material processing. Then, we will look at how furniture travels from showrooms to homes and its role in everyday life. We will also address the important topic of what happens to furniture at the end of its life, concentrating on sustainable disposal and recycling. Organizing and funding a program that allows students to experience this cycle firsthand will require years of effort, resources, and collaboration.

Taking students into the forest provides a powerful educational experience, helping them appreciate nature. This hands-on experience will deepen their appreciation for the environment and enhance their understanding of sustainable design. It will also foster an emotional connection to the products and materials, leading to the development of mindful designers.

Keywords

Sustainable Design; Immersive Storytelling; Furniture Life Cycle; Virtual Reality (VR); Circular Economy

Proceedings of the International Convention of
Society of Wood Science and Technology

The New European Bauhaus Academy: a novel skills, knowledge and innovation platform to boost sustainable construction within the built environment

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Abstract

The New European Bauhaus (NEB) is a policy initiative of the European Commission aiming 'to make the built environment beautiful, sustainable and inclusive'. It has inspired a large grassroots movement: about 2,000 organisations and 500 projects are co-creating and testing new visions and practices, how local neighborhoods, communities, and the built environment at large can become more livable, affordable, resilient, and sustainable. Through NEB, wood building materials gained a lot of interest by architects, builders and public authorities, being recognized as an aesthetic, healthy material and a decisive lever to decarbonize buildings. A significant bottleneck is the need for skilled workers and educated professionals capable of transforming the construction ecosystem towards a regenerative model. To address this gap, the NEB Academy will establish a European point of reference for knowledge, skills, and innovation in bio-based, circular, and digital solutions for the built environment, providing a full support system for practitioners by integrating different EU funding instruments.

The NEBA Alliance project was tasked to set the foundation of the NEB Academy: it launched a European network of 14 organisations in education and training from 11 countries and co-designed a governance structure of 4 regional training hubs under one common umbrella. A series of pilot trainings mainly related to wood construction has been carried out. An open online sharing platform for NEBA training courses was developed, along with a quality framework based on NEB principles and criteria. Through an open call, 28 institutions from 11 other countries contributed further trainings and partnered with the hubs. The Alliance reached out to international partners in Ukraine, Japan, and Brazil. The first NEB Academy Conference in Barcelona showcased all results to a wider international audience.

The NEB Academy is set to grow into a main pillar of Europe's ambitious transformation towards a climate neutral, circular economy that is also socially just and inclusive. Enabling local actors to imagine and demonstrate that NEB can become a reality is even more important in times when the model of Europe's open democratic societies is being pressured in a new global power confrontation.

Acknowledgement

Co-funded by Horizon Europe projects NEBA Alliance, WoodStock

Key words

co-creation; training; green transformation; empowerment; wood construction

Transforming Underutilized Hardwood into Biophilic Learning Environments

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Abstract

Two challenges remain insufficiently addressed: the underutilization of local wood resources in the US hardwood regions and the mental health of university students. Vast quantities of underutilized wood resources—small-diameter timber, lesser-used wood species, and urban wood lack value-added applications and are primarily converted into low-value products. On the other hand, student distress is increasing—with 33% of U.S. university students reporting moderate to severe anxiety and 37% reporting depression. Recent studies have explored the use of hardwoods for hybrid cross-laminated timber and mass timber structural components. Beyond these applications, however, they remain largely used for low-value products, such as pallets, chips, or firewood. Meanwhile, increasing evidence suggests that biophilic interventions improve student well-being. However, such approaches have not been widely used in university classrooms. There are limited strategies for upgrading underutilized hardwood into value-added non-structural products while simultaneously demonstrating economic feasibility across production scales. Likewise, few empirical evidence evaluating whether biophilic classrooms measurably improve university students' well-being. This study proposes to integrate student mental health improvement with value-added hardwood utilization to create a biophilic classroom. We hypothesize that upgrading existing classroom components with wood will enhance students' well-being while increasing the economic value of underutilized hardwoods. The research is designed to evaluate the long-term social and environmental benefits and the investment scale required to achieve cost-effective production. The outcome of this study may provide decision-makers with an evidence-based strategy to simultaneously enhance student well-being and promote the sustainable utilization of underutilized hardwood resources.

Taking students into the forest provides a powerful educational experience, helping them appreciate nature. This hands-on experience will deepen their appreciation for the environment and enhance their understanding of sustainable design. It will also foster an emotional connection to the products and materials, leading to the development of mindful designers.

Keywords

Underutilized hardwood; Biophilic classroom design; Student well-being; Value-added wood products; Economic analysis

Proceedings of the International Convention of
Society of Wood Science and Technology

Collaborative Modular Biophilic Design: An International Student-Built Wall Panel System for Wood Science Education

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Abstract

The study investigates the collaborative development of an expandable, modular educational wall panel system designed to merge multi-species wood expression with biophilic design principles. Conceived as a shared physical platform for students from Purdue University and the Technical University in Zvolen. The project enables participants from multiple countries to co fabricate components over time. The system is built around a parametric hexagonal tile template that ensures consistent geometry, allowing the wall to grow as new contributors add panels. Each tile functions as both a material demonstrator and an educational artifact, showcasing diverse hardwood species, biomaterials, and regionally significant woods through contrasts in color, grain, texture, and anatomical features. These material choices are paired with biophilic imagery—plants, animals, wood anatomy, and forestry motifs—integrated through surface relief, engraving, and nature-derived pattern languages. A curated motif library supports repeatable engraving and inlay work.

The construction concept uses layered wood-based panels optimized for CNC fabrication, supported by a standardized documentation package that includes DWG/DXF templates, CNC toolpaths, assembly instructions, and a guide for future tile makers. The system also incorporates interactive elements such as dual face "info board" tiles, which present species information on one side and a clean aesthetic face on the other, along with additional components intended to enhance outreach and educational engagement. For installation, the project specifies a concealed French cleat mounting system, combined with a hidden locking mechanism to ensure stability while preserving visual continuity.

Beyond producing a functional prototype and a set of exemplary fabricated samples, the project emphasizes international co-design, multidisciplinary collaboration, and long-term adaptability. By enabling students from different institutions to contribute to a shared, evolving artifact, the initiative fosters global engagement, supports hands-on learning in digital fabrication and wood science. It demonstrates how modular biophilic design can serve as both an educational tool and a platform for sustained creative exchange.

Key words

Co-Design; Wood-based Panels; Biophilic Design; International Collaboration

Digital Transformation in Furniture Design: Emerging Trends and Implications for Design Education

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Abstract

This study examines the effects of digitalization and technological innovations on the furniture industry across design, production processes, personalization opportunities, and user experiences. In this context, we developed educational content structured around 10 emerging trends in furniture design for students in the field. These new trends reflect digital innovation in furniture design. Such as digitalization of transforming processes; the Internet of Things (IoT) and artificial intelligence (AI) enabling smart systems; the sustainability approaches; robotic automation increasing production efficiency; additive manufacturing (AM) and 3D printing providing design and production flexibility; smart furniture strengthening user interaction; AR/VR-supported personalization tools; contemporary materials; biophilic design; and unique production approaches. The methodology is based on evaluating the effectiveness of the developed educational content using quantitative data from a pre- and post-test. The findings are expected to reveal changes in students' levels of knowledge and understanding of awareness regarding digitalization-based design trends.

As a result of this study, we aimed to present a framework for systematically addressing digitalization-based contemporary trends in furniture design education. It is intended that students comprehend contemporary design approaches and apply them in their future practices. Furthermore, the findings are expected to contribute to the development of relevant educational content and the restructuring of design pedagogy in line with current technologies.

Keywords

Digitalization; Furniture Design; Education; Contemporary Furniture Trends

Proceedings of the International Convention of
Society of Wood Science and Technology

Natural Durability of Softwood Species against Wood Decay Fungi

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Abstract

Wood is sustainable material naturally produced through photosynthesis and widely utilized across various sectors due to its mechanical properties, carbon sequestration capacity, and environmental advantages. However, wood is susceptible to degradation caused by both biotic and abiotic factors. In particular, wood-decaying fungi significantly reduce the service life of wooden structures and cellulose-based materials, resulting in considerable economic losses. Moreover, natural durability varies among species, and even within the same species, it may differ depending on growth region and environmental conditions. In particular, precise understanding of the species-specific durability is essential for the efficient utilization of wood materials. Therefore, this study aimed to evaluate the natural durability of Korean softwood species. Here, eight Korean major domestic softwood— Abies holophylla, Chamaecyparis obtusa, Cryptomeria japonica, Larix kaempferi, Pinus densiflora, P. koraiensis, P. rigida, and P. thunbergii—were examined for their natural durability against wood-decaying fungi (Fomitopsis palustris). The natural durability was evaluated in accordance with KS F 2213. Detailed experimental procedures followed the Evaluation Manual of Domestic Wood Properties (NIFoS, 2024). The results revealed clear interspecific differences in natural durability. C. obtusa exhibited weight loss (WL) of 2.1% and was rated as 'highly resistant'. L. kaempferi and P. thunbergii were rated as "resistant", while P. koraiensis, C. japonica, and A. holophylla exhibited "moderate resistance." In contrast, P. rigida showed the lowest decay resistance and was classified as "slightly or nonresistant". A comparison of P. densiflora specimens origination from two different regions, Pyeongchang and Yeongyang, revealed substantial regional differences in natural durability. The specimen from Pyeongchang exhibited a WL of 57.7%, corresponding to the 'slightly or nonresistant', whereas the specimen from Yeongyang showed a WL of 21.6%, classified as 'resistant'. This contrast provides clear evidence that environmental and site-specific growth conditions influence natural durability, even within the same species. These findings demonstrate substantial variation in natural durability among major domestic softwood species and provide foundational data for the development of a national durability database to support optimized utilization strategies for Korean wood resources.

Key words

Korean domestic wood; Decay resistance; Brown-rot fungi; Coniferous wood

Modeling the Relationship Between the Natural Frequency and Elastic Modulus of Table Tennis Blade Based on Laser Resonance

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Abstract

This study systematically investigated the vibration characteristics of table tennis blades using non-destructive laser techniques (Laser Doppler Vibrometry and Interferometry) combined with finite element analysis (FEA). Natural frequencies, mode shapes, density, and elastic modulus were determined experimentally. The first-mode exhibited out-of-plane bending, and the second-mode torsional vibration, with high consistency between both measurement techniques. For PC and YJ series blades, measured densities were 494.5 and 525.6 kg/m^3, and elastic moduli were 8968.9 and 9922.3 MPa, respectively. Characteristic constants (k) were derived using Kirchhoff-Love and Reisner-Mindlin plate theories. Results showed closer agreement between calculated and theoretical values for k_1 than for k_2, validating the analytical approach. FEA simulations yielded first-order natural frequencies of 105.68 Hz (PC) and 119.93 Hz (YJ). Although frequency deviations from experiments were observed, simulated mode shapes closely matched experimental measurements, confirming model reliability. The integrated methodology of laser-based measurement and FEA provides a robust, non-destructive framework for analyzing blade dynamics, offering reliable data to inform and optimize blade design.

Keywords

Modal Analysis; Table Tennis Blade; Finite Element Method (FEM); Laser Doppler Vibrometry; Laser Interferometry

Proceedings of the International Convention of
Society of Wood Science and Technology

Improving the weather resistance of wood by impregnation with active aminated low molecular weight alkali lignin

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Abstract

Outdoor wood products are susceptible to UV-induced degradation. To address this, protective coatings that incorporate UV-absorbing and shielding agents are applied to resist degradation, thereby mitigating weathering-induced losses in color, quality, and mechanical properties of the wood. However, many protective agents are biologically toxic and exhibit limited stability, which makes it challenging to develop high-efficiency, durable UV absorbers from green renewable materials for wood weathering. Alkali lignin (AL), as a bio-based industrial byproduct, has certain potential in improving the photostability of wood in outdoor applications based on its UV absorption feature. The present study developed aminated low molecular weight depolymerized AL for wood impregnation, and evaluated the pre- and post-modification weathering resistance of the wood. The filling of aminated AL within the wood matrix was demonstrated using methods including scanning electron microscopy, Fourier-transform infrared spectroscopy and fluorescence microscopy. Compared with AL-treated wood, the weight gain rate of modified poplar and Chinese fir increased by 251.8% (from 3.03% to 10.66%) and 320.9% (from 6.07% to 25.55%), respectively, after impregnation in a 2.5 wt% amino-functionalized low-molecular-weight AL solution. And the loss resistance rate decreased by 39.9 and 32.5%, respectively. Free radicals exhibited a reduced generation during in situ irradiation. Changes in composition over the same period of weathering treatment were minimized, thereby delaying the structural and morphological alterations induced by weathering. Macroscopic photodegradation and morphological damage observed in the modified wood were substantially mitigated, with the integrity of the anatomical structure preserved, that the cell wall disruption time is improved for 24 h to above 168 h. These findings substantiate the protective effect of aminated AL treatment on wood weathering behavior, which is beneficial for enhancing the stability of wood in outdoor applications.

Key words

fast-growing plantation wood; alkali lignin; amination modification; weathering resistance

Design of wooden multistable metamaterials based on fractal theory and their functionalization

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Abstract

Based on the multiscale hierarchical, porous, and anisotropic structural characteristics of natural wood, this study focuses on the design and functionalization of wooden multistable metamaterials guided by fractal theory. By introducing controllable cellular configurations, including hexagonal, square, triangular, Kagome, diamond, and Voronoi honeycombs, and combining wood cell-wall deconstruction, nanostructural reorganization, and multiscale modeling, a new class of wood-based metamaterials with multistable responses, lightweight high strength, and thermomechanical tunability is proposed. The results indicate that the coupling of fractal geometry and hierarchical architecture can effectively regulate deformation modes, buckling behavior, and energy dissipation characteristics, while achieving outstanding specific strength, thermal insulation performance, and pronounced anisotropy under ultrahigh porosity. Furthermore, finite element analysis combined with deep learning provides theoretical support for the inverse design, structural optimization, and functional regulation of wood-derived metamaterials. This work not only expands the pathway for the high-value utilization of wood resources, but also lays a foundation for their applications in building insulation, flexible devices, intelligent responsive structures, and multifunctional mechanical, thermal, and acoustic metamaterials.

Keywords

wooden metamaterials; fractal theory; multistable structures; multiscale design; functionalization

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Society of Wood Science and Technology

Integrated co-production biorefinery of *Phyllostachys pubescens* via NaOH-HPAC pretreatment for biofuels, platform chemicals, and value-added products

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Abstract

The expansion of bamboo habitats driven by global warming has increased biomass residues from bamboo management, necessitating sustainable valorization strategies. *Phyllostachys pubescens* is an attractive biorefinery feedstock due to its rapid growth, high CO_2 sequestration capacity, and abundant structural carbohydrates. However, commercialization of lignocellulosic biorefineries remains constrained by high process intensity, energy demand, and enzyme costs. Here, we propose an integrated co-production biorefinery strategy that enhances process economics by simultaneously generating high-value coproducts alongside biofuels and platform chemicals. A sequential NaOH-HPAC pretreatment enabled effective biomass fractionation and selective xylan utilization, achieving an xylooligosaccharide (XOS, DP2-DP6) yield of 83.9%. The pretreated solids were enzymatically hydrolyzed to produce glucose-rich hydrolysates, which were further converted into rare sugars and fermentation products. Specifically, glucose was transformed into psicose (40.1%), bioethanol (83%), succinic acid (63.2%), and lactic acid (91.3%).

These results demonstrate the feasibility of an integrated valorization platform for bamboo, coupling prebiotic XOS production with fuels and organic acids to improve economic viability and sustainability. This approach provides a practical pathway for converting bamboo management residues into diversified, value-added bioproducts, contributing to carbon mitigation and reducing reliance on petroleum-derived chemicals.

Key words

Bamboo; Biorefinery; bio-fuel; platform chemical; value-added products

Decay resistance of mycelium-bound biocomposites for exterior uses

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Abstract

Applied mycology is increasingly focusing on transforming side streams from the forest and agroforest industry into value-added materials through solid-state fermentation. Fungal mycelium growing around and within wood fibers acts as a bio-adhesive forming composite materials. In Finland, several lignocellulosic side-streams from mechanical wood processing have been tested to produce biocomposite materials with mycelium-based binders. Such biocomposites are generally lightweight and present competitive mechanical and thermal properties. However, their decay resistance has received much less attention, hindering their potential applications in decay-prone environments.

The present study investigated for the first time the decay resistance of biocomposites of Inonotus obliquus mycelium and wood material. Sawdust side-streams of Populus tremula were collected from a mechanical wood processing industry in North Karelia, Finland. The sawdust was sterilized at 121 ˚C for 1.5 hours. An I. obliquus strain originating from Finnish Lapland was used for the solid-state fermentation of P. tremula sawdust following its inoculation in sterilized barley and incubation at room conditions. After full colonization, the colonized barley was mixed with the P. tremula sawdust. The substrate mixture was distributed in silicon molds and incubated for 14 weeks in a condition chamber at 80% RH and 24 ˚C. After demolding, the biocomposites were compressed using a manual heat-press equipment and kept at 40 ˚C for 48 hours to stabilize. The wood decay test was performed by following the European standard EN 113 with some modifications. The biocomposites were tested against Trametes versicolor, maintaining them on a mesh above the fungal culture for 12 weeks and recording the mass loss to determine the decay resistance. P. tremula wood specimens (5 x 40 x 10 mm3) were used as reference.

The production of the mycelium-bound biocomposites by heat compression allowed the production of homogeneous samples. However, the biocomposite presented lower density than the reference specimens. The preliminary results on the wood decay test suggest that the biocomposite presents a low decay resistance to T. versicolor. Further tests applying coating treatments, fiber modification or use of chemical preservatives are suggested to enhance the decay resistance of the mycelium-bound biocomposites.

Key words

Wood decay; biocomposite; Inonotus obliquus, Populus tremula, valorisation

Proceedings of the International Convention of
Society of Wood Science and Technology

Mechanical performance of mycelium-based composites for insulation panel products

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Abstract

Lignocellulosic side streams represent a valuable and sustainable resource to produce bio-based materials, particularly in the development of mycelium-based composites. Mycelium-based composites have potential applications across various sectors, particularly in construction materials and mycelium foams. The present study investigated the compression resistance of mycelium-based composites made from Inonotus obliquus mycelium and wood side-streams for their application as insulation panel products.

Sawdust and plywood side-streams of Populus tremula were collected from a mechanical wood processing industry in Finland and from a plywood manufacturer in Spain, respectively. The plywood side streams were crushed using a Weima WL2 laboratory grinder (crushed plywood), followed by a hydrothermal treatment using VTT's Fiberline pulping pilot to partially remove the urea-formaldehyde resin present in the crushed plywood (resin-lean plywood). The crushed and resin-lean plywood chips were mixed with the P. tremula sawdust at different ratios (5, 10 and 20% dry weight). The wood side-stream mixtures were sterilized at 121 ˚C for 1.5 hours. An I. obliquus strain from Luke's fungal collection was inoculated onto sterilized barley and incubated at room temperature. The colonized barley was used for the solid-state fermentation of the wood side-stream mixtures. The substrate mixture was distributed in plastic molds and incubated in a conditioning chamber at 80% RH and 24 ˚C. After full colonization, the biocomposites were dried at 40 ˚C for 48 hours. The compression strength of the mycelium-based composites was tested using a Zwick Z050 material testing machine.

The plywood and sawdust side-streams were successfully fermented and transformed into a lightweight mycelium-based material. The presence of resin in the plywood side-streams did not inhibit the growth of I. obliquus mycelia. The addition of both crushed and resin-lean plywood to the P. tremula sawdust had a positive effect on the compression resistance of the mycelium-based composites. The highest modulus of elasticity (707 ± 8 kPa) was observed in the composites consisting of a mixture of P. populus sawdust and crushed plywood (80 and 20 % dry weight respectively). Further tests investigating the thermal insulation properties are recommended to evaluate their suitability for use as insulation panels.

Keywords

Side-streams; Lignocellulose; Circular economy, Populus tremula, Compression resistance

Enhancing Material Flow Analysis of Wood Resources in Korea through Improvements in Wood Utilization Statistics

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Abstract

Material Flow Analysis (MFA) is a quantitative approach used to examine the inputs and outputs of materials across defined system boundaries, typically encompassing the stages of resource extraction, raw material processing, production, industry, and end-of-life management. By verifying material balances, MFA provides an essential evidence base for resource management and circular economy policies. This study aims to enhance the MFA framework for domestic wood resources in Korea by analyzing international statistical practices and proposing improvements to the Wood Utilization Survey, which serves as the primary statistical basis for national wood flow analysis. Particular attention was given to internationally harmonized questionnaire systems and their statistical structures. The analysis of international cases revealed that countries with well-established statistical infrastructures integrate data from multiple institutions and apply supplementary surveys to refine estimates. In contrast, countries with limited statistical systems rely on international databases and scenario-based assumptions. Notably, the Joint Forest Sector Questionnaire (JFSQ), jointly administered by FAO, UNECE, Eurostat, and ITTO, standardizes terminology, classifications, and units for forest product statistics, thereby ensuring international comparability. A comparison between the JFSQ and Korea's Wood Utilization Survey identified gaps in data collection, particularly regarding post-consumer recovered wood, recycled paper, cross-laminated timber (CLT), and other recycled or construction-related products. In addition, the need to expand the conventional four-stage MFA framework (resource-production-industry-disposal) to explicitly incorporate a recycling stage was highlighted. Based on these findings, this study proposes several improvements to the Wood Utilization Survey, including expanding coverage to paper products, separating structural particle board and CLT into distinct categories, and refining the classification of raw materials used in particle board production. Furthermore, it suggests extending the classification of softwood and hardwood species to the industrial stage and incorporating end-use data for sawmill by-products to enhance the resolution of the material flow model. Future research will conduct a pilot survey reflecting these proposed revisions to evaluate their feasibility and effectiveness, thereby contributing to improved resource management policies and more robust greenhouse gas accounting.

Key words

Wood decay; biocomposite; Inonotus obliquus, Populus tremula, valorisation

Proceedings of the International Convention of
Society of Wood Science and Technology

A Data Driven Framework for Environmental Sustainability in the Conservation and Rejuvenation of the River Ganga in the Indian Himalaya

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Abstract

Ecosystem services provisioning, regulating, cultural, and supporting are essential for sustaining life, economies, and policy frameworks. The Payment for Ecosystem Services (PES) incentivizes environmental conservation by rewarding sustainable practices. This study utilizes data analytics to assess the impact, efficiency, and sustainability of the Ganga's PES initiative in the National Mission of Clean Ganga in the National River Ganga, India. The analysis examined a diverse dataset covering both environmental and socioeconomic factors including water quality indices, carbon emissions, and biodiversity statistics, while socioeconomic data encompassed population density, agricultural usage, and the economic benefits of ecosystem services. Several pre-processing steps were undertaken to ensure data accuracy and reliability. Data cleaning involved removing null values, duplicates, and inconsistencies, as well as standardizing data. Outlier detection and treatment were conducted using quartile-based analysis. Advanced data visualization tools were employed to create interactive dashboards and comprehensive reports, simplifying complex data for stakeholders and enhancing decision making processes. A range of analytical methods was applied to derive meaningful insights. Comparative analysis identified trends and discrepancies, such as pollution hotspots through regional water quality assessments. Hypothesis testing validated assumptions regarding the relationship between industrial activities and water contamination, using statistical tests like t-tests and ANOVA to evaluate the effectiveness of various PES supported conservation practices. Data driven strategies highlighted critical pollution hotspots and established significant correlations between industrial discharge and water quality degradation. These insights help to form a policy framework for regulating the targeted conservation efforts. This study confirms that PES can be a powerful mechanism for balancing ecological sustainability with economic development. However, its long term success depends on data driven policy refinements, stricter industrial regulations, and sustained investment in monitoring.

Keywords

Payment for Ecosystem Services (PES); National Mission; Environmental Sustainability; Conservation; Rejuvenation

Advancing Sustainability and Innovation in the Built Environment Through Wood and Bio-based Materials: Degree Programmes at the University of Primorska

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Abstract

The study programmes Wood Innovation for Sustainability (undergraduate), Sustainable Built Environments (Master's), and Renewable Materials for Healthy Built Environments (Doctorate) at the University of Primorska in Koper, Slovenia, form a vertically integrated, educational pathway focused on wood innovation, sustainability, and healthy built environments. These programmes connect foundational knowledge, advanced applications, and research, while providing opportunities to work with international experts in innovation, sustainability, and built environments.

The undergraduate programme Wood Innovation for Sustainability introduces wood as a key renewable resource within the circular bioeconomy. It combines engineering basics, material science, digital tools, and sustainability-oriented thinking. Emphasis is placed on practical skills, collaboration with industry, and the development of innovative wood-based solutions, preparing graduates to contribute to a sustainable transformation in the wood sector.

The master's programme Sustainable Built Environments advances interdisciplinary knowledge in the design, construction, and management of sustainable buildings. It focuses on the use of wood and other bio-based materials, integrating environmental performance, human well-being, and technological innovation. Students develop the ability to address complex challenges in the built environment through applied research and collaboration with international professionals.

The PhD programme Renewable Materials for Healthy Built Environments provides advanced research training in wood-based and renewable materials, with a focus on their role in sustainable and healthy living environments. It supports independent scientific work, innovation, and collaboration within global research networks, enabling doctoral candidates to contribute to cutting-edge developments in sustainable materials and construction.

Together, these programmes position wood innovation for sustainability at the core of education and research, linking academic excellence with real-world impact. We welcome you to come study at the University of Primorska!

Key words

Education; Sustainability; Built Environment; Renewable Materials; Circular Bioeconomy

2026 SWST
International Convention

Innovating with Wood:
Science and Materials for a Sustainable Future

June 9 (Tue) 08:30~10:00

Poster Student Competition

Computational Modeling for Predicting Moisture Content Change of Wood During Air Drying

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Abstract

Air drying is a fundamental, energy-efficient process in the wood industry. However, a major limitation of this method is its reliance on qualitative and empirical approaches. Non-uniform moisture content distribution of the wood induces internal stresses, causing mechanical defects such as checking, warping, and splitting. Due to the technical difficulty of real-time monitoring of internal moisture gradients, drying schedules have largely depended on trial-and-error. Therefore, reliable predictive models are necessary to optimize the drying process and minimize material loss.

This study presents a computational simulation to quantitatively predict the spatial and temporal evolution of the moisture content of wood during air drying. The numerical model is based on mass transfer in porous media, governed primarily by Fick's second law. To simulate actual air-drying conditions and anisotropic properties, the model incorporates dynamic boundary conditions driven by external temperature and relative humidity variations.

Current research focuses on algorithm implementation. A three-dimensional Finite Difference Method (3D FDM) is employed to solve the governing partial differential equations. The computational framework—including the solver, data preprocessing, and visualization—is developed in Python. This utilizes Python's scientific libraries to manage the complex boundary conditions and large multi-dimensional arrays required for high-resolution simulations.

The simulation framework is applied to domestic logs and lumber, encompassing major species such as Pinus densiflora and Quercus spp. In contrast to conventional models restricted to kiln drying, this approach integrates regional and seasonal meteorological data to simulate moisture dynamics characteristic of natural environments. Consequently, the study derives drying durations and methodologies optimized for specific local climates.

The developed tool provides a quantitative framework for predicting moisture dynamics under fluctuating natural environments. By replacing empirical practices with computational quantification, this study proposes a method for estimating climate-specific air-drying times and assessing defect risks. This contributes to the optimization of air-drying schedules and supports efficient, sustainable wood processing strategies.

Key words

Wood Drying; Air Drying; Drying Simulation; Computational Simulation; FDM;

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Engineering Characteristics of Structural Lumber from Small-Diameter Logs: Small Clear Specimens

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Abstract

Restorative forest thinning is an effective procedure for mitigating risk of outbreaks of diseases, insects and catastrophic wildfires. These procedures generate substantial volumes of small-diameter logs considered low value because of higher processing costs, lower yields and lumber of lower quality than lumber from commercial harvests. Utilization of this material in structural applications is expected to add market value. However, there is limited evidence that lumber from small logs does not meet benchmark modulus values for its visual grade published in National Design Specification (NDS), presumably due to high content of juvenile wood, casting doubts on its suitability for construction and applicability of current grading procedures for that material.

This study is a part of a larger project whose goal is to verify that earlier findings on material better representing the growing region and on broader set of engineering characteristics. If confirmed, the second goal is to revise assumptions and correlations between visual grade markers and strength when applied to lumber from small logs. Like earlier studies, instead of targeting all species removed in forest restoration thinnings in Western forests, this project is focused on Ponderosa pine considered the weakest of Western Wood species.

The specific objective of this study is to compare mechanical characteristics determined on small clear specimens (SCS) of ponderosa pine from small logs with engineering characteristics measured earlier on dimension lumber from the same material, and with published data of characteristics established for commercial harvests. Design values derived from ponderosa SCS are compared to those currently published in the NDS for Western Woods.

Standard methods for determination of strength and elastic modulus in compression parallel and perpendicular to grain and shear parallel to grain on SCS are followed. Design values are derived following ASTM D2555 and D245 standard.

The outcome of this study will be used to verify correlations between properties determined for structural-size lumber and small clear specimens of the same material in comparison with lumber from commercial harvests.

Key words

Restorative forest thinning; Small-diameter logs; Juvenile wood; Design values; mechanical characteristics

Restorative forest thinning; Small-diameter logs; Juvenile wood; Design values; mechanical characteristics

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Abstract

This study presents a comprehensive review of the relationship between wood shrinkage behavior and anatomical characteristics based on previous literature. Microfibril angle (MFA), density, growth ring structure, and ray tissues are identified as key factors governing shrinkage behavior. MFA typically ranges from 5° to 45°, and an increase in MFA leads to a rise in longitudinal shrinkage from approximately 0-0.3% to over 1-2%, while tangential shrinkage tends to decrease. A nonlinear increase in longitudinal shrinkage is commonly observed around 25-30°, indicating that MFA serves as a critical threshold parameter. However, even under similar MFA conditions, compression wood, juvenile wood, and mature wood exhibit different shrinkage behaviors due to variations in cell wall structure. Compression wood, in particular, shows significantly higher longitudinal shrinkage (over 1-2%) and relatively lower tangential shrinkage. In contrast, density and cell wall fraction primarily influence transverse shrinkage. As density increases, both tangential and radial shrinkage tend to increase. Typical ranges are 6-12% for tangential and 3-6% for radial shrinkage, resulting in a tangential-to-radial (T/R) ratio of approximately 1.5-2.5. In hardwoods, ray tissues play an important role in restricting radial shrinkage, thereby increasing anisotropy. Overall, wood shrinkage is a multi-scale phenomenon governed by the interaction of factors at the cell wall, tissue, and macroscopic levels. However, previous studies often focused on limited species or did not measure shrinkage and anatomical characteristics from the same specimens, limiting direct comparison. Future research should integrate these variables and quantitatively evaluate their interactions through precise measurements on the same specimens, which is expected to enable the development of more accurate models for predicting shrinkage behavior.

Key words

Wood Shrinkage; Microfibril angle; Density; Wood ray

Proceedings of the International Convention of
Society of Wood Science and Technology

Multiscale Structural Evolution of Lignin under Long-Term UV Exposure: Mechanism and Stabilization Strategies

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Abstract

Lignin is a key structural component in lignocellulosic materials and is known for its intrinsic ultraviolet (UV) absorption capability. However, prolonged UV exposure induces photochemical degradation, leading to discoloration and structural transformation that compromise the durability of wood-based and natural fiber materials. A mechanistic understanding of lignin's long-term behavior under continuous irradiation is therefore essential for improving photostability in light-exposed applications.

In this study, the long-term photochemical evolution of lignin was systematically investigated under continuous UV irradiation for up to 90 days. Comprehensive molecular and surface analyses revealed a dual-phase degradation pathway characterized by initial depolymerization followed by oxidative re-condensation. Quantitative spectroscopic results confirmed substantial depletion of aliphatic and phenolic hydroxyl groups accompanied by progressive formation of carbonyl- and carboxyl-enriched structures. Surface-sensitive measurements further demonstrated oxygen enrichment, increased polarity, and enhanced hydrophilicity, indicating depth-dependent oxidation and significant interfacial modification. These findings collectively identify phenolic radical formation and subsequent oxidative propagation as dominant mechanisms governing long-term lignin photodegradation.

Based on these mechanistic insights, stabilization strategies targeting reactive phenolic sites were explored via benzoylation of kenaf fibers. Chemical modification effectively suppressed radical-mediated oxidation and reduced UV-induced discoloration, resulting in improved color stability and sustained structural integrity under prolonged irradiation.

This work elucidates the multiscale structural evolution of lignin under extended UV exposure and highlights mechanism-guided approaches to enhance photostability in lignocellulosic systems for durable wood-based and natural fiber applications.

Key words

Lignin photodegradation; UV irradiation; Radical-mediated oxidation; Benzoylation; Lignocellulosic materials

Analysis of anatomical discriminants of major commercial pinaceae species

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Abstract

This study investigated the anatomical characteristics of three major Pinaceae species—Pinus densiflora, Pinus sylvestris, and Pinus radiata—to identify key discriminants and verify the consistency between commercial names and actual wood species distributed in South Korea. For the analysis, seven specimens of P. densiflora were harvested from the campus forest of Kangwon National University. Regarding the imported species, P. sylvestris and P. radiata, five commercial items each (including lumber and engineered wood) were purchased from domestic markets as sample materials.

Comparative anatomical analysis revealed distinct qualitative and quantitative traits. Qualitatively, cross-field pitting in P. densiflora specimens consistently exhibited a window-like pattern. In contrast, P. sylvestris primarily showed taxodioid pitting with occasional pinoid patterns, while P. radiata mostly displayed pinoid pitting with minor variations. Notably, ray tracheids were clearly observed in P. densiflora, whereas they were absent in the sampled specimens of P. sylvestris and P. radiata. Quantitatively, the mean ray height was highest in P. sylvestris, followed by P. densiflora and P. radiata, showing significant interspecific variation. The diameter of axial intercellular canals was largest in P. densiflora, showing a statistically significant difference from the other two species.

To verify the accuracy of commercial names in the domestic market, the identified anatomical features were converted into IAWA codes and cross-referenced using the InsideWood database. The results revealed several instances where the commercial names of P. sylvestris and P. radiata did not align with their actual anatomical characteristics. These findings suggest the misuse of inaccurate species names during importation and distribution in the domestic market. While these species are traditionally difficult to distinguish based solely on qualitative traits, this study demonstrates that a multi-faceted analysis of both qualitative and quantitative anatomical features can significantly enhance identification accuracy. Consequently, this investigation highlights the necessity for more rigorous and systematic verification procedures in timber customs and distribution to ensure transparent market management.

In future research, more diverse and precise analysis techniques will be introduced to strengthen the accuracy of species identification and contribute to transparent wood distribution management.

Key words

Pinaceae, wood anatomy, wood identification, commercial species, softwood

Proceedings of the International Convention of
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EVALUATING THE NATURAL DURABILITY PROPERTIES OF Albizia Ferruginea, (Guill. & Perr.) Benth; A LESSER-USED TIMBER SPECIES FROM THE EASTERN PART OF GHANA

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Abstract

The durability of wood in ground contact is influenced by both its intrinsic material resistance and the environmental conditions it is exposed to in the soil. Ground contact presents one of the most severe exposure scenarios due to constant moisture and direct contact with a well-colonized microbial community. Besides physical, chemical, biological, and ecological soil parameters, the design and size of wooden structures in ground contact can significantly impact their durability. In this study, weight loss due to decay was used as an indicator of wood durability, based on the assumption that weight loss is directly correlated with natural durability. The objective of this study was to compare the durability of Albizia ferruginea wood sourced from different sections of the stem. Specimens of varying sizes - standard EN 252, smaller mini-stakes, and larger double-size stakes - were prepared from the bottom, middle, and top portions of the Albizia ferruginea stem. These were subjected to in-ground testing at the AAMUSTED field site in Ghana, while standard-sized specimens were also subjected to on-ground tests. Decay rates and corresponding durability classifications were determined following European standards. The results indicated that smaller specimen sizes generally decayed faster, although the effect was not statistically significant for most materials. However, for Albizia ferruginea, specimen size had a clear impact on durability. The wood was classified as durable (Durability Class 2) using double-sized stakes, moderately durable (DC 3) using standard specimens, and less durable (DC 4) with mini-stakes. Additionally, specimens exposed on-ground decayed significantly more slowly than those partially buried in the ground. Based on these findings, it is recommended to use larger test specimens, closer in dimension to real-size wood products, to avoid underestimating the durability of certain wood-based materials.

Key words

Albizia ferruginea; durability; in-ground testing; on-ground testing, Macrotermes termites

Early Decay Detection in Mass Timber Using Resistance Drilling: Correlation with Mass Loss and Density Changes in CLT and MPP

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Abstract

Early detection of decay in mass timber structures is essential for preventing structural failures and extending service life, yet many current inspection methods fail to identify deterioration until advanced stages. Resistance drilling has shown promise as a minimally invasive technique for detecting internal decay, but its effectiveness at identifying incipient degradation, particularly before 5% mass loss, remains underexplored in engineered mass timber products. This research investigates the capability of resistance drilling to detect early-stage fungal decay in Cross-Laminated Timber (CLT) and Mass Plywood Panel (MPP) by establishing correlations with mass loss and density changes. A study is being conducted using a total of 288 specimens (144 CLT and 144 MPP blocks) with some exposed to two brown rot fungi and one white rot fungus over an 8-month period. Mass loss and density measurements serve as reference indicators of decay progression, with data collected at 2, 4, 6, and 8-month intervals. Mass loss is determined on an oven-dry basis, while density changes are calculated relative to sound control samples. At each timepoint, resistance drilling profiles are captured and analyzed to identify whether measurable changes in drilling resistance correspond with physical deterioration, particularly at mass loss levels below 5% where decay is typically undetectable through visual inspection. The study seeks to establish whether resistance drilling profiles can reliably indicate early decay, determine the sensitivity thresholds for detecting incipient degradation, and develop regression models correlating drilling metrics with mass loss and density changes. Additionally, comparative analysis between CLT and MPP will assess whether product type or species composition affects detection sensitivity, providing insights into material-specific calibration requirements for field applications. Preliminary data will be presented, demonstrating the potential of resistance drilling as an early warning system for decay in mass timber buildings.

Key words

Mass timber; Resistance drilling; Mass loss; Density loss

Proceedings of the International Convention of
Society of Wood Science and Technology

Termite Prevention and Monitoring for the Care and Maintenance of a Traditional Wooden Architecture: The Daeungjeon Hall of Ssanggyesa Temple, Nonsan (National Heritage)

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Abstract

The Daeungjeon Hall of Ssanggyesa Temple, located in Nonsan, is a historic wooden Buddhist architecture designated as a Treasure in 1964. Traces of pest damage, including termite activity, were identified on multiple structural wooden members. This research aimed to establish a preventive termite treatment and monitoring strategy for the long-term maintenance of traditional wooden architecture. Preventive treatment and colony elimination systems were applied to the Daeungjeon Hall, followed by periodic monitoring to evaluate their effectiveness.

Preventive treatments, including surface cleaning, insecticide application, and soil treatment, were conducted in accordance with national conservation guidelines to reduce the risk of termite infestation. A termite monitoring and baiting system was installed at regular intervals around the building perimeter. The system was periodically evaluated to determine the need for colony elimination. When necessary, bait cartridges containing termiticides were selectively applied to induce colony elimination.

Over four monitoring cycles, no active termite colonies were detected, although minor feeding traces and physical changes in bait materials were observed. This appears to be due to other pests and moisture influx. These results indicate that the combined application of preventive treatment and monitoring systems can effectively suppress termite activity and contribute to the sustainable care and maintenance of wooden architecture. This study highlights the importance of continuous monitoring and adaptive pest management strategies for the conservation of historic wooden architecture.

Key words

traditional wood maintenance; wood preservation; pest management; termite control; preventive conservation

Effect of Surface Roughness on Moisture Uptake in Coated Exterior Wood Cladding: An X-ray Computed Tomography (CT) Study

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Abstract

Exterior wood cladding is a traditional, widely used façade material on low- to medium-rise buildings globally and is now gaining increased interest in high-rise construction. An ongoing problem with exterior timber cladding is wood's moisture uptake, which increases the risk of appearance deterioration and biological degradation. The mechanisms for moisture uptake through coatings are not fully understood, and methodologies for non-destructive studies at high structural resolution are rarely established. This study introduces X-ray CT-scanning as a non-destructive technique to investigate the effect of surface roughness on moisture penetration through the coating layer of wooden cladding. CT can visualise and quantify three-dimensional moisture distribution in the timber, enabling a highly detailed assessment that conventional methods cannot capture.

Samples (20×20×20 cm) were taken from large-scale wood-cladding elements originally bandsawn to a fine surface cleaned of loose fibres, or a rough surface where no loose fibres were removed. The bandsawn surfaces were coated with an exterior coating (one layer Reafen topcoat, Becker Acroma, Sweden). The specimens were conditioned at 20 C and 65% relative humidity (RH) until equilibrium. All other surfaces were then sealed to prevent moisture uptake.

The samples were CT scanned (Zeiss Metrotom 1500, Oberkochen, Germany) before and after the coated surfaces were submerged in water for 24 hours. This procedure enabled visualisation and quantification of internal moisture distribution before and after water exposure.

Differences in moisture penetration behaviour between fine and rough surfaces were observed in both wet and dry states. CT imaging reveals variations in moisture accumulation zones and potential preferential pathways associated with surface topography and coating continuity. Ongoing quantitative analysis aims to correlate roughness parameters with moisture-distribution characteristics from CT data.

The results demonstrate the potential of X-ray CT as a powerful non-destructive tool for evaluating coating performance and moisture ingress in wood-based products such as exterior cladding. This approach provides a more comprehensive understanding of the effects of surface conditions on durability and service performance.

Key words

coating, non-destructive testing, permeability, timber

Proceedings of the International Convention of
Society of Wood Science and Technology

Wooden Dowel vs. Epoxy Resin: Comparative Study on Timber Heritage Surface Repair Techniques

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Abstract

This study investigates the applicability of the Dutchman repair method, which employs wooden dowels instead of epoxy resin bonding, for morphologically restoring surface damage in traditional timber cultural heritage structures. Such damage typically arises from prolonged environmental exposure, biological and physical deterioration, and mechanical stress, while conventional epoxy methods suffer from material incompatibility, aesthetic degradation, reduced long-term durability, irreversibility, and challenges during disassembly or re-restoration. The proposed Dutchman approach inserts matching timber filler secured by wooden dowels, promoting integral behavior with the original wood to minimize deformation from temperature and humidity fluctuations and enhance overall stability.

Tensile tests demonstrated that wooden dowel joints provide comparable short-term strength to epoxy bonding, with the restored areas exhibiting unified mechanical performance alongside the parent timber rather than functioning as separate reinforcements. For long-term viability, the use of identical materials ensures superior visual and mechanical compatibility, limits synthetic material exposure on heritage surfaces, and supports reversibility. Ultimately, this wooden dowel-based Dutchman technique emerges as a practical, material-compatible alternative to epoxy resin, offering foundational data to guide its implementation in cultural heritage conservation practices.

Key words

Timber heritage restoration; Wooden dowel; Dutchman repair; Epoxy resin; Restoring Appearance

Structural Behaviour of Screw-Laminated Truss Members Assembled from Short-Length Reclaimed Timber

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Abstract

The use of reclaimed timber in residential, commercial, and some structural applications is increasing globally, as evidenced by market data and sustainability-driven building practices. The structural reuse of reclaimed timber, however, is frequently constrained by the short variable lengths of available wood material. This study investigated the development of a truss system based on screw-laminated truss members assembled from short-length reclaimed timber with minimal material processing. In this study, the term truss members refers to the chord and web members of the truss. The objective was to create load-bearing truss members by layering reclaimed lamellae of different lengths and fastening them exclusively with screws, thereby forming composite truss members suitable for truss applications. The research examined the mechanical behaviour of layered assemblies constructed from reclaimed timber only, as well as hybrid configurations combining reclaimed and lamellae from virgin (non-reclaimed) timber. Particular attention was given to mixed grading strategies and stiffness compatibility between lamellae of different grades. The influence of lamella length, the spatial distribution of end joints within the layered matrix, and the repetition frequency of segment overlaps were systematically investigated.

An experimental investigation was conducted to evaluate global stiffness, load-bearing capacity, slip behaviour, and failure modes under bending and axial loading conditions. The study also analysed how the positioning of lamella terminations within different layers affects stress redistribution and structural continuity. Additionally, the effects of screw spacing and screw density on composite action efficiency and overall stability of the screw-laminated truss members were assessed.

Comparative testing between fully reclaimed and hybrid reclaimed-new configurations enables evaluation of failure redistribution mechanisms and structural robustness. The results demonstrate how short-length reclaimed timber can be transformed into mechanically efficient truss members and to identify performance thresholds related to connection stiffness and layer arrangement. The findings contribute to the understanding of composite action in screw-laminated reclaimed timber systems and provide design-oriented insights for the development of engineered truss structures based on layered short-length elements.

Key words

Engineered Wood Products; Built-Up Structural Elements; Composite Action; Hybrid Timber Systems; Connection Stiffness; Failure Modes

Proceedings of the International Convention of
Society of Wood Science and Technology

Cyclic Performance of a Full-Scale T-Shaped Glued-in Rod Moment Connection

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Abstract

Moment-resisting connections are a key component for improving the lateral performance and architectural flexibility of timber structures. Glued-in rod (GIR) systems have been widely studied due to their high stiffness and strength; however, the structural response of GIR moment connections at full scale under cyclic loading still requires further validation for practical design and application. This study presents an experimental investigation on a full-scale GIR moment connection, focusing on its overall rotational behavior under repeated loading. The experimental specimen consisted of a beam-steel-column moment-resisting connection assembled using glued-in rods.

Full-scale cyclic tests were conducted twice using a displacement-controlled loading protocol determined with reference to KBC 2016 (Korean Building Code). The test program aimed to observe the moment-rotation response and to examine whether the initial rotational stiffness estimated from component-level characteristics can reasonably represent the response of the assembled connection.

To support this discussion, the rotational stiffness of the beam-steel joint and the column-steel joint were separately evaluated as 47,650 kN·m/rad and 18,195 kN·m/rad, respectively. Based on these component stiffness values, the initial rotational stiffness of the moment connection was analytically estimated as 29,884 kN·m/rad. From the cyclic tests, the average initial rotational stiffness of the full-scale connection was measured as 33,008 kN·m/rad, which was higher than the analytical estimate. The maximum moment level observed in the tests was approximately 327 kN·m.

Overall, the full-scale test results provide basic evidence regarding the cyclic response and stiffness characteristics of the proposed GIR moment connection. The comparison between analytical estimation and experimental measurements suggests that a component-based stiffness approach may be useful for approximating the initial rotational stiffness of the connection, although further verification is needed considering variability in fabrication, material properties, and load history. The findings can be used to support ongoing discussions on performance evaluation and stiffness estimation methods for full-scale timber moment connections using GIR systems.

Key words

Moment connection; Timber engineering; Beam-column connection; Glued-in rod; Timber frame

Failure Mode Analysis of Pre-Cambered Glulam Beams Under Dead-Load-Compensating Curvature

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Abstract

Pre-cambering is a notable technique in structural timber design to overcome material's weakness (relatively low modulus), maintaining the intended geometry and serviceability of floor and roof systems. When applied to glued laminated timber beams, however, the introduction of curvature inherently induces stresses perpendicular to the grain direction. It is a concern of particular significance given that timber's strength perpendicular-to-grain is substantially lower than parallel-to-grain strength, typically by a factor of ten or more. Although curved beam theory is well documented in research and design standards, the practical significance of perpendicular-to-grain stress under specific curvatures has not been directly addressed. This uncertainty has led many structural designers to approach pre-cambered glulam beams with unwarranted caution, and in some cases to forgo the technique.

This study investigates the governing failure mode of pre-cambered glulam beams whose curvature is sized to offset deflections due to dead loads alone. Representative dead load and beam spacing values are adopted for the analysis. Notably, varying these parameters proportionally does not influence the relation between bending stress and perpendicular-to-grain stress, as both increase as same rate; the adopted values therefore capture the essential mechanics without loss of generality. The pre-camber radius of curvature is derived from curvature formulae, and curved beam theory is applied to determine which failure mode governs the design.

Based on this analytical framework, the governing failure mode of pre-cambered glulam beams under dead-load-equivalent curvature is identified by comparing bending stress and perpendicular-to-grain stress against their respective design capacities. The study thereby provides a direct assessment of whether perpendicular-to-grain stress or bending stress controls the design in this context.

It is anticipated that these results will offer a rational, quantitative basis for resolving designer concerns regarding pre-cambered glulam beams. By directly addressing the question of whether dead-load-level pre-camber poses a meaningful perpendicular-to-grain stress risk, this study aims to support more confident and consistent application of pre-cambering as a standard detailing practice in glulam floor and roof beam design.

Key words

Glued laminated timber; Pre-camber; Curved beam; Perpendicular to grain stress

Proceedings of the International Convention of
Society of Wood Science and Technology

Anatomy Informed Intelligent 2D Mapping for Evaluating Localized Properties of Large Diameter Timber Members

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Abstract

In response to the global climate crisis and carbon neutrality, extending service life and ensuring structural safety of high-rise timber constructions and traditional wooden heritage are critical challenges. This study advances safety evaluation techniques for large-scale timber members by analyzing Korean red pine (Pinus densiflora) disks through an intelligent sectional reconstruction model that synchronizes density, localized compressive strength, and drill resistance with internal anatomical features. Our analysis revealed that while drill resistance aligns well with density, it shows a remarkably weak correlation with compressive strength, illustrating a distinct mechanical decoupling between these indicators. Notably, maximum strength occurred in normal wood regions characterized by stable annual rings rather than in high-density compression wood. This demonstrates that mechanical performance of wood is governed by anatomical features such as annual ring uniformity and juvenile wood distribution rather than bulk density alone. To overcome these diagnostic limitations, we developed an anatomy-informed intelligent reconstruction algorithm that integrates mathematical interpolation with high-resolution annual ring textures. The model utilizes visual intelligence preprocessing to identify anatomical boundaries and ensures property gradients strictly follow the actual anatomical flow of the wood. This approach allows for the successful restoration of spatial information lost during discrete sampling while precisely distinguishing between structurally sound regions and zones affected by anatomical and chemical factors, such as juvenile wood, lignin accumulation, and extractives. These findings provide scientific validation for correlating non-destructive drill resistance with actual mechanical performance and can be incorporated into advanced structural design such as identifying load concentration during buckling in hybrid columns. This intelligent mapping technology will serve as a key algorithm for establishing precision safety diagnostic systems and evaluating the structural reliability of both traditional and modern timber structures. Future research will focus on extending this 2D anatomy-informed framework into 3D volumetric reconstruction to predict the compressive strength of column members and construct advanced systems for the automated detection of structural defects. In particular, these achievements will serve as a core indicator to enhance accuracy of compressive strength prediction models by projecting anatomical context onto drill resistance data and resolving observed mechanical decoupling.

Key words

Anatomy-informed modeling; Drill resistance; Spatial property mapping; Non-destructive testing; Large-diameter timber;

Construction of Bio-Based Adsorbent Networks: Crosslinking Aminated Lignin with Dialdehyde Xylan for Efficient Pd Capture

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Abstract

Palladium (Pd) is a critical precious metal widely used in semiconductors, electronic components, and heterogeneous catalysis. The growing demand for Pd and the environmental risks associated with its discharge into wastewater highlight the need for sustainable recovery strategies. In this study, we developed an eco-friendly Pd(II) adsorbent based entirely on wood-derived biomass components, namely lignin and hemicellulose, to establish a green platform for high-value metal recovery. Lignin was chemically modified to introduce primary amine functionalities through reaction with 2-chloroethylamine hydrochloride, enhancing its affinity toward Pd(II) ions via coordination interactions. In parallel, xylan, a major hemicellulosic polysaccharide, was oxidized using sodium periodate to produce dialdehyde xylan (DAX). The aldehyde groups of DAX enabled covalent crosslinking with aminated lignin and cationic polyethyleneimine (PEI) through Schiff base formation, resulting in a hybrid polymeric network. This structure provides abundant amine binding sites while maintaining structural stability under acidic conditions.

The chemical structure and interfacial interactions of the synthesized adsorbent were characterized by FTIR and XPS analysis, confirming successful amination and aldehyde-mediated crosslinking. Zeta potential measurements revealed enhanced positive surface charge in acidic media, favoring electrostatic interaction with negatively charged Pd chloride complexes. The Pd adsorption performance was evaluated using ICP-AES, and preliminary results demonstrated efficient Pd(II) uptake under acidic conditions relevant to industrial wastewater. Importantly, the network design integrates renewable biomass components with a green crosslinking strategy, avoiding conventional formaldehyde-based systems and thereby improving environmental compatibility. The aldehyde-amine crosslinking mechanism provides structural integrity while preserving active binding sites for metal coordination.

This study demonstrates the feasibility of converting lignin-based biomass into a functional adsorbent for selective Pd recovery, offering a promising route toward sustainable resource recycling and circular utilization of precious metals.

Key words

Palladium recovery; Biomass-based adsorbent; Aminated lignin; Dialdehyde xylan

Proceedings of the International Convention of
Society of Wood Science and Technology

From Plant Proteins to Durable Wood Adhesives using thermo-mechanical treatments

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Abstract

Adhesives used in engineered wood are still predominantly produced from fossil-based materials, while the shift toward bio-based alternatives remains limited despite extensive research efforts in Europe. Protein based adhesives present a promising renewable option due to their good dry strength and high wood failure; however, their poor moisture resistance and high viscosity restrict processability and reduce performance under humid conditions. To address these challenges, proteins require modification through physical or chemical treatments or the addition of suitable crosslinkers.

This study investigates the use of thermo-mechanical pretreatment methods such as high-pressure homogenization and extrusion to enhance the rheological and adhesive properties of plant protein dispersions. These techniques promote partial unfolding and polymerization of proteins, improving rheological behavior and adhesion strength. Importantly, thermo-mechanical modifications are cost-effective, safe, and environmentally friendly, reducing or eliminating the need for chemical additives and minimizing residuals in the final adhesive product.

The results demonstrate that thermo-mechanical pretreatments can effectively modify the structural and functional characteristics of plant proteins, leading to improved bonding performance. This approach provides a sustainable and scalable pathway toward developing high-performance, bio-based adhesives for engineered wood products and supports the broader transition away from fossil resources in the wood industry.

Key words

Thermo-mechanical treatment; plant protein; High pressure homogenization; extrusion process, rheological characteristics, tensile shear strength

Fabrication of HKUST-1 Nanozyme Supported on Sulfated Cellulose Nanofibril and Its Laccase-like Activity

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Abstract

Metal-organic frameworks (MOFs) exhibit promising nanozyme activity owing to their intrinsic metal catalytic properties and high surface area with abundant active sites; however, their reusability remains challenging. Nanocellulose, with its outstanding features including a large surface area, high abundance, and functional groups on the surface emerges as a supporting material. In this study, copper-based MOF (HKUST-1) was in situ grown on sulfated cellulose nanofibril (SCNF), and its laccase-like activity was evaluated. Morphological studies using SEM revealed that a well-defined octahedral structure of HKUST-1 was observed on the surface of SCNF. XRD patterns further confirmed the successful formation of HKUST-1@SCNF. The decrease in FTIR peak intensities at 1206 and 810 cm-1 suggested sulfate groups on SCNF stabilized the HKUST-1. Laccase-like activity of HKUST-1@SCNF composite was evaluated using 2,4-dichlorophenol (2,4-DP) and 4-aminoantipyrine (4-AP). Optimal reaction conditions were 0.04 mg/mL catalyst reacting with 0.14 mg/mL of 2,4-DP at pH 8, 55 ˚C, for 50 min. Kinetic parameters were calculated: Vmax = 1.812 × 10-4 mM s-1, Km = 28.49 μM. Overall, this study demonstrates that SCNF can be used as an effective support for MOF growth and catalytic applications.

Acknowledgement

This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (No. RS-2018-NR031068)

Key words

Nanocellulose; MOFs; Nanozyme

Proceedings of the International Convention of
Society of Wood Science and Technology

Chemical Engineering of Oxypropylated Lignin toward Flame-Retardant Rigid Polyurethane Foams

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Abstract

Rigid polyurethane (PU) foams are extensively used in construction and thermal insulation owing to their low density and superior mechanical performance. However, their intrinsic flammability and the emission of toxic gases during combustion pose significant safety concerns. In this study, alkali lignin was utilized as a bio-based polyol precursor and chemically modified via oxypropylation to enhance its hydroxyl reactivity toward isocyanate groups. A phosphorus-containing component was further incorporated to construct a bio-based/phosphorus hybrid flame-retardant system.

Structural modification of lignin was confirmed by Fourier transform infrared (FTIR) spectroscopy and 31P nuclear magnetic resonance (31P NMR) analysis, demonstrating successful oxypropylation and quantitative variation in hydroxyl group distribution. The modified lignin was subsequently integrated into rigid PU foam formulations. Flame-retardant performance was evaluated using limiting oxygen index (LOI) and UL-94 vertical burning tests. Mechanical properties were assessed by compressive strength measurements, while scanning electron microscopy (SEM) was employed to analyze cellular morphology.

The results indicate that oxypropylated lignin functions effectively as a reactive bio-polyol, enabling partial substitution of petroleum-derived components without disrupting the closed-cell architecture of rigid PU foams. The combined effect of lignin's inherent aromatic structure and phosphorus-assisted char formation contributed to improved flame-retardant performance. This work demonstrates a sustainable lignin valorization pathway for the development of structurally stable and fire-resistant rigid polyurethane foams suitable for construction and insulation applications.

Key words

Oxypropylation; Alkali lignin; Phosphorus; Rigid polyurethane foam; Flame retardancy;

Rapid Hydrothermal Engineering of Alkali Lignin toward Fluorescent Carbon Quantum Dots: Response Surface Optimization

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Abstract

Lignin-derived carbon quantum dots (L-CQDs) have attracted considerable attention as sustainable fluorescent nanomaterials; however, conventional hydrothermal synthesis typically requires prolonged reaction times of 4-12 h. In this study, a rapid alkaline-oxidative hydrothermal strategy was developed to significantly reduce synthesis time while maintaining controllable photoluminescent properties. The total reaction duration was shortened to approximately 2.5 h, consisting of a 60 min temperature ramp and 90 min holding period.

Response surface methodology (RSM) analysis revealed significant interaction effects between alkaline activation and oxidative dosage on emission behavior, indicating that the balance between carbon core formation and surface functionalization governs fluorescence performance. Reaction temperature further influenced the degree of carbonization and emissive domain development.

The results demonstrate that lignin-based CQDs can be synthesized under substantially shortened hydrothermal conditions and that their optical properties can be statistically tuned through multivariable optimization. This study provides a rapid and controllable synthesis framework for biomass-derived carbon nanomaterials with improved process efficiency and scalability potential.

Key words

lignin-derived carbon quantum dots; rapid hydrothermal synthesis; alkaline-oxidative activation; response surface methodology; quantum yield optimization

Proceedings of the International Convention of
Society of Wood Science and Technology

Wood-Derived Quaternized Lignin Nanoparticles for Adsorptive Removal of PFAS in Aqueous Systems

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Abstract

Per- and polyfluoroalkyl substances (PFASs) are artificial organofluorine chemicals extensively applied in textiles, food packaging, and various consumer products because of their remarkable resistance to water, oil, and thermal degradation. Nevertheless, the exceptional strength of the carbon-fluorine bond renders these compounds highly persistent in natural environments. Their resistance to chemical and biological degradation, combined with a tendency to bioaccumulate, has raised significant environmental and public health concerns worldwide. Developing effective and sustainable materials for PFAS removal from water systems is therefore of considerable importance.

In this work, quaternized lignin nanoparticles (QLNPs) were engineered as high-performance adsorbents for PFAS remediation. Kraft lignin was first separated into high- and low-molecular-weight fractions through ethyl acetate extraction. The high-molecular-weight portion was subsequently etherified using epichlorohydrin to introduce reactive sites and improve structural integrity. This modified fraction was then co-assembled with the low-molecular-weight lignin via an antisolvent precipitation method, yielding nanoparticles with a core-shell architecture. The resulting structure featured a relatively hydrophobic core surrounded by a more hydrophilic shell, and thermal crosslinking was employed to stabilize the nanoparticle framework while preserving accessible surface functional groups.

To enhance affinity toward PFAS molecules, a C12 long-chain alkylamine was quaternized and chemically grafted onto the lignin backbone, generating positively charged sites capable of interacting electrostatically with anionic PFAS species. The prepared QLNPs exhibited improved colloidal stability across a broad pH range and demonstrated superior adsorption capacities for PFOA and PFOS compared to unmodified lignin, highlighting their promise as sustainable adsorbents for advanced water treatment applications.

Key words

Lignin Nanoparticles; Quaternization

Artificial Bark-Inspired Flame-Retardant Wood via Polyelectrolyte Complex Formation of Phosphorylated Nanocellulose

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Abstract

Wood is a sustainable structural material with excellent specific strength and notable carbon sequestration capability; however, its inherent flammability remains a critical limitation. To address this challenge, various modification strategies have been developed. Among these, delignification followed by impregnation of polymer having flame retardancy has recently been widely adopted. Delignification exposes cellulose surface functionalities and enlarges pore structures, thereby facilitating subsequent capillary-driven infiltration of polymers and functional agents. However, because this approach requires chemical treatment of the entire wood bulk, it is resource- and energy-intensive and inherently inefficient for applications where only surface functionality is required. Meanwhile, layer-by-layer (LbL) polyelectrolyte assembly offers a surface-based approach with improved durability, but requires multiple deposition-rinse cycles that limit industrial scalability. To overcome these limitations, a surface-confined engineering strategy that selectively targets only the fire-exposed near-surface region is required.

Inspired by the protective function of tree bark, this study proposes a surface-confined engineering strategy for flame retardancy that specifically targets the near-surface region exposed to fire while preserving the inner structural integrity. UV-H2O2 photocatalytic oxidation activated the surface by selectively oxidizing lignin chromophores and enriching hydroxyl groups, thereby maximizing wettability and capillary absorption. Subsequently, cationic branched polyethyleneimine (PEI) anchors were introduced into the activated capillary network, followed by single-cycle vacuum-assisted infiltration of an anionic phosphorylated nanocellulose (PNC) dispersion to impart flame retardancy. Upon pressure release, PNC was driven into evacuated pores before premature complexation could block pore entrances, resulting in the formation of leaching-resistant polyelectrolyte complex (PEC) nanoplugs within cell lumens. The resulting surface-adjacent nanoplugs physically blocked diffusion pathways while simultaneously enhancing surface mechanical strength. Cone calorimetry results confirmed that the engineered surface drastically suppressed heat release and delayed ignition, while repeated washing tests demonstrated excellent leaching resistance. Mechanical characterization further verified enhanced scratch resistance and flexural strength. This work establishes a low-carbon, scalable, efficient electrostatic immobilization process for manufacturing durable, high-performance structural timber without the need for repeated LbL cycles.

Key words

Flame-retardant wood; Artificial bark; Phosphorylated nanocellulose; Polyelectrolyte complex

Proceedings of the International Convention of
Society of Wood Science and Technology

Enhanced Flame Retardancy and Antifungal Durability of Wood via Surface Delignification-Assisted Bio-based Modification

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Abstract

Wood is a sustainable structural material; however, its inherent flammability and susceptibility to biological degradation limit its broader application in engineered wood products. To address these challenges, this study developed an eco-friendly flame-retardant and antifungal modification strategy involving surface delignification followed by impregnation with bio-based furfuryl alcohol (FA), phytic acid (PA), and tannic acid (TA).

The surface delignification was performed using either deep eutectic solvent (DES) or alkaline hydrogen peroxide (NaOH/H2O2) treatments. These treatments were designed to selectively modify the lignin-rich surface regions and increase chemical accessibility without compromising the bulk wood structure. Following delignification, the specimens were sequentially impregnated with FA and PA/TA solutions, then thermally cured to form a bio-based network capable of imparting flame-retardant and antifungal properties.

The DES and NaOH/H2O2 treatments exhibited distinct delignification mechanisms, suggesting that surface activation pathways can be tailored to specific wood species to optimize interfacial formation and overall performance. The synergistic effect of PA and TA significantly enhanced char formation and fire resistance of the wood. The modified wood showed a reduction of over 60% in peak heat release rate (pHRR) and a 20% increase in residual char yield. Furthermore, the limiting oxygen index (LOI) rose from 20.5% to over 30%, confirming substantial improvements in flame retardancy. The treated wood also exhibited superior biological durability, with no observable fungal proliferation even under high-temperature and high-humidity conditions. The FA-derived matrix effectively stabilized these functional components, ensuring high leaching resistance.

This work demonstrates a sustainable, halogen-free strategy for developing multifunctional wood featuring integrated flame retardancy and antifungal durability, offering a promising route toward next-generation engineered wood.

Key words

Surface delignification; Flame retardancy; Antifungal property; Bio-based network; Furfuryl alcohol treatment

Quantitative Analysis of Tree Structural Stability: Sensitivity to Cavity Location, Size, and Wood Material Properties

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Abstract

Accurate assessment of tree structural stability is essential for preventing mechanical failure. This study evaluated the stability of the Jeongipumsong pine tree using the finite element method (FEM) based on 3D LiDAR data. Parametric simulations revealed that the eccentric distance of internal cavities significantly increases stress concentration by locally minimizing the residual area. Specifically, the maximum von Mises stress at the Leeward 1 measuring point increased from 35.21% to 170.90% relative to the control as the cavity was displaced toward the outer periphery. To validate the robustness of these results, a sensitivity analysis was conducted relative to the baseline scenario (stress: 13.84MPa) by varying the elastic modulus (± 20%) and mass density (± 10%). The results showed that the stress fluctuations caused by elastic modulus and mass density were 3.02 MPa and 1.22 MPa, respectively, whereas cavity displacement induced a significantly larger variation of 8.44 MPa. This confirms that the spatial location of the cavity is a more dominant determinant of structural stability than inherent material variability. These findings provide a robust quantitative foundation for tree safety diagnosis and offer objective criteria for the management of timber cultural heritage.

Key words

Finite Element Method; Tree structural stability; Cavity eccentricity; Parametric study; Stress concentration

Proceedings of the International Convention of
Society of Wood Science and Technology

The Effects and Mechanism of High Temperature Saturated Steam Heat Treatment on moso bamboo (*Phyllostachys edulis*)

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Abstract

Bamboo, a renewable biomass material, is valued for its rapid growth and favorable mechanical properties. However, its inherent porous structure and chemical composition lead to poor dimensional stability and high hygroscopicity. These characteristics, along with its susceptibility to biological degradation, restrict its broader application. To improve its performance, thermal modification, particularly saturated steam treatment, has been widely adopted due to its efficiency and environmental friendliness. Nevertheless, the treatment rate and limited compatibility with dry bamboo materials remain challenges for practical application. This study investigated the modification of air-dried moso bamboo using saturated steam heat treatment at 140°C, 160°C, and 180°C for durations ranging from 5 to 40 minutes. The effects on physical-mechanical properties, microstructure, chemical composition, and cellulose supramolecular structure were systematically analyzed. Results identified 180°C for 10 min as the optimal process. Treated bamboo exhibited a significantly reduced moisture content (below 16%), a decreased equilibrium moisture content (from 11.24% to 8.05%), and improved dimensional stability, with an 18.6% reduction in air-dry volumetric shrinkage. Mechanical testing showed a slight decrease (2.4%) in modulus of rupture but a 12.7% increase in modulus of elasticity. Microstructural analysis revealed preserved cell morphology with a more compact structure. Chemically, hemicellulose and cellulose contents decreased by 2.63% and 5.36%, respectively, while lignin content relatively increased. Furthermore, cellulose crystallinity increased (from 52.0% to 55.5% in parenchyma cells and 57.7% to 59.2% in fiber cells), the proportion of stable cellulose Iβ increased, and free hydroxyl groups decreased. This study demonstrates that saturated steam treatment is an efficient and eco-friendly method for enhancing the dimensional stability and mechanical performance of bamboo. These improvements are attributed to modifications in the chemical composition and supramolecular structure of cellulose, thereby supporting the high-value utilization of bamboo.

Key words

Bamboo; heat treatment; saturated steam; mechanical properties; cellulose supramolecular structure

Plant-Derived Biopreservatives for Sustainable Wood Protection: A Biorefinary Based Approach

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Abstract

Wood is a complex polymeric structure composed of cellulose, hemicellulose and lignin along with inorganic material and extractives. These chemical structures are responsible for providing strength, flexibility and durability behavior of wood. A comprehensive understanding of these macromolecules—including cellulose crystallinity, hemicellulose heterogeneity, lignin aromatic structure and their interlinkages—is essential for efficient conversion and utilization. Increasing environmental concerns associated with synthetic wood preservatives have encouraged the exploration of plant-derived bioactive compounds as eco-friendly alternatives. In this context, the present study investigates the antifungal efficacy and preservative potential of methanolic extracts of Parthenium hysterophorus L. and Vitex negundo L., followed by solvent-solvent fractionation using hexane, chloroform, ethyl acetate, and methanol fractions. Among these, the hexane fraction of both plant extracts exhibited the highest antifungal activity and was selected for further evaluation. Minimum inhibitory concentration (MIC) analysis revealed strong antifungal efficacy of the hexane fraction, with Parthenium hysterophorus recording an MIC of 0.03 per cent and Vitex negundo showing 0.04 per cent against Polyporus rubidus and Pycnoporus sanguineus. In decay resistance studies of wood, the highest fungal colonization (93.95%) was observed in untreated wood, whereas the lowest colonization (18.75%) was recorded in treated samples. Maximum fungal inhibition (79.60%) and minimum mass loss (16.52%) were observed at 0.50 per cent concentration of Vitex negundo extract. Overall, the hexane fractions of Parthenium hysterophorus and Vitex negundo demonstrate considerable potential as eco-friendly wood preservatives. The findings highlight the role of plant secondary metabolites in enhancing decay resistance while maintaining the inherent physical and mechanical properties of wood. This approach supports the development of sustainable, bio-based preservation strategies aligned with green chemistry and circular bioeconomy principles.

Key words

Wood preservatives; Minimum inhibitory concentration; Vitex negundo extract, sustainable preservative.

Proceedings of the International Convention of
Society of Wood Science and Technology

Valorization of Bamboo Tree-Derived Lignin for High-Value Functional Biomaterials: Toward Sustainable Wood-Based Materials

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Abstract

The transition to a sustainable bioeconomy requires innovative strategies to make better use of lignocellulosic biomass. Among the main parts of wood biomass, lignin—making up about 15-35% of lignocellulosic materials—remains largely underused despite its abundance and unique chemical structure. Rich in phenolic hydroxyl groups, lignin has natural antioxidant and ultraviolet (UV) absorption properties, making it a promising renewable resource for creating high-value functional materials. In particular, bamboo, a quickly renewable woody biomass with high lignin content, shows strong potential as a sustainable feedstock for lignin valorization.

In this study, lignin was extracted from bamboo tree stems using a steam explosion pretreatment and subsequently fractionated via successive organic solvent extractions to obtain structurally distinct lignin fractions. The structural characteristics and molecular weight distributions of the lignin fractions were analyzed using gel permeation chromatography and spectroscopic techniques, including FT-IR and NMR analyses. These analytical approaches enabled the identification of key structural features of the lignin fractions, including their phenylpropane units and dominant β-O-4 linkages.

The functional properties of the obtained lignin fractions were evaluated in terms of antioxidant activity, tyrosinase inhibition, and ultraviolet absorption capacity. Among the fractions, the methanol-soluble lignin fraction exhibited the strongest antioxidant activity and significant tyrosinase inhibition effects. Cellular studies using B16F10 melanoma cells further revealed that this fraction suppressed melanogenesis by regulating the PKA/CREB signaling pathway, suggesting its potential as a natural skin-whitening and anti-melanogenic agent. In addition, bamboo-derived lignin demonstrated strong UV-absorbing properties within the 250-400 nm wavelength range. When incorporated into commercial cosmetic formulations, lignin significantly enhanced UV protection and exhibited synergistic antioxidant effects.

These results demonstrate that lignin extracted from bamboo can be transformed into multifunctional biomaterials with applications in cosmetics and bio-based functional materials. This study highlights the potential of lignin valorization as a strategy to convert wood-derived biomass into high-value products while contributing to the development of sustainable materials aligned with the theme of “Innovating with wood: science and materials for a sustainable future.”

Key words

Bamboo tree; Lignin; Valorization; Biomaterials; UV protection

Development of lignocellulosic lightweight foams for cavity insulation in beverage coolers using cellulose nanofibrils (CNFs) as a binder

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Abstract

Conventional beverage coolers rely on expanded polyurethane (PU) foams for thermal insulation. While effective, this material poses significant environmental challenges due to their fossil-fuel dependency and lack of biodegradability. My research focuses on developing cavity-filling insulation foam from Lignocellulosic materials (Themomehanical pulp fibers & wood flour) using cellulose nanofibrils (CNFs) as an adhesive in a surfactant assisted foaming method. The goal of the study is to optimize the foam forming process to achieve low thermal conductivity and strong lignocellulosic foam with a similar shape of beverage cooler's cavity insulation and find an efficient encapsulation method for it. We also aim at evaluating the efficiency of CNFs recovery from dry mix of ingredients and its rehydration's effect on foam formation. Overall, the study demonstrates the potential of wood-derived materials as a promising pathway toward sustainable insulation foams for cool boxes application, contributing to the reduction of fossil-based foam materials.

Key words

Lignocellulosic foam; Cellulose nanofibrils; Wood flour; Thermomechanical pulp fibers; Insulation foam

Proceedings of the International Convention of
Society of Wood Science and Technology

Phenolated Lignin for Biobased Functional Nanomaterials: Tailoring via Nanoprecipitation and Solvent Exchange

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Abstract

Lignin is a renewable biopolymer with strong potential for biobased functional materials due to its inherent antioxidant and antimicrobial properties. However, its structural heterogeneity and limited reactivity hinder its broader application. In this study, Kraft lignin and milled wood lignin were phenolated to enhance their reactivity and suitability for nanoscale material formation. The modified lignins were processed into nanostructured materials using nanoprecipitation and solvent exchange, enabling a direct comparison of both methods. Phenolation increased the phenolic hydroxyl content to 3.65 mmol g^{-1} for Kraft lignin and 2.10 mmol g^{-1} for milled wood lignin, as confirmed by ^{31}P NMR and 2D-HSQC analyses. These modifications improved lignin solubility and facilitated the formation of stable nanostructures. Nanoprecipitation produced uniform and stable particles with sizes of 90-160 nm (PDI < 0.1) and zeta potentials between 26 and 45 mV, while solvent exchange resulted in larger and less stable structures (550-800 nm).

The phenolated lignin nanomaterials exhibited enhanced antioxidant activity, indicating their potential as functional components in biobased materials. Overall, phenolation combined with nanoprecipitation provides an effective strategy for developing stable and functional lignin-based nanomaterials for sustainable applications.

Key words

Lignin nanoparticles; Phenolation; Nanoprecipitation; Biomedical application; Antioxidant and antimicrobial activity

Operationalizing Lean Construction for Construction-Phase Decarbonization in Mass Timber Buildings: A Process-Based Life Cycle Assessment Framework

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Abstract

The construction phase of buildings is an important yet insufficiently quantified source of greenhouse gas (GHG) emissions, particularly in mass timber projects where construction logistics, heavy equipment operation, and long-distance transportation contribute significantly to environmental impacts. While mass timber has been widely recognized for its potential to reduce embodied carbon during material production, emissions associated with construction-phase activities—typically represented by modules A4 (transportation) and A5 (construction and installation) in life cycle assessment (LCA)—remain poorly characterized in current research. At the same time, Lean Construction has been widely promoted as an approach for improving efficiency and minimizing waste on construction sites. Despite growing recognition of potential synergies between lean practices and sustainability, the environmental implications of Lean Construction are predominantly discussed qualitatively, with limited integration into quantitative LCA frameworks.

This study develops a methodological framework for systematically quantifying the environmental impacts of Lean Construction in mass timber buildings using process-based LCA. The framework reconceptualizes Lean Construction not as a managerial philosophy but as a set of operational interventions that can be explicitly modeled within an LCA structure. A key contribution of this research is the establishment of a transparent and traceable causal pathway linking lean practices to environmental outcomes. Lean practices are first associated with the non-value-added activities (NVAs) they are designed to reduce or eliminate within construction workflows. These NVAs are subsequently translated into quantifiable process-level parameters, including equipment operating time, transportation distances, fuel consumption, and material waste rates, which are directly incorporated into the LCA model.

The framework is demonstrated through a case study of a mass timber building, where site-specific construction-phase data are used to establish a conventional (non-lean) baseline scenario. Multiple lean-enabled scenarios are then developed to represent varying levels of lean implementation. By embedding lean interventions within a process-based LCA model, the approach enables systematic evaluation of the environmental effects of lean-driven process optimization.

This research addresses a critical methodological gap at the intersection of Lean Construction, mass timber research, and life cycle assessment, and provides a transferable framework for quantifying construction-phase decarbonization strategies in the built environment.

Key words

global warming potential; mass timber building; lean construction, life cycle assessment

Proceedings of the International Convention of
Society of Wood Science and Technology

A Comparative LCA of Mass Timber and Steel Structures

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Abstract

The main objective of this study is to quantify and compare the embodied carbon (EC) associated with the structural materials used in the construction of Adohi Hall, a residence building located on the University of Arkansas campus in Fayetteville, Arkansas. Adohi Hall was constructed as a mass timber structure, and for comparative purposes, an equivalent building design employing a steel structural system was evaluated. A comparative life cycle assessment (LCA) was conducted to assess the global warming potential (GWP) of the structural materials. The system boundary was defined as cradle-to-construction site, encompassing raw material extraction, processing, manufacturing, and transportation to the construction site. These stages correspond to modules A1-A4 in accordance with EN 15804. GWP was selected as the primary impact category, while other environmental indicators were excluded. The LCA analysis was performed using Tally®, a widely applied building-scale LCA tool. The study focuses on substituting the mass timber structural system with a steel frame incorporating a corrugated steel deck and concrete topping, enabling a direct comparison of GWP impacts between the two structural alternatives under identical design conditions. Results demonstrate that the mass timber structure exhibits lower embodied carbon emissions compared to the steel alternative. The mass timber building produces 198 kg CO_2 eq per square meter of gross floor area, whereas the steel structure generates 243 kg CO_2 eq per square meter. This corresponds to a 19% reduction in embodied carbon emissions for the mass timber option within modules A1-A4. In addition to reduced emissions, the mass timber structure provides substantial carbon storage benefits. Approximately 2,757 tonnes of CO_2 eq are stored in the timber materials, contributing to delayed carbon emissions over the building's service life. The substitution benefit of replacing steel with mass timber was further evaluated using the displacement factor (DF) approach, resulting in a DF value of 0.28 for this case study. Overall, the findings highlight the potential of mass timber construction to reduce greenhouse gas emissions and support more environmentally efficient material choices in building design, contributing to global warming potential mitigation in the building sector.

Key words

Global warming potential; displacement factor; substitution benefit, whole building lca

2026 SWST International Convention

June 7~12, 2026
Seoul, Korea

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