JULY 8-10

ICSHM

10th International Conference on Self-healing Materials

10th International Conference on Self-Healing Materials (ICSHM2026)

Conference Program

Venue: Bossone Research Enterprise Center,
Drexel University
Address: 3140 Market Street, Philadelphia, PA 19104

Organizing Committees

Executive Committee:
- Dr. Geetika Mishra (Drexel University, USA)
- Prof. Ahmad Najafi (Drexel University, USA)
- Prof. Christopher Sales (Drexel University, USA)
- Prof. Jialuo He (Widener University, USA)

Scientific Committee:
- Prof. Amir Alavi (University of Pittsburgh, USA)
- Prof. Abir Al-Tabbaa (University of Cambridge, UK)
- Prof. Dimitrios Angelis (Vrije Universiteit Brussel, Belgium)
- Prof. Zhenan Bao (Stanford University, USA)
- Prof. Nele De Belie (Ghent University, Belgium)
- Dr. Cristina De Nardi (Cardiff University, UK)
- Prof. Charles Diesendruck (Technion, Israel)
- Prof. Santiago Garcia Espallargas (TU Delft, Netherlands)
- Prof. Liberato Ferrara (Politecnico di Milano, Italy)
- Prof. Diane Gardner (Cardiff University, UK)
- Prof. Ali Ghahremaninezhad (University of Miami, USA)
- Prof. Yury Gogotsi (Drexel University, USA)
- Prof. Mija Helena Hubler (University of Colorado Boulder, USA)
- Prof. Henk Jonkers (TU Delft, Netherlands)
- Prof. Riccardo Maddalena (Cardiff University, UK)
- Prof. Mo Li (University of California Irvine, USA)
- Prof. Reza Moini (Princeton University, USA)
- Prof. Abhijit Mukherjee (Curtin University, Australia)
- Prof. Kalyana Nakshatrala (University of Houston, USA)
- Prof. Jose Norambuena-Contreras (Swansea University, UK)
- Prof. Kevin Paine (University of Bath, UK)
- Prof. Etelvina Javierre Pérez (Universidad de Zaragoza, Spain)
- Prof. Moe Pourghaz (North Carolina State University, USA)
- Prof. Marianella Hernández Santana (Institute of Polymer Science & Tech., Spain)
- Prof. Erik Schlangen (TU Delft, Netherlands)
- Prof. Nancy Sottos (University of Illinois Urbana-Champaign, USA)
- Prof. Didier Snoeck (Université Libre de Bruxelles, Belgium)
- Prof. Wil V. Srubar (University of Colorado Boulder, USA)
- Prof. Kim Van Tittelboom (Ghent University, Belgium)
- Prof. Russell Varley (RMIT University, Australia)
- Prof. Pablo Zavattieri (Purdue University, USA)

Steering Committee:
- Chair: Nele De Belie (Concrete, Belgium)
- Wolfgang Binder (Polymers, Germany)
- Santiago Garcia Espallargas (Polymers, The Netherlands)
- Etelvina Javierre (Modelling, Biological materials, Spain)
- Mo Li (Concrete, USA)
- Veronique Michaud (Composites, Switzerland)
- Tomoya Nishiwaki (Concrete, Japan)
- Jason Patrick (Composites, USA)
- Eric Schlangen (Asphalt and Concrete, The Netherlands)
- Aude Simar (Metals, Belgium)
- Russell Varley (Polymers, Australia)
- Nakao Wataru (Ceramics, Japan)

Message from the Chairs

Welcome to ICSHM2026!

The 10th International Conference on Self-Healing Materials (ICSHM2026) will take place from July 8-10, 2026, at Drexel University in Philadelphia, PA, USA. ICSHM2026 continues the long-standing tradition of this biennial conference to bring together leading researchers, engineers, and practitioners from around the globe to discuss and advance the field of self-healing materials. At this 10th edition, we will again provide a high-quality international platform for showcasing the latest developments in self-healing materials and related technologies including advancements in understanding chemistry, processing, characterization, modeling, applications, and beyond.

ICSHM 2026 is organized by a dedicated team of researchers, professionals, and volunteers committed to advancing the field of self-healing materials. Building on the successful tradition of the International Conference on Self-Healing Materials (ICSHM), the organizing committee is proud to welcome the global self-healing community to Drexel University in Philadelphia for ICSHM 2026.

The ICSHM 2026 Technical Program brings together leading researchers, engineers, and innovators from more than 18 countries across 6 continents to share the latest advances in self-healing materials. The conference features more than 70 presentations, including keynote and plenary lectures by internationally recognized leaders, technical presentations, poster presentations featured in an interactive poster session, and a commercialization and technology transfer forum. Spanning concrete, polymers, composites, bio-inspired materials, modeling, and emerging applications, the program highlights the breadth, diversity, and global impact of research in self-healing materials.

In addition to a comprehensive technical program, ICSHM 2026 offers several opportunities for networking and community engagement. The conference will begin with an Opening Reception on Wednesday evening, providing attendees with an opportunity to reconnect with colleagues, meet new collaborators, and engage with the international self-healing materials community in an informal setting. The conference Gala Dinner, held at the Museum of the American Revolution, will celebrate the achievements of our field while fostering meaningful interactions among researchers, industry professionals, and students.

We thank you for attending and hope you have an enjoyable and successful conference!

Conference Chair
Yaghoob (Amir) Farnam
Drexel University, USA

Co-Chair
Jason Patrick,
NC State University, USA

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Conference Information

In addition to the information on the conference website (www.icshm2026.org), please also consult the notes below for important contacts, venues, and other relavant information.

Badges
For security purposes, delegates must wear their name badges at all times during the conference. Entrance to the conference areas will be limited to badge holders only. Replacement of lost name badges can be requested at the Registration Desk.

Badge Colors and Identification:

Yellow	Chairs
Red	Executive Committee
Dark red	Event Liaison
Purple	Keynote Speakers
Green	Sponsors
Blue	Participants
Black	Students

Breakfast/Coffee/Lunch
For registered participants wearing their name badges, breakfast is available on all three days of the conference, while lunch is available on Wednesday and Thursday. In additon, coffee and tea will be served along with refreshments at several catering points throughout the poster and conference areas during the breaks.

Dress Code
Recommended dress code for the conference and all social events is business casual.

Emergencies
In case of an emergency at the conference venue, please call the Drexel University Emergency number +1.215.895.2222 or dial 911.

Important Locations
Registration desk, coffee, lunch: Bossone Lobby
Keynote lectures and Session A talks: Mitchell Auditorium
Session B talks: Hill Conference Room
Opening reception and conference photoshoot: Drexel Main Building
Gala dinner: Museum of the American Revolution

Internet Access
The Drexel Guest Network can be used for internet access at the conference venue. The network offers basic web browsing and is limited to specific services that are publicly available.

How To Connect:
- Choose "DrexelGuest" from the list of available wireless networks.
- Open a browser and attempt to access a web site, you should be directed to the Drexel Guest login page. If you are not automatically redirected, please browse to http://drexelguest.drexel.edu.
- Follow the instructions, providing your email address to login to the guest network.

Please visit https://drexel.edu/it/help/a-z/drexelguest/ for more information.

Conference Information

Lost Property
If you see any unattended parcel/baggage, please report to one of the Conference staff members. Should you loose anything at The Study at University City, please inquire at the Registration Desk where any lost items will be held.

Presentation Guidelines
Oral Presentations: Technical presentations are allocated approximately **18 minutes**, including time for audience questions and discussion. Presenters are kindly requested to manage their time accordingly to ensure a smooth transition between talks and to maintain the conference schedule.

Presentation Upload: To facilitate efficient session management and avoid technical delays, all presenters should upload their PowerPoint presentation files at the **registration desk upon arrival**. Presentations will be transferred to a shared conference laptop that will be used during all sessions. Presenters are encouraged to bring their files on a USB drive and verify proper display of multimedia content, animations, and embedded videos. Please make sure that the presentation is uploaded at least one hour before the start of the session to ensure appropriate transfer of files to the designated session and room by the conference staff.

Poster Presentations: Posters should be prepared in **portrait orientation** with dimensions of **36 × 48 inches (91.4 × 121.9 cm)**. **A0-size posters (84.1 × 118.9 cm)** are also acceptable. Authors are encouraged to ensure that text, figures, and tables are clearly legible from a distance of approximately 1–2 meters and to be present during the designated poster session to discuss their work with attendees. Poster needs to be set up at least 1 hr before the start of the session on Friday. A dedicated person will be at the Bossone Lobby to help poster presenters.

Program Changes
The organizers cannot accept liability for any changes in the program due to external or unforeseen circumstances.

Registration and Information
The Registration Desk will be located at the lobby of the Bossonne Research Enterprise Center, and will operate during the following hours:
Wednesday July 8, 8:00 A.M. – 5:30 P.M.
Thursday July 9, 8:00 A.M. – 5:30 P.M.
Friday July 10, 8:30 A.M. – 1:00 P.M.

Services for Disabled Persons
All the rooms at the conference venue are fully accessible to delegates with disabilities. The hotel is fully compliant with ADA standards.

Tickets
Entry to the Opening Reception is included in the registration fee. However, the Gala Dinner is limited to people who have registered for it separately. For those attending the Gala Dinner, please note that there is a sticker on your badge that indicates your entree choice, please make sure to bring your badge to the museum.

Day 1 - Morning Session

Time	Wednesday, July 8, 2026 - Session 1	
08:00 – 08:30	**Registration with Breakfast** (Location: Bossone Lobby)	
08:30 – 09:00	**Opening Session and Welcome** (Moderator: Amir Farnam; Location: Mitchell Auditorium)	
8:30	Prof. Amir Farnam, ICSHM 2026 Chair, Drexel University	
8:40	President Antonio Merlo, PhD, President, Drexel University	
8:50	Prof. Dr. Ir. Nele De Belie, Chair of the ICSHM Steering Committee and RILEM President, Ghent University	
09:00 – 10:30	**Keynote Lecture** (Moderators: Jason Patrick and Amir Farnam; Location: Mitchell Auditorium)	
9:00	Space: The Final Frontier for Self-healing Polymers; **Prof. Nancy Sottos**, University of Illinois Urbana-Champaign, USA	
9:45	Multi-scaled Biomimetic Materials to Regulate Tissue Regeneration; **Prof. Peter X. Ma**, University of Michigan, Ann Arbor, USA	
10:30 – 11:00	**Coffee Break** (Location: Bossone Lobby)	
11:00 – 12:30	**Parallel Technical Sessions** (Location: Session A in Mitchell Auditorium, and Session B in Hill Conference Room)	
	Session A1: Fundamentals, Limitations, and Advanced Strategies in Concrete Self-Healing; Moderator: Nele De Belie	**Session B1:** Dynamic Self-healing Polymers; Moderator: Charles Diesendruck
11:00	Self-Healing Concrete with Emphasis on Bio-Based Techniques; **Abhijit Mukherjee** (Curtin University, Australia)	Energy-Dependent Impact Damage and Healing Response in Sandwich Panels: Post-Impact Flexural Performance and Visual Evidence; **Jung-il Song** (Changwon National University, Republic of Korea)
11:18	Beyond Bacteria: What Really Drives Carbonate-based Self-healing in Cementitious Cracks; **Martyna Janek** (Lublin University of Technology, Poland)	Proof-of-Concept: Healable and Recyclable Flax Fiber Composites with Catalyst-Free Vitrimer Matrix for Infrastructure Applications; **Shagata Das*** (University of Delaware, USA)
11:36	Self-healing Functionalisation Strategies of Textile-Reinforced Mortars; **Liberato Ferrara** (Politecnico di Milano, Italy)	High-Performance Epoxy Anhydride Vitrimers for Repairable and Recyclable Composite Structures; **Russell Varley** (RMIT University, Australia)
11:54	Electrical Impedance Tomography and Spectroscopy for Imaging Bio-Mediated Healing in Vascularized Concrete; **Moe Pourghaz** (North Carolina State University, USA)	Moisture-Activated Durable and Autonomous Self-Healing Epoxy Coating Using Boronic Ester Dynamic Bonds; **Sachini Dissanayake*** (Deakin University, Australia) & **Russell Varley** (RMIT University, Australia)
12:12	Self-Healing Mechanisms in Ultra-Ductile High-Strength Cementitious Materials and Structural Components; **Mo Li** (University of California, Irvine, USA)	Self-Healing Mitigation Strategies for Droplet-Induced Impact Damage in Wind Turbine Blade Leading-Edge Coatings; **Po-Wen Wang*** (University of Illinois Urbana-Champaign, USA)
12:30 – 14:00	**Lunch Break** (Location: Bossone Atrium, 3rd floor)	

Note: An asterisk (*) denotes student presenters.

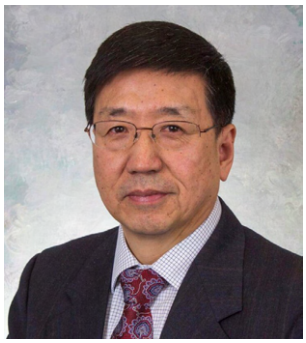
Day 1 - Keynote Speakers

Space: The Final Frontier for Self-healing Polymers

Prof. Nancy Sottos

University of Illinois Urbana-Champaign, USA

Nancy Sottos holds the Maybelle Leland Swanlund Endowed Chair and is Head of the Department of Materials Science and Engineering at the University of Illinois Urbana Champaign. She is leader of the Autonomous Materials Systems (AMS) group at the Beckman Institute for Advanced Science and Technology, director of the EFRC on Regenerative Energy Efficient Manufacturing of Thermoset Polymeric Materials (REMAT), and director of the University of Illinois spoke of the BP International Center for Advanced Materials (ICAM). Sottos is also a co-founder of the start-up companies Autonomous Materials Inc. (AMI) and RapiCure Solutions. The Sottos group develops polymers and composites capable of self-healing and regeneration, self-reporting, and self-protection to improve reliability and extend material lifetime. Her current research interests focus on circular additive and morphogenic manufacturing strategies for polymeric and composite materials with programmed end of life. She is a member of the National Academy of Engineering, the National Academy of Sciences, and the American Academy of Arts and Sciences. She is a Fellow of the Society for Experimental Mechanics, the Society for Engineering Science and the American Association for the Advancement of Science. Sottos is also the recipient of the American Society of Mechanical Engineers Nadai Medal and the Society of Engineering Science Medal.



Multi-scaled Biomimetic Materials to Regulate Tissue Regeneration

Prof. Peter X. Ma

University of Michigan, Ann Arbor, USA

Dr. Peter X Ma received his PhD in Polymer Science and Engineering from Rutgers University (US). He then did his postdoctoral research at MIT and Harvard Medical School on Biomaterials and Tissue Engineering. He is the Richard H. Kingery Endowed Collegiate Professor and a tenured Full Professor in Dentistry, Engineering, and Medicine at the University of Michigan. His research is in the areas of biomaterials and tissue engineering, including scaffold design, biomolecule delivery, bone, cartilage, dental, and cardiovascular tissue engineering. His research has been funded by NIH, DOD, NSF, NASA, various foundations, and industry. Dr. Ma has published 330 full-length articles, published 5 books and is the inventor of 43 distinct US patents and patent applications. Among various recognitions, Dr. Ma received a Whitaker Foundation Biomedical Engineering Young Investigator Award, a DuPont Young Professor Award, and a Distinguished Scientist Award (Isaac Schour Memorial Award) from the International Association of Dental Research. He was named one of the Top 100 materials scientists in the world by Thomson Reuters. He is an elected Fellow of several bodies including the American Institute for Medical and Biological Engineering, Fellow of Biomaterials Science and Engineering, and Fellow of the Materials Research Society.

Day 1 - Afternoon Session

Time	Wednesday, July 8, 2026 - Session 2	
14:00 – 15:30	**Parallel Technical Sessions** (Location: Session A in Mitchell Auditorium, and Session B in Hill Conference Room)	
	Session A2: Healing Performance and Efficiency in Cement-based Composites; Moderator: Chris Sales	**Session B2:** Self-healing Composites & Manufacturing; Moderator: Russell Varley
14:00	Gelatin as a Nucleation Scaffold to Enhance Enzyme-Induced CaCO3 Precipitation for Self-Healing Concrete; **Chris Sales** (Drexel University, USA)	Additive Manufacturing for Scalable Fabrication of Self-Healing Thermoplastic Composites; **Daniel Therriault** (Polytechnique Montréal, Canada)
14:18	Exploring Fungal-Induced Mineralization for Crack Healing in Cementitious Mortar; **Nuo Bao*** (Louisiana State University, USA)	Self-Healing Biomanufactured Protein Fibers; **Hasanur Rahman*** (Penn State University, USA)
14:36	Bacterial Nanocellulose for Repair and Repeated Self-healing of Concrete; **Mija Hubler** (University of Colorado at Boulder, USA)	Self-Healing Energetic Materials; **Charles Diesendruck** (Technion – Israel Institute of Technology, Israel)
14:54	Fatigue-Induced Healing Mechanisms in Self-Compacting Natural Hydraulic Lime Concretes; **Gonzalo Ruiz** (Universidad Rey Juan Carlos, Madrid, Spain)	Study of the Reaction of Pyrex Powder and BaCO2 as a Function of Temperature as a Probe for Generated Silica Reactivity; **Jacob Hormadaly** (Ben-Gurion University, Israel)
15:12	Evaluation of the Healing Capacity of Limestone Calcined Clay Mortars; **Marwa Hassan*** (Universite de Rennes, France)	Repeatable Self-Healing of Interlaminar Fracture in Prepreg Composites via In Situ Thermal Remending; **Yerassyl Kuan*** (North Carolina State University, USA)
15:30 – 16:00	**Coffee Break** (Location: Bossone Lobby)	

Note: An asterisk (*) denotes student presenters.

Day 1 - Evening Session

Time	Wednesday, July 8, 2026 - Session 3	
16:00 – 17:30	**Parallel Technical Sessions** (Location: Session A in Mitchell Auditorium, and Session B in Hill Conference Room)	
	Session A3: Self-healing Concrete Durability; Moderator: Aveline Darquennes	**Session B3:** Nature-inspired Self-Healing Strategies; Moderator: Liberato Ferrara
16:00	Effect of Crack Pre-healing on Sulfate Degradation for Self-healing Concrete with Bacteria-based or Crystalline Admixture Healing Agents; **Nele De Belie** (Ghent University, Belgium)	Bone-Inspired Self-Adaptive and Self-Healing Materials for Resilient Future; **Sung Hoon Kang** (Korea Advanced Institute of Science and Technology, Republic of Korea)
16:18	Influence of Micro-climate Conditions on Concrete Carbonation; **Kosmas Sideris** (Democritus University of Thrace, Greece)	Design and Integration of Architected Vascular Network in Cementitious Materials; **Niyousha Niknezhad*** (Drexel University, USA)
16:36	Case Study in the Tren Maya Project, Mexico using Enzyme Based Waterproofing; **Mario Baggio** (Alchemco, USA)	Biomimetic Vascular Networks for Cyclic Self-Healing of Lime Mortars in Heritage Masonry; **Cristina De Nardi** (Cardiff University, UK)
16:54	Antimicrobial Self-Healing Concrete to Mitigate Biogenic Sulfuric Acid Corrosion: Confocal Microscopy and SEM Evidence from Pseudomonas aeruginosa Biofilms; **Emilio Takagi*** (Aeronautical Institute of Technology, Brazil)	Frontier of Extrusion-Based 3D-Printing for Design of Complex Tubular and 3D Vascular Architected Toolpaths; **Shashank Gupta*** (Princeton University, USA)
17:12	Microbial Self-Healing Concrete with Smart Magnesium Oxychloride Cement Capsules; **S.H. Chu** (Aalto University, Espoo, Finland)	From Root Canal to Concrete: Endodontics-Inspired Vasculature for Targeted Bio-Healing of Aged Cementitious Materials; **Mohammad Irfan Iqbal** (Drexel University, USA)
18:30 – 21:30	**Opening Reception** (Location: Drexel Main Building Court, 3141 Chestnut Street)	
20:30	Conference Photoshoot	

Note: An asterisk (*) denotes student presenters.

Day 2 - Morning Session

Time	Thursday, July 9, 2026 - Session 1	
08:00 – 09:00	**Registration with Breakfast** (Location: Bossone Lobby)	
09:00 – 10:30	**Keynote Lecture** (Moderators: Mo Li and Ahmad Najafi; Location: Mitchell Auditorium)	
9:00	**20 Years of Self-healing Construction Materials; Prof. Erik Schlangen, Delft University of Technology, Netherlands**	
9:45	Temporal Sequence in the Growth of Hard and Soft Domains in Polymer Layers Affects Final Morphology; **Prof. Anna Balazs**, University of Pittsburgh, USA	
10:30 – 11:00	**Coffee Break** (Location: Bossone Lobby)	
11:00 – 12:30	**Parallel Technical Sessions** (Location: Session A in Mitchell Auditorium, and Session B in Hill Conference Room)	
	Session A4: Fracture Mechanics and Modeling in Concrete Self-Healing; Moderator: Moe Pourghaz	**Session B4:** Gelatin-Based Self-Healing Strategies; Moderator: Mija Hubler
11:00	Prolonged Crack Healing in Concrete with Microencapsulated Secondary Healing: A Numerical Study; **Ahmad Najafi** (Drexel University, USA)	The Effect of Temperature, Relative Humidity and Binder-Sand Ratio Variations on Compressive Strength of Living Building Materials; **Gadisa Merdassa*** (University of Colorado Boulder, USA)
11:18	Fracture and Statistical Mechanics for Design of Architected Cementitious Composites: Experiment, Theory, and Simulation; **Reza Moini** (Princeton University, USA)	Super Tough Multi-Bond Network Hydrogels with Self-Healable Properties; **Xu-Ming Xie** (Tsinghua University, China)
11:36	Multi-physics Modeling of Fracture-healing Response in Self-healing Concrete with MICCP and Phase-field Model; **Hsiao Wei Lee** (Cheng Kung University, Taiwan)	Internal-External CO_2 Curing Synergy: Enzymatic Hydrogel Strategy for Improved Carbonation of Wollastonite-Based Cementitious Materials; **Mehdi Khanzadeh Moradllo** (Temple University, USA)
11:54	Laboratory Assessment and Numerical Modeling of Self-healing Concrete with Lightweight Aggregates Encapsulated by Modified PVA; **Jialuo He** (Widener University, USA)	Mechanically Activated Autonomous Self-Healing of Volcanic-Clay Cement Pastes Using a Novel Superabsorbent Hydrogel–Cellulose Microfiber System; **Ángel De La Rosa Velasco** (Universidad Rey Juan Carlos, Spain)
12:12	Direct Tensile Testing and Fracture Behavior of Microcapsules; **Alireza Ashkpour*** (Drexel University, USA)	Self-Healing Performance of Cementitious Materials with Hydrogel under Marine Environment; **Farzad Rezaeicherati*** (University of Miami, USA)
12:30 – 14:00	**Lunch Break** (Location: Bossone Atrium, 3rd floor)	

Note: An asterisk (*) denotes student presenters.

20 Years of Self-healing Construction Materials

Prof. Erik Schlangen

Delft University of Technology, Netherlands

Erik Schlangen is professor "Experimental Micromechanics' at the Civil Engineering and Geosciences faculty at Delft University of Technology. Central to his work is micromechanics, which involves studying materials at the microscopic level to understand and manipulate their structural properties. This research provides insights into the intrinsic behaviour of construction materials, allowing for the development of more durable and sustainable solutions. The studies on the micromechanical properties of concrete and asphalt have also led to breakthroughs in self-healing materials, enhancing the longevity and resilience of infrastructure. Additionally, his research encompasses smart construction materials, discrete element modelling, and 3D printing of concrete. The advanced testing facilities at the Microlab of Delft University support these innovative studies. In 2025, he was awarded an ERC-advanced-grant MAGICON, which is the most prestigious personal grants for research in Europe.

Temporal Sequence in the Growth of Hard and Soft Domains in Polymer Layers Affects Final Morphology

Prof. Anna Balazs

University of Pittsburgh, USA

Anna C. Balazs is a Distinguished Professor of Chemical Engineering and holds the John A. Swanson Endowed Chair in Engineering at the University of Pittsburgh. She received her B.A. in physics from Bryn Mawr College and her Ph.D. in materials science from the Massachusetts Institute of Technology in 1981. Balazs is a Fellow of the American Physical Society, the Royal Society of Chemistry, and the Materials Research Society. She received the Gutenberg Research Award, Mainz Germany (2025), American Physical Society Polymer Physics Prize (2016), the Royal Society of Chemistry S F Boys-A Rahman Award (2015), the American Chemical Society Langmuir Lecture Award (2014) and the Mines Medal from the South Dakota School of Mines (2013). She is a member of the National Academy of Science and the National Academy of Engineering.

Day 2 - Afternoon and Evening Sessions

Time	Thursday, July 9, 2026 - Session 2	
14:00 – 15:30	**Parallel Technical Sessions** (Location: Session A in Mitchell Auditorium, and Session B in Hill Conference Room)	
	Session A5: Long-term Performance and Case Studies in Self-Healing Concrete; Moderotor: Abhijit Mukherjee	**Session B5:** Polymeric Self-healing & Self-sensing I; Moderator: Daniel Therriault
14:00	Durability Indicators and Concrete Service Life: Difference in Values Measured in the Laboratory Concrete and On-Site Concrete; **Kosmas Sideris** (Democritus University of Thrace, Greece)	AI Meets Self-Healing Polymers: PINN-Driven Approach in Unlocking Structure-Property Relationships of Reversible Diels–Alder Polymers; **Seppe Terryn** (Vrije Universiteit Brussel (VUB), Belgium)
14:18	Self-healing Properties of Hennebique Concrete over 130 Years Old; **Didier Snoeck** (Universie Libre de Bruxelles, Belgium)	Autonomous Alignment and Healing in Multilayers of Immiscible Dynamic Polymers for Damage-Perceptive Soft Electronics; **Samuel Root** (Case Western Reserve University, USA)
14:36	Case Study – The Use of the Crystalizing Additive in the Mitigation of Leakage in a Water Treatment Plant; **Mitchell Glaze** (THOMCO Inc.) & **Leonardo Coutinho** (Alchemco, Brazil)	Interface Behavior of Periodic Dynamic Polymers with Identical Backbones and Distinct Dynamic Bonds; **Alexandra Ramos Figueroa*** (Stanford University, USA)
14:54	Building the Bridge: Bringing European Concrete Innovation into the American Construction Market; **Anna Jensen** (Restoration Partners, USA)	Statistically Optimized Polymer Inclusion Membranes for Intelligent and High-Selectivity Calcium-Ion Separation; **Arash Adhami*** (Drexel Univerity, USA)
15:12	Life-Cycle Cost Optimization of Concrete Repairs: Reducing Total Ownership Cost Without Increasing Risk; **Mario Baggio** (Alchemco, USA)	Sustained Self-Sensing and Autonomous Self-Healing via Electro-Thermal Coupling in Fiber-Reinforced Composites; **Jack Turicek*** (North Carolina State University, USA)
15:30 – 16:00	**Coffee Break** (Location: Bossone Lobby)	
Time	**Thursday, July 9, 2026 - Session 3**	
16:00 – 17:30	**Special Plenary Forum Session: Commercialization & Technology Transfer** (Moderator: Reza Moini; Location: Mitchell Auditorium)	
16:00	Building Confidence in Commercializing Self-Healing Materials: From Research Validation to Field Implementation; **Mario Baggio Bionote**, Alchemco	
16:12	Planning for Commercialization during Ideation; **Mija Hubler**, University of Colorado at Boulder	
16:24	The Startup Path to Commercialization: from Incorporation to Exit; **Dennis Gilmore**, Structeryx, Inc.	
16:36	Navigating Commercial Needs and Cultural Differences; **Anna Jensen**, Restoration Partners	
16:50	Q&A Forum	
18:30 – 22:30	**Gala Dinner**** (Location: Museum of the American Revolution, 101 S 3rd St, Philadelphia, PA) Sponsored by PENETRON	
18:30	Cocktail Reception and Museum Access (Location: Oneida Atrium and Museum)	
19:45	Dinner (Location: Liberty Hall)	

** Limited transportation will be available leaving at 6:10 PM and returning at 9:50 PM. Pick-up: In front of the Drexel Mario the Magnificent Statue (S 33rd Street and Market Street) Destination: The Museum of the American Revolution (101 South Third Street)

Note: An asterisk (*) denotes student presenters.

Day 2 - Special Plenary Panelists

Moderator

Reza Moini, PhD
Assistant professor, Princeton University

Dr. Moini earned his Ph.D. from the Lyles School of Civil Engineering at Purdue University in 2020. He is a core Robotic Faculty and an associated faculty member of the Princeton Materials Institute (PMI), Princeton Center for Computational Science & Engineering (PICSciE).

His work is motivated by the intellectual challenges in understanding the fracture and statistical mechanics of architected and disordered materials. His group uses experiments, simulation, and theory to engineer the mechanics of materials, by developing numerical frameworks that help probe hypotheses in layered materials and by advancing autonomous robotic fabrication processes that assist in realization of complex materials. He is the recipient of several awards, most recently, Walter P. Moore Jr., Faculty Achievement Award from American Concrete Institute in 2025, Howard B. Wentz Jr. Junior Faculty Award in 2024 from the School of Engineering and Applied Science at Princeton University, and National Science Foundation (NSF) early CAREER award in 2023.

Panelists

Mario Baggio Bionote
Chief Executive Officer, Alchemco

Mario Baggio is the Founder and CEO of Alchemco, a U.S.-based company focused on advancing technologies that enhance the durability, resilience, and service life of concrete infrastructure. Over the past three decades, he has worked at the intersection of materials innovation and practical engineering applications, helping bridge the gap between research, technology development, and field implementation. His experience spans transportation, water, industrial, and commercial infrastructure projects across multiple countries, with a particular interest in long-term concrete durability, sustainability, and the adoption of innovative construction materials. Mario is an active advocate for collaboration betweenbacademia, industry, and asset owners to accelerate the successful implementation of emerging technologies in the built environment.

Mija Hubler
Associate Professor, University of Colorado, Boulder

Mija Hubler is an associate professor in Civil, Environmental, and Architectural Engineering at the University of Colorado, Boulder. Her research focuses on concrete infrastructure degradation mechanics and innovative concrete materials development. She has received the EMI Leonardo Da Vinci award and Gustavo Colonnetti Medal for her creative contributions in these areas. She is a co-founder of two startups on biological concrete (Prometheus Materials) and bio-based repair of concrete (RipaLith).

Day 2 - Special Plenary Panelists

Anna Jensen
Chief Operating Officer, President and Board Chair, Restoration Partners, LLC

Anna Jensen is COO of Restoration Partners and brings over 20 years of experience in operations, management, and economic development. She spent a decade as a partner at ACDS, LLC, a management and economic development firm, and served as Executive Director of the New York AgriDevelopment Corporation, where she demonstrated her ability to grow organizations and lead larger teams. Her background also includes managing software distribution for an oilfield geosteering company, giving her firsthand experience navigating technologically driven industries. Additional roles as Associate Faculty at Tyler Junior College and Director of Special Projects for the Texas Department of Agriculture have given her a broad understanding of organizational development across diverse sectors. Anna is also a certified Project Management Professional.

Dennis Gilmore, Ph.D.
Chief Operating Officer, Structeryx, Inc.

Dr. Dennis Gilmore is an executive with over four decades of experience in technology creation for aerospace, energy, electronics, healthcare and defense industries. In addition to his executive position at Structeryx, he is also the President of Crosslynk Research & Consulting which focuses on providing technology commercialization guidance services to universities, research institutes and start-up companies. Prior to Crosslynk Research he held positions of Vice President of Discovery Science & Technology at RTI International, Executive Director of Research Product Development Company in Saudi Arabia, and global technology leadership positions in PPG Industries and Royal Dutch Shell. Dennis has led the development and global commercialization of more than 200 new products and processes in multiple industries and has extensive experience in formation and operation of international joint ventures as well as technology licensing activities. Dr. Gilmore received his B.S. from Missouri State University and his Ph.D. in Chemistry from Duke University.

Day 3 - Morning Session

Time	Friday, July 10, 2026	
8:30 – 9:30	**Parallel Technical Sessions** (Location: Session A in Mitchell Auditorium, and Session B in Hill Conference Room)	
	Session A6: Microbial Induced Calcite Precipitation for Self-Healing in Concrete; Moderator: Cristina De Nardi	**Session B6:** Polymeric Self-healing and Self-sensing II; Moderator: Hsiao Wei Lee
8:30	Understanding Calcium Carbonate Polymorph Formation during Microbially Induced Calcium Carbonate Precipitation; **Yacoub Alqenai*** (Drexel University, USA)	Recyclable and Reconfigurable Soft, Self-Healing Electronics: A Reality or a Myth?; **Ehsan Mirabdollah* & Seppe Terryn** (Vrije Universiteit Brussel, Belgium)
8:50	Enhancing MICCP Process in Self-Healing Concrete by Addressing Cell Encapsulation and Investigating the Impact of Exogenous Carbonate Ions; **Kiana Ahmari*** (Drexel University, USA)	A Model Reaction for Metathesis-Based Self-Healing in Conductive Polymers; **Henrike Zacher*** (TU Ilmenau, Germany)
9:10	Genetic Regulation for Microbial Self-Healing Concrete; **Suzy Chen** (Princeton University) and **S. H. Chu** (Aalto University, Finland)	Simple Solvent-Swell Method for Fabrication of Complex Microvascular Networks in Fiber Reinforced Polymer Composites; **Wojciech Guziewicz*** (AGH University of Krakow, Poland)
9:30 – 11:00	**Poster Session with American-style Brunch** (Moderators: Jialuo He and Chris Sales; Location: Bossone Lobby)	
11:00 – 13:00	**Closing Session & Awardees' Keynote Lectures Ceremony** (Moderators: Amir Farnam, Jason Patrick, and Nele De Belie; Location: Mitchell Auditorium)	
11:00	Mid-Career Award Keynote: Healing and Beyond: Superabsorbent Polymers in Cement-based Materials; **Prof. Didier Snoeck**, Université Libre de Bruxelles, Belgium	
11:45	Early-Career Award Keynote: Self-healing Soft Robots: Bridging Material and System-level Research; **Prof. Seppe Terryn**, Vrije Universiteit Brussel, Belgium	
12:30	Best Research, Oral Presentation and Poster Winner Announcements	
12:40	ICSHM 2026 Team Recognition	
12:50	ICSHM2028 Announcement and Closing Remarks	

Note: An asterisk (*) denotes student presenters.

Day 3 - Awardee Keynote Speakers

Mid-Career Awardee

Healing and Beyond: Superabsorbent Polymers in Cement-based Materials

Prof. Didier Snoeck

Université Libre de Bruxelles, Belgium

Didier Snoeck is an Associate Professor at Université Libre de Bruxelles (ULB) Belgium, and holds the chair on Sustainable Structural Design. His work focuses on innovative and sustainable concrete, with particular attention to durability, self-healing materials, and fiber-reinforced cementitious materials. He conducts research on superabsorbent polymers in concrete, which enhance crack control, mitigate shrinkage, and promote self-sealing and autogenous healing. Didier Snoeck has received the RILEM Gustavo Colonnetti Medal in recognition of his contributions to advanced concrete and cementitious materials research. Through academic publications and collaborations, he supports the development of more resilient and environmentally responsible construction materials.

Early-Career Awardee

Self-healing Soft Robots: Bridging Material and System-level Research

Prof. Seppe Terryn

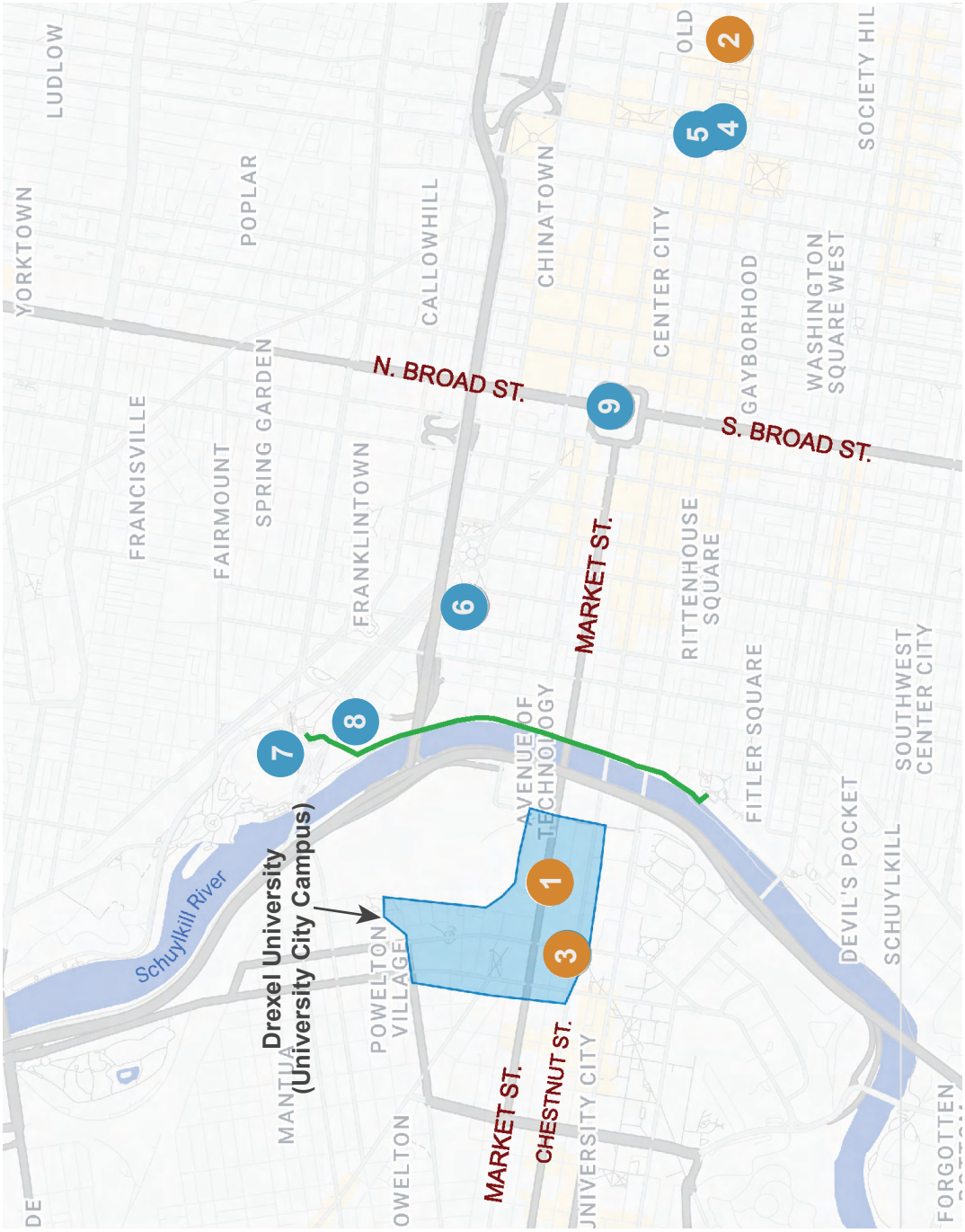
Vrije Universiteit Brussel, Belgium

Seppe Terryn is an assistant professor at Brubotics, the sustainable human-centered robotics laboratory of the Vrije Universiteit Brussel (VUB), and imec. His research bridges materials science, robotics, and machine learning, creating a strong synergy between self-healing polymers and damage-resilient systems. He pioneered self-healing soft robots, publishing a landmark paper in Science Robotics in 2017. He has co-led major national and EU projects (EIC FET Open SHERO, MSCA SMART, EIC Transition SHINTO), focusing on the interface between self-healing polymers and soft robotics. During his postdoctoral fellowship, partly conducted at the University of Cambridge (UK), he developed the novel idea of combining material-based healing—often limited to partial recovery—with software compensation through machine learning. Recently, he initiated a new research line on self-healing medical phantoms for repeated surgical training. Moreover, S. Terryn is also a part-time Business Developer at imec and co-created the start-up Valence Technologies that aim to commercialize self-healing polymers in transport and robotics. Today he acts as a scientific advisor for the company.

Day 3 - List of Posters

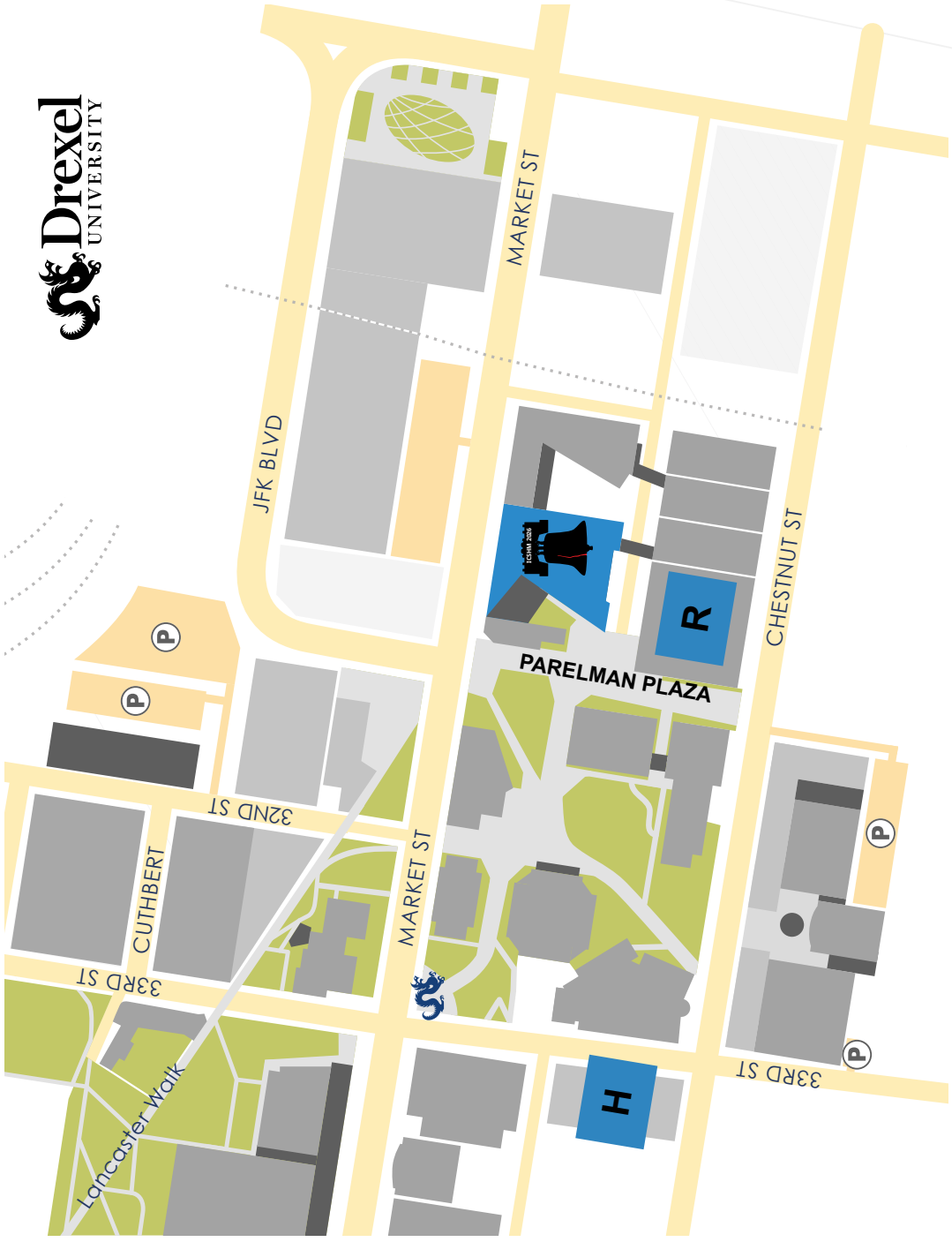
Number	Title	Affiliation(s)
P-1	Self-healing Concrete Mixed with CCU-Based Calcium Carbonate and GGBS	Wakaba Takaishi, and Keiyu Kawaai (Ehime University, Ehime, Japan)
P-2	Latent DCPD-Based Photo-Triggered Self-Healing Formulation	Sandra Idelman , and Charles E. Diesendruck (Technion, Israel)
P-3	Self-Healing Energetic Composites Based on Microencapsulation of Isocyanates	Cheli Kotler, Charles E. Diesendruck (Technion, Israel)
P-4	Enhanced Crack-Healing Performance of Bacteria-Based Self-Healing Mortar through Alginate–Vacuum Encapsulation in Off-Spec Fly Ash Lightweight Aggregates	Mohammad Irfan Iqbal (Drexel University, USA), Puput Risdanareni (State University of Malang, Indonesia), Monita Olivia (State University of Riau, Indonesia), Yousif Alqenai, Bankole Tejuoso, Geetika Mishra, and Yaghoob (Amir) Farnam (Drexel University, Philadelphia, PA, USA)
P-5	Efficiency Analysis of Inorganic Pollutant Removal Using Mineral Cement and Aggregate Replacements in Pervious Concrete	Joanna Fronczyk (Warsaw University of Life Sciences, Poland), and Wojciech Franus (Lublin University of Technology, Poland)
P-6	Advancing Self-Healing of Aged Concrete: A Hydrogel-Based Vascular Approach for MICCP Activation	Geetika Mishra, Noelle Lilan, and Yaghoob (Amir) Farnam (Drexel University, USA)
P-7	Self-Healing Biomanufactured Protein Fibers	Hasanur Rahman, and Melik Demirel (Penn State University, USA)
P-8	Enhancing MICCP Process in Self-Healing Concrete by Addressing Cell Encapsulation and Investigating the Impact of Exogenous Carbonate Ions	Kiana Ahmari, Seyed Ali Rahmaninezhad, and Christopher Sales (Drexel University, USA)
P-9	Bi-based Mitigation of Concrete Corrosion in Marine Environments Using Bacterial Activity	Parsa Namakiaraghi, Geetika Mishra, Irene Verdu, S. Musfirah, Ahmad Najafi, Chris Sales, and Yaghoob (Amir) Farnam (Drexel University, USA)
P-10	Design and Material Principles for Autonomous Alignment and Healing Multilayer Soft Electronics	Alexandra L. Ramos Figueroa, Christopher B. Cooper, Samuel E. Root, Lukas F. Michalek, Hyunchang Park, Yuran Shi, Jian Qin, and Zhenan Bao (Stanford University, USA)
P-11	Vascularized Microbial Systems for Self-Healing Concrete: Experiments and Phase-Field Modeling	Li Meng, Alireza Ashkpour (Drexel University, USA), Hsiao Wei Lee (National Cheng Kung University, Taiwan), and Ahmad Najafi (Drexel University, USA)
P-12	Numerical Study of Prolonged Crack Healing in Concrete with Microencapsulated Healing Agents	Alireza Ashkpour, Li Meng (Drexel University, USA), Hsiao Wei Lee (National Cheng Kung University, Taiwan), and Ahmad Najafi (Drexel University, USA)
P-13	Beyond Crack Filling: Predicting the Post-Healing Fracture Behavior of MICCP-Treated Cementitious Composites	Hsiao Wei Lee (National Cheng Kung University, Taiwan), Seyed Ali Rahmaninezhad, Li Meng, Alireza Ashkpour, Mohammad Irfan Iqbal, Geetika Mishra (Drexel University, USA), Wil V. Srubar, Mija H. Hubler (University of Colorado, Boulder, USA), Christopher M. Sales, Yaghoob Amir Farnam, and Ahmad Najafi (Drexel University, USA)
P-14	Beyond bacteria: what really drives carbonate-based self-healing in cementitious cracks	Martyna Janek (Lublin University of Technology, Poland), Joanna Fronczyk (Warsaw University of Life Sciences-SGGW, Poland), and Wojciech Franus (Lublin University of Technology, Poland)

Philadelphia City Map



1. Bossone Research Enterprise Center (Conference Venue)
2. Museum of the American Revolution (Gala Dinner)
3. The Study at University City (Hotel)
4. Independence Hall
5. Liberty Bell
6. The Franklin Institute
7. Rocky Statue and Phil. Museum of Art
8. Schuylkill River Trail
9. City Hall

Drexel Campus Map

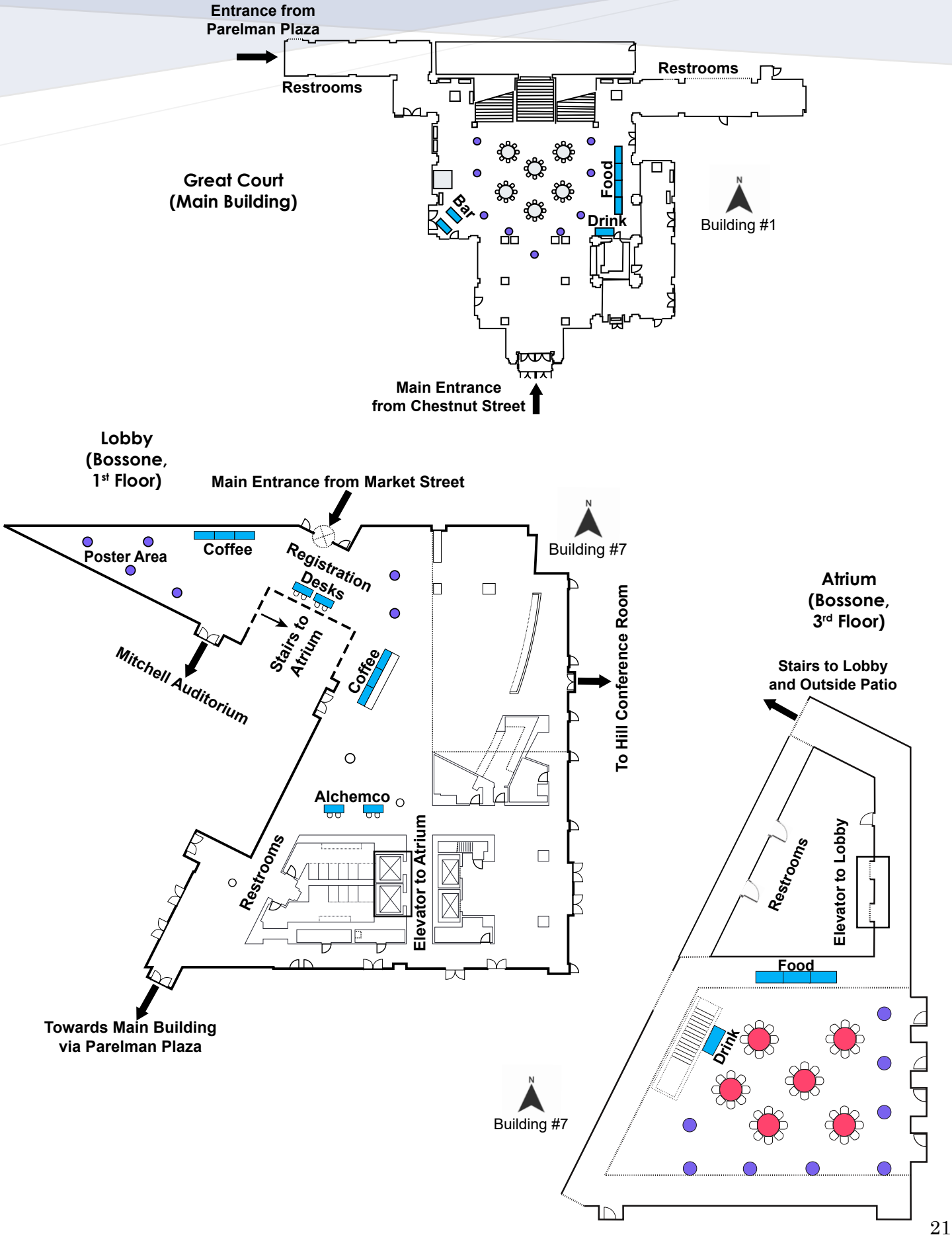


Bossone Research Enterprise Center (Conference Venue)

R Main Building (Opening Reception Venue)

H The Study at University City (Hotel)

Conference Venue Maps



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ICSHM2026

See you at ICSHM2028!

PHILADELPHIA 2026 JULY 8-10 ICSHM 10th International Conference on Self-healing Materials

Self-healing Concrete with Emphasis on Bio-based Techniques

Abhijit Mukherjee, *Curtin University, Australia;*

Section: A1; **Presented by:** Abhijit Mukherjee

Self-healing materials represent a transformative class of smart systems capable of autonomously repairing damage, thereby extending service life and reducing maintenance requirements. Among these, self-healing concrete has emerged as a particularly promising solution for addressing its inherent brittleness and crack-susceptibility on one hand and the difficulties of access and compatible material systems on the other. Cracking in concrete not only compromises structural integrity but also facilitates the ingress of water and aggressive agents, accelerating deterioration and increasing lifecycle costs.

This presentation will discuss the evolution self-healing concrete. Starting from the autogenous healing of concrete, it will expand to augmented self-healing where the healing material is embedded inside concrete. It will discuss different healing formulations and strategies of embedding them. Our research on biologically driven self-healing mechanisms, with particular emphasis on bacterial concrete will be introduced. The numerical models for designing the self-healing concrete systems will be presented. The lifecycle, cost and environmental implications of self-healing systems will be discussed. Finally, our attempts to commercialize self-healing concrete additives will be presented.

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Beyond Bacteria: What Really Drives Carbonate-based Self-healing in Cementitious Cracks

Martyna Janek, *Lublin University of Technology;*
Joanna Fronczyk, *Warsaw University of Life Sciences - SGGW;*
Wojciech Franus, *Lublin University of Technology;*
Section: A1; **Presented by:** Martyna Janek

Microbially induced carbonate precipitation (MICP) is widely explored for autonomous crack healing in cementitious materials; however, the influence of environmental conditions, precursor chemistry, and curing regime on healing efficiency and precipitation behavior remains insufficiently understood. This study investigates how variations in Ca/Mg ratios, precipitation precursors, and curing environments affect carbonate formation and crack-scale healing in cement mortars modified with MICP-based healing agents.

Controlled precipitation experiments were performed using selected calcium and magnesium precursors, with and without Bacillus subtilis. In parallel, cement mortars incorporating the corresponding healing systems were prepared, and carbonate products formed under controlled conditions and within the cementitious matrix were analyzed for healing product identification. Mortar specimens were exposed to different curing conditions (water and precursor solutions), and healing performance was quantified by crack area reduction together with recovery of mechanical and transport-related properties.

Multiple polymorphic forms of calcium carbonate were identified, along with additional crystalline phases formed in the absence of bacterial activity. The cementitious matrix promoted mineral precipitation and supported abiotic crack filling, demonstrating the strong influence of the matrix environment on healing behavior. Functional assessment of mortars revealed high healing efficiency, enabling near-complete crack closure and substantial restoration of transport-related properties under appropriate curing. Mechanical recovery was partial, reaching up to 49% depending on the healing regime.

The results indicate that carbonate formation and crack-scale healing are primarily governed by precursor chemistry, Ca/Mg ratio, and curing environment. These findings provide a framework for optimizing MICP-based healing systems through targeted control of compositional and environmental parameters.

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Self-healing Functionalisation Strategies of Textile-reinforced Mortars

Niki Trochoutsou*, Politecnico di Milano;*
Liberato Ferrara*, Politecnico di Milano;*

Section: A1; **Presented by:** Liberato Ferrara

Next generation retrofitting systems should integrate sustainable and durable technologies to address the increased vulnerability of cultural heritage structures, in an era of climate change. Integration of self-healing technology into Textile-Reinforced Mortar (TRM) systems, which are currently regarded as one of the most suitable retrofitting solution for heritage structures, offers a promising, yet largely unexplored pathway. It is still uncertain whether key parameters known to govern autogenous healing also affect the self-healing mechanisms in TRM systems, and to what extent.

This study summarises the key outcomes, potential and challenges of the development of self-healing TRM systems, comprising an alkali-resistant glass textile embedded into either cement- or lime-based mortars. Both TRM constituents (i.e. textile and mortar) were imparted with self-healing characteristics, through the development of inorganic textile coating solutions and sustainable mortar formulations incorporating crystalline admixtures and silica fume, including a systematic investigation of their individual and synergistic effects. The self-healing performance was assessed in detail, through sorptivity, crack sealing and stiffness recovery indices.

The results highlight the favourable action of silica fume and crystalline admixtures in promoting distributed internal healing, while silica-fume based coatings were found to enhance interfacial bond and facilitate localised calcite precipitation. The underlying decoupled and synergistic self-healing mechanisms are elucidated, new assessment self-healing performance indices are proposed, providing a framework for the functionalisation of TRM systems, tailored to meet the specific performance criteria of heritage structures.

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Electrical Impedance Tomography and Spectroscopy for Imaging Bio-mediated Healing in Vascularized Concrete

Moe Pourghaz, *North Carolina State University;*
Panji N. Darma; *North Carolina State University;*
Irene Verdú, *Drexel University*;
Sumeet Musfirah; *Drexel University*;
Erica Alston, *Drexel University*;
Mija H. Hubler, *University of Colorado at Boulder;*
Ahmad R. Najafi, *Drexel University*;
Christopher M. Sales, *Drexel University*;
Geetika Mishra, *Drexel University*;
Wil Srubar, *University of Colorado at Boulder;*
Yaghoob (Amir) Farnam, *Drexel University*;
Section: A1; **Presented by:** Moe Pourghaz

Microbially Induced Calcium Carbonate Precipitation (MICP) is an emerging bio-based technique with significant potential to enhance the healing capacity and durability of concrete. The process utilizes specific bacteria that precipitate calcium carbonate ($CaCO_3$) as a byproduct of their metabolic activity, enabling crack filling and improved structural integrity. To better understand and optimize MICP, we employ Electrical Impedance Tomography (EIT) and Electrical Impedance Spectroscopy (EIS) to monitor and visualize calcium carbonate precipitation. A series of experimental scenarios were designed to investigate the MICP process using combined EIT and EIS measurements. Results demonstrate that sequential differential imaging techniques enable both qualitative and quantitative visualization of calcium carbonate formation during the MICP process.

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Self-healing Mechanisms in Ultra-ductile High-strength Cementitious Materials and Structural Components

Jianlei Wen, *University of California, Irvine;*
Wei Geng, *University of California, Irvine;*
Amadeu Malats Domenech, *University of California, Irvine;*
Mo Li, *University of California, Irvine;*

Section: A1; **Presented by:** Mo Li

This study aims to understand the intrinsic healing process and mechanisms in novel cementitious materials that integrate ultra-high compressive strength and tensile ductility. Robust self-healing was observed from the top surface of full-scale bridge slab connections made of the novel cementitious materials, under complex field conditions. To understand the fundamental chemical and physical mechanisms responsible for the observed self-healing in full-scale and field conditions, small-scale laboratory specimens were fabricated and subjected to various controlled environmental exposure conditions. Using scanning electron microscopy, X-ray computed microtomography, chemical analyses and mechanical characterization, the experiments analyzed the healing products and quantified the healing ratios at the top surface of cracks as well as along the crack depth. In addition, a coupled transport-thermodynamics model was formulated to explain crack wall profile change with time due to healing. The results shed light on the intrinsic healing mechanisms in ultra-ductile high-strength cementitious materials within structures, in both laboratory and field conditions.

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Gelatin as a Nucleation Scaffold to Enhance Enzyme-induced $CaCO_3$ Precipitation for Self-healing Concrete

Irene Verdú, *Drexel University;*
Parsa Namakiaraghi, *Drexel University;*
Erica Alston, *Drexel University;*
Yaghoob (Amir) Farnam, *Drexel University;*
Christopher M Sales, *Drexel University;*
Section: A2; **Presented by:** Irene Verdu

Microbial-induced calcium carbonate precipitation (MICCP) is an emerging approach for self-healing concrete. In MICCP, microorganisms generate carbonate ions through different metabolic pathways; these ions react with calcium ions (Ca^{2+}) available in the surrounding environment to precipitate calcium carbonate ($CaCO_3$). In addition to supplying carbonate, bacterial cells contribute directly to mineral formation: their negatively charged cell walls provide nucleation sites that attract Ca^{2+}, enabling crystal growth, attachment, and long-term stabilization. A key limitation, however, is that MICCP performance is strongly dependent on bacterial viability and sustained growth, which can be difficult to maintain in cementitious environments.

To reduce this biological dependence, enzyme-induced carbonate precipitation (EICP) has emerged as an alternative that uses the responsible enzyme directly. This approach offers a more controllable reaction and typically produces $CaCO_3$ more rapidly. Nevertheless, because EICP lacks bacterial cell walls, it also lacks the nucleation surfaces needed to effectively initiate, bind, and organize mineral crystals.

To address this challenge, the present study explores gelatin, a negatively charged biological hydrogel, as an artificial nucleation scaffold to enhance EICP. Different concentrations of gelatin type B (isoelectric point 4.7–5.3) were mixed with urease (extracted from bean meal), urea, and calcium acetate, then incubated at room temperature for 24 hours. The precipitates were characterized using X-ray diffraction and scanning electron microscopy to identify mineral phases and morphology. Results indicate that increasing hydrogel concentration promotes the formation of multiple crystalline $CaCO_3$ polymorphs (vaterite, calcite, and aragonite) while decreasing the overall amorphous fraction. This suggests gelatin supports crystallization, which may improve mineral stability and enhance self-healing efficiency in concrete applications.

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Exploring Fungal-induced Mineralization for Crack Healing in Cementitious Mortar

Nuo Bao, *Lousiana State University;*
Yen-Fang Su, *Lousiana State University;*
Hai (Thomas) Lin, *Lousiana State University;*

Section: A2; **Presented by:** Nuo Bao

Fungal-induced mineralization is a promising pathway for healing cracks in cementitious materials, yet quantitative, time-resolved monitoring of healing remains limited. This study evaluates two filamentous fungi (Neurospora crassa and Aspergillus niger) selected based on the mineral precipitation screening in urea–calcium media, where XRD indicates distinct mineral products (calcite for N. crassa and calcium oxalate for A. niger). Mortar cylinders (2 in. × 4 in.) were pre-cracked using controlled splitting tensile strength tests to generate cracks. Healing was conducted for up to 90 days, and additional specimens were maintained as controls at the same age to isolate the net healing effect. Healing progression was tracked using shear-wave velocity measurements (bender elements) at multiple time points through 90 days. At 90 days, compressive tests were performed on both healed and non-healed specimens to assess mechanical property recovery attributable to healing. Preliminary results indicate that, at 90 days, fungal-treated specimens achieved 70% higher compressive strength than age-matched controls.

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Bacterial Nanocellulose for Repair and Repeated Self-healing of Concrete

Hyun-Woo Joo, *Colorado School of Mines;*
Yao Wang, *University of Texas at Arlington;*
Wil V. Srubar III, *University of Colorado at Boulder;*
Mija H. Hubler, *University of Colorado at Boulder;*
Section: A2; **Presented by:** Mija Hubler

Sustainable repair technology is required to extend the service life of concrete infrastructure. This study explores the potential of using bacterial nanocellulose (BNC) for biological concrete repair via fibrous interfacial bridging combined with regenerative performance. Flexural tests in biologically repaired concrete show that the use of in situ BNC restores flexural strength comparable to biomineralization-based methods, with further improvement achievable through integration with biomineralization technologies. Beyond in-situ application, a novel ex-situ BNC taping strategy delivers high flexural strength recovery (up to 78%), operational simplicity, as well as repeated self-healing across three splitting tensile cycles. Scanning electron microscopy (SEM) on BNC reveals fibrous bridging on concrete, interaction with biomineral, and nanofiber regeneration, while Fourier transform infrared spectroscopy (FT-IR) indicates structural disturbance on BNC by biomineralization and progressive adhesion loss during repeated healing. These results establish BNC as a versatile repair material restoring mechanical performance and durability and offer a pathway toward practical self-sustaining infrastructure repair.

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Fatigue-induced Healing Mechanisms in Self-compacting Natural Hydraulic Lime Concretes

Ángel De La Rosa, *Universidad Rey Juan Carlos;*
Gonzalo Ruiz, ETSI Caminos, C. y P., *Universidad de Castilla-La Mancha*;
Section: A2; **Presented by:** Gonzalo Ruiz

This study examines the activation of autogenous self-healing in self-compacting natural hydraulic lime concretes containing pozzolanic additions when subjected to cyclic compressive loading. Six mixtures were designed, incorporating silica fume, metakaolin, fly ash, natural volcanic pozzolan, limestone powder, and one steel fiber reinforced variant. Fatigue tests were conducted under load-controlled cycles at 1 Hz, with stress levels ranging from 0.20 to 0.85 fc.

Only the metakaolin, fly ash, and natural pozzolan concretes developed runout specimens. The metakaolin mixture (HPLC 3) exhibited the most pronounced self-healing response. Runout specimens showed increases of up to 12% in compressive strength and 17% in elastic modulus compared with non-fatigued controls, as well as enhanced pre-peak stiffness in stress–strain curves. Fatigue curves displayed a stable secondary strain phase whose slope correlated logarithmically with fatigue life, evidencing the interplay between damage accumulation and healing.

Microstructural analyses (TGA–DSC, XRD, MIP) revealed that specimens subjected to high numbers of cycles developed increased $CaCO_3$ and $Ca(OH)_2$ contents, indicating carbonation, hydration, and rehydration as dominant healing mechanisms. Mercury intrusion porosimetry confirmed refined pore structures and reduced macroporosity in runout specimens, consistent with densification and crack filling. In contrast, low-cycle specimens exhibited higher porosity and macropores associated with fatigue damage.

These results demonstrate that cyclic compressive loading can effectively activate autogenous self-healing in lime-based concretes enriched with reactive pozzolans, enhancing microstructural recovery and mechanical performance. The findings support their potential use in sustainable and heritage construction exposed to cyclic actions.

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Evaluation of the Healing Capacity of Limestone Calcined Clay Mortars

Marwa Hassan , *LGCGM, INSA Rennes, Université de Rennes;*
Kinda Hannawi , *LGCGM, INSA Rennes, Université de Rennes;*
Aveline Darquennes , *LGCGM, INSA Rennes, Université de Rennes;*
Section: A2; **Presented by:** Marwa Hassan

The development of sustainable cementitious materials with enhanced durability is a major challenge in modern construction. Autonomous self-healing has emerged as a promising strategy to extend service life while reducing environmental impact. Limestone Calcined Clay Cement (LC3) represents a low-carbon alternative to conventional Portland cement, combining reduced clinker content with favorable alumina-rich chemistry. Its composition suggests potential for continued hydration and secondary phase formation that may contribute to crack closure.

This study evaluates the intrinsic autogenous self-healing capacity of LC3 mortars. Pre-cracked specimens were monitored under water curing conditions, and crack-sealing performance was assessed through crack width reduction and water flow test. The findings indicate that the crack-sealing efficiency of LC3 remains limited, particularly for cracks exceeding typical autogenous healing thresholds.

These observations suggest that intrinsic autogenous mechanisms alone may not be sufficient to ensure effective crack closure in LC3-based systems. Supplementary strategies should therefore be considered. Potential approaches include the incorporation of expansive agents, which have shown promising performance in repair mortars for ageing concrete structures in recent studies, or the implementation of internal curing techniques to sustain hydration and enhance continued reaction within the matrix.

This work carried out within the framework of the ANR SHREM project funded by a French national grant, establishes a foundation for future development of enhanced self-healing strategies in sustainable LC3-based repair materials.

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Effect of Crack Pre-healing on Sulfate Degradation for Self-healing Concrete With Bacteria-based or Crystalline Admixture Healing Agents

Vanessa G. Cappellesso, *Ghent University;*
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Section: A3; **Presented by:** Nele De Belie

Cracked and uncracked concrete specimens containing different types of healing agents were subjected to a sulfate containing environment before and after completing a dedicated 3 months wet–dry cycle healing regime. The healing agents studied were a bacteria-based healing agent and a crystalline admixture and the induced cracks had widths of around 100 or 300 µm. All samples were submerged in a 50 g/L Na_2SO_4 solution for up to 18 months. The degradation was followed by measuring expansion, mass variation, and strength, supported by microstructural analyses.

The healed bacteria-based specimens showed delayed early sulfate ingress and expansion, but this effect diminished over time, especially after 12 months. The crystalline admixture reduced permeability of the matrix and limited sulfate ingress in this way, hereby limiting the formation of expansive reaction products and exhibiting minimal expansion. The results indicated that the primary contribution of crystalline admixture lies in transport control and matrix densification rather than extensive crack filling.

Crack width significantly influenced expansion in healed specimens, where larger cracks were less completely healed. In unhealed specimens, expansion was even higher due to unrestricted sulfate ingress in the cracks, with a less pronounced effect of crack width. While a healing period for the cracks before exposure reduced early sulfate penetration, its effectiveness reduced under prolonged exposure.

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Influence of Micro-climate Conditions on Concrete's Carbonation

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Panagiota Manita, *Democritus University of Thrace;*
Kosmas Sideris, *Democritus University of Thrace;*
Section: A3; **Presented by:** Kosmas Sideris

Having attained strength requirements, the new problem arising in last decades is the durability of concrete structures. During the research, it has resulted that it is not enough to know the factor that affects concrete (i.e. carbonation, chloride ingress, etc). It is also important to know the influence of the microclimate conditions, such as temperature, relative humidity, and CO2 percentage, on the exposure class.

Focusing on carbonation, as the one of the most common causes of deterioration, four (4) regions of Greece with different climatical conditions were selected in order to assess the influence of the microclimate on concrete's carbonation. Six (6) concrete mixtures were tested using as design parameters the strength class of concrete (3 classes) and the addition of crystalline admixture. All the mixtures were exposed in the selected areas and the exposure class was XC4, according to EN 206-1. Measurements were taken at the ages of 90 and 180 days and the results quantify the effect of the local microclimate on the carbonation index.

Results available indicate that addition of crystalline admixtures reduces the carbonation rate of concrete in all exposure sites tested, thus increasing the service life against carbonation induced corrosion of concrete mixtures.

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Antimicrobial Self-healing Concrete to Mitigate Biogenic Sulfuric Acid Corrosion: Confocal Microscopy and SEM Evidence From Pseudomonas Aeruginosa Biofilms

Emilio Minoru Takagi, *Aeronautical Institute of Technology (ITA)/Penetron international;*
Maryangela Geimba de Lima*, Aeronautical Institute of Technology (ITA);*
Ronaldo A. Medeiros Junior*, Federal University of Paraná (UFPR);*
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Section: A3; **Presented by:** Emilio Minoru Takagi

Concrete is widely used in wastewater infrastructure, yet it remains highly vulnerable to microbially induced corrosion of concrete (MICC) driven by biogenic sulfuric acid (BSA). Conventional mitigation approaches typically rely on either dense concrete design or surface protection; however, severe sewer atmospheres, characterized by elevated H2S, high humidity, and active biofilms, demand multifunctional solutions. This study proposes and evaluates an antimicrobial self-healing concrete concept intended to simultaneously (i) hinder microbial colonization and acid generation at the surface and (ii) reduce ingress of aggressive agents and microcrack connectivity through self-healing mechanisms, thereby improving durability in splash and vapor-phase exposure zones.

An in-situ exposure program was conducted for 180 days at the Berazategui Wastewater Treatment Plant (Buenos Aires, Argentina), where specimens were subjected to operational conditions associated with advanced MICC. The protective strategy integrates antimicrobial and crystalline/self-healing functionalities and is conceived for future applications not only in sewer assets but also in emerging concrete structures for biomethane production systems (e.g., biodigesters), where biofilm control and chemical resistance are critical.

To directly assess antimicrobial performance, biofilm development on concrete surfaces was investigated using Pseudomonas aeruginosa inoculated media. Confocal Laser Scanning Microscopy (CLSM) and Scanning Electron Microscopy (SEM/MEV) were employed to visualize biofilm formation and surface colonization, enabling qualitative and semi-quantitative comparison among concrete formulations. The combined field exposure and microscopy-based biofilm evaluation provides an integrated framework to guide the design of maintenance-efficient, MICC-resistant concrete systems for aggressive wastewater environments.

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Case Study in the Tren Maya Project, Mexico Using Enzyme Based Waterproofing

Mario Baggio, *Alchemco USA;*

Section: A3; **Presented by:** Mario Baggio

This presentation will highlight an international infrastructure case study where reinforced concrete structures were exposed to harsh environmental conditions accelerating corrosion risk. The session will review the project challenges, performance requirements, and the waterproofing/corrosion protection strategy implemented to reduce permeability, limit moisture and chloride intrusion, and improve long-term durability. Practical lessons learned will be shared, focusing on constructability, speed of installation, and sustainability for large-scale bridge and transportation projects.

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Prolonged Crack Healing in Concrete With Microencapsulated Secondary Healing: a Numerical Study

Li Meng, *Drexel University;*
Hsiao Wei Lee, *National Cheng Kung University;*
Alireza Ashkpour, *Drexel University;*
Section: A4; **Presented by:** Ahmad R. Najafi

The idea of concrete capable of self-repair (namely, the self-healing concrete) was proposed around two decades ago, initially with a focus on various healing mechanisms and kinetics, with a recent focus shift to the development of advanced technologies to implement the healing material that push forward the healing duration and cycles (i.e., capable of multiple crack-healing cycles). The inner vascularized networks that deliver healing agents to crack sites, or the embedded microcapsules or various biofibers that break along with the concrete fracture to release healing agents, are two of the widely investigated approaches. However, to reach a prolonged healing performance, where concrete's re-cracked surfaces after first-time healing can still regain certain strength after closure without repeated treatment during crack-healing cycles, requires special consideration. In this study, a prolonged healing strategy that combines the primary healing matrix with microcapsules as a secondary healing effector is investigated numerically using the cohesive zone model. A concrete cylinder with a middle crack surface subjected to the proposed treatment is investigated, where its direct tensile strength is utilized as a metric for strength recovery. Critical factors, including material parameters of the healing effectors, capsule volume ratio, and capsule center-to-center distance, are investigated. The results demonstrate a suitable setting for conducting the experiment and the essential consideration of balancing the initial structural strength and secondary healing effect.

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Direct Tensile Testing and Fracture Behavior of Microcapsules

Alireza Ashkpour, *Drexel University;*
Li Meng, *Drexel University;*
Hsiao Wei Lee, *National Cheng Kung University;*
Ahmad Najafi, *Drexel University;*

Section: A4; **Presented by:** Ahmad Najafi

Microencapsulated self-healing concrete systems rely on controlled capsule rupture during fracture; therefore, understanding the fracture-stage mechanics prior to healing is critical for reliable design. This study presents a numerical investigation of fracture behavior in capsule-embedded concrete specimens subjected to direct tensile loading, focusing on the effects of boundary conditions, interface properties, and capsule mechanical characteristics before healing is activated. A combined computational framework is employed in which the phase-field fracture method is used to simulate crack evolution and loading-condition effects, while cohesive zone modeling represents interfacial debonding and capsule–matrix interactions. Two tensile-test configurations, namely the clamped configuration and the cable-type configuration, are examined to evaluate the influence of eccentricity, surface irregularities, and porosity on structural response. Parametric analyses investigate the role of concrete–healing matrix interface strength, capsule–matrix bonding, capsule volume fraction, and capsule size. Results indicate that weak interfacial bonding promotes interfacial failure and suppresses capsule rupture, whereas strong bonding shifts fracture to the capsule shell and surrounding matrix, enabling effective activation of healing agents. Increasing capsule volume fraction or reducing shell strength enhances rupture probability but may reduce the initial tensile strength of the composite, revealing a trade-off between structural integrity and activation reliability. Capsule size also affects stiffness and fracture response; for the same volume ratio, using a larger number of smaller capsules slightly decreases the stiffness. These findings provide design guidelines for optimizing encapsulated self-healing concrete systems and establish the mechanical baseline for subsequent healing-stage simulations.

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Fracture and Statistical Mechanics for Design of Architected Cementitious Composites: Experiment, Theory, and Simulation

Reza Moini, *Princeton University;*
Aimane Najmeddine, *Princeton University;*
Shashank Gupta, *Princeton University;*

Section: A4; **Presented by:** Reza Moini

Concrete has limited damage dissipation mechanism. There is a growing possibility of using additive manufacturing techniques to design more advanced cementitious composites for fracture and damage resilience. This talk presents how advanced multi-material additive manufacturing can be coupled with advanced numerical tools (phase field-cohesive zone modeling) to engineer the next generation concrete composites and rethink concrete as a composite material. Advanced design tools based on statistical mechanics are proposed for the field of architected materials broadly, and provide a powerful tool to capture and quantify order in arrangements of heterogeneous natural such as concrete and architected counterparts. “Disorder” curves and statistical mechanics parameters, radial distribution function, g2(r), and translational (T) orientational (Q) order parameters are proposed for the first time to quantitatively and characterize the degree of disorder. The approach can quantify heterogenous and architected arrangement of materials such as in tubular motifs in cortical bone or in cement-based counterparts, in lieu of otherwise inadequate “periodicity” classification and misperceived disorder parameters. This approach formalizes a quantifiable metric into design of materials arrangement (solid or pore). The design, mechanics, and manufacturing approaches proposed to study fracture can be used for engineering morphologies applicable to self-healing applications in the future.

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Multi-physics Modeling of Fracture-healing Response in Self-healing Concrete With MICCP and Phase-field Model

Hsiao Wei Lee, *National Cheng Kung University;*
Seyed Ali Rahmaninezhad, *Terracon Consultants, Inc.;*
Li Meng, *Drexel University;*
Alireza Ashkpour, *Drexel University;*
Mohammad Irfan Iqbal, *Drexel University;*
Geetika Mishra, *Drexel University;*
Wil V. Srubar, *University of Colorado Boulder;*
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Christopher M. Sales, *Drexel University;*
Yaghoob Amir Farnam, *Drexel University;*
Ahmad Najafi, *Drexel University;*
Section: A4; **Presented by:** Hsiao Wei Lee

Self-healing concrete has gained research momentum due to its potential to substantially reduce maintenance costs. Among various candidate healing mechanisms, microbial-induced calcium carbonate precipitation (MICCP) is often preferred over other alternatives when sustainability and compatibility are focused. MICCP is a biomineralization process utilizing microbial metabolic activities to precipitate calcium carbonate (CaCO3) crystals, offering an autonomous repair solution that is highly compatible with the concrete matrix. However, despite extensive experimental literature, the complete numerical modeling of the fracture-healing response resulting from such treatments in concrete cracks remains relatively scarce. In this work, a MICCP model that considers the entire biochemical and enzyme kinetics during the healing process is first established, with additional consideration for fluid mechanics if spatial distribution information is needed. Then, a fracture simulation method based on the finite element method with the phase-field model (PFM) is introduced. The integration of these two models leads to the development of an uncoupled damage-healing framework, which links MICCP healing with PFM fracture, comprising three stages: Stage 1 fracture, Stage 2 healing, and Stage 3 re-damage of the post-healing structure. The framework is used to predict damage-healing performance based on different governing factors, and the results are compared with experimental data. It is shown that healing time, which contributes to increasing the crack-filling ratio, is of equivalent importance to the stiffness provided by the MICCP. Moreover, the results are sensitive to whether the loading pattern remains consistent between the pre- and post-healing stages.

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Laboratory Assessment and Numerical Modeling of Self-healing Concrete With Lightweight Aggregates Encapsulated by Modified PVA

Jialuo He, *Widener University;*
Yong Deng, *South China University of Technology;*
Sinisa Mesarovic, *Washington State University;*
Xianming Shi, *University of Miami;*
Section: A4; **Presented by:** Jialuo He

The technology of using lightweight aggregates (LWAs) in external self-healing systems for concrete emerged in 2010s and it has been mainly employed to reserve bacteria in microbial self-healing concrete. On the other hand, research related to self-healing concrete with polymer encapsulated LWAs mainly focuses on evaluating the healing performance of different abiotic healing agents in strength or durability recovery by crack sealing. In this study, the optimal modifying strategy for enhancing the compatibility of polyvinyl alcohol (PVA) encapsulation and its bonding strength with concrete matrix was developed upon response surface methodology. By measuring the contact angle of distilled water on the modified PVA film and its bond strength with cement paste, the hydrophilicity and bond strength of modified PVA film revealed the desired values for PVA concentration and dosage of modifier as well as curing time and temperature. Additionally, a numerical model based on linear elastic fracture mechanics was established to predict the mechanical healing efficiency of the LWAs-based external self-healing system in concrete. It is verified by experimental data of the three-point bending test from pre-cracked mortar specimens after various healing periods.

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Durability Indicators and Concrete Service Life: Difference in Values Measured in the Laboratory Concrete and on Site Concrete

Konstantinos Androutsos, *Democritus University of Thrace, Greece;*
Panagiota Manita, *Democritus University of Thrace, Greece;*
Kosmas Sideris, *Democritus University of Thrace, Greece;*
Section: A5; **Presented by:** Kosmas Sideris

It is widely accepted that the values of durability of concrete provided from a laboratory test according to standards differ from those obtained from the corresponding concrete used on site. In an attempt to quantify this difference, a broad research plan was initiated into the main durability problems facing Greece, i.e. carbonation and chloride ingress.

Six (6) concrete mixtures were produced using as design parameters the strength class and the content of crystalline admixture. The mix design of each concrete was provided by the concrete industry. The six mixtures were produced and cured on site and the exposure classes were XC4, XS1, XS2 and XS3. At the testing age, the specimens were transferred and tested in the laboratory. The measurements lasted up to 180 days.

At the same time, the corresponding mixtures were produced, cured and measured in the laboratory, according to the standards. The properties measured were compressive strength, carbonation resistance according to EN 12390-10 (natural and chamber conditions), carbonation resistance according to EN 12390-12, chloride diffusion according to EN 12390-11 and chloride migration according to NT Build 492 standards. The measurements lasted up to 180 days, when permitted by the standards.

Results reveal that service life estimated using the laboratory tests differ significantly from the actual one on site. Addition of crystalline materials reduced this difference and increased the service life of concrete mixtures on site.

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Self-healing Properties of Hennebique Concrete Over 130 Years old

Daan Appeltans, *Université libre de Bruxelles;*
Didier Snoeck, *Université libre de Bruxelles;*

Section: A5; **Presented by:** Didier Snoeck

The deterioration of old reinforced concrete structures constitutes a growing technical challenge, particularly for historically significant systems such as those developed by Hennebique. A better understanding of the intrinsic properties, durability, and healing potential of this Hennebique concrete is essential to support sustainable conservation strategies. This research investigates the autogenous crack-healing capacity of historical Hennebique concrete extracted from the Law Court of Verviers, one of Belgium's earliest large-scale reinforced concrete buildings. The research focuses on autogenous healing driven by calcium carbonate crystallization, identified as the dominant healing mechanism in aged concrete. Cracks were induced through splitting tests, and crack closure was monitored using microscopic observations. Healing was stimulated under controlled environmental conditions, including continuous water submersion and wet–dry cycling in both tap water and seawater. The results demonstrate a significant self-healing potential, with crack closure reaching up to 75%, and up to 94% for narrower cracks. The durability of Hennebique concrete was evaluated through water absorption, low-pressure water permeability, and porosity assessment. The material showed elevated water absorption, low bulk density, and high porosity. Durability performance was inferior to that of modern concretes, with pronounced carbonation and substantial chloride ingress under seawater exposure. Overall, the work establishes a novel experimental basis for evaluating self-healing in historical concretes and supports informed decisions on conservation, reuse, and sustainable extension of the service life of heritage concrete structures.

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Case Study - the use of the Crystalizing Additive in the Mitigation of Leakage in a Water Treatment Plant

Leonardo Otto Coutinho*, Alchemco, Brazil*;

Section: A5; **Presented by:** Leonardo Coutinho

This article aims to present the results obtained through visual inspection of a case study carried out in a water treatment plant that used the crystallizing additive in reinforced concrete. This water treatment plant at the time of its filling presented several points of water percolation and that over time, it was possible to visually observe the formation of crystals that in several cases ended up filling the cracks in the structure. The objective of this case study is to visually verify the reaction resulting from the use of crystallizing additives presented in the formation of an insoluble crystalline structure in the pores and capillaries of the concrete, and its ability to prevent the passage of water through capillarity, microcracks or cracks in the reinforced concrete structure. The research results demonstrated that the crystallizing additive was effective in mitigating and blocking the passage of water within the reinforced concrete structure. Over time, an evolution of the crystallization process was observed, further strengthening the resistance to water penetration. However, some technical limitations of the additive were also identified, mainly in relation to its performance in the face of cracks that exceed these limits.

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Self-healing Concrete Commercialization in the US

Anna Jensen, *Restoration Partners;*

Section: A5; **Presented by:** Anna Jensen

The commercialization of Basilisk self-healing concrete technologies in the United States presents unique challenges that extend beyond traditional technology transfer paradigms. Since October 2024, Restoration Partners has been working to introduce Basilisk Self-Healing Agent (SHA), MR3 Self-healing Repair Mortar, and ER7 Liquid Repair System to the US construction market, navigating complex regulatory, economic, and industry-specific barriers.

This presentation will examine three critical challenges encountered during the commercialization process. First, the impact of evolving trade policies and tariffs on importing specialized biotechnology products from Europe, including cost implications and supply chain complexities. Second, the inherent conservatism of the concrete construction industry, where new technologies face skepticism despite proven performance benefits, requiring extensive demonstration projects and regulatory approvals. Third, the strategic considerations for establishing domestic manufacturing capabilities to reduce costs, ensure supply security, and meet "Buy American" requirements for infrastructure projects.

Drawing from real-world commercialization experience, this presentation will discuss market entry strategies, stakeholder engagement approaches, and the development of US-based manufacturing partnerships. Key topics include navigating ASTM and ACI standards adoption, building relationships with contractors and specifiers, addressing liability concerns, and the economic modeling required to justify transitioning from traditional repair methods to self-healing technologies.

These insights provide valuable lessons for researchers and companies seeking to commercialize innovative self-healing materials in established construction markets, highlighting the intersection of technical innovation, regulatory compliance, and market dynamics in successful technology transfer.

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Life-cycle Cost Optimization of Concrete Repairs: Reducing Total Ownership Cost Without Increasing Risk

Mario Baggio, *Alchemco USA;*

Section: A5; **Presented by:** Mario Baggio

Life-cycle cost analysis (LCCA) is a core component of DOT decision-making for bridge preservation and rehabilitation. However, durability considerations are not always fully integrated into LCCA models, leading to solutions that minimize initial cost but increase long-term maintenance risk.

This presentation examines how durability-focused repair and protection strategies can improve life-cycle cost outcomes without compromising performance or safety. It explores the relationship between repair longevity, intervention frequency, and total ownership cost, emphasizing the role of corrosion mitigation and moisture control in extending service life.

Using comparative scenarios, the presentation illustrates how investing in durability-enhancing measures can reduce the number of future interventions, lower user-delay costs, and improve budget predictability. The discussion aligns with DOT asset management objectives by framing durability as a risk-management strategy rather than an added expense.

The presentation concludes by proposing a durability-integrated LCCA approach that supports transparent, defensible decision-making consistent with FHWA and AASHTO preservation principles.

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Understanding Calcium Carbonate Polymorph Formation During Microbially Induced Calcium Carbonate Precipitation

Yacoub Alqenai, *Drexel University;*
Geetika Mishra, *Drexel University;*
Irene Verdú Fillola, *Drexel University;*
Christopher Sales, *Drexel University;*
Yaghoob Farnam, *Drexel University;*
Section: A6; **Presented by:** Yacoub Alqenai

Microbially induced calcium carbonate precipitation (MICCP) has been widely investigated for self-healing concrete applications; however, achieving reliable polymorph control and maintaining precipitation efficiency especially under alkaline conditions remain critical challenges. This study examines the combined influence of bacterial strain, calcium source chemistry, environmental pH, and time on calcium carbonate formation and stability. Two ureolytic bacteria, Lysinibacillus sphaericus and Bacillus subtilis, were cultivated in media containing yeast extract and urea with either calcium lactate or calcium acetate as the calcium source. Precipitation behavior was evaluated under native pH, pH 9, and pH 12 conditions to simulate cementitious environments.

Scanning electron microscopy, x-ray diffraction (and thermogravimetric analysis were performed to characterize and quantify calcium carbonate and its polymorphs. Systems containing calcium acetate yielded dominantly vaterite for both bacterial strains, indicating rapid formation of the metastable phase. In contrast, calcium lactate promoted slower mineralization, resulting in 55–60% calcite and 40–45% amorphous content at the same age. Environmental pH of 9 produced the highest calcium carbonate yield, whereas pH 12 significantly reduced and delayed precipitation. To evaluate the stability of the initially formed phases, recovered precipitates were stored and reanalyzed after 14, 28, and 56 days. Minimal polymorphic transformation was observed during storage, suggesting that phase distribution was largely established during active biomineralization rather than post-formation aging. These findings demonstrate that precipitation kinetics, governed by calcium source chemistry, environmental pH, and strain-dependent alkaline tolerance, play a central role in determining polymorph selection and overall MICCP efficiency in concrete-relevant environments.

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Enhancing MICCP Process in Self-healing Concrete by Addressing Cell Encapsulation and Investigating the Impact of Exogenous Carbonate Ions

Kiana Ahmari, *Drexel University;*
Seyed Ali Rahmaninezhad, *Drexel University;*
Christopher Sales, *Drexel University*;
Section: A6; **Presented by:** Kiana Ahmari

Bacterial cells play an important role in calcium carbonate formation during microbially-induced calcium carbonate precipitation (MICCP) reactions in bio-self healing of concrete. Recent microbiological studies unveiled the inhibitory effects of cell encasement by calcium carbonate crystals on bacterial behavior and metabolism. However, mitigating the negative impact of cell encasement remains a challenging subject. To fill this research gap, this study aims to address the negative impact of cell encapsulation on biomineralization efficacy and enhance bacterial growth and metabolism in calcium-rich environments. Through in vitro and cement mortar experiments, this research study investigated the role of the buffering capacity of the micro-environment on cell encapsulation, urea hydrolysis, and biomineralization kinetics in MICCP reactions. This study revealed that in calcium-rich environments, bacterial cell surfaces are encapsulated by calcium carbonate crystals, reducing cell growth and consequently urea hydrolysis and calcium carbonate production. However, maintaining the buffering capacity of the micro-environment by adding exogenous sodium carbonate can accelerate bacterial growth, urea hydrolysis, and biomineralization, expediting crack-filling in cement mortar specimens. These findings provide mechanistic insight into the importance of mitigating cell encapsulation during MICCP, specifically by maintaining the buffering capacity to enhance the concrete crack-filling rate.

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Harnessing *Bacillus Subtilis* for Self-healing Concrete: A Case Study on Sandcrete Mortar

Ewane Michael Ebongpende, *University of Bue;*
Ines Ngassam, *University of Buea;*
Section: A6; **Presented by:** Ewane Micheal Ebongpende

Cracks are one of the major contributors to the deterioration of concrete structures, significantly reducing its durability and serviceability. Cracks develop due to natural structural settlement, shrinkage and external loads, providing pathways for harmful agents. The induction of CaCO3(S) precipitation via bacterial action, has a promising conclusion that microbiologically induced CaCO3(S) Could be a useful approach for remediation of shallow cracks on existing concrete structures, by introducing the followings (bacteria, its nutrients and organic precursors) during concrete mix. In this probing, Bacillus subtilis a gram-positive, alkali-resistant, and spore-forming bacterium was cultivated and incorporated into mortar specimens alongside urea and calcium chloride as nutrients. Laboratory evaluations were conducted to compare the performance of bacteria-infused mortar (bio-mortar) with conventional (control) mortar. Key parameters assessed include water permeability via capillary absorption, compressive strength at multiple curing intervals, apparent density, setting time, calcium carbonate precipitation, and microbial viability post-curing. The bio-mortar exhibited a substantial reduction in water absorption, with enhanced compressive strength compared to the control mortar. Microscopic visualization and chemical analysis confirmed the presence of CaCO3(S) deposits in cracked zones, evidencing successful precipitation of calcium carbonate. Furthermore, the bacteria remained viable after curing, demonstrating resilience under harsh alkaline conditions and validating their role in long-term healing activity. This investigation highlights the promises of biomineralization as a sustainable, cost-effective, and environmentally friendly approach to improving the durability and service life of concrete infrastructures.

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Genetic Regulation for Microbial Self-Healing Concrete

Suzy Chen, *Princeton University;*
S.H. Chu, *Aalto University, Finland;*

Section: A6; **Presented by:** Suzy Chen

Microbial self-healing concrete typically relies on bacteria that can survive alkaline concrete conditions and form calcium carbonate when cracks admit water and oxygen. A key question is therefore biological as well as materials-based: which bacteria should be used, and how can their activity be guided without compromising concrete performance? This study focuses on genetics-guided bacterial mineralization as a route to address this question. Concrete-relevant alkaliphilic, spore-forming bacteria, including *Bacillus pseudofirmus* and *B. cohnii*, provide suitable starting points because of their high-pH tolerance and established relevance to bacterial concrete. *Bacillus subtilis* provides a genetically tractable reference system for testing regulatory principles. The main biological variables are survival in simulated pore solutions, recovery after wetting, and carbonate-mineralization activity. Functional screening, promoter-reporter assays, inducible expression, and targeted gene perturbation can be used to connect these variables with genes involved in alkaline-stress tolerance, spore maintenance, metabolic activation, and mineral formation. Candidate targets include carbonate-generating enzymes such as carbonic anhydrase and urease-associated pathways, while by-products and carrier compatibility must be monitored. Comparing wild-type, loss-of-function, and regulated-expression strains provides a direct way to link microbial genetics with capsule and carrier design. By positioning bacteria as tunable functional agents rather than passive additives, this approach connects microbial genetics directly with capsule and matrix design, pointing toward more controllable microbial self-healing concrete.

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Moisture Activated Durable and Autonomous Self-healing Epoxy Coating Using Boronic Ester Dynamic Bonds

Sachini Dissanayake*, Deakin University, Australia;*

Section: B1; **Presented by:** Sachini Dissanayake

Achieving reliable healing without compromising mechanical stability in boronic ester assisted self-healing systems remains a significant challenge. In moisture-activated systems, the benefits of dynamic bond exchange must be balanced against the risk of humidity-driven softening and degradation. In this work, we first investigate how environmental factors govern autonomous healing by examining the interplay between temperature, humidity, and chain mobility in boronic ester–based epoxy coatings under realistic ambient conditions. Healing behaviour was assessed under four representative environments (i.35 °C/85 % RH, ii.35 °C/50 % RH, iii.25 °C/85 % RH, and iv.25 °C/50 % RH) using quantitative scratch recovery, supported by mechanical, thermal, and moisture-response characterisation. The results showed that healing efficiency is governed by the cooperative action of temperature and humidity: elevated humidity facilitates bond exchange, while increased temperature enhances molecular mobility. When the glass transition temperature approaches or exceeds the service temperature, humidity partially compensates for restricted chain motion, enabling healing even under limited mobility.

To address material deterioration observed under prolonged humidity exposure, a second set of networks was designed incorporating both dynamic and static crosslinks to balance healing capability with structural stability. These hybrid networks exhibited rapid humidity-assisted healing while retaining load-bearing capacity and suppressing moisture-induced plasticisation, in contrast to highly dynamic systems. Overall, this study demonstrates that effective self-healing under realistic environmental conditions requires not only responsive dynamic bonds but also deliberate control of network architecture to mitigate long-term moisture damage, providing design guidance for developing durable self-healing epoxy coatings suited for real-world service environments.

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Proof-of-concept: Healable and Recyclable Flax Fiber Composites With Catalyst-free Vitrimer Matrix for Infrastructure Applications

Shagata Das, *University of Delaware;*
Dan Luckenbill, *University of Delaware;*
Karim Garifullin, *University of Delaware;*
Megan Malherb, *University of South Carolina;*
Sagar Doshi, *University of Delaware;*
Srikanth Pilla, *University of Delaware;*
Jovan Tatar, *University of Delaware;*
Section: B1; **Presented by:** Jovan Tatar

Sustainable alternatives to conventional fiber-reinforced polymers (FRPs) are needed to reduce the carbon footprint and end-of-life waste associated with commonly used glass and carbon fiber systems. With a focus on bridge applications in the northeastern United States, this study evaluates flax fiber–reinforced (vitrimer) polymer composites (vFFRPs) engineered for intrinsic healing and recyclability. A vitrimer matrix formulation was optimized to balance healing capability with structural performance, achieving a flexural strength of 77 MPa, elastic modulus of 3,329 MPa, glass transition temperature of 62 °C and a topology-freezing transition temperature of 124 °C. Mode I interlaminar fracture tests on vFFRP composite showed that healing restored 23 to 48% of the crack-initiation load after the first healing cycle and 44 to 50% after the second cycle. In contrast, recovery of fracture toughness was lower—8.4% and 15.8%—because healed interfaces lack the fiber-bridging mechanisms that normally contribute substantially to toughness in virgin composites. Recyclability was demonstrated through solvolysis, which dissolved the vitrimer matrix and enabled recovery of intact flax fibers. Recycled fibers retained stiffness comparable to virgin fibers, and composites remanufactured with recycled flax preserved 72% of the tensile strength and 76% of the modulus. These results demonstrate the promise of vFFRPs as repairable, recyclable composites that can significantly reduce environmental impact of composites in construction applications.

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High Performance Epoxy Anhydride Vitrimers for Repairable and Recyclable Composite Structures

Jeffrey Masten-Davies, *Deakin University;*
Houlei Gan, *RMIT;*
Juan Zhang, *Jiangsu University of Technology;*
Russell Varley, *RMIT;*

Section: B1; **Presented by:** Russell Varley

New materials and technologies that enable the world to transition to more resource efficient practises and net zero emissions are urgent and necessary. Integral to this is the need to embed sustainability principles across all sectors of the economy, such as the right-to-repair, cost-effective recycling and re-use of materials and structures. Fibre reinforced epoxy composites are ubiquitous because of their highly desirable lightweight, high strength and stiffness properties and corrosion resistance, but are particularly problematic because their highly stable covalent bonds render them extremely difficult to recycle or even re-use. Until now, a common approach to recycling composites has been to grind them down and use the powder as a filler for some low value application. This approach is not sustainable and better, more innovative solutions must be found. An emerging family of resin systems known as vitrimers, presents an opportunity to overcome many of these challenges. By incorporating dynamic covalent bonding into their chemical structure, cured epoxy networks can be remoulded at elevated temperature, much like a high melt viscosity thermoplastic, despite being fully crosslinked. Furthermore, damaged composite structures can be repaired via polymer welding given sufficient heat and pressure. This talk will present recent progress towards the development high-performance epoxy based vitrimers, optimizing processing, and presenting examples of their weldability, re-use and repairability.

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Self-healing Mitigation Strategies for Droplet-induced Impact Damage in Wind Turbine Blade Leading-edge Coatings

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Nancy Sottos, *University of Illinois Urbana-Champaign;*
Section: B1; **Presented by:** Po-Wen Wang

Leading-edge erosion is the primary failure mode of wind turbine blades, with damage often occurring within the first two years of operation, well before the turbine's 25-30-year service life. Erosion is driven by repeated high-speed impacts from rain, sand, and hail, with blade tip velocities reaching 100 m/s. Even small water droplets and solid particles can substantially damage the surface. Developing strategies to mitigate erosion damage is critical to maximizing energy generation, extending blade lifetime, and reducing maintenance costs.

This study has two objectives (1) the selection of suitable materials for mitigating damage due to droplet-induced stress waves and (2) the development of an in-house protocol to simulate raindrop impact conditions in small coupon specimens. Conventional turbine erosion testing methods, such as whirling arm facilities, require large samples and are less accessible in academia. The experimental droplet-impinging simulating setup provides an accessible, material-efficient method for assessing performance under droplet impact conditions, suitable for exploring new materials and accelerating iteration. This setup is designed to simulate droplet impacts, as water droplets are the most frequent source of erosion for wind turbine blades and the unique damage mechanisms they induce.

We have successfully developed a laser spallation setup capable of generating stress waves that analogous to those generated during single droplet impact. We have utilized the platform to demonstrate the stress wave mitigation performance of polyurethane coatings made with different chain extenders and are working to incorporate dynamic bonding into polyurethane to make a coating that can dissipate stress and autonomously recover from erosion damage.

Study of the Reaction of Pyrex Powder and Baco3 as a Function of Temperature as a Probe for Generated Silica Reactivity

Jacob Hormadaly,*Ben-Gurion University Mariana Dov, Ben-Gurion University;*
Lonia Friedlander, *Ilse Katz Institute for Nanoscale Science and Technology, The Ben-Gurion University of the Negev;*
Beer-Sheva, *Israel Natalia Pears, Ben-Gurion University;*
Section: B2; **Presented by:** Jacob Hormadaly

Reaction between BaCO3 and Pyrex powder was studied as a function of temperature (500 to 950 °C), to understand the high reactivity of Pyrex as a silica source. Reaction progress was monitored by XRD and weight loss methods. XRD shows that some silica phases are formed at fairly low temperatures by the decomposition of Pyrex. It is speculated that these silica phases are the source of very reactive silica leading to the formation of silicates from Pyrex at previously unreported fairly low temperatures and short reaction times. Synthesis of blue and purple pigments via the reaction of Pyrex powder, alkaline earth carbonates, and cupric oxide to form MCuSi4O10 and BaCuSi2O6 where M=Ca,Sr,Ba are briefly discussed

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Self-healing Biomanufactured Protein Fibers

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Section: B2; **Presented by:** Hasanur Rahman

The history of regenerated protein fibers spans 150 years, encompassing the transition from the recycling of natural fibers (e.g., silk, wool) to the development of fermentation technology. The Demirel group has recently addressed this significant challenge by combining precision and biomass fermentation, thereby achieving scalable, cost-effective protein-based fibers. Protein fermentation is not limited to fibers resembling silk or wool; rather, it encompasses a broad spectrum of protein-based materials that rely on hierarchical structural assembly from repeated units. The evolution of these repeating units (e.g., coiled-coils, β-sheets, and β-turns/spirals) has produced structures with remarkable properties. Protein materials provide biological systems with impressive capabilities, including adjustable control over self-healing and structural, optical, electrical, and thermal properties. The properties of structural proteins are influenced by the identity of their repetitive units, which form long-range contacts and drive both assembly and function. Several natural protein materials exhibit exemplary properties, such as silks, squid ring teeth (Demirel Lab), and viral capsid. We established the “rules” for designing these repetitive units and programming their assembly to enhance specific material properties, such as self-healing, thermal or electrical conductivity, optical emissivity or reflectivity, and mechanical extensibility or strength.

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Additive Manufacturing for Scalable Fabrication of Self-healing Thermoplastic Composites

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Jack S. Turicek, *North Carolina State University;*
Jason F. Patrick, *North Carolina State University;*
Daniel Therriault, *Polytechnique Montreal;*
Section: B2; **Presented by:** Daniel Therriault

Self-healing thermoplastics are primarily studied with regards to soft materials with specialized applications, while their usage in structural thermoplastic polymer composites (TPCs) remain underexplored. Although thermally remendable copolymers have been used as healing agents in thermoset-based composites, their integration requires complex manufacturing methods, limiting them to the laboratory scale. The thermal activation requires additional heating elements, which further complicates the fabrication process and retention of mechanical performance. Here instead we utilize multimaterial extrusion-based additive manufacturing to fabricate structural self-healing TPCs in a single manufacturing step. This approach incorporates a low-melting-point thermoplastic healing agent and an electrically-conductive particulate-filled thermoplastic as the resistive heating element. Double cantilever beam-like specimens are fabricated using short glass fiber-reinforced polyamide filament, with conductive heating elements printed symmetrically in each beam arm. The healing agent is printed in narrow serpentine-shaped channels at the midplane within the desired crack region. Each specimen requires only 2.5 h to print with minimal post-processing. After testing in mode-I fracture, the heaters are activated to melt the healing agent such that it flows in the crack and adheres to the structural composite, while staying below the glass transition temperature of polyamide to maintain structural properties even during heating. After cooling by natural convection, repeated fracture tests show an average 97% recovery of the mode-I strain energy release rate compared to the virgin state with at least two cycles of healing. Overall, the multimaterial self-healing TPC achieves repeatable self-healing with a simplified production process, facilitating its possible integration in industrial applications.

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Self-healing Energetic Materials

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Section: B2; **Presented by:** Charles Diesendruck

Microcapsules are a well-established extrinsic self-healing technology, demonstrated in numerous polymers and composite materials. Although energetic materials are not classical candidates for self-healing, they are produced in large volumes and stored for years, undergoing experiencing repeated daily heating-cooling cycles. Given conventional energetic formulations contain over 80% solid crystalline inorganic oxidizers and about 20% soft polymeric binder, mismatch in thermal expansion coefficient promotes microcracking, which degrade both performance and safety. In this work, I describe the use of isocyanate-filled polyurethane microcapsules that withstand the hard mixing and casting processes of energetic formulations yet reliably rupture under mechanical stress to trigger autonomous healing.

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Repeatable Self-healing of Interlaminar Fracture in Prepreg Composites via in Situ Thermal Remending

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Jack S. Turicek, *North Carolina State University;*
Jason F. Patrick, *North Carolina State University.*

Section: B2; **Presented by:** Yerassyl Kuan

Fiber-reinforced polymer (FRP) composites engender lightweight structures with high performance but are inherently susceptible to interlaminar delamination arising from fiber-matrix debonding. This subsurface damage is difficult to detect and more challenging to repair, limiting the lifetime of structural composites. To address this challenge, self-healing strategies have emerged to auto-repair interlaminar fracture. Among these approaches, in situ thermal remending of thermoplastic interlayers has demonstrated delamination self-healing with hundreds to thousands of repair cycles in epoxy resin infused composites. However, translation of such repeatable self-healing strategies to prepreg (i.e., fiber reinforcement with pre-impregnated resin) remains limited, despite these FRP materials being the dominant manufacturing route for high performance/fiber volume fraction composite structures (e.g., aircraft).

Here we present a recently developed self-healing strategy in prepreg-based FRP composite laminates using a new thermoplastic healing agent (TPHA) and industrially compatible interlayer incorporation method. This new platform is compared to a prior thermal remending system (in both prepreg and infused composites) using a well established healing agent poly(ethylene-co-methacrylic acid) (EMAA). While thermal remending of EMAA interlayers provides repeatable self-healing of infused composites, it exhibits minimal fracture recovery for prepreg laminates. In contrast, the TPHA provides stable and repeatable recovery (> 100%) of mode-I fracture resistance (GIc) over ten healing cycles in both prepreg and infused composites. These latest results demonstrate the viability of thermal remending in prepreg composites and provide a practical pathway towards extending the performance and service life of FRP composite structures across application spaces.

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Bone-inspired Self-adaptive and Self-healing Materials for Resilient Future

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Section: B3; **Presented by:** Sung Hoon Kang

Living systems possess a remarkable ability to adapt, providing the resilience necessary to flourish in dynamic environments. Inspired by bone's ability to regulate mineral density in response to mechanical stress, this study investigates synthetic self-adaptive materials that modulate their properties based on loading conditions and repair/mitigate damages.

While natural structures like bone achieve optimal performance by strengthening areas under high load, replicating this in synthetic materials has remained a significant challenge. To address this, we developed a material system that triggers mineral deposition from electrolytes onto piezoelectric matrices upon mechanical loading. By controlling these loading conditions, we observed a 30–180% increase in material modulus.

Our research demonstrates that minerals preferentially form near crack tips where stress is concentrated. This process effectively blunts the crack and mitigates damage, resulting in a 90% reduction in crack propagation speed compared to controls. The material can also repair damages by preferential formation of minerals on damaged sites.

Furthermore, we have expanded the use environment of this mechanism by synthesizing liquid-infused porous piezoelectric composites—a design inspired by both bone and the pitcher plant. This approach yielded extraordinary results: over a 3,600% increase in modulus and a 3,000% increase in energy dissipation after 12 million cycles. These findings offer transformative strategies for developing resilient, sustainable materials capable of self-repair and adaptation in infrastructure, vehicles, medical implants, and other demanding mechanical environments.

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Design and Integration of Architected Vascular Network in Cementitious Materials

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Eleni Tsangouri, *Vrije Universiteit Brussel (VUB);*
Nele De Belie, *Ghent University (Ugent);*
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Section: B3; **Presented by:** Niyousha Niknezhad

Vascular networks in nature represent a promising approach to enabling autonomous functionalities (e.g., self-healing) in natural structures (e.g., skin tissue). This study attempts to integrate architected vascular network in mortar to create functional vascular cementitious composites (VASCC). Bio-inspired architectural designs are fabricated using 3D printing technology: parallel architectures inspired by bamboo structure, honeycomb architectures inspired by natural hexagonal cellular systems, sinusoidal architectures inspired by skin surface topology, and diamond and triangular architectures based on tessellated patterns. Each architecture is embedded within mortar and after curing, subjected to uniaxial tensile loading to characterize mechanical response. Nano-computed tomography (Nano-CT) imaging is performed after the tensile test to analyze crack initiation, propagation patterns, and void distribution within the composite matrix. The correlation between stress-strain curves and three-dimensional image analysis reveals that vascular network geometry significantly affects fracture behavior. Sinusoidal and triangular architectures demonstrate enhanced mechanical performance through improved toughness and crack deflection mechanisms via polymer slippage within the vascular channels. In contrast, diamond architecture reduces load-bearing capacity due to stress concentration effects at the vascular network and mortar interfaces. This integrated experimental-imaging approach provides quantitative insights into structure-property relationships in VASCC and establishes design guidelines for optimizing vascular network architecture for various functionalities, including self-healing.

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Biomimetic Vascular Networks for Cyclic Self-healing of Lime Mortars in Heritage Masonry

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Diane Gardner, *Cardiff University;*
Section: B3; **Presented by:** Cristina De Nardi

Built heritage faces increasing deterioration pressures as climate change amplifies the frequency and severity of damaging mechanisms, such as freeze-thaw cycling, moisture fluctuations, and salt crystallisation, placing unprecedented stress on lime-based masonry systems. Recent evidence indicates that these processes are accelerating, often reducing the durability of conventional repair strategies. This study presents an integrated biomimetic approach to autonomous crack repair in natural hydraulic lime (NHL) mortars, drawing on two complementary experimental investigations into the use of inorganic mineral-based healing agents delivered through sacrificial vascular networks.

Sacrificial vascular networks, created by removing embedded polyurethane tubes from prismatic NHL mortar samples, were used to deliver two classes of inorganic healing agents: nanolime dispersions ($Ca(OH)_2$ in water-ethanol solutions at 50:50 and 80:20 ratios) and lithium silicate solutions (LS15 and LS20 at 15 and 20 wt%). Healing performance was evaluated over periods ranging from 14 to 365 days using three-point bending tests, complemented by FT-IR, XRD, SEM, and EDS characterisation.

Nanolime treatments achieved up to 12% flexural strength recovery, with healing activity persisting for 280 days and microstructural analyses confirming compatibility with the NHL matrix. Lithium silicate demonstrated significantly stronger performance: LS20 achieved 187% strength recovery in early-age single-cycle tests, while LS15 showed superior repeatability across three successive damage-healing cycles, reaching up to 68% strength and 51% stiffness recovery after one year. SEM-EDS confirmed progressive C-S-H formation and matrix densification in treated specimens.

These findings establish vascular delivery of inorganic healing agents as a viable, compatible, and repeatable strategy for the durable preservation of historic masonry under evolving climatic conditions.

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Frontier of Extrusion-based 3d-printing for Design of Complex Tubular and 3D Vascular Architected Toolpaths

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Lara Tomholt, *Princeton University;*
Reza Moini, *Princeton University;*
Section: B3; **Presented by:** Shashank Gupta

Engineering tubular channels within cementitious materials offers pathways to enhance the crack-resilience in brittle construction materials, while vascular networks offer promising pathways for transport-driven self-healing. However, extrusion-based additive manufacturing of built-in channels/cavities remains challenging due to the absence of support materials, early-age deformations, and conventional slicing algorithms that generate layered non-continuous toolpaths. These factors limit geometric complexity and restrict the feasible design space for 3D-printing. These constraints highlight the need for creative approaches to expand this design space by advancing the 3D-printing processes and the design tools capable of generating stable, non-planar continuous toolpaths. Here, advancements for the design of complex toolpaths are proposed through the development of a parametric design-to-fabrication workflow that customizes toolpaths for tubular and vascular channel networks.

Grasshopper/Rhino-based parametric scripts are developed to generate toolpaths for tubular architected systems and inclined channel networks. Channel fidelity and stability are validated using micro-computed tomography and fluid flow analyses. These designs expand exploration for advanced crack-resistance or crack-healing applications, including engineered systems inspired by natural counterparts (e.g., cortical bone, leaf venation). Inspired by cortical bone, where tubular osteons and weak cement lines guide crack deflection while Haversian canals enable transport, tubular architected cementitious materials are designed to couple fracture resistance with functional transport pathways. Channel networks can also enhance carbonation through improved CO2 diffusion and establish predefined pathways that may enable targeted delivery of healing agents. Enabled by the parametric toolpath framework, these findings demonstrate how channels can integrate fracture resistance and transport functionality in 3D-printed cementitious materials.

From Root Canal to Concrete: Endodontics-inspired Vasculature for Targeted Bio-healing of Aged Cementitious Materials

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Geetika Mishra, *Drexel University;*
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Mija H. Hubler, *University of Colorado, Boulder;*
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Section: B3; **Presented by:** Mohammad Irfan Iqbal

Self-healing is a natural response to damage in living organisms. Recent research focuses on self-healing of cementitious materials that can restore structural integrity and mechanical performance of post-damage. Drawing inspiration from root canal technology in dentistry, we have developed a robust approach by creating artificial crack networks comprising drilled channels inside aged cementitious composites for self-healing activity. Drilled channel design serves adaptable approach within the cement composites such as (i) it provides delivery networks up to cracks ii) facilitates targeted delivery of healing-agents, and iii) ensures the retention of healing-agents until the damage occurs. Our preliminary study confirmed that the biological healing reagents can be delivered through the drilled channel at fracture location. Additionally, the effect of drilled channels on mechanical performance of concrete has been evaluated considering different aspects of channel design and integration. Furthermore, microbially induced calcium carbonate precipitation (MICCP) activity was investigated using optical microscopy, thermogravimetric analysis (TGA) and X-ray diffraction (XRD) to examine transportation of these biological healing agents and production of self–healing end–products, i.e., calcium carbonate, within the crack volume. The findings of this study revealed that utilizing a drilled channel can efficiently deliver healing agents in the desired region of interest which enhanced MICCP based crack healing on aged concrete.

Internal-external CO2 Curing Synergy: Enzymatic Hydrogel Strategy for Improved Carbonation of Wollastonite-based Cementitious Materials

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Abdullah Al Fahim, *Temple University;*
Section: B4; **Presented by:** Mehdi Khanzadeh Moradllo

Carbonatable binders present a promising pathway for carbon sequestration and sustainable construction materials. However, their broader adoption is limited by chemical, physical, and processing barriers that restrict CO2 transport into the matrix. Surface carbonation often leads to premature pore refinement and dense carbonate layer formation, which inhibits further CO2 penetration and reduces internal carbonation. These depth-dependent limitations significantly constrain the mechanical performance and carbon uptake capacity of carbonatable cementitious materials (CCMs). To address this challenge, this study introduces an innovative internal carbonation acceleration strategy based on hydrogels impregnated with a urea–urease enzymatic solution. The functionalized hydrogels act as internal microreactors that regulate local pH, supply bicarbonate ions, and provide nucleation sites for calcium carbonate precipitation during external CO2 curing. A multiscale experimental program was conducted to elucidate carbonation mechanisms, microstructural evolution, and bulk performance. The results demonstrate that hydrogels markedly enhance internal carbonate formation, achieving up to 15 times higher CaCO3 precipitation at internal depth compared to control specimens and reaching 82% of the theoretical degree of carbonation. External CO2 exposure stimulates urease catalytic activity, enabling sustained bicarbonate generation and promoting a uniform carbonation profile throughout the specimen thickness. Consequently, CCMs incorporating enzymatic hydrogels exhibited refined pore structures, reduced bulk porosity, increased electrical resistivity, and up to 80% higher compressive strength relative to control systems. Overall, the proposed internal–external CO2 curing synergy provides a scalable pathway for producing high-performance, carbon-sequestering construction materials with enhanced mechanical integrity and durability, advancing sustainable CO2 mineralization technologies for structural applications.

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Mechanically Activated Autonomous Self-healing of Volcanic-clay Cement Pastes Using a Novel Superabsorbent Hydrogel–cellulose Microfiber System

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Ester Vázquez, *Universidad de Castilla-La Mancha,*
Jesús Rodríguez, *Universidad Rey Juan Carlos,*
Rodrigo Moreno, *Instituto de Cerámica y Vidrio (CSIC);*
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Section: B4; **Presented by:** Ángel De La Rosa Velasco

This study presents an experimental investigation of the autonomous self-healing behavior of volcanic clay-based cement pastes incorporating a novel superabsorbent polymer–cellulose microfiber (SAP–CMF) system under cyclic compressive loading. The superabsorbent polymer, not previously applied in cementitious materials, enables mechanically triggered internal water release, while cellulose microfibers provide crack-bridging capacity and promote localized moisture retention in damaged regions. Volcanic clay derived from mining residues is used as a supplementary cementitious component to enhance sustainability and contribute to microstructural refinement. Cyclic compression acts as the activation mechanism, inducing localized moisture redistribution and facilitating crack closure. The results reveal a clear healing response, characterized by effective crack sealing and partial recovery of mechanical performance after repeated loading cycles. These findings demonstrate the potential of mechanically activated SAP–CMF systems for developing durable and sustainable self-healing cementitious materials.

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Self-healing Performance of Cementitious Materials with Hydrogel Under Marine Environment

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Ali Ghahremaninezhad, *University of Miami;*
Section: B4; **Presented by:** Farzad Rezaeicherati

Concrete infrastructures in marine engineering are highly vulnerable because service-induced cracks provide pathways for chloride and sulfate ions from seawater (SW), accelerating reinforcement corrosion and matrix degradation. This study examines the self-healing performance of hydrogel-modified cementitious materials under marine-relevant exposure, emphasizing how hydrogel-mediated moisture regulation interacts with the chemistry and microstructure of products that form within cracks. Two hydrogel systems (H2 and H3) were incorporated into Ordinary Portland Cement (OPC) and Portland Limestone Cement (PLC) pastes and subjected to cyclic wet/dry conditioning in deionized water (DIW) and SW to simulate field-like moisture and ion transport. Crack closure was monitored using digital microscopy, while crack-filling phases and interfacial characteristics were evaluated using thermogravimetric analysis (TGA), Fourier-transform infrared spectroscopy (FTIR), and scanning electron microscopy with energy-dispersive spectroscopy (SEM/EDS). By linking crack closure metrics with the nature and distribution of healing products, the work provides mechanistic insight into hydrogel-enabled self-healing in both non-aggressive and marine ionic environments. The outcomes support the development of durable, self-healing strategies for cementitious systems exposed to seawater, clarifying the coupled roles of internal curing, environmental ion composition, and binder chemistry on crack sealing and interfacial recovery.

Super Tough Multi-bond Network Hydrogels with Self-healable Properties

Xu-Ming Xie, *Tsinghua University, China;*

Section: B4; **Presented by:** Xu-Ming Xie

The intermolecular interactions and interface characteristics of materials play a crucial role in determining their physicochemical properties and functionalities. This study has systematically characterized the intermolecular and interface interaction mechanisms in self-healing multi-bond network hydrogels. The fundamental mechanisms elucidated, including polymer-metal ion coordination, hydrophobic, and hydrogen bonding interactions in aqueous media, have been further applied to the development of multifunctional soft materials, such as the intrinsic self-healability and high stretchability problems of a supercapacitor. Supramolecular interactions can not only improve the mechanical properties of hydrogels but also endow hydrogels with self-healing ability. To investigate the self-healing properties quantitatively, tensile tests are performed to measure the mechanical properties of healed cylindrical PAA-Fe3+ hydrogel hydrogel samples in comparison to the as-prepared gels. At a certain temperature, with the increase of healing time, the long polymer chains and ferric ions diffuse across the interface and form new ionic interaction between ferric ions and polymer chains in the contacted surfaces of the cut off cylindrical gel samples, leading to the recombination of the gel network in the interface. As a result, the healing efficiency increases along with lapsing time. The factors on promoting self-healing are deeply explored and the dynamic multi-bonds are regarded to trigger the self-healing along with the mutual diffusion of long polymer chains and ferric ions. These findings offer valuable insights into self-assembly processes of polymer gels and suggest new approaches to developing multifunctional soft materials via tunable noncovalent molecular interactions.

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The Effect of Temperature, Relative Humidity and Binder-sand Ratio Variations on Compressive Strength of Living Building Materials

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Mija Helena Hubler, *University of Colorado Boulder;*

Section: B4; **Presented by:** Gadisa Merdassa

The compressive strength properties of living building materials (LBMs) vary with individual variations in temperature, relative humidity, and binder content because LBMs are composites and have an environmentally sensitive hydrogel constituent as the main binding agent, which is highly susceptible to these factors. However, little is known about how these factors affect strength when acting together. This research examines this gap by using the response surface methodology (RSM) to formulate the combined effect of temperature, relative humidity, and the binder-sand ratio on compressive strength using the central composite design method of (CCD) design of experiment to quantify the main, interaction, and quadratic effects of environmental variables and mix designs on compressive strength. Specimens are prepared at controlled temperatures ranging from 10 to 80\(^\circ C\) with binder-sand ratios varying between 0.1 and 0.3 \(ml/g\), and a relative humidity range of 10-80\% kept constant at the intended value using various salt solutions for the specified temperature, followed by uniaxial compression tests after 24 hours of exposure. The results are expected to demonstrate how the compressive strength of LBMs varies with these factors by formulating the compressive strength as a function of the factors and identifying the factor (s) that have a significant impact on compressive strength. The study is relevant to establishing the guidelines for the structural application of LBMs in varying environmental and mix design scenarios.

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Interface Behavior of Periodic Dynamic Polymers With Identical Backbones and Distinct Dynamic Bonds

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Section: B5; **Presented by:** Alexandra Ramos Figueroa

Periodic dynamic polymers with periodically placed dynamic bonding sites are highly tunable chemical structures, providing a promising platform for robust, multifunctional soft electronic devices. By careful selection of polymer backbone and dynamic bonding chemistry, they enable reconfigurable networks and efficient self-healing at accessible temperatures. Despite progress in self-healing polymer-based devices, achieving robust adhesion and autonomous healing across multilayer systems remains a challenge. Here we investigate the thermodynamic immiscibility in pairs of self-healing polymers with identical flexible backbone (polydimethylsiloxane, PDMS) but different dynamic bonding interactions (i.e. hydrogen bonding (HB) and metal-ligand coordination (ML)). While polymer networks exhibit comparable thermo-rheological behavior and self-healing temperatures, interfacial adhesion tests show that less work is required to separate samples with different dynamic bond types, indicating dynamic bond-driven immiscibility. Atomic force microscopy confirmed the temperature and molecular architecture dependence in interfacial widths, with increased PDMS backbone length between dynamic motifs promoting enhanced diffusion. These findings provide a foundation for advancing multifunctional self-healing polymer networks by elucidating the role of molecular architecture and temperature in interfacial adhesion, selective healing, and autonomous multilayer alignment, enabling the design of more robust and adaptable smart materials.

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Recyclable and Reconfigurable Soft, Self-healing Electronics: a Reality or a Myth?

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Section: B5; **Presented by:** Ehsan Mirabdollah

Soft electronic systems are expected to play a central role in future technologies such as wearable devices, soft robotics, and human–machine interfaces. However, their widespread adoption is still limited by mechanical fragility, limited lifetime, poor recyclability, and constrained fabrication strategies. Conventional soft sensors often rely on irreversible polymers, require external stimuli for healing, or suffer from high hysteresis and signal drift. These limitations hinder long-term deployment, reconfiguration, and sustainable use. There is therefore a strong need for soft electronic platforms that combine intrinsic self-healing, stable sensing performance, recyclability, and design freedom within a single material system.

In this work, we present a family of self-healing and recyclable soft electronic sensors based on a Diels–Alder (DA) polymer matrix combined with gallium-based liquid metals (Galinstan). The DA polymer enables autonomous self-healing at room temperature without the need for external stimuli such as heat, light, or pressure. Thanks to the fluid nature of the liquid metal, the resulting sensors exhibit low hysteresis, low signal drift, and fast response under mechanical deformation. Importantly, both the polymer and the liquid metal can be recovered through a simple recycling process using heat and centrifugation, allowing the fabrication of fully recycled sensors with preserved functionality.

We demonstrate the versatility of this platform through several representative devices. First, we introduce a recyclable self-healing strain gauge sensor fabricated via liquid metal injection, highlighting the robustness of the sensing performance under repeated damage and healing cycles. Second, we integrate the strain sensor into a modular pneumatic soft gripper, where the sensor enables real-time detection of object grasping and mechanical damage to the actuator. Third, we present a multilayer touch sensor combining resistive and capacitive layers, enabled by strong interlayer bonding between different self-healing DA-based polymers.

Beyond individual devices, this material system offers a high degree of freedom in design and fabrication. The injection of liquid metals removes concerns related to multiple punctures, pressurized channels, and complex layer-by-layer alignment. Strong DA bonding enables multi-material and isotropic designs, which are particularly beneficial for three-dimensional architectures and additive manufacturing. Additionally, the intrinsic self-healing and fluid conductors allow reconfiguration and adaptation of devices over time, opening opportunities for multimodal wearable electronics, adaptive sensors, and soft robotic systems capable of sensing, actuation feedback, and object differentiation.

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Statistically Optimized Polymer Inclusion Membranes for Intelligent and High-Selectivity Calcium-Ion Separation

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Section: B5; **Presented by:** Arash Adhami

The rational design of multifunctional polymeric materials that exploit reversible molecular interactions is increasingly important for sustainable water treatment, resource recovery, and advanced separation technologies. Polymer inclusion membranes (PIMs) constitute a versatile class of supramolecular membrane materials, in which selective ion transport is governed by reversible host–guest interactions between carrier molecules and target ions while benefiting from the structural robustness of a polymer matrix. Compared with conventional liquid–liquid extraction systems, PIMs exhibit improved stability, reduced carrier loss, and enhanced selectivity for ion separation. In this work, a poly(vinylidene fluoride) (PVDF)-based PIM incorporating ZIF-8 metal–organic framework nanoparticles, benzo-18-crown-6 as the host carrier, and the ionic liquid 1-butyl-3-methylimidazolium chloride was developed and statistically optimized for selective Ca^{2+} transport. The crown ether reversibly complexes Ca^{2+} through host–guest molecular recognition, enabling facilitated transport across the membrane. Response Surface Methodology (RSM) with a Central Composite Design established quantitative composition–structure–performance relationships using only 18 experiments.

Statistical analysis identified a power-transformed quadratic model (R^2 = 0.94) that accurately described the dependence of calcium-ion flux on membrane composition. Among the investigated variables, ionic liquid content exerted the strongest influence on transport performance, while significant nonlinear and interaction effects highlighted the importance of balancing ionic liquid and crown ether contents to maximize facilitated ion transport. The optimized membrane composition (15 wt% ZIF-8, 1.5 g ionic liquid, and 0.61 g crown ether) achieved an experimental calcium flux of 51.12 $\mu mol \cdot cm^{-2} \cdot h^{-1}$, in close agreement with the model prediction of 55.35 $\mu mol \cdot cm^{-2} \cdot h^{-1}$. The optimized membrane further exhibited excellent selectivity toward Ca^{2+} over K^+, Na^+, and Mg^{2+}, with separation factors of 138.67, 392.52, and 1256.00, respectively. FTIR, XRD, SEM, and BET characterization confirmed successful incorporation of all membrane constituents while preserving the crystalline structure of ZIF-8 and the integrity of the membrane architecture.

Beyond demonstrating a high-performance separation platform, this study highlights how statistical modeling and optimization can accelerate the rational design of supramolecular polymeric materials whose functionality originates from reversible molecular recognition. The proposed framework provides a practical strategy for engineering next-generation functional membrane materials with enhanced transport efficiency, selectivity, and long-term stability. More broadly, because many stimuli-responsive and self-healing polymer systems are likewise based on reversible non-covalent interactions, the presented statistical design methodology offers a transferable approach for optimizing future supramolecular and self-healing material platforms.

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Design and Material Principles for Autonomous Alignment and Healing Multilayer Soft Electronics

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Autonomous realignment after damage is essential for restoring function and enabling long-term performance in multilayer self-healing devices, yet the molecular and geometric parameters governing this process remain unclear. Here, we establish molecular and geometric design parameters for directional realignment using periodic dynamic polymers (PDPs) that share similar hydrogen-bonding motifs but possess distinct flexible backbones (PDMS, PPG, and PFPE). We synthesize PDPs with different backbone chemistries to exhibit comparable modulus, thermo-rheological behavior, and self-healing temperatures. Bulk interfacial adhesion between polymer pairs is quantified using modified rheology techniques, revealing temperature-dependent reductions in work of separation consistent with dynamic-bond-driven immiscibility. Atomic force microscopy stiffness mapping confirms molecular-architecture dependence of interfacial width, enabling nanoscale quantification of interfacial mixing and adhesion. Preliminary observations suggest realignment behavior depends on both separation distance between damaged layers and individual polymer film thickness, indicating geometry plays a role in the realignment process. Differences in alignment rate across polymer pairs further imply surface energy variations influence alignment kinetics. By mapping structure-property-function relationships governing alignment speed and directionality within PDP pairs, this work establishes design principles enabling programmable autonomous realignment in multilayer self-healing electronic devices.

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Sustained Self-sensing and Autonomous Self-healing via Electro-thermal Coupling in Fiber-reinforced Composites

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Natural composites (e.g., bone, wood) have evolved sophisticated damage detection and self-repair capability which help preserve structural function throughout their lifespan. Like their biological counterparts, synthetic fiber-reinforced polymer (FRP) composites exhibit superior mechanical properties (high specific strength / stiffness) via a hierarchical arrangement of constituent materials. However, FRP composites do not yet mimic synergistic sensing/healing functionality. One longstanding challenge—interlaminar delamination (i.e., debonding of fiber reinforcement from the matrix)—has plagued FRP composites since their introduction nearly a century ago. This subsurface damage is difficult to detect and if so, often requires costly and labor-intensive manual repair. While self-healing and damage sensing strategies have been independently developed to help tackle these challenges, coupling such bioinspired abilities for reliable and repeatable performance in structural materials has remained elusive.

Here we present a new approach for sustained self-sensing and self-healing of delamination damage in FRP composites. Electrical monitoring of conductive polymer fibers (cPFs) signal and autonomously regulate in situ thermal remending of thermoplastic interlayers. By synchronizing the sensing and self-healing processes, 100 autonomous fracture/repair cycles are achieved. Self-healing efficiency, quantified by mode-I critical strain energy release rate (GIC), sustains 80% of the virgin fracture resistance for all cycles. Automatically probing electrical conductance of the cPF can accurately, repeatedly, and in real-time track damage plus self-repair, even showing sensor improvement with increased cycling. Thus, this newfound self-sensing/healing strategy creates competitive advantage for FRP composites, particularly those in harsh and inaccessible environments (e.g., space) where remote structural interrogation and autonomous self-repair is mission critical.

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Autonomous Alignment and Healing in Multilayers of Immiscible Dynamic Polymers for Damage-perceptive Soft Electronics

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Section: B5; **Presented by:** Samuel Root

Self-healing soft electronic and robotic devices, like human skin, can recover from damage. Existing multi-layer devices generally employ a single type of dynamic polymer embedded with different functional nano–micro materials for each layer, providing a cohesive interface. In such devices, successful healing from damage requires precise manual alignment of the fractured interfaces, limiting functional recovery from diverse forms of damage. To overcome these limitations, we designed a pair of dynamic polymers, which have immiscible polymer backbones, but similar dynamic bonding units (hydrogen bonding interactions), to maintain interlayer adhesion while providing selectively self-healing layers with similar viscoelastic behavior and self-healing dynamics. These dynamic polymers exhibit an adhesive interface, whose width and toughness are programmable through processing temperature. When multilayered polymer films are misaligned after damage, these structures autonomously realign during the healing process to minimize their interfacial free energy. Our experimental observations are captured by both coarse-grained molecular dynamics simulations and continuum phase field simulations, suggesting the generality of the proposed mechanism to other pairs of polymer backbones or dynamic bonding chemistries. Moving past multilayers of neat polymers, we designed and characterized a set of functional composites embedded with resistive, conductive, and dielectric particles. Using these composites, we developed an electronic skin capable of sensing three-dimensional damage inflicted by scalpel-incisions and needle-punctures at millimeter resolution. The ability to precisely detect punctures and incisions in soft, self-healable materials may have implications in the development of reusable, multisensory surgical simulation technology for training medical personnel and evaluating efficacy of surgical robotic systems.

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AI Meets Self-healing Polymers: Pinn-driven Approach in Unlocking Structure-property Relationships of Reversible Diels-alder Networks

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Section: B6; **Presented by:** Seppe Terryn

It has been demonstrated that Diels–Alder–based reversibly crosslinked networks can combine mechanical strength with room-temperature self-healing within minutes. They can be bio-based, recyclable, and compatible with additive manufacturing, with mechanical properties tuneable from ultra-soft to rigid—enabling applications from self-healing wound patches, suction cups, surgical phantoms to roofing, food packaging, and high-performance prototyping. However, this broad tunability—driven by numerous compositional parameters—makes it difficult to establish clear structure–property relationships for targeted material design. Here, we use AI-based tools to uncover these relationships, turning extensive experimental trial-and-error into a faster, more efficient design process. We adopted a physically informed neural network (PINN) approach, suited to our relatively small dataset (100 compositions), as it incorporates fundamental physical principles, including constitutive laws and general structure–property relationships for polymer networks. Compared with a standard neural network, PINNs showed lower prediction errors, demonstrating superior robustness and accuracy. We validated this approach with a novel use case: reusable skin patches for surgical training. After experimentally measuring the mechanical properties of a commercial skin phantom as the target, both models proposed candidate compositions. These were synthesized and tested, with the PINN delivering the closest match to the nonlinear mechanical response, while the standard NN also provided useful guidance. This led to the first prototype of a reusable, self-healing skin patch for surgical training. Overall, this work establishes a powerful, expandable toolbox for rapidly tailoring self-healing polymers to new applications with minimal experimental effort, unlocking the potential of this next generation of materials.

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A Model Reaction for Metathesis-based Self-healing in Conductive Polymers

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Section: B6; **Presented by:** Henrike Zacher

Conductive polymers such as polyacetylene are investigated as sustainable alternatives to conventional electronic components within the Ilmenau School of Green Electronics. Oxidative damage interrupts π-conjugation and leads to a loss of electrical conductivity.

Olefin metathesis, particularly cross-metathesis, is explored as a potential self-healing strategy. The central question is whether oxidised segments can be selectively replaced, thereby restoring π-conjugation. Since the selectivity of ruthenium-based metathesis catalysts toward conjugated, electron-deficient structures remains challenging, initial investigations are performed on a model substrate that mimics the structural and electronic features of oxidised polymer segments. This substrate consists of a central keto group bearing conjugated double bonds on both sides. Reactions with a moderately reactive alkene are monitored by LC-MS, and metathesis selectivity is derived from the resulting product distribution, specifically whether conversion preferentially occurs at the conjugated double bond adjacent to the oxidised functionality.

Initial LC-MS studies reveal various cross-metathesis products, confirming reactivity at different metathesis sites within the model substrate. Subsequent catalyst screening with Grubbs II (G2), Grubbs–Hoveyda I (GH1) and Grubbs–Hoveyda II (GH2) demonstrates pronounced catalyst dependence, with significant conversion observed exclusively for GH2. Time-resolved LC-MS data for the GH2-catalysed reaction indicate initially high catalytic activity followed by gradual deactivation.

Based on the established model reaction, this approach provides a foundation for further studies aimed at tuning metathesis selectivity through catalyst and ligand design to establish self-healing systems based on olefin metathesis.