In The News

U.S. interstates consider Purdue concrete invention to reduce road repairs

An increasing number of U.S. interstates are set to try out a new sensor from Purdue University in West Lafayette, Ind., that could save millions of taxpayer dollars and significantly reduce traffic delays.

The sensor allows concrete to "talk," decreasing construction time and how often concrete pavement needs repairs, improving the road's sustainability, and cutting its carbon footprint.

Embedded directly into the concrete when it is placed, the sensor sends engineers more precise and consistent data about the concrete's strength and need for repair than is possible using current methods.

"Traffic jams caused by infrastructure repairs have wasted 4 billion hours and 3 billion gallons of gas on a yearly basis. This is primarily due to insufficient knowledge and understanding of concrete's strength levels," says Luna Lu, the Reilly Professor and acting head of Purdue's Lyles School of Civil Engineering. "For instance, we don't know when concrete will reach the right strength needed to accommodate traffic loads just after construction. The concrete may go through premature failure, leading to frequent repairing."

Sensors developed by Luna Lu and her team at Purdue are installed into the formwork of Interstate 35 in Texas. Courtesy of Luna Lu.

Luna Lu's lab at Purdue University in West Lafayette, Ind., is focused not just on making roads stronger and safer but also on helping the environment. Lu is the Reilly Professor and acting head of Purdue's Lyles School of Civil Engineering. Courtesy of Purdue University/ Rebecca McElhoe.

Lu and her lab started developing the technology in 2017, when the Indiana Department of Transportation requested help in eliminating premature failure of newly repaired concrete pavement by more accurately determining when the pavement is ready to be opened to traffic. After embedding an early prototype of the sensor into sections of various Indiana highways, INDOT added the sensor technology to its Indiana Test Methods Index.

The sensor communicates to engineers via a smartphone app exactly when the pavement is strong enough to handle heavy traffic. The ability to instantly receive information about the concrete's strength levels allows roads to open to traffic on time or sooner following a fresh pour.

Construction workers install the sensors simply by tossing them onto the ground of the concrete formwork and covering them with concrete. Next, they plug the sensor cable into a reusable handheld device that automatically starts logging data. Using the app, workers can receive information on real-time changes in the concrete strength.

According to data from the Federal Highway Administration, concrete pavement makes up less than 2% of U.S. roads but approximately 20% of the U.S. interstate system. Lu's research has focused on improving the conditions of concrete pavement first because it is the most challenging road material to repair. Concrete interstate pavement also must reliably support a large proportion of the nation's traffic.

More than half of U.S. states with concrete interstate pavement have signed up to participate in a Federal Highway Administration pooled fund study to implement the sensors. The participating states are California, Colorado, Indiana, Kansas, Missouri, North Dakota, Tennessee, Texas, and Utah.

The technology also is on track to hit the market later this year as the REBEL Concrete Strength Sensing System, a product of WaveLogix. Lu founded WaveLogix in 2021 to manufacture the technology on a larger scale. The company licenses the technology from the Purdue Research Foundation Office of Technology Commercialization, which has applied for patent protection on the intellectual property.

WaveLogix is also developing a way to curb carbon emissions by cutting the amount of cement needed in concrete mixtures. WaveLogix has made progress on a solution that uses artificial intelligence to optimize the design of concrete mixtures based on data that the sensors would collect from highways across the country. Based on code requirements and data from the Global Cement and Concrete Association, Lu estimates that concrete mixture overdesign causes more than 1 billion tons of carbon emissions per year.

Lu says she believes that this new method using artificial intelligence could potentially reduce by 20% to 25% the amount of the cement used in concrete mixes – and simultaneously make pavement more durable and less expensive.
—Source: Luna Lu, luna@purdue.edu, and Kayla Wiles, wiles5@purdue.edu

Pitt research develops self-sensing metamaterial concrete for infrastructure

New research from the University of Pittsburgh in Pennsylvania introduces metamaterial concrete for the development of smart civil infrastructure systems. The *Advanced Materials* paper, "Multifunctional Nanogenerator-Integrated Metamaterial Concrete Systems for Smart Civil Infrastructure," presents a new concept for lightweight and mechanically tunable concrete systems that have integrated energy harvesting and sensing functionality.

"Massive use of concrete in our infrastructure projects implies the need for developing a new generation of concrete materials that are more economical and environmentally sustainable yet offer advanced functionalities," says Amir Alavi, assistant professor of civil and environmental engineering at Pitt, who is the corresponding author on the study.

Alavi and his team previously developed self-aware metamaterials and explored their use in applications such as smart implants, which monitor spinal fusion healing. This new study introduces the use of metamaterials in the creation of concrete, making it possible for the material to be specifically designed for its purpose. Attributes such as brittleness, flexibility, and shapeability can be fine-tuned in the creation of the material, enabling builders to use less of the material without sacrificing strength or longevity.

"This project presents the first composite metamaterial concrete with super compressibility and energy harvesting capability," Alavi says. Although the material cannot produce enough electricity to send power to the electrical grid, the generated signal will be more than enough to power the roadside sensors. The electrical signals self-generated by the metamaterial concrete under mechanical excitations can also be used to monitor damage inside the concrete structure or to monitor earthquakes while reducing their impact on buildings.

Eventually, these smart structures may even power chips embedded inside roads to help self-driving cars navigate on highways when GPS signals are too weak or lidar is not working.

The material is composed of reinforced auxetic polymer lattices embedded in a conductive cement matrix. The composite structure induces contact electrification between the layers when triggered mechanically. The conductive cement, which is enhanced with graphite powder, serves as the electrode in the system. Experimental studies show that the material can compress up to 15% under cyclic loading and produce 330 microwatts of power.

The project included researchers from Johns Hopkins University in Baltimore, Md.; New Mexico State University in Las Cruces; the Georgia Institute of Technology in Atlanta, Beijing Institute of Nanoenergy and Nanosystems in China, and Pitt's Swanson School of Engineering.
—Source: Swanson School of Engineering, University of Pittsburgh

Pankow prestandard for performance-based wind design update available

The Charles Pankow Foundation has released an updated version of the *Prestandard for Performance-Based Wind Design*, which was originally released in 2019. This research project was funded by the Pankow Foundation with additional funding from the American Institute of Steel Construction and the American Society of Civil Engineers (ASCE) Structural Engineering Institute.

The 2016 edition of ASCE 7, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, introduced the target reliability tables into the basic requirements for structural design within chapter 1, "General Provisions." As part of the pathway to develop and provide a performance-based design approach for wind, system reliability targets were developed into the basic requirements to achieve target performance objectives corresponding to various levels of wind hazard. Previously funded ongoing work to develop system reliabilities for wind needed to be peer reviewed and proposed into the consensus process of ASCE 7-22 for inclusion into chapter 1. Until now, there has been no existing guidance for designers on how to conceive of a performance-based approach for wind beyond the ASCE 7 provisions that permit its use.

The principal investigator for the project was Don Scott, and the industry champions were Terri McAllister, Bruce Ellingwood, Xingzhong Chen, and Peter Irwin.
—Source: Pankow Foundation

Automatable process from Purdue improves viability of incorporating phase change materials into concrete panels

Mirian Velay-Lizancos, a Purdue University assistant professor of civil engineering from the Lyles School of Civil Engineering in the College of Engineering, and researchers in her laboratory have developed a patent-pending, scalable, automatable process that improves on the traditional method of incorporating phase change materials (PCMs) into construction materials.

Incorporating PCMs such paraffin, esters, and salt hydrates into building envelope elements can moderate the effects of outside temperature changes on the indoor environment. They convert changes in thermal energy into phase changes by transitioning from a solid to a liquid or vice versa and provide cooling or heat by absorbing or releasing energy during those transitions.

"Incorporating PCMs reduces energy consumption in buildings, which reduces carbon dioxide emissions and operational costs," Velay-Lizancos says. "It also decreases water permeability of construction materials."

PCMs are used in a building's envelope, the doors, exterior walls, foundations, roofs, windows, or other components that create a barrier between the indoors and the outdoors. The thermal properties of building envelopes play a key role in a building's energy consumption.

"Currently, PCMs are incorporated into other materials via microencapsulation or macroencapsulation," Velay-Lizancos says. "However, these methods limit the use of PCMs. Microencapsulation has a negative effect on the strength and durability of construction materials. Macroencapsulation limits the shape and production method of construction materials."

Velay-Lizancos' method uses liquid immersion and a vacuum to incorporate PCMs after construction materials such as concrete, bricks, and drywall have already been placed.

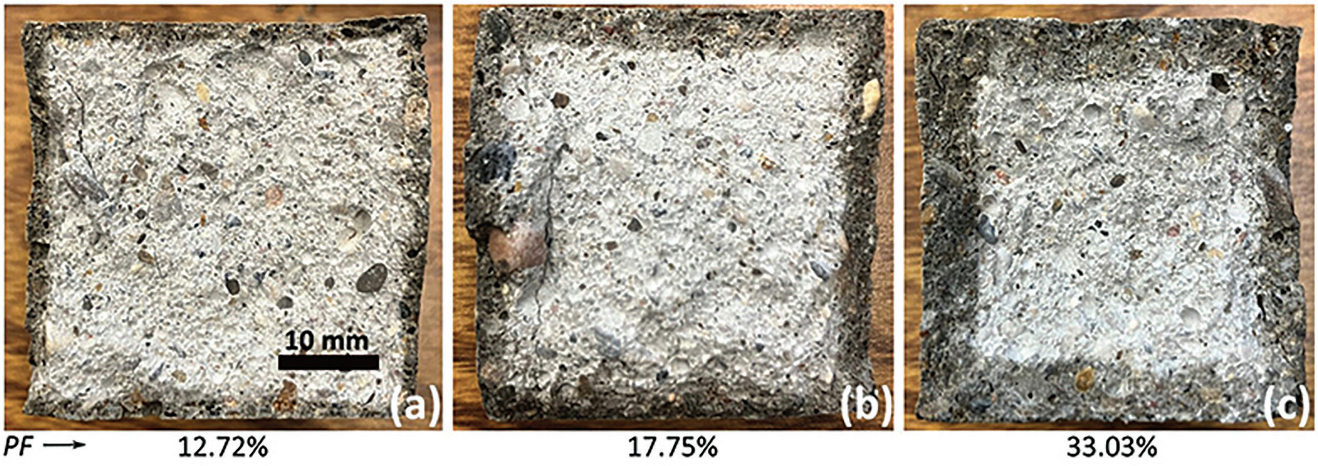
"This increases the strength, enhances the durability and increases the thermal inertia of the construction materials," Velay-Lizancos says. "This new method also distributes PCMs so they are concentrated in the surface layer of the construction materials. More of the PCMs are in contact with external surfaces of the building envelope, which makes the PCMs more effective."

Velay-Lizancos' method requires only a vacuum system, which she says is very accessible and easy for manufacturers to work with.

"Users will need to be familiarized with the process, but they will not need special training," Velay-Lizancos says. "The process could be easily automatized and incorporated into the production chain of precast elements like bricks, concrete panels, drywall and pavers, among others."

Velay-Lizancos and her research group tested the innovation at the Pankow Laboratory in the Lyles School of Civil Engineering. The initial tests were conducted with commercial bricks and 15 minutes of vacuum time.

A large experimental campaign was conducted on cement mortars with three water-to-cement ratios and, therefore, different initial porosity levels. PCMs were incorporated into the mortars for three different vacuum periods: 15 minutes,



Darker areas show how far phase change materials (PCMs) have penetrated the pores of construction materials that spent 15 minutes, 1 hour, and 4 hours in a process developed by Mirian Velay-Lizancos, a Purdue University assistant professor of civil engineering, and her research team. The process improves on the traditional method to incorporate PCMs into construction materials, which could reduce a building's energy consumption, leading to a reduction in carbon dioxide emissions and operational costs. Courtesy of Purdue University/Marina Garcia Lopez-Arias.

1 hour, and 4 hours. Velay-Lizancos and her team observed an increase on the thermal inertia of 24% and more than a 22% of increase in the compressive strength, with just 7% of the volume of the element filled with PCM.

Velay-Lizancos says the uneven distribution of the PCM concentrated in the surface layer makes the PCM more effective in enhancing thermal properties.

The paper about these research methods and results, "High thermal inertia mortars: New Method to Incorporate Phase Change Materials (PCMs) While Enhancing Strength and Thermal Design Models," has been published in the March 2023 issue of *Construction and Building Materials*. —Source: Mirian Velay-Lizancos, mvelayli@purdue.edu, and Steve Martin, sgmartin@prf.org

Industry Calendar

Event details are subject to change.

AASHTO Spring Meeting Hyatt Regency Seattle, Seattle, Wash.	May 15–18, 2023
SEI Structures Congress New Orleans, La.	May 26, 2023
***fib* Symposium 2023** Istanbul, Turkey	June 5–7, 2023
SynerCrete '23 Milos Island, Greece	June 15–16, 2023
***fib* International Symposium on Conceptual Design of Concrete Structures** Oslo, Norway	June 29–July 1, 2023
BEI-2023 "Sustainability in Bridge Engineering" Roma Eventi-Fontana di Fontana Trevi, Rome, Italy	July 17–20, 2023
CACRCS 2022 Parma, Italy	September 12–15, 2023
Greenbuild Walter E. Washington Convention Center, Washington, D.C.	September 26–29, 2023
PTI 2023 Committee Days Cancun, Mexico	October 3–6, 2023
ACI Concrete Convention Boston Convention Center and Westin Boston Waterfront, Boston, Mass.	October 29–November 2, 2023
AASHTO Annual Meeting J. W. Marriott Indianapolis, Indianapolis, Ind.	November 12–16, 2023
ASBI 35th Annual Convention Westin La Paloma Resort and Spa, Tucson, Ariz.	November 5–8, 2023
World of Concrete Las Vegas Convention Center, Las Vegas, Nev.	January 22–25, 2024
ACI Concrete Convention Hyatt Regency New Orleans, New Orleans, La.	March 24–28, 2024
PTI Convention Indianapolis, Ind.	April 14–17, 2024

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