Fuchs Consulting Inc.

With a novel approach to using infrared technology, Fuchs Consulting takes a closer look at concrete bridges

by Monica Schultes

Fuchs Consulting Inc. (FCI) was established in 1998 by Dr. Paul Fuchs. With a background in the field of electrical engineering, Fuchs has brought a fresh perspective to the field of nondestructive evaluation (NDE) and condition inspections of concrete bridges. The firm Fuchs started from his home remains small, with just two employees. FCI specializes in developing NDE systems and instrumentation used to assess highway bridge structures and for military applications.

Improving Bridge Inspection Techniques

Fuchs became interested in NDE when his doctorate research in electrical and electronics engineering brought him to the Federal Highway Administration (FHWA) Turner-Fairbank Highway Research Center. "My PhD project was sponsored by FHWA, and I developed an ultrasonic strain gauge system to rapidly take strain measurements on bridge structures. My work with FHWA was an introduction to the bridge community," says Fuchs, who is president and CEO of FCI.

The work that Fuchs performed at the FHWA Turner-Fairbank Highway Research Center helped launch FCI, with the firm taking on consulting and research projects related to the bridge industry. During that time, Fuchs developed a partnership with Dr. Glenn Washer, and the two made significant headway in using infrared technology to acquire data for assessing concrete bridge decks.

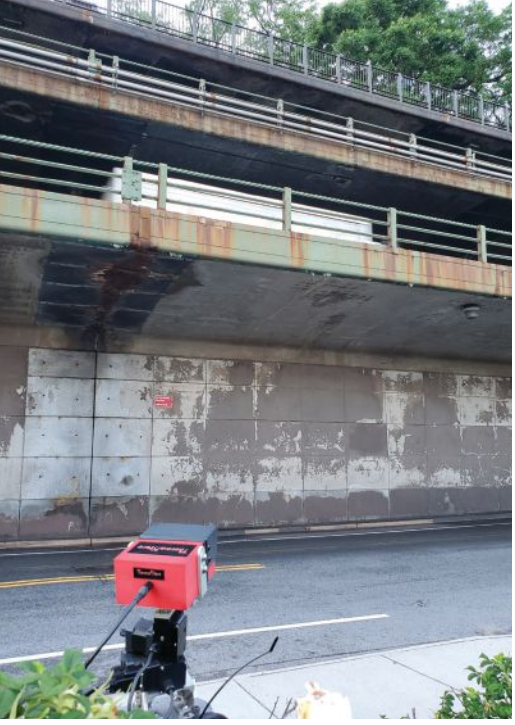
Initially, FCI researched concepts to improve the inspection and assessment of all types of infrastructure, such as concrete bridges. In 2009, about a decade after Fuchs founded his consulting business, the U.S. Department of Transportation awarded a Small Business Innovation Research (SBIR) grant to FCI for a project to develop a method to inspect bridge paints. FCI's approach used an infrared-based system to assess and quantify subsurface defects. That initial concept ultimately led to FCI's patented ThermalStare technology for the concrete bridge industry. (For more information on this technology, see the Concrete Bridge Technology article in this issue of *ASPIRE*®.)

On the Hanover Street Bridge (Vietnam Veterans Memorial Bridge) in Baltimore, Md., infrared ultra–time domain measurements were taken to assess subsurface defects in the concrete deck. All Photos: Fuchs Consulting Inc.

Infrared Thermography

Thermal imaging can be an effective tool for the condition assessment of concrete, and specifically for the detection of subsurface delamination. While FCI was developing its infrared technology for the SBIR-funded project, Fuchs recalls thinking, "If this localized system measures a small area of paint on a steel structure, can we expand that and examine larger areas and different substrates?" During those pilot stages, the investigators examined all types of materials, and both concrete and steel bridges. FCI also performed concrete deck assessments and studied the current methods of NDE and bridge-condition evaluations. The firm developed the concept of placing an infrared camera above a bridge deck and leaving it in place to operate for an extended period. "No one had ever used that approach to find internal subsurface defects before," says Fuchs.

In 2014, Fuchs and Washer founded the company ThermalStare to focus on developing and applying their innovative infrared-based NDE technologies. Since then, Fuchs and Washer have created a suite of products for the bridge industry inspired by the original time-lapse thermography concept. Their technology can show subsurface damage in concrete, and



Infrared ultra–time domain measurements were taken on the triple cantilever design section for the Brooklyn-Queens Expressway for the New York City Department of Transportation. Measurements of the soffit or underside of the deck were taken with the equipment at ground level.

The Indiana Department of Transportation was an early adopter of the ThermalStare system, using it to measure defects in Indiana's concrete bridges. The camera attached to the bridge parapet uses time-lapse infrared thermography to detect damage.

it can also detect defects in coatings used in military applications. Today, FCI and ThermalStare offer a diverse range of options to their customers, from building the thermal imaging equipment to performing inspection services to analyzing the data. While most of their work focuses on bridges, their applications extend to cooling towers at power plants, tunnels, dams, and military installations.

A New Inspection Paradigm

FCI and ThermalStare are based in Leesburg, Va., but their small team is often on the road, deploying ThermalStare equipment on bridges and demonstrating the benefits of this technology to departments of transportation and others. While much of their work is on the East Coast, the consultants have also crisscrossed the United States, completing work from Washington, D.C., to Salt Lake City, Utah, and Portland, Ore.

Agencies and owners can make use of FCI services and ThermalStare technologies in a variety of ways. For example, FCI and ThermalStare may serve as consultants to a prime contractor or as an engineering consultant for an owner seeking to evaluate a bridge deck as part of a larger rehabilitation study.

The Indiana Department of Transportation (INDOT) was an early adopter of ThermalStare technology. INDOT operates the systems with their own personnel and then sends the accumulated data to FCI to analyze. In other states, including Maryland, South Carolina, North Carolina, Missouri, Oregon, New Jersey, New York, Virginia, Utah, Pennsylvania, Ohio, and Washington D.C., agencies have used FCI as an independent consultant to examine bridge decks or substructures.

"We have proposed and developed a new paradigm for the way inspections are done on structures," says Fuchs. "We are introducing our capabilities to the industry, so that is why we offer a combination of services, depending on the owners' needs."

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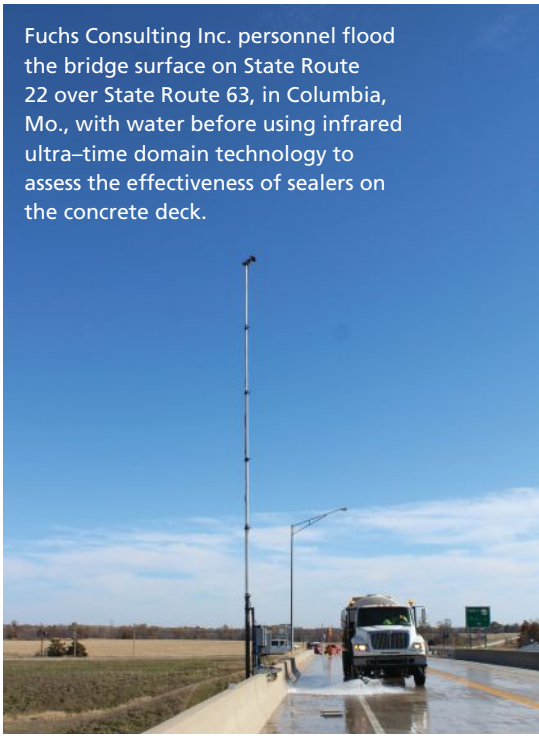
Reliability and Safety Advantages

Because deterioration in bridges from subsurface damage cannot be seen through visual inspections, owners need alternative inspection methods for early detection of such damage. The infrared technologies developed by FCI address this need for early detection and provide accurate measurements that were not previously achievable.

The concept of finding defects in concrete with infrared technology has a storied past. While the industry has used infrared imaging for decades, concerns about unreliable data have



Fuchs Consulting Inc. personnel flood the bridge surface on State Route 22 over State Route 63, in Columbia, Mo., with water before using infrared ultra–time domain technology to assess the effectiveness of sealers on the concrete deck.

been raised. When measurements are taken at one point in time, there will be uncertainty as to the best time to perform the inspection and there is a high likelihood that the imaging will miss some defects.

Compared with traditional infrared imaging technology, the equipment and methodologies developed by FCI are highly innovative. The time-lapse approach to take measurements is uniquely their own, and so is the camera equipment packaged into the system for bridge inspection. FCI has also developed software to capture and analyze the data, and the firm's offerings can be customized to the client's specifications or applications.

FCI's infrared ultra–time domain (IR-UTD) methodology vastly increases measurement reliability because the data are collected over time, providing more information than can be gathered at a single point in time. As a result, owners can identify and analyze defects more effectively than was previously possible. Data collected with ThermalStare technology provide a deeper look into concrete than is possible with conventional infrared cameras. "In a side-by-side comparison, owners are shocked at how much more information is available," Fuchs says.

The reach of IR-UTD technology is a matter of optics and positioning. The equipment is typically installed approximately 36 ft above the deck. From that vantage point, inspectors can view 12,000 to 15,000 ft^2 of bridge deck at one time. The camera is usually mounted for two days, which will generally provide sufficient data. The equipment is robust and built for all conditions, so variations in weather and traffic do not affect the data gathered. As Fuchs explains, "the measurements are ideal for structures with heavy traffic that cannot be easily disrupted to assess the deck."

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Another advantage of the technology is improved safety. Because ThermalStare cameras are attached to a pole or similar perch and left in place, their use avoids safety concerns related to lane closures and inspectors performing bridge soundings and other NDE on sites adjacent to traffic.

Fuchs predicts that small IR-UTD assemblies similar to traffic cameras could eventually be used in ways that have not yet been identified. States have thousands of bridges of all different ages and conditions, and reliable data that can be collected economically will lead to more informed decisions. "Our goal is to make the technology economical enough to put these assemblies on all major structures," he says.

Ramp to Whitehurst Freeway, Washington, D.C.

In 2021, when the District (of Columbia) Department of Transportation (DDOT) retained RK&K to create a condition assessment report of the Interstate 66 ramp bridge to the Whitehurst Freeway in Washington, D.C., FCI doing business as ThermalStare was part of the investigative team. This bridge had a total deck thickness of 9 in. (a 6½-in.-thick top flange of the multiple cell box girders with a 2½-in.-thick concrete overlay). ThermalStare used stationary, time-lapse infrared imaging systems mounted to the bridge parapet at five locations to perform infrared imaging of all 11 spans of the bridge over a two-day period.

In addition to the infrared imagery, the condition assessment involved a visual inspection, concrete coring, compressive-strength testing, chloride-content analysis, petrographic analysis, half-cell potential testing, and ground-penetrating radar. The infrared imagery data were used to plan the coring and half-cell potential measurement locations. Using these data,

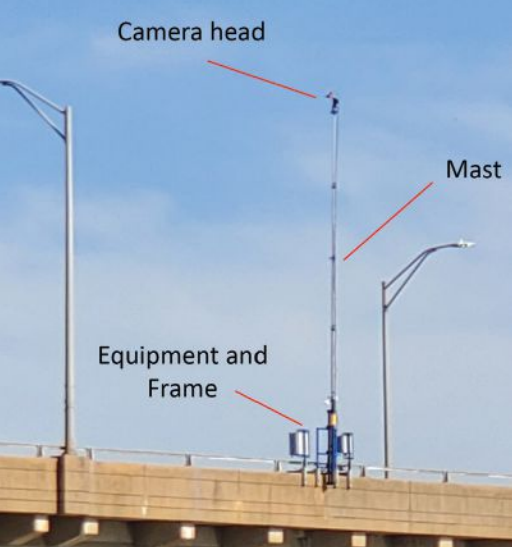
Using infrared ultra–time domain equipment, Fuchs Consulting Inc. was part of an investigative team that performed a condition assessment of the 11-span Interstate 66 ramp bridge to the Whitehurst Freeway in Washington, D.C. The ramp bridge is a concrete box-girder structure with a concrete overlay.

History of Fuchs Consulting

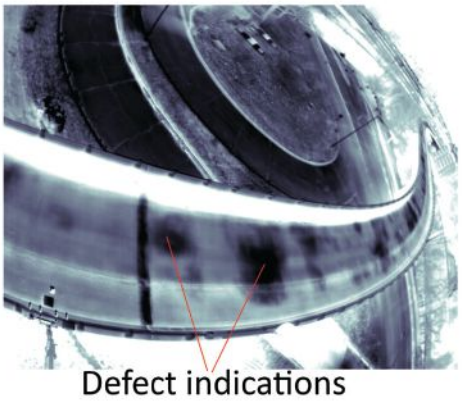
Dr. Paul Fuchs, founder of Fuchs Consulting Inc. (FCI), established his firm in 1998. A major milestone in the FCI's history was its award of the highly competitive Small Business Innovation Research (SBIR) grant from the U.S. Department of Transportation in 2009. The SBIR program helps small businesses like FCI develop solutions for transportation challenges, and FCI used the funding to develop an infrared-based system to assess and quantify subsurface defects.[1] That system offers alternatives to bridge owners in condition assessments of their concrete structures. The success of the SBIR-funded project enabled FCI to acquire a new facility for research and development as well as manufacturing and expand their patented technology.

FCI has continued to have success turning research into commercial products. Fuchs and Dr. Glenn Washer formed ThermalStare in 2014 as a new company for commercial applications.

Today, the FCI/ThermalStare team remains committed to developing promising ideas, refining their methods, and creating innovative applications.



The assembly for taking measurements with infrared ultra–time domain equipment, shown here on the Hanover Street Bridge in Baltimore, Md., is similar to the light poles that are supported by the bridge parapet.



Infrared ultra–time domain equipment can capture data over a large bridge deck area with a single setup, allowing inspectors to view 12,000 to 15,000 ft^2 of bridge deck at one time to find deteriorating or delaminated concrete.

ThermalStare correctly predicted 95% (21 of 22) of the concrete cores to be either defective or intact. The average depth to a defect was 3.25 in. (2.25 in. minimum to 4.50 in. maximum). The assessment helped DDOT determine the necessary repairs to extend the service life of the structure, evaluate alternatives, and estimate the repair cost.

Hanover Street Bridge, Baltimore, Md.

Working as a consultant to RK&K, FCI/ThermalStare recently completed bridge condition measurements for the five-lane Hanover Street Bridge (Vietnam Veterans Memorial Bridge) over the middle branch of the Patapsco River in downtown Baltimore, Md. The historic, 2200-ft-long concrete arch bridge, built in 1916, is in poor condition, and stakeholders are grappling with the decision to rehabilitate or replace the structure. The bridge experiences high traffic volumes, and FCI technology facilitated data collection while minimizing inconvenience for the traveling public.

Studying Surface Sealants

While surface sealants are frequently used on bridges across the United States, there are currently no standardized methods to assess the need for resealing a concrete deck or the quality of the sealant installation. When the FHWA's Innovations Deserving Exploratory Analysis (IDEA) Program funded research into the effectiveness of sealants applied to concrete bridge decks, FCI began to study sealants as an extension of their success with IR-UTD technology.

"Instead of looking at the defects deep in the concrete, we used the same idea to assess if the sealant applied to the top of the concrete is working effectively or not," says Fuchs. In 2021, FCI developed Thermal SealCheck, which uses time-lapse thermography to measure water evaporation.

To evaluate sealant effectiveness, FCI floods a concrete deck with water, measures the evaporation of the water with time-lapse thermal imaging, and analyzes the data to determine whether the sealant is working to prevent water from penetrating the concrete. This technology can differentiate sealed from unsealed concrete, and the measurement test is completed in 1 hour in the field. This method also evaluates whether the initial sealant was applied effectively. With enough accumulated data, transportation departments could develop prescriptive protocols related to sealants, rather than relying exclusively on periodic applications every few years.

Future Innovations

Going forward, FCI intends to expand the use of IR-UTD technology for applications beyond the deck. For example, the technology can be used to inspect concrete abutments, column caps, piers, and the undersides of bridges. The collected data could help agencies better understand what types of elements perform better, where typical defects occur, and when the optimal time is to make repairs.

Furthermore, if the technology is stationed on structures for lengthy periods of operation, a constant flow of information could improve decision-making processes related to maintenance, repair, and rehabilitation. "Usually, nondestructive testing of a bridge deck is a one-time measurement, which gives you limited information. In the future, we envision cameras mounted on critical structures constantly collecting data," says Fuchs.

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Bridge engineers design structures for a long service life, but do not always have the tools to visualize how their decisions impact the maintenance phase. FCI explores how infrared technology, something that has been used for NDE for decades, can be used as a practical data-driven tool to support maintenance and serviceability goals. Data from their IR-UTD products can add value to future maintenance efforts and help owners make informed decisions regarding rehabilitation schedules.

Reference

1. U.S. Department of Transportation Volpe Center. 2018; updated 2022. "Detecting Damage in Structural Components with New Infrared Technologies." https://www.volpe.dot.gov/news/detecting-damage-structural-components-with-new-infrared-technologies.