Rutgers 'BEAST' Designed to Accelerate Bridge Evaluations

RUTGERS UNIVERSITY has designed and constructed a laboratory facility that can simulate decades of bridge deterioration in a matter of months. The Bridge Evaluation and Accelerated Structural Testing laboratory, also known as the BEAST, was unveiled by the university's Center for Advanced Infrastructure and Transportation (CAIT) late last year and is expected to begin conducting tests of full-scale bridge deck and superstructure systems, new bridge components and materials—including joints, bearings, coatings, and sealants—and other bridge-related products and systems early this year, explains Ali Maher, Ph.D., M.ASCE, the director of CAIT and a professor of civil and environmental engineering at Rutgers.

The idea for the BEAST grew out of discussions that CAIT officials held with officials from various state departments of transportation and the Federal Highway Administration's Long-Term Bridge Performance Program, notes Maher. The resulting $5-million testing facility was funded by various sources, including the New Jersey Department of Transportation, the U.S. Department of Transportation's University Transportation Centers Program, of which CAIT is a member, and Rutgers.

The BEAST will utilize both a wheeled carriage that rolls back and forth over the bridge segments being tested—simulating traffic loads of up to 60,000 lb—and environmental control systems that can subject the samples to freezing or scorching temperatures, rain and ice conditions, and a deicing salt brine. Operating 24 hours a day seven days a week over extended periods, the testing process can simulate 15 to 20 years of deterioration in just six months, explains Franklin Moon, Ph.D., M.ASCE, a professor at Rutgers, the director of the undergraduate civil and environmental engineering program there, and the technical director of the BEAST program.

A wheeled carriage that simulates traffic loads of up to 60,000 lb, *above,* and environmental control systems that subject bridge segment samples to freezing or scorching temperatures, rain and ice, or a deicing salt brine are key features of Rutgers University's Bridge Evaluation and Accelerated Structural Testing laboratory, also called the BEAST, *below.*

The BEAST was designed to help solve a series of problems for the engineers in state departments of transportation who are responsible for maintaining America's bridges. These engineers find that their bridges are deteriorating, but they aren't always certain why, Moon says. With an average age of more than 40 years, the nation's approximately 607,000 bridges earned a grade of just C^+ in ASCE's *2013 Report Card for America's Infrastructure.* Roughly one in every nine bridges is rated structurally deficient, ASCE reported, and more than 200 million trips are taken every day across deficient bridges in the nation's 102 largest metropolitan regions.

"We do know that if you put deicing chemicals on a bridge, it will deteriorate, and we also know that heavy trucks can really beat up bridges," Moon explains. "But there is not a one-to-one correlation between the inputs and poor bridge performance, so other influential factors or combinations of factors—including construction quality, structural characteristics, and preventive maintenance, among others—certainly exist." Some bridges around the country that are not exposed to these damaging influences experience relatively poor long-term performance, whereas others "that see harsh environmental conditions, heavy trucks, et cetera, actually perform well long term," Moon says. "So there's still some uncertainty about how all these influences work together."

At the same time it can take decades for bridge deterioration to become serious enough to be detected, Moon adds. That long-term time frame makes it difficult for state officials to evaluate new materials or practices, including new sealants, components, or even construction techniques. Moon says he often hears from state transportation engineers that "we can't afford to wait 15 to 20 years to determine what practices will produce longer-lasting bridges."

Although there are other testing facilities that can simulate the rolling live-load applications of traffic on bridges, as well as facilities that can test the effects of heating, freezing, and other environmental conditions, the BEAST is the only known facility designed to address all of these concerns simultaneously, Moon says.

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The BEAST is composed of a set of parallel steel I beams 120 ft long by 7 ft deep, steel-framed end towers, and concrete abutments approximately 15 ft tall.

The BEAST was designed by a team of Rutgers engineers and other bridge experts, with assistance from Applied Research Associates, Inc., headquartered in Albuquerque, New Mexico. This firm constructed some of the massive components of the BEAST, especially a set of parallel steel I beams 120 ft long by 7 ft deep, at its plant in Randolph, Vermont. DuBois & King, Inc., which has offices in Vermont and New Hampshire, assisted Applied Research Associates with structural engineering, permitting services, and site and civil work.

The BEAST was constructed at the Rutgers Livingston campus, in Piscataway, New Jersey, on the north side of CAIT's Asphalt Pavement Laboratory. The combined site "really puts us in a position to…leverage what we have there" in terms of the two laboratories, technicians, and researchers, explains Andrés Roda, M.ASCE, who as the operations manager of the BEAST oversaw its development and construction. A pit approximately 15 ft deep was excavated to accommodate the closed chamber in which the tests were to be conducted. As an example of the highly collaborative process that helped to create the BEAST, Roda notes that it was Applied Research Associates that actually recommended putting the facility in the ground not only to take advantage of the insulating properties that come from being underground but also to help muffle the noise of the system as it operates.

The design of the facility included concrete abutments approximately 15 ft tall founded on spread footings; steel-framed end towers that support the massive I beams; a series of air-conditioning and heating units that can lower the temperature inside the test chamber to 0°F or raise it to as much as 104°F; an approximately 400 hp electric winch system that pulls the wheeled carriage back and forth across the test surface at a constant speed of 20 mph; an external tank of approximately 1,200 gal that contains the brine for simulating deicing conditions; and a modular roof on the test chamber that can be opened to, for example, position the rolling carriage for a particular test.

Although the details of the individual tests, including costs, are still being determined, the testing process will probably involve both a primary test sample, for example, a concrete bridge deck or superstructure segment or a metal deck system up to 50 ft long by 28 ft wide, and secondary items that can be assessed simultaneously. The tests of the secondary items, referred to as payload projects, will involve products or materials "that are unlikely to influence the behaviors associated with the primary test objectives but that can be studied just by incorporating them into the bigger experiment," notes Moon. For example, one experiment could focus on a primary specimen composed of four steel girders and a reinforced-concrete deck, but each girder could feature a different new coating, the coatings serving as secondary items, he explains.

Potential customers of the BEAST include not just state departments of transportation but also the manufacturers of bridge components, products, and systems, and this involvement could spur innovation, Moon notes. "I think you're going to see industry be much more interested in developing new sealants, new materials, [and] new components because they know they can be evaluated and potentially implemented more quickly," he says.

Throughout the testing process, sensors and nondestructive evaluation techniques will be used to constantly measure strain, displacement, and other effects of the test procedures. As bridge deterioration becomes evident during the tests, the researchers will probably halt the process frequently to "capture that deterioration curve," says Moon. "Eventually, we hope we'll learn an awful lot about the rates of initiation and propagation of deterioration." Initially, though, Moon expects that "we'll probably collect more data than we might really need, because right now we really don't understand how and how rapidly bridges deteriorate—we just have some general consensus based on observations and heuristics."

—ROBERT L. REID

Turbine-Based Desalination Method Freezes Water To Remove Salt

AS PART OF A project sponsored by the U.S. Department of Energy, the research arm of General Electric (GE), of Fairfield, Connecticut, recently began bench-scale testing of a turbine-based approach for removing salt from water. GE Global Research is headquartered in Niskayuna, New York, and its desalination method, which freezes salt water to remove the brine, shows promise as an inexpensive way to treat highly saline wastewater. If successful, the technology could ultimately help to reduce the volume of concentrate discharged by membrane-based seawater desalination facilities.

Historically, desalination of highly saline water has typically been conducted thermally by means of distillation. The water is boiled, and the resulting steam is condensed, leaving the salt behind. Although effective, the process requires significant amounts of energy. By contrast, the desalination process developed by researchers at Niskayuna uses a turbine to freeze the water quickly. In this way, the ice crystallizes as pure water, while the salt crystallizes as pure salt. "We're trying to separate salt from water by freezing the water," says Douglas Hofer, GE's senior principal engineer for aerodynamic and thermal systems. The "potential advantage" of such an approach, he notes, is that the energy required to freeze the water is significantly less than that required to boil water. In fact, GE's researchers estimate that the process might require just half the energy consumed by traditional thermal methods. All told, the turbine-based approach could cost approximately 40 percent less than the thermal evaporation methods used to treat highly saline water.

For the project, the researchers have developed a miniature version of a turbine similar to the type used in power plants. However, instead of generating electricity, the proprietary turbomachinery compresses and pressurizes a refrigerant, raising its temperature. The refrigerant is then cooled to ambient temperature and expanded within the turbine, a process that extracts the warmth from the refrigerant, causing its temperature to drop. Brine is then injected into the stream of cold refrigerant within what is known as the turbine's hypercooling loop. "That cycle is the mechanism by which we do the refrigeration," Hofer says. The "innovation" of the turbomachinery-based refrigeration cycle is that it enables the water droplets to "freeze as they are suspended in the flow through the turbine," he says. As the brine droplets freeze, the salt and ice crystals separate, and the ice subsequently melts, returning to water.

To generate the components for the miniature turbine, GE Global Research used additive manufacturing, also known as 3-D printing, because the process facilitated parts production.

COURTESY OF GE GLOBAL RESEARCH

Freezing water to remove salt is not a new concept. However, previous efforts have relied on the use of refrigeration and a heat exchanger to cool the water and remove the salt. Because the water must keep moving through the heat exchanger for the process to work, the approach is unable to freeze the water completely, says Vitali Lissianski, a chemical engineer and project leader for GE. As a result, the process is not efficient and has a relatively low rate of water recovery.

The ability to freeze the water entirely is what makes GE's process unique, Lissianski says. "Because of the way we do it, we can theoretically freeze all the