McCormick

Northwestern Engineering

Field Notes

The newsletter of the Infrastructure Technology Institute at Northwestern University

Spring 2011

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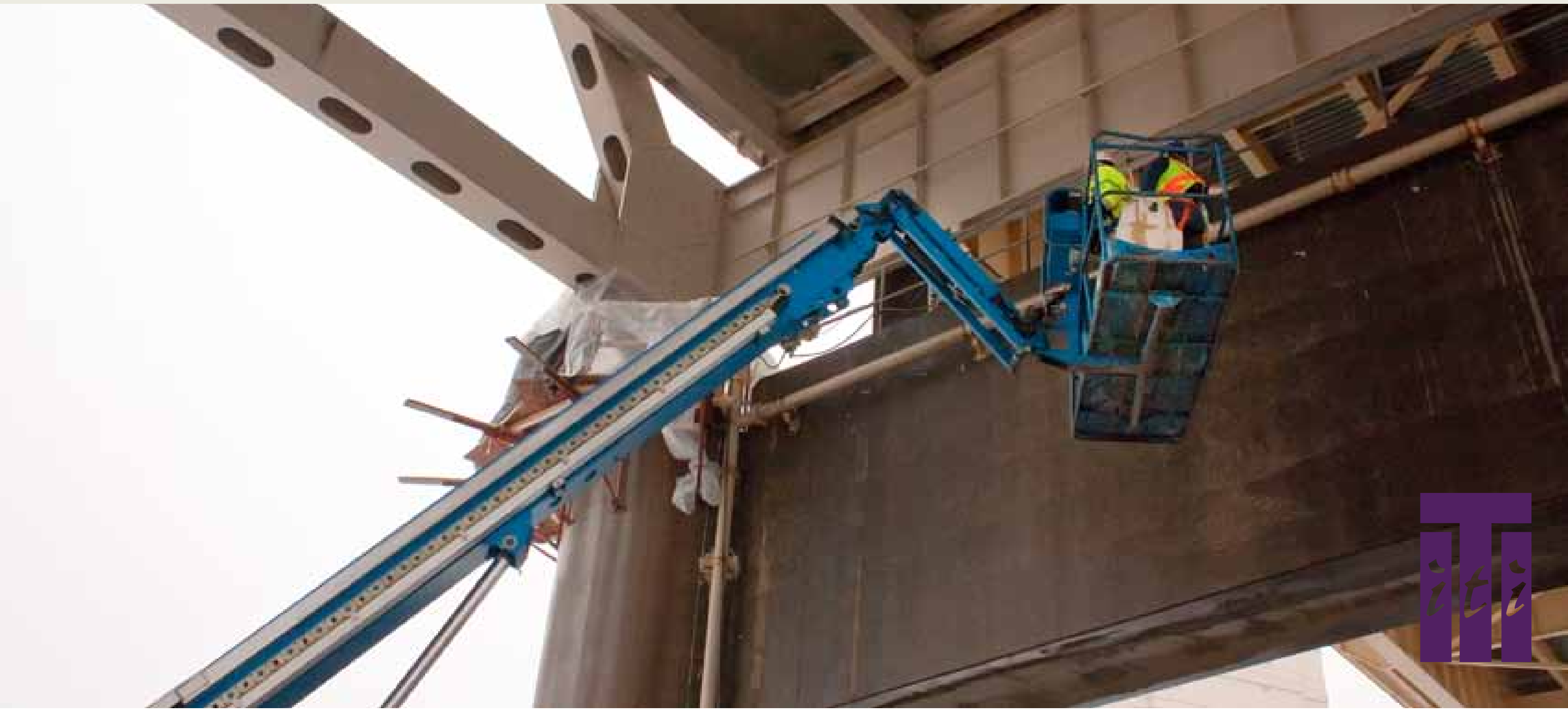

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Above: ITI engineers coordinate re-installation of the structural health monitoring system on the John F. Kennedy Memorial Bridge during a bearing retrofit.

Front Cover: Students Ken Fuller and Lizabeth DuBay apply sensors to a student steel bridge contest entry.

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Data for Infrastructure Management

The Transportation Research Board just released "How We Travel: A Sustainable National Program for Travel Data[1]," a policy study that assesses the state of Americans' travel data and recommends an integrated national program designed to meet the evolving needs of transportation decision making. This report responds to the erosion of resource support for, and extent of, national travel data – measures of flows of freight and passengers, as well as transportation system performance and condition across the nation and for all modes. The recommendations call for increased investment in data programs – only a modest amount is needed – to assure that comprehensive, good quality data are available to support critical decisions about transportation infrastructure investments, policies, and system management.

Data are an often-invisible resource that (should) underlie major transportation infrastructure choices. While decision makers may use analyses, reports and advice to guide their choices, few recognize the source of the underlying data, or who paid for them. As a consequence, it is often difficult to secure the resources necessary to underwrite critical data programs. This is particular true when resources are tight and decision makers at all levels are trying to do more – or the same – with less. Arguably, when times are tough, the need for good data increases, because the investment choices become more difficult and more important.

We have argued that data are an asset of a transportation system, just as bridges, pavements, and rolling stock are assets[2]. Data are part of the value of a transportation system because they guide management and decision making. In the absence of data, a good transportation system can wander off track: its performance can deteriorate, and its ability to fulfill its mission can decline. The value of data is determined by its use – and sometimes its non-use. That value comes from better decisions, choices of more cost-effective pavement, or safer bridge designs, and from avoiding poor decisions – infrastructure investments that do not return enough to society because they are under- (or over) utilized, their durability is less than required, or because their lack of resilience leaves us by the side of the road when floods or snowstorms hit.

Data that track the performance of transportation infrastructure over time have special value. They reveal trends in performance, telling us the direction we're headed and sometimes signaling – warning us – what the future may be. Long-term data streams allow us to assess the effectiveness of programs, facilities, or technologies, e.g., ridership effects of transit service improvements or the corrosion resistance of new steels. Tracking multiple measures, particularly inputs and outputs or stimuli and responses – such as loads on bridges and strains or deflections, allows us to build analytic and predictive relationships, or to verify theories used in design.

The work of the Infrastructure Technology Institute is substantially built on collecting and analyzing data to learn how specific infrastructure systems are performing, and to build or extend our capabilities to predict that performance over time.

Some important examples illustrate the roles of data in infrastructure evaluation, learning and management.

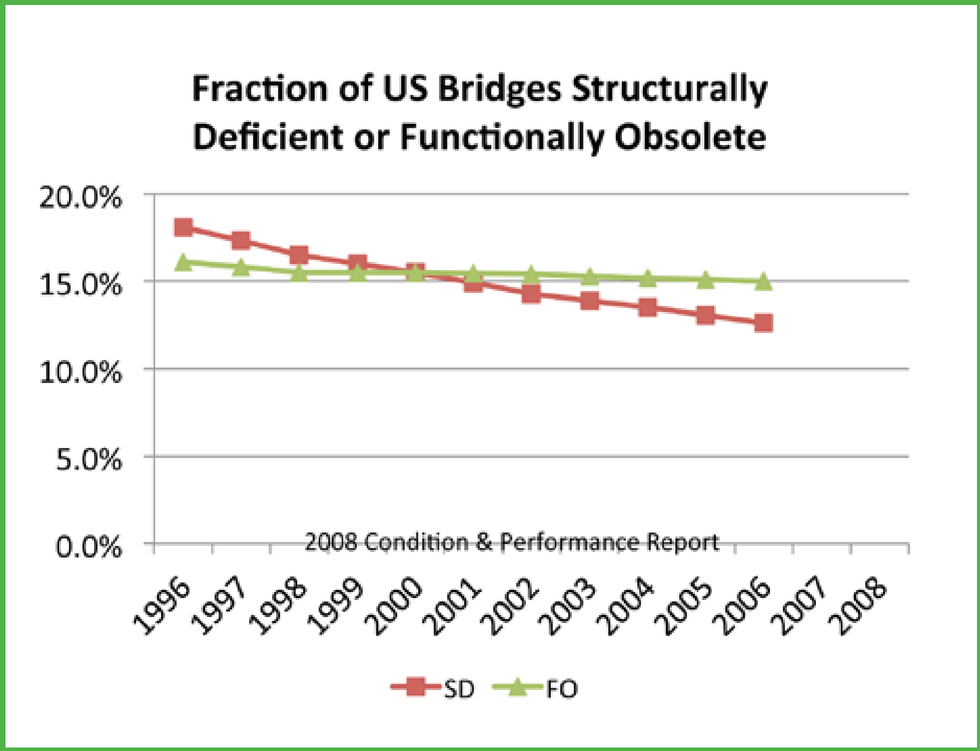
• Prof. Zdenek Bazant studies long-term deflection in large concrete structures, looking for evidence of the size effect which can lead to very large deflections that threaten and even destroy the integrity of these structures, particularly large, post-tensioned concrete box girder bridges, a design that has become increasingly common. These deflections arise after many (but not that many) years - 20-30 years, a period that is well within the design life of these structures. This risk may be a serious threat to highway infrastructure, one that calls for important changes in design codes. Beyond theory and laboratory experiments, which are integral parts of Bazant's research program, the institutional process of effecting changes in design codes requires convincing field - evidence of the need for those changes.

Such research requires large data sets that cover many bridges over extended time periods. Prof. Bazant has assembled deflection data on over 60 bridges from around the world to support his research. This meticulous task relied on personal and professional contacts and persistence, and it was facilitated by the fact that some agencies and individuals archived their deflection data – saved it for future use and made it available for research. This does not always happen, particularly in cases of structural failure, where litigation and settlement often lead to sealing records that could be invaluable for research that may someday protect public safety.

• Capturing and integrating multiple data streams can provide a basis for understanding the complex responses of infrastructure to loadings, weather,

1. How We Travel, Transportation Research Board Special Report 304, Washington, DC, 2011, http://onlinepubs.trb.org/onlinepubs/sr/sr304.pdf

2. J.L. Schofer, T. Lomax, T. Palmerlee, J. Zmud, Transportation Information Assets and Impacts, Transportation Research Circular E-C 109, Transportation Research Board, December 2006. http://onlinepubs.trb.org/onlinepubs/circulars/ec109.pdf

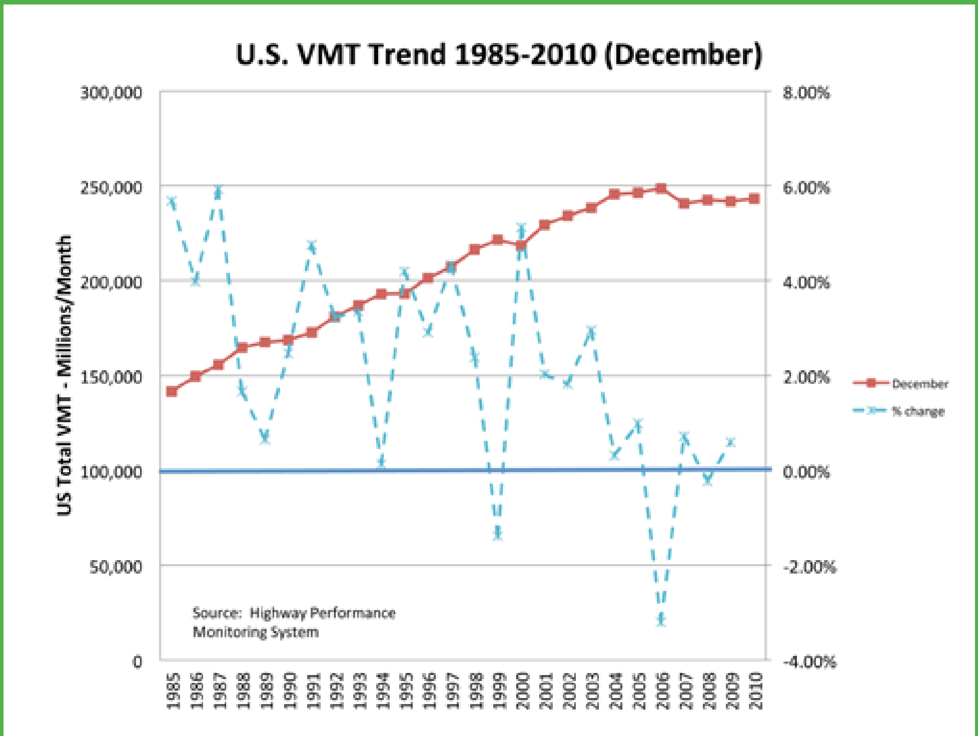


and aging. Working with the Wisconsin Department of Transportation (WisDOT), the ITI Research Engineering Group (REG) has been measuring strains, displacements, accelerations, and temperatures on a bridge near Hurley, Wisconsin, that carries heavy logging trucks. WisDOT installed a weigh-in-motion system next to this bridge to measure vehicle loadings. The result is a multidimensional data set that captures inputs (loads and temperature variations) and structural responses (strains and displacements). Clinical Associate Professor David Corr is using these data to analyze and model the effects of these inputs on bridge condition. Associate Professor Pablo Durango-Cohen is using long-term data from the Hurley bridge to build statistical process control models that may lead to algorithms that autonomously detect significant changes in bridge performance and provide early warning of potential failures.

• The ITI REG – Dan Marron, Dave Kosnik, Mat Kotowsky, and Brian Quezada - is working with the California Department of Transportation (Caltrans) to build and analyze a large data set containing tilt sensor records from scour-critical bridges across California. Scour, the process by which bridge piers and abutments are undermined by flowing water, is the leading cause of bridge failures in the United States.

More than a decade ago, ITI partnered with Caltrans to develop a simple and reliable method to measure the response of bridge structures to scour. This method uses precision tilt sensors to measure small changes in the orientation of bridge piers as scour holes develop around and under them. Caltrans subsequently adopted this simple empirical method to monitor scour-critical bridges statewide. Caltrans has collected a large data set, but to make those data useful for research and program management requires organizing and converting them into systematic information about past and current structural response during periods of high water. ITI is now collaborating with Caltrans to build an Internet-enabled data management system that will support automated analysis of the long-term performance of selected bridges under various stream flow conditions, comparative assessment of the scour responses of multiple California bridges, and innovative ways of visualizing bridge scour performance to support informed strategic management. The data warehouse will support research at both Northwestern and Caltrans, and at the same time it will become a management tool for Caltrans.

In this project, ITI is working with the owner agency to make effective use of an existing database, taking it the next steps to archive (preserve), organize, analyze, and interpret the data,



thus converting them into information that is useful for both long-term learning (research) and asset management.

Long-term, multi-dimensional data sets describing infrastructure condition and performance can be key assets for managing transportation infrastructure. They can support research to understand performance trends and the factors affecting them; they can track transportation assets to support strategic management; and they provide early warnings of emergent problems needing attention and remediation. These three applications illustrate an important principle of data program management – collect it once and use it many times – a strategy that maximizes the cost-effectiveness of data collection efforts.

To support informed decision making about transportation infrastructure, it is important that we assure that we have the right data in hand when we need them – and that we don't spend money needlessly on data. These steps are important for assuring that we meet the data needs for infrastructure evaluation, management, and research:

- Structure the data program to support the goals of the transportation system or agency; collect the data that we need to protect our investments and to make wise decisions about them.

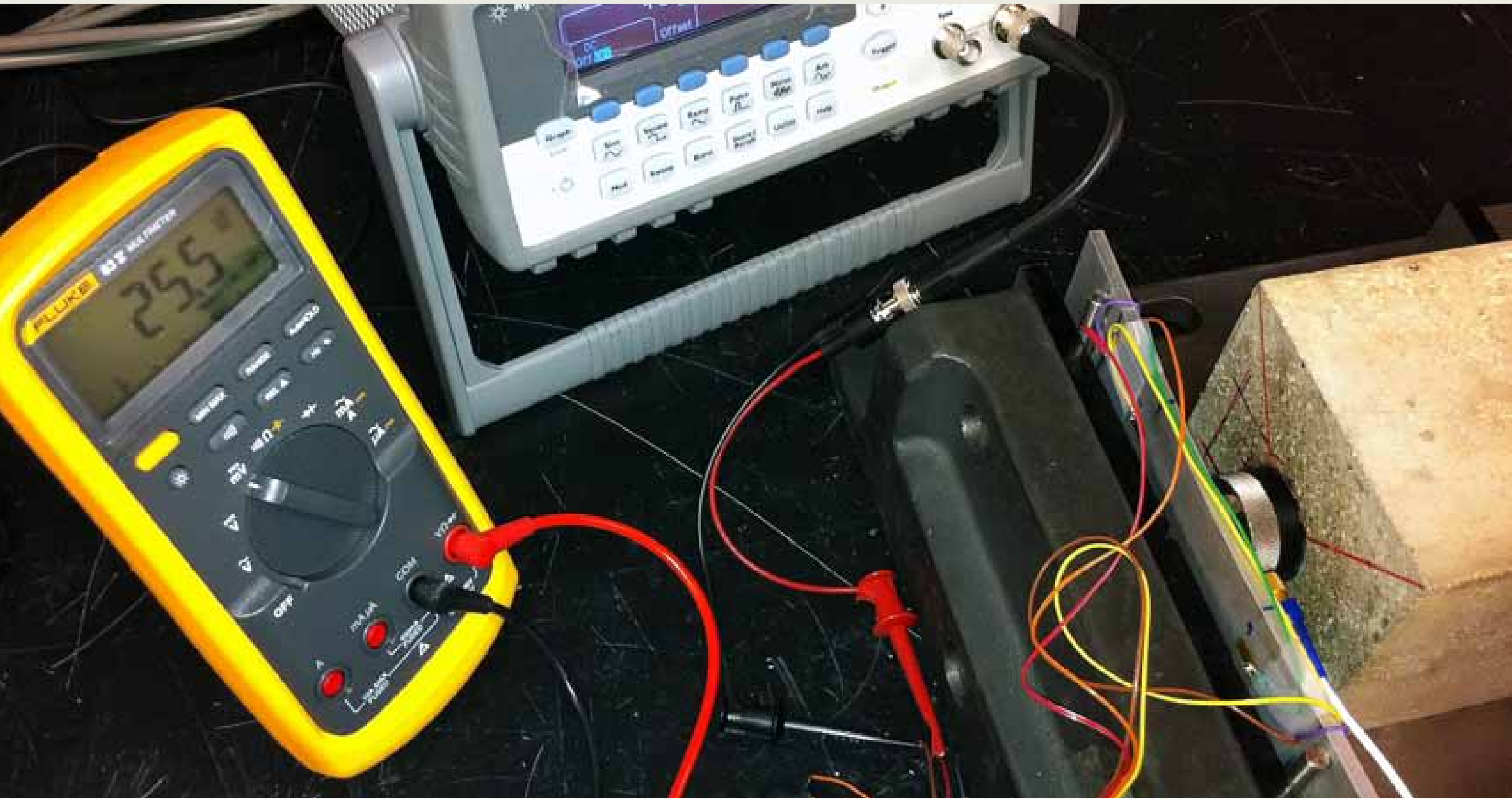
- Organize and archive the data to preserve long term data streams essential for research and understanding.

- Collect data on all of the factors of importance: the inputs and impacts on facilities; the response of the infrastructure itself; and the consequences of that response, including the costs of disruptions when they occur.

- Organize data to facilitate easy access and retrieval to encourage convenient and appropriate use.
- Use the data for learning as well as tracking – before-after studies, long-term monitoring, and analysis to understand and model relationships and to track changes in them;

- Review data programs periodically to be sure that what is needed is gathered and archived, and what is gathered is used.
- Share data appropriately. Providing liberal access to data encourages research and learning, grows new ideas, and ultimately benefits transportation in cost-effective ways.

Data are the fuel that supports transportation management, decision making, and policy setting. They energize research that identifies and solves problems and leads to better ways to manage transportation systems. For these reasons it is essential to ensure the quality and sustainability of transportation data programs.



Assuring More Durable Concrete: An Interview with Jianmin Qu

Jianmin Qu is a professor and the department chair of Civil and Environmental Engineering at Northwestern. His research focuses on areas of applied mechanics and mechanics of materials. Prof. Qu joined Northwestern from Georgia Tech in the fall of 2009. In addition to his work with ITI, he has conducted research sponsored by the Defense Advanced Research Projects Agency, Air Force Research Laboratory, Motorola, Ford Motor Company, MCMD Consortium, and the National Science Foundation Packaging Research Center at Georgia Tech.

You and your students are working on a new method to evaluate alkali-silica reactivity (ASR) for aggregates used in concrete production.

What is ASR and why is it a problem for the nation's infrastructure?

ASR is a destructive process that occurs when chemicals in cement interact with some aggregates in ways that cause swelling, cracking, and eventually reduced performance and durability. Aggregates are a key component of concrete, and tens of billions of metric tons of aggregates are consumed each year for this purpose. Knowing the alkali reactivity of aggregates is essential for managing and mitigating ASR induced damage. Current tests of ASR can take several weeks. We're looking for a much faster test. In technical terms ASR happens in cement-based materials such as mortars and concretes, when the hydroxyl ions in the highly alkaline pore solution attack the siloxane groups (Si-O-Si) of siliceous mineral components in the aggregates. Hydroxyl ions together with alkali metal cations (sodium or potassium) bind with siliceous species derived from the reactive minerals to form a crosslinked alkali-silica gel. The alkali-silica gel swells in the presence of moisture.

Expansion of this gel can lead to cracking, the cracks can grow and eventually coalesce, threatening the strength and reducing the service life of the concrete structure.

How is ASR currently evaluated? (i.e., what are the common methods in practice now?)

Currently, several standard test methods are used in practice in different parts of the world. In the US, the most commonly used testing methods are the accelerated mortar bar test, the concrete prism test, and the accelerated concrete prism test. These tests

Above: Laboratory testing of the ultrasonic ASR evaluation equipment equipment.

all rely on measuring the expansion of concrete samples under exposure to an alkali environment. This means that the tests take a long time ranging from weeks to years. This becomes a serious impediment to the construction process.

Testing is required because the alkali reactivity of aggregates can vary significantly from source to source and sometimes even within a single source. In addition, with the growing use of higher alkali supplementary cementitious materials to develop advanced properties in concrete, screening aggregates for alkali reactivity is more critical than ever.Therefore there is a real need for more reliable, low cost and rapid test methods to assess aggregate alkali reactivity.

What are the advantages of the nonlinear ultrasonic techniques you're investigating?

In this project, we are developing a nondestructive testing method to assess the alkali reactivity of aggregates. The method is based on the mixing of nonlinear ultrasonic waves. In the test, a piezoelectric transducer attached to the sample induces two ultrasonic waves of different frequencies into a concrete sample with possible ASR damage. As the ultrasonic waves propagate through the concrete sample, they mix in the presence of the alkali gel, a byproduct of ASR damage. The mixing produces a resonant wave that can then be detected by another sensor attached to the sample. The magnitude of this resonant wave is called the acoustic nonlinearity parameter. Since the wave mixing is induced by the ASR damage, our hypothesis was that this acoustic nonlinearity parameter is directly related to ASR damage in the concrete sample.

Preliminary results from the first 8 months of our project clearly show that, indeed, the acoustic nonlinearity parameter is very well correlated to the degree of ASR damage in the sample. Furthermore, almost all existing methods require standardized sample size and geometry, because they measure the sample expansion caused by ASR damage. This prevents the field application of these methods to existing concrete structures. In contract, the acoustic nonlinearity parameter measured in our ultrasonic test characterizes the intrinsic state of ASR damage, independent of the sample size or geometry. This unique capability enables the application of our ultrasonic method to existing concrete structures. By attaching transmitters and sensors to an existing structure, ultrasonic measurements can be conducted to assess the ASR damage without damaging the structure.

What is the potential for widespread future deployment of nonlinear ultrasonic evaluation for ASR? What would the impacts be?

This new method detects the earlier stages of ASR damage. Therefore, screening the aggregates for alkali reactivity can be performed in much shorter duration than the existing technology. Considering the large quantity of aggregates used, substantial shortening of test duration of this test would mean tremendous saving for the construction industry. Further, the new ultrasonic method Could be developed into a portable tool for field tests. This would produce a huge impact on the maintenance of civil infrastructures because it permits in-the-field, nondestructive assessment of ASR damage.

You have over 20 years of experience in use of ultrasound for nondestructive evaluation of various materials, including cement and concrete. What do you think the role of ultrasonic evaluation in civil engineering will be 20 years from now?

Ultrasound has been widely used for nondestructive evaluation (NDE) in different industries for many decades. One of the earlier adopters of ultrasonic NDE methods is the medical community. Today, ultrasonic scan is commonly used for diagnosis of various diseases. In aerospace engineering, ultrasonic NDE is one of the standard methods for routine inspection of air frames and engine components. Even in civil engineering, ultrasonic NDE is being used widely to detect corrosion damage in oil pipelines and for structural health monitoring. An example of such applications is the ITIsupported work on bridge condition monitoring being conducted by Northwestern Professors Achenbach and Krishnaswamy.

It is always difficult to predict how a technology will evolve over time. However, I do see that ultrasonic NDE is going through a transition from a diagnostic tool to a prognostic tool. To put it simply, most of the existing ultrasonic NDE methods nowadays mainly detect (diagnose) the abnormality (cracks, delamination, etc.) in the materials or structures being monitored. However, these techniques are typically unable to estimate (prognosticate) the remaining service life of the structure. The next technology breakthrough in ultrasonic NDE would be the prognostic capabilities. I believe that nonlinear ultrasonic NDE, such as the one we are developing now, is one step in this direction.

You earned your Ph.D. in Theoretical and Applied Mechanics at Northwestern. How does it feel to return to campus as a professor?

Qu: The Chinese have a saying, "Leaves eventually fall under the tree." That is how I felt upon my returning to my alma mater. NU had provided me with a great education that enabled me to enjoy an exciting academic career. I owe NU a debt of gratitude. Since being an engineering professor for the last 20 years at Georgia Tech has not made me wealthy enough to give millions to NU, but I figure the best way to pay my debt to NU is to work for it.

Novel Sensor Captures Performance of Critical Highway Bridge

In the right circumstances, structural health monitoring of large bridges can be a useful management tool, with the potential to improve safety, extend the useful life of a bridge, and reduce the costs of maintaining the bridge over its decades. Unfortunately, standard sensing technology is not always well-suited for the unique and often unpredictable monitoring challenges found on many bridges.

Encountering such a situation while designing a structural health monitoring system for the John F. Kennedy Memorial Bridge in Louisville, Kentucky, the ITI Research Engineering Group (REG) adapted off-the-shelf sensing technology to develop a new sensor capable of measuring the performance of threaded rod assemblies used in a bridge retrofit.

Due to its asymmetrical cantilever design, the two ends of the JFK Bridge must be held down by large bearing assemblies anchored into concrete piers. This type of design, unusual for large through-truss bridges, required an equally unusual repair when inspectors discovered that one of the bearings was suffering from corrosion damage caused by runoff of deicing chemicals and precipitation. To ensure the downward restraint of the end of the JFK Bridge, the Kentucky Transportation Cabinet (the bridge owner) installed a retrofit that effectively clamped the end of the bridge more securely to the concrete pier below. The clamping strength of the retrofit is obtained from sixteen

Above: The John F. Kennedy Memorial Bridge carries Interstate 65 over the Ohio River at Louisville, Kentucky.

threaded anchor roads embedded into the top of the concrete pier. Nuts on the end of the rods were tightened against the bearing retrofit to prevent the bearing from pulling away from the top of the pier.

While designing a system to monitor the performance of this retrofit, the REG soon realized that it would be quite useful to know exactly how much these threaded rods were "pulling" down on the bridge. If this pulling lessens over time, it can be inferred that the threaded rods are being wrenched out of their anchor holes and must be repaired. To use off-the-shelf sensing technology to measure tension in these rods, a portion of each rod would have to be flattened to attach the sensor, damaging the rod and compromising the repair. The REG had to invent a new sensor to measure the tension on these rods without damaging the rods themselves.

The solution took the form of an external clamping mechanism composed of off-the-shelf strain gages, several large nuts and a simple bar of steel. First, the two nuts are split in half so that they can be re-assembled around the threaded rod with six small screws. Then, a steel bar is welded between the two nuts. Finally, strain gages are affixed to the bar. When the bracket is placed on a threaded rod, the strain in the bar is approximately equal to the strain in the rod, allowing calculation of the tensile forces in the rod.

The REG installed four of these sensors on the JFK Bridge in February, after the rods were placed in the concrete pier but before the clamping force was applied. The sensors reported the tension developed in the rods as the retrofit was tightened down and continue to provide insight as to the continued performance of the retrofit. The REG is in the process of analyzing the data from the bridge and performing additional controlled laboratory testing to further calibrate the sensors. Once this testing is complete, the new sensors may be used to evaluate the performance of the other retrofits that employ threaded rods to develop tensile forces.

Above: The ITI-develped clamped strain sensor for threaded rods deployed on the Kennedy Bridge bearing retrofit.

Showcasing the Products: University Research Technology Transfer Day

In early April, members of the REG traveled to Washington, D.C. to participate in the University Research Technology Transfer Day at US DOT headquarters, hosted by the Research and Innovative Technology Administration (RITA). This one-day demonstration/exhibition displayed prominent university transportation products developed through US DOT sponsorship, highlighting the accomplishments and impact of university-based research and education programs. This included meaningful technology transfer from the university transportation programs in use at various federal, state and local agencies. The event also included poster sessions, remarks by Deputy Secretary of Transportation John Porcari and RITA Administrator Peter Appel, and panel discussions about research.

At the event, Research Engineer David Kosnik presented the REG's work on advanced techniques for retrofit performance and reliability monitoring on the John F. Kennedy Memorial Bridge in Louisville, Kentucky. Since 2007, ITI has used advanced computer-controlled sensing systems for real-time measurement of critical engineering quantities, which has provided important insight for detection and repair of corrosion-related failures of uplift bearing components, helping keep this bridge of both regional and national importance in good repair and safe for the 120,000 vehicles that cross it daily.

On the evening of September 29, 2008, the automated structural health monitoring system measured a large, sudden shift in strain measurements on an uplift bearing anchor rod, suggesting that the rod had fractured. ITI researchers in the Chicago-area lab reviewed the data and promptly alerted the bridge owner. Upon inspection, the rod was found to be completely severed. Without monitoring, no one could have known about the fracture until the next routine inspection - even then, the fracture would have been nearly invisible, as the paint remained intact.

The goal of this research is to develop structural health monitoring systems that can be deployed readily by state DOTs and other transportation infrastructure owners.

Above: RITA Administrator Peter Appel addresses attendees at University Research and Technology Transfer Day in Washington, DC.

Caltrans: A Steady Partner for ITI

The Northwestern University Infrastructure Technology Institute (ITI) has enjoyed a long and productive partnership for structural health monitoring of highway bridges with the California Department of Transportation (Caltrans). Highlights include acoustic emission monitoring for retrofit evaluation, innovative bridge scour monitoring techniques based on tilt sensors, and Internet-enabled data management systems for structural health monitoring.

Acoustic Emission and Strain Gage Monitoring for Fatigue-Prone Details and Retrofit Evaluation

1. ***I-80 Bryte Bend Bridge, Sacramento***

ITI conducted acoustic emission monitoring on fatigue-prone bridge details before and after installation of various prototype retrofit designs. Monitoring showed one retrofit design to be clearly superior; that retrofit was deployed throughout the bridge, and further monitoring showed that the completed retrofit reduced fatigue crack activity overall.

2. ***I-680 Benicia-Martinez Bridge, Martinez***

Bridge Scour Monitoring with Tilt Sensors

3. ***SR-96 Klamath River Bridge, Siskiyou County***
4. ***SR-32 Stony Creek Bridge, Glenn County***
5. ***SR-3 Hayfork River Bridge, Trinity County***

ITI and Caltrans deployed innovative systems based on precision tilt sensors to monitor the effect of scour, the undermining of bridge piers and abutments by moving water, on these bridges. Prior to electronic monitoring, these bridges required on-site observation by Caltrans personnel during high water. In each case, ITI monitoring continued until the bridges were replaced as programmed or additional scour countermeasures were installed. In an important instance of technology transfer from university transportation research, Caltrans has since adopted this tilt-based scour monitoring technique statewide.

Internet-Enabled Data Management for Bridge Scour Monitoring

6. ***SR-39 San Gabriel River Bridge, Los Angeles County***
7. ***I-10 San Gorgonio Wash Bridge, Banning***
8. ***I-10 Whitewater River Bridge, Riverside County***
9. ***SR-1 Greenwood Creek Bridge, Mendocino County***
10. ***SR-29 St. Helena Creek Bridge, Lake County***
11. ***SR-20 Feather River Bridge, Yuba City***

To maximize the return on scour monitoring investment, it is necessary to archive and display the years of data that are collected in a useful way. Since many of the waterways spanned by the monitoring bridges have dramatic seasonal variations in flow, it is particularly important to compare each year's high water response to those of previous years. ITI and Caltrans have partnered to use ITI's existing Internet-enabled data management systems for structural health monitoring for Caltrans bridges, and to develop improved methods for automated analysis of scour monitoring data.

Wireless Monitoring for Bridge Scour

12. ***SR-1 Trancas Creek Bridge, Los Angeles County***

NU-ITI is developing a wireless monitoring system for this scour-critical bridge. Deployment is expected in summer 2011.

Above: ITI's field deployments in partnership with the California Department of Transportation.

Thermal Imaging of Composite Wrapped Bridge Columns

All bridges depend upon their substructure - piers, columns, and abutments - to safely transfer loads to the ground. Reinforced concrete, the most commonly used substructure material, is vulnerable to damage from corrosion, impacts, overloads, and earthquakes, to name a few damage mechanisms. One common repair for concrete columns that have suffered limited damage or need increased load capacity is a column wrap, in which the outer surface of the substructure element is wrapped with layers of high strength fibers and adhesive to form a composite shell.

Composite column wrapping can increase the flexural ductility (ability to bend without breaking) and increase the shear strength (ability to resist side loading) of concrete columns. The column wrap accomplishes this by radially confining the concrete core, thereby taking advantage concrete's innately high compressive strength. As long as the column stays column-shaped, it remains strong. This confinement will also increase the column's resistance to buckling even after a plastic hinge has formed in the wrapped region. Column wrapping also improves blast resistance and provide additional corrosion protection. However, proper installation of a column wrap is critical - improperly installed wrapping can appear acceptable under visual inspection, but not provide any benefits.

Northwestern University's Center for Quality Engineering & Failure Prevention and ITI jointly developed a pulsed themography imaging system for non-destructive testing of installed composite column wrapping. This technique uses portable high intensity flash lamps to briefly induce localized heating of the wrapping surface. The elevated surface temperature of the wrap from the flash drops as the heat is conducted through the wrap and into the underlying column. This changing temperature pattern on the surface is then recorded for several seconds with a sensitive infrared video camera. Poorly bonded areas will retain heat longer than those securely bonded to the concrete because the gap between layers acts as a thermal insulator. The result is an easily interpreted video showing problem areas staying brighter longer than others for a few seconds as the heat from the initial flash dissipates. Pulsed thermography can be used as both a long term inspection tool and a quality control check for newly installed wraps.

Northwestern researchers and IDOT engineers recently field tested the new system during an inspection of the approach structure to the I-57 Mississippi River Bridge located in Cairo, Illinois. This bridge has been extensively reinforced with composite column wrappings for seismic protection. In Cairo, the pulsed thermography inspection system proved capable of detecting and quantifying disbonds between the concrete/wrapping interface and also between layers within wrappings. Prior to this demonstration, the best method to detect disbonds was by visual inspection and manual tapping to find "dead" sounding areas. The thermography system provided results quickly, which is critical for minimizing inspection costs on large structures. Pulsed thermography techniques also generate a video record of testing, which is important for inspection records and long-term monitoring of these composite wraps.

Above: Northwestern researchers field test a flash thermography system on the I-57 Mississippi River bridge at Cairo, Illinois.

REG Partners with Northwestern's Engineers for a Sustainable World

The Centennial Solar Panel System (CSPS), Northwestern's first on-site renewable energy system, was recently installed on the roof of the Ford Motor Company Engineering Design Center, the building which houses ITI and several other departments on Northwestern's Evanston campus.

Students from Northwestern's Engineers for a Sustainable World and the Northwestern Sustainability Fund have been working for two years on the funding and logistics of purchasing, installing, and configuring the panels. The two student groups raised more than $117,000 from a variety of on- and off-campus sponsors and worked with many university groups, including the Northwestern's Initiative for Sustainability and Energy and Facilities Management, to bring the project to fruition. The largest single donation was a grant of more than $65,000 from the Illinois Clean Energy Community Foundation.

The CSPS will reduce the University's reliance on the power grid by generating approximately 20,000 kilowatt-hours of electricity per year - enough to power a computer lab.

ITI's Research Engineering Group partnered with the student groups to apply ITI's Web-based data display technology, developed for remote structural health monitoring of bridges, to management of the solar panel system. Additionally, ITI will be able to use the rooftop installation as a test platform for new sensors and monitoring equipment destined for deployment on transportation related structures. The infrastructure available at the rooftop solar site will be especially useful for ITI's work on solar powered wireless sensor networks.

The data made available through this cooperative effort will provide Northwestern students with a large and constantly growing source of real data for projects across many engineering disciplines. As the data set grows, ITI's unique abilities in data display technology will allow the creation of custom Web-based tools for the management of the solar panels.

Above: Students from Engineers for a Sustainable World and the Northwestern Sustainability Fund present their work at the ribbon-cutting ceremony for the Centennial Solar Panel System, held in ITI's flexible student work space in the Ford Motor Company Engineering Design Center.

ITI Supports Students in Steel Bridge Competition

Guided by ITI faculty and staff engineers, Northwestern University's student chapter of the American Society of Civil Engineers (ASCE) revived its Steel Bridge Competition team during this past school year when its membership decided to compete in the ASCE Great Lakes Student Conference for the first time since 2003.

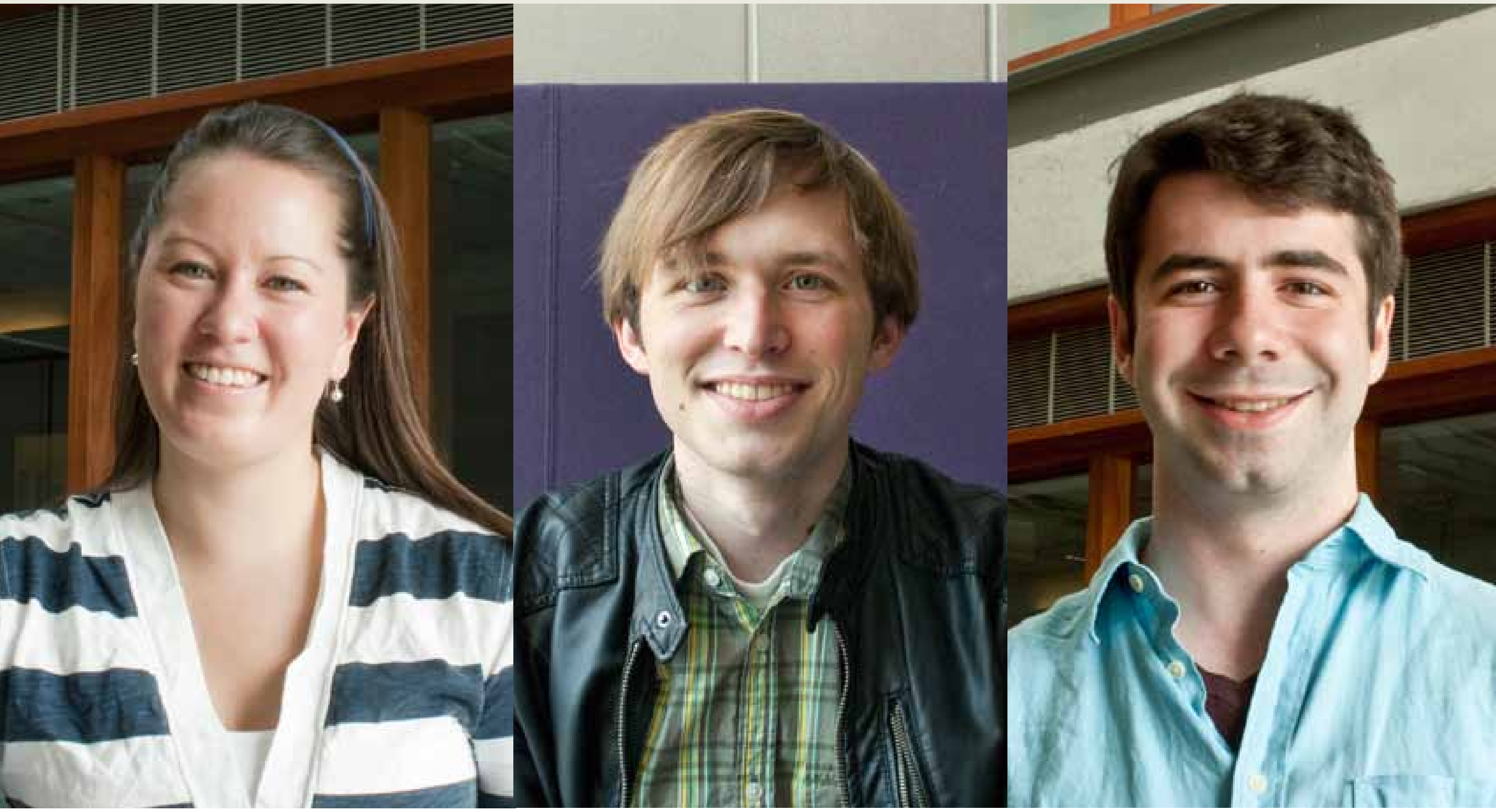
The team of six students raised over $8,000 in corporate donations to fund a fabrication of the 21-foot long bridge. Starting in the fall of 2010, the students spent long hours designing, machining, welding, testing, and practicing assembly of the bridge, preparing it and themselves for the competition, held in Milwaukee, Wisconsin, on April 2, 2011.

On the day of the competition, the bridge was assembled and tested to see how much weight it could support. Although the bridge was disqualified from final competition due to a technicality, the student team was pleased with the performance. ITI Research Engineer David Corr, who advised the students during the bridge construction, said that "While most teams at these competitions have built up years of experience, the NU team began the process with no members who had previously taken part in the competition. The most competitive teams have a lot of institutional knowledge that is handed down," Corr said. "All of ours is gone because it has been a number of years since NU competed."

The team's final act was to sacrifice the product of their efforts to make next year's bridge better: On May 16, they loaded the bridge to failure in public view as part of a campus-wide Engineering Week event. With assistance from ITI engineers, the ASCE students instrumented the bridge with strain and deflection sensors and collected live data throughout the load test. Students will use the collected data to verify their analysis and improve next year's design.

Above: Student members of the NU ASCE steel bridge team pose with their bridge.

The NU-ASCE students, with the assistance of ITI engineers, load test (to failure) the steel bridge they designed and constructed for the 2011 AISC Student Steel Bridge Competition.



Graduating Seniors Discuss Their ITI Experience

Corey Bertelsen, Amanda Chen, and Ken Fuller are seniors in the Northwestern's Department Civil and Environmental Engineering. Each joined the ITI engineering staff as an undergraduate research assistant, participating extensively in both laboratory and field research. Student assistants are an essential part of the team; they enable ITI to increase the number and scope of research activities while bolstering their education through unique real world work experience.

Corey Bertelsen

When did you start working at ITI? What was the first project you worked on?

I started working at ITI spring quarter of my junior year. The first project I really started getting into was the Metro North Railroad Fulton Avenue Bridge in New York, and I'm still working on it today. My first task was to take some hundred-year-old construction documents and put them into CAD drawings. Now, I'm working on developing a wireless sensor network that we want to use on this bridge.

During your time at ITI, did you work on any project that expanded your view of what you thought you were interested in? What effect did your work at ITI have on your career development?

My work at ITI has provided me with a number of skills, from data acquisition and analysis to wire soldering, that I know will be invaluable in any career that I choose. I've gained an appreciation for seemingly mundane structures and bridges. I'd like to pursue a career in architecture and structures; as such, it's important to consider how buildings and bridges will change over time, and how to plan for the future. A great engineer or architect doesn't just create good-looking, useful structures; she also plans for the monitoring and maintenance that will be required decades down the line.

What was the best (most interesting or most fun, etc.) project that you worked on at ITI?

I really enjoy field work, and have fond memories from our trips to [install structural health monitoring systems in]Hurley, Wisconsin and Louisville, Kentucky. The Louisville trip was especially fun, as we were

Above, left to right: Amanda Chen, Corey Bertelsen, Ken Fuller.

climbing around on a bridge pier while 50 feet off the ground.

What are you doing after graduation?

Following graduation, I plan on doing a year of service through Americorps. The programs I am considering involve a range of tasks, including construction and restoration, after-school tutoring, and community development work. Following Americorps, I plan on attending a graduate program that combines architecture studio experiences and structural engineering coursework. My life goals include working on small scale, sustainable community buildings and housing; restoring, renovating and reducing energy requirements of existing buildings; and designing artistic virtual experiences through video games and other interactive media.

Ken Fuller

When did you start working at ITI? What was the first project you worked on?

I started working at ITI late in my sophomore year—cleaning the lab a lot. But seriously, OMPW [the One Museum Park West project, in which ITI engineers installed vibrating wire strain gages in concrete floor slabs as they were being poured] was the first big thing I worked on. Then the structural health monitoring system on US-2 bridge over the Montreal River in Hurley, Wisconsin.

During your time at ITI, did you work on any project that expanded your view of what you thought you were interested in? What effect did your work at ITI have on your career development?

Seeing the application of technology in the field to provide useful data to the user has expanded my views of the possible applications. Technologies today have the ability to make design and construction much more efficient, cost-effective and convenient, and my time at ITI has not only showed me what options exist but also what capabilities can be developed for new and cutting edge systems. ITI has also helped me realize the importance of conveying information effectively. Having information alone is not useful; interpreting useful data and displaying it for the end user well is just as, if not more, important than the actual information.

What was the best (most interesting or most fun, etc.) project that you worked on at ITI?

Hurley. It has been really interesting to see the full life cycle of the project, from project definition and implementation to long term maintenance and data interpretation. I also really enjoyed the CTA/ Devon overpass [bridge structural health monitoring] project.

What are you doing after graduation?

I will be working for CN Railway in their systems engineering department.

Amanda Chen

When did you start working at ITI? What was the first project you worked on?

I started working at ITI spring quarter of my junior year. During my first week, I spent 3 days in the field working on the Autonomous Crack Monitoring project. It was exciting to get right into the hands-on field work, even though at that point I had no idea what most of the instruments we were using were!

During your time at ITI, did you work on any project that expanded your view of what you thought you were interested in? What effect did your work at ITI have on your career development?

Basically all of my work at ITI has helped me to develop career skills. It is one thing to learn about circuits during class, but at ITI I've been able to wire up resistors, power sources, and sensors, make mistakes and work backwards until I've found them. I've had to look at a bridge without all the convenient assumptions used in classes and determine how the supports are actually behaving, despite how they were designed. Working at ITI has helped me to look at problems with a much more realistic and comprehensive sense, something that I am sure I will need to do in the years to come.

What was the best (most interesting or most fun, etc.) project that you worked on at ITI?

The most interesting project I worked on was the JFK I-65 Bridge. I spent a lot of time last summer researching the project and recreating one of the retrofits to measure strain in all directions. I learned about applying strain gages, the data acquisition systems, and how to integrate the two together. When I finally took the trip to Louisville and got to work on the pier cap, I really felt like I knew what I was doing and why I was doing it - I just had a great understanding of the project as a whole.

What are you doing after graduation?

After graduation, I will be moving to Connecticut to work for General Dynamics - Electric Boat. Electric Boat designs and builds nuclear submarines for the US Navy. I will be doing structural design work on a boat that will be used as a training ship for naval crews learning to run the nuclear propulsion systems.

NU-ASCE and ITI Give Middle School Students a Taste of Engineering

Northwestern's student chapter of the American Society of Civil Engineers (NU-ASCE) and the Infrastructure Technology Institute (ITI) addressed a group of 90 middle school students from Waukegan, Illinois, to give them a glimpse of the lives of engineering students in college. The NU-ASCE/ITI demonstration was part of a larger, day-long event coordinated by Promote 360, a student organization that aims to enhance social, academic, and professional well-being of minority and under-represented students.

The goal of the day was to immerse underprivileged students in a broad survey of activities that would educate them about campus life and inspire them to pursue higher education . After introductions and ice-breaking activities, the students ate lunch in a dining hall and toured the campus. In the afternoon, the students attended performances and presentations from various Northwestern student groups, including NU-ASCE/ITI.

The NU-ASCE speakers, Civil Engineering juniors Hannah Iezzoni and Kendra Pickard, focused their presentation on a general introduction to engineering, showing the students the many ways engineers benefit society. The speakers touched upon many of the different engineering majors available at Northwestern as well as the extracurricular activities in which they both take part, including joining a team that designed and built real bridges from scratch.

Above: Research Engineers Mat Kotowsky and Brian Quezada assist visiting middle school students as they cross the steel bridge recently constructed by Northwestern students for a competition.

The second portion of the presentation was a live demonstration of the steel bridge that NU-ASCE members had just constructed for the annual ASCE-sponsored Student Steel Bridge Competition, held the previous month in Milwaukee, Wisconsin. With instruction and assistance from ITI staff engineers, NU-ASCE members installed strain sensors on portions of the bridge, allowing the visiting students to see measurements showing how the bridge “felt” the weight of the ASCE members as they showed that the bridge could easily support several adults standing on it at once.

At the end of the presentation, the visiting students were invited to walk across the bridge on a special wooden deck constructed for the demonstration. As NU-ASCE members guided the students over the bridge, the audience watched in amazement as the sensor readings showed their footsteps as they walked across the wood and steel structure. As the students finished their walk, they were treated to a close-up view of the strain sensors, smaller than the size of a postage stamp, which made possible the demonstration that they’d just seen.

Andrea Abel, coordinator of the Special Projects Office of Northwestern’s President, praises the students of Promote 360, and says that bringing student groups to campus is a valuable extension of the Good Neighbor, Great University initiative, which seeks to make Northwestern accessible to students in the Chicago area. It’s an opportunity for Northwestern students to work with younger students, and “President Schapiro is interested in connecting to the community,” she emphasized, noting that the University would like to bring more K-12 student groups to campus.

Above: Civil Engineering juniors Kendra Pickard and Hannah Iezzoni discuss their experiences in engineering with visiting middle school students.

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