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UTC Spotlight

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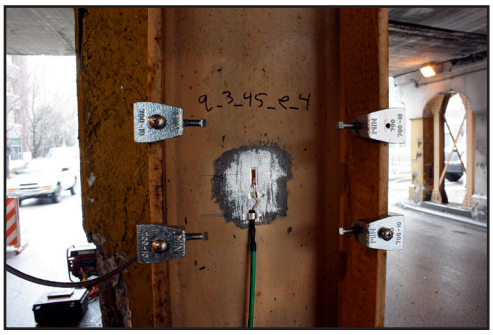
Moving Toward a State of Good Repair: Remote Structural Integrity Monitoring

Keeping aging transportation infrastructure, such as bridges, in a state of good repair with limited resources is a nationwide challenge. One way to get the most value per dollar is to apply technologies that deliver objective information on the condition of transportation assets that can then be used to set maintenance and rehabilitation priorities. Northwestern University's Infrastructure Technology Institute (NU-ITI) is developing tools and methods for collecting and analyzing data to not only learn how specific infrastructure systems are performing but to build capabilities that can predict system performance over time as well. As a part of its research program, the NU-ITI team has developed a remote structural health monitoring system for in-service bridges and deployed this system on a century-old Chicago Transit Authority (CTA) mainline bridge. The data that engineers capture from this remote system will help the agency manage dozens of similar bridges for years to come.

Melissa Mattenson

An overall view of the Chicago Transit Authority's Devon-Sheridan Overpass.

CTA's Devon-Sheridan Overpass is severely deteriorated—mostly due to decades of chemical attack from deicing salts. The reinforced concrete columns that support the bridge are particularly affected; in many areas, the reinforcing steel is exposed to the elements. This bridge and many comparable bridges on the CTA elevated train line on the north side of Chicago suffer from similar deterioration and would be expensive and inconvenient to replace—closing a bridge for overhaul or replacement would impact tens of thousands of commuters daily. As an interim measure, the CTA installed additional steel supports to supplement the deteriorating concrete columns. But it was not clear how much load had shifted to these new supports, which, in turn, would indicate loss of strength in the original structure. Knowing the load on the added supports would give the CTA an indication of the remaining life of this aging concrete bridge, and thus guide priorities for rehabilitation or replacement.



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A typical steel strain gauge installed on one of the supporting columns.

To measure the performance of the supplementary steel columns, NU-ITI installed an Internet-accessible structural health monitoring (SHM) system on the bridge. The SHM system autonomously records key engineering parameters at critical areas of the structure using a computer-controlled data logger. Measurements are taken from strain gauges bonded to the supplementary steel columns and others embedded in their supporting concrete foundations. The gauges measure the elastic movement of the steel columns under loads from trains crossing the bridge, which happens as many as 450 times each weekday. From this, the load imposed on each column can be calculated. The instruments are sensitive enough to

detect each truck[1] on a passing train. Post-processing of this data can distinguish between local and express trains in either direction.

The SHM system records sensor data in two modes:

- long-term data are recorded hourly to provide a record of the bridge response to environmental changes and long term load cycles, and
- burst data are recorded at high speed for a short time whenever a train crosses the bridge.

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ITI Research Engineer David Kosnik (left) installs a strain gauge while Professor David Corr (right) aligns a cover plate over an already installed gauge.

Together, these data modes give a comprehensive representation of the response of the bridge to both slowly and quickly varying conditions. NU-ITI structural engineering and statistical modeling faculty are using the data to develop models to predict long-term bridge performance.

The SHM system is composed almost entirely from commercial off-the-shelf components, which reduces hardware cost and facilitates and encourages future adoption of the system by infrastructure owners. It is expected that future installations will approach "turn-key" operation, under which infrastructure owners could install and operate a remote SHM system with minimal assistance from researchers.

[1] Set of swiveling wheels at either end of a rail car.

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ITI Research Engineers at work under the Devon-Sheridan Overpass. Some deteriorating concrete is visible.

ITI's around-the-clock monitoring of the Devon-Sheridan Overpass will provide early warning to changes that could compromise the bridge's integrity as well as clues about the condition of other similarly constructed bridges and any temporary support structures installed on them. The cost-effectiveness and noninvasiveness of the SHM system makes it applicable to all kinds of transportation structures nationwide, particularly as a part of preservation and life-extension efforts for highway and railroad bridges. This approach will be particularly useful for aging rapid transit infrastructure, where the economic impact of disruption is very high and no convenient alternate routes are available.

About This Project

The NU-ITI Research Engineering Group is composed of Chief Research Engineer Daniel Marron, Clinical Associate Professor David Corr, and Research Engineers David Kosnik, Mathew Kotowsky, and Brian Quezada. Undergraduate student J. Ken Fuller also contributed to this project. The Director of the NU-ITI University Transportation Center is Prof. Joseph L. Schofer (j-schofer@northwestern.edu).