NDEC News

NONDESTRUCTIVE EVALUATION CENTER

U.S. DEPARTMENT OF TRANSPORTATION FEDERAL HIGHWAY ADMINISTRATION

Volume 3, Issue 1 **March 2010**

Evaluation of NDE Technologies for Fatigue Crack Detection

According to the National Bridge Inspection Standards requirements, all publicly owned highway bridges (including steel bridges) that are longer than 20 ft (6 m) undergo an inspection at least once every 24 months. The United States has approximately 200,000 steel bridges; however, the inspection of steel bridges is primarily visual, followed by magnetic particle or dye penetrant inspection for validation purposes. The Federal Highway Administration (FHWA) Nondestructive Evaluation (NDE) Center is undertaking a program to evaluate NDE technologies and demonstrate advanced methods offering better accuracy, wider ranges of applicability and reduced costs.

The ***Steel Bridge Testing Program*** addresses the inspection issues in steel bridges that are primarily focused on detection and monitoring of fatigue cracks. The cyclic loads that bridges are subjected to over their lifetimes due to varying traffic patterns can result in fatigue cracks. Advanced NDE technologies can provide valuable information on the location of cracks, geometric features of cracks, and the status (active or stable) of cracks. The program has two phases: Phase I evaluated NDE technologies in a laboratory setup, and Phase II will involve field inspections of bridges. The NDE technologies were classified into two categories: crack detection technologies, and crack monitoring technologies. The crack detection technologies currently being evaluated under this program are the phased array ultrasonic testing (PAUT) systems, and the eddy current array sensors (ECAS). The electrochemical fatigue sensors (EFS) and acoustic emission (AE) systems are evaluated as a part of the crack monitoring technologies.

PAUT systems are advanced ultrasonic inspection systems that can electronically steer and focus ultrasonic beams. This steering capability enables the user to inspect components without moving the probe. In addition, the commercial probes currently available, enable probe selection based on the thickness of the component under inspection and the accuracy of flaw sizing needed. PAUT systems are designed to locate and size surface and subsurface cracks, and can also be used to detect porosity and lack of fusion in welds. PAUT systems offer a variety of scanning options that include linear, sectorial, lateral, combination, and depth focusing.

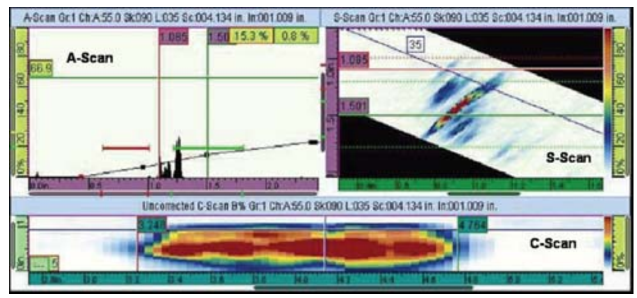

Figure 1. Graph. Composite Scan Image from PAUT System.

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Gusset Plate Testing Program

Following the I-35W Bridge collapse in Minneapolis, MN, significant attention has been focused on the procedures and tools to assess gusset plate section loss due to corrosion, even though the main reason for the bridge collapse was faulty design. The use of NDE technologies like conventional ultrasonic thickness gauges, phased array ultrasonic testing systems and other technologies can enhance the ability to accurately quantify and document section loss. The NDE Center currently is starting a program to develop and evaluate NDE technologies that are most suitable to determine this section loss. The Gusset Plate Testing Program is focused on difficult inspection areas, such as multilayer plates, where visual inspection and conventional NDEs are not possible. The use of advanced NDE technologies will enhance the inspection capabilities and provide inspectors more information about the condition of a gusset plate.

Developing a New NDE Tool for Rapid Load Testing of Highway Bridges

Data from the National Bridge Inventory indicate that the Nation has a large population of bridges with an average age of 42 years. There is an urgent need to quickly measure the load rating of these aged bridges. The FHWA NDE Center is working to develop an NDE tool for rapid bridge load rating applications. The research will integrate microwave interferometric radar scanning, and advanced chaos theory analysis techniques into a unique, rapid, detecting system, which can collect bridge responses remotely from large numbers of critical locations and conduct advanced analysis to determine a bridge load rating.

Microwave interferometric radar scanning is a ground based radar device that can measure wide areas, and remotely monitor vibrations of a bridge structure under various loading conditions. Chaos theory analysis is a new technique that uses modern nonlinear chaotic dynamics, information theory, and topologic dynamics analysis for extracting nonlinear system invariants for structural health condition monitoring applications. These nonlinear system invariants can be used to characterize the inherent nonlinear behavior of a general nonlinear system and reveal potential local instabilities due to changes in aging structures.

The focus of this research is to develop a working NDE screening tool for rapid bridge load rating applications. FHWA NDE Center staff will use the microwave interferometric radar scanning technique to collect real-time bridge vibrations under various load conditions from large numbers of critical locations on a bridge structure. The staff then will use chaos theory analysis to conduct advanced analysis to provide rapid condition assessment, and determine a bridge load rating. The development of such a new NDE system will simplify the bridge load rating process and provide better information in revealing bridge load behaviors and capacities.

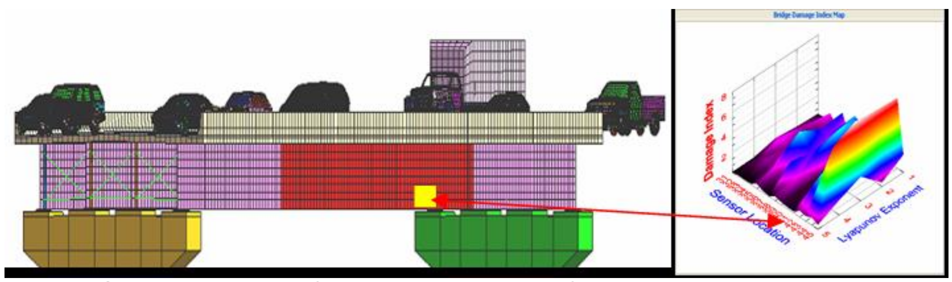

Figure 2. Graph. An example of chaos theory analysis of bridge vibrations to detect weakened structural locations in bridge girders.

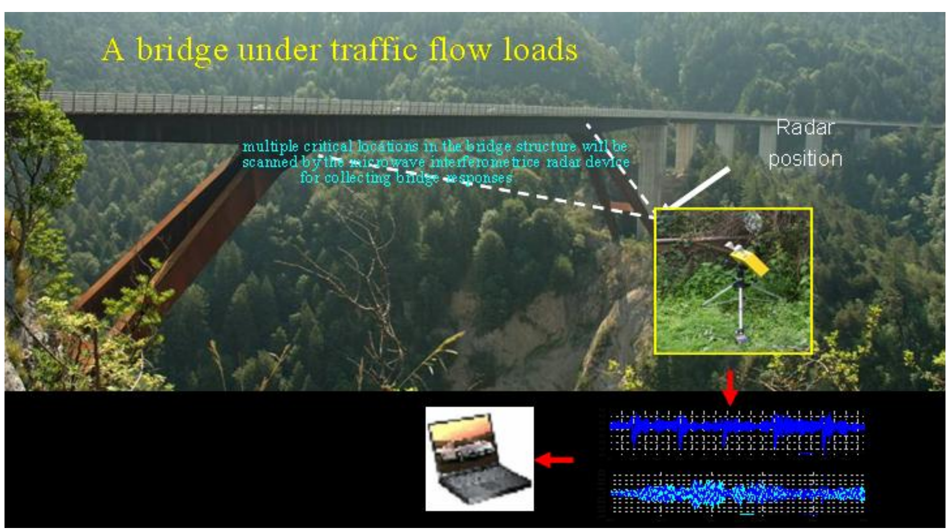

Figure 3. Photo. The research concept—rapid load rating application using a new NDE detecting system based on microwave interferometrice radar scanning and chaos theory analysis techniques.

NDEC NEWS is the newsletter of the Federal Highway Administration's (FHWA) Nondestructive Evaluation (NDE) Center.

The FHWA NDE Center was established in 1998. The objective of the NDE Center is to improve the state of the practice for highway bridge inspection. The NDE Center is a resource for State transportation agencies, industry, and academia involved in the development and testing of innovative NDE technologies. The NDE Center provides State highway agencies with independent evaluation and validation of NDE technologies, develops new NDE technologies, and provides technical assistance to States exploring the use of these advanced technologies. The NDE Center uses a series of unique resources to assess the factors affecting the reliability and performance of NDE systems.

The NDE Center is located at the Turner-Fairbank Highway Research Center in McLean, VA. To supplement the capabilities of these laboratory facilities, a series of bridges located in northern Virginia and southern Maryland are used to conduct field investigations. In addition, a collection of component test specimens are used in various test programs.

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New Development of NDE Technologies for Steel Bridge Testing

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In the composite scan image from PAUT (figure 1), the A-scan, B-scan, C-scan and S-scan are available as part of the report for each test. Phase I laboratory evaluations were performed using an Olympus NDT OmniScan portable phased array unit. This instrument is a high-end portable instrument capable of controlling phased array transducers or transducer combinations with as many as 128 elements, and with instructions provided to 32 elements at any given beam formation. The phased array probe used in testing was a 5 MHz linear array probe with 64 available elements (5L64 Olympus).

The Meandering Winding Magnetometer (MWM) is a fully integrated ECAS system designed to measure absolute properties of conducting materials (i.e., electric conductivity and magnetic permeability), detect and image defects, and monitor stresses. The system uses an eddy current array in combination with a model based grid measurement to determine the material properties. The system is very sensitive to stress changes in magnetic materials and to cracks oriented perpendicular to the longer segments of the sensor winding. The system can be used in both a scanning mode, producing images of materials properties and flaws, and an embedded mode, providing continuous or intermittent monitoring of material condition. Lift-off/permeability grid shows that permeability increases when MWM sensor scans over cracks. The MWM array system used is an advanced eddy current

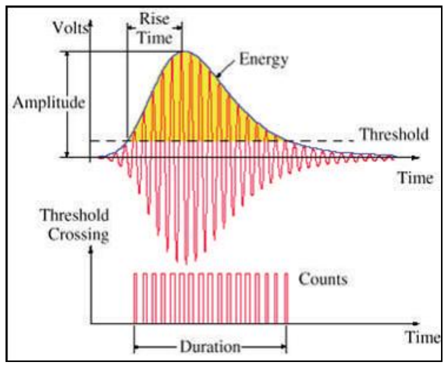

Figure 5. Graph. AE monitoring scheme.

inspection system. The MWM is a thin and conformable sensor that incorporates both eddy current type sensing and magnetic induction sensing methods to measure both conducting and magnetic properties of nonferrous and ferrous metals.

For bridge structures, AEs may be generated from crack initiation and/or growth, crack opening and closing (i.e., fretting/rubbing of crack faces and bolts), and friction. The Sensor Highway (SH) II Smart Remote AE data acquisition system was evaluated as a part of this research study. The SH-II system provides up to 16 high speed AE monitoring channels and up to 16 additional parametric input channels. The system uses a set of resonant sensors, each with built-in 26dB preamplifiers and a resonant frequency of 150 kHz. This AE system performs all the tasks of data collection, full signal processing, analysis and alarming for standalone surveillance monitoring, 24 hours a day.

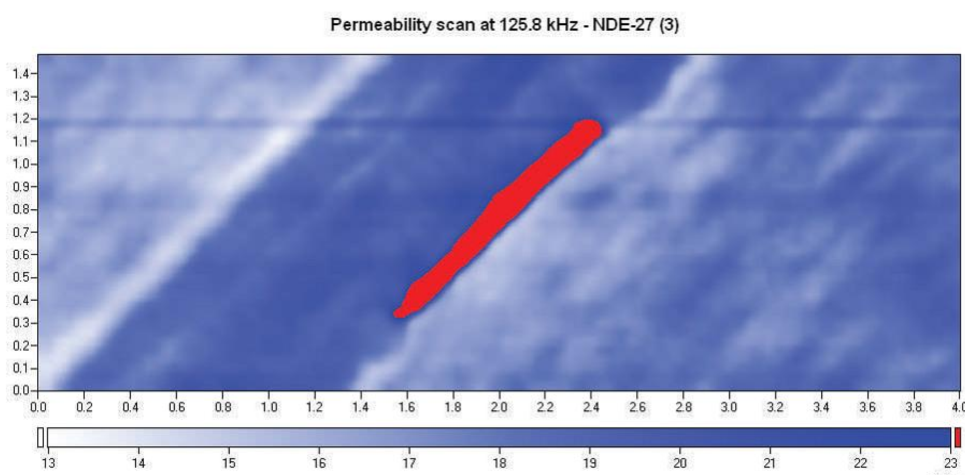

Figure 4. Graph. Permeability C-scan image using an FA28 MWM Sensor oriented 45 degrees with respect to weld on butt-weld specimen with a surface flaw of length 30.48 mm (1.2 inches). The defect is shown as a red line on the image.

The EFS System is a nondestructive fatigue crack inspection system for detecting actively growing fatigue cracks in dynamically loaded steel structures. The EFS system uses electrochemical principles to detect the presence of actively growing fatigue cracks in the area of a sensor. In particular, the EFS is proposed as a method to determine if a known fatigue crack is actively growing or if an unidentified growing fatigue crack is present in the inspection area.

Prestressed Strands Study

The most used material for construction of concrete bridges is prestressed concrete, which can be used to produce a bridge with a longer span than is practical with ordinary reinforced concrete. Prestressed strands and tendons are generally made of high tensile steel cable or rods.

Corrosion of steel strands or tendons is a common reason for fracture of prestressed concrete. The most direct damage resulting from corrosion is the reduction of steel diameter and cross-sectional area. As the cross-section decreases, the magnitude of the stresses carried by the remaining prestressed steel increases and the steel is at risk of breaking. It is beyond the capability of visual inspections to identify and evaluate corrosion damages on strands and tendons in prestressed concrete.

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Additionally, it is a difficult task to accurately estimate corrosion damage or detect broken strand in prestressed concrete using NDE methods. Many NDE methods have been proposed for this purpose and some promising research has been done using NDE methods to evaluate prestressed strands and tendons. The NDE Center is starting a study intended to evaluate existing technologies and instruments for accurately measuring and detecting corrosion damage on prestressed strands/tendons. The identified technology will be further developed for field testing of prestressed concrete bridges.

NDE for Corrosion Detection in Reinforced Concrete Structures

Corrosion of reinforcement in bridge decks is a major problem for the U. S. infrastructure. A rapid, spatially resolved, and objective inspection tool for detecting corrosion of reinforcement in concrete at an early stage could lead to better planning, reliability, and cost savings—billions in U.S. dollars. Both traditional methods and NDE methods have limitations. For example, the NDE methods used can be costly and require expert operators, while traditional methods might not detect problems in earlier stages.

The FHWA NDE Center is trying to fill the gap by performing a benchmark project for the evaluation of NDE methods for concrete assessment. To accomplish this plan, an expert committee was founded with corrosion specialists and NDE experts as members from the United States and Europe, including experts from the Technical University of Berlin, University of Vermont, and University of California, Irvine.

The focus of this collaborative effort cosponsored by the National Research Council and FHWA's Exploratory Advanced Research program is to devise a test protocol for structural health monitoring and asset management of concrete structures by performing automated or semiautomated periodic baseline nondestructive testing (NDT) surveys.

The main objective of this research is to evaluate the ability of NDT methods to detect differing phases of corrosion progression in concrete. Research includes designing and building typical concrete test specimens, artificially inducing, accelerating and monitoring corrosion, and performing automated multisensor NDE inspections, and following with three-dimensional (3-D) imaging and destructive validations. Research began with the casting of typical concrete slabs representing bridge elements. The casts consist of a bridge deck with reinforcing bars of varying covers (figure 6), and a box girder plate specimen with unstressed prestressing tendons (figure 7).

A data acquisition system was set up to monitor the corrosion process by collecting potential, current, resistance, and temperature data—including that from an embedded anodeladder system. The methods used for half-automated NDT structural health monitoring consist of half-cell potential, an advanced ultrasonic linear array for early crack detection, 0.9 and 2.3 GHz ground penetrating radar (GPR), a 10 GHz microwave camera, and infrared thermography with induction heater. Using induction thermography, the rebar can be heated in the concrete by using an alternating current electrical induction heater, external to the concrete structure. The half-automated NDE scanner system setup in the NDE Center with support of upward vertical motion (UVM) is shown in figure 8.

The main goal of this study is to promote the use of NDE as a tool for bridge maintenance and preservation by performing periodic baseline NDE measurements.

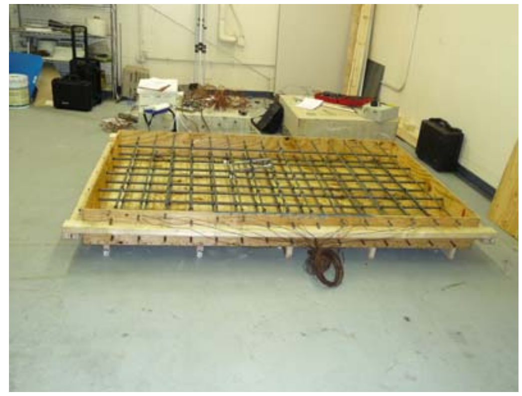

Figure 6. Photo. Bridge deck specimen with reinforcing bars.

Figure 7. Photo. Prestressed concrete specimen with untensioned tendon strands.

Figure 8. Photo. Half-automated scanner with bridge deck specimen with reinforcing bars (top) and specimen with prestressing tendons (bottom).

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