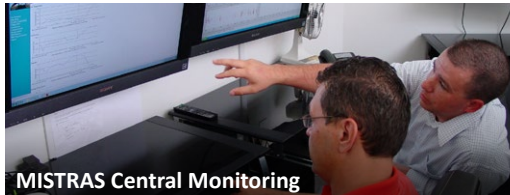


**Structural
Health Monitoring
Advanced NDT
Solutions**

Bridges

Systems | Services | Monitoring



MISTRAS & STRUCTURAL HEALTH MONITORING

With more than 35 years of infrastructure and structural health monitoring experience, MISTRAS has become a name that bridge owners can trust. As the largest and most experienced non-destructive testing (NDT) and structural health monitoring (SHM) company in the world, MISTRAS' expertise can be applied to many industries and clients. FHWA, state DOTs, NASA, NIST, FAA and major Universities go to MISTRAS for their on-going developments, technological innovations and top of the line infrastructure expertise. MISTRAS provides bridge owners and clients with full turn-key systems or installations including MOT and electrical and lift equipment. MISTRAS also offers long-term monitoring services, to provide continuity and piece-of-mind for asset owners. Because of the multiple technologies, system design, support and automated monitoring available, MISTRAS ranks the highest (96%) in a Minnesota DOT 2010 SHM survey. With worldwide locations and over 2500 skilled employees, MISTRAS Group is the best choice for honest and reliable Structural Health Monitoring and Infrastructure needs.

COST AND DATA ANALYSIS

Before a bridge owner can monitor and detect flaws in their structures, they need to consider the cost of the systems and the data analysis needed for inspection. At MISTRAS, an in-house team of electrical engineers are continuously redesigning SHM systems to take advantage of smaller, low power, lesser cost electronics while still maintaining and increasing their high performance components. Additionally, application and software engineers have automated

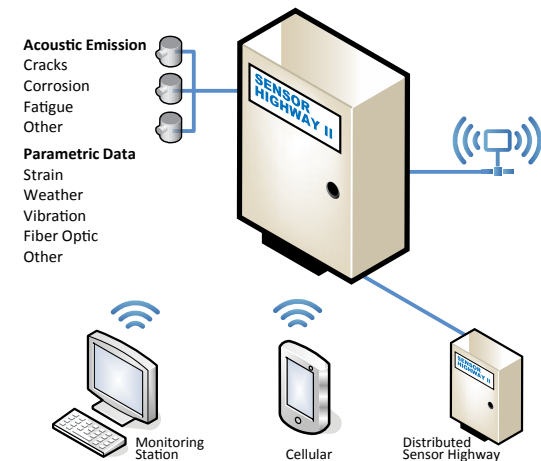
their data analysis, systems check, and calibration, which are controlled by the latest real-time communication devices. In order to control costs further, MISTRAS manufactures and supplies all products and units in-house, eliminating the additional cost created by outside suppliers.

VALUE ADDED APPROACH: UNIQUE PROBLEM SOLVING AND DESIGN OF THE MOST SOPHISTICATED SYSTEMS

Worldwide DOTs, industries and universities approach MISTRAS daily for solutions to their NDT and SHM needs. With the most advanced R&D staff, hardware and software engineers, and in-house automated electronics manufacturing, MISTRAS works in harmony with the Infrastructure Centers of Excellence (COE), providing the best technologies, industrial networking and training available to solve problems by synthesizing all types of SHM and NDT techniques.

ACOUSTIC EMISSION AND SENSOR FUSION - "QUANTIFIABLE CAUSE AND EFFECT"

Acoustic Emission (AE) technology has been researched, vetted, proven, documented and recommended by DOTs, FHWA, engineering firms and universities worldwide for concrete, steel, wire breaks and composite bridges. AE is a passive technology that can identify and classify crack propagation, fretting, corrosion and wire breaks from a significant distance. MISTRAS instrumentation can use multiple types of sensors simultaneously, creating a more complete evaluation of the structural health, and making the process more cost effective. If AE detects



a problem, secondary transducers, such as LVDTs, vibration, temperature, strain and weather station sensors, can be installed to provide a "Quantifiable Cause and Effect" analysis of the problem. Acoustic Emission and Sensor Fusion are a bridge owner's best chance of a "silver bullet" solution for SHM applications. MISTRAS Sensor Fusion, gives bridge owners the ability to pinpoint when, where and why a problem happened while providing a real-time, quantifiable cause and effect.

AUTOMATED DATA ANALYSIS AND SELF-CALIBRATING SYSTEMS

Bridge owners don't want to be concerned with the time and effort that goes into performing a data analysis. MISTRAS is aware of this and has developed systems that are automated to locate and alarm on crack, corrosion, wire breaks and other selectable sources with extremely high probability. SHM systems are programmed at regular intervals to perform a self-test or calibration by "pinging" each sensor, ensuring it is calibrated. This process allows the bridge owner to cut down on expensive site visits to see if the SHM system is properly working, saving them both time and money.



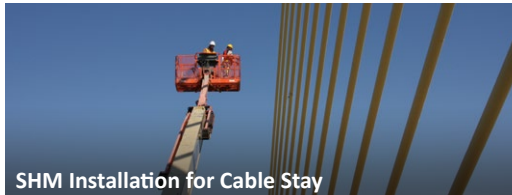
Advanced Gusset Plate Inspection

STRUCTURAL HEALTH MONITORING PROVIDES:

- Daily, weekly or monthly check by system manager
- Condition Ranking from multiple bridges & prioritize repair or replacement.
- Real-time damage location of crack or wire breaks
- Reduce inspection and lane closure costs
- Monitor fracture critical members
- Continuous remote monitoring
- Prolong service life
- Finds non-visible defects
- Cause and effect
- Safety

TECHNOLOGY ROAD MAP

Before the development of wireless communication and PCs, MISTRAS engineers were hard at work, developing a company that specializes in signal processing monitoring systems. As MISTRAS monitoring systems began to develop and wireless became more prevalent, organizations like FHWA, began contacting MISTRAS to design wireless SHM systems. In the following years, more bridges and structures required MISTRAS' systems to properly and effectively monitor cables for defects and flaws. In 2000, the Delaware River Port Authority requested a system to monitor wire breaks in suspension cables; in 2007, MISTRAS delivered the 3rd generation system to FHWA; and in 2011, the 4th SHM system was introduced. As technology changes and the industry grows, MISTRAS plans to introduce future innovations in order to further reduce installation time and costs.



SHM Installation for Cable Stay

TRADITIONAL NDT SERVICES

MISTRAS' certified personnel provide a range of traditional inspection services with their visual inspectors providing comprehensive traditional NDT techniques and advanced NDT services.

Additionally, MISTRAS has more than 2,000 ASNT Level I, II, III experts skilled in many key technologies, including Liquid Penetrant Testing, Radiographic Testing, Visual Inspection, Ultrasonics, Phased Array Ultrasonics, Digital Radiography, Ground Penetrating Radar, Magnetic Particle Testing, Electromagnetics, Resistivity, Vibration and Strain Gages, Impact Echo, Acoustic Emission, Eddy Current, and Scanning Infrared Thermography.

ROPE ACCESS INFRASTRUCTURE INSPECTION AND MAINTENANCE SERVICES

The MISTRAS Ropeworks® team specializes in bridge, dam and structure inspection, and maintenance using rope access. By using a broad range of access techniques, MISTRAS specialists can place themselves within arm's reach of critical members in the most safe, efficient and economical way possible.

Rope access capabilities allow technicians to work on structures that would otherwise be inaccessible or too expensive to reach using other means. Minimizing or eliminating lane or track closures is just one way Ropeworks® lowers cost to the project and regional economy.



Rope Access Inspection

Rope Access Inspection Services include inspection of steel, concrete and wood bridges to NBI Standards, FHWA certified bridge inspectors, and ASNT qualified NDE Technicians

MISTRAS MILE STONES

Over the past 35 years, MISTRAS has monitored hundreds of bridges and thousands of additional structures. Outlined are a few significant mile stones:

- 2,000 American Society of Non-Destructive Testing (ASNT) certified personnel
- Multiple awards from NASA for SHM, ultrasonic & development of Acoustic Emission Fiber Optics
- First AE bridge monitoring in 1972 for the Dumbarton Bridge near San Francisco
- Partnerships with leading engineering firms and universities worldwide
- Largest known SHM project, CALTRANS San Francisco Oakland Bay Bridge
- Prestigious NIST Technology Innovation Program (TIP) Awards
- Corporate safety governance and hundreds of safety awards
- Global offices for local installation & maintenance
- Multiple FHWA awards for SHM programs
- 15 Technology Centers of Excellence

Installations of wire break monitoring systems on many iconic bridges and major structures allows for the monitoring, recording, interpreting, identifying, and reporting of possible wire breaks and other activities (e.g. vandalism) on main suspension cables. In addition, MISTRAS also performs diagnostic checks, maintenance, calibration and upgrades, as needed, to maintain the operation and performance of the AE system.

The reasons for using AE on suspension cables are beneficial and valuable. Opening a cable is a destructive method of inspection due to wedging and exposure to the elements. Typically opening and performing wedging inspection, samples about 3% of all the panels, and at each wedged location only 5-10% of all wires in a cross section are visible. As a result, cable wedging reveals information over a very small percentage of all wires, less than 0.3% of total cable length. While this is a useful inspection tool for assessing general cable condition, the cost limits the scale of use. This percentage gives a low probability of detecting (PoD) of broken wires, costing millions of dollars to perform this periodic inspection. AE has been in use for over a decade on bridges in the US and worldwide, with almost 100% probability of detection and monitoring being deployed along the whole cable length, from anchorage to anchorage.

NCHRP REPORT 534, Guidelines for Inspection and Strength Evaluation of Suspension Bridge Parallel Wire Cables states, *"Monitoring devices cannot determine existing conditions directly, and are not diagnostic. However, the technology can be used to determine which panels have wires that are breaking, and hence which panels are most likely to have damage. This could eliminate much of the current guesswork involved in selection of panels to be opened."* As NCHRP 534 suggests, if opening panels, monitor the suspension cable for 6 to 12 months, otherwise its like trying to locate a needle in a hay stack and spending millions of dollars in the process.

CASE STUDY

A DOT required wire breaks monitoring for one of their suspension bridges in order to pinpoint which panels to open. The DOT felt that gathering 6-12 months of wire break data would locate the worst panels that would need to be opened for wedging/inspection. MISTRAS installed the system in three weeks and the cost was less than \$500k. By monitoring, the DOT's probability of detecting the bad panels went to nearly 100% and saved the state millions of dollars and a significant amount of time.



CASE STUDY

MISTRAS has continuously monitored a Virginia DOT cable stay bridge and, to date, no problems have been found with the tendons. Because of the system's sensitivity, concrete cracking was initially detected from the tower. The conclusion from VTRC Final Report 10-R24 states, "AE provides a useful means for determining areas of interest and insight into what is occurring. By locating the AE source and determining what is generating the source, AE can provide feedback to inspectors and engineers that surpass tra-

ditional inspection methods. Therefore, since AE equipment is commercially available and contracts can be established to have AE services performed, AE should be performed periodically on the Varina-Enon Bridge as indicated in the recommendations to ensure inspection provides the greatest value to VDOT."

Even though more cable stay bridges are being built, a majority of the relatively new bridges are already experiencing wire breaks and other structural problems. MISTRAS has used this opportunity to install and support research for monitoring bridges in the US, UK, Canada and China. For long-term monitoring, NCHRP SYNTHESIS 353 highlights acoustic and vibration monitoring to detect wire breaks and wind loads. MISTRAS systems can provide both of these functions with no added cost or additional wiring.

NCHRP 353 University of Texas–Austin prepared a write-up of the test plan and a summary of their findings based on two Master's theses. The research team's conclusions for the acoustic monitoring system are given here: "[The system] provides an accurate method for monitoring wire breaks due to fatigue damage in grouted stay cables. The system was able to identify the number of wire breaks accurately. The locations of the estimated wire breaks along the free length of the cable were typically within 6 in. of the actual breaks. The accuracy of the system was less near the anchor heads, but the geometry of the specimen is much more complex in this region. The locations of the estimated wire breaks near the ends of the cable tended to be better/less than 18 in. of the actual breaks."

The sensor photo (upper right) shows the first ever Vibration/AE Sensor quantifying vibration and wire breaks. The bottom two photos on the right show a fatigue test of a stay cable using acoustic emission, with the number of wire breaks and locations successfully identified during lab and field testing. Similar work has been performed on bridges and nuclear structures in Japan, China and the UK.



CASE STUDY

With 240,000 commuters each day on the San Francisco Oakland Bay Bridge, it was important to install the largest known SHM. MISTRAS is monitoring 384 fracture critical eye bars, up to 75 feet long with an average of 640 sensors or only 1.6 sensors per eyebar. Simple linear location (Δt) and the alarm classifiers will detect a 0.1" crack within several inches of accuracy. This is a typical example of how MISTRAS' technology investigates and detects a known concern by keeping bridges open and safe, eliminating nightly inspection costs. This proof test was conducted at UC Berkeley and oversight was provided by University of Illinois, Chicago and University of Missouri, Columbia. Third party verification was provided by UCLA, where they stated in the review that, *"In conclusion, I strongly recommend the implementation of AE Monitoring on the SFOBB in order to detect the presence of growing fatigue cracks in real-time."*

STEEL BRIDGES

Fatigue cracking on fracture critical components is a major concern for steel infrastructure. Not only has MISTRAS had the opportunity to monitor over 100 steel bridges on critical components, such as eyebars, beams, stringers, pin and hangers, box girders, I-beams, orthotropic decks, rivets, shear studs, and gusset plates, but they also offer a full array of NDT and SHM systems for other steel applications, including phased array, strain gauge, vibration, computed radiography, TOFD UT, R & C Scan (corrosion mapping), and rope access inspection. MISTRAS' array of techniques, including AE inspection, have successfully been used by many high profile customers for their steel bridge studies. FHWA, University of Minnesota and Caltrans all used MISTRAS' services to perform comprehensive vetting programs on their structures.

MinnDOT outlines an extensive survey of 38 SHM companies and their technologies, published in a report called "Bridge Health Monitoring and Inspections Systems - A Survey of Methods." In 2010, they published another report called "Development of an Advanced Structural Monitoring System." In this report, MinnDOT aimed to demonstrate the selection of bridge health monitoring systems for fractured critical bridges. With the knowledge that AE technology provides the most suitable and applicable monitoring capabilities, it is the recommendation of the authors that MISTRAS Group be used as the commercial manufacturer of all AE devices required for this project. This recommendation is based on customer satisfaction surveys, instrumentation, support, software, maintenance and many other factors.

In addition, a research report done by University of Minnesota/MinnDOT in 1999 also recommended that MISTRAS be used for bridge monitoring. The technology and company values exhibited by MISTRAS have been proven time and again.

GUSSET PLATE THICKNESS MAPPING

MISTRAS manufactures a unique ultrasonic system with a rolling UT probe that traditionally uses one thickness reading every 10". In the same distance, the Pocket UT®, also from MISTRAS, records 100 thickness readings in 30 seconds, making the readings exportable to excel and providing a thickness map for shear calculations. One DOT stated that, *"Visual didn't give enough confidence,"* and in regards to savings, stated, *"We used 3 DOT inspectors and required 2 days with the Pocket UT® and an inspection company with D Meters quoted 6 inspectors over 2 weeks."* Currently these systems are used by OhioDOT, MinnDOT, FHWA and many engineering firms that supply the systems and services to a variety of bridge owners.

BASCULE BRIDGES, BEARINGS AND LIFTS

On moveable bridges MISTRAS' systems have been used to locate big bangs from misalignments. MISTRAS has also tested and monitored bearing problems, as well as lift cables on various structures and bridges, using their unique technology to locate the defects well before the damages cause vibration to occur.

SECURITY, 3RD PARTY IMPACT, HURRICANE, EARTHQUAKE - DAMAGE DETECTION

Technologies from MISTRAS are ideal for structural security on tunnels and bridges where single or multiple sensor technologies are used to detect and monitor problems before they happen. After a natural disaster such as an earthquake or hurricane, would the structure be fit for service? MISTRAS systems can answer this within hours instead of weeks of inspection.



CONCRETE BRIDGES

Bridge inventories can have hundreds to thousands of concrete bridges, making it economically impossible to monitor and detect structural flaws in all of them. To solve this problem, MISTRAS has perfected a fast, low cost method to sort the structurally deficient bridges from the structurally sound ones, by performing a quick and easy test.

As traffic crosses the bridge, MISTRAS systems can distinguish between new crack propagation, existing cracks fretting, wire breaks in tendons and, in some cases, corrosion. When existing cracks are hidden the friction from crack surfaces can be heard from tens of feet away.

This technique was highlighted in a report by Dr. Kanji Ono, Professor Emeritus at UCLA, called “Diagnostics or Reinforced Concrete Bridges by Acoustic Emission.” The report highlights MISTRAS’ 1980 MonPAC technology, which was a grading methodology on more than 5,000 structures. The report states, *“Extensive acoustic emission (AE) studies of concrete structures have been reported [1-5]. However, most concrete bridges and other structures are still inspected using traditional methods. In Poland, there are about 30,000 concrete bridges, many of which were built over 30 years ago. These structures have sustained various degrees of damage and their continued usage requires maintenance and renovation. We need a method to select the bridges that must be renovated urgently, but conventional testing methods for concrete structures do not provide the full information about the severity of defects.”*

Dr. Ono concludes with, *“Acoustic emission method is useful for the evaluation of the integrity of reinforced*

concrete structures. It can be successfully used for selecting bridges or their elements that need to be renovated or scrapped.”

GROUND PENETRATING RADAR (GPR)

GPR uses radar technology to locate problems, rebar or delamination in concrete. This technology replaces radiographic inspection for determining post tension cables, rebar and conduit in concrete structures that need to be located prior to coring, boring or drilling. MISTRAS’ GPR services are multi-configurable, using a variety of high resolution antennas that allow the operator to locate obstructions up to a depth of 18” of concrete. All scans are stored for post processing of the data to accurately determine the location of defects.

POST TENSIONED

Failures in high strength steel tendons are becoming a serious problem in post tensioned and/or prestressed concrete structures. These failures are mainly attributed to salt or grout problems causing corrosion. MISTRAS and their research partners from around the world have produced laboratory and field studies to detect and locate these wire break failures. MISTRAS also has experience in all forms of post-tensioning including steel bar, strand, and parallel wire cable as well as different grouted conditions (unbonded, partially grouted and fully grouted). AE is ideal to use in this application because of the extreme energy signals released from high tensioned breaks, making them easy to locate with minimal equipment.



One Source for Asset Protection Solutions

CORPORATE HEADQUARTERS

195 Clarksville Road
Princeton Junction, NJ 08550
United States

TEL: +1.609.716.4000
FAX: +1.609.716.4145
E-MAIL: sales@mistrasgroup.com
WEB: www.mistrasgroup.com



UNITED STATES

GULF REGION	SOUTHEAST REGION
MIDWEST REGION	MISTRAS-IMPRO
NORTHEAST REGION	MISTRAS Q.PRO
MOUNTAIN REGION	MISTRAS ROPEWORKS
WEST REGION	SERVICES
MID-ATLANTIC REGION	PRODUCTS & SYSTEMS

INTERNATIONAL

CANADA TEL: +1.403.556.1350	HOLLAND TEL: +31.10.245.0325
CHINA TEL: +86.10.5877.3672	INDIA TEL: +91.22.2586.2444
FRANCE TEL: +33.149.826.040	SCANDINAVIA TEL: +46.031.252040
GERMANY TEL: +49.40.2000.4025	SOUTH AMERICA TEL: +55.11.3082.5111
GREECE TEL: +30.210.2846.801	UNITED KINGDOM TEL: +44.(0)195.423.1612

