



ENGINEERING
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Research Group Profile

Structural Health Monitoring Research Group at Columbia University

Aging Suspension Bridge Cables

Problem

One of the most crucial elements for the overall safety of suspension bridges is, without doubt, the main cable. After many years of service, in-depth inspections of cable systems in suspension bridges often show that there are many broken wires inside the cables and at the anchorages. This is indicative of brittle fractures and extensive corrosion. Today, the most pressing challenge for a suspension bridge owner is to estimate the current and remaining strength of the main cable in order to decide whether it is safe to operate the bridge under such conditions or necessary to provide immediate maintenance and/or rehabilitation (or replacement) of such cables. Currently, all state and local agencies responsible for maintenance of suspension bridges base their maintenance plan mainly on previous experiences and on limited information based on limited inspection. Our research focuses on developing an integrated methodology that uses state-of-the-art sensing capabilities and NDT technologies to assess the remaining strength of such cables and its variation over time as function of the environmental conditions.

Approach

An integrated sensor network has been developed using a variety of sensors that measure either directly the corrosion rate of bridge wires (direct sensing) or indirectly the environmental parameters (temperature, relative humidity, etc.) related to the corrosion rate of the wires (indirect sensing). Sensors were first tested in a cyclic corrosion chambers to assess their reliability and to correlate their readings with corrosion rate in wires. The selected sensors are based on different principles: for example, for direct sensing, we selected 1) linear polarization resistance, 2) bi-metallic, and 3) coupled multiple array sensors. In addition to the sensor

Core Competencies

- Corrosion mechanisms and modeling in high-strength steel wires .
- Fracture mechanics of corroded high-strength wires.
- Stochastic mechanics for modeling cable strength.
- Data fusion and analysis.
- Analytical/computational/experimental approaches for solving contact problems and large scale FEM models.



Full scale cable mock-up

network, global non-destructive testing (NDT) technologies based on magnetic flux leakage, magnetostriction and acoustic emission, for the entire cross section of the cable were developed and tested on a full

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<http://www.civil.columbia.edu/carleton/research/suspension.html>



scale mock-up of a suspension bridge cable built in the Carleton Laboratory at Columbia University. This cable mock-up is 10.7m (35 ft) long, and has more than 9,000 5 mm diameter high-strength steel wires. Subjected to 5.3 MN (1,200 kips) tension force, it is placed inside a corrosion chamber that can create cyclic aggressive environments. A network of 76 sensors monitors corrosion rate as well as environmental parameters inside the cable.

Recent Finding

Experimental results show that the sensor network provides reliable readings of the variation of conditions inside the main cable. Strong correlations were found between the temperature sensor readings and the corrosion rate sensor readings. Interesting new insights on the friction mechanism among corroded and new wires appeared that have been confirmed by neutron diffraction measurements conducted at Los Alamos National Laboratory. These results show that the friction mechanism among wires is critical for strain transfer mechanism.

Impact

The results are now incorporated in a stochastic methodology that will allow us to assess the residual strength of cables as a function of environmental conditions. Such a monitoring system will ultimately allow bridge authorities to assess online the reliability of suspension bridge cables.

Selected Publications

1. I.C. Noyan, A. Brugger, R. Betti, B. Clausen and D. Brown, "Measurement of Strain/Load Transfer in Parallel Seven-wire Cable Strands with Neutron Diffraction", *Experimental Mechanics*, 2010, DOI 10.1007/s11340-009-9313-y.
2. Y.W. Shi, G. Deodatis, and R. Betti, "Cable Strength Evaluation for Suspension Bridges Using a Random Field Approach", *ASCE Journal of Structural Engineering*, 133(12), 1690-1699, 2007.
3. R. Betti, A.C. West, G.W. Vermaas, and Y. Cao, "Corrosion and Embrittlement in High-Strength Wires of Suspension Bridge Cables", *ASCE Journal of Bridge Engineering*, 10(2), 151-162, 2005.
4. R. Betti and B. Yanev, "Conditions of Suspension Bridge Cables: The New York City Case Study", *Transportation Research Board Record*, 1654(12), 105-112, 1999.

Current Research Team Members:

- Raimondo Betti (Professor)
- George Deodatis (Professor)
- I. Cevdet Noyan (Professor)
- Haim Waisman (Assistant Professor)
- Adrian Brugger (Laboratory Manager)
- Arturo Montoya (Ph.D. candidate)
- Efe Karanci (Ph.D. candidate)
- Ah Lum Hong (Ph.D. Candidate)
- Matthew Sloane (M.S. Candidate)

Industrial Partners:

- Dyab Khazem (Parsons Transportation Group).
- Mark Carlos (Physical Acoustics Corporation).

Current Research Collaborations:

- Fatigue effects on high-strength steel wires: Monseff Idriss (Laboratoire Central des Ponts et Chaussees, France).
- Friction mechanisms in high-strength steel wires: Bjorn Clausen and Donald Brown (Los Alamos National Laboratory).



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