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Monitoring the Structural Health of Main Cables of Suspension Bridges

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Abstract

Suspension bridges have become essential elements in the transportation network of major metropolitan areas worldwide: in New York City alone, seven suspension bridges service nearly 1 million commuters each day. However, some of these bridges are reaching a service life of over 100 years and, during this time, they experienced a dramatic change in loading conditions and have been exposed to harsh environmental conditions. For these bridges, the main cables, with thousands and thousands of high-strength steel wires compacted together, are undoubtedly the most critical elements for the overall safety of such structures; however, it is very difficult to inspect and assess the condition of a main cable of a bridge that has been in service for many years.

Currently, all state and local agencies responsible for the maintenance of suspension bridge cables base their maintenance plan mainly on previous experiences and on limited information from previous inspections. If visual inspections reveal some deterioration problems, main cables are unwrapped at a few locations along the cable length and wedged into the center. After this, a visual inspection of the wires' conditions is performed and, in some cases, a few wires are cut and removed for laboratory testing.

In this paper, the results of a study focused on the development of a corrosion monitoring system for main cables of suspension bridges is presented. These sensors measure corrosion rate as well as quantities like temperature and relative humidity that are directly correlated to corrosion activity. Such a sensor network was first tested in a laboratory setting using a full-scale cable mock and, later, tested on the main cable of one of the major suspension bridges in the New York metropolitan area. The results show that the selected sensor network system was successful in providing information on the interior environment of a suspension bridge's main cable, thereby helping to understand the conditions in which main cables of suspension bridges operate. These sensors proved to be reliable in all the testing phases, from the stand-alone sensor test in a small corrosion chamber to the insertion into a real main cable of a bridge. Once the laboratory phase was completed, field testing of the developed monitoring system on the Manhattan Bridge in New York City was used to determine the functionality of the system in in-service conditions. The results from the field pilot test validated the laboratory results and showed good correlation with the original assumptions. During the field test, the sensor monitoring system was successful in detecting the onset of corrosion at one location, caused by a damaged protective wrapping. This showed that this system could also work as an early warning system for the safety of the cable.

Having the possibility of measuring temperature and relative humidity inside the cross-section of a main cable also allowed us to test the effectiveness of the cable dehumidification strategy. Cable dehumidification systems are designed to protect main cables from corrosion through the hindrance of water infiltration, the isolation of the interior of the cable from the external environment, and the removal of internal moisture. While cable dehumidification has been implemented in several main cables around the world since the late 1990's, no complete scientific verification of the functionality of such systems has been performed.

Bio

Professor Raimondo Betti received his Laurea degree magna cum laude in Civil Engineering from the University of Rome "La Sapienza" in 1985 and his Master of Science (1988) and PhD (1991) from the University of Southern California. In 1991, Dr. Betti joined the Department of Civil Engineering and Engineering Mechanics at Columbia University as an Assistant Professor and has been there since, being promoted to Associate Professor (1998) and to Full Professor (2002). From 2010 to 2013, he served as the Chairman of the Department. He is also an Adjunct Professor in the School of Transportation Science and Engineering at the Harbin Institute of Technology in China. Since 2006, Dr. Betti has served as expert advisor for the Metropolitan Transportation Authority in New York City.

As a professor at Columbia, he received in 1995 the National Science Foundation Young Investigator Award and the 1997 the Foreign Specialist Award from the Public Work Research Institute in Japan. For his teaching at Columbia he received, in 1996, the Distinguished Teaching Award from the School of Engineering and Applied Science and the Great Teacher Award in 2000.

Dr. Betti's research interests are in the area of structural health monitoring, ranging from the development of identification algorithms to corrosion monitoring in main cables of suspension bridges. He is currently an active member of the Dynamics and Structural Health Monitoring Committees of ASCE and is an elected member of the Board of the International Association for Structural Control and Monitoring.

Raimondo Betti, PhD

Chair, Department of Civil Engineering & Engineering Mechanics

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Education

- **PhD, Civil Engineering, *UNIVERSITY OF SOUTHERN CALIFORNIA***
- **MS, Structural Mechanics, *UNIVERSITY OF SOUTHERN CALIFORNIA***
- **BS, Civil Engineering, *UNIVERSITY OF ROME***

Research Interests

- **Structural health monitoring**
- **Rapid damage assessment**
- **Vibration-based identification of structural models**
- **Deterioration mechanisms in structures**

Selected Service and Awards

- **1995 NSF Young Investigator Award**
- **1996 Distinguished Teaching Award**
- **2000 Great Teacher Award**
- **Associate Editor of the ASCE Journal of Engineering Mechanics**
- **ASCE Dynamics and Structural Health Monitoring Committees**