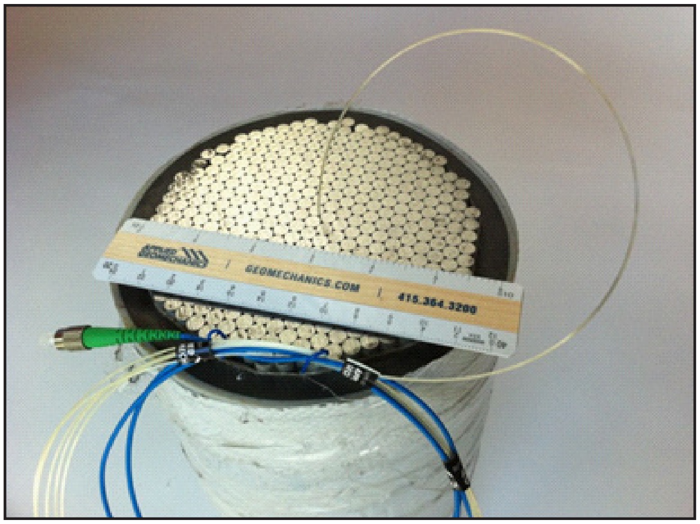
Stay Cable Monitoring with Fiber Optics

CASE STUDY

30-SECOND SUMMARY: Continuous cable force and temperature monitoring programs help reduce long-term maintenance costs for many types of cable stay bridge structures. Long-term cable monitoring programs also provide valuable performance data for structures subject to event driven conditions.

Shanghai Pujiang Cable Company Ltd. (SPCC) has recently implemented a program to develop SMART Cable technology, utilizing Applied Geomechanics Inc. (AGI) fiber-optic monitoring solutions to better measure strain and cable forces over time.



A fiber-optic sensor inserted in a PWS cable.

BACKGROUND

As existing cable-stay and suspension bridges age worldwide they become increasingly more susceptible to deterioration and decay. As a result, many of these bridges have undergone extensive cable inspection programs to better assess cable quality and condition. Corrosion and load distribution are particular causes for concern; corrosion is the number one maintenance concern for all bridges of considerable age, and is often responsible for cable section losses and uneven load distribution.

Main cables are typically comprised of wire rope or parallel wire systems (PWS), which make up the entirety of the cable. The bundle is clamped together about its circumference before being wrapped in a protective outer sheath, which shields the structural members from the elements and debris. Because of their design, support cables are difficult to monitor retroactively, and recent inspection programs have highlighted the limitations of traditional monitoring solutions.

Current cable force monitoring programs are often performed on an "as-needed" basis through vibration analysis. Another common practice involves using external accelerometers in conjunction with vibration analysis software to determine average forces over a set time period. Vibration analysis surveys, however, can only provide information for a single data point at any given time, and can potentially miss critical events of interest. Traditional analog and digital sensors also present numerous problems due to their design and mode of operation. When installed within cable bundles high radial compression forces can often cause conventional senors to fail, and necessary exit wires can perforate and compromise protective cable moisture barriers. Analog and digital sensors are also vulnerable to electrical transients, lightning damage, and signal noise over long cable lengths.

Such limitations have made dynamic-response cable monitoring quite difficult under ambient conditions. AGI fiber-optic technologies, however, offer effective alternatives to traditional cable monitoring solutions without the disadvantages of conventional methods and equipment.

Instrumented test specimen

Tension test setup

THE PROJECT

SPCC Ltd. and their international sales agent TechStar have begun to develop cutting edge SMART Cable technology as part of their drive to become the leading providers of PWS cables for suspension bridges worldwide. As part of this program SPCC and TechStar approached AGI to develop and implement sensor installation procedures, and to perform verification, and proof-of-concept testing and evaluation.

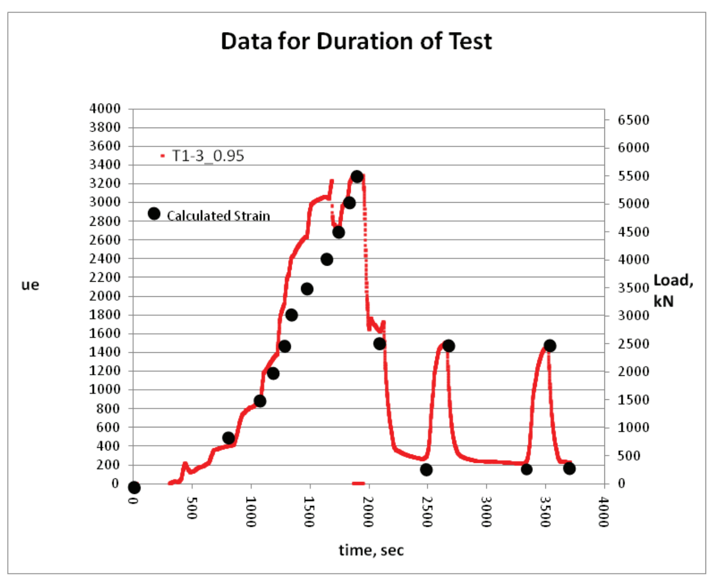
SMART Cable utilizes embedded fiber-optic sensors—installed during fabrication—to monitor new and existing cable forces over time. This innovative technology makes conventional monitoring programs a thing of the past, and allows for better data coverage over the entire lifespan of the cable.

Typical PWS cables consist of multiple galvanized wires, each approximately 7 mm in diameter, which comprise the whole of the bundle. In a SMART Cable assembly the fiber-optic Fiber-Bragg Grating (FBG) sensor occupies select spaces between these wires; FBG sensors are anchored to the surface of adjacent wires with epoxy from one sensor point to the next. When placed under load, these sensors detect strain along select internal wire elements commensurate with the overall load on the support cable.

THE RESULTS

Testing was conducted on a 223 count wire cable at SPCC's facilities in China. AGI evaluated multiple installation techniques before proceeding with tensile testing. After completing initial sensor installation testing a 4 m long cable specimen was instrumented with four fiber-optic sensors and tensioned to 40% Guaranteed Ultimate Tensile Strength in 500 kN increments. All four sensors showed very good correlation between calculated and measured strain values to a load of about 2500 kN. The maximum load of 5000 kN was achieved with subsequent load cycling, and showed very good sensor performance in relation to calculated strain values while maintaining high levels of measurement repeatability.

Refinements to installation methods and further sensor developments are expected to ultimately provide the ability to continuously measure cable forces, temperature, and moisture/humidity conditions in cable systems for long-span bridges throughout the world.



APPLIED GEOMECHANICS , INC.
140 Chestnut St.
San Francisco, CA 94111
T: +1-415-364-3200
F: +1-415-861-1448
geomechanics.com

A CARBO Company